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HILL ROAD MANUAL

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CONTENTS

FIGURES

APPENDICES

PLATES

1. INTRODUCTION

1.1. India has a vast area in hilly regions consisting of the Himalayan region from North to North-East, the Central Highlands of Aravalli, Vindhya and Satpura ranges, the Sahyadri (Western ghats) and the Eastern ghats. Out of 25 states and 7 union territories, 9 states are predominantly in hilly regions in North and North East, whereas 9 other states have substantial hill areas. The Himalayan region itself covers about a fifth of the country's total area and about 3000 kms of the country's sensitive international borders lie along this region. Economic development and strategic needs have resulted in launching of massive road construction programme in the hilly regions and in the recent past the activity has increased manifold.

1.2. These hilly regions, generally, have extremes of climatic conditions, difficult and hazardous terrain, topography and vast high altitude areas. The region is sparsely populated and basic infrastructural facilities available in more developed plains of hinterland are mostly absent. The areas and, therefore, the roads are affected by floods consequent to torrential rainfall, land-slide, snow-fall, avalanche etc., compelling certain roads to be kept closed in part of the year, especially in winter months. However, the areas are rich in natural resources, flora and fauna, and are important to launch development projects, industries, tourism etc.

1.3. In view of the diverse problems met in the area, the necessity for preparation of a manual for "Design, Construction and Maintenance of Hill Roads" to bring in uniformity of standards and to serve as a guideline has been engaging the attention of the Indian Roads Congress for past several years. The matter was deliberated upon in several meetings of the Indian Roads Congress.

1.4. A sub-committee for compilation of the Manual was initially constituted in 1980. This matter was further discussed in details during Seminar on "Construction of Roads in Hill Areas" held in Nainital in July 1985 and the Sub-Committee formed earlier was reconstituted in 1986.

1.5. The Hill Roads Committee (composition given below) deliberated on various aspects of the manual.

Lt. Gen. M.S. Gosain, PVSM AVSM VSM	-	Convener
D.S.N. Ayyar, PVSM	-	Member-Secretary

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Ex-officio Members

President, Indian Roads Congress

Director General (Road Development) & Additional Secretary to Govt. of India

Secretary, Indian Roads Congress

It was agreed that each Chapter of the Manual should contain both guidelines as well as the code of practice with type-design, tables etc., so that the Manual in itself is a complete document and the existing IRC: 52-1981 "Recommendations About the Alignment Survey and Geometric Design of Hill Roads (First Revision)" could also form part of the Manual. The format of the chapters and sub-chapters was discussed and the drafting of the chapters of the Manual were assigned to the various specialists. The Technical Chapters were authored by the following engineers :

Chapter Number	Subject	Author
3	Definitions of Terms Relating to Hill Roads	D.S.N. Ayyar, PVSM
4	Planning Criteria	D.P. Gupta
5	Survey and Alignment of Hill Roads	Padmashri N.N. Lama
6	Geometric Design	D.S.N. Ayyar, PVSM
7	Formation Works	S.N. Mane, AVSM VSM
8	Drainage and Cross Drainage	M.L. Bansal
9	Structures and Protective Works	J.S. Sodhi
10	Pavement Design	Dr. M.P. Dhir & Brig. S.S. Cheema
11	Slide stability, Erosion Control and Landslide Correction	P.J. Rao
12	Snow Clearance and Avalanche Treatment	Brig. S.S. Cheema
13	Road Construction Tools, Plant and Equipment	I.D. Kalra
14	Maintenance of Hill Roads	D.S.N. Ayyar, PVSM & K. Balagopalan
15	Roadside Amenities	
16	Safety in Hill Roads	J.B. Mathur
17	Traffic Management	
18	Rock Blasting	I.D. Kalra
19	Ecology and Environment	D.S.N. Ayyar, PVSM & I.D. Kalra
20	Preparation and Presentation of Project Documents	D.S.N. Ayyar, PVSM & K. Balagopalan

The chapters drafted by various experts were also discussed at length by committee in its meetings held on 6-5-86, 20-8-87 and 7-12-87. All the Chapters of the Manual were received by the end of 1991. During the final meeting of Hill Road Committee held on 23-12-91, an editorial Committee consisting of Shri D.S.N. Ayyar as its head and Shri S.N. Mane and DS(R), IRC (Shri Nirmaljit Singh) was constituted to edit and re-write the Manual in IRC format.

Thereafter the draft Manual was placed before the meeting of Highways Specifications & Standards Committee in its meeting held on 12-5-94. The Committee felt that the draft Manual needed refinement. For this purpose a Sub-committee was set up consisting Shri S.N. Mane as the Convenor, Shri Nirmaljit Singh as Member-Secretary and S/Shri K.B. Rajoria, P.J. Rao and S.C. Sharma as members. The draft manual finalised by this Sub-committee was placed before Highways Specifications & Standards Committee in its meeting held on 19.3.96, when members were of the view that more time should be given to them for reviewing the manual. It was, therefore, decided that the members may send their comments in writing to Member-Secretary, Highways Specifications & Standards Committee for further orders of the Convenor of Highways Specifications & Standards Committee. Comments received from Members were reviewed by a sub-group, formed by the Convenor, Highways Specifications & Standards Committee consisting of the following :

1.	Shri Indu Prakash Chief Engineer (R) S&R, Ministry of Surface Transport	-	Member-Secretary, Highways Specifications & Standards Committee
2.	Shri A.P. Bahadur Director, Indian Roads Congress	-	Member
3.	Shri Nirmal Jit Singh Superintending Engineer (T&T), Ministry of Surface Transport	-	Member

The above sub-group modified the draft in the light of the written comments from the members and then put up to the Convenor. The Convenor, HSS Committee approved the modified draft to be placed before the Executive Committee.

The Executive Committee considered the draft on "Hill Road Manual" in its meeting held on 21.12.96 and approved for its being placed before the Council. The Council in its 148th meeting held at Nagpur on 13th January, 1997 approved the Manual for printing with the proviso that Convenor, HSS would consider the written comments of Members. Accordingly, the Convenor, H.S.S. Committee considered the written comments and sent the final documents for printing after carrying out necessary modifications.

2. SCOPE

2.1. The manual covers the various aspects of design, construction and maintenance of roads in Hilly areas.

2.2. The guidelines contained in the Manual have largely been drawn from relevant Indian Roads Congress Codes, Ministry of Surface Transport Specifications for Road and Bridge Works, DGBR Technical Instructions, IS codes and other similar publications and Technical papers available on the subject. To make the guidelines exhaustive, the standard practices prevailing in different Departments, which have stood the test of time, have also been included in the Manual. The Manual, based on codes, practices etc., as per standard engineering norms, has been compiled using the experience and expertise of the authors of various Chapters as well as other members of the Hill Roads Committee and Engineers who participated and contributed to the deliberations and discussion of the Chapters in the Hill Roads Committee meetings.

2.3. The guidelines contained in the Manual will apply to all phases of construction and maintenance of hill roads. Where the guidelines are silent, the relevant IRC Codes, Ministry of Surface Transport Specification and/or IS Codes would apply. Considering the vast variations in terrain, climatic and topographic conditions in the different hill regions of the country, an uniform system cannot obviously, apply to all areas. As such, the guidelines in the manual relevant to the areas have to be applied. The experience and feedback from the engineers on adoption of the guidelines in the manual will enable upgradation and updation of the same.

3. DEFINITIONS OF TERMS RELATING TO HILL ROADS

3.1. General

3.1.1. Construction of hill roads comprises various stages of works viz. Reconnaissance, Survey and Trace cutting, Formation, Protective and Drainage Works, Pavement Works, Bridges etc. Each stage is further divided into different items of works. Definitions of typical terms used normally in reference to hill roads are given in the succeeding paras. For easy reference, these terms are grouped under the following headings:

(i) Classification
(ii) Reconnaissance, Survey and Trace cutting
(iii) Geometrics
(iv) Formation works
(v) Protective and drainage works
(vi) Pavement works
(vii) Bridges
(viii) Miscellaneous

3.2. Classification

3.2.1. Hill Road is a road passing through mountainous or steep terrain. As in the case of other roads, hill roads may be classified as per IRC: 52-1981, as one of the following:

(a) National Highways
(b) State Highways
(c) Major District Roads
(d) Other District Roads
(e) Village Roads

3.2.2. Each classification may also be qualified by a suffix indicative of the maximum laden weight of vehicles in tonnes which could negotiate the road safely.

3.2.3. **Terrain classification:** The classification of the terrain is normally done by means of cross slope of the country viz., slope approximately perpendicular to the centre line of the highway location. The following classification is generally followed:

Terrain Classification		Per cent cross slope of country
i)	Plain	0 to 10
ii)	Rolling	Greater than 10 upto 25
iii)	Mountainous	Greater than 25 upto 60
iv)	Steep	Greater than 60

3.3. Reconnaissance, Survey and Trace Cutting

3.3.1. **Reconnaissance**: is a preliminary and usually rapid, examination or survey of a region in reference to its natural features, or other local conditions to determine the location of a proposed highway or other work.

3.3.2. **Trace cutting**: is the footpath of prescribed width made along the proposed alignment for facilitating detailed survey, collection of data etc.

3.4. **Geometrics**

3.4.1. **Camber**: is the convexity given to the cross section of the surface of the carriageway to facilitate drainage.

3.4.2. **Crossfall**: is the fall at right angles to an alignment given to the surface of any part of a roadway. It may be expressed as ratio of vertical to horizontal or equivalent percentage.

3.4.3. **Curvature (degree of)**: is the angle in degrees subtended at the centre of a circular arc by a chord of a given length, usually 30 meters.

3.4.4. **Curve horizontal**: is the curve in plan to change the direction of the centre line of a road.

3.4.5. **Curve transitional**: is a curve whose curvature goes on changing at a certain rate from one radius to another radius for giving smooth change of direction of road.

3.4.6. **Curve vertical**: is a curve in the longitudinal section of a roadway to provide for easy and safe change of gradient.

3.4.7. **Curve compound**: is a curve consisting of two or more arcs of different radii curving in the same direction and having a common tangent at the point or points of junction.

3.4.8. **Curve reverse**: is a curve consisting of two arcs of the same or different radii curving in opposite directions and having a common tangent at the point of junction.

3.4.9. **Gradient (incline or grade)** : is the rate of rise or fall with respect to the horizontal along the length of a road expressed as a percentage or as a ratio or in degrees.

3.4.10. **Gradient ruling**: is a gradient which in the normal course must never be exceeded in any part of a road.

3.4.11. **Gradient limiting**: is a gradient steeper than the ruling gradient which may be used in restricted lengths where keeping within the ruling gradient is not feasible.

3.4.12. **Gradient exceptional**: is a gradient steeper than the limiting gradient which may be used in short stretches only in extra-ordinary situations.

3.4.13. **Hairpin bend**: is a bend in alignment resulting in reversal of direction of flow of traffic. A bend may be for reversing road direction on same face of hill slope.

3.4.14. **Lateral clearance**: is the distance between the extreme edge of the carriageway to the face of the nearest structure/obstruction.

3.4.15. **Ruling minimum radius of a curve**: is the minimum radius of curvature of the centreline of a curve necessary to negotiate a curve at ruling minimum design speed.

3.4.16. **Absolute minimum radius of a curve**: is the minimum radius of the centreline of a curve necessary to negotiate a curve at absolute minimum design speed.

3.4.17. **Roadway width**: is the sum total of carriageway width and shoulder width on either side. It is exclusive of parapets and side drains.

3.4.18. **Road lane width**: refers to the width of carriageway of the road in terms of traffic lanes. Single lane 3.75 m, intermediate lane 5.5 m and double lane 7.0 m (7.5 m with raised kerbs), multilane 3.5 m per additional lane.

3.4.19. **Sight distance**: is the distance along the road surface at which a driver has visibility of objects, (stationary or moving) at a specified height, above the carriageway.

3.4.20. **Skidding**: The lateral motion of the contact area of the tyre of a moving vehicle over the surface of the road.

3.4.21. **Slope**: is the inclination of a surface to the horizontal expressed as one vertical linear unit to the number of horizontal linear units.

3.4.22. **Superelevation**: is the inward tilt or transverse inclination given to the section of a carriageway on a horizontal curve to reduce the effects of centrifugal force on a moving vehicle. Superelevation is generally expressed as a slope.

3.4.23. **Transition length**: is the centreline length along a curve, radius of which goes on changing at a certain rate of change of acceleration.

3.4.24. **Vertical clearance**: is the height above the highest point of the travelling way, i.e., the carriageway and part of the shoulders meant for vehicular use, to the lowest point of the overhead structure or rock surface.

3.5. **Formation**

3.5.1. **Benching**: is the formation of a series of level platforms or ledges upon an incline.

3.5.2. **Berm**: is the horizontal ledge or margine formed at the top or bottom of an earth slope.

3.5.3. **Boulder**: is rock fragment with diameter minimum plan dimension greater than 300 mm and weight not less than 40 kg.

3.5.4. **Cliff**: a high, steep or over-hanging mass of rock.

3.5.5. **Compaction**: is the process by which the soil particles are consolidated by rolling, vibrating or other means, to pack more closely together, thus increasing the dry bulk density of the soil.

3.5.6. **Cut and fill**: is a term used to describe any section of earth work which is partly in cutting and partly in filling.

3.5.7. **Embankment**: is an earth work raised above the natural ground by the deposition of material to support construction at a higher level.

3.5.8. **Escarpment**: a steep slope or long cliff resulting from erosion or faulting and separating two areas of different elevations.

3.5.9. **Formation width**: is the finished width of earth work in fill or cut.

3.5.10. **Pass**: a narrow space between mountain peaks that can be used as a way through or on which one can travel.

3.5.11. **Passing Place**: is an area provided on the side of the road at convenient locations to facilitate crossing of vehicles approaching from the opposite direction and toe aside a disabled vehicle so that it does not obstruct traffic.

3.5.12. **Precipice**: an extremely steep high face of a cliff or mass of rock.

3.5.13. Road land width (also termed the right of way) is the land acquired for road purposes.

3.5.14. **Rock**: is natural accumulation of mineral matter in earth's crust or upper mantle consisting of atleast two crust minerals.

3.5.15. **Rock, hard**: covers any rock, excavation of which involves intensive drilling and blasting. This can stand vertical or even over-hanging cut depending on the type/mass and dip of the rock.

3.5.16. **Soft rock**: This comprises of soft varieties of rock such as lime stone, sand stone, laterite, conglomerate or other disintegrated rocks which can be excavated by crow bars and/or pick axes or mechanical excavators normally without use of blasting.

3.5.17. **Rock, dip of**: is the angle with which the rock is dipping against horizontal plane.

3.5.18. **Rock, fault in**: are rock fractures along which the opposing blocks of rock have moved or moving.

3.5.19. **Saddle**: is a saddle shaped depression in the ridge of a hill.

3.5.20. **Valley**: is an elongated low land between ranges of mountains or hills often having a river or stream running along the bottom.

3.6. Protective and Drainage Works

3.6.1. **Angle of repose**: is the maximum angle between the horizontal plane and the slope at which earth or other loose material stabilizes without tending to slide.

3.6.2. **Angle of surcharge**: is the angle between horizontal plane and sloping face of a surcharge of earth or other matter.

3.6.3. **Back filling**: is the earth or other material used to fill cavity on earth retaining structures such as in culvert trenches and behind the bridge abutments, retaining walls etc.

3.6.4. **Box culvert**: is a monolithic drainage structure rectangular in section having clear span less than or equal to 6 m.

3.6.5. **Box drain**: is a covered drain of rectangular section.

3.6.6. **Catch pit**: is a pit excavated or a chamber constructed below the normal bed level of a ditch, drain, stream or sewer to trap bed silt and solid matter.

3.6.7. **Catch water drain**: is a drain excavated on the upper slope of a hill road area to intercept and collect water flowing towards the road, and to lead it to a point where no damage will result to the road or in general it is a drain to catch water flowing to a certain area and drain it off to another area.

3.6.8. **Causeway**: is a paved dip in a road across a shallow drainage course, at the bed level.

3.6.9. **Causeway, vented**: is a paved dip appreciably above the bed level of a stream, usually provided with vents to pass low water flow or is a causeway with vents below road level to drain off low water flow.

3.6.10. **Coefficient of roughness or rugosity**: is a reduction factor which has to be applied in formulae, such as Kutter, Manning and Barfen when calculating the discharge of a stream, to allow for the frictional and other losses engendered by the characteristics of the wetted perimeter.

3.6.11. **Culvert:** is a structure used for purpose similar to that of a minor bridge having total linear opening of 6 m or less measured at right angles to faces of abutments.

3.6.12. **Curtain wall:** is a wall used as a shield or protection against scouring action.

3.6.13. **Cut-off wall:** is a wall, collar, or other structure intended to cut off or reduce percolation of water in smooth surface, or through porous strata.

3.6.14. **Drain:** is a conduit or channel, either artificial or natural, for carrying off surplus ground water or surface water.

3.6.15. **Erosion:** is the process of removal of matter from the banks of a stream or other surfaces by the action of natural forces like flowing water, wind etc.

3.6.16. **Retaining wall:** is a wall constructed to maintain in position material capable of exerting lateral pressure, generally a mass of earth.

3.6.17. **Return wall/wing wall:** is a retaining wall built parallel or at an angle to the centreline of a road and in continuation of an abutment to retain the embankment.

3.6.18. **Revetment:** is a facing of stone or other material laid on a sloping face of earth to maintain the slopes in position.

3.6.19. **Run-off:** is the total quantity of precipitated water from a catchment area, reaching a given point within a given time.

3.6.20. **Safe bearing capacity:** is the pressure which may be applied over the soil without causing it to settle to an extent deterimental to the structure built over it.

3.6.21. **Side drain:** is a drain along the side of a road.

3.6.22. **Storm water:** is that portion of the precipitation which runs off the surface of the ground during a rain storm and for a short period following it when the flow exceeds the normal or ordinary rate of run-off.

3.6.23. **Sub-surface:** is the undisturbed strata lying below the natural top soil.

3.6.24. **Sub-surface drain:** is a drain below the ground surface to drain away sub-soil water.

3.6.25. **Surcharge:** is the load superimposed above the level of the top of the retaining wall on the earth resting against it.

3.6.26. **Toe wall:** is small retaining wall structure at the foot of an earth slope.

3.6.27. **Viaduct:** is a structure which carries a road or across a wide and deep valley or ground having generally no flow of water.

3.6.28. **Water cushion:** is a pool of water maintained to absorb the impact of water flowing over a dam, chute, drop or other spillway structure.

3.6.29. **Weep hole:** is a small opening left through soil retaining structure to drain away percolated water.

3.7. Pavement Works

3.7.1. **Bituminous concrete (asphaltic concrete):** is a mixture of bitumen, coarse aggregates, fine aggregates and filler material and used as a wearing course without any seal coat. It is also termed as Asphaltic Concrete.

3.7.2. **Base course:** is that part of the construction resting upon the sub-base or in its absence the subgrade, through which the load is transmitted to the subgrade or the supporting soil.

3.7.3. **Bitumen emulsion:** is a liquid product in which substantial amount of bitumen is suspended in finely divided condition in an aqueous media and stabilised by means of one or more suitable reagents.

3.7.4. **Bitumen/Tar macadam:** is a type of construction in which the fragments of coarse aggregates are bound together either by bitumen or tar applied either by premix or grouting method. Bitumen macadam may be semi-dense or dense.

3.7.5. **Bituminous Penetration macadam:** is a macadam crust in which the stone aggregate is bound together by a binder applied to penetrate to the designed depth.

3.7.6. **Black top surface:** is a general term applied to wearing coats or surface of road in which tar or bitumen is used as binder.

3.7.7. **California Bearing Ratio (CBR):** is a measure of the shearing resistance of a soil to penetration under carefully controlled density and moisture conditions. The ratio is expressed as a percentage of the unit load required to force a standard piston into the soil at a rate of 1.25 mm per minute divided by the unit load required to force the same piston the same depth at the same rate into a standard sample crushed stone.

3.7.8. **Built-up spray grout:** is a two layer composite granular construction with application of bituminous binder after each layer.

3.7.9. **Carpet:** is a finished top surface obtained by the application of premixed aggregate or bitumen/tar concrete and is called premix carpet and may consist of mix seal, open graded, semi-dense or dense.

3.7.10. **Carriageway:** is that portion of the roadway designed and constructed for use of vehicular traffic.

3.7.11. **Cement concrete surface:** is a surface obtained by placing and compacting cement concrete.

3.7.12. **Coarse aggregate:** is a relative term to denote the larger mineral fragments usually limited to a size greater than 4.75 mm.

3.7.13. **Cutback bitumen:** is a bitumen whose viscosity has been increased by a volatile dilutant.

3.7.14. **Earth road:** is a road with the carriageway composed of natural soil.

3.7.15. **Edging:** is the block of concrete, brick, stone or the like embedded along the edges of a pavement to protect them from damage caused by traffic.

3.7.16. **Expansion joint:** is the self-adjusting connection formed between two parts of the same structure, and so designed as to permit small relative movements under thermal changes without destroying continuity or structural properties.

3.7.17. **Fine aggregate:** is a relative term to denote the smaller mineral fragments and particles passing through 4.75 mm square mesh.

3.7.18. **Gravel road:** is a road with the carriageway composed of a compacted layer or layers of gravel.

3.7.19. **Grouting:** is the action in which a fluid cementitious binder is made to penetrate into joints, fissures, or cracks between stones or blocks, or void spaces in mineral aggregates either under the action of gravity or by externally applied pressure.

3.7.20. **Moisture content:** is the loss of weight expressed as percentage of the dry material, when a soil sample is dried to constant weight at 105^{0}C.

3.7.21. **Pavement:** is the structure consisting of superimposed layers of selected and processed materials placed on a subgrade to support the applied traffic loads and distribute them to the soil foundation.

3.7.22. **Percolation:** is the slow passage of water through soil or a porous solid under the action of gravity.

3.7.23. **Premixing:** is the process of mixing of coarse or fine aggregate with a binder prior to laying at site.

3.7.24. **Prime coat:** is the single coat application of a binder of low viscosity to an absorbent granular surface preparatory to any super-imposed bituminous treatment or construction.

3.7.25. **Rapid curing cut-back bitumen:** is cut-back bitumen which sets or stabilises rapidly.

3.7.26. **Resurfacing:** is the complete renewal of an old wearing surface by new layer of surfacing.

3.7.27. **Slow curing cut-back bitumen:** is a cut back bitumen which sets or stabilises slowly.

3.7.28. **Soil stabilisation:** is the process of treating a soil in such a manner as to improve or alter its physical properties so as to serve a specific purpose.

3.7.29. **Stone set paving:** is a paving of rectangular blocks of stone sets laid in regular courses.

3.7.30. **Subgrade:** The top 50 cm of the embankment over the entire formation width, directly supporting the pavement.

3.7.31. **Sub-base:** is a layer of material placed between the base course and the subgrade.

3.7.32. **Surfacing:** is a wearing coat laid upon a prepared foundation in the form of a continuous surface layer.

3.7.33. **Tack coat:** is the initial application of binder to an existing surface given to ensure thorough bond between the new construction and the existing surface.

3.7.34. **Traffic lane:** is a longitudinal strip of the carriageway of a road, regarded as an unit width to accommodate safely the traffic going in one direction.

3.7.35. **Water bound macadam:** is the layer consisting of clean, crushed aggregates, mechanically interlocked by rolling and bonded together with the screening, binding material and water.

3.7.36. **Wet mix macadam:** is a type of surfacing in which graded aggregate and granular material, premixed with water is laid uniformly on a prepared subgrade/sub-base/base or existing pavement and compacted to a dense mass.

3.8. Bridges

3.8.1. **Abutment:** is an end support of the superstructure of a bridge or similar structure generally sustaining the pressure of the abutting earth or back fill.

3.8.2. **Afflux:** is the rise in level of water above the normal level of water due to obstruction caused to normal flow of water.

3.8.3. **Aqueduct:** is an artificial channel through which water, flowing with a free surface, is taken across a valley, drain, canal, river, road or railway.

3.8.4. **Backwater:** is the water in a stream rising above its normal level due to some obstruction in flow down stream.

3.8.5. **Bridge:** is a drainage structure, with a total linear opening of more than 6 m erected for carrying traffic across a natural or artificial water course, a railway track, another roadway or any other obstruction.

3.8.6. **Catchment area:** is the area from which the rainfall flows into a drainage channel at any specified section.

3.8.7. **Coffer dam:** is a temporary box like structure or enclosure formed to isolate the area which it encloses for excluding water therefrom.

3.8.8. **Deck level:** is the level of the crown of the carriageway over the deck.

3.8.9. **Diversion:** is an alteration in the course of the road, river, or a stream, as a temporary expediency, during construction, improvement or repairs.

3.8.10. **Free board:** is the vertical distance between the designed maximum flood level, allowing for afflux, if any, and the road surface level at its lowest point whether on the bridge structure or its approaches.

3.8.11. **Ledge:** is a shelf like level projection on rock or mountain.

3.8.12. **Pier:** is an intermediate support between the end support of a bridge or culvert.

3.8.13. **Pile:** is a column driven or screwed into or formed in the ground in order to consolidate the soil or to transmit the weight or the thrust of a structure to firm zones of the subsoil.

3.8.14. **Rocker bearing:** is a bearing or a support which permits slight angular movement at the supported ends of a bridge superstructure.

3.8.15. **Roller bearing:** is a bearing assembly, consisting mainly of rollers with suitably designed top and bottom plates which permit slight longitudinal movements at the supported ends of a bridge superstructure.

3.8.16. **Scour:** is the process of erosion and removal of matter by the action of running water on the bed stream.

3.8.17. **Shuttering:** is temporary timber or metal forms or other means used to mould the structure to shape.

3.8.18. **Silt:** is the fine grained soil (particles size from 75 micron to 2 micron) with little or no plasticity or no strength when air dried.

3.8.19. **Skew bridge or culvert:** is a bridge or culvert the centreline of which is not at right angle to the axis of the crossing.

3.8.20. **Submersible bridge:** is a bridge designed to allow normal floods to pass through its vents but allowed to be overtopped during high floods.

3.8.21. **Substructure:** is that part of the bridge or culvert which lies above the foundation level and below the superstructure seats, or below the springing line of the arches.

3.8.22. **Superstructure:** is that part of the structure which lies above the bridge seats or above the springing line of arches.

3.8.23. **Through bridge:** is a bridge in which the roadway is at or near the bottom chord level of the main supporting members.

3.8.24. **Water shed:** is the line of separation between adjacent catchment areas.

3.9. **Miscellaneous**

3.9.1. **Avalanches:** is a hurtling of a mass of snow/ice moving down from a height and gathering momentum in the descent which may carry rock fragments or earth from hill slope during movement.

3.9.2. **Improvement:** is reconstruction in whole or in part to a higher standard of strength, efficiency or quality.

3.9.3. **Landslide:** is earth slips on a large scale.

3.9.4. **Maintenance:** is the upkeeping of a construction to a definite standard of efficiency and quality.

3.9.5. **Pothole:** is a marked local depression in a surface layer, roughly circular in plan, arising from the displacement or wearing away of material by traffic or other causes.

3.9.6. **Settlement:** is the downward movement (depression) of the soil or structure, which it supports due to shrinkage by consolidation or subsidence caused by the movement of subsoil.

3.9.7. **Slip:** is the local soil movement produced by a mass of soil sliding over a slope.

3.9.8. **Spur:** The word is normally used in hill roads to indicate the convex portion of the hill feature on the road alignment sloping in one direction only. These are also structures made to train the flow and reduce the velocity of water in channel.

3.9.9. **Subsidence:** is the downward movement of the soil produced by removal or displacement of the underlying strata.

3.9.10. **Tunnel:** is a passage through a hill to be used as a road, rail track or water channel.

4. PLANNING CRITERIA

4.1. Transportation Needs

Transport is a vital infrastructure for rapid economic growth of a country. Rail and Road are the dominant modes of transport in the country with railways providing trunk service for bulk movement of commodities as well as passenger traffic and road transport taking up most of the medium and short haul traffic including feeder and distribution activities. In the near absence of network of railways in interior hill areas, roads are the main, if not the only, means of communications. Hill areas, by and large have remained to an extent remote, inspite of a large network of roads to interior areas constructed since independence, due to inadequate road system connecting far interior and remote villages. The need for roads in the hill areas will be ever increasing considering the vastness of the hill areas and the density of roads required to cater all infrastructural development and strategic needs.

4.2. Traffic Surveys

4.2.1. The fundamental measure of traffic on a road system is the volume of traffic using the road in a given interval of time. The traffic is usually expressed in terms of vehicles per hour or vehicles per day. When the traffic is composed of a number of types of vehicles, it is a normal practice to convert the flow into equivalent Passenger Car Units (PCUS) by using equivalency factors given in Table 10-2 .

4.2.2. Judicious location of traffic count stations is very important. For trunk routes serving inter-city traffic, the census site should be placed well away from all urbanised developments and villages. Every road should be divided into convenient sections each carrying approximately similar traffic between points of substantial traffic change. Count stations should be set up for each section. Traffic should be counted at each point at least twice a year. One count should be taken during peak season of harvesting and marketing and the other during lean season. Guidelines given in IRC:9-1972 'Traffic Census on Non-Urban Roads' should be followed for carrying out traffic census on all important trunk routes like National Highways, State Highways and Major District Roads. A field data sheet form for the normal recording of hourly traffic flows is given in Appendix-1. Form for daily traffic summary is given in Appendix-2.

4.2.3. For new roads connecting new areas an estimation of traffic likely to be generated can be done by population and consumer need studies, development plans for the area and traffic on adjacent roads.

4.3. Capacity of Roads

4.3.1. Capacity analysis is fundamental to the planning, design and operation of roads and provides among other things the basis for determining the carriageway width to be provided at any point in a road network with respect to the volume and composition of traffic. It is also a valuable tool for evaluation of the investments needed for future road construction and improvements and for working out priorities between competing Projects.

4.3.2. IRC:64-1990 'Guidelines for Capacity of Roads in Rural Areas' contains recommended design service volumes for hill roads also. These are given in Table 4.1.

4.3.3. The capacity of two lane roads can be increased by providing paved and surfaced shoulders at least 1.5 m width on either side. Provision of hard paved shoulders results in slow moving traffic being able to travel on the shoulder which reduces the interference to fast traffic on the main carriageway. Under these circumstances, 15 per cent increase in capacity can be expected vis-a-vis the values given in Table-4-1.

Table 4.1. Recommended Design Service Volumes for Hill Roads

S. No.	Type of Road	Design Service Volume in PCU/day		
		Carriage-way width	For low curvature (0-200 degrees per km)	For high curvature (above 200 degrees per km)
1.	Single lane	3.75 m	1,600	1,400
2.	Intermediate lane	5.5 m	5,200	4,500
3.	Two lane	7 m	7,000	5,000

4.4. Planning of Roads in Hill Areas

4.4.1. Planning of roads in hill areas is much different from plains. Villages are small and scattered in valleys and over slopes of numerous hill ranges located at different altitudes. These cannot be connected by straight roads as in plains. Alignment of roads has thus to be circuitous and is primarily governed by topography.

4.4.2. In hilly areas, road links should be provided on the basis of cluster or group of villages as far as feasible because the population of each village may be very low. Villages located within a radius of 1.6 km and having an altitude difference of not more than 200 m can be considered as one cluster or group. Isolated villages, having population of more than 500 should be provided with an all-weather link road. For a cluster of villages of population less than 500, a selective approach of an all-weather road within 5 kms from the village may be considered to start with. Where funds do not permit construction of regular motor road, road may be constructed for light vehicular traffic to link villages.

4.4.3. Due to topographical constraints and location of small isolated villages, it may not be possible to connect all villages with motorable roads. However for the development of the area and its economic growth, there is a need to connect all villages and production centres with some means of communication. The isolated villages/habitations can be connected by bridle roads after bringing them within 2 to 3 km of a motorable road, with an altitude difference of, say, not more than 200 m. Gravity type aerial cableways can also be provided for cheaper and easier transportation of produce to road-head from such isolated habitation, where necessary.

4.4.4. As in the rest of the country, roads in hill areas are also classified as National Highways, State Highways, Major District Roads, Other District Roads and Village Roads according to specifications, traffic needs, socio-economic, administrative or strategic considerations. However, from topographical considerations, these can broadly be divided into Arterial roads and Link roads. Arterial roads are trunk routes and can be further divided into Major valley roads and Inter-valley roads. While former run in major valleys along rivers/streams or in some cases, depending upon topography, near to the ridge line, the latter traverse through different valleys, connecting one major valley to another either running near to the ridge line or across slope of hill ranges, rising from one valley to the ridge and going down to the next valley and so on, connecting enroute a number of villages to market or administrative centres. Arterial roads will include National/State Highways and Major District Roads. Link roads take off from Arterial roads to link villages/production areas in small/sub-valleys. These will comprise Other District Roads and Village Roads.

4.5. Priority Strategies

4.5.1. The priority for hill roads in rural areas should be as under:

i) Village connectivity as per criteria proposed in para 4.4.2. For hamlets (Wadis) of villages located away from main villages connection may be provided by pathways and foot bridges.

ii) **Upgrading of existing unsurfaced roads.** Such roads can be used only as fair weather roads with limited level of service. These roads require to be surfaced and provided with cross-drainage works for serving as an all-weather road connection.

4.5.2. While deciding interse priority for upgradation of the existing unsurfaced road length vis-a-vis new connections, the thrust should be for providing new connections, unless all weather route is essential for the traffic needs.

4.6. Ecological Considerations

4.6.1. Construction of roads in hilly region disturbs the ecosystem in many ways. The main ecological problems associated with hill roads construction are:

i) Geological disturbances
ii) Land degradation and soil erosion
iii) Destruction and denuding of forest
iv) Interruption and disturbance to drainage pattern
v) Loss of forestry and vegetation
vi) Aesthetic degradation
vii) Siltation of water-reservoirs

These factors underline the need to plan, align and construct hill roads after careful thought. The help of geologists and environmental specialists should, therefore, be enlisted while planning for hill roads. Details in this regard are given in Chapter 19 and can be referred.

5. SURVEY AND ALIGNMENT OF HILL ROADS

5.1. General

5.1.1. In this Chapter, guidelines for carrying out survey work in fixing alignment of hill roads situated primarily in a rural or non-urban area are given.

5.1.2. The requirement of the road is decided based on administrative, developmental, strategic, other needs and the obligatory points to be connected by the road. Control points between obligatory points are governed by saddles, passes, valleys, river crossings, vertical and over-hanging cliffs, forest and cultivated land and other natural features like escarpments, slide-prone, avalanche-prone and other unstable areas. The control points are determined by the appropriate technical authority.

5.1.3. In order to explore the possibility of various alternative alignments, preliminary investigation should start from the high obligatory or control summit points and proceed downwards. The alignment finally selected linking the obligatory and control points should fit in well with the landscape. The aim should be to establish a safe, easy, short and economically possible line of communication between the obligatory points considering the physical features of the region and traffic needs apart from least disturbance to the eco-system. Ideal road alignment is the one which will cause the least over-all transportation cost taking into account the costs of construction, maintenance, and recurring cost of vehicle operation.

5.1.4. The route should avoid the introduction of hair-pin bends as far as possible. However if such a provision becomes inevitable, the number of hair-pin bends should be reduced to absolute minimum and the inevitability of each hair-pin bend should be recorded in the reconnaissance report. Further, the bends should be located on stable and flat hill slopes, and their location in valleys avoided. Also, a series of hair-pin bends on the same face of the hill should be avoided.

5.1.5. Economy in operating cost of transport vehicles is achieved by adopting easy grades, minimising rise and fall and by following a direct line as far as possible between obligatory points. Although shortest distance is an important factor, it may have to be sacrificed, at times, in order to obtain easy curvature and gradients, to avoid prohibitive cuts or fills and long river crossings. Even a longer road length to ease gradient and curves may result in a more economical operating cost.

5.2. Sequence of Survey and Survey Methods

5.2.1. With the guidelines enumerated under para 5.1 the work, right from the initial survey to fixing final alignment of a hill road, should follow sequence as under.

(a) Reconnaissance
(b) Preliminary Survey.
(c) Determination of Final Centre line
(d) Final Location Survey

5.2.2. To facilitate the survey team in the tentative selection of alternative alignments for subsequent detailed ground reconnaissance it will be advisable, if economy of the project permits, to take advantage of modern techniques like Aerial Survey, Photogrammetry and Remote Sensing.

5.3. Reconnaissance

5.3.1. **General:** Once the obligatory points are known the next step will be to undertake reconnaissance survey in the following sequence:-

(a) Study of topographical survey sheets, geological and meteorological maps and aerial photographs, where available.
(b) Preliminary aerial reconnaissance (as against aerial photographs), where practicable.
(c) Ground reconnaissance.
(d) Final reconnaissance of inaccessible and difficult stretches

5.3.2. **Study of survey sheets, maps etc:-** Topographical sheets are available in the scale of 1 : 50000, i.e. 2 cm to 1 km, showing towns, villages, rivers and terrain features with altitudes and contour lines at intervals of 20 m. Close study of these sheets and the geological and meteorological maps of the area is essential in order to locate the obligatory and control points and to mark tentatively alternative feasible routes on the topo sheet for further survey on ground. Such study should be done by a Senior Civil Engineer to select tentatively and mark the possible routes on the map keeping in view the guiding principles given in Appendix-3 as reproduced from Appendix-1 of IRC-52-1981 "Recommendations About the Alignment Survey and Geometric Design of Hill Roads".

Aerial photographs of the area under survey, if available, to the scale of 1 in 20,000 to 1 in 50,000, will supplement the information obtained from topographical maps. With stereoscopic techniques a skilled photo-interpreter can not only gather quantitative data but also obtain significant soil and sub-soil information from such photographs which will be very useful in selecting the alignments.

5.3.3. **Aerial reconnaissance**: Aerial Reconnaissance will provide a bird's eyeview of the alignments under consideration and the surrounding area. It will help identify factors which call for rejection or modification of any of the alignments. Final decision about the alignments to be studied in detail on the ground can be taken up on the basis of aerial reconnaissance.

5.3.4. Where required, this should be done by a Senior Civil Engineer in charge of the Project alongwith two other assistants. This aerial reconnaissance is essential to verify the correctness of the details of obligatory and control points indicated in the top sheets and also to find out other control points, if any, not shown in the map. Such reconnaissance will confirm the feasibility of the routes for proceeding further with ground reconnaissance. The team doing the aerial reconnaissance will have to carry the following documents and equipment alongwith them:-

(a) Topographical sheets, where tentative routes are marked along with the details of obligatory and control points obtained on study of maps.
(b) Photo mosaics or aerial photographs of the area, if available, with pocket stereoscopes.
(c) Binoculars
(d) Altimeters

5.3.5. The aerial recce party will have to fly over the area covering the possible routes selected from study of maps and air photographs and examine the following points making notes of observations:-

(a) Correctness of obligatory points as given in the map.
(b) Correctness of control points as marked in the map.
(c) Existence of any other control points not marked in the map like -

(i) Major saddless/passes
(ii) River crossings
(iii) Slide/slip areas
(iv) Marshy areas

(v) Camping sites
(vi) Rocky areas
(vii) Vegetation

5.3.6. The altitudes of various obligatory and control points can also be recorded roughly from the altimeter, taking due consideration of the height at which the aircraft hovers over the required points. On completion of the reconnaissance, the team should do following:-

(a) Selection of various alternative feasible routes.

(b) Decide on control points.

(c) Preparation of the tentative route maps, if so needed, for taking up ground reconnaissance.

5.3.7. **Ground reconnaissance**: The various alternative routes found feasible as above are further verified physically in the field by ground reconnaissance to recommend the final route. It consists of general examination of the ground by walking or riding along the probable routes and collecting all essential and available data as per guidelines given in Appendix-4.

5.3.8. This part of the survey is very important in the selection of the final route and should be carried out by a Recce Team headed by an engineer of some experience and associated with the survey right from map study and aerial reconnaissance (preferably not less than an Assistant Executive Engineer) supported and assisted by necessary technical and administrative staff and labour. It will be beneficial to associate a Geotechnical Engineer or Geologist with this work.

5.3.9. A suggested composition of the team and equipment required to be available for efficient and effective conduct of the ground survey is given in Table 5.1.

Table 5.1. Suggested Composition of Team and Equipment

Team			Equipment Required		
1.	Assistant Executive Engineer (Civil)	- 1	1.	Topographical sheets	
			2.	Binocular	- 3
			3.	Altimeter	- 2
2.	Junior Engineer or Senior Supervisor-	1	4.	Ghat Tracer & Staff	- 2
			5.	Quick setting level	- 2
3.	Geotechnical Engineer/ Geologist	- 1	6.	Measuring tape (30m)	- 2
			7.	Prismatic Compass	- 2
			8.	Wireless set	- 1
4.	Surveyor/Overseer	- 2	9.	Ranging Rods	- 20
			10.	Datri for bushes/shrubs cutting	- 2
			11.	Red and white flags	
5.	Local Interpreter (if required)	- 1	12.	Graph paper	
			13.	Writing equipment	
			14.	First-Aid Kit	
6.	Labour with T & P		15.	Tents, rope, utensils	
			16.	Personal clothing	
7.	Administrative staff like sentry, cook etc.		17.	Walkie Talkie (if possible)	- 2
			18.	Items for preparing food	

5.3.10. Where necessary, local habitants may also be associated with ground reconnaissance.

5.3.11. The general method of ground reconnaissance and fixing route/grade pegs by the reconnaissance team are described below:-

(a) A starting point is fixed near the first obligatory point at a higher ground from the surrounding area from where one can see the next obligatory and/or some nearby control points. Being the starting point of the traverse survey, a cement concrete masonry block of dimensions 30 cm x 30 cm x 60 cm (deep) with upper surface 20 cm above the ground should be erected on which the bench mark/altitude, chainage, etc. should be marked. From the altitudes of the two control points the approximate distance to be traversed between these two points can be ascertained taking into consideration a gradient flatter than the ruling gradient by 20 per cent or so (if ruling grade is 5%, grade assumed is 4%) depending on slope of the hill side. The jungle ahead of the fixed point is cleared along the route for placing and sighting the alignment and ranging poles. The width of jungle clearance should be 0.6-1.2 m or even more if required. The direction of, route should be checked with the aid of survey instruments.

(b) With abney level and/or ghat tracer the route line along the hill face should be ranged at the required grade and the corresponding position on ground located by ranging rod and driving the grade peg into the ground, keeping the top of peg at level as per required gradient. Such grade pegs may be positioned at intervals between 25-100 metres or closer where required.

(c) The distance of the grade peg from the preceding one is measured and recorded in field book. On the peg, the serial number, distance, gradient (rise/fall) are marked in paint. The process is repeated at next location.

(d) The indication of the grade peg for the detailed survey party should be marked by a clearly visible sign noticeable from a distance on the route. This is generally done by debarking a portion of a nearby tree of size 20 cm by 10 cm at the eye level and indicating in red paint direction, distance, the serial number and chainage of the connected grade peg. In places, where trees are not available, the hill face near the grade peg may be levelled about 30 cm square and then a pole at about 2 meter high with a cross piece tied to it is firmly fixed near the peg to indicate the position of the connected grade peg. In rocky area the level, line could be marked on the rock face with red paint and details required, as above, be written just above the level line. Any other method, depending upon the terrain and local facility available, may be adopted; the main aim being that the survey party for detailed survey, to be done later, should not have any difficulty in locating the reference and grade pegs on the route. However, the method adopted should be clearly indicated in the field book and reconnaissance report.

(e) Whenever a high hill range has to be crossed, it is essential to select a suitable pass or saddle (which becomes a control point) and to work from the top downwards. This is more convenient than working from bottom upwards, as in the latter case, there is a possibility of missing the pass or saddle especially when the area is dense jungle.

(f) Cross sections are taken with Abney level at about 25 to 100 meters apart or any other interval convenient to indicate the hill slope. Notes will have to be recorded in field book on the following points:-

(i) Nature and classification of soil (including rock out-crops, if any) encountered

(ii) The character of waterways and streams

(iii) Approximate span and type of culverts and bridging required

(iv) Availability of materials such as timber, stone, gravel, sand, etc.

(v) Location of quarries

(vi) Possible camping places and availability of drinking water

(vii) Any other useful information like availability of local labour, air dropping zone, helipad, etc.

(g) It has to be ensured that the survey and recording are made accurately by timely checking. A fortnightly progress report in the format given at Appendix- 5 alongwith a diagramatic chart showing the rough L-Section and also hill slopes (which need not be to scale) has to be prepared and submitted to the engineer authority who ordered the survey. It should contain adequate information to enable the Engineer who ordered the survey to get a fairly good idea, not only on the progress of the ground reconnaissance, but also on the suitability of the proposed alignment.

Similar procedure for carrying out the preliminary ground reconnaissance and submission of fortnightly report should be followed by the Survey Team in respect of all alternative alignments also.

5.3.12. **Reconnaissance report**:- On completion of reconnaissance survey on all the alternative routes a report alongwith a comparative statement of the alternative alignments in the proforma given at Appendix-6 should be prepared alongwith recommendations on the alignment to the Engineer authority who ordered the reconnaissance survey. The report should contain a plan on the scale of 1 : 50,000, showing alternative alignments alongwith their general profile and rough cost estimate. A sample of topo-sheet, showing two alternative alignments proposed, is given in Plate-1. The Senior Civil Engineer-in-Charge of the area should carry out inspection of the alternative alignments personally. Ground reconnaissance may disclose certain difficult stretches which call for detailed examination. A trace-cut might be made in such sections for inspection. Apart from this, before the alignment is accorded approval by the competent authority, it may be desirable to have one last round of aerial reconnaissance to resolve any remaining doubts. The reconnaissance report is processed to the competent authority for approval.

5.4. Ground Survey

5.4.1. **General:** This survey consists of pegging at 20 or 25 m intervals the route previously selected on the basis of the reconnaissance survey more accurately and at regular and close intervals, cutting a trace 1.0 to 1.2 m wide and running an accurate traverse line along it by taking longitudinal and cross sections of the alignment establishing hench marks at convenient intervals and fixing reference pegs where the direction of the alignment changes. The data collected at this stage forms the basis for the determination of the final centre line of the road. For this reason it is essential that every precaution is taken to maintain high degree of accuracy. Besides the above, general information concerning traffic, soil conditions, construction materials, drainage etc., which may be relevant for fixing the design features should also be collected during this phase. The Survey Team may be similar to that for reconnaissance with supporting staff and equipment.

5.4.2. This survey may be done in the following sequences:-

(a) Jungle clearance
(b) Pegging the alignment
(c) Trace cut
(d) Survey
(e) Map preparation

5.4.3. **Jungle clearance:** An advance party with required labourers and tools should commence clearing the jungle along the selected alignment to provide clear sight distance for three or four ranging pole/levelling staff positions at a time on each direction of the alignment. The party should commence work at least three days before the pegging party. The necessary clearance from forest department as required has to be obtained.

5.4.4. **Pegging the alignments:** A party consisting of the following personnel with necessary equipment should commence checking grade level, directions and curvature of the alignment arrived at earlier, during the reconnaissance refixing the correct alignment and repegging the alignment at convenient and workable distance, two to three days after the jungle clearance has progressed:-

Personnel

(a)	Junior Engineer	- 1 No.
(b)	Overseer/Surveyor	- 1 No.
(c)	Helper	- 4 Nos.
(d)	Labour	- as required

Equipment

(a)	Levelling Instrument (quick setting level)	- 2 Nos.
(b)	Ghat tracer	- 1 No.
(c)	Theodolite	- 1 No.
(d)	Surveyor's chain	- 2 Nos.
(e)	Mettalic tape 30 m	- 3 Nos.
(f)	T & P for labour	- as required
(g)	Prismatic Compass	- 1 set
(h)	Binoculars	- 2 pairs
(i)	Plain Table survey equipment	- 2 sets

5.4.5. The line, grade and direction of the selected alignment should be properly checked and corrected with the levelling instrument and theodolite with more details and accuracy. The gradient to be followed at this stage should be easier than the proposed to be achieved on the road by a margin of 20 per cent or so as stated in para 5.3.11(a). Procedure for pegging will be the same as in para 5.3.11 sub paras (c) and (d). However, the intervals of the pegs should be 20 or 25 m as per ground and terrain condition. The size of the pegs may be 6 cm dia or square and 60 cm long out of which 45 cm be driven into the ground. The indication about the grade should be provided at conspicuous locations so as to be easily visible from a distance as mentioned in para 5.3.11 subparas (b) to (d). To avoid confusion, the earlier markings made in the trees or roads or poles will have to be removed or erased once the corrected and revised makings are ascertained and displayed.

5.4.6. **Trace cut:** A party consisting of the following personnel, should carry cut the trace out along the selected alignment and follow the pegging party:-

(a)	Junior Engineer	- 1 No.
(b)	Surveyor/Overseer	- 1 No
(c)	Helper	- 2 Nos.
(d)	Labour with T&P	- as required

Trace Cut will be about 1.0 metre wide track cut along the selected alignment to facilitate access to the area for inspection and survey. It may not be possible to cut a trace where the pegged route traverses precipices and may, therefore, be detoured by cutting the trace either along the top or bottom periphery of these areas.

5.4.7. **Machans:** In continuous long stretches of rock, with sheer vertical faces where trace cutting is not possible, machans can be constructed by erecting framework with locally available ballies, resting on suitable ledges or pegs driven in the crevices/cracks in the rock-face on the valley side. 0.75 to 1.0 m wide platform/decking of ballies/bamboos with suitable railing wherever required, is provided on the top of the framework. Where suitable ledge/support is not available, the machans are constructed by hanging cane suspenders from trees or pegs driven in crevices/cracks on the rock-face on hill side and the platform/decking is tied to these cane suspenders. Typical sketches of machans are shown in Fig. 5.1. Where the rock is steep and inaccessibly deep for construction of machans, temporary pathways can also be developed by driving jumpers of iron rods into the rock-face and putting wooden ballies or planks over them for the men to safely walk along.

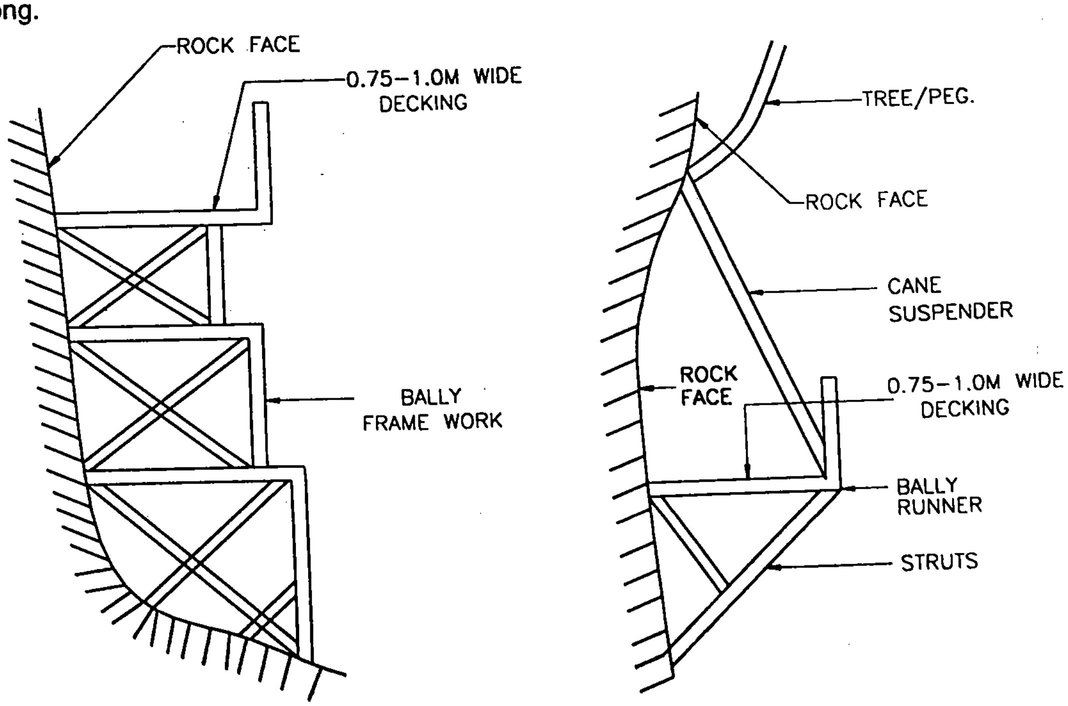

FIG. 5.1. MACHANS

The speed of construction of trace cut machans depends on the terrain and strength/skill of working party. For guidance and planning purpose, it may be assumed that a working party of about 50 - 100 labourers under a resourceful/imaginative supervisor/officer can achieve a daily progress of about 0.5 to 1.0 km of trace-cut in ordinary soil and 0.25 to 0.5 km in average rocky area, depending on cross slopes and jungle growth. The speed of construction of machans depends on availability of local materials like ballies/bamboos/cane, suitability of location for construction and skill of labourers. A gang of about 20 to 25 labourers can construct about 50 to 60 metres of machans per day in easy locations, whereas the speed can be as low as 10 to 15 metres per day in difficult locations.

Where ballies/bamboos are not easily available either because of non-availability or because of restrictions for their extraction, machans may be constructed using pre-fabricated angle iron section of 1.0 m to 1.5 m length which could be easily bolted at site.

5.4.8. **Survey procedure**: The survey should cover a strip of sufficient width taking into account the degree and extent of cut/fill, with some allowance for possible shift in the centre line of the alignment at the time of final design. Normally a strip width of about 30 m in straight or slightly curving reaches (i.e. 15 m on either side of centre line) and 60 m at sharp curves and hair-pin bends (i.e. 30 m on either side of centre line) should meet the requirement.

Traverse along the trace cut should be run with a theodolite and all angles measured by double reversal method. Alternatively this can be done by prismatic compass for less important roads. Distance along the traverse line should be measured with metallic tape or chain.

No hard and fast rule can be laid down as regards distance between two consecutive transit stations. In practice, the interval will be dictated by directional changes in the alignment, terrain condition and visibility. The transit stations should be marked by means of stakes and numbered in sequence. These should be protected and preserved till the final location survey.

Physical features such as buildings, monuments, burial ground, burning places, places of worship, pipelines, power/telephone lines, existing roads and railways lines, stream/river/canal crossings, cross drainage structures, etc. that are likely to affect the project proposals should be located by means of off-sets measured from the traverse line. Levelling work includes taking ground levels along the trace cut at intervals of 20-25 m and at closer intervals whenever there are abrupt changes in slope and also establishing bench marks at intervals of 250 metres, exceptionally 500 metres, by running check levels on a closed traverse basis independently. While levelling along the tentative centre line, readings of bench marks should also be taken so as to have a cross check in regard to accuracy of field work. It is particularly important that a single datum, preferably GTS datum, is used.

Cross sections should be taken at intervals of 20 or 25 m and at points of appreciable change in soil conditions. While taking cross sections, soil classifications should also be recorded. At sharp curves and difficult locations, detailed levelling may be done for the plotting of contours. Interval of contours may be 2 m though this could be varied according to site conditions.

5.4.9. **Map preparation**: At the conclusion of the ground survey plan and longitudinal sections (tied to an accurate base line) are prepared for detailed study to determine the final centre line of the road. At critical locations like sharp curves, hair-pin bends, bridge crossings etc, the plan should also show contours at 2 m intervals, so as to facilitate taking final decision. The map of the final road alignment may be prepared, where required, with the help of plain table survey as well.

Scales for the map should generally be the same as adopted for the final drawings. Normally horizontal scale might be 1 : 1000 and the vertical scale 1 : 100. However, for study of difficult locations such as steep terrain, hair pin bends etc., it may become necessary to have plans to a larger scale.

It will be a good practice to do survey work in the forenoon and plotting work in the afternoon so that any doubts arising can be cleared immediately thereafter by ground verification.

5.5. Final Location Survey

5.5.1. **Determination of final centre line:** Determination of final centre line of the road in the design office involves the following operations:-

(a) Detailed study should be done of the plans, longitudinal profile, cross-sections and contours of the final alignment prepared during the ground survey to work out various alternatives for the centre line of the proposed road. Out of these, the best one satisfying the engineering, aesthetic, economic and environmental requirements should be selected as the final Centre Line. Factors like economy in earth work, least disturbance to hill slope stability, efficient drainage, balanced cut and fill, requirement of protective works such as retaining/breast walls, etc. should be kept in view while making the final choice.

(b) For the selected final centre line, a trial grade line is drawn taking into acccount the control points which are established by mountain passes, intersections with other roads, river crossings, unstable areas etc. In the case of improvements to an existing road, the existing levels are also kept in view.

(c) For the centre line finally chosen, study of the horizontal alignment in conjunction with the profile is carried out and adjustments made in both, as necessary for achieving proper co-ordination.

(d) Horizontal curves including spiral transitions are designed and the final centre line marked on the map. A typical example of Final Centre Line chosen is given in Plate-2.

(e) The vertical curves are designed and the profiles are shown on the longitudinal sections.

5.5.2. The sub-group of this operation may comprise of the following personnel:-

(i)	Assistant Executive Engineer	- 1 No.
(ii)	Junior Engineer	- 1 No.
(iii)	Surveyor/Overseer	- 1 No.
(iv)	Helper	- 4 Nos.
(v)	Labour	- as required

5.5.3. **Transit survey:** The Final Centre Line of the road, as determined in the design office, is translated on the ground by means of a continuous Transit (Theodolite) survey and pegging of the centre line on the ground as the survey proceeds. All angles should be measured with a theodolite. It will be necessary to fix reference marks, to be pegged along the final centre line for this purpose. These marks should be generally 20 m apart in straight reaches and 10 m apart in curves. To fix the final centre line, reference pillars/control blocks of cement concrete of size 30 cm x 30 cm x 60 cm deep should be firmly embedded in the ground. These should be located beyond the expected edge of the cutting on the hill side. The maximum spacing of reference pillars may be 100 m. The following information should be put down on the reference pillars:-

(a) Reduced distance of the reference pillar/block

(b) Horizontal distance of the pillar/block from the centre line of the road

(c) Reduced level at the top of the reference pillar

(d) Formation level of the final centre line of the road.

The reference pillars should be so located that these do not get disturbed during construction. Description and location of the reference pillars should be noted in the field book for reproduction on the final alignment plans. Distance of the reference pillars from centre line of road should be measured along the slope, the slope angle determined with theodolite, and the actual horizontal projection calculated.

The final centre line of the road should be suitably pegged at 20 metres or closer intervals. The pegs are intended only for short period for taking levels of the ground along the centre line and the cross-sections with their reference. In the case of existing roads, paint marks may be used instead of pegs. Distance measurements along the final centre line should be continuous, following the horizontal curves, where these occur. At road crossings, the angles which the intersecting roads make with the final centre line should be measured with the help of a transit theodolite.

The sub-group for this operation may comprise of the following personnel:-

(a)	Junior Engineer	- 1 No.
(b)	Surveyor/Overseer	- 1 No.
(c)	Helper	- 2 Nos.
(d)	Labour	- as required

5.5.4. **Detailed levelling**: Bench marks: To establish firm vertical control for location, design and construction, bench marks established during the preliminary survey should be re-checked and where likely to be disturbed during construction re-established at intervals of 250 metres (but not more than 500 metres), and at or near all drainage crossings.

5.5.5. **Longitudinal sections and cross-sections:** Levels along the final centre line should be taken at all pegged stations and breaks in the ground. Cross-sections should be taken at 20 m intervals. In addition, cross-sections should be taken at points of beginning and end of spiral transition curves, at the beginning, middle and end of circular curves, and at other critical locations. All cross sections should be with reference to the final centre line, extend normally upto the right-of-way limits and show levels at every 2-5 metre intervals and all breaks in the profile.

Centre line profile should normally be continued atleast 200 metres beyond the limit of the road project. This is intended to ensure proper connecting grades at both ends. With the same objective, profile along all intersecting roads should also be measured upto a distance of about 150 metres. Further, at railway level crossings, the level of the top of the rails, and in the case of subways the level of the roof, should be noted. On existing roads, level should be taken at all points of intersection in order to help fix the final profile.

The sub-group for this operation may comprise of the following personnel:-

(a)	Surveyor/Overseer	- 1 No.
(b)	Helper	- 2 Nos.
(c)	Labour	- as required

5.5.6. Proper protection of points of reference: The final location survey is considered complete when all necessary data and information are available and ready for the designer to be able to plot the final profile and prepare the project drawings and detailed estimate. Among other things, field notes should give a clear description and location of all the bench marks and reference points. This information should be transferred to the plan drawings so that at the time of construction, the centre line and the bench marks could be located in the field without any difficulty.

At the time of execution, all construction lines will be set out and checked with reference to the final centre line established during the final location survey. It is important, therefore, that not only all the points referring the centre line are protected and preserved but these are so fixed at site that there is little possibility of their being disturbed or removed till the construction is completed.

5.5.7. Short notes on the following items that are relevant to survey and fixing of alignment or Hill Roads are given in Appendices-7 and 8.

(a) **Aerial Survey, Photogrammetry and Remote Sensing**

(b) **Geological Survey and Considerations**

5.5.8. **The survey and fixing of alignment having been done, the stage has been reached to design the road as per standards.**

6. GEOMETRIC DESIGN

6.1. General

6.1.1. Hill roads have mostly to negotiate through difficult topography, inhospitable terrain and extremes of climatic conditions. As such, design of hill roads to predetermined standards, considering importance of safety and free flow of traffic, is necessary so that travel is safe and comfortable.

6.1.2. Geometric design standards have been laid down keeping above in view.

6.2. Basic Principles of Geometric Design

6.2.1. Design criteria of hilly terrain should be applied for those roads located mostly in hilly terrain where stretches of plain/rolling terrain are short and isolated. Similarly where hilly terrain intervenes only for short and/or isolated stretches in plain/rolling terrain, criteria for such stretches should be as per standards for plain/rolling terrain.

6.2.2. A uniform application of design standards is desirable for safety and flow of traffic. The use of optimum design standards will reduce the possibility of early obsolescence of the facilities likely to be brought about by inadequacy of the original standards.

6.2.3. As a general rule, geometric features of a highway except cross sectional elements do not lend to stage construction, particularly in the case of hill roads. Improvement of features like grade and curvature at a later date can be very expensive and sometimes be impossible. It is, therefore, necessary that ultimate geometric requirements of hill roads are kept in view right in the beginning.

6.2.4. Development of cross-section in stages is technically feasible. But this should be decided only after very careful consideration, since hill roads need a lot of protective and drainage works like retaining walls, breast walls, drains of various types and categories etc, consistent with safety and sometimes the road may have to be altogether rebuilt when same is upgraded. If stage construction is unavoidable, better strategy will be to use dry masonry and/or crated masonry for drains, breast walls, pitching etc, locate the intercepter drain well back at the very start and provide culverts to full width formation/roadway to avoid the need for their widening subsequently. However, road being an important part or rather forerunner of all development activities, stage development will become inevitable over a period of time and as such a decision on this issue should be based on needs for a period of 15-20 years or so.

6.2.5. The design standards indicated are absolute minimum. However, the minimum values should be applied only where serious restrictions are placed by technical or economic considerations. General effort should be to exceed the minimum values on safer side to the extent possible. Where the minimum design standards cannot be adopted for inescapable reasons, proper signs should be put sufficiently in advance to inform the road users. The intention should be to provide a road to the user with such geometrics which gives safe and reasonably comfortable travel.

6.2.6. The standards have been classified separately for mountainous and steep terrain. Generally, the standards for steep terrain take lower values of design speed, radii of curve etc. It is likely that in many sectors, the terrain change from mountainous to steep or vice versa may be within short distances. It is, however, not the intention to change standards frequently. In practice, stretches should be classified as mountainous or steep depending on pre-dominant terrain in the stretch and accordingly standards adopted for that stretch. The same standards should, generally, continue for maximum distance possible/practicable.

6.2.7. **Elements of a Roadway (in hills and plains), classification of terrain and Road-land widths are depicted in Figs. 6.1, 6.2 & 6.3 respectively.**

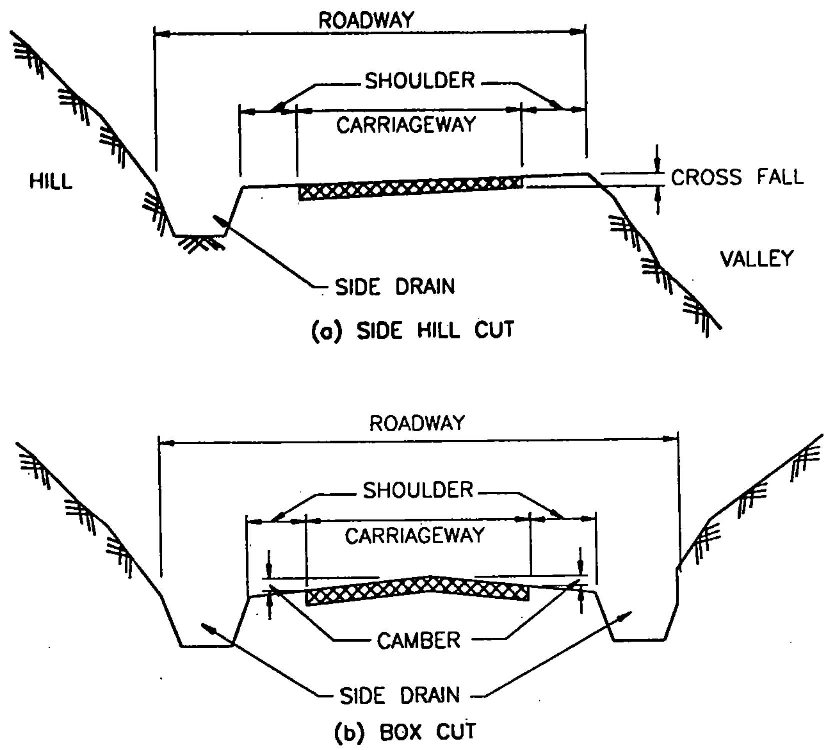

FIG. 6.1. ELEMENTS OF A ROADWAY

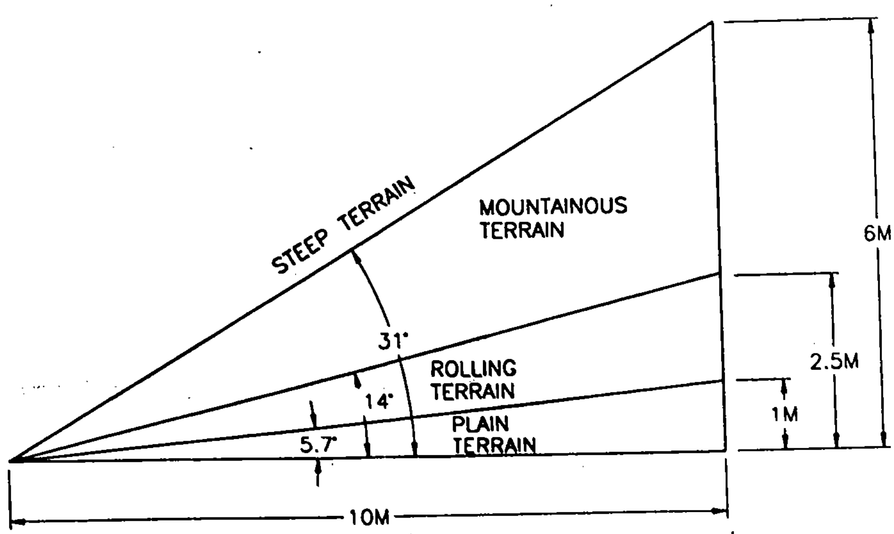

FIG. 6.2. CLASSIFICATION OF TERRAIN

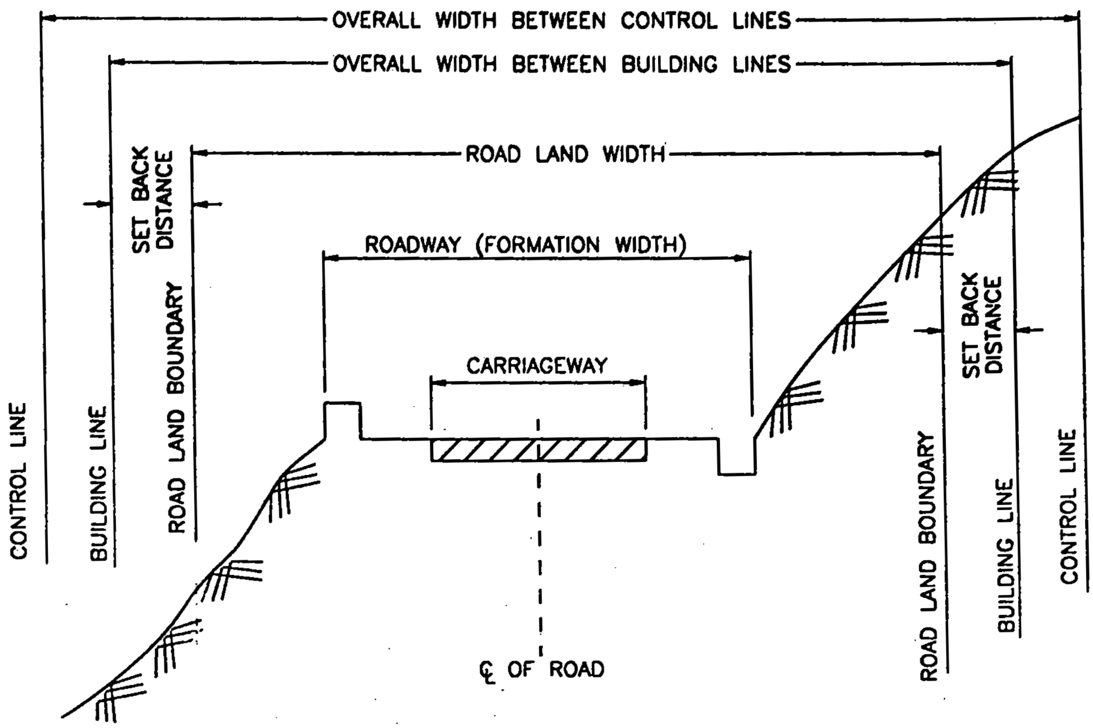

FIG. 6.3. ROAD LAND

6.3. Design Speed

6.3.1. The design speeds for various categories of hill roads are given in Table 6.1.

Table 6.1. Design Speed (km /h)

Sl. No.	Road Classification	Mountainous Terrain		Steep Terrain	
		Ruling	Min	Ruling	Min
1	National and State Highways	50	40	40	30
2	Major District Roads	40	30	30	20
3	Other District Roads	30	25	25	20
4	Village Roads	25	20	25	20

6.3.2. Normally, ruling design speed should be the guiding criteria for correlating the various geometric standards. Minimum design speed may, however, be adopted in sections where site conditions including costs do not permit adoption of ruling design speed.

6.4. Sight Distance

6.4.1. Visibility is an important requirement for safety on roads. For this, it is necessary that sight distance of sufficient length is available to permit drivers enough time and distance to control their vehicles to avoid accident.

6.4.2. Two types of sight distances are considered in design of hill roads. These are :

a) Stopping sight distance which is the clear distance ahead needed by a driver to bring his vehicle to a stop before meeting a stationary object in his path. It is the sum of braking distance at the particular speed plus the distance travelled by the vehicle during perception and brake reaction time.

b) Intermediate sight distance is defined as twice the stopping sight distance.

6.4.3. Design values of both sight distances and criteria for measurement of sight distance are given in Tables 6.2 and 6.3 below :-

Table 6.2. Design values of stopping and intermediate sight distance for various speeds

Speed (km/h)	Design values - metres	
	Stopping sight distance	Intermediate sight distance
20	20	40
25	25	50
30	30	60
35	40	80
40	45	90
50	60	120

Table 6.3. Criteria for measuring sight distance

Sl. No.	Sight Distance	Driver's eye height	Height of object
1	Safe stopping distance	1.2 m	0.15 m
2	Intermediate sight distance	1.2 m	1.2 m

6.4.4. On hill roads stopping sight distance is absolute minimum from safety angle and must be ensured regardless of any other considerations. It would be a good practice if this value can be exceeded and visibility corresponding to intermediate sight distance provided in as much length of road as possible. Advantage of intermediate sight distance is that the driver is able to get reasonable opportunities to overtake with caution and driving task becomes much easier.

6.4.5. Though a third category of sight distance i.e. Overtaking Sight distance is considered for roads in plains, it is not normally feasible/practicable on hill roads and hence not dealt with.

6.5. Width of Road Land, Roadway, Carriageway and Shoulders

6.5.1. Desirable widths of road land (right of way) for various categories of roads are given in Table 6.4

Table 6.4. Desirable Road Land widths (Metres)

Sl. No.	Road Classification	Open areas		Built up area	
		Normal	Exceptional	Normal	Exceptional
1	National and State Highways	24	18	20	18
2	Major District Roads	18	15	15	12
3	Other District Roads	15	12	12	9

In order to ensure proper sight distance, it may be necessary to acquire additional right of way over that indicated in the Table.

Notes
1. Right of way should be enough to ensure minimum set back of 5 m for building line from edge of road land boundary.
2. Additional land is required at locations involving deep cuts, high fills and unstable/landslide area.
3. If the road is planned to be upgraded in the future, land width should correspond to higher class of road.

6.5.2. Width of carriageway, shoulders and roadway for various categories of roads are given in Table 6.5.

Table 6.5. Widths of Carriageway, Shoulder and Roadway

	Highway Classification	Carriageway width (m)	Shoulder width (m)	Roadway width (m)
a	National Highways and State Highways			
	i. Single lane	3.75	2 x 1.25	6.25
	ii. Double lane	7.00	2 x 0.9	8.8
b	Major District Roads and other District Roads	3.75	2 x 0.5	4.75
c	Village Roads	3.00	2 x 0.5	4.00

Notes
1. The roadway widths are exclusive of parapets (usual width 0.6 m) and side drains (usual width 0.6 m)
2. In hard rock stretches or unstable locations where excessive cutting may lead to slope failure, width may be reduced by 0.8 m on two lane and 0.4 m on other roads. Where Such stretches are to be provided continuously for long distances, passing places should be provided.
3. On horizontal curves, roadway width should be increased to provide for extra widening at curve.
4. On roads subject to heavy snow fall, where snow clearance is done over long periods, roadway width may be increased by 1.5 m. However, the requirement of such widening may be examined with reference to ground conditions in each case considering terrain, traffic and other influencing conditions/factors.

6.5.3. The clear roadway width on culverts and causeways (measured from inside to inside of parapet walls or kerbs) should be the same as given in Table 6.5 but for village roads the desirable is 4.25 m.

6.5.4. For bridges, the clear width between kerbs should be 4.25 m for single lane bridges and 7.5 m for double lane bridges.

6.6. Camber/Cross Fall

6.6.1. Generally, the pavement in straight reaches should be provided with a crown in the middle and surface on either side sloping towards the edge. In case of winding alignments where straight sections are few and far between, a uni-directional cross fall towards the hill side may be given having regard to factors such as the direction of superelevation at the flanking horizontal curve, easy drainage and problem of erosion of downhill face etc. Typical section of road with camber and cross-fall is given in Fig. 6.4.

6.6.2. Camber/crossfall on straight section should be as follows :-

a. Earth road - 3 to 4 per cent (1 in 33 to 1 in 25)
b. Gravel or WBM surface - 2.5 to 3 per cent (1 in 40 to 1 in 33)
c. Thin bituminous surfacing - 2.0 to 2.5 per cent (1 in 50 to 1 in 40)
d. High type bituminous surfacing - 1.7 to 2.0 per cent (1 in 60 to 1 in 50)

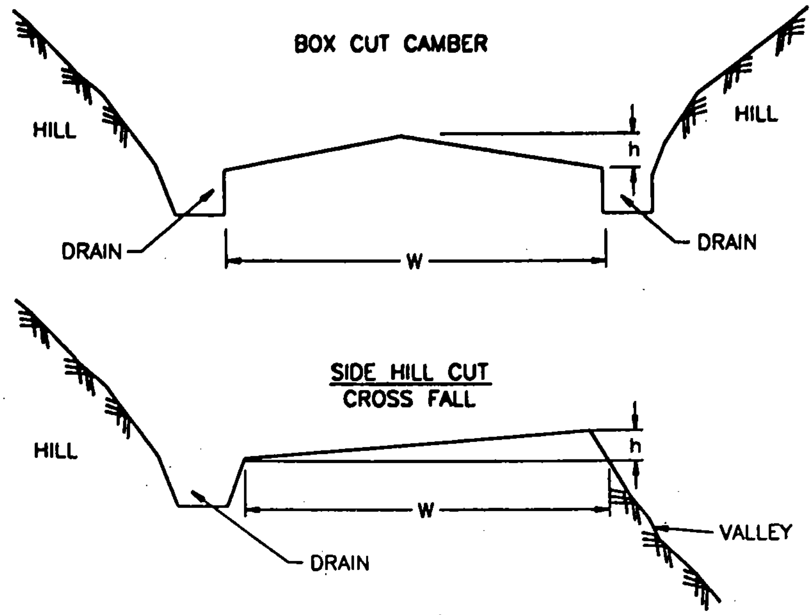

FIG. 6.4. CAMBER/CROSS FALL

W = ROAD WIDTH
h = CROSS FALL

6.6.3. For a given type of surface steeper values should be adopted for high intensity rainfall area and lower values for low intensity rainfall area.

6.6.4. Cross fall for earth shoulders should be atleast 0.5 per cent more than the pavement camber subject to a minimum of 3 per cent. If the shoulders are paved, crossfall appropriate to the type of paved surface as given in para 6.6.2 should be provided. On superelevated sections, the shoulders should normally have the same crossfall as the pavement.

6.6.5. As the provision of cross-fall and superelevation tend to oppose each other in re-entrants and drainage gets affected, appropriate transition and drainage arrangements should be made.

6.7. Clearance

6.7.1. Lateral clearance

6.7.1.1. Desirably the full roadway width at the approaches should be carried through the underpass. This implies that the minimum lateral clearance (i.e. the distance between the extreme edge of the carriageway and the face of the nearest structure/obstruction) should be equal to normal shoulder width. On lower category roads in hill areas, having comparatively narrow shoulders, it will be desirable to increase the roadway width at underpasses to a certain extent.

6.7.2. Vertical clearance

6.7.2.1. Minimum vertical clearance of 5 metres should be given over the entire roadway at all underpasses and similarly at overhanging cliffs and semi-tunnel sections. The vertical clearance should be measured from the highest point of carriageway i.e. crown or superelevated edge to the lowest point of overhead sturctures/rock out crop. Due allowance for future raising/strengthening of pavement should also be made.

6.7.3. Fig. 6.5 gives typical details of lateral and vertical clearance on a hill road.

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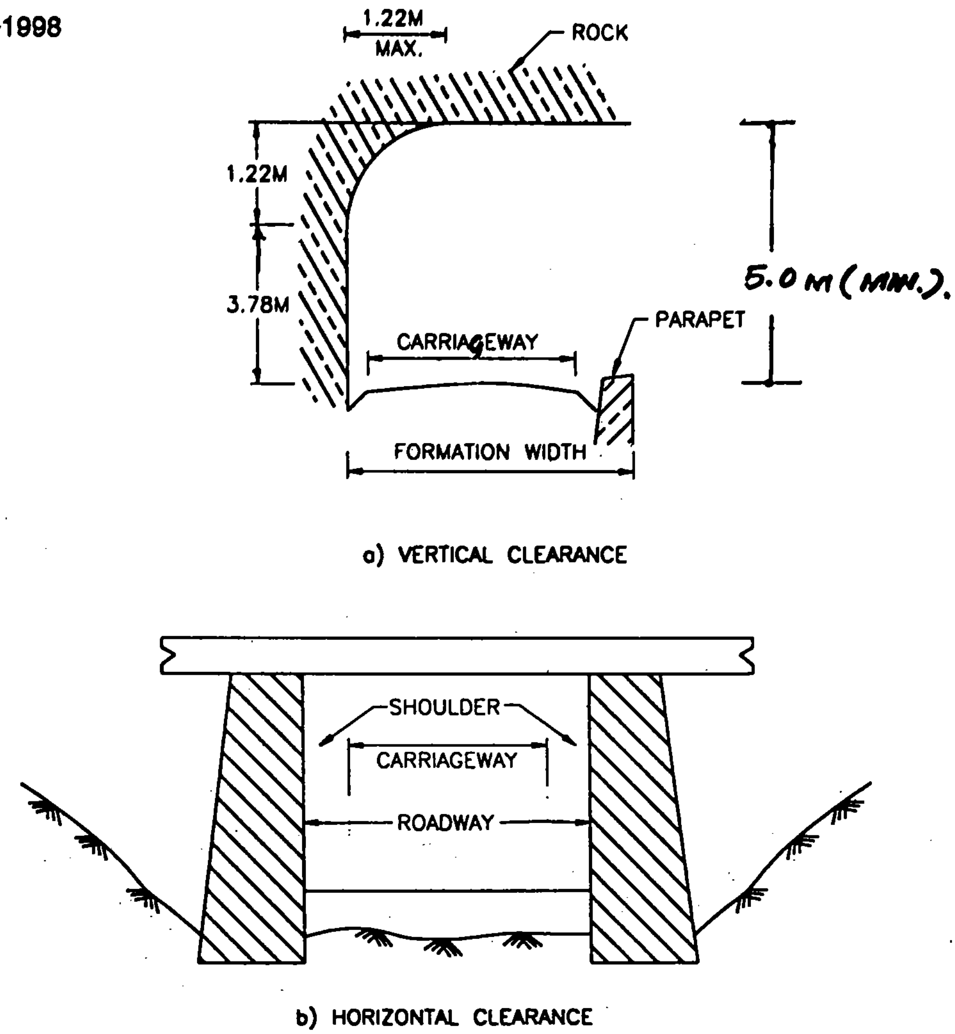


FIG. 6.5. TYPICAL DETAILS OF VERTICAL/HORIZONTAL CLEARANCE

6.8. Horizontal Alignment

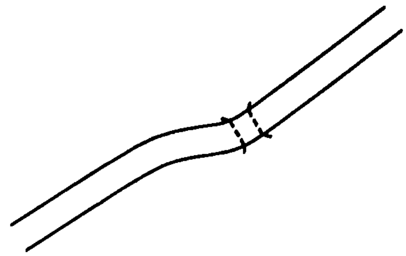
6.8.1. General

6.8.1.1. The horizontal alignment should be fluent and blend well with the surrounding topography. A flowing line which conforms to natural contours is aesthetically preferable to one with long tangents slashing through the terrain. The horizontal alignment should be co-ordinated carefully with the longitudinal profile.

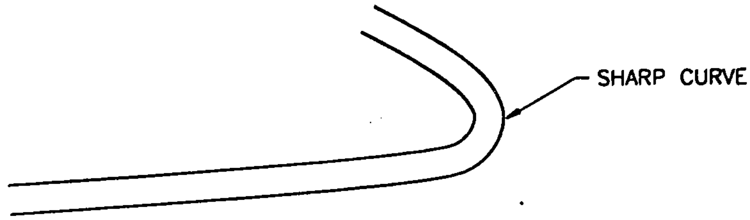
6.8.1.2. Breaks in horizontal alignment at cross-drainage structures and sharp curves at the end of long tangents/straight sections should be avoided, Fig. 6.6.

6.8.1.3. Short curves give appearance of kinks, particularly for small deflection angles, and should be avoided. The curves should be sufficiently long and have suitable transitions to provide pleasing appearance. Curve length should be atleast 150 metres for a deflection angle of 5 degrees and this should be increased by 30 metres for each degree decrease in the deflection angle. For deflection angles less than one degree, no curve is required to be designed.

6.8.1.4. Reverse Curves may be needed in difficult terrain by very sparingly used. It should be ensured that there is sufficient length between the two curves for introduction of requisite transition curves, Fig. 6.7.



(a) BREAK IN HORIZONTAL ALIGNMENT AT CROSS DRAINAGE STRUCTURE



(b) SHARP CURVE AT THE END OF LONG TANGENT

FIG. 6.6. BAD ALIGNMENT

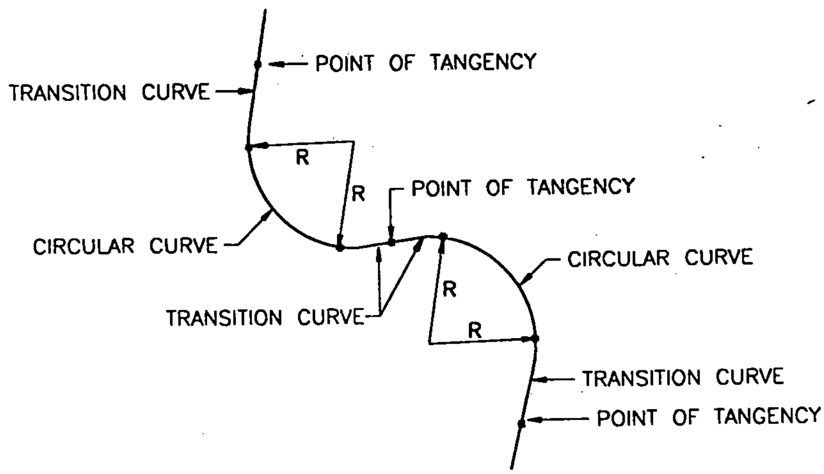


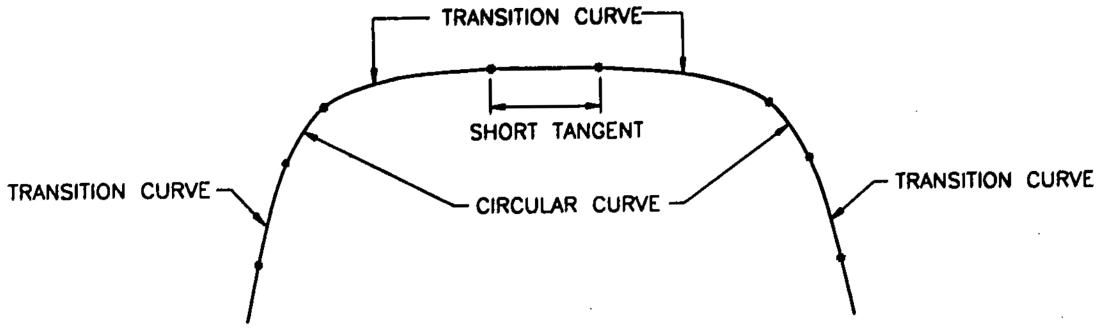
FIG. 6.7. REVERSE CURVE

6.8.1.5. Curves in the same direction separated by short tangents, known as broken-back curves, should be avoided as for as possible in the interest of aesthetics and safety and replaced by a single curve. If this is not feasible, a tangent length corresponding to 10 seconds travel time must atleast be ensured between the two curves, Fig. 6.8.

6.8.1.6. Compound curves may be used in difficult topography but only when it is impossible to fit in a single circular curve. To ensure safe and smooth transition from one curve to the other, the radius of the flatter curve should not be disproportional to the radius of the sharper curve. A ratio of 1.5 : 1 should be considered the limiting value, Fig. 6.9.

6.8.1.7. In general, horizontal curves should consist of circular portion of the curve followed by spiral transitions on both sides. Design speed, superelevation and coefficient of friction affect the design of curves.

Length of transition curve is determined on the basis of rate of change of centrifugal acceleration or the rate of change of superelevation.



CURVES IN THE SAME DIRECTION
WITH A SHORT TANGENT

FIG. 6.8. BROKEN-BACK CURVE

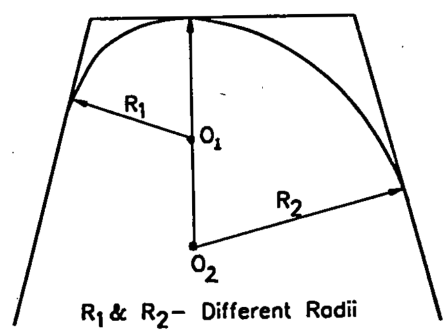


FIG. 6.9. COMPOUND CURVE

6.8.2. Superelevation

6.8.2.1. Superelevation is required to be provided at horizontal curves to counter the effects of centrifugal force and is calculated from the formula :-

$$e = \frac{v^2}{225\,R}$$

where

e	=	superelevation in metre per metre width of roadway
V	=	speed of vehicle in KMPH and
R	=	radius of curve in metres

The above formula assumes that the centrifugal force corresponding to three-fourth of design speed is balanced by superelevation and one-fourth counteracted by the side friction between the tyres of vehicles and the road surface.

6.8.2.2. Superelevation obtained from the above formula should, however, be kept limited to the following values :-

a.	In snow bound areas	-	7%
b.	In hilly areas not bound by snow	-	10%

6.8.2.3. The change over from normal section to superelevated section should be achieved over full length of transition curve. In case transition curve is not there or adequate length can not be provided due to some reason, two-third superelevation should be attained on the straight reach and balance on circular curve.

6.8.2.4. From the drainage point of view, the superelevation should not be less than the camber/crossfall appropriate to the type of wearing surface. Accordingly, when the value of superelevation obtained from formula in para 6.8.2.1 above is less than road camber/cross-fall, the later may be continued on the curved portion without providing any superelevation.

6.8.2.5. **Superelevation at culverts in curves** : The top surface of the wearing course of culverts should have the same cross profile as the approaches, The superelevation may be given on the abutments keeping the deck slab thickness uniform as per design. The level of the top of the slab of the culverts should be the same as the top level of the approaches so that any undue jerk while driving on the finished road is avoided.

6.8.2.6. Radii beyond which no superelevation is required; Table 6.6 shows the radii of horizontal curves for different camber rates beyond which superelevation will not be required.

Table 6.6. Radii beyond which superelevation is not required

Design speed (km/h)	Radii (Metres) for camber of				
	4%	3%	2.5%	2%	1.7%
20	50	60	70	90	100
25	70	90	110	140	150
30	100	130	160	200	240
35	140	180	220	270	320
40	180	240	280	350	420
50	280	370	450	550	650

6.8.2.7. **Methods of attaining superelevation** :The normal cambered section of the road is changed into superelevated section in two stages, First stage is the removal of adverse camber in outer half of the pavement. In the second stage, superelevation is gradually built up over the full width of the carriageway so that required superelevation is available at the beginning of the circular curve. There are three different methods for attaining the superelevation: (i). revolving pavement about the centre line; (ii). revolving pavement about the inner edge; and (iii). revolving pavement about the outer edge. Plate 3 illustrates these methods diagrammatically. The small cross sections at the bottom of each diagram indicate the pavement cross slope condition at different points.

6.8.2.8. Each of the above methods is applicable under different conditions. Method (i). which involves least distortion of the pavement will be found suitable in most of the situations where there are no physical controls, and may be adopted in the normal course. Method (ii). is preferable where the lower edge profile is a major control, e.g. on account of drainage. Where overall appearance is the criterion, method (iii) is preferable since the outer edge profile, which is most noticeable to drivers, is not distorted.

6.8.2.9. The superelevation should be attained gradually over the full length of the transition curve, so that the design superelevation is available at the starting point of the circular portion. Sketches in Plate 3 have been drawn on this basis. In cases where transition curve cannot, for some reason be provided, two-third superelevation may be attained on the straight section before start of the circular curve and the balance one-third on the curve.

6.8.2.10. In developing the required superelevation, it should be ensured that the longitudinal slope of the pavement edge compared to the centreline (i.e. the rate of change of superelevation) is not steeper than 1 in 150 for roads in plain and rolling terrain, and 1 in 60 in mountainous and steep terrain.

6.8.3. Minimum curve radii

6.8.3.1. On a horizontal curve, the centrifugal force is balanced by the combined effect of superelevation and side friction. Basic equation for this condition of equilibrium is as follows:-

$$\frac{v^2}{gR} = e + f$$

$$\text{or} \quad R = \frac{V^2}{127\,(e+f)}$$

where

v	=	vehicle speed in metres per second
V	=	vehicle speed in Km/hr
g	=	acceleration due to gravity in metres/Sec^2
e	=	Superelevation in metre
f	=	Coefficient of side friction between vehicle tyre and pavement (taken as 0.15)
r	=	Radius in metres

Based on this equation and maximum permissible value of superelevation, radii for horizontal curves corresponding to rulling minimum and absolute minimum design speeds are given in Table 6.7.

Table 6.7. Minimum Radii of Horizontal Curves for Various Classes of Hill Roads

Classification	Mountainous terrain				Steep terrain			
	Areas not affected by snow		Snow bound areas		Areas not affected by snow		Snow bound areas	
	Ruling Min (m)	Absolute Min (m)	Ruling Min (m)	Absolute Min (m)	Ruling Min (m)	Absolute Min (m)	Ruling Min (m)	Absolute Min (m)
National Highways and State Highways	80	50	90	60	50	30	60	33
Major District Roads	50	30	60	33	30	14	33	15
Other District Roads	30	20	33	23	20	14	23	15
Village Roads	20	14	23	15	20	14	23	15

Note: Ruling minimum and Absolute Minimum Radii are for ruling design speed and minimum design speed respectively.

6.8.4. Transition curves

6.8.4.1. Transition curves are necessary for a vehicle to have smooth entry from a straight section into a circular curve. The transition curves also improve aesthetic appearance of the road besides permitting gradual application of the superelevation and extra widening of carriageway needed at the horizontal curves. Spiral curve should be used for this purpose.

6.8.4.2. Minimum length of the transition curve should be determined from the following two considerations and the larger of the two values adopted for design.

i. The rate of change of centrifugal acceleration should not cause discomfort to drivers. From this consideration, the length of transition curve is given by:

$$L_s = \frac{0.0215\,V^3}{CR}$$

where

L_s = length of transition in metres
V = speed in Km/h
R = radius of circular curve in metres
$C = \frac{80}{75+V}$ (subject to a maximum of 0.8 and minimum of 0.5)

ii. The rate of change of superelevation (i.e. the longitudinal grade developed at the pavement edge compared to through grade along the centre line) should be such as not to cause discomfort to travellers or to make the road appear unsightly. The formulae for minimum length of transition on this basis are:

For Plain and Rolling Terrain :

$$L_s = \frac{2.7\,V^2}{R}$$

For Mountainous and Steep Terrain :

$$L_s = \frac{1.0\,V^2}{R}$$

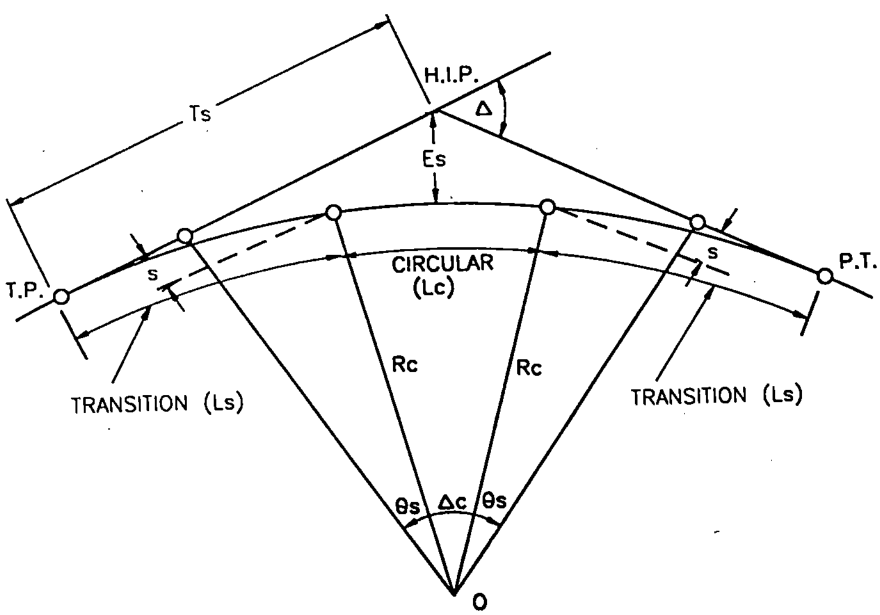
6.8.4.3. Having regard to the above considerations, the minimum transition lengths for different speeds and curve radii are given in Table 6.8.

6.8.4.4. The elements of a combined circular and transition curve are illustrated in Fig. 6.10. For deriving values of the individual elements like shift, tangent distance, apex distance, etc. and working out coordinates to lay the curves in the field, it is convenient to use curve tables. For this, reference may be made to IRC:38-1988 "Design Tables for Horizontal Curves for Highways".

Table 6.8. Minimum Transition Length for Different Speeds and Curve Radii

Curve radius (metre)	Design speed (km/h)				
	50	40	30	25	20
15				NA	30
20				35	20
25			NA	25	20
30			30	25	15
40		NA	25	20	15
50		40	20	15	15
55		40	20	15	15
70	NA	30	15	15	15
80	55	25	15	15	NR
90	45	25	15	15	
100	45	20	15	15	
125	35	15	15	NR	
150	30	15	15		
170	25	15	NR		
200	20	15			
300	15	NR			
400	15				
500	NR				

NA - Not applicable
NR - Transition not required



TANGENT POINT	T.P., P.T.
HORIZONTAL INTERSECTION POINT	H.I.P.
TOTAL DEVIATION ANGLE	Δ
DEVIATION AND CENTRAL ANGLE OF CIRCULAR ARC	Δc
DEVIATION ANGLE OF TRANSITION CURVE	θs
RADIUS OF CIRCULAR CURVE	Rc
SHIFT	s
TANGENT DISTANCE	Ts
APEX DISTANCE	Es
LENGTH OF TRANSITION	Ls
LENGTH OF CIRCULAR CURVE	Lc

FIG. 6.10. ELEMENTS OF A COMBINED CIRCULAR & TRANSITION CURVE

6.8.5. Widening at curves

6.8.5.1. At sharp horizontal curves, it is necessary to widen the carriageway to facilitate safe passage of vehicles. The widening has two components i.e. Mechanical widening to compensate the extra width occupied by the vehicle due to tracking of rear wheels and Psychological widening to permit easy crossing of vehicles, since vehicles tend to wander more on curve. Both the components are to be taken care of in double lane and mechanical components on single lane roads. However, at blind curves double-laning may be considered.

6.8.5.2. Extra width to be provided on horizontal curves is given in Table 6.9.

Table 6.9. Widening of Pavement at Curves

Radius of Curve (m)	Upto 20	21 to 40	41 to 60	61 to 100	101 to 300	Above 300
Extra Width (m)						
Two-lane	1.5	1.5	1.2	0.9	0.6	Nil
Single-lane	0.9	0.6	0.6	Nil	Nil	Nil

6.8.5.3. Extra width should be given by increasing the width at uniform rate along transition curve and full width given along circular curve. Entire widening should preferably be provided on inside of the curve. The extra widening may be attained by means of offsets radial to the centre line. It should be ensured that the pavement edge lines are smooth and there is no apparent kink.

6.8.6. Set-back distance at horizontal curves

6.8.6.1. Requisite sight distance should be available to sight the inside of horizontal curves. Lack of visibility in the lateral direction may arise due to obstructions like walls, cut slopes, wooded areas, high crops, etc. Set-back distance from the centre line of the carriageway, within which offending obstructions should be cleared, to ensure the needed visibility, can be determined as given in para 6.8.6.2. However, in certain cases, due to variations in alignment, road cross-section and the type and location of obstructions, it may become necessary to resort to field measurements to fix the exact limits of clearance.

6.8.6.2. The set-back distance is calculated from the following equation (see Fig. 6.11 for definitions):

$$m = R-(R-N)\ \cos\theta$$

where $\theta = \dfrac{S}{2\,(R-n)}$ radians;

m = the minimum set-back distance to sight obstruction in metres (measured from the centre line of the road);

R = radius at centre line of the road in metres'

n = distance between the centre line of the road and the centre line of the inside lane in metres; and

S = sight distance in metres

In the above equation, sight distance is measured along the middle or inner lane. On single-lane roads, sight distance is measured along centre line of the road and 'n' is taken as zero.

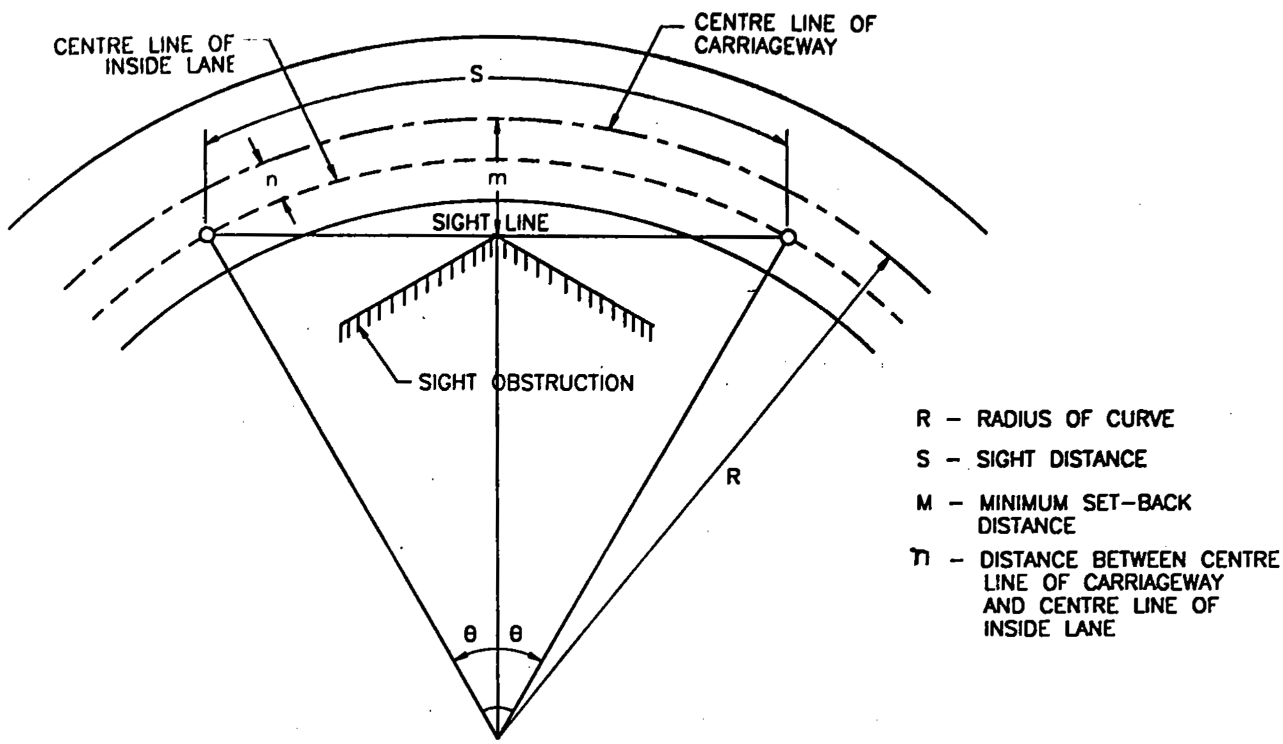


FIG. 6.11. VISIBILITY AT HORIZONTAL CURVES

6.8.6.3. Utilising the above equation, the design values for set-back distance corresponding to safe stopping distance for single lane carriageway are given in Table 6.10. These design values relate basically to circular curves longer than the design sight distance. For shorter curves, the values of set-back distance given in Table 6.10 will be somewhat on the higher side, but these can, however, be used as a guide. Lateral clearances for two lane carriageway can be computed similarly from the above equation.

Table 6.10. Recommended set-back Distance for Single-Lane Carriageway

Radius of Circular Curve in Metres	Set-Back Distance in Metres				
	S=20m (V=20 Km/h)	S=25m (V-25 Km/h)	S=30m (V-30 Km/h)	S=45m (V-40 Km/h)	S=60m (V-60 Km/h)
14	3.4	-	-	-	-
15	3.2	-	-	-	-
20	2.4	3.8-	-	-	
23	2.1	3.3-	-	-	
30	1.7	2.6	3.7	-	-
33	1.5	2.3	3.4	-	-
50	1.0	1.6	2.2	5.0	-
60	-	1.3	1.9	4.2	-
80	-	1.0	1.4	3.1	5.6
100	-	0.8	1.1	2.5	4.5
120	-	0.7	0.9	2.1	3.7
150	-	0.5	0.8	1.7	2.3

6.8.6.4. Lateral clearance for intermediate sight distance can be computed similarly but the set-back required is usually too large to be economically feasible in the case of hill roads.

6.8.6.5. Where there is a cut slope on the inside of the horizontal curve, the average height of sight line can be used as an approximation for deciding the extent of clearance. For stopping sight distance, this may be taken as 0.7 m. Cut slopes should be kept lower than this height at the line demarcating the set-back distance envelope, either by cutting back the slope or benching suitably, Fig. 6.12. Such a provision is also generally known as better benching or vision berms.

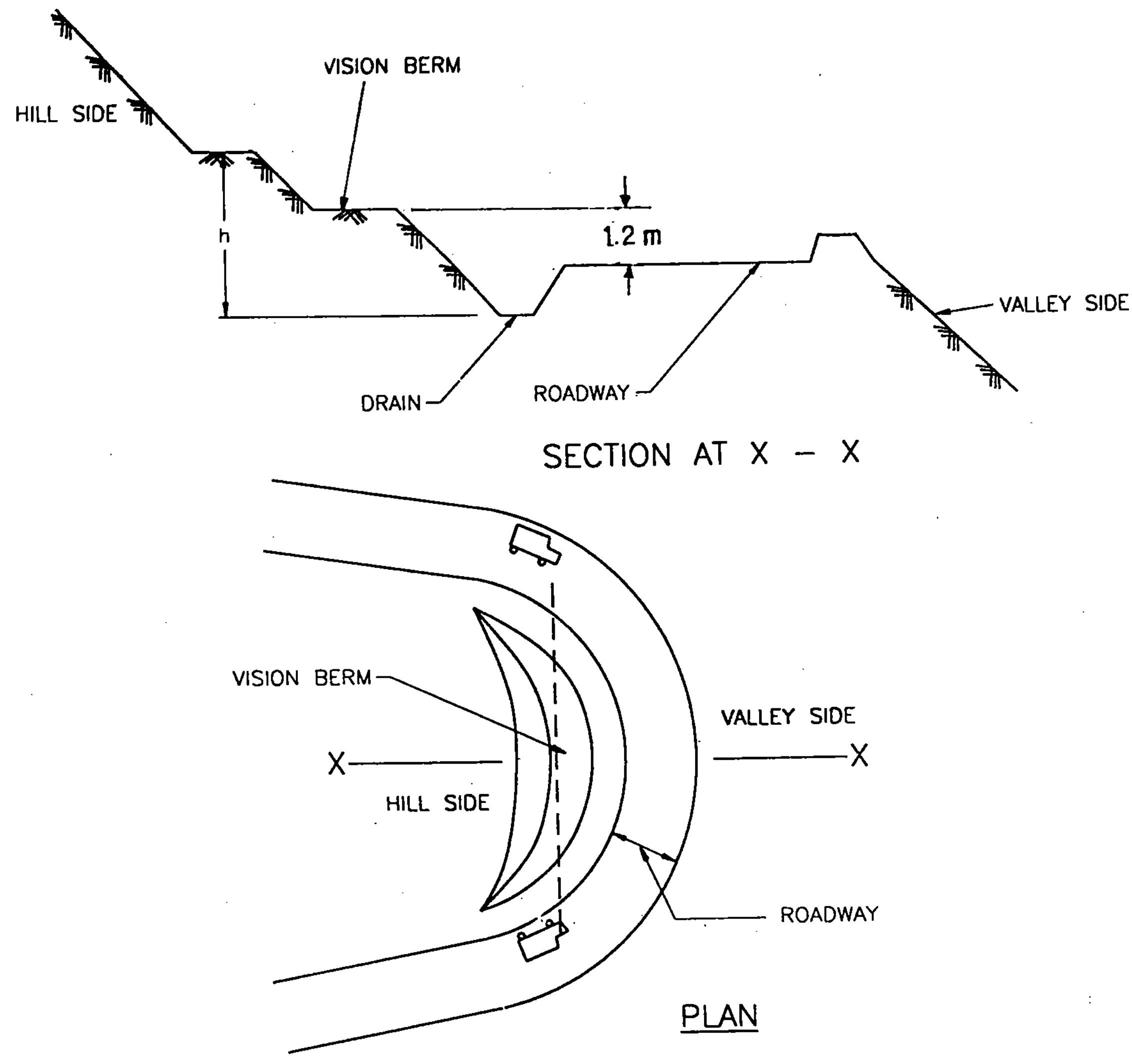


FIG. 6.12. VISION BERMS

6.8.7. Blind curves

6.8.7.1. Blind curves are those on which sight distance available is less than the safe stopping sight distance i.e. absolute minimum from safety point of view. While clearance of obstructions within the minimum set-back distance is expected to ensure the minimum sight distance required as per standards, in hill roads it may not always be possible to ensure this due to terrain conditions. In such cases certain curves will have sight distance less than minimum as per standards and hence blind.

6.8.7.2. In a blind curve there is always the danger of a vehicle not being able to come to a stop before reaching danger point or a vehicle coming from the opposite direction which is likely to collide with it, due to lack of adequate sight distance. The remedy for this problem, to ensure better traffic safety, may be provided as under:-

a) better benching or vision berms (Para 6.8.6.5 & Fig. 6.12 refers) in a more liberal manner as required on ground by survey.

b) making the road two - lane width in the stretch and providing lane dividers in the form of central studs or medians etc.

c) restriction of traffic to one way at a time in the stretch, if otherwise practicable.

6.8.7.3. It has to be ensured that blind curves are accepted only where it is un-avoidable and that also rarely in any stretch of road since trafficability and safety of a hill road is considerably reduced by blind curves.

6.8.8. Measurement of radius of an existing curve at site.

6.8.8.1. It is often necessary to know radius of an existing curve on a hill road to plan improvements etc. As it may not always be possible to reach the centre of curve, an indirect method may have to be adopted. A simple method is given below, Fig. 6.13.

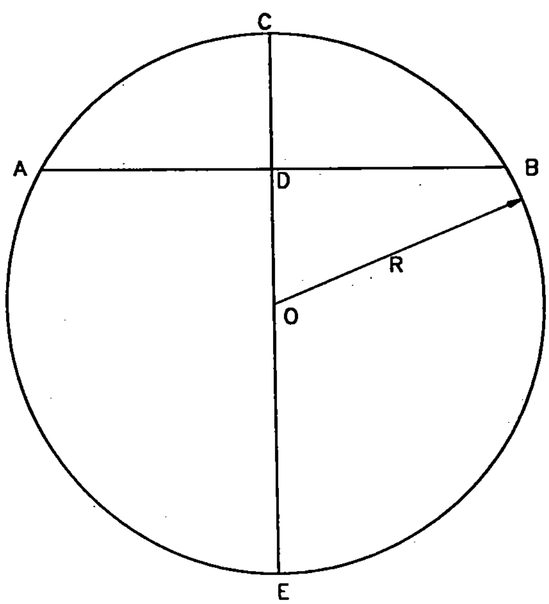


FIG. 6.13. AT SITE MEASUREMENT OF RADIUS OF EXISTING CURVE

Measure any chord AB and offset DC

Now AD x DB = CD x DE

$(1/2 \text{ chord})^2 = \text{offset} \times (2R - \text{offset})$

$= 2R \text{ offeset} - \text{offeset}^2$

ignoring offset^2; $1/4 \text{ chord}^2 = 2R \text{ offset}$

or

$$R = \frac{\text{Chord}^2}{8 \text{ offset}}$$

6.9. Vertical Alignment

6.9.1. General

6.9.1.1. Broken-back grade lines, i.e. two vertical curves in the same direction separated by a short tangent, should be avoided due to poor appearance, and preferably replaced by a single curve.

6.9.1.2. Decks of small cross-drainage structures (i.e. culverts and minor bridges) should follow the same profile as the flanking road section, with no break in the grade line.

6.9.1.3. Recommended gradients for different terrain conditions, except at hair-pin bends, are given in Table 6.11.

Table 6.11. Recommended Gradients for Different Terrain Conditions

Classification of Gradient	Mountainous terrain and steep terrain more than 3000 m above MSL	Steep terrain upto 3000 m height above MSL
Ruling Gradient	5% (1 in 20.0)	6% (1 in 16.7)
Limiting Gradient	6% (1 in 16.7)	7% (1 in 14.3)
Exceptional	7% (1 in 14.3)	8% (1 in 12.5)

6.9.1.4. Gradients upto the 'ruling gradient' may be used as a matter of course in design.

6.9.1.5. The 'limiting gradients' may be used where the topography of a place compels this course or where the adoption of gentler gradients would add enormously to the cost. In such cases, the length of continuous grade steeper than the ruling gradient should be as short as possible.

6.9.1.6. 'Exceptional gradients' are meant to be adopted only in very difficult situations and for short lengths not exceeding 100 m at a stretch. Successive stretches of exceptional gradients must be separated by a minimum length of 100 m having gentler/flatter gradient.

6.9.1.7. The cumulative rise/fall in elevation over 2 Km length shall not exceed 100 m in mountainous terrain and 120 m in steep terrain.

6.9.2. Grade compensation at curves

6.9.2.1. At horizontal curves, the gradients should be eased by an amount known as 'grade compensation' which is intended to offset the extra tractive effort involved at curves. This is calculated by the following formula.

$$\text{Grade compensation (per cent)} = \frac{30+R}{R} \text{ subject to}$$

maximum of 75/R where R is radius of the curve in metres. Since grade compensation is not necessary for gradients flatter than 4 per cent, when applying grade compensation correction, the gradients need not be eased beyond 4 per cent.

6.9.3. Vertical curve

6.9.3.1. Vertical curves are introduced for smooth transition at grade changes. Convex vertical curves are known as summit curves and concave vertical curves as valley or sag curves. Both these should be designed as square parabolas.

6.9.3.2. The length of the vertical curve is controlled by sight distance requirements, but curves with greater length are aesthetically better.

6.9.3.3. Curves should be provided at all grade change exceeding those indicated in Table 6.12. For satisfactory appearance, the minimum length should be as shown in the Table.

Table 6.12. Minimum Length of Vertical Curves

Design speed (Km/h)	Maximum Grade Change (percent) not requiring a vertical curve	Minimum Length of vertical curve (m)
Upto 35	1.5	15
40	1.2	20
50	1.0	30

6.9.3.4. Where horizontal and summit vertical curves overlap, the design should provide for the required sight distance both in the vertical direction along the pavement and in the horizontal direction on the inside of the curve.

6.9.4. **Summit curves** ***(Fig. 6.14)***

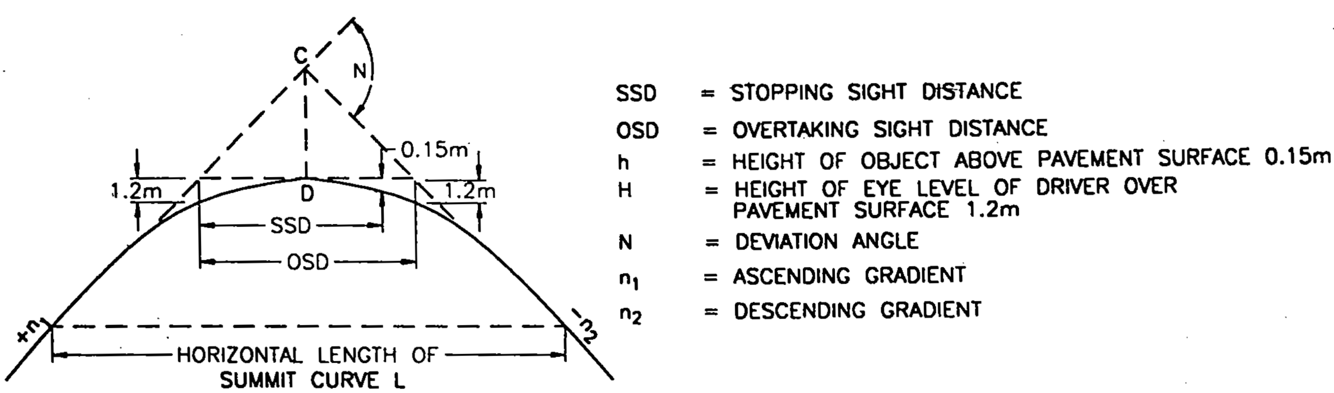


FIG.. 6.14. SUMMIT CURVE

6.9.4.1. The length of summit curves is governed by the choice of sight distance. The length is calculated on the basis of the following formulae.

a. For safe stopping sight distance

Case (i) When the length of the curve exceeds the required sight distance, i.e. L is greater than S.

$$L = \frac{NS^2}{4.4}$$

where

N = Deviation angle, i.e. the algebraic difference between the two grades.
L = Length of parabolic vertical curve in metres.
S = Sight distance in metres.

Case (ii) When the length of the curve is less than the required sight distance, i.e. L is less than S.

$$L = 2S - \frac{4.4}{N}$$

b. For intermediate sight distance

Case (i) When the length of the curve exceeds the required sight distance, i.e. L is greater than S.

$$L = \frac{NS^2}{9.6}$$

Case (ii) When the length of the curve is less than the required sight distance, i.e. L is less than S.

$$L = 2S - \frac{9.6}{N}$$

6.9.4.2. The length of summit curve for various cases mentioned above can be read from Plates 4 and 5. In these Plates, value of the ordinate "M" to the curve from the intersection point of grade lines is also shown.

6.9.5. **Valley curves (*Fig. 6.15*)**

6.9.5.1. The length of valley curves should be such that for night travel, the head light beam distance is equal to the stopping sight distance. The length of curve may be calculated as under:

Case (i) When the length of the curve exceeds the required sight distance, i.e. L is greater than S.

$$L = \frac{NS^2}{1.50 + 0.035\,S}$$

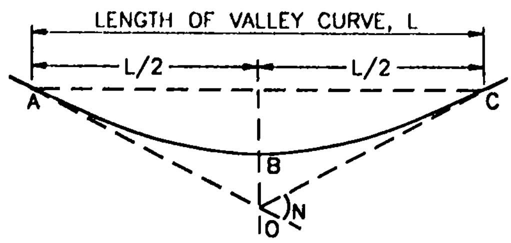


FIG. 6.15. VALLEY CURVE

Case (ii) When the length of the curve is less than the required sight distance, i.e. L is less than S.

$$L = 2S - \frac{1.5 + 0.35\,S}{N}$$

In both cases

N = deviation angle, i.e. the algebraic difference between the two grades
L = length of parabolic vertical curve in metres
S = stopping sight distance in metres

6.9.5.2. Length of valley curve for various grade differences is given in graphical form in Plate 6.

6.10. Design Criteria for Hair-Pin Bends (*Fig 6.16*)

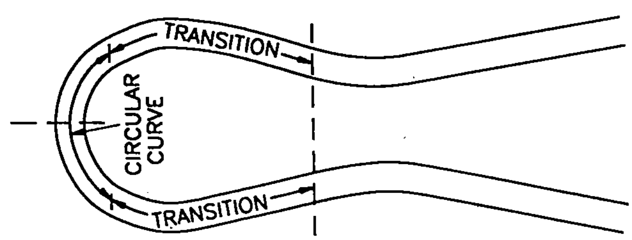


FIG. 6.16. HAIR PIN BEND

6.10.1. Hair-pin bends, where unavoidable, may be designed either as a circular curve with transition at each end, or as a compound circular curve. The following criteria should be followed normally for their design:

a	Minimum design speed	-	20 km/h
b	Minimum roadway width at apex		
	i. National/State Highways		11.5 m for double-lane 9.0 m for single-lane
	ii. Major District Roads and Other District Roads	-	7.5 m
	iii. Village Roads	-	6.5 m
(c)	Minimum radius for the inner curve	-	14.0 m
(d)	Minimum length of transition curve	-	15.0 m

(e)	Gradient		
	Maximum	-	1 in 40 (2.5 %)
	Minimum	-	1 in 200 (0,5 %)
(f)	Superelevation	-	1 in 10 (10 %)

6.10.2. Inner and outer edges of the roadway should be concentric with respect to centre line of the pavement. Where a number of hair-pin bends have to be introduced, a minimum intervening distance of 60 m should be provided between the successive bends to enable the driver to negotiate the alignment smoothly.

6.10.3. Widening of hair-pin bends subsequently is a difficult and costly process. Moreover, gradients tend to become sharper as generally widening can be achieved only by cutting the hill side. These points should be kept in view at the planning stage, especially if a series of hair-pin bends are involved.

6.10.4. At hair-pin bends, preferably, the full roadway width should be surfaced.

6.11. Passing Places (*Fig. 6.17*)

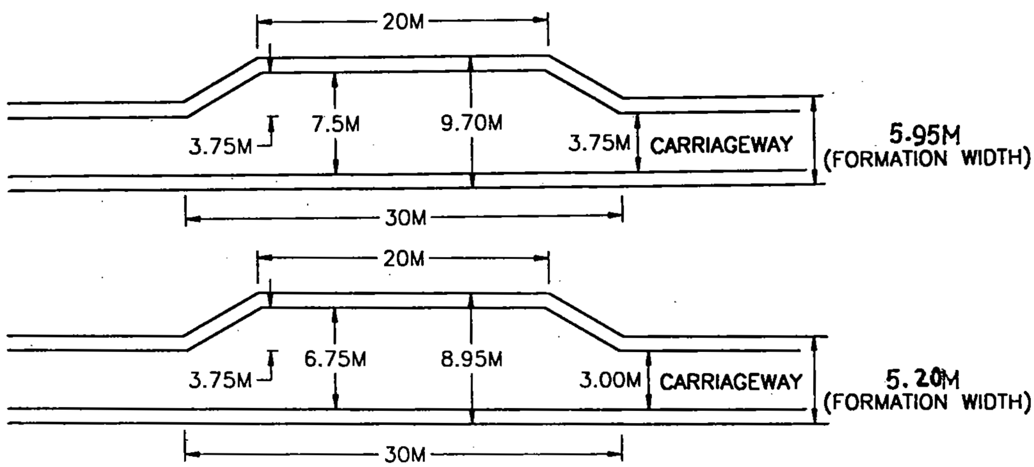


FIG. 6.17. PASSING PLACES ODR & VR

6.11.1. Passing places are required on single lane hill roads to facilitate crossing of vehicles approaching from the opposite direction and to tow aside a disabled vehicle so that it does not obstruct traffic. They should be provided at the rate of 2-3 per kilometre.

6.11.2. Normal size of passing place is 3.75 m wide, 30 m long on inside edge and 20 m long on the farther side. The exact location of passing places should be judiciously determined taking into consideration the available extra width and visibility.

6.12. Co-ordination of Horizontal and Vertical Alignments

6.12.1. The overall appearance of a highway can be enhanced considerably by judicious combination of the horizontal and vertical alignments. Plan and profile of the road should not be designed independently but in unison so as to produce an appropriate three dimensional effect. Proper co-ordination in this respect will ensure safety, improve utility of the highway and contribute to overall aesthetics.

6.12.2. Vertical curvature superimposed upon horizontal curvature gives a pleasing effect. As such the vertical and horizontal curves should coincide as far as possible and their length should be more or less equal. If this is difficult for any reason, the horizontal curve should be somewhat longer than the vertical curve.

6.12.3. Sharp horizontal curves should be avoided at or near the apex of pronounced summit/sag vertical curves from safety point of view.

6.12.4. Plate 7 illustrates some typical cases of good and bad alignment co-ordination.

6.13. **Bridle Road and Bridle Path**

As earlier brought out in para 4.4.3, the isolated villages habitations can be connected by bridle roads. Bridle paths are also provided in border areas (generally called border tracks or village tracks). These may also be necessary for pockets of very small population in remote areas. Typical specifications of Bridle road, Bridle path and Operational tracks (OP tracks) are given in Table 6.13.

Table 6.13. Specifications of Bridle Road and Bridle Path

Sl. No.	Items	Bridle Road	Bridle Path (Border/Village Track)	OP Track
1.	Road land width in open areas	6 m	3.0 m	4.00 m
2.	Formation width			
	a. Normal	2 m	1.0 m	2.75 m
	b. Exceptional	1.7 m	0.8	
3.	Radius of Curves (Minimum)	5 m	5 m	12 m
4.	Widening at sharp curves upto 3 M radius	1.0 m	0.3 m	1.5 m
5.	Inside slope (cross fall)/Camber	3 to 4%	3 to 4%	
6.	Minimum radius at H.P. Bends	3.0 m	1.0 m	
7.	Gradients			
	a. For Ghat tracing	12%	-	Ruling
	b. Ruling	17%	17%	1:15 Max.
	c. Limiting	-	25%	1:10
	d. Exceptional (not more than 30 M length)	25%	30%	may be upto 1 in 7
8.	Drains	0.30 m	0.2 m	0.50
9.	Scuppers	1 m span 3 to 10 Nos per km	0.6 m span 3 to 5 Nos per km	
10.	Bridges and Culverts			
	a. Design load	400 kg/sqm	400 kg/sqm	
	b. Clear roadway between kerbs	2.0 m	1.0 m	
11.	Surface	Un-surfaced. In slushy stretches stone/ brick paving or some other treatment.		

7. FORMATION WORKS

7.1. General

7.1.1. Formation is the finished profile of the road, ready for construction of protective/drainage works, carriageway/pavement, shoulders, drains, parapets etc. Some typical sections of formation in different terrains are shown in Fig. 7.1.

7.1.2. Construction of formation on hill roads generally comprises of the following items of works:

a) Jungle clearance including clearing of under-growth, brush wood, shrubs, creepers and cutting down of trees.

b) Earthwork in excavation in ordinary soil, soft rock and hard rock or soil mixed with boulders.

c) Earthwork in embankment with suitable material including protection of slopes (by turfing, pitching etc. as suitable).

d) Temporary expedients during initial construction like temporary side/cross drains, dry stone/bally revetments, service soling/shingling in weak soils to keep the road traffic worthy (mainly for construction/supervision traffic) till proper structures and pavement are constructed.

7.1.3. On the finalised alignment, construction of formation is taken up with reference to the trace-cut made along the selected alignment. Various aspects of construction of formation, including the trace-cut, are brought out in the succeeding paragraphs.

7.2. Trace-cut

7.2.1. The subject of Trace-cut has been dealt in Chapter 5 "Surey and Alignment". This is a primary operation for formation work.

7.2.2. The trace-cut provides an inspection path for inspection of the alignment by the inspecting officers. It facilitates detailed survey (like levelling, plane table/compass surveys) of the alignment for preparation of detailed estimates for the works. It also serves as approach track for the formation cut construction parties deployed forward ahead of the main construction party. Trace-cut also helps in determination of the classification of soil close to the actual one likely to be encountered in the formation cut.

7.3. Jungle Clearance

7.3.1. The alignment of hill road generally passes through dense vegetation except for barren snow clad areas and cultivated habitations. The land is either Government (forest/revenue) or privately owned or in some areas owned by village. Clearance of vegetation/jungle along the proposed alignment is the first activity in actual construction of the road. Before commencement of the work, various formalities like allotment/acquisition of land from revenue/land acquisition authorities and dereservation of forest land from Forest Authorities under Forests (conservation) Act 1980 should be completed so as to obviate any complications/delays. As clearance of jungle results in reduction of green cover and is harmful to environment and ecology, and upsets eco-balance, when done on a large scale, it is essential that alignment is so chosen to minimise jungle clearance. Even when clearance is inevitable, only the barest minimum must be cleared.

7.3.2. Jungle clearance is generally done in two stages as under :

a) Clearance of undergrowth, shrubs, bushes creepers and ballies upto 30 cm girth

b) Cutting down trees exceeding 30 cm girth

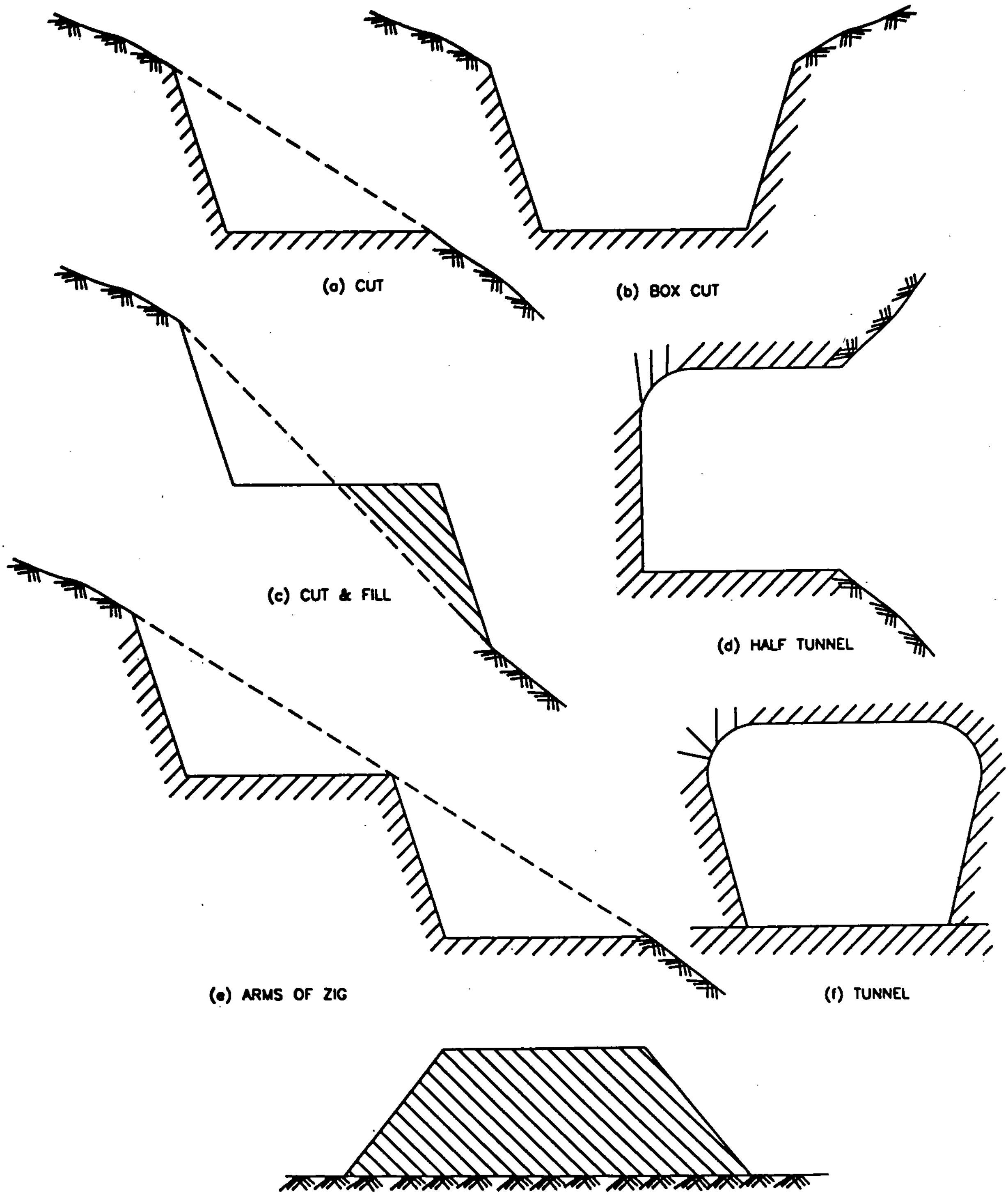


FIG. 7.1. TYPICAL SECTIONS OF FORMATION

7.3.3. The actual area to be cleared should be marked on ground with reference to the trace-cut. The hill side edge should be marked about 1 or 2 meters above the edge of formation cutting determined from the cross section survey details at the particular location and the valley side edge is marked about 1 or 2 meters below the trace-cut (formation) level. The clearance is done manually using datris, kukris and axes felling. The forward working party of about 4 to 5 labourers keep on cutting the jungle, followed by another working party of 10 to 15 labourers sorting out retrievable materials like cane, bamboo, ballies, etc. which can be used for camp construction and/or for other construction expedients/temporary structures. The creepers, brushwood, stumps and other rubbish having no utility are rolled down the hill side about 1 or 2 metres below the trace-cut level. This during the subsequent stage of earthwork, helps retention of the earth sliding down the hill and thus protects the hill-side from erosion. Some of this material takes roots depending on soil/weather conditions and helps in stabilizing the slopes. No uprooting or grubbing of undergrowth/shrubs, etc. should be done as it causes damage to the top soil cover, except for the areas coming under road bed where all vegetation and other deleterious materials have to be removed and surface has to be furrowed/stepped.

7.3.4. Cutting/clearance of trees follows the clearance of the undergrowth, shrubs, etc. In order to restrict cutting down of the trees to the bare minimum, the area should be inspected by an experienced/responsible officer and the trees not interfering directly with the construction of road should not be cut. Similarly, trees and shrubs, having some valuable properties, which are required to be protected should not be cut as far as possible, unless they are directly, within the marking of the formation cut. Generally the hill features offer lot of scope to adjust the alignment either towards the valley side or towards the hill side to avoid unnecessary cutting of trees. For protection of environment, tree cutting should be limited to the barest minimum.

7.3.5. Cutting of trees is normally done by using axe felling and cross cut saws. Portable electric/mechanical saw may also be used for jungle clearance of large magnitude. The technique and pattern of cutting of trees should be such that the trees from hill side as well as valley side fall on to the proposed alignment and not away from it, so as to avoid damage to the jungle on either side. The pattern of initial cut and the final cut to facilitate falling of the tree on the desired side is shown in Fig. 7.2. Initial V-notch is cut about 0.3 to 0.5 metres above the ground level on the side on which tree is required to fall. The initial cut is taken up to the centre of the standing tree.

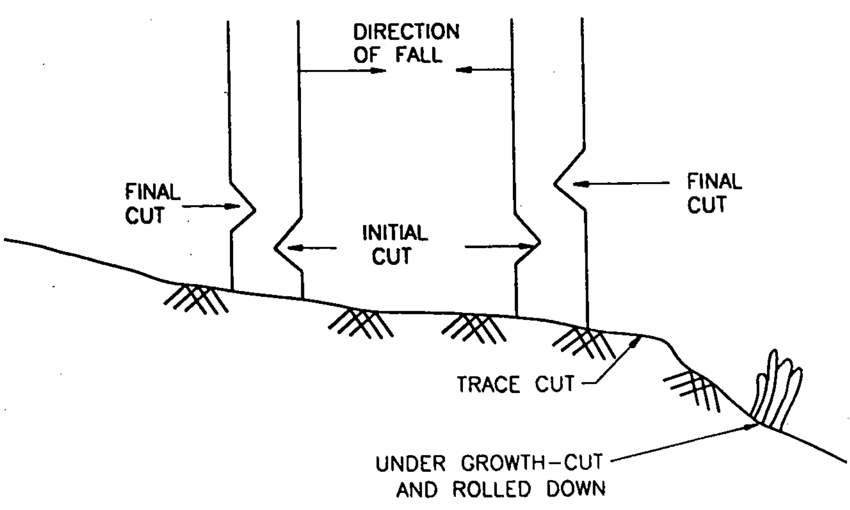


FIG. 7.2. TREE CUTTING

The final cut is then done on the reverse side of the initial cut about 25 to 30 cm above the initial cut. With this pattern, the tree falls on the side of the initial cut. Suitable precautions for warning the workers have to be taken when the tree is on the verge of fall so as to avoid any accident. After the tree has fallen, it is logged in suitable lengths by cutting with cross-cut saw or power saw. The branches are hacked/sawn. The logs are retrieved for future sawing into sizes for use in camp/other construction expedients or for disposal. The stumps and roots of the trees within the area of actual formation cut are removed either manually or allowed to remain at site for eventual removal by dozers during the earthwork operation. Other stumps/roots should not be removed so as to obviate damage to top soil.

7.3.6. For cutting down very large trees special attachments like tree feller, rooter etc., to be fitted to dozers are available and can be used depending on the quantum of the work involved. In exceptional cases, with the prior permission of the appropriate authorities, clearance of large diameter trees can be done by using explosives. This, however, needs considerable experience for working out and placing the charges correctly and should, as far as possible be avoided.

7.3.7. In some locations where the jungle growth is very heavy and the soil conditions are perpetually moist, there may be a requirement of additional jungle clearance to expose the formation to direct sun light and air circulation. In such cases some of the trees away from the alignment may have to be cleared. This should preferably be done by pruning the branches of the trees to permit sun light to penetrate upto the alignment and cutting of tree as a whole, should be avoided, as far as possible.

7.4. Earthwork-Excavation

7.4.1. The earthwork for formation of the hill road involves mostly side-cut excavation to achieve designed formation width. For the purpose of excavation the soil is classified in three broad categories as under.

a) **Ordinary/Heavy Soil:-** This comprises of organic soil, clay, sand, moorum and stiff clay which can be excavated manually by pick axes and/or shovels or with dozers/excavators with normal efforts. This can be cut to side slopes of 1 : 1 to ½ : 1 (H:V). Soil mixed with boulders is also deemed to come under this category.

b) **Ordinary/Soft Rock:-** This comprises of soft varieties of rocks such as lime stone, sand stone, laterite, conglomerate or other disintegrated rocks, which can be excavated by crow bars and/or pick axes without blasting or with casual blasting. This can be cut to side slope of ¼ : 1 to 1/8 : 1 (H:V).

c) **Hard Rock:-** This covers any hard rock, excavation of which involves intensive drilling, and blasting. This can stand vertical or even overhanging cut depending on the type/mass and dip of rock. Normally the cut may vary from 80^0 - 90^0 to horizontal.

Note: Classification of earthwork is at times done based on tools of excavation viz spade-work, pick work, jumper work and blasting, which also more or less corresponds to the above classification.

7.4.2. The excavation for formation cut follows the jungle clearance with approproate distance lag. The excavation is done manually or mechanically using angle dozers (Tracked dozers with angle dozing blades) based on various relevant factors. If done manually, the work is commenced generally from the top edge of the cut working downwards. If done by mechanical means, the work is commenced generally using dozers, and started at trace-cut level cutting sideways into the hill side. The work can be done either in one operation or in two stages i.e. construction of a 2.5 m wide track in first stage and widening it to designed width in second stage. While single stage construction obviates redeployment of resources in the same stretch, the two-stage construction is preferred where there is an urgent requirement to establish some sort of early communication at least for light vehicles, initially.

7.4.3. The choice of manual/mechanised cutting and single/two-stage construction has to be made on detailed examination in individual cases depending on various individual factors, viz terrain, availability of man power and machinery, workability, time constraints and cost aspect. However, a combination of manual and mechanical cutting (with about 25 to 30% work being done manually and 70 to 75% work being done mechanically) and single stage construction is considered to be most suitable for construction of hill roads under normal circumstances. However as dozers can operate only on about 2.5 m width at a time, the construction operation has to be initial cut by forward dozers followed by widening to final width by rear dozers. However two stage cutting has the advantage that a road of adequate width becomes available after first stage cut itself for equipment/machines to move and also to undertake work from forward road heads to which machines and stores can be easily moved.

7.4.4. The deployment of resources and execution of earthwork may be planned as under:

a) For area with hill side slope steeper than 30°, an initial cut of 2.5 to 3 meters width is made by manpower so as to enable a light dozer (D-50 or equivalent) to move forward, widening the track to about 4 meters on its own power. When this forward dozer moves about 50 to 100 metres, a heavier dozer (D-80 equivalent) should be deployed in the rear to widen the road to full formation width. This rear dozer should be assisted by man-power for dressing the side slopes from the top so that vertical hill side does not fall accidentally on the dozer/operator.

b) For hill slope flatter than 30°, man power may not be required for initial cut as the forward light dozer can make its own track by cutting into the hill side. This should be followed by heavier rear dozer assisted by manpower for dressing the side slopes, and for widening to the final width as indicated above.

c) For rocky areas, the general deployment pattern will be the same as above except that drilling and blasting party will have to work ahead of the dozer party to loosen the rock for removal by dozers. (The details of rock cutting are covered in a subsequent part of this chapter).

d) In case of widening of the existing road, manual labour with wheel barrows for disposal of the earth from the hill side to the valley may be utilised. Alternatively, wheel dozers or excavators/loaders on pneumatic tyres may be utilised so that the existing road surface is not damaged.

7.4.5. While the pattern of deployment discussed above is basically machine oriented for consideration of speed of construction, there may be projects where the road construction is a part of long term plan and speed of construction is not the guiding factor for deciding the pattern of deployment. In such cases labour intensive approach may be more beneficial for its job generation as well as for economy. In such cases the deployment pattern could be 75% by man power and balance by machinery.

7.4.6. In order to achieve maximum output the dozer should be deployed to work down hill assisted by gravity to enable greater loads to be pushed. When the starting point of the road sector is at lower altitude, the dozer may be moved to higher location by cross country move or by makiing approach track along the trace-cut to minimum essential width for move of dozer and then start working down hill from that point backwards. The blade of the dozer is used as angle blade for side hill cutting with the leading edge of the blade towards the hill and tilted downwards so as to get maximum bowl fill of the blade.

7.4.7. Typical deployment of dozers is given in Fig. 7.3.

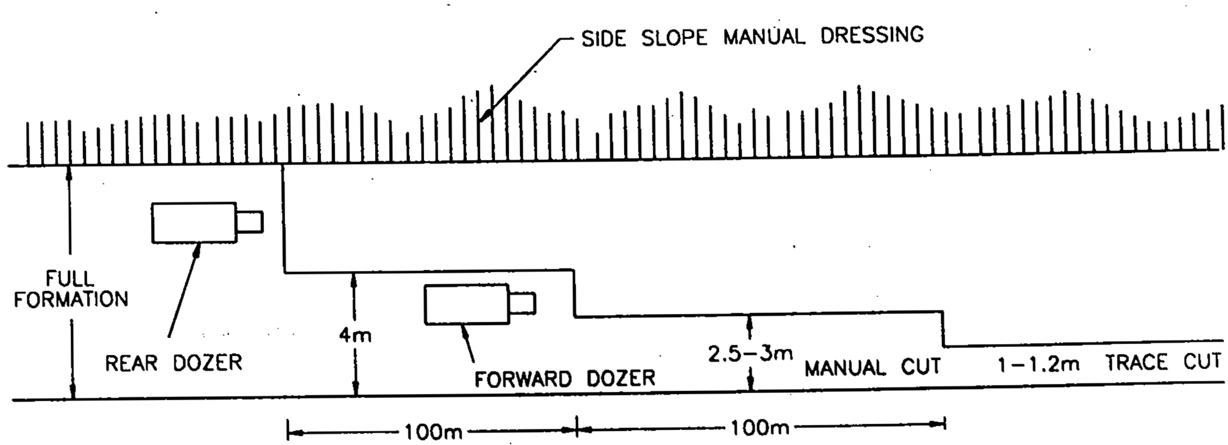


FIG. 7.3. TYPICAL DEPLOYMENT OF DOZERS

7.4.8. The rate of progress in ordinary soil is much faster than that in rocky areas. As a result, at times the progress gets hampered when rock is met with and earthwork resources remain idle. To avoid such a situation, the Officer-in-charge should inspect the trace-cut well ahead of the construction party and if any isolated bottlenecks like rocky stretches or bridge sites are encountered, the work on these bottlenecks should be commenced by sending working parties well in advance, so that the bottleneck is cleared by the time main working party reaches that location. The trace-cut can be used as approach track for such parties or initial formation cut with minimum width to move compressor/dozer should be made, if necessary. It is often possible to take dozers to forward location cross-country and commence work from that road-head also to overcome delays due to intermediary rocky stretches, etc., to accelerate progress.

7.5. Rock Cutting

7.5.1. Rock cutting involves drilling with specialist equipment, blasting with explosives and the clearance of blasted debris with dozers. These, being very expensive and risky operations, call for thoughtful planning and careful execution by personnel having thorough knowledge and extensive practical experience in rock cutting work and use of drilling and blasting equipment and explosives. Apart from the immediate cost and risk, improper/excessive use of explosives may result in large scale disturbance of hill side creating slide areas leading to erosion and expensive control measures.

7.5.2. There is a wide choice of drilling equipment, compressors, explosives and accessories. Selection of these items may be made after careful assessment of job requirements and technical data supplied by the manufacturers of various products. All statutory laws, rules and regulations pertaining to procurement, transportation, storage, handling and accounting of explosives should be strictly followed. The subject of rock cutting and related blasting techniques are dealt with extensively in Chapter 18 "Rock Blasting". However, this being an essential operation of formation work, important aspects related to formation work are given here.

7.5.3. The planning of rock cutting work comprises of :

a) Determination of resources/stores required based on estimated quantum of work, output norms and target time for completion of the work.

b) Location of most advantageous points/faces to commence the work based on detailed ground reconnaissance.

c) Working out the drilling pattern most suitable to the particular location, assessing the quantum of individual charge and sequence of blasting.

d) Special precautions for wet/under-water/cold weather blasting and dealing with misfires.

e) The effort should be to collect and store as much blasted rock as possible to use the same for subsequent protective, drainage and pavement works.

7.5.4. **Drilling**:- The first step after detailed planning is drilling operation. The main points pertaining to drilling are:

a) In forward/isolated locations where compressors cannot be taken, light portable mechanically operated drills are used.

b) The most commonly used drilling equipment is pneumatically operated jack hammer capable of drilling about 40 mm dia holes upto 3 meters in depth. Generally, the maximum depth of holes for blasting in continuous rock is restricted to 1 m.

c) In very exceptional cases where deeper holes are essential to be drilled, in order to avoid the drill rods getting stuck, the first 1 m of the hole is drilled with 42 mm bit dia rods, and the next 1 m with 38 mm dia rods.

d) For cutting fresh/initial formation, hill-slope is cut into benches of 1 to 1.5 mts vertical face. These benches are brought down to trace cut level in stages by drilling vertical holes of depth equal to or slightly more than the face height. The burden (distance of the nearest row of holes from the face to the face) is kept about two thirds of the depth of the hole and spacing (distance between two adjacent holes) is equal to the burden. The successive rows of holes are drilled in zig zag pattern. A typical drilling pattern and cutting sequence are shown in Fig. 7.4.

e) For widening the initial cut or widening an existing road, one row of holes about 1.25 to 1.5 metre deep are drilled about 1 metre apart and 1 metre above road level on the vertical face at a slope of about 45° to the face dipping downwards. The hole is taken about 10 to 15 cm below the formation level so that toes and lumps are not left after

the blast. The second row is drilled horizontally with about 1.0 to 1.25 metres spacing in zig zag pattern with relation to lower row. The typical pattern and layout of holes are shown in Fig. 7.5.

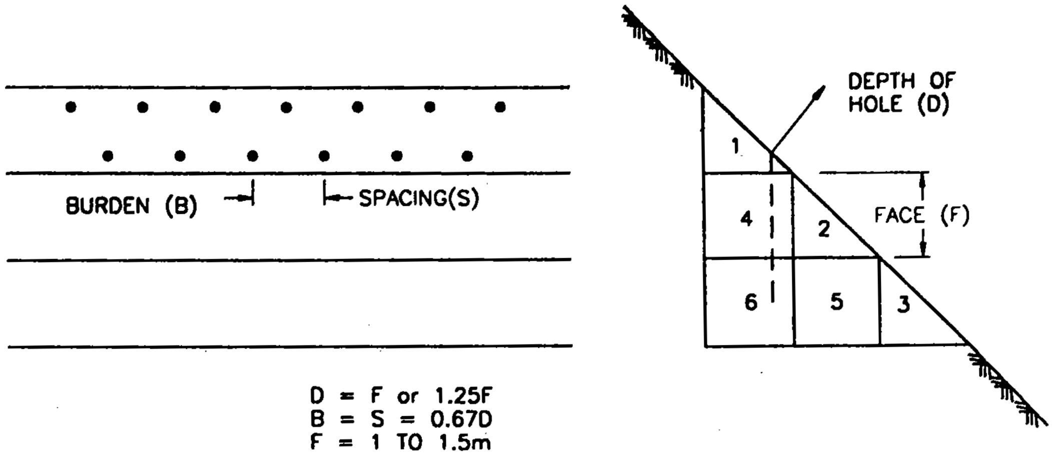


FIG. 7.4. DRILLING FOR FRESH/INITIAL CUT

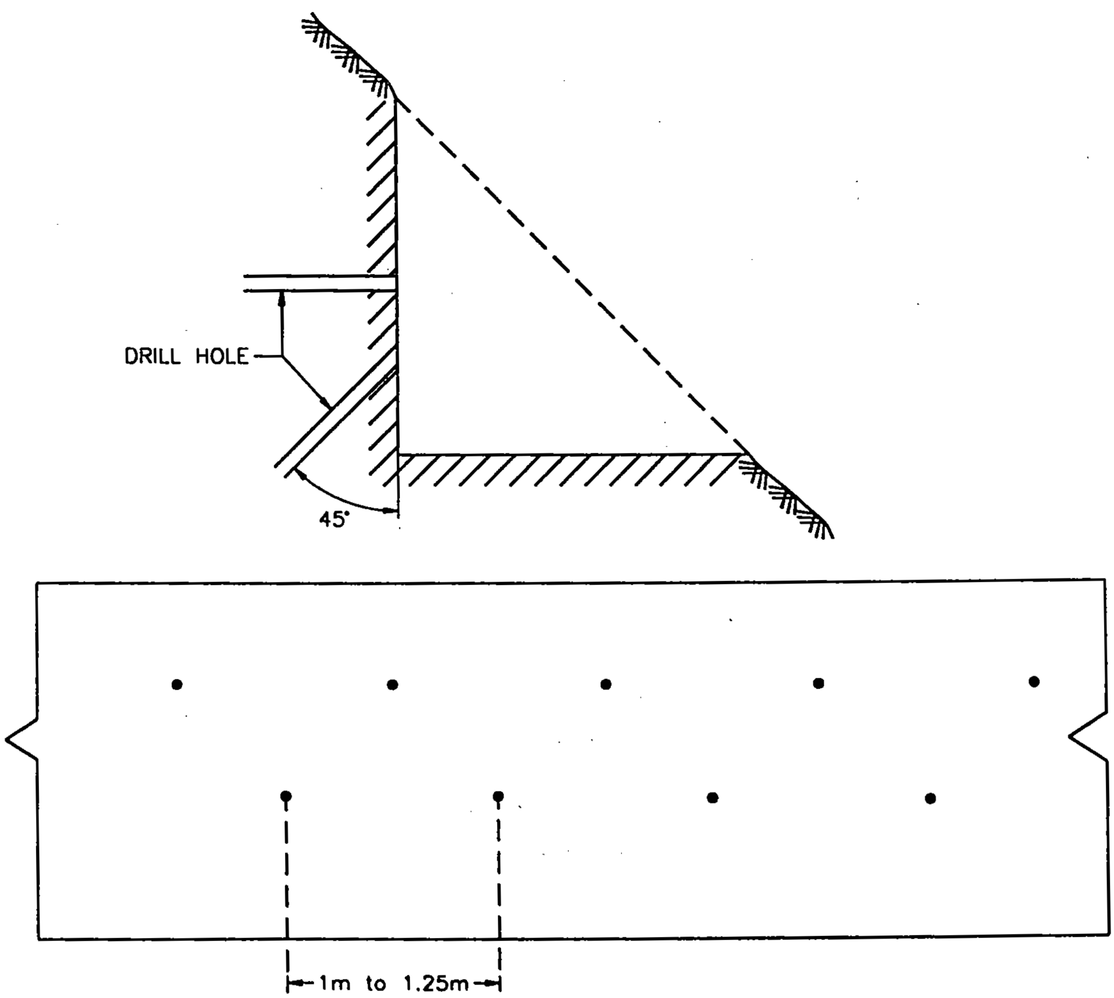


FIG. 7.5 DRILLING FOR WIDENING

f) In heavy rock cut areas, wagon drills capable of drilling approximate 10 cm dia holes and depth upto 10 to 15 metres are used. This, however, needs extreme caution as, with heavy charge, large disturbances are likely to take place and may destabilise the hill face. Wagon drill can be used to drill in any desired direction. The drilling pattern is similar to (c) above except that spacing can be increased to about 1.5 to 2 metres and a third row of holes sloping 45° upwards can be drilled and larger output can be obtained. Use of this practice has to be restricted to massive rock-cutting work areas only.

7.5.5. **Blasting**:- After drilling the holes, their charging for blasting is taken up. The charge per hole depends on the type of explosive used and blasting ratio expected. Special gelatine 60% or 80% is the most commonly used explosive and blasting or firing is done normally with detonating fuse initiated by ordinary detonator and safety fuse or electric detonators. The main points to be observed in charging/blasting are:-

a) The charging of holes is commenced after the drilled hole has cooled down.

b) Lower one third or half of the hole is filled with explosives (gelatine) by light tamping with wooden rod. The last cartridge of gelatine is primed with knotted detonating fuse or detonator and safety fuse or electric detonator. The upper empty space in the hole is filled with suitable stemming material, preferably clay, by proper tamping with wooden rod. The other end of safety fuse/electric detonator/detonating fuse is kept outside the hole for firing.

c) The holes primed with ordinary detonator and safety fuse are fired individually. Those primed with detonating fuse are connected to each other with another detonating fuse on the surface and fired with ordinary detonator or connected in series to a lead cable and fired by an exploder dynamo. The continuity of the connection and whether the number of holes are within the capacity of the exploder dynamo, is tested with ohmmeter or circuit tester.

d) Blasting may be done at fixed timing, either just before lunch break or evening break, so that there is no work immediately after blasting and loose stones if any are allowed to fall on their own.

e) Warning/precautions should be taken by whistle, red flags or any other effective signals. Equipments must be moved to safer distance or suitably covered. After the blasting is over, clearance is given by whistle and red flags shall be withdrawn only after checking the site for misfire, if any.

f) In case of misfire, the primed cartridge should, if possible, be removed by removing the stemming very carefully. Otherwise a fresh hole is drilled about 30 to 40 cm away from the misfired hole and the new hole is blasted. This will also blast the misfired hole.

g) While working in extreme cold weather, the explosives get frozen and is dangerous. No forcing, pricking or rolling of explosives should be done to soften them. Similarly, the outer coating of safety fuse cracks in extreme cold and water may enter the inner core through the cracks. The explosive as well as safety fuse should in such circumstances be kept in a warm place (about 20°c to 25°c) before use.

h) In wet weather conditions, firing is done with detonating fuse by a single detonator placed at dry location.

i) Blasting, specially with electric detonators, should be stopped during thunder storm and workers should leave the site to safe distance.

j) Careful day-to-day account of explosives drawn from stores, consumed at site and returned to store unconsumed should be maintained.

7.5.6. As a caution, it is mentioned that blasting should always be controlled. Deep holes with less charge causes shattering of rock and does not allow it to fly off. Similar is the case with larger diameter shallow holes. A burden of clay and other loose material filled in gunny bags prevents rock fragments flying off.

7.5.7. **Clearing**:- After blasting, sufficient time should be allowed to elapse to allow for any loose stone to fall. The site is inspected for any dangerous overhang or loose stone. These are removed carefully to avoid accidents. The clearance of blasted debris is then taken up either manually or with dozers under proper supervision. During the clearing of debris, maximum possible stone should be retrieved and stocked/shifted to suitable locations for use in protective, drainage, pavement works etc. subsequently.

7.5.8. The three operations of drilling, blasting and clearing the debris should be synchronised in such a manner that none of the resources are allowed to remain idle. The work should be planned at two or three adjoining locations, so that drilling and charging at one site is under progress while clearing of previous blasting at other site is being done. The deployment is reversed after blasting at the first site by which time the second site should be ready for drilling/charging.

7.6. Embankment

7.6.1. In hill roads, heavy embankment work is very limited. The ratio of cut and fill method can vary with the slope and terrain of hill. However, there is scope/requirement for adopting cut and fill method at few places in mountainous region except where valleys are to be negotiated between hill features or mountain ranges. The area where the embankment/fill is to come is cleared of all organic matter. Selected material for new embankment is spread and consolidated in layers with roller. In case of cut-and-fill with dozer, the consolidation is normally achieved under dozer operation. Typical cross section of embankment/cut and fill are shown in Fig. 7.6.

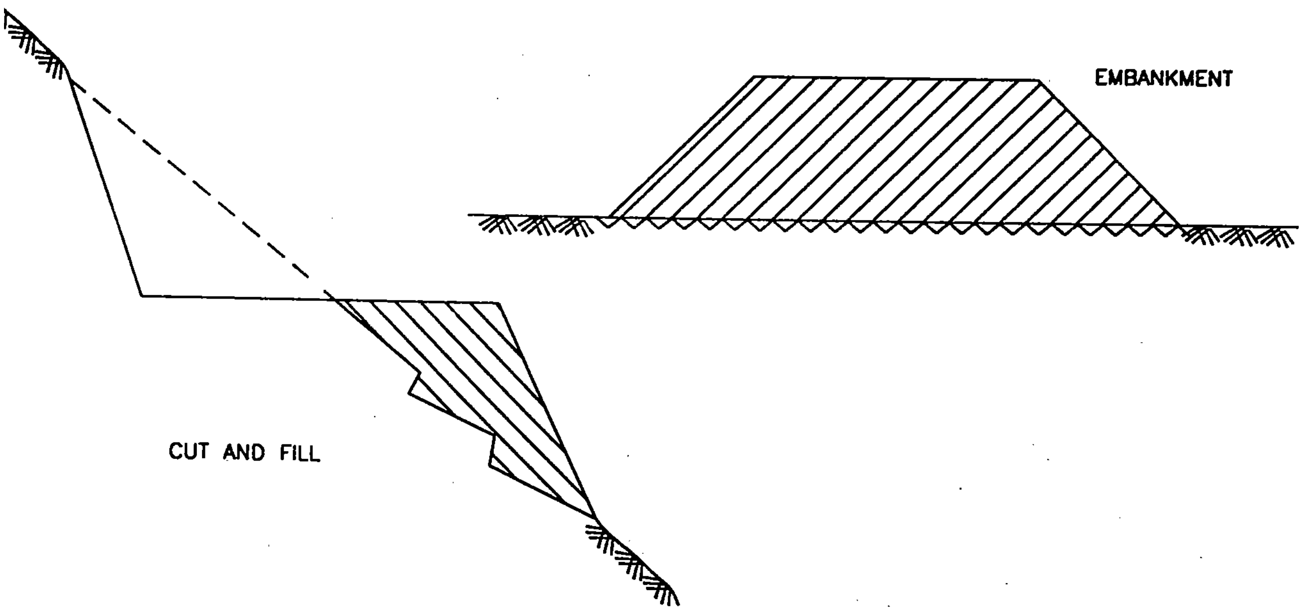


FIG. 7.6. EMBANKMENT/CUT & FILL

7.6.2. The slopes of embankment/fill should be protected from erosion by planting turf/grass/locally available plants.

7.7. Profile Finishing

7.7.1. During the main earthwork/rock cut operation, it is not possible to achieve the final desired profile according to design gradients, super elevation, camber, side slopes etc, unless the entire work is done manually. The final finish is done in such cases, by deployment of a separate working party with a grader assisted by adequate labourers. The requirement of dressing (cut/fill) at each location is worked out by proper survey and guidelines given to grader operator/supervisor. The unevenness in the rock cut is filled up with broken pieces of appropriate size and blindage of suitable material is spread over the surface to give smooth riding. Kutcha drains made at the time of formation cutting for surface/hill side drainage are made pucca when suitable breast and retaining structures are made.

7.8. Expedients

7.8.1. In order to keep the road in traffic worthy condition during the period intervening between the formation cut and completion of drainage structures/protective/pavement works, certain expedients/temporary works are done alongwith the formation cutting so as to minimise the damage/deterioration of fresh formation. These are treated as part of formation work and are either provided for in the estimates of work or executed as contingent to the main work.

7.8.2. **Temporary side drains**:- Most of the road work estimates provide for proper lined side drains along the hill side for taking the surface run off to the nearest cross drain. These can be taken up for construction after stabilization of hill slopes to some extent. In the meantime, temporary unlined drains of appropriate size are provided. At places these drains get stabilized and the requirement of lined drain is dispensed with. But at places where the water flow is likely to erode the bed and sides of the drain, lining is necessary. In inhabited areas, the lining of drains could be on aesthetic reasons also.

7.8.3. **Temporary cross drains**: Till construction of regular culverts, temporary culverts using ballies/logs retrieved from jungle clearance or any other material are provided on the road. Some typical bally culverts are shown in Fig. 7.7.

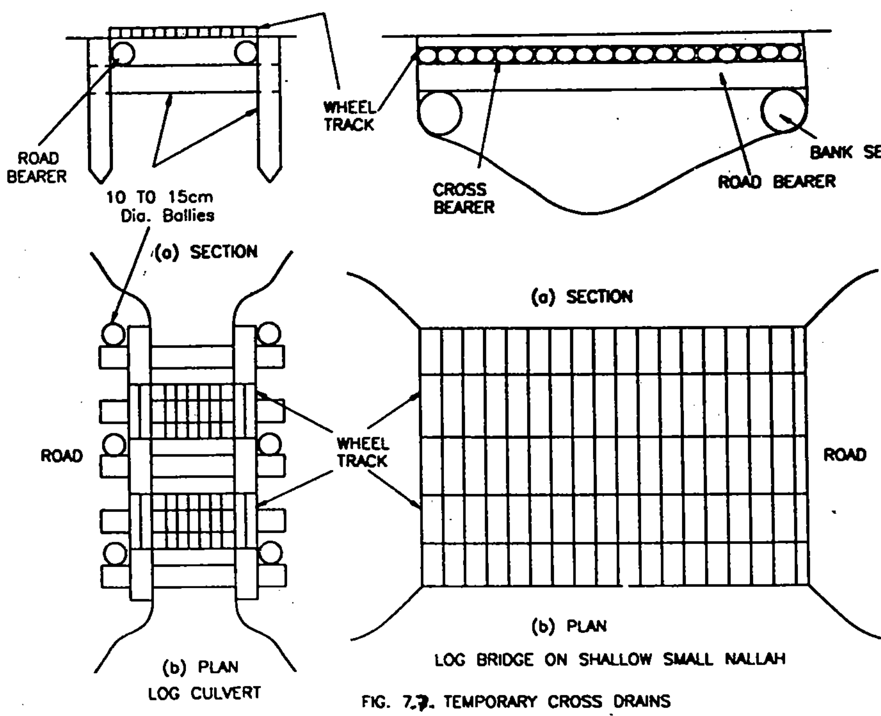


FIG. 7.7. TEMPORARY CROSS DRAINS

7.8.4. **Scupper**:- One other reliable and popular structure for cross drains is the scupper made of stones, wider at the bottom and narrower at the top by corbelling and covering by a flat stone and given adequate cushion of local material to the extent of 0.6 to 0.7 mts which can be constructed out of excavated stones at nominal cost at the time of formation cutting. These have withstood the loading of traffic successfully. Fig. 7.8. shows the sketch of a scupper.

7.8.5. **Temporary bridges**: On larger water courses proper investigation, design and construction of bridges take considerable time. In the initial stages, temporary log bridges or portable steel bridges are constructed to open the road for traffic. Care is required in locating firm foundation for such temporary bridges to avoid damages during floods. These bridges, as far as possible, should not be constructed, at the prospective permanent bridge site as it would involve their dismantling and providing another diversion during permanent bridge construction. Full care should be taken that the structure is safe against loading norms.

Fig. 7.8

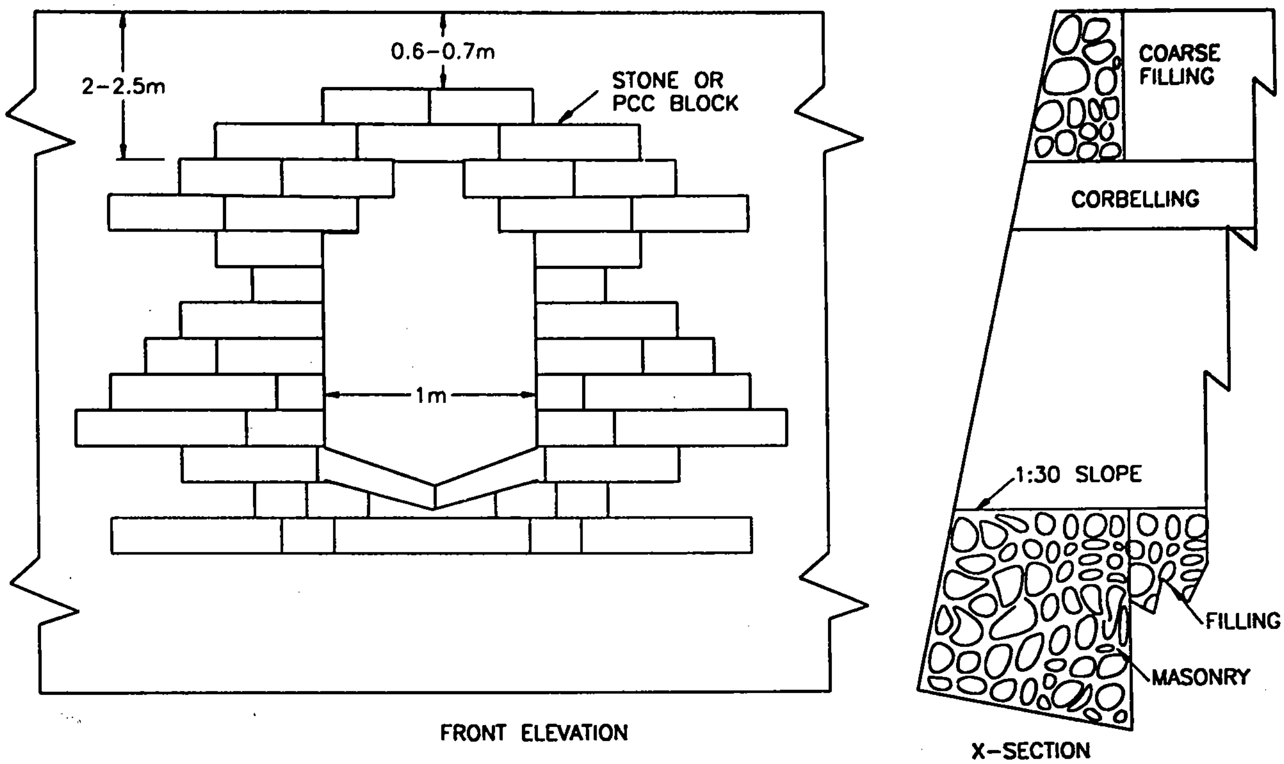


FIG. 7.8. DRAINAGE SCUPPER

7.8.6. Hill streams have occasionally large flow and till the permanent structure of the bridge comes up, it will always be expedient to have diversions made in nallahs (streams) by constructing multi-vented hume pipe low level crossing with masonry head walls. These have proved successful to cater for the needs of traffic.

7.8.7. Where the discharge is low, the alignment is taken along the contours in the nallah by raising its bed with the help of excavated and locally available stone i.e. a stone paved bed for flow of discharge.

7.8.8. **Dry stone revetment**: In rocky stretches, dry stone walls/revetments may be provided at narrow gullies and re-entrants to provide additional width for movement of traffic taking construction materials to site till the road is widened. Proper dressing and levelling of foundation sloping towards hill side is essential.

7.8.9. In areas prone to water seepage a structure of wire crated stone work proves very useful. These are flexible and help stabilisation of slope. These are robust structures to withstand the pressure of back fill. Once the area gets stabilised, the stone from these structures can be retrieved for reuse in permanent structures elsewhere on the road.

7.8.10. **Bally revetments**:- In weak/wet sliding area, revetments of ballies driven vertically and tied horizontally in rows parallel to the road along the hill slopes above and below the formation level as shown in Fig. 7.9 provide temporary stability to the slope. These can be replaced by breast walls of masonry or crated masonry in due course. At times the temporary revetment is enough to stabilise the slopes permanently. If the revetment is made with selected varieties of fresh cut ballies, which take roots quickly under wet conditions, it provides vegetation cover and adds to stability of the slope.

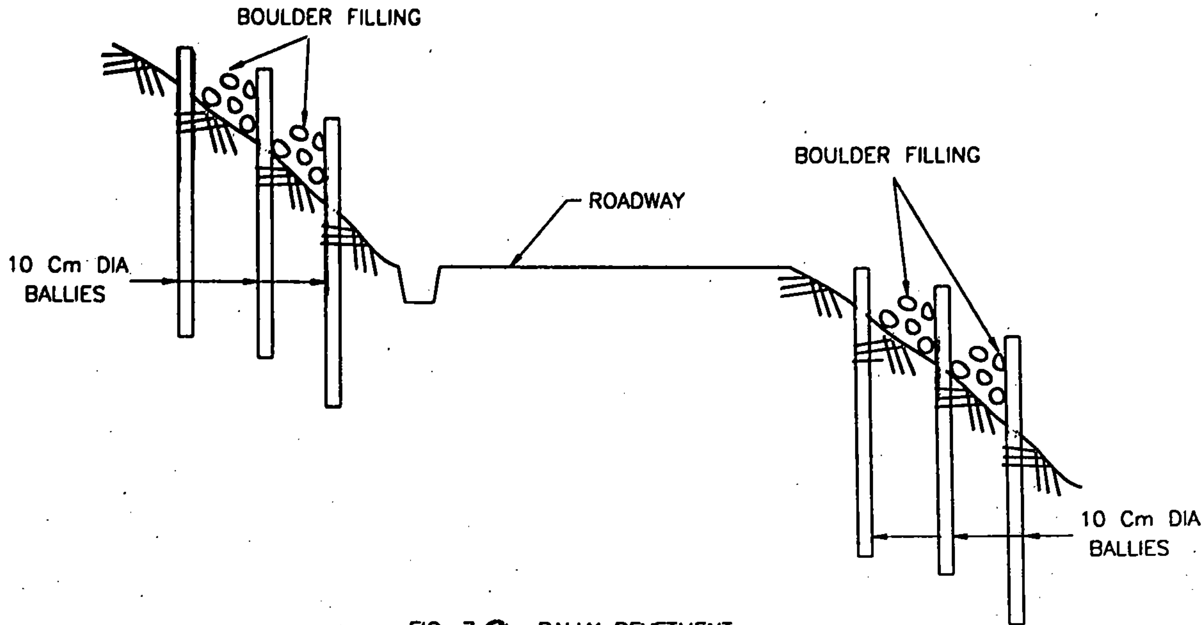


FIG. 7.9. BALLY REVETMENT

7.8.11. Another method of retaining the hill side can be by using wire crates filled with stones and used as breast wall. The suggested specification for wire crate walling is as follows, Fig. 7.10.

"Wire crates of 3 m x 1.5 m size, consisting of 15 cm x 15 cm size square mesh of 10 gauge GI wire interwoven each other in one or two tiers as required"

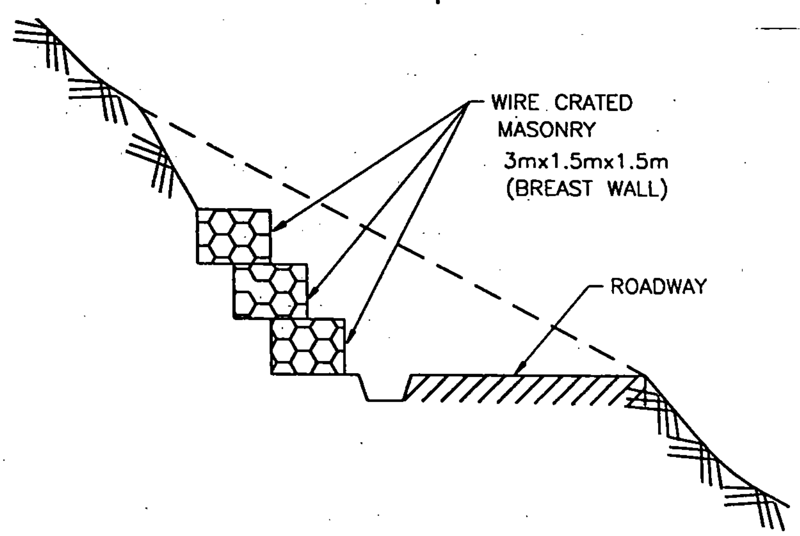


FIG. 7.10. WIRE CRATED MASONRY SLOPE PROTECTION

7.8.12. In certain locations it may be appropriate to cut a 2 m ledge above road level to ease slope and to intercept drainage, Fig. 7.11.

7.8.13. **Service soling**: In weak soils, temporary service soling/shingling with granular material, spalls from rock cut areas or locally available shingle can be provided to facilitate movement of traffic during rainy season. This is restricted to wheel tracks in case of shortage of sand/granular material in near-by areas. Where time-lag between formation cutting and pavement work is considerable, it becomes obligatory. In such cases, provision of soling of granular material as well as proper drainage structures are essential with formation cutting.

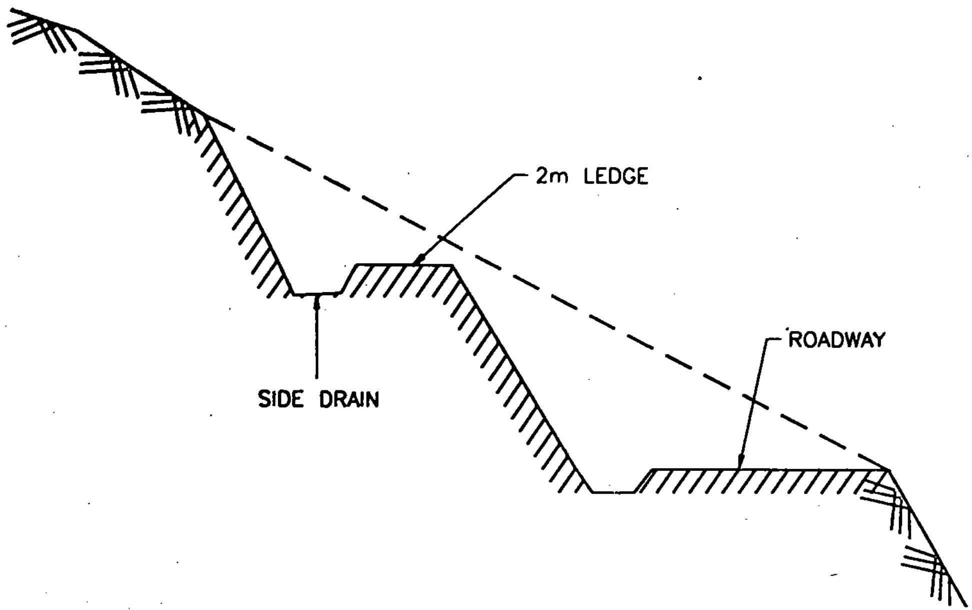


FIG. 7.11. LEDGE AND DRAIN

7.9. Special Points

7.9.1. **Geosynthetics**: Geosynthetics which include geotextile, geogrids, geonets, geomembranes and geocomposites can be used in various applications of road and bridge works. Some of the application areas for geosynthetics and their functions are given in Table 7.1.

Table 7.1. Applications and Functions of Geosynthetics

Sl. No.	Application Area	Geosynthetics Involved	Functions for Performance
1.	Embankments on soft soils	GT, GG	R,S
2.	Retaining Walls	GG, GT	R
3.	Drainage and Filtration	GT	F,S
4.	Drainage-prefab, composite	GC, GN	D,F,S,B
5.	Erosion Control rip rap	GT	F,S
6.	Sediment control-silt fence	GT	B,R,S,
7.	Asphalt overlay	GT, GC	B,R,S

Note : GT - geotextile; GG - geogrid; GC - geocomposite; GN - geonet

S - separation; R - reinforcement; F - filtration; D - drainage; B - barrier

Specifications for various applications are given in Section 700 of MOST Specifications.

7.9.2. **Temporary catch water drains:** Drains provided on hill side away from the road to intercept and divert the flow of water before it reaches the road side drain are known as catch water drains. Their location, size, gradient and lining helps in checking potential slides.

7.9.3. **Box cut**: At steep and narrow spurs, box cut or through cuts may be provided. These reduce the length of the road and also improve the radius of curves. Such cuts, however, have their own problems. During excavation, the cutting and disposal of spoils take more time and efforts as compared to hill side cut. Drainage of road surface and surrounding areas is difficult. Sub-surface springs get activated on the formation during wet weather. If the soil is unstable box cuts become trouble spots due to frequent slides and blockage of road, requiring expensive protective works, like breast walls, sub-soil drains, catch water drains etc. A careful study and comparative cost analysis of reduction in length vis-a-vis provision of additional protective works should be made before taking a decision on providing box cuts. A typical cross section of box cut is shown in Fig. 7.12.

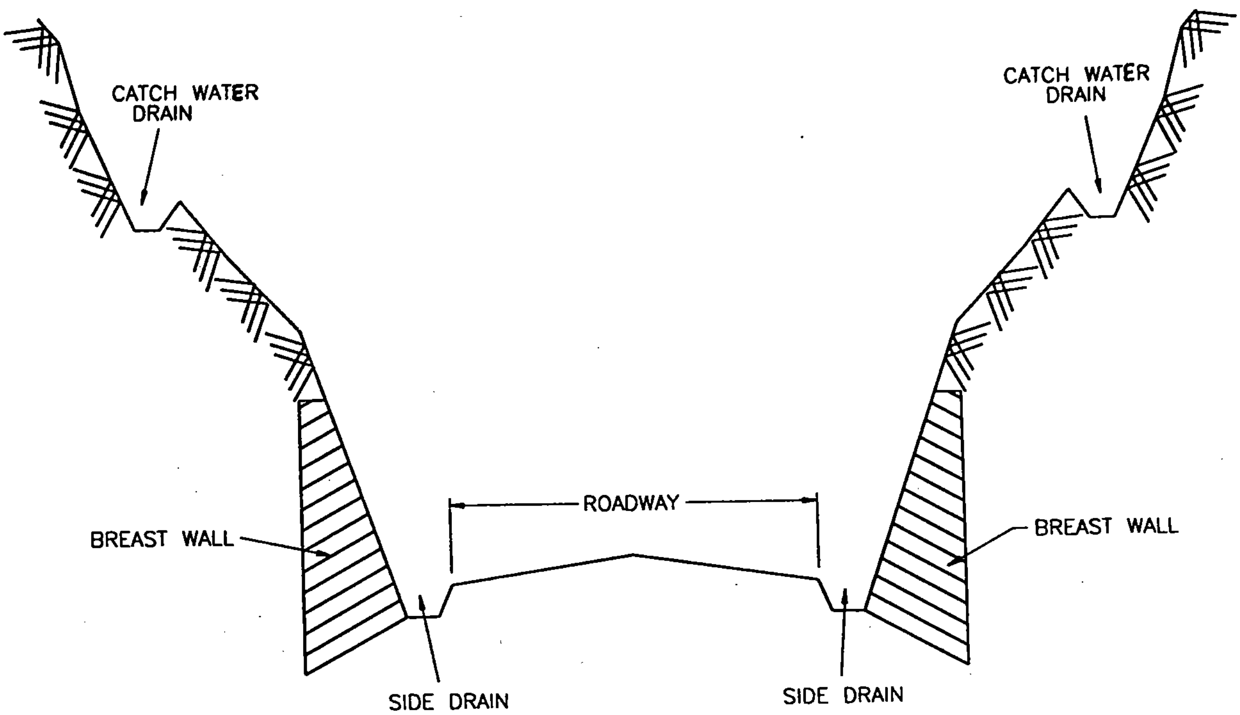


FIG. 7.12. TYPICAL BOX CUT

7.9.3.1. However it will be good to provide a box-cut at suitable sites, not only for reduction of length, but to ensure safer road for traffic, as it eliminates possible sharp or blind curves with lesser sight distance.

7.9.4. **Dry gap bridge**: At narrow re-entrants in steep rocky stretches, at times, it will be economical to provide a bridge even if there is no water flow. Detailed cost analysis of bridge vis-a-vis rock cutting or providing a high retaining wall should be done to arrive at an appropriate solution.

7.9.5. **Zigs**: When the space available on the hill face is not adequate to connect the two obligatory points within the ruling gradients or when heavy rock cut or potential slide zones are to be avoided, zigs are provided. The zigs are however trouble prone spots. Their location has to be carefully sited at reconnaissance stage in fairly flat hill side. During execution, the work may be commenced on the upper arm which is required to be taken well into the hill side and often becomes box cut. The lower arm is either in cut or cut-and-fill or on embankment. Extensive protective works like breast walls, catch water drains, lined box drains on upper arm, breast/retaining walls on lower arm and culverts with lined chutes between the two arms are required. A typical sketch of zig is shown in Fig. 7.13.

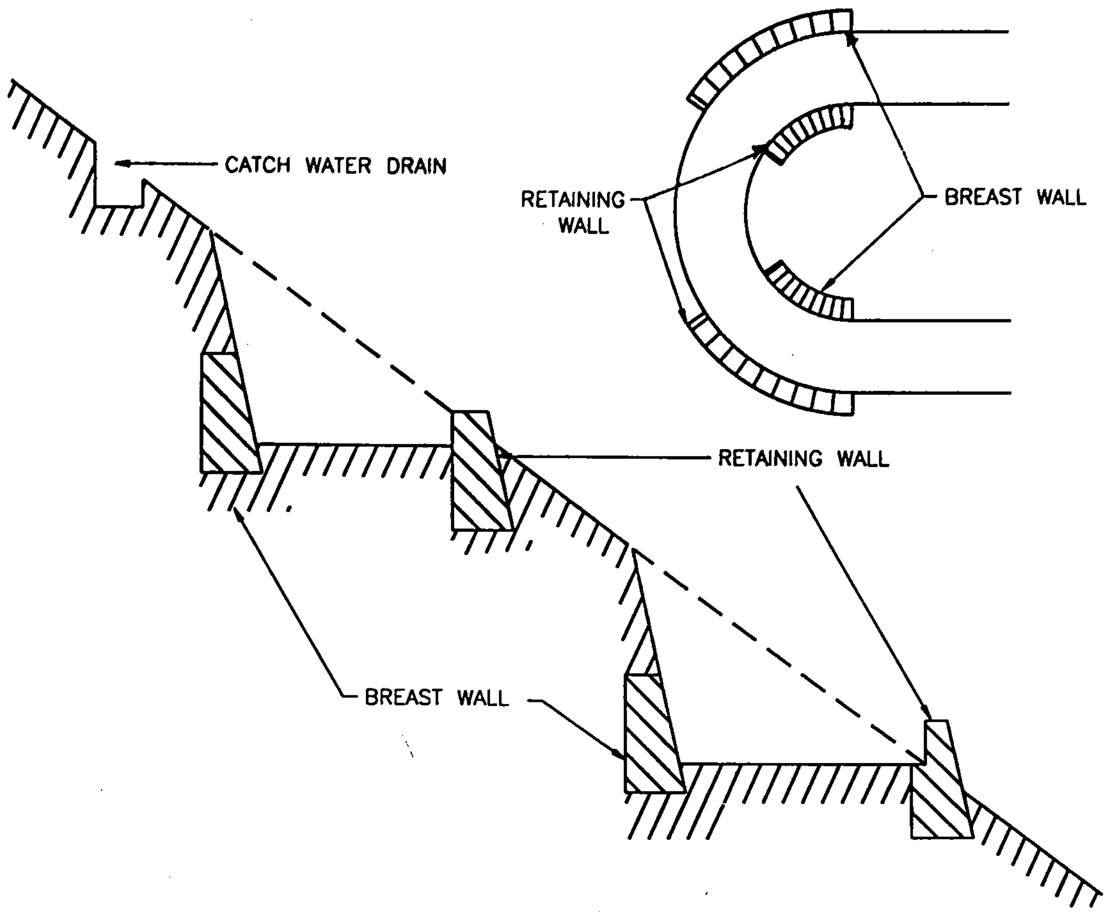


FIG. 7.13. TYPICAL ZIG

7.9.6. **Sight distance**: On sharp curves on spurs, visibility is restricted due to steep hill slopes. For safety of driving, bench cutting is provided on the hill side on the inner edge of the curve to improve visibility as shown in Fig. 7.14. These are also known as vision berms.

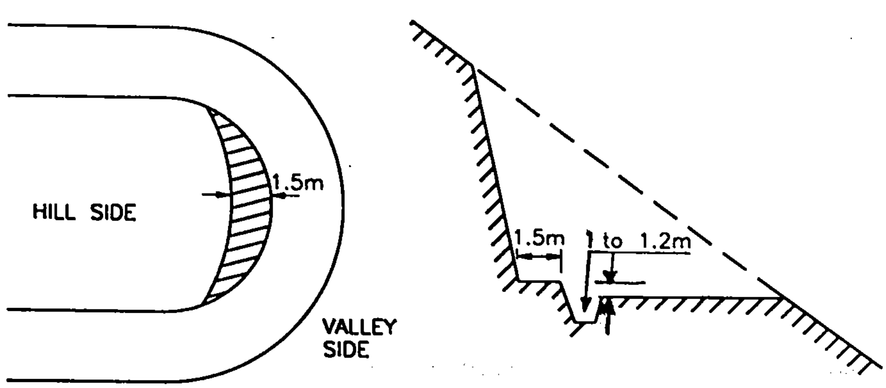


FIG. 7.14. VISION BERM

7.9.7. **Half tunnelling**: In solid/stable rocky stretches with vertical hill face, half tunnelling is done to economise on rock cut. Very careful planning of drilling and blasting is required to achieve speed, economy and safety in half tunnelling work. A typical drilling pattern for half tunnelling is shown in Fig. 7.15.

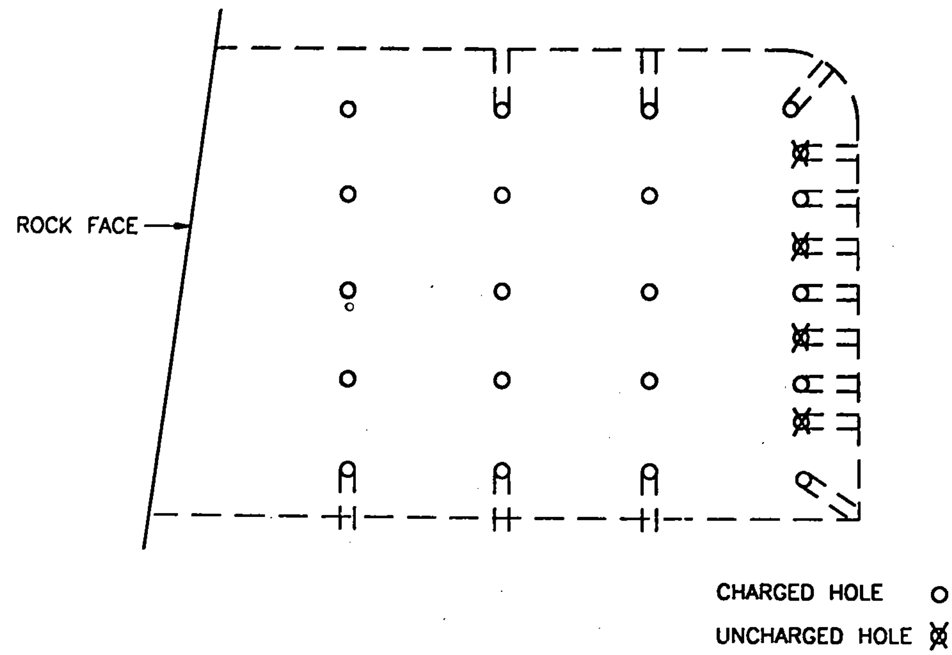


FIG. 7.15 TYPICAL DRILLING PATTERN FOR HALF TUNNELING

7.9.8. **Roadside arboriculture:** Most of the hill roads (except those in snow clad areas) pass through forests or through fertile areas. As such, roadside arboriculture does not present any major problem. However selection of right type of sapling, right season for plantation and proper upkeep for first one or two years have to be attended to properly. Help of the local forest authorities may be sought for this purpose, wherever this is to be done.

7.10. Ecological Aspects

7.10.1. Ecological and environmental aspects

The formation of road in a hill area, which is normally forest area, causes disturbance of environment due to jungle clearance, tree-cutting, movement of earth, altering slope stability, rock blasting etc. and affecting flora and fauna. As such, every caution has to be taken in planning road cutting in hills so that least disturbance to environment is caused.

8. DRAINAGE AND CROSS - DRAINAGE

8.1. General

8.1.1. Topography of hill generates numerous water courses. This coupled with continuous gradient of roads in hills and high intensity of rain-fall calls for effective drainage of roads. Uncontrolled water is the primary cause of problems like soft surfaces, pot holes, rutting, washed out shoulders, and even failure of complete sections of roadway structures. Prevention of such failures makes roads safer for motorists and pedestrians, reduces maintenance costs and adds immeasurably to the pleasure and satisfaction of the road user. A hill road is good if the degree of drainage achieved is good.

8.1.2. The cost of controlling water is a significant part of total highway construction cost. It is therefore important to plan and develop adequate facilities for drainage and erosion control.

8.1.3. A cardinal rule while planning drainage would be least interference with natural drainage. Ideally, this might be achieved by aligning all roads along ridges or drainage divides. For most roads, however, alignment is already determined by various other obligatory considerations. Minimum interference with natural drainage will mean stable earth face/surface with some kind of vegetative cover preventing erosion and allowing free drainage.

8.1.4. On hill roads the moisture content in the subgrade is liable to considerable seasonal variation on account of the following:-

a) Water seepage through the adjacent hill face of the road.
b) Fluctuation in the water-table.
c) Percolation of water through the wearing surface.
d) Transfer of moisture/water vapour through different soil layers.
e) Snow fall and snow accumulation in the area.

8.1.5. Water flowing towards the road surface may be diverted and guided to follow a definite path and the flow on the valley side controlled so that stability is not affected. This will help in protecting the road bed and pavement. A network of drains helps in confining and controlling flow of water and thus check adverse effect on road structures. In hill roads, where the surface and sub-soil water run rapidly towards subgrade, interceptor drains would trap the flowing water and prevent it from reaching the road side. In the lower slope i.e. near the pavement, the in-flow of water in side drains will be local only. This has to be intercepted by catch pits which will collect the flow from side drain, reduce velocity and divert the flow to cross drain/culvert for disposal.

8.1.6. When viewed in totality against the back-drop of the hills, the road acts as an interceptor and its longitudinal cut on hill slope obstructs the natural drainage and the road ledge therefore acts as a collection area of all water from hill side. As such adequate drains in the form of catch water drains collecting flow from hill side to bring it to side drain leading to cross drains and further discharge in into natural drainage channels through valley side drain/chutes (if erosion is likely on valley side), are essential for stability of road.

8.2. Hydrological Study of Rain and Snowfall

8.2.1. Precipitation on hill roads may be in two forms:

a) Liquid precipitation : i.e. Rainfall
b) Frozen precipitation : This consists of:
   i) Snow
   ii) Hail
   iii) Sleet
   iv) Freezing

8.2.2. Run off is that portion of precipitation which does not get evaporated. Run-off may be classified as:

a) Surface run-off
b) Interflow or sub-surface run-off
c) Ground water flow or base flow

8.2.3. **Measurement of rainfall:** The amount of precipitation is expressed as the depth in centimetre which falls on a level surface and is measured by rain gauge which may be automatic or non-automatic type.

8.2.4. **Run-off:** The run-off of catchment area in any specified period is the total quantity of water draining into a stream or into a reservoir in that period. The principal factors affecting the flow from a catchment area are:-

a) Precipitation characteristics
b) Shape and size of the catchment
c) Topography
d) Geological characteristics
e) Meteoroligical characteristics
f) Character of the catchment surface
g) Storage characteristics

8.2.5. **Computation of run-off:** The run-off can be computed either by empirical or rational formulae.

8.2.5.1. **Empirical formulae for peak run-off from catchment:** Although records of rain-fall exist to some extent, actual records of floods are seldom available sufficiently to enable the engineer to accurately infer the worst flood condition, for which provision has to be made in designing structures. Therefore, the help of theoretical computation has to be taken. Some of the most popular empirical formulae are:-

a) Dicken's formula: $Q = CM^{3/4}$ where Q is the peak run-off in cum/sec and M is the catchment area in square km, C is a constant depending upon the rain-fall.

b) Ryve's formula: (For Tamil Nadu Hills)

$$Q = CM^{2/3}$$

c) Inglis formula: (For Western Ghats) $Q = \frac{125\,M}{M + 10}$ where Q is the maximum flood discharge in cum/sec and M is the area of catchment in sq. km.

8.2.5.2. These empirical formulae involve only one factor, viz., the area of the catchment. Many other factors that affect the run off have to be taken care of in selecting an appropriate value of co-efficient. This is an extreme simplification of the problem and can not be expected to yield accurate results.

8.2.5.3. In recent years hydrological studies have been made and theories set forth which comprehend the effect of the characteristics of the catchment on the run-off. Attempts have also been made to establish relationships between rainfall and run-off under various circumstances. These formulae are not, however, strictly applicable to hill areas (especially in the North and North East) and as such, appropriate evaluations by collection of data from ground in each case may have to be resorted to.

8.2.5.4. **Rational formula (velocity area method):** The hydraulic characteristics of the stream that influence the maximum discharge are:

a) Velocity of flow
b) Slope of the stream
c) Cross-sectional area of the stream
d) Shape and roughness of the stream

In case of streams with rigid boundaries, the shape and size of cross-section is significantly same during a flood as well as after its subsidence. But when a stream is flowing in alluvium, the bed gets eroded during a flood and it gradually silts up again after the flood subsides.

8.2.5.5. **Determination of velocity:** The velocity of a stream can be determined by:

a) Actual observation during a high flood
b) Use of empirical formulae

In making velocity observations the selected reach should be straight, uniform and reasonably long. The following methods are usually used:

a) Measurement of velocity by float
b) Measurement of velocity by pressure instruments
c) Measurement of velocity by current meter
d) Empirical Formulae commonly used
i) Manning's formula:

$$V = \frac{1}{N} (R)^{2/3} (S)^{1/2}$$

where

V	=	Mean velocity of flow in M/Sec
R	=	Hydraulic mean depth = A/P
A	=	Cross sectional area in square metre
P	=	Wetted perimeter in metre
S	=	Bed slope
N	=	Co-efficient of Rugosity

For measurement of the discharge, the cross-sectional area is generally divided into small vertical strips as shown in Fig. 8.1.

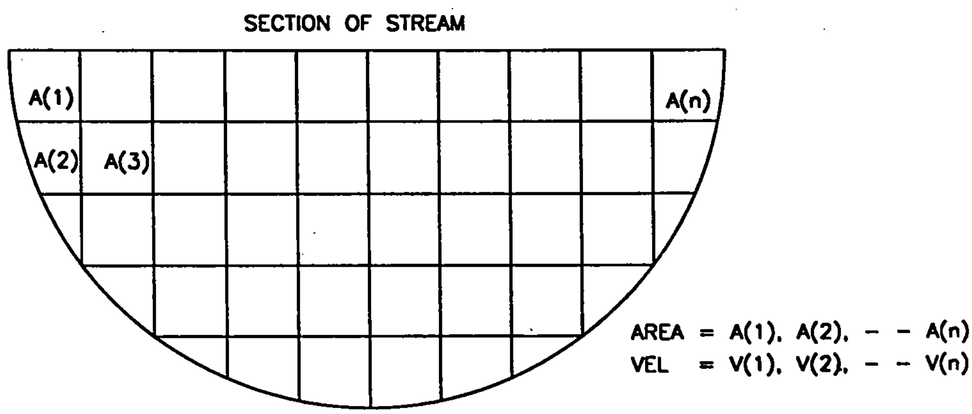


FIG. 8.1. DISCHARGE BY AREA – VELOCITY METHOD

The width of the strip is so chosen that each strip be taken as a rectangle. The velocity of each compartment can be calculated with fair accuracy with any of the methods described earlier. The products of area of strip and mean velocity of the strip gives the discharge of the strip. The discharge of the channel can be obtained by summing up the discharge of all individual strips.

If A (1), A (2) --- A (n) etc. are the area of the strips and V (1) V (2) --- V (n), are the corresponding mean velocities then the channel discharge is given by:

$$\text{Discharge } Q = A(1) \times V(1) + A(2) \times V(2) + \text{---} A(n) \times V(n)$$

$$= \Sigma (A \times V)$$

The normal practice is to compute the slope from the bed level at two cross-sections over a long distance. Since it is difficult to take any particular level in a cross-section at the bed level, it is recommended that the slope of the stream be calculated from one section at low water level of the proposed site and one section each at upstream and downstream of the proposed site and same be treated as the correct slope.

The use of empirical formulae should be as far as possible avoided. They are primitive and are safe only in the hands of an expert. The rational formulae explained above is the most commonly used in the determination of discharge.

8.3. Snow

8.3.1. Most high altitude regions are subject to heavy snowfall during winter. The average snowfall varies from sector to sector depending upon various factors. In certain sectors, the annual snowfall is less than 1.5 metres, whereas there are sectors having moderate snow fall varying between 1.5 to 4 metres and heavy snowfall areas with average snowfall exceeding 4 metres. In sectors having snowfall not exceeding 4 metres the intensity and frequency of snowfall is considered not very high. The roads in such sectors are kept open to traffic during winter by resorting to snow clearance operation. In other sectors, the intensity as well as frequency of snowfall are so high that it is neither economical nor feasible to keep the road open to traffic mechanically or manually during winter (which are confined to some high passes only) and is cleared in spring by launching a major snow clearance operation.

8.3.2. At the end of winter, when there is steep rise in temperature, snow starts melting from top as well as from the bottom of frozen layers. As the coefficient of thermal conductivity of snow is high the melting is always associated with enormous and instantaneous release of water. The water thus released, normally collects and flows on the road pavement in the absence of any outlet due to snow accumulation or ice formation.

8.3.3. Run-off from snow varies with its physical characteristics. The physical characteristics vary with the region depending upon meteorological conditions. Snow is classified as crystalline, granular, powdery pallet snow or mixtures. For run off purposes, it will be appropriate to classify snow as dry, damp and wet according to moisture content/density. Snow density varies from 0.40 - 0.45 (fresh snow) to 0.7 - 0.8 (wet snow). The snow with low density is termed as dry whereas snow having moderate and high density are termed as damp and wet snow respectively.

8.3.4. Chapter 12 on "Snow Clearance and Avalanche Treatment" gives details of snowfall, its effects etc.

8.4. Roadside Drains

8.4.1. Inadequate cross drainage on a hill road causes softening of the sub-grade and renders it too weak to take the load of the moving traffic. Roadside drains are therefore necessary on a hill road. They should be taken below the subgrade of the road or in a kutcha road these are invariably taken about 300 mm below the road surface. Where cross-fall and super-elevation oppose each other in valley side curves, proper arrangement to the layout of drain has to be done.

8.4.2. Roadside drains should generally be of uniform section throughout irrespective of the location of road on the hill slope. Road on ridge alignment may not require the same section of drains due to lesser quantity of flow of water. For convenience of construction, it may be necessary to have uniform section of a drain but the frequency of culverts could be regulated to the catchment area that it has to cater to.

8.4.2.1. Roadside drains are constructed to parabolic (Saucer shape), trapezoidal, triangular, V-Shape, kerb and channel or U-Shaped cross-sections. The parabolic section is hydraulically the best and most erosion resistant. The trapezoidal section is easier to construct and is more generally used. Kerb and channel drain gives extra width in case of emergencies for vehicles to use. U-Shaped drains are generally deep drains and are provided where higher discharge has to be catered and adequate road width is available.

8.4.2.2. Generally drains are made of size 60 cm x 60 cm and should have a gradient of 1:20 to 1:25 to develop self cleansing velocity to disperse floating debris conveniently. In continuous long stretches of road with steep grades, the road side drains should be stepped to break the velocity. A 0.6 m high toe wall along the hill side will be required to prevent erosion of hill-slope-as an integral part of side drain. In U-Shaped drain, road side edge should be provided with guide stones (duly white washed) to maintain distance of vehicles for safety.

8.4.2.3. Fig. 8.2 gives details of various types of side drains and their arrangements as described in preceding paras.

8.4.2.4. To discharge runoff from hill side drain to valley side, 8 to 10 culverts or scuppers can be provided per km or the side drains may be connected to discharge into natural water course.

8.5. Catch-Water Drains/Intercepting Drains

8.5.1. Such drains are provided on hill slopes to intercept water flowing from upper reaches and guide such flow into culverts. These drains should be trapezoidal shape and should be at least stone lined and cement pointed. Catch water drains must carry the intercepted water to the nearest cross-drainage point and it should be well cleaned and repaired before the onset of every monsoon.

8.5.2. Such catch-water drains should be provided in stable hill slopes outside the periphery of slide/unstable areas so that stability of hill is not further worsened. In such cases, additional intermediate drains may also have to be provided in some cases depending on ground conditions. Figs. 8.3 & 8.4 depict catch-water drain arrangement on a stable hill slope and in a slide area.

8.6. Chutes

8.6.1. Surface run off on a hill slope generally flows down in the form of natural gulleys/chutes. The water entrapped in the catch water drains is also brought down either by connecting them with existing natural gulleys or through specially provided chutes. The cumulative discharge with its increasing momentum causes immense erosion. It is, therefore, desirable to provide lined chutes to lead the discharge to the catch pit of culvert or to a natural drainage channel (Fig. 8.5). Box type stepped chutes of stone masonry have been found more appropriate because of their stability and long life. A typical section is given in Fig. 8.6.

8.7. Pavement Drainage

8.7.1. Drainage problem may be considered in two-categories, surface and sub-surface. Surface drainage or in other words, pavement drainage includes the disposal of all water present on the surface of the pavement and adjacent ground.

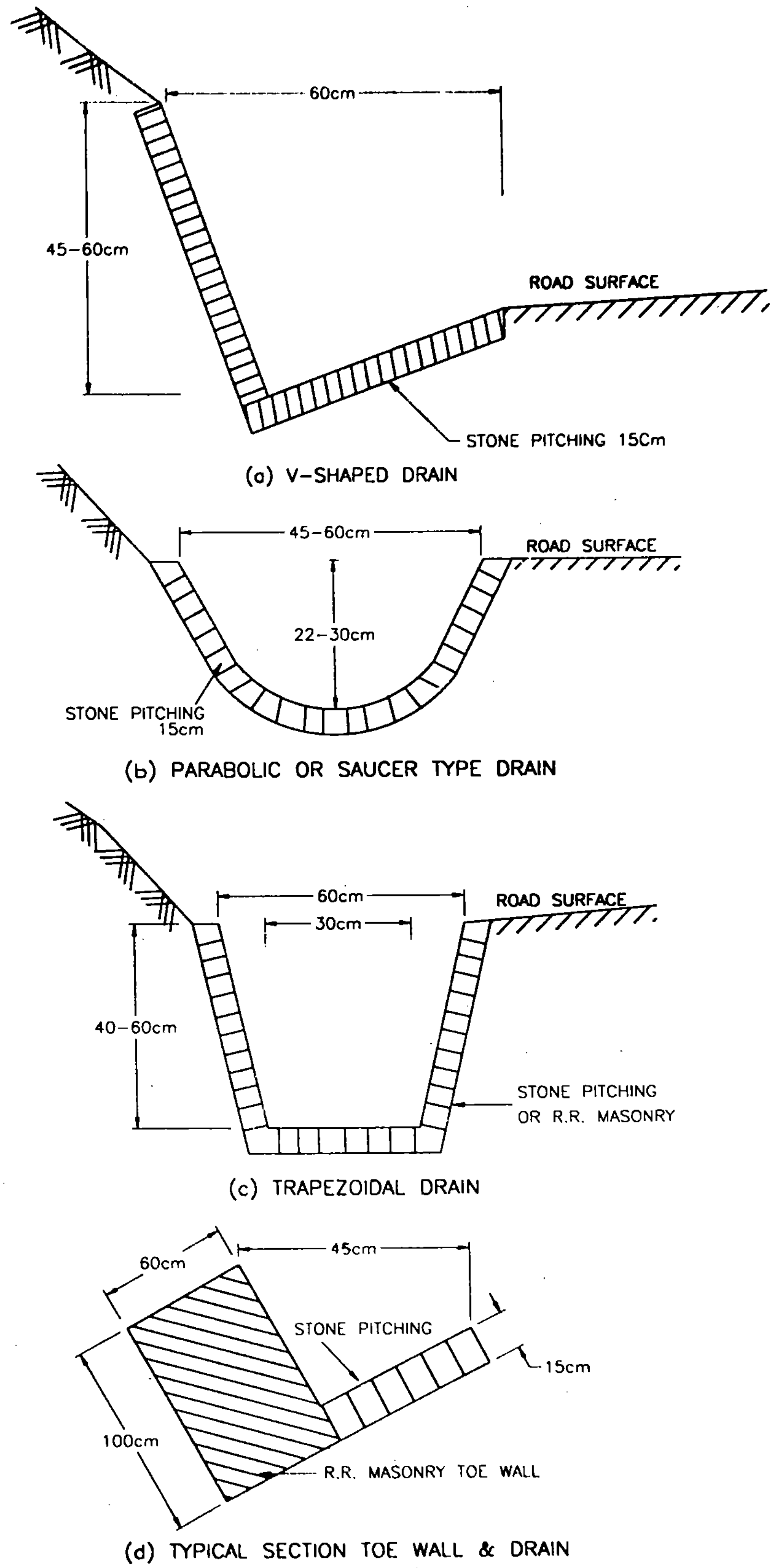
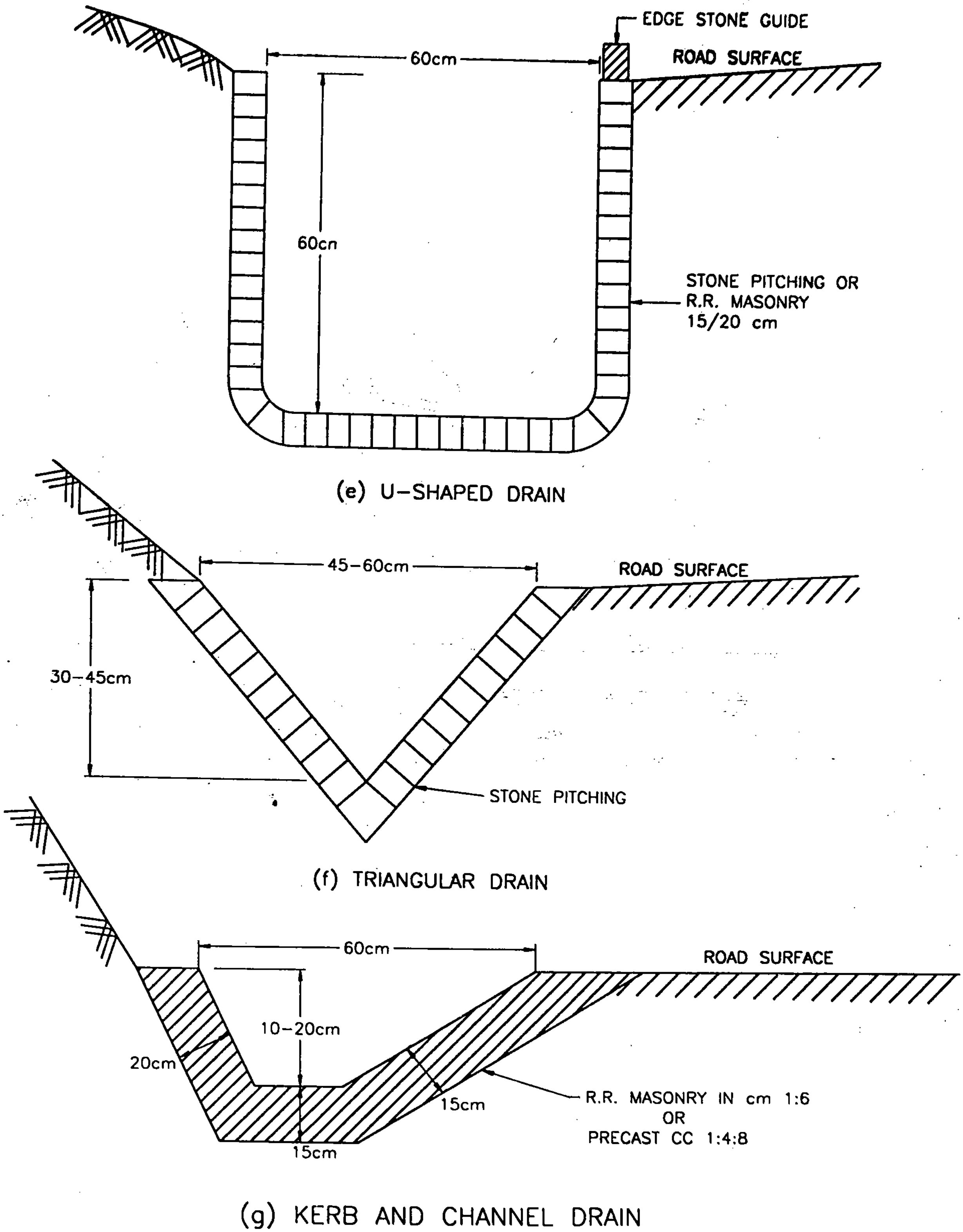


FIG. 8.2. SIDE DRAINS



(e) U–SHAPED DRAIN

(f) TRIANGULAR DRAIN

(g) KERB AND CHANNEL DRAIN

FIG. 8.2. SIDE DRAINS

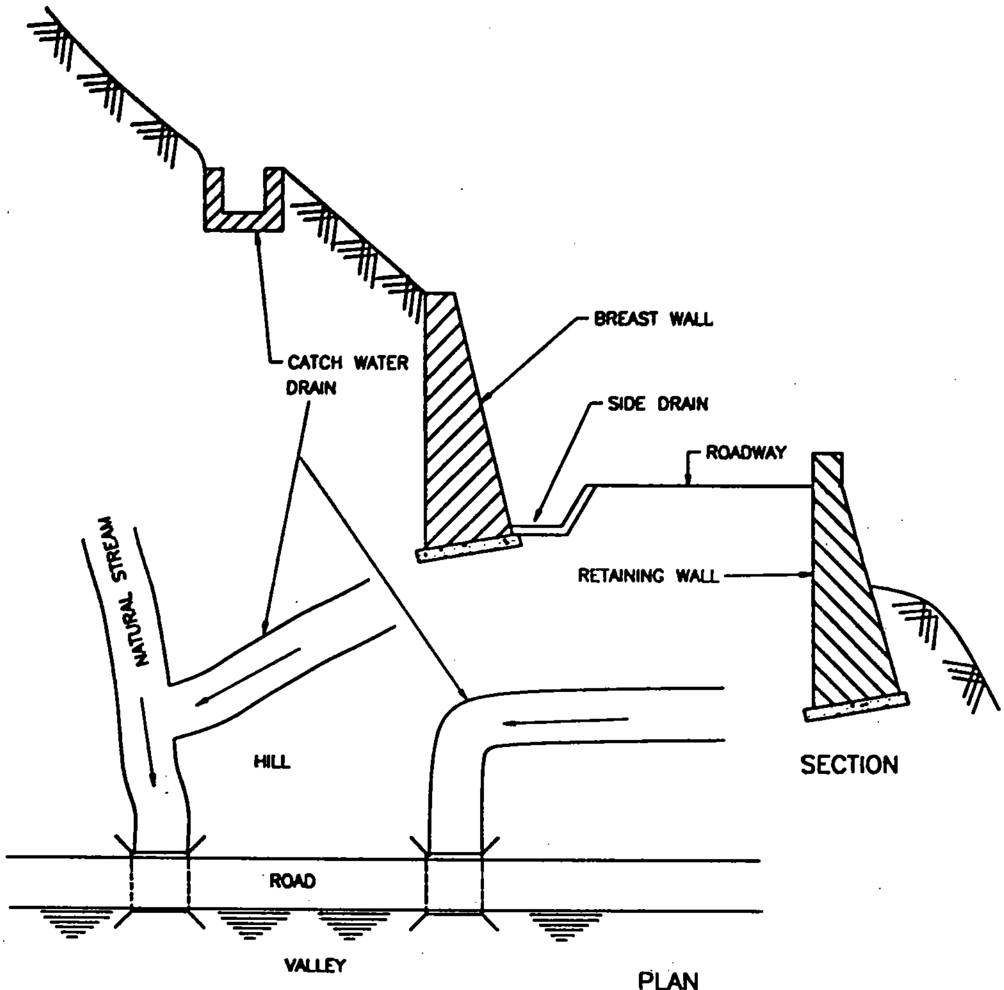


FIG. 8.3. CATCH-WATER DRAIN IN STABLE AREA

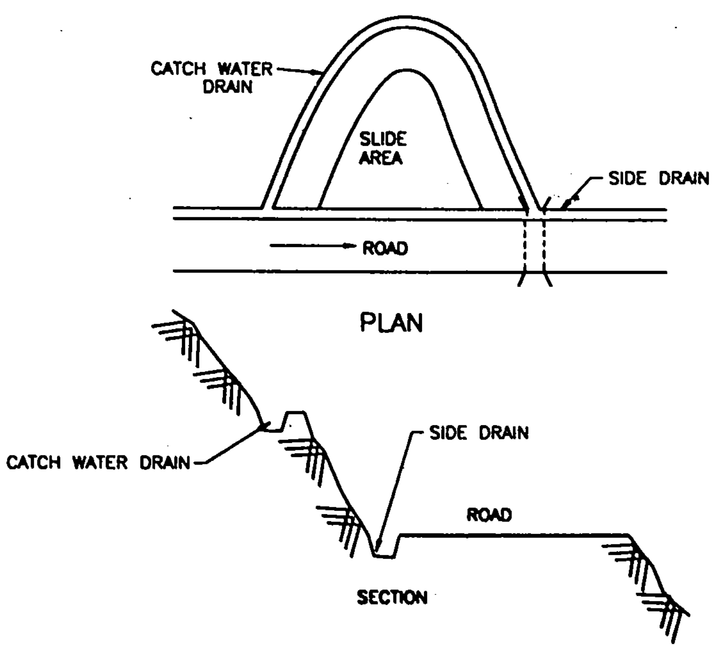


FIG. 8.4. CATCH-WATER DRAIN IN SLIDE AREA

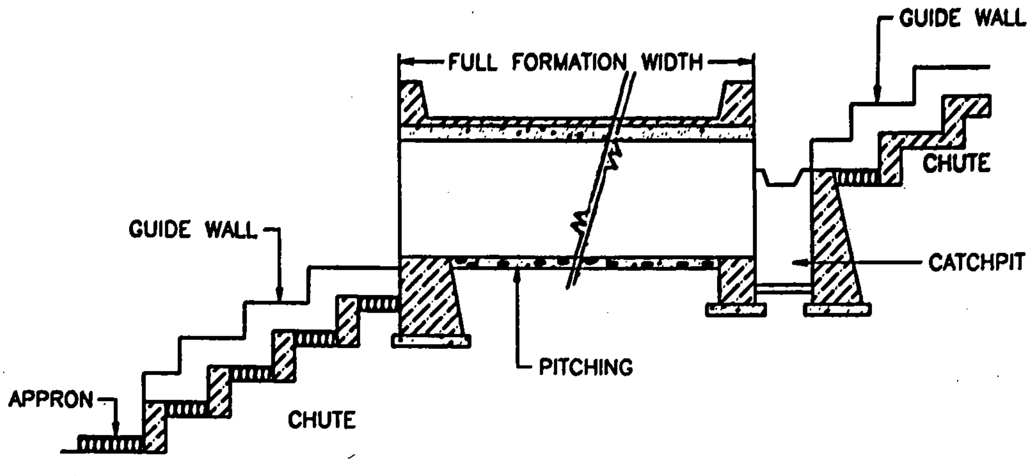
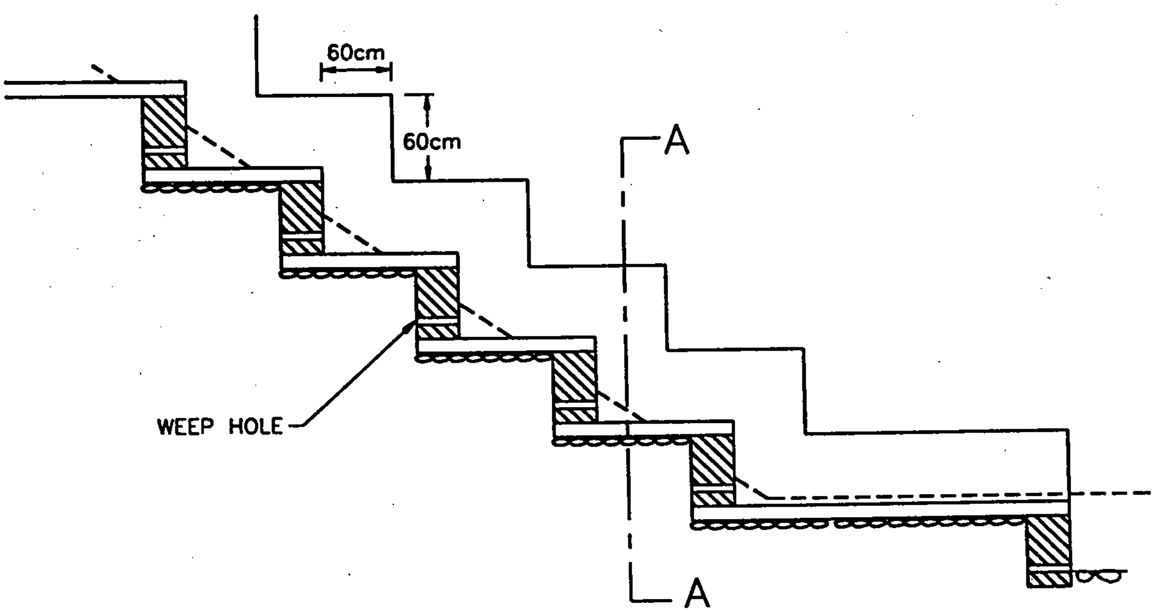
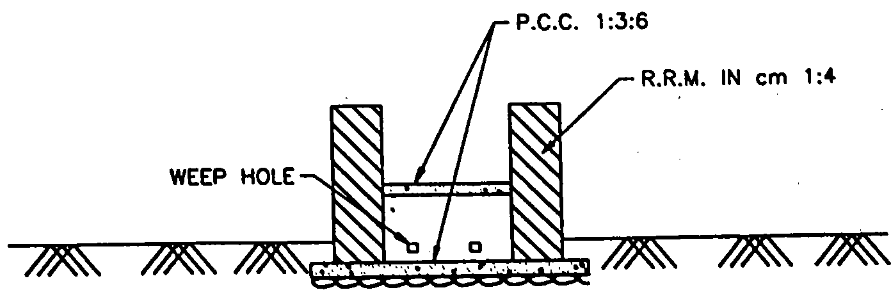


FIG. 8.5. CULVERT WITH CATCHPIT, CHUTE, GUIDE WALL AND APPRON



LONGITUDINAL SECTION OF CHUTE



CROSS SECTION A–A

FIG. 8.6. CROSS SECTIONS OF CHUTE

8.7.2. In the case of re-entrants, which necessarily have to be cross drainage points, cross fall is given towards the valley side. Surface drainage should provide for the surface water run-off from the carriageway/shoulders. The surface run-off, which is mostly due to local rainfall on the roadway is allowed to flow down quickly to the adjacent natural ground where appropriate cross fall is available.

8.7.3. The water collected on the surface of road and the adjacent ground is taken away by the side drains and disposed off into natural water courses nearby. As such the berms/shoulders should be well dressed and maintained to drain off the surface water either towards valley side or hill side. Roads in areas subject to heavy rainfall and snowfall are generally provided with hard or surfaced shoulders. It has been seen in actual practice that inadequate provision of proper crossfall/longitudinal gradient coupled with the temporary overflow of side drains, damages the shoulders considerably and the water finds easy access into the subgrade thereby causing damage to the pavement. Overflow along the road length damages the shoulders on the valley side.

8.7.4. Adequate care has to be taken in geometrics to ensure channelised drainage to avoid damage to road shoulders. On the valley side, protective parapets with intermittent gaps will help in surplus water to drain off on valley side. In straight reaches, camber to the road surface should be provided for disposal of surface water. Use of granular soil in slushy reaches has been found useful.

8.8. Sub-surface Drainage

8.8.1. Increase in the moisture content of subgrade reduces its strength and bearing capacity and hence it should be ensured that the moisture content in the sub-grade is kept as minimum as possible. Further, changes in the moisture content of clayey soil in the subgrade may lead to corresponding volume changes, i.e., swelling of the soil takes place with increase in moisture content. In order to correct these problems it is necessary to install drains below ground level which will intercept and carry the ground water to a stream or open drainage system.

8.8.2. The various causes due to which changes in soil moisture content occur below a pavement are indicated in Fig. 8.7. To counteract such possible changes, a sub-soil drainage system should be provided on these sections of the road wherever necessary.

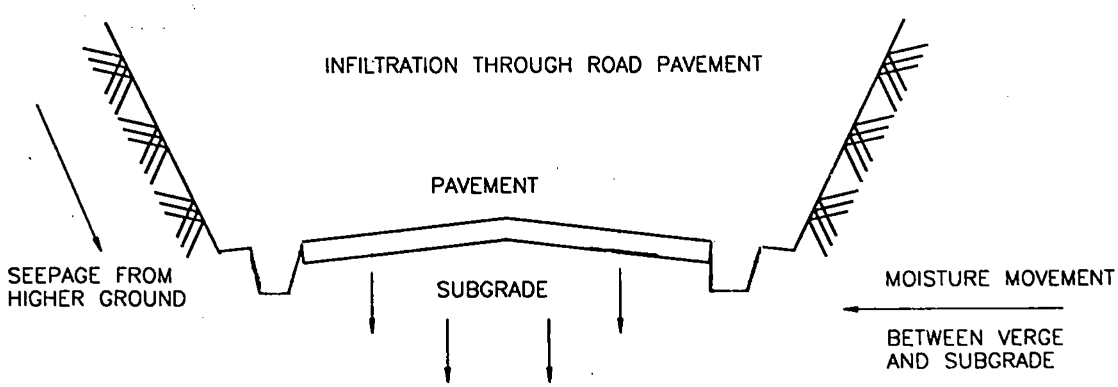


FIG. 8.7. MOISTURE MOVEMENT RESULTING FROM RISE AND FALL OF WATER TABLE SUB-SOIL DRAINAGE

8.8.3. Transverse tench drains

8.8.3.1. Transverse trench drains are generally made below the road pavement in a sinking area to facilitate the drainage of seepage water from the hill slopes without damaging the road structure. Sausage blocks of 1.2 m x 1.2 m in a trench of 1.8 m width are constructed on uphill and downhill site. In between these blocks, boulders are properly packed to take the load of road structure and traffic over the transverse trench. Fig. 8.8 shows the cross section of Transverse Trench Drain.

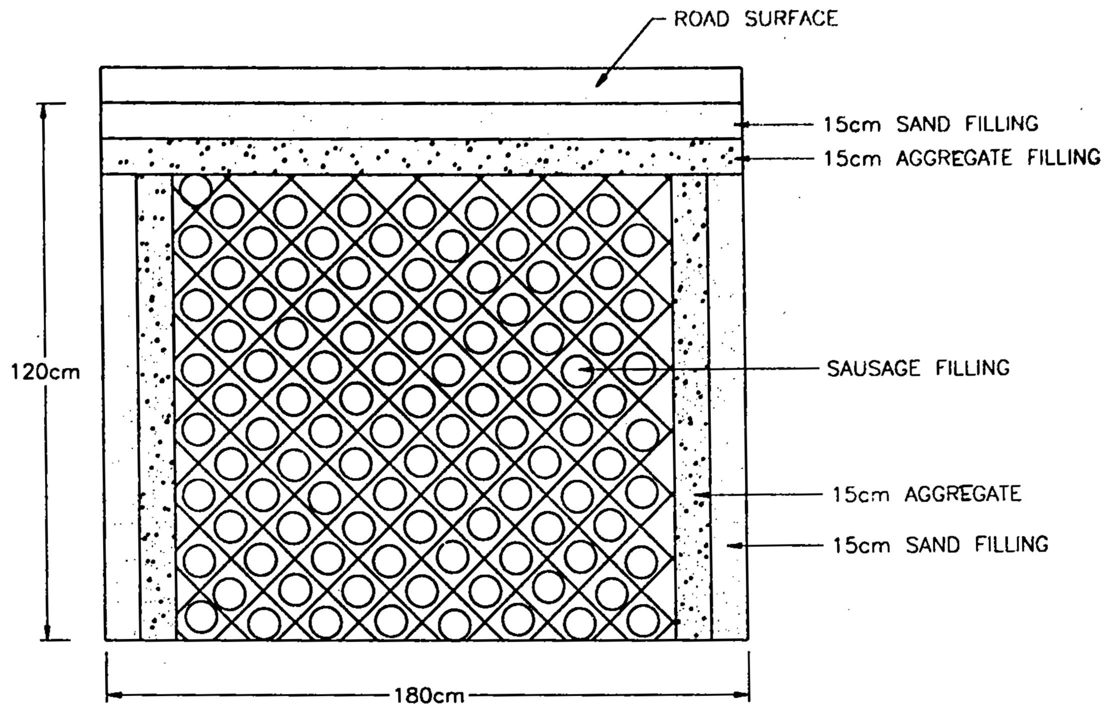


FIG. 8.8. CROSS SECTION OF TRANSVERSE TRENCH DRAIN

8.9. Application of Sub-surface Drains

8.9.1. Seepage from High Ground: Seepage from high ground occurs when a layer of permeable soil overlies an impermeable layer. Cut slopes, which continually slough away at a point where free draining water reaches the face can be stabilised by installing sub-soil drains at back of the cutface.

8.9.1.1. In such cases, a drain is constructed as a cut-off drain and installed to a depth slightly below the pervious material and backfilled with clean sand. A pipe is usually bedded on stone or lean concrete on impervious material to prevent water from collecting underneath the pipe and eventually causing deterioration of the subgrade. The underground water is carried away in the drain to an outlet or a stream, removing the cause of sloughing. When the impermeable stratum is at a lower level and the seepage zone is deep, it is generally not practicable to intercept all the seepage water and the intercepting sub-surface drain is positioned so as to keep the seepage water at least one metre below formation level. Fig. 8.9. shows a sub-surface drain intercepting free water in a slope before it reaches the face where it would cause sloughing or sliding.

8.9.2. **Subgrade drainage**: The underground water flows in a layer near the road surface. This water can weaken the road and create soft spots and rutting. The subgrade drainage controls the moisture movement due to water table effect.

8.9.3. **Water table effect**: Where the road is in cutting or at ground level it is important to prevent the water table from rising too close to formation level, since moisture content by capillary action can cause changes in sub-grade moisture content. It is considered that a stable sub-grade can be maintained if the water-table is kept at least one metre below formation level. Sub-soil drains running along the pavement at appropriate depths will achieve this.

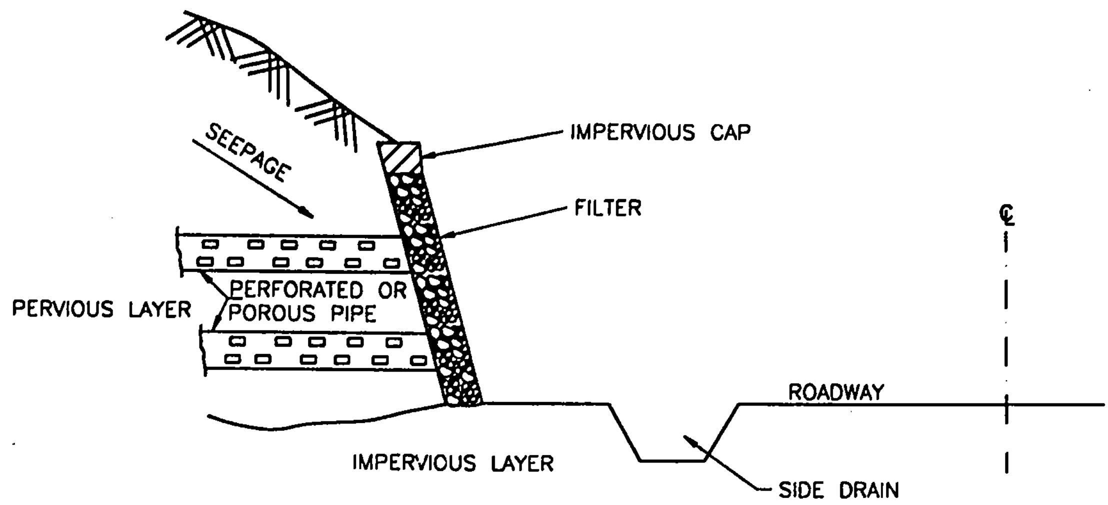


FIG. 8.9. SEEPAGE FROM HIGH GROUND SUB-SOIL DRAIN

8.9.4. **Moisture movement between berms/shoulders and subgrade**: Changes in the moisture content of the road pavement and subgrade materials may take place as a result of the transfer of moisture to and from the soil in the road berms. The berm will normally have a higher moisture content than the subgrade in winter and a lower one in summer and, therefore moisture will be transferred to the subgrade in winter and vice-versa in summer with clay subgrade. This will result in swelling and shrinkage of the subgrade along the carriageway edges with consequent differential rise and fall with respect to the road crown and in spells of prolonged drought, may give rise to longitudinal cracking along the road surface. A sub-surface drain situated between the berm and the carriageway removes the point of weakness from the edge of carriageway to the outside of the shoulder where its effect is much less critical.

8.9.5. **Infiltration through pavement**: Most of the road surfaces are topped with open-graded bitumen premix carpet only and ingress of moisture through the porous surfacing may penetrate into the subgrade. If the pavement has surface cracks, the inflow through the pavement into the sub-grade during rainy season will be much more and cause further deterioration of the pavement.

8.9.6. **Due to snow**: Thawing of snow creates problem and the resultant water thereof should be drained off the road from the nearest exits. These exits can be developed by cutting snow on the berm on valley side. A regular flow of this water will help in quick melting of snow also. Use of common salt, saw dust/sand is made to counter the problem posed by ice formation/frost. Chapter 12 dealing with snow clearance gives more details.

8.9.7. A drainage blanket of selected filter material below the structural section of the pavement, will take care of the infiltration through the pavement, lower the water table and arrest moisture movement by capillary action from the soil all around. Figs. 8.10, 8.11 & 8.12 indicate such arrangements.

8.9.8. Sub-surface drainage is also achieved by having trenches filled with filter material, i.e. sand, gravel, etc. which drain off the underground water.

8.9.9. As an alternative to conventional filter material, geotextiles can also be used as indicated in para 7.9.1.

8.10. **Cross-Drainage-Hydrological Considerations**

8.10.1. Whenever streams have to cross the road, cross drainage structures have to be provided. Similarly water from the side drains is taken across by these cross drains in order to divert the water away from the road to a water course or valley.

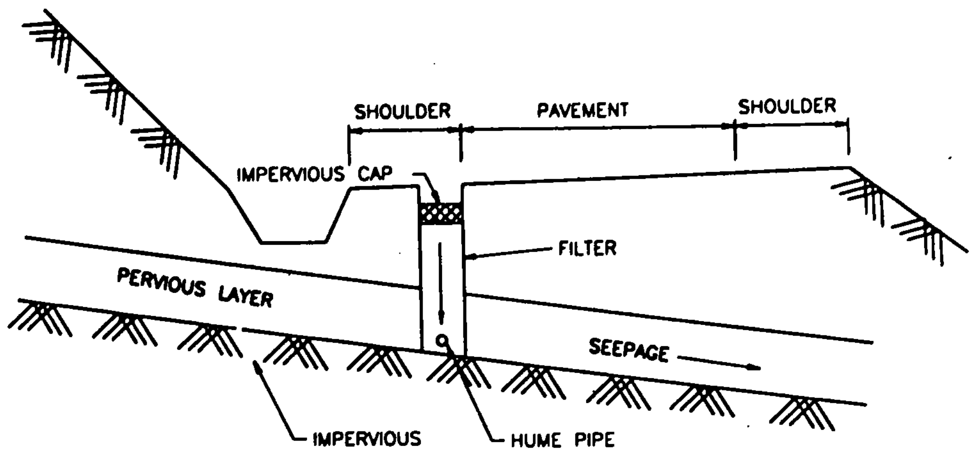


FIG. 8.10. SUB-GRADE DRAINAGE

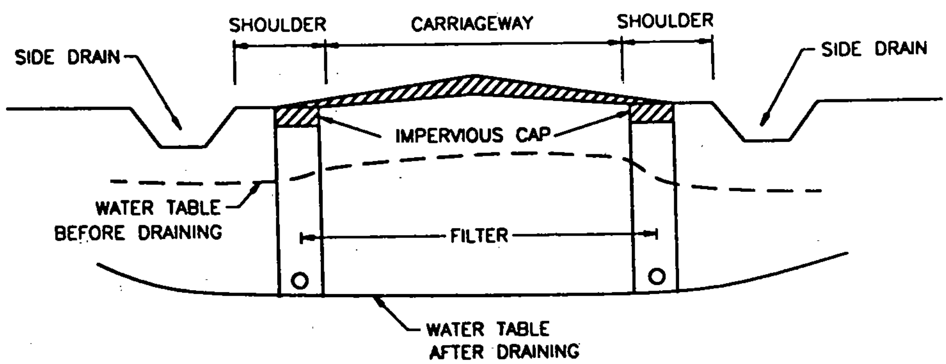


FIG. 8.11. LOWERING WATER TABLE

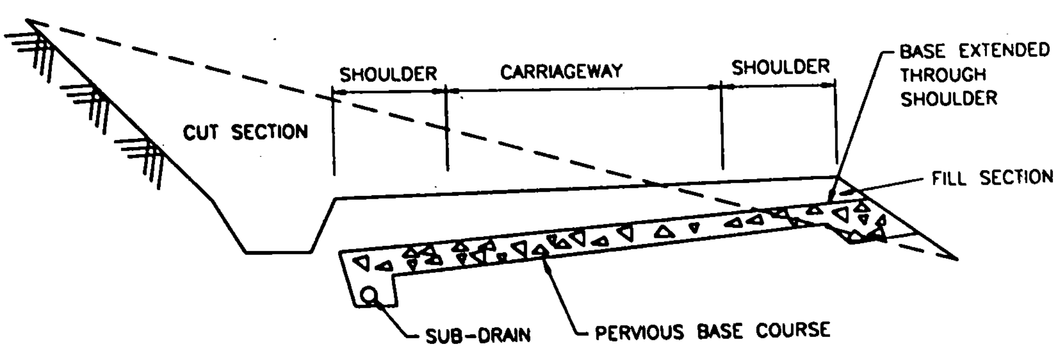


FIG. 8.12. PAVEMENT DRAINAGE

8.10.2. A variety of Cross-Drainage structures are possible. These can be considered under two broad groups namely:

a) Crossings that are submersible, such as fords, paved dips, causeways, and submersible bridges.

b) Crossing that are not submersible, such as culverts, bridges and ferries.

Each type of crossing has an appropriate place for use.

8.10.3. The considerations in the proper choice of the type of crossing are:

a) Functional
- i) Number of vehicles delayed.
- ii) Length of time of each delay.
- iii) Number of times per year these delays occur.

b) Technical
- i) Nature and width of stream and flood flows - whether flashy or sustained.
- ii) Velocity of flow and bed slope.
- iii) Maximum and minimum depth of flow.
- iv) Presence of floating debris, boulder movement on the bed etc.
- v) Local materials and skills available.

c) Economical
- i) Cost of initial construction.
- ii) Cost of maintenance or reconstruction.
- iii) Cost of delays to vehicles (in the case of submersible crossings).

Normally experience and local practice will be highly helpful in the choice of the appropriate crossing. However, there can be overlapping cases suggesting more than one alternative. In such cases, where doubt exists, it would be worthwhile to evaluate alternatives taking all the aboe mentioned aspects into account. For quick selection of promising alternatives, the guidelines given in Table 8.1 will be helpful.

Table 8.1. Guidelines for the Choice of Cross Drainage Structures for Hill Roads

Sl. No.	Type of Structure	Locations where the structure will be found suitable
1.	Ford	Shallow non-perennial stream where maximum depth of flow does not exceed 1.6 m and the period of interruption at one stretch does not exceed 12 hours for ODRs and 24 hours for VRs in hilly terrain. Also, the total period of interruption in a year may not exceed 10 days for ODRs and 15 days for VRs. Suitable for roads in isolated areas carrying very low traffic. Also for roads in a network where alternative route is available during the rainy season. Low in initial cost and ideal for crossing of men on foot and cattle.
2.	Paved dip (flush or low-level causeway)	Same as for Sl. No. 1 except that the traffic on the road may be somewhat higher.
3.	Vented Causeway	Shallow streams having permanent dry weather flow exceeding 0.6 m in depth. The same criterion indicated for Sl.No. 1 as regards interruption equally apply to this case also.
4.	Submersible bridge	In case where high level bridge is too expensive to construct.
5.	Culvert	This is a high level structure having length between abutments upto 6 m. Suitable for narrow streams.
6.	High Level bridge	Ordinarily high level bridges are designed to cater for the maximum possible flood discharge. Situations warranting such bridges are crossings of deep narrow streams or ravines in hilly terrain.
7.	Steel Equipment Bridges (Portable)	Portable steel bridges are quite easy and quick to construct even for emergent needs.
8.	Suspension Bridges	Ideally suitable to bridge long and deep gaps in hilly terrain.
9.	Boat ferry and Pontoon/boat bridges	In case of large streams where it is not economical to provide a bridge, ferry service or pontoon/boat bridge may be appropriate.
10.	Other Crossings	Wire rope trolley may be used for remote and unimportant areas.

8.10.4. Details of submersible types of cross-drainage structures are given below:-

a) Ford

8.10.4.1. Location for the ford is chosen at a place where the stream runs in shallow channel. A trench about 1 m wide and 1 to 1.2 m deep is dug on the bed of the stream along the downstream edge of the road. The trench is then filled with stones in wire crates upto the level of the road. As an alternative, a masonry (stone or brick in cement mortar 1:4) wall could be built along the down-stream edge to retain the road in position. The road surface is formed by levelling the stream bed with gravel. After one or two seasons, fines transported by the stream will fill in the voids in the gravel surface, leaving a satisfactory stream crossing. Details of a typical ford are illustrated in Fig. 8.13.

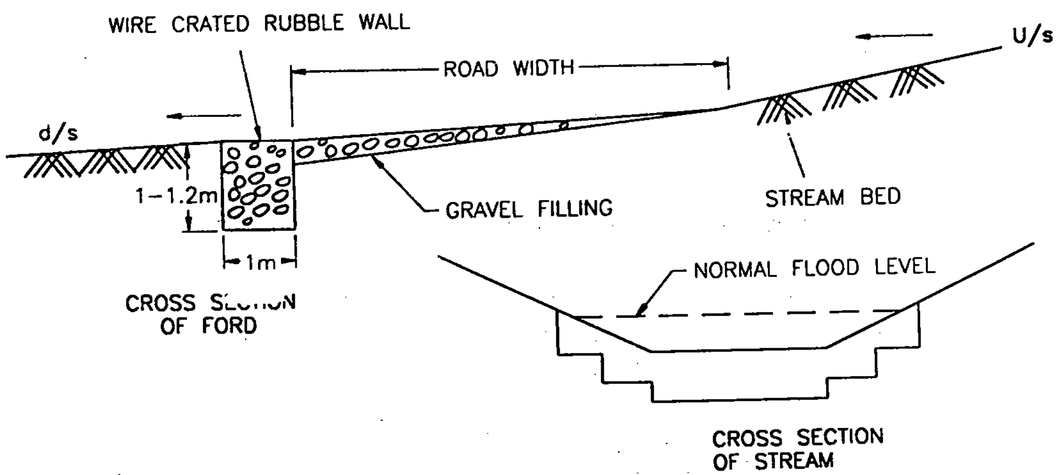


FIG. 8.13. FORD

b) Paved Dip or Flush Causeway or Low Level Causeway

8.10.4.2. This is similar to a ford constructed flush with the stream bed except for the provision of permanent riding surface protected by cut-off walls both on the upstream and downstream sides. Fig. 8.14 illustrates the details of a paved dip. The criteria for design is restricted depth, required length and shock-free vertical curves.

c) Vented Causeway or High Level Causeway

8.10.4.3. Vented causeways have the double function of passing normal discharge through the vents below the roadway and the flood discharge both through the vents and over the road-way itself. Some of the important considerations in the design of this type of structure are:-

a) The vents should be sufficient to pass the normal water flow without overtopping. This should be checked for the maximum annual flood to ensure that the interruption criteria given in Table 8.1 are not transgressed.

b) The vents should be distributed throughout the length of the causeway. All entry faces should be bell-mouthed to reduce hydraulic losses and thereby the afflux. The vents may consist of pipes, reinforced concrete slabs, arches or stone slabs depending on the availability of materials and local conditions.

c) The roadway should preferably be given one way crossfall towards the downstream side. This will have the advantage of reduced afflux and avoid the chance of a standing wave (consequent turbulence and serious erosion) being formed.

d) Other measures for reducing the hydraulic resistance are rounding/bevelling the upstream edge of the causeway and provision of streamlined guard stones.

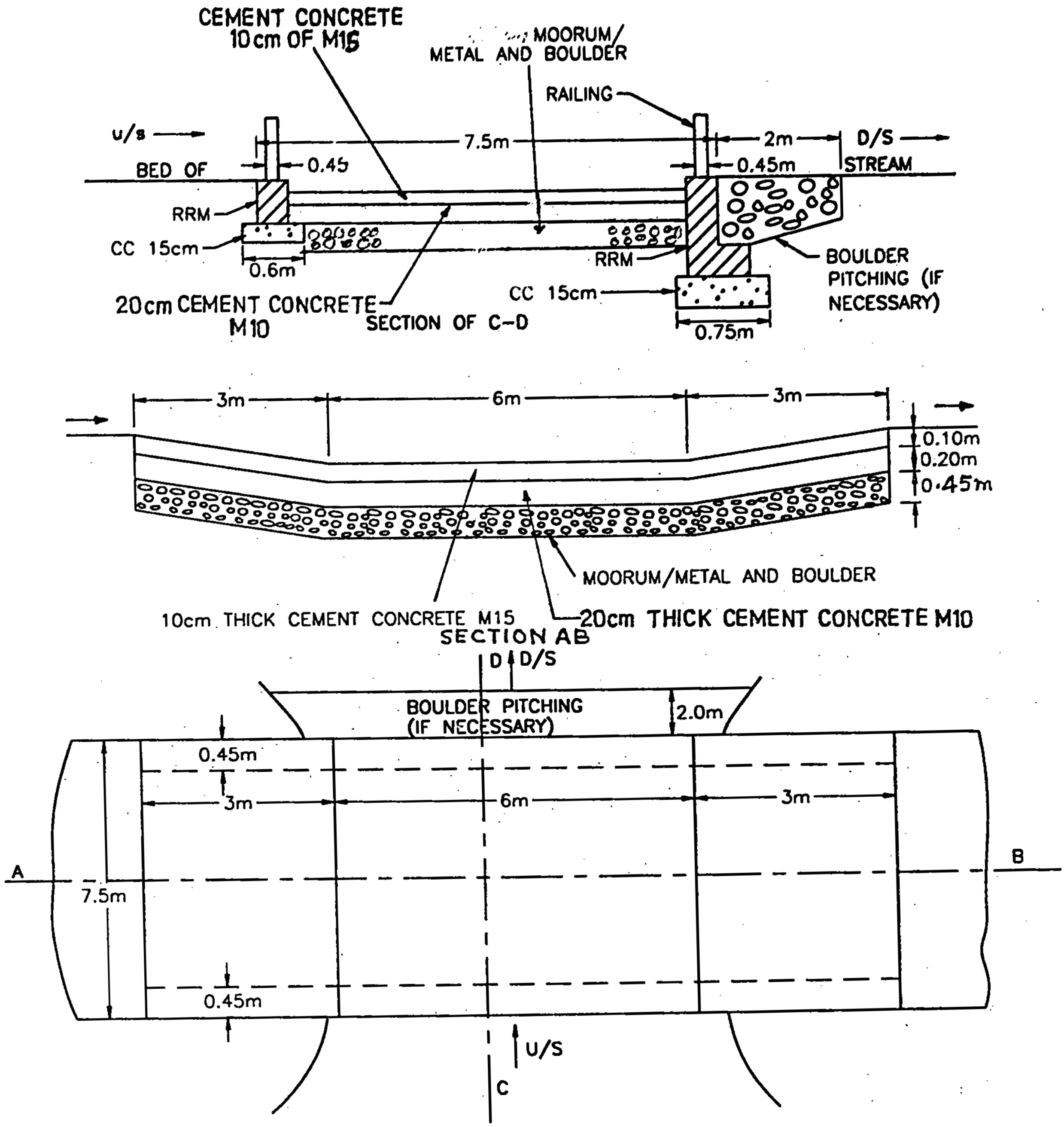
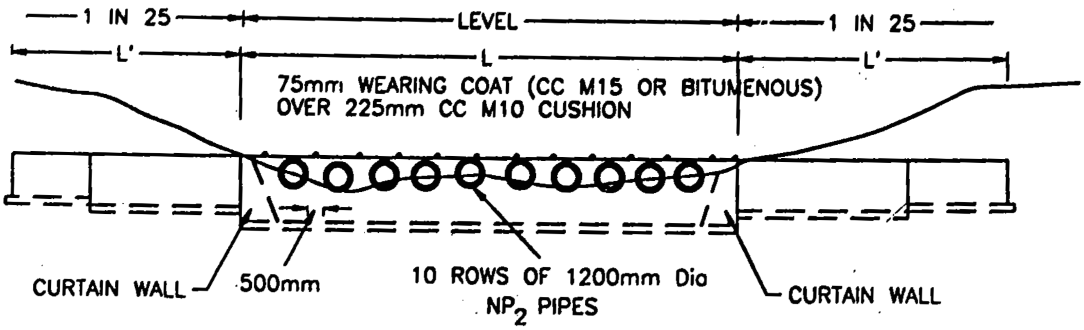


FIG. 8.14. PAVED DIP/FLUSH CAUSEWAY (12m) PLAN

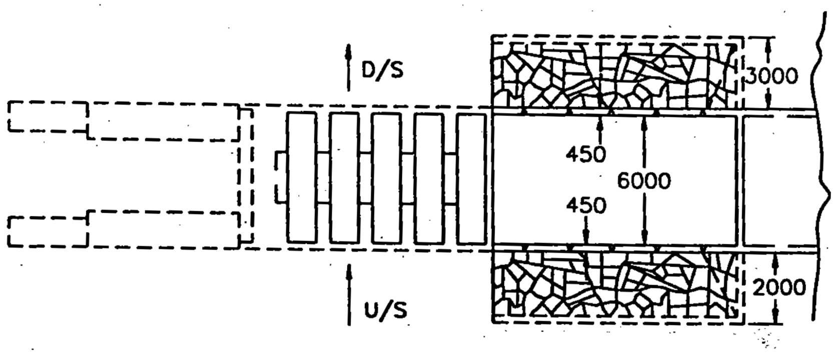
e) The final road levels (grade line on the causeway) should be kept as low as possible, consistent however with satisfying the interruption criteria. It should be clearly understood that the flood levels will increase (because of afflux) on the upstream side after the construction of the structure depending on the extent of obstruction.

f) Suitable cut-off walls should be provided at both the upstream and down stream sides. Unless rock is met with at higher levels, these walls should go down to at least 1 m and 2 m on the upstream and downstream sides respectively. These walls should be protected by means of apron comprising rubble stone or cement concrete block of a width of 2 m and 5 m on the upstream and downstream sides respectively.

Fig. 8.15 shows two typical vented causeways using R.C.C. pipes for the vents.

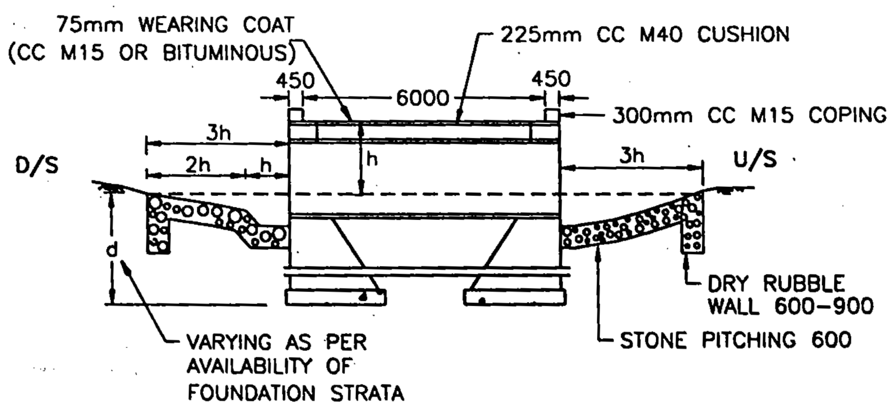


LONGITUDINAL SECTION



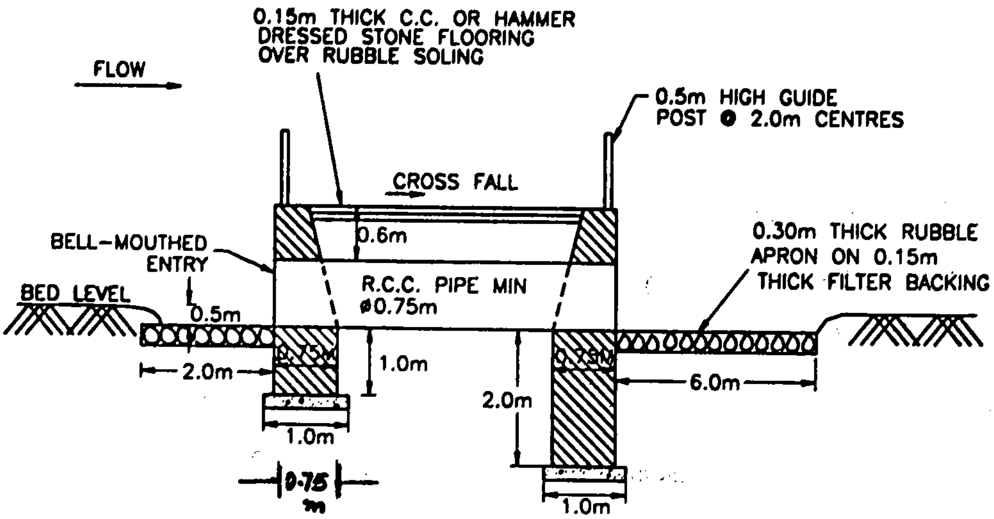
PLAN

(ALL DIMENSIONS IN mm)



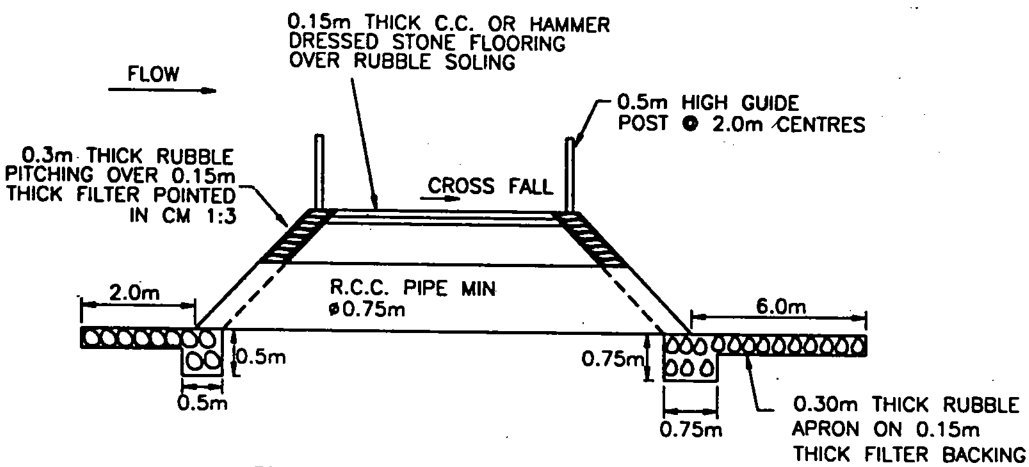
CROSS SECTION

FIG. 8.15. VENTED CAUSEWAY WITH (SKETCH–1) RCC PIPES FOR VENTS



ALTERNATIVE-I WITH MASONRY HEAD/CUT-OFF WALL

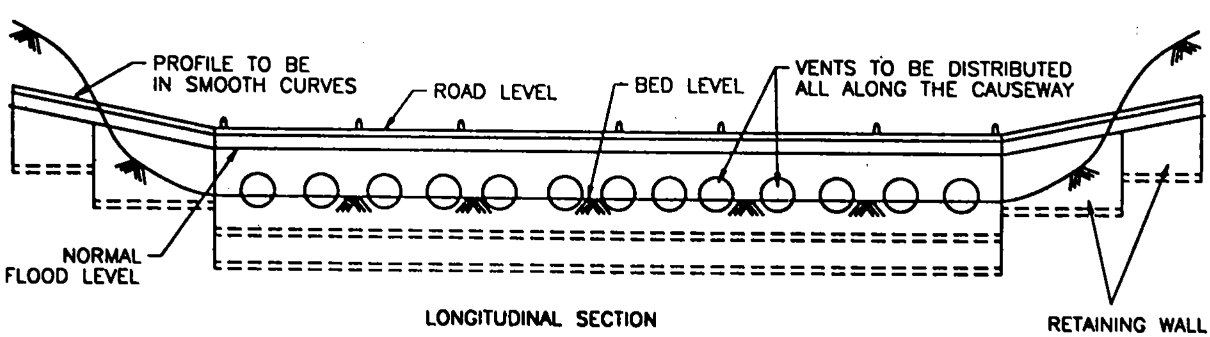
CROSS-SECTION



ALTERNATIVE-II WITH STONE PITCHED BANK

CROSS-SECTION

(ALL DIMENSIONS IN METRES)



LONGITUDINAL SECTION

FIG. 8.15. VENTED CAUSEWAY WITH R.C.C. PIPES FOR VENTS (SKETCH-2)

d) Submersible Bridges

8.10.4.4. Obviously, for rivers which have considerable difference between HFL and OFL and if the road is of minor importance submersible bridges are generally considered adequate. These are eminently suitable in hilly areas where the floods are flash and do not interrupt the traffic for long.

8.10.4.5. Submersible bridges are normally built on in-erodible bed rock. Otherwise the design becomes more complicated and requires careful consideration both in design and the sequence of construction. In case of submersible bridges built on erodible soil, protective pitching or apron should go hand in hand with the construction of other bridge elements.

8.10.4.6. Though submersible bridges are cheap compared to high level bridges, they need greater maintenance of their approaches if there is considerable spread of water. The design of submersible bridge needs consideration of certain additional aspects of design like that of hand rails, impact of floating debris and the hydrodynamic effect of the water acting over the whole bridge, theoretical condition being when the river is just about to overtop the bridge. These have to be considered along with buoyancy in design.

8.10.4.7. A typical sketch of submersible bridge is given in Fig. 8.16.

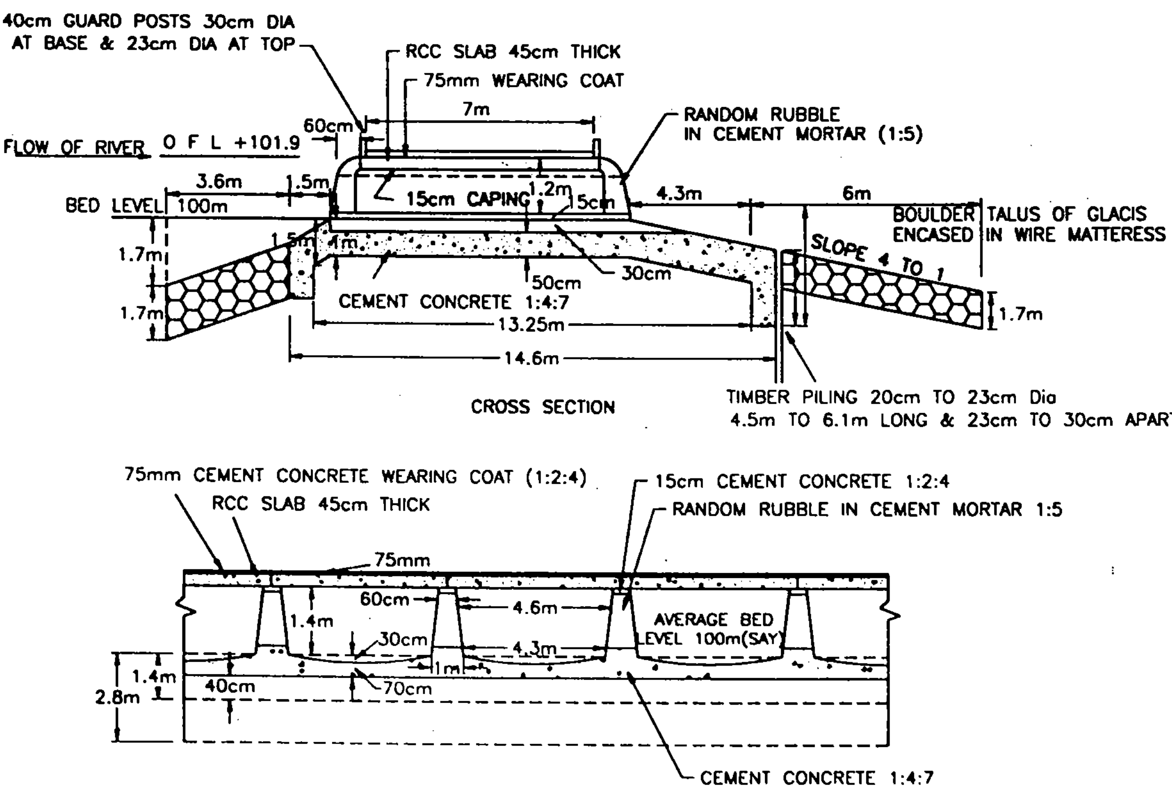


FIG. 8.16. SUBMERSIBLE BRIDGE

8.10.5. **Details of non-submersible drainage structures are given below:-**

a) Culverts

8.10.5.1. It is a bridge having a length of six metres or less between the faces of abutments or extreme ventway boundaries and measured at right angles thereto. Culverts are generally provided 5 to 6 per kilometre for efficient drainage and at every small rivulet. The vent should be about 1.0 m x 1.5 m so as to afford ample space for the maintenance staff to clean them before and after the rainy season. Blockage and choking of these vents can cause serious damage to the road structure as water spills over to the road.

8.10.5.2. Adequate protective works are required at the discharge point which should preferably be in the form of stepped walls to dissipate the kinetic energy of the discharged water outfall.

8.10.5.3. Culverts may be any one of the following types :-

a) Pipe Culvert b) Slab Culvert c) Arch Culvert	Typical sections are given in Figs. 8.17, 8.18 & 8.19

8.10.5.4. **Arch culvert** : This consists of abutments, wing walls, arch, parapets and the foundations. The construction materials, commonly used, are stone masonry or concrete. Floor and curtain wall may or may not be provided depending upon the nature of foundation soil and velocity of water flow.

8.10.5.5. **Slab culvert** : A slab culvert consists of RCC slab with or without beams or a stone slab, with or without steel girders to cover the span across the abutments and piers. The deck slab should be designed as one way slab.

8.10.5.6. **Pipe culvert** : They are provided when discharge of stream is small or when sufficient headway is not available. Usually one or more pipes of diameter not less than 60 cm, preferably 90 cm - 100 cm, are placed side by side. Their exact number and diameter depends upon the discharge and height of bank. These pipes can be made of masonry, stoneware, or cement concrete. A concrete bedding should also be given below the pipes and earth of sufficient thickness on the top to protect the pipe and their joints. As far as possible the gradient of the pipe should not be flatter than 1 in 30. As the pipe culverts need a cushion of 60 cm or so, these culverts may be adopted only at locations where it is suitable.

b) Foot Bridges

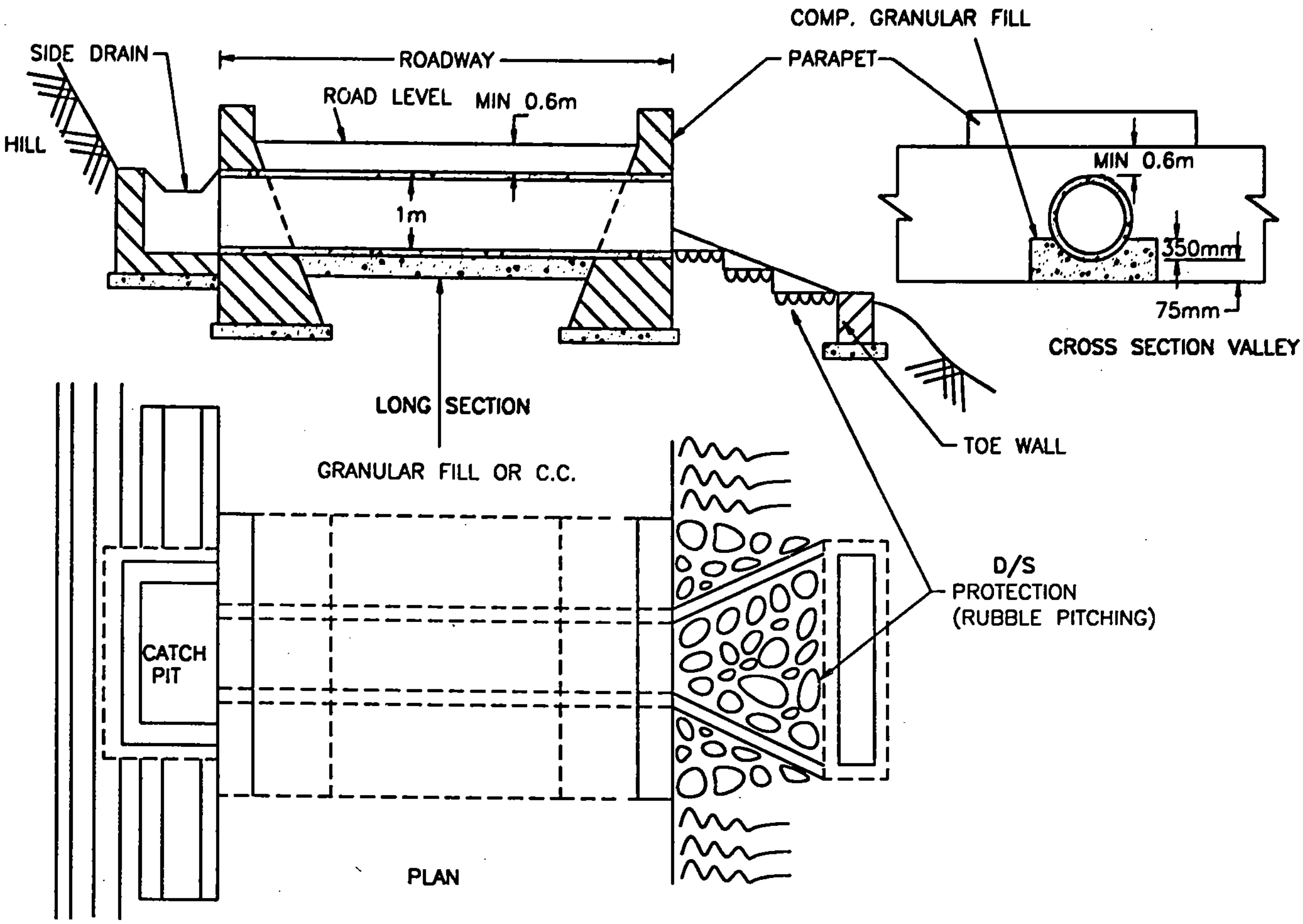
8.10.5.7. In isolated areas, in locations where provision of a motorable bridge may not be economically feasible and where a crossing is required only for people and cattle, provision of foot bridges will be an expedient solution. Foot bridges may vary in shape and details of construction depending on the local materials available. A variety of materials, like tree trunks, wooden sections, R.S.Js or used rails can be used for the main beams over which wooden deck could be constructed. In areas where bamboo is available in plenty, two to four pieces of bamboo can be clamped or fixed together to act as a single beam for span upto 3 m.

8.10.5.8. For foot bridges, the minimum width of deck shall be 1.5m. Where the crossing stream is deep, or the water current is fast, hand railings should be provided.

c) Timber Bridges

8.10.5.9. In areas where timber is locally available, it can be used both for the substructure and the superstructure of a bridge. Timber bridges should be considered as temporary structures having a life span of 10-20 Years.

CULVERT IN SIDE HILL CUTTING



RCC SINGLE PIPE CULVERT 1m Dia

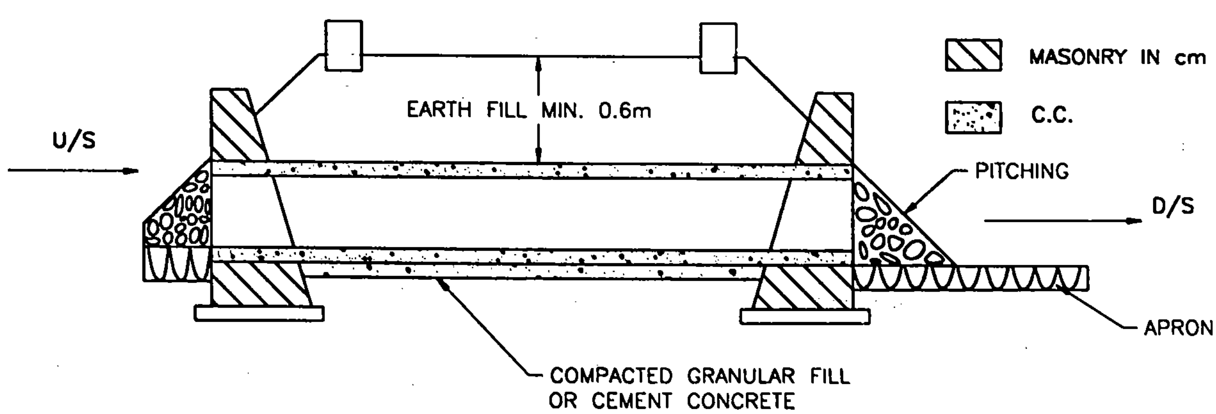


FIG. 8.17. CULVERT IN EMBANKMENT – PIPE CULVERT

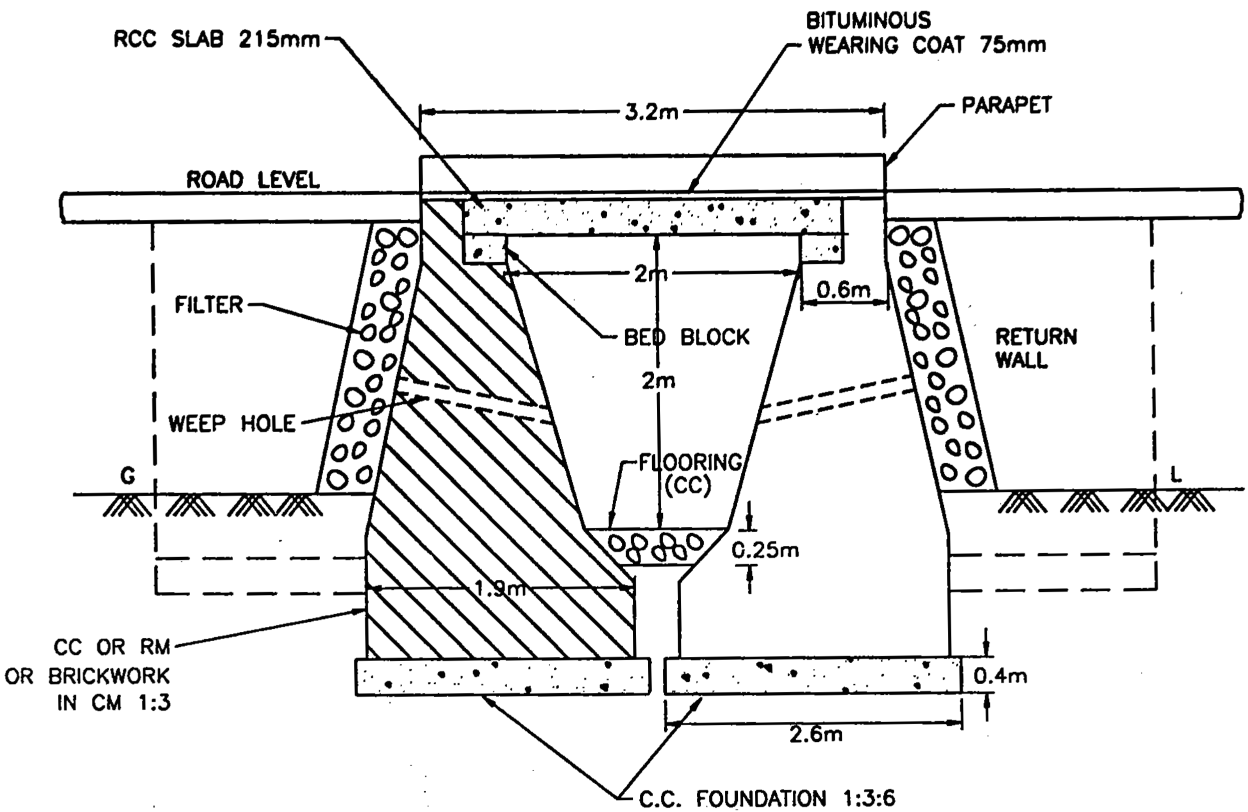


FIG. 8.18. RCC SLAB CULVERT 2m x 2m (SECTION)

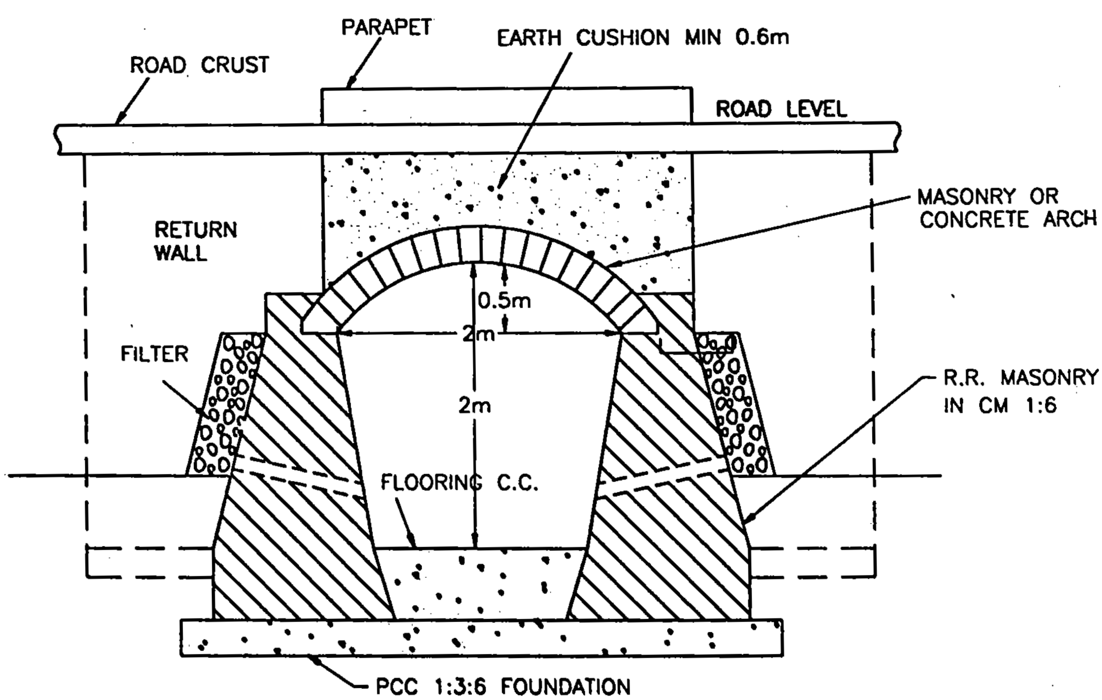


FIG. 8.19. 2mx2m ARCH CULVERT SECTION

8.10.5.10. The substructure may consist of timber piles of trestles depending on local conditions. Pile type supports should be used when site conditions are affected by deep water or swift current causing scour, low bearing capacity soil overlaying rock, or un-consolidated soil with low bearing capacity. Typical timber trestle pier and piile pier are illustrated in Fig. 8.20. For spans greater than 5 m, a double row of piles/trestles should be used for a pier.

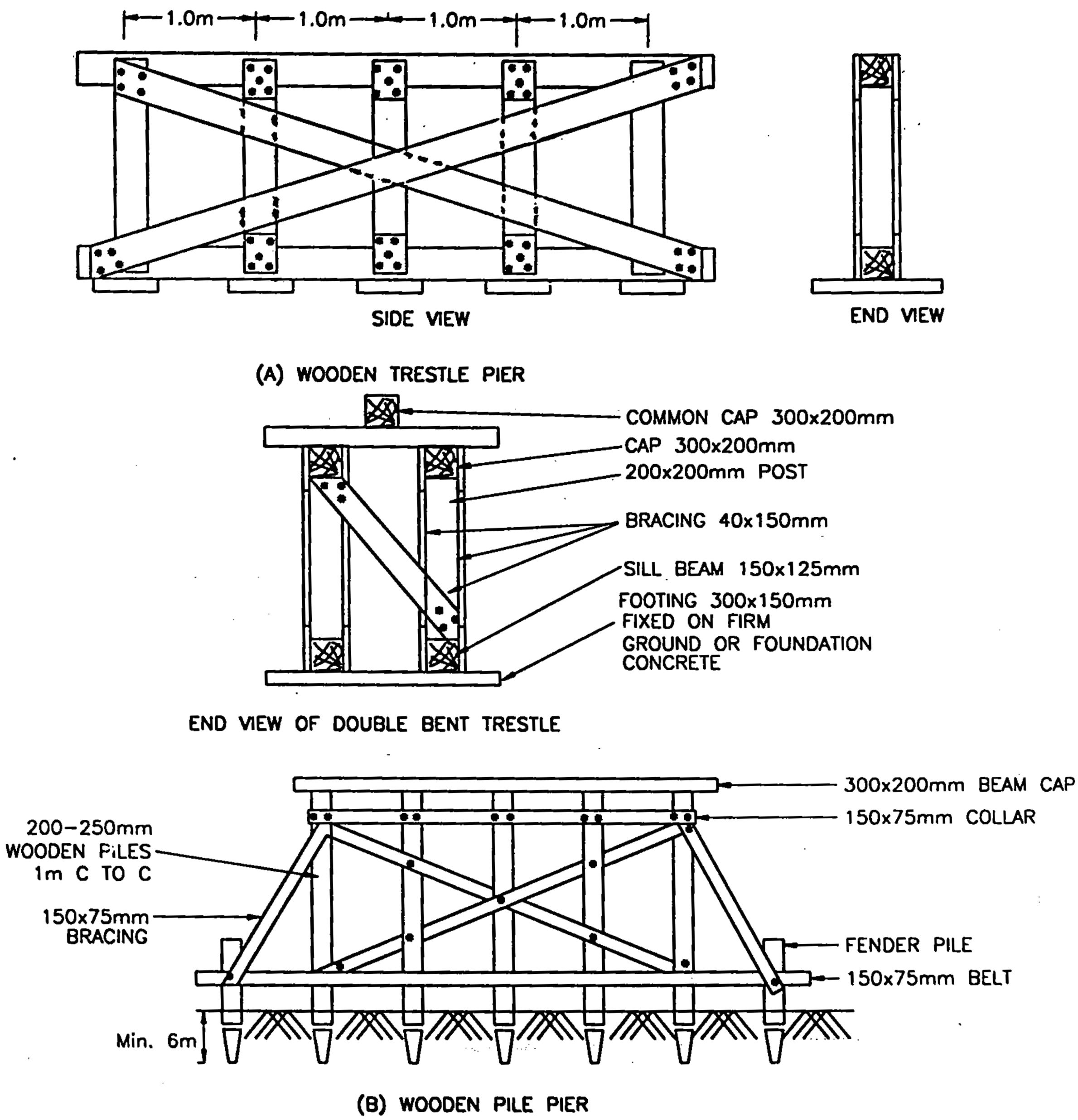
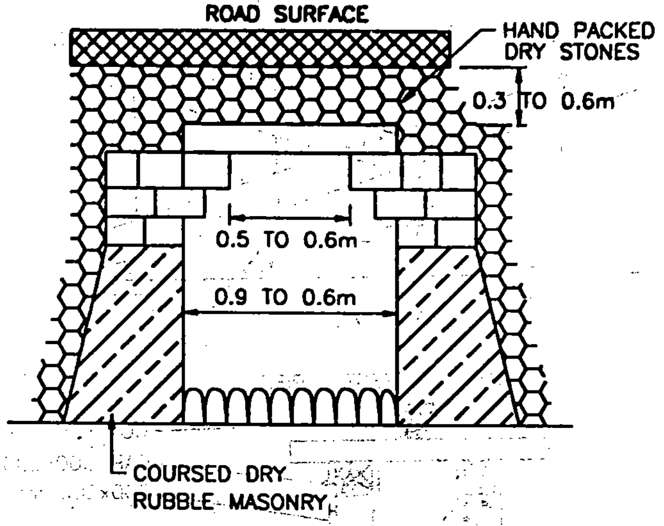


FIGURE 8.20. WOODEN TRESTILE/PILE PIER

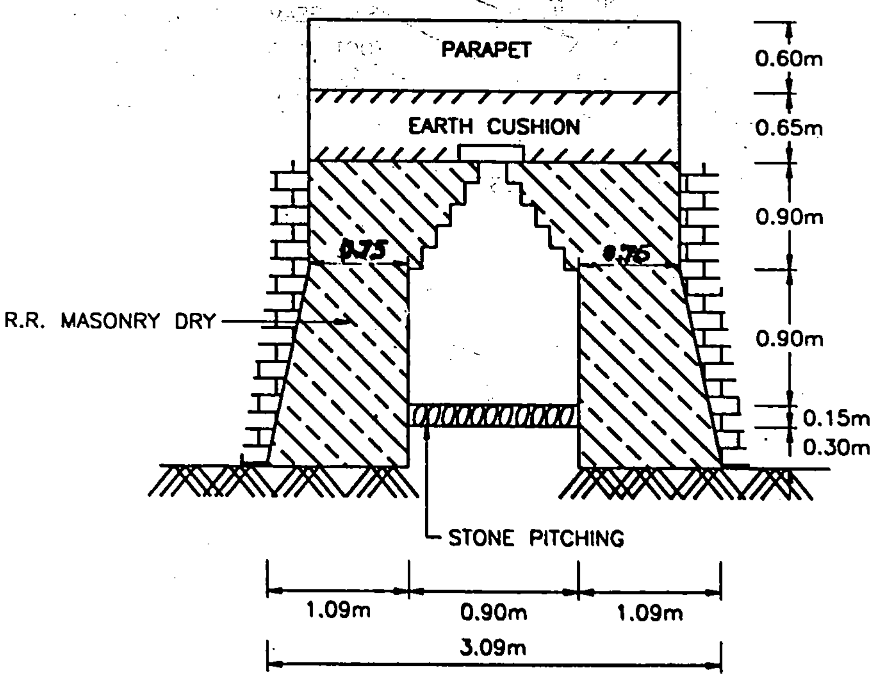
8.10.5.11. Considering the effect of extracting timber in denuding forests and adverse environmental impact, timber bridges are best avoided unless timber is available from trees cut as part of road formation work.

d) Scupper

8.10.5.12. It is a cheap type of culvert or cross drain about 1 metre wide made of course rubble dry masonry abutments. The top of the abutments are corbelled with a few layers of stones till the gap is 0.5 - 0.6 m, and a stone slab is laid on the top. Hand packed stones are placed on top (0.3 - 0.6 m thick) and also all round the scupper. Retaining walls are provided on both ends of the scupper. Retaining walls are provided on both ends of the scupper. Typical section of two types of scuppers are given in Fig. 8.21. Fig. 7.9 also gives a type of scupper section.



SECTION – 1



SECTION – 2

FIG. 8.21. SCUPPER

8.10.5.13. Scupper is a very cheap cross drainage structure and plays vital and significant role in drainage of hill roads. It requires more attention during construction as well as in maintenance. The following points need care:

a) Opening should be kept clean. The catchpit of the scupper, which gets easily filled with debris and/or vegetation should be kept clean. It is also necessary that there is no erosion or scour at the outlet of the scupper. Retaining wall may be constructed at least 1.00 m approximately above the road level, to avoid choking of the catchpit.

b) In case, suitable corbelling stones are not available in the vicinity of the scupper site, RCC prescast slab of size 1.5 m x 0.060 m x 0.15 m be cast and placed over the opening.

c) For efficient drainage the road side drains along with scuppers should be cleaned regularly, for free flow of water, specially in reaches prone to land slides.

e) High Level Bridges

8.10.5.14. Bridges are structures facilitating a communication route for carrying road traffic or other moving loads over a depression or obstruction such as river, stream, channel, road or railway. They are also very good cross-drainage structures. Bridges are classified as Major or Minor on following criteria:

a) Bridges with waterway of more than 60 m between the two abutments are generally termed as major bridges, whereas those with waterways less than 60 m and more than 6 m are termed as minor bridges. Since the bridge structures are of vital importance for communication system, more so in hilly areas where alternative routes are generally not available, the design and construction of the bridges needs special attention. I.R.C. Bridge Codes covering subsurface investigations, design and execution already exist and the same should be made use of.

b) Depending upon the merits of each case, the foundations of the bridges in hilly areas may be either open foundations or on wells. Similarly the superstructure may be in R.C.C., prestressed concrete, timber, steel or some composite construction. The final choice should, however, be arrived at most judiciously, keeping in view the economy and practical feasibility. Detailed field studies and inspection by senior engineers are very necessary. However special points relating to hilly areas are given below.:

   i. While making temporary crossing on a river the same be built on a second best site, the best site being kept for construction of the permanent bridge.

   ii. Since the bed level of the nallahs (stream) are steep, cross sections should be taken at appropriate short intervals so as to cover all topographical details.

   iii. Since the flow of water in hill streams is very fast and in most cases they carry boulders and also construction of diversions is not easily possible, it may be preferable to provide single span bridges depending of course on economics and feasibility.

   iv. In case of suspension bridges, the safety of the bridge depends upon the safety of the anchor block. The geology of the hill below the anchor, should be very carefully studied.

8.10.5.15. Certain types of bridges, generally in use are described below.

8.10.5.16. **Arch bridges**: The use of arches for bridging relatively long spans of about 200 m is an old structural method. It is essentially a compression member and it is possible for an arch to support a load without developing any bending stresses provided the shape of the arch axis coincides exactly with the line of thrust for the applied loading. Any change in loading will change the line of thrust. Three types of arches commonly used for reinforced concrete bridges are:

a) Three hinged arches.
b) Two hinged arches (Bowstring type bridges)
c) Fixed or encastre arches.

8.10.5.17. **Reinforced cement concrete bridges**: These type of bridges are universally used for highways. Their durability, rigidity, economy and ease with which pleasing appearance can be obtained make them

suitable for this purpose. There are numerous type of bridges built in reinforced cement concrete. The following are in general use:

a) Slab Bridges

8.10.5.18. This is the simplest type of reinforced cement concrete bridge and easiest to construct. It is suitable for spans upto 10 m.

b) Girder Bridges

8.10.5.19. This type of bridge is economical for spans between 10 m - 20 m. Depending on the width of the roadway following are the types of girder bridges :

(i) T-beam bridges:

8.10.5.20. In these bridges, the T-beam functions as main girders. For two lane or wider bridges the roadway is supported on a number of T-beams as longitudinal girders, with or without transverse beams. These bridges are economical in 10 m to 25 m span.

(ii) Hollow girder bridges:

8.10.5.21. These bridges are economical for spans between 25 to 30 m. They comprise of closed box section. They can be made multi-cellular of rectangular or trapezoidal shape.

8.10.5.22. **Steel bridges:** Depending upon the type of structural arrangements the bridges are classified as beam bridges, girder bridges, truss bridges etc. as under:

(i) I - Beam Bridge:

8.10.5.23. In case of beam bridges, rolled steel I-Beam with or without cover plate are used as main girders. The top flanges of the rolled beams are well embedded in the flooring for lateral support. The cross I-beams act as bracing for main I-beams.

(ii) Plate Girder Bridges:

8.10.5.24. A plate girder bridge is essentially a built-up beam to carry heavier load over longer spans. This simple type of rivetted plate girder consists of pair of angles connected to a solid web plate. Generally girder bridges are adopted for simply supported spans less than 50 mts and for continuous span upto 260 mtrs.

(iii) Steel Truss Bridges :

8.10.5.25. Generally a truss bridge is economical for spans greater than 30 metres and are suitable for a span range of 40 to 90 metres. There are three types of truss bridges viz. through type, deck type and semithrough type. The erection of a truss bridge is considerably easier because of the relative lightness of the component members.

8.10.5.26. **Prestressed concrete bridges:** The principle of prestressed concrete has been widely applied for the design of bridges. The inherent advantages of prestressed concrete bridges are higher load capacity and fewer expansion joints. The prestressing members are light and best suited for artistic and architectural treatment. These are economical for spans ranging from 25 m to 50 m. For prestressed concrete Box sections, span of 50 to 75 m is viable and for prestressed cantilever construction, bridges of span of 75 to 120 m are generally suitable.

8.10.5.27. **Portable steel equipment bridges**: Portable steel equipment bridges like the Bailey Bridge is formed by joining pre-fabricated panels and members. This bridge is easy to assemble and quick to erect. Such bridges are in extensive use by the Armed Forces and are also being adopted for hill roads as a normal bridging system.

8.10.5.28. **Suspension bridges:** A suspension bridge consists of a set of cables hanging in a curve form from which the road way is supported. They can be divided into two main classes:-

i) Unstiffened
ii) Stiffened

A typical scheme of a suspension bridge is given in Fig. 8.22(A), 8.22(B).

In case of unstiffened suspension bridges, the moving load is transferred direct to the cables by each suspender in turn. In stiffened type suspension bridges moving loads are transferred to the cables through the medium of trusses.

8.10.5.29. Suspension bridges are usually provided in the following cases:

a) Where the flow of water is very fast.

b) Where the spans are very large; usually spans of about 100 metres onwards are considered economical due to less dead load.

c) To negotiate gorges.

8.10.5.30. A low cost suspension bridge, consisting of wooden plank decking and ribands as superstructure suspended directly from cables is used as mule Track and Jeepable roads. These are used generally for spans of 30-100 m.

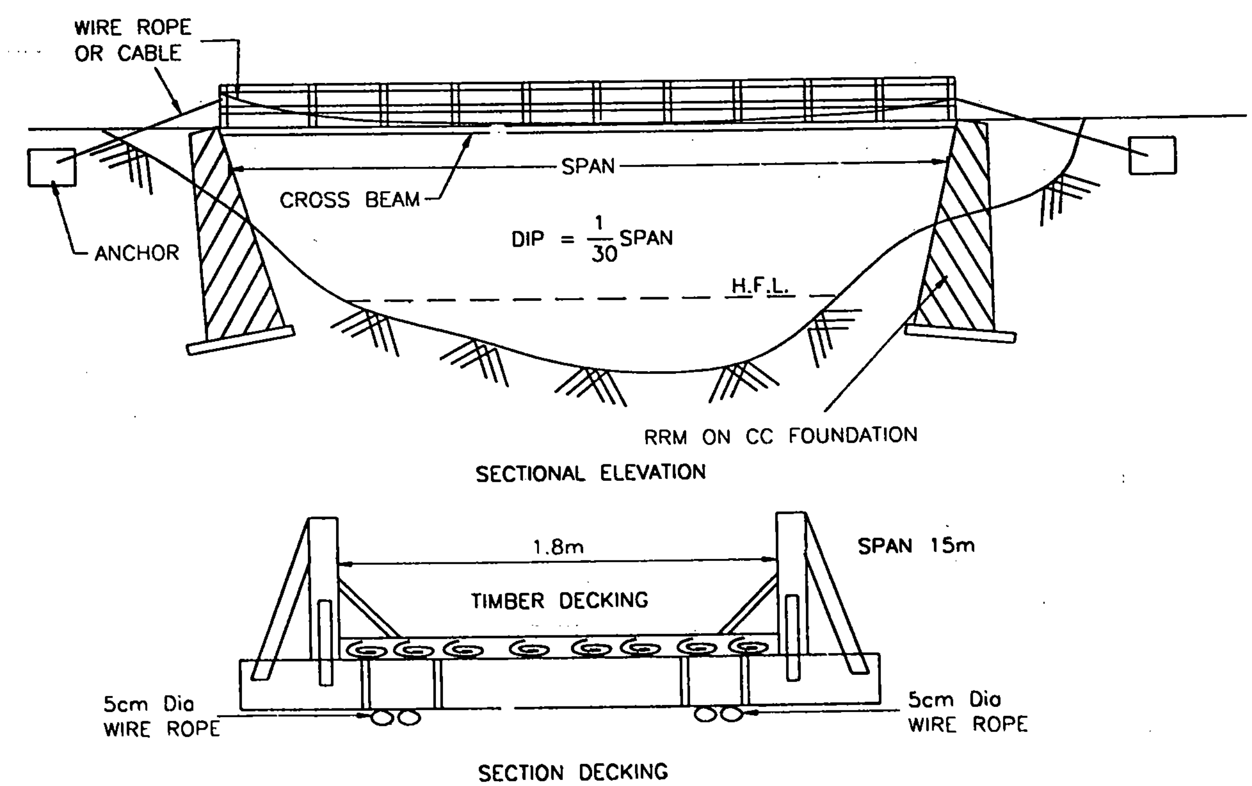


FIG. 8.22(A) SUSPENSION BRIDGE (LIGHT LOAD) ON JEEP ROAD/MULE PATH

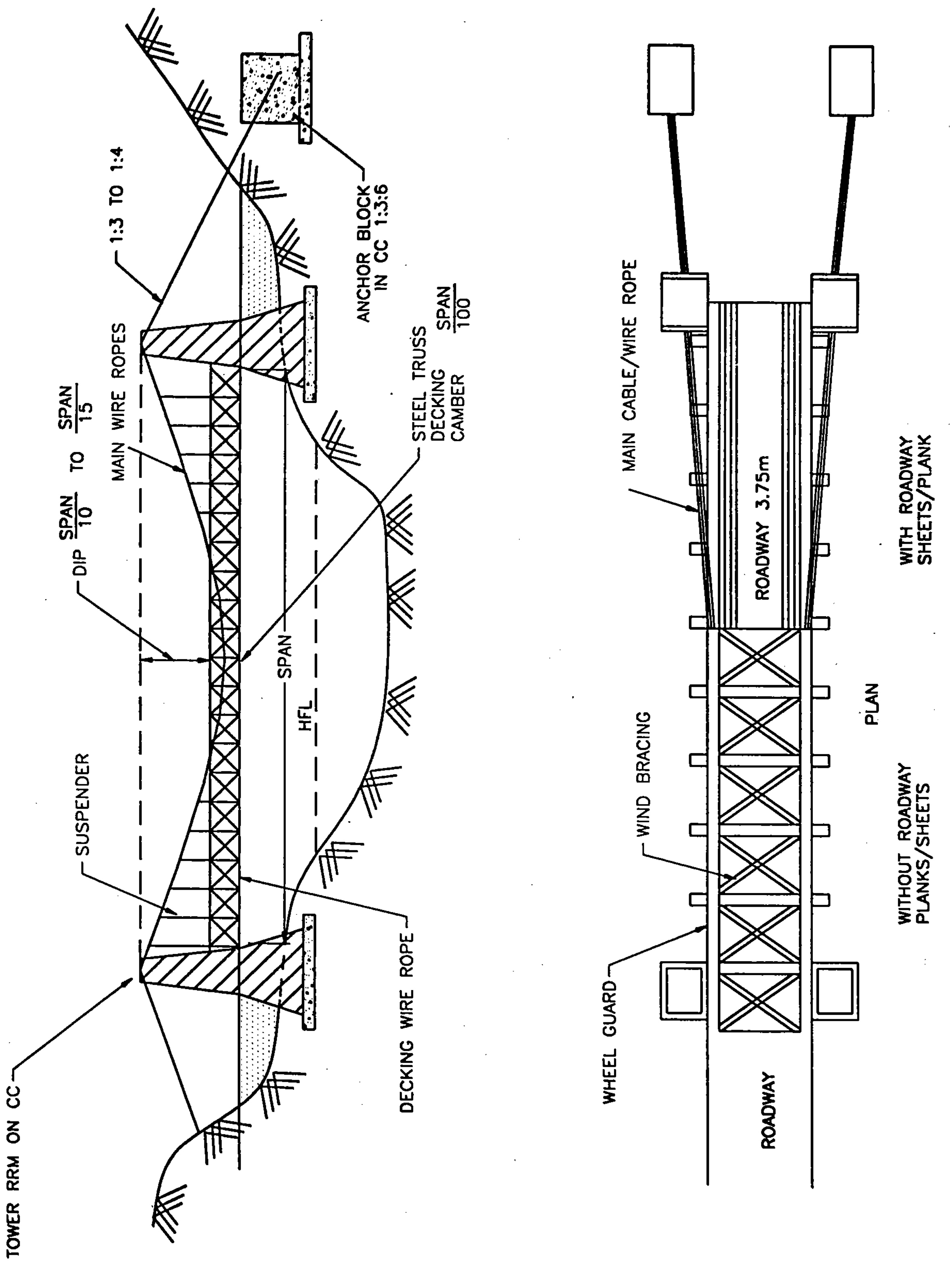


FIG. 8.22(B). SCHEME OF 30m LONG SUSPENSION BRIDGE

8.10.5.31. **Cable-stayed bridges**: Cable-stayed bridge, also called the stayed-girder (or truss) or the cable-stiffened girder (or truss) has come into wide use since about 1950 for medium-and-long-span bridges, because of its economy, stiffness, aesthetic qualities, and ease of erection without falsework. Design of such bridge utilises stay cables connecting pylons to a span to provide intermediate support. The cable-stayed bridge has the advantage of greater stiffness over a suspension bridge. These are generally provided in the span ranging from 180 m to 500 m. A scheme of cable-stayed bridge is given in Fig. 8.23.

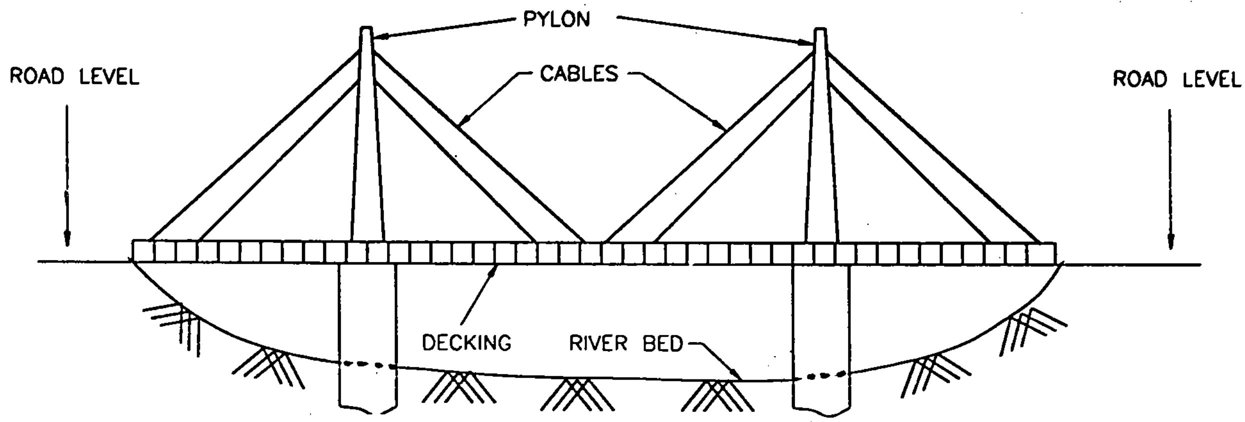


FIG. 8.23. CABLE STAYED BRIDGE

f) Boat Ferriers and Pontoon Bridges

8.10.5.32. **Boat ferry**: Ferry is a floating device that operates between two terminal points of a road network interrupted by a water barrier. Ferry should normally be considered only where the draft is adequate for playing of boats, there is not much seasonal fluctuations in water level or widths and where the river current is within manageable limits. The site of crossings should allow the economical construction of terminal facilities such as ramps, loading/unloading platforms, etc. In adverse weather and high spate conditions of the river, the ferry will not be safe and the operation should be suspended. For passenger traffic, country boats having capacity of 15-20 passengers can be operated economically. For transport of vehicles like lorries and passengers/cattle in larger numbers, large sized boats or two boats joined together may be warranted.

8.10.5.33. **Flying bridge**: When sufficient funds are not forthcoming or sufficient material is not available to make a regular bridge across a stream, a boat or a raft may be used as a ferry. Ferry boats are usually rowed or poled across. The action of the current on the boat or raft may also be utilised to move a ferry boat across a stream. A ferry working in this manner is termed as 'Flying Bridge'.

8.10.5.34. There are three methods of making Flying Bridges:- (1) By Suspension Cable, (2) By using anchors and "Swinging Cables" and (3) By using a "Warp".

8.10.5.35. In the first method a steel wire cable is stretched between 2 posts or shear-legs erected on either bank away from the water line at a height sufficient to keep the centre of the cable well above the flood level. A traveller with 2 wheels moves over the suspended cable and the ferry raft is connected to the traveller with the help of 2 lines. The length of the longer line is varied as required to keep the length of the raft inclined approximately at an angle of 55^0 to the direction of the stream. For return journey the lengths of the lines are reversed.

8.10.5.36. In the second method i.e. swing bridge, the length of the cable should be from one and half times to twice the width of the river, and if a long one is used, it should be kept out of the water by being supported on intermediate floats. The end of the cable is secured to a short mask fixed in the boat or raft, about one-third of its length from the bow, or the cable may be secured to a rope bridle as shown in the sketch. In a very rapid current, the cable may be anchored to both banks instead of to a float in the middle of the stream. In this case four landing-places and two cables will be required, one of the cables being taken across in the boat for the return journey.

8.10.5.37. In the third method a cable is stretched across the river as tightly as possible and the boat or raft runs along through rollers on the raft. A typical flying bridge arrangement is given in Fig. 8.24.

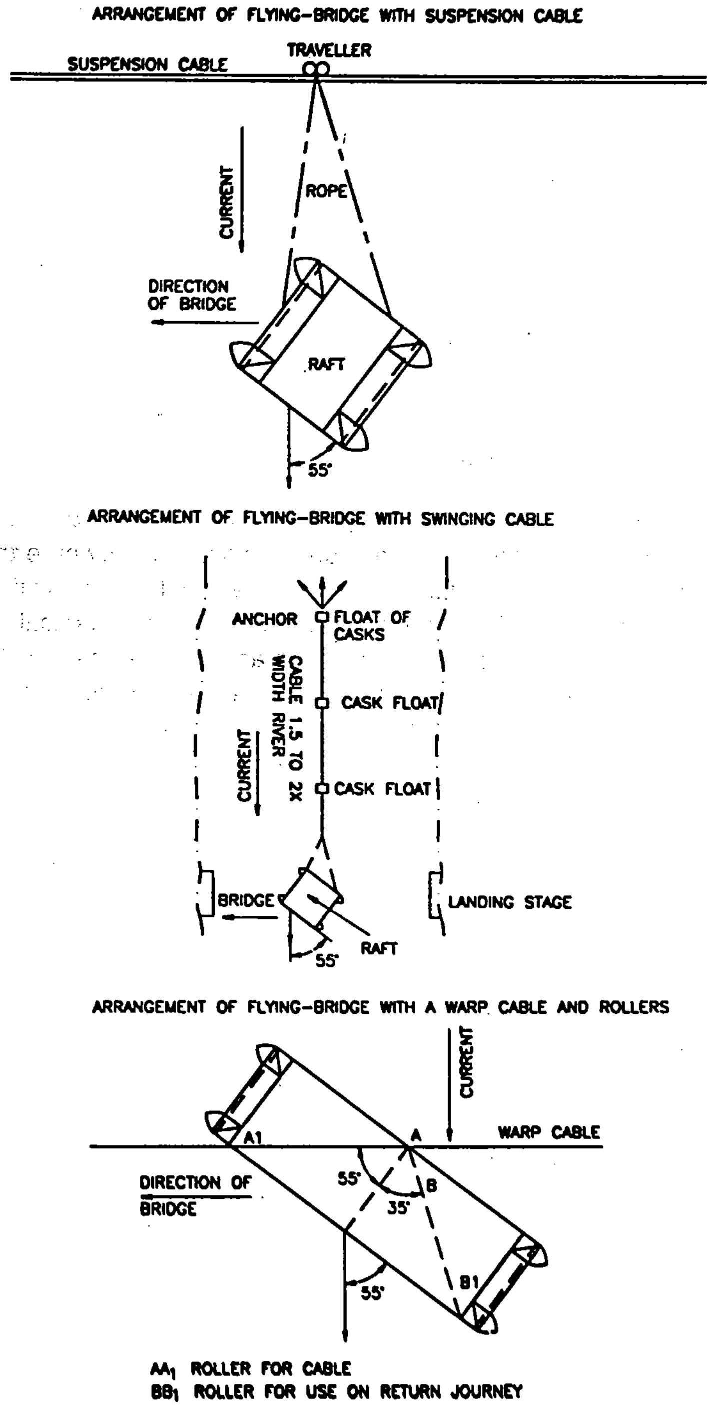


FIG. 8.24. A TYPICAL FLYING BRIDGE ARRANGEMENT

8.10.5.38. Wire rope and trolley: These are useful on village tracks where suspension bridges are not justified due to low traffic. These are manually operated. However even use of mechanically operated trolley system to negotiate hills where road construction may take too long or difficult is not uncommon. A typical arrangement is given in Fig. 8.25.

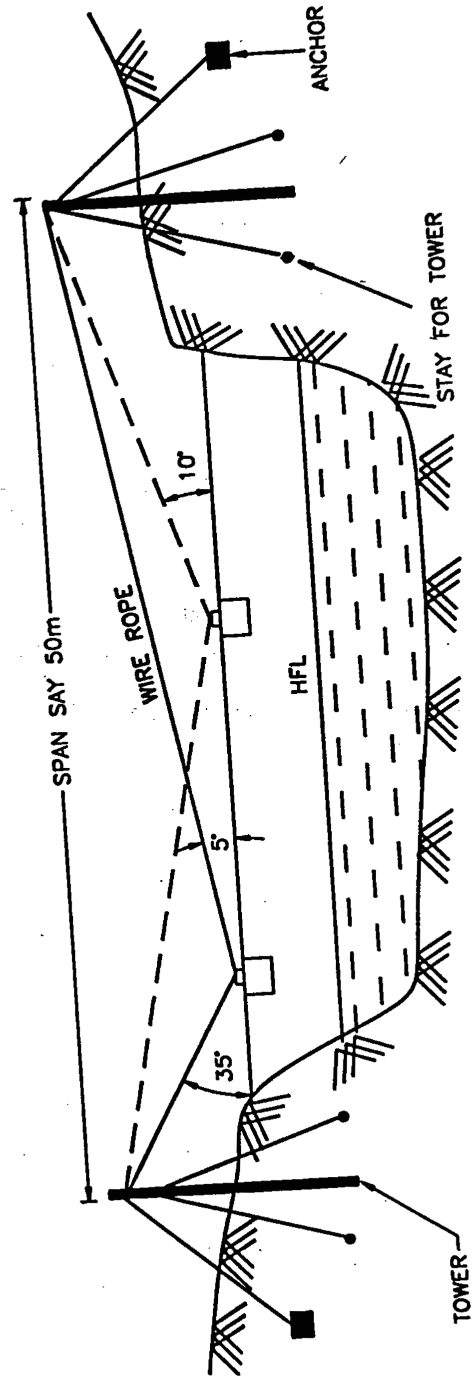


FIG. 8.25. WIRE ROPE & TROLLEY

9. STRUCTURES AND PROTECTIVE WORKS

9.1. General

9.1.1. Hill Road is formed mostly by cutting into the hill and thereby disturbing natural stability of slopes. Water courses along the slopes cause erosion affecting road stability. Soil movement along slopes tend to disturb the road formation. All these have to be effectively countered to obtain a stable road by provision of structures to act as retaining, restraining and protective structures. Similarly safety of traffic also needs structures to be provided on the road. Where the road is aligned along a river bank or a nallah (stream) slope failure and erosion of toe has also to be prevented and valley side slope made stable. This can be achieved by construction of retaining walls, breast walls, parpet walls, railings, edge stones, toe walls, check-walls, river training structures etc. While each problem has to be studied, analysed and structure designed to suit the location and problems thereon, general features and arrangements are discussed in this chapter.

9.2. Retaining Walls

9.2.1. During the formation cutting of a road, the natural hill slope gets disturbed. Masonry structures to support the down hill side unstable strata or fills are called retaining walls. They can be constructed in stone masonry, cement concrete, reinforced cement concrete, wire crated masonry, wooden/timber/poles etc. depending on ground condition. Reinforced earth is also now being used.

9.2.2. Generally for hill slopes with gentle slope retaining walls may not be required. For steeper slopes, relative economy of cost of earth cutting and retaining wall has to be compared. From stability point of view full hill cutting should be preferred as retaining walls involve weakness in the road structure.

9.2.3. Other situations requiring the construction of retaining walls are:

a) Places where the valley side surface gets saturated in the monsoons and is likely to result in slip taking a part of road with it.

b) Places where undercutting by a stream or other water course causes damage to the valley side and the road.

c) In valley point, where water flows over the road.

d) To achieve width of road way, where cutting into hill is not economical or has to be restricted due to other reasons.

9.2.4. **Specifications:** According to the strength and service required, retaining walls may be constructed of:

a) Rough dry stone with lime concrete/cement concrete foundations if necessary.

b) Rough dry stone with strengthening bands of stone in lime/cement.

c) Masonry in lime mortar, or lime with puzzolana or cement concrete foundations.

d) Masonry in cement mortar on cement concrete foundations.

9.2.4.1. Para 9.2.4 (a) and (b) apply to ordinary retaining and breast walls, not impinged upon by floods and not required to hold water and 9.2.4 (c) and (d) apply to abutments and to important retaining walls or portions thereof.

9.2.4.2. Retaining walls will generally be constructed of dry stone masonry with strengthening bands of R.R. masonry in mortar as per Fig. 9.1 except where these are impinged on by floods or where high degree of strength is necessary. This figure is representative of the scheme for other specifications also.

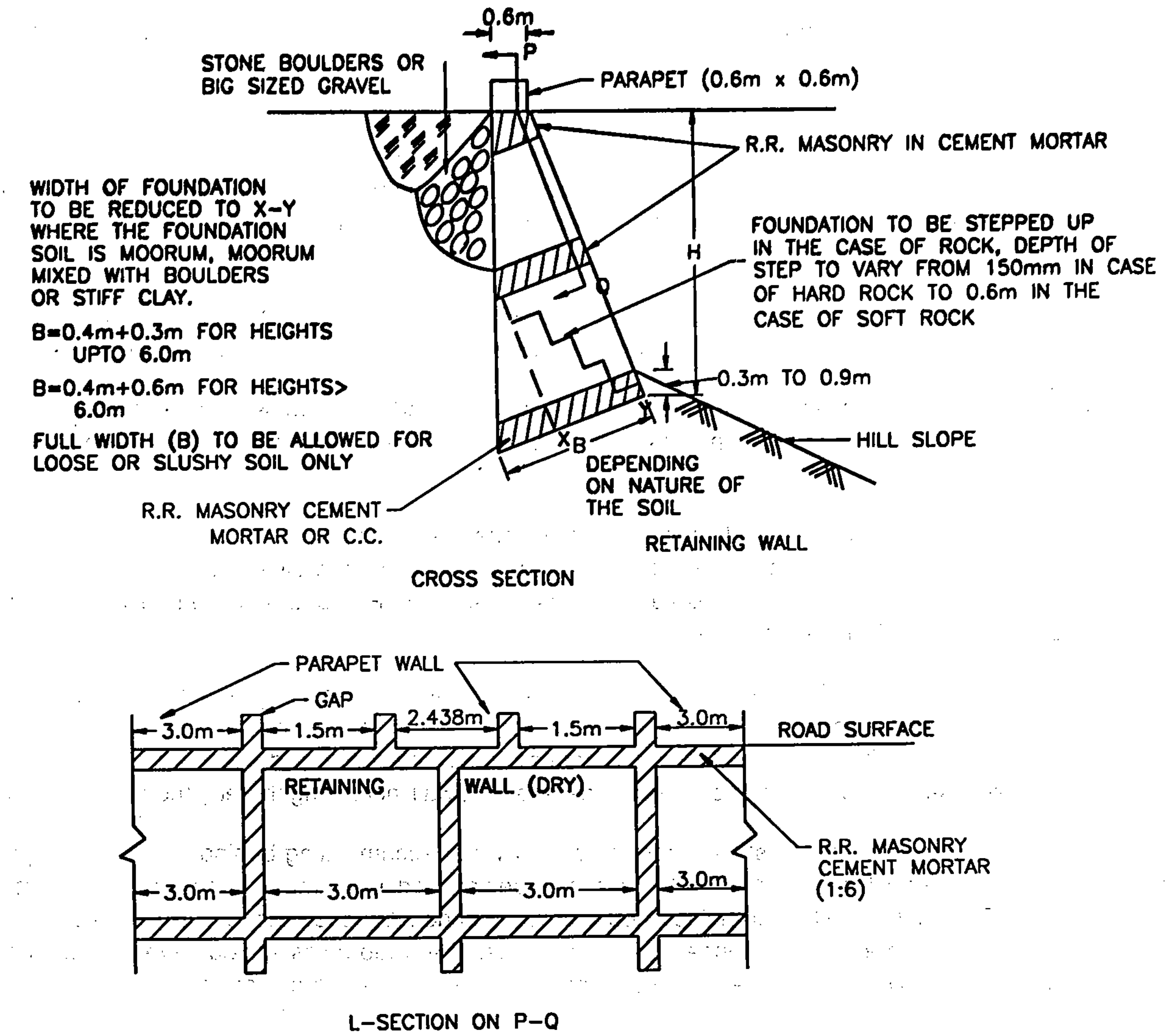


FIG. 9.1. CROSS SECTION – RETAINING WALL

9.2.4.3. Retaining walls upto about 4 metres height should generally be in RR dry masonry, walls from 4 to 8 metres in RR dry masonry with 1:6 cement masonry bands or with a course of cement concrete 1:4:8 throughout the section both in lengthwise and breadthwise directions of the retaining wall to break the joints and to cover up short-comings in the execution of dry retaining wall. Beyond 8 metres height walls should be avoided and when unavoidable these should be stepped and built in cement mortar.

9.2.4.4. Retaining walls in RR dry stone masonry with proper bond stones can safely be constructed upto 4 metres height and should be adopted. Bond stones should be provided at least one set per 0.5 sq. metre of wall face. They should overlap each other by at least 15 cm. Where natural bond stones are not available, precast cement concrete bond stones of 20x20x60 cm size with nominal reinforcement should be used.

9.2.5. **Foundations:** Foundations must be taken deep enough to rest on sound foundation materials which must be safe from scour, frost and surface water. Rock must be cut in level steps or to a downward slope towards the filling. Rock bed slope should be towards the hill and not away. The necessity of filling foundation pits in front of toe of the retaining wall back upto original ground level, so as to avoid pooling of water leading to toe erosion, is to be considered.

9.2.6. **Walls-masonry construction:** The base width must be substantial and capable of distributing the pressure over the foundation. The projections of any footing course should not exceed half the depth of the course. The top thickness is usually 0.60 m. The front batter is given as 1 in 3 upto 4 m height and thereafter made flatter and the back face is kept vertical.

9.2.6.1. Walls should be made in rubble masonry consisting of hammer dressed hard stones brought to course every 0.6 m (approx). Masonry courses must be normal to face batter; and the back of the wall can be left rough. Masonry work should proceed in an uniform level.

9.2.6.2. The least dimension of stone should be 20 x 15 x 10 cm. Approximately half the stones should tail into the wall by twice their height. Stones must break joint by half the height of the course.

9.2.6.3. In case of dry rubber walls, it is generally advisable to bed each course in stone dust or earth, to spread the load and increase the frictional resistance between courses, particularly where shale slabs are used.

9.2.7. **Coping:** The coping should consist of large stones, laid and pointed in cement mortar or PCC 50-75 mm thick. The top of the coping should be, weather sloped towards valley side. Coping, preferably, should be with stones on edge so that these are not easily dislodged. Parapets with weather slope may be provided on retaining walls in lieu of coping.

9.2.8. **Backfill:** The backfill layer immediately behind the wall should consist of hand packed stone or some granular material, as shown in Fig. 9.1. Remainder of the backfill should be rammed in 150 mm thick layers sloping towards the back of the wall. The top surface should better be sealed with bituminous macadam to prevent unnecessary direct seepage of water in the retaining wall increasing thereby the back pressure.

9.2.9. **Drainage:** Provision must be made to prevent water accumulating behind the wall. Adequate staggered weep-holes not less than 15 cm x 10 cm should be provided at one metre interval both horizontally and vertically. The inlets of all weep-holes should be surrounded by loose stones. In wet situations a continuous loose stone drain should connect the weep-holes. The weep-holes should have a slope of 1 in 10 towards valley side. Weep-holes are not necessary in dry masonry walls due to open joints though it may be better to provide weep-holes.

9.2.10. **Design:** Most of the retaining walls on hill roads are gravity type and hence only design procedure for such type of walls are given here for ready reference.

9.2.10.1. The forces acting on a retaining wall to be considered, are:

a) **Horizontally**

P = the total horizontal pressure of the backfill

b) **Vertically**

$$F = W_m + W_b + P \tan \phi + W_s$$

where

W_m	=	the wt. of the backfill between the back of the wall and a vertical line through the heel.
β	=	angle of the surcharge slope
$P \tan \phi$	=	the vertical component of the backfill pressure which is zero in the case of level backfill

W_s	=	any super-imposed load on wall such as the superstructure and live load on bridge as in the case of abutments
W_b	=	Dead weight of wall

c) **Resultant**

of P & F =	R acting at an angle with vertical and cutting base at a distance (eccentrically) from the centre.

9.2.10.2. **Principles of design:** The principal cause of failure of a retaining wall (Figs. 9.2 & 9.3) are:

a) Overturning
b) Tension in masonry
c) Sliding
d) Pressure on foundations

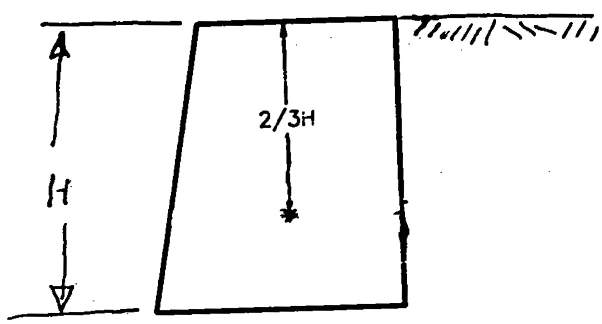


FIG-9.2

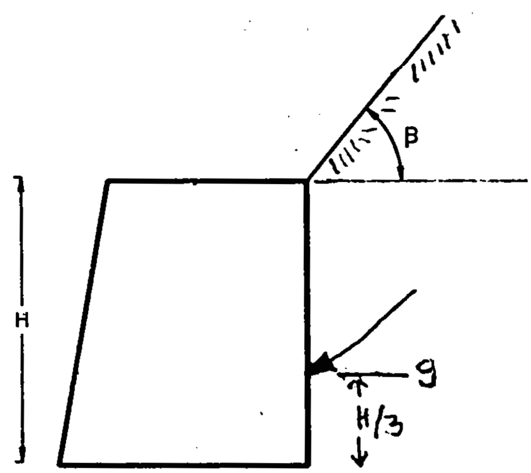


FIG. 9.3.

NOTE:
FOR VARIOUS SURCHARGE CASES PLEASE REFER TO STANDARD BOOK ON SOIL MECHANICS

9.2.10.3. **Overturning**: For safety against overturning, the resultant R of the horizontal and vertical forces must pass through middle third of the base of the wall.

9.2.10.4. **Tension in masonry**: To avoid tension in the masonry, the resultant R should pass through the middle third of any horizontal section of the retaining wall. This can be checked by taking moments about

the toe of the wall. The earth pressure (P) can be computed by the following formulae for vertical-backed wall :

a) Without surcharge

$$P = \Upsilon H^2 \times \frac{(1 - \sin\phi)}{(1 + \sin\phi)} \qquad ..2$$

where

Υ = wt of unit vol. of earth
H = Total ht. of wall
ϕ = Angle of repose of soil
P = Earth pressure acting at depth of 2/3 H below the horizontal earth surface.

b) With surcharge (angle of surcharge = β)

$$P = \frac{\Upsilon H^2}{2} \times K_a$$

where

K_a = Co-efficient of active earth pressure

$$= \frac{\cos\beta \times \sqrt{\cos\beta - \cos^2\beta - \cos^2\phi}}{\sqrt{\cos\beta + \cos^2\beta - \cos^2\phi}} \qquad ..3$$

$$= \frac{1 - \sin\phi}{1 + \sin\phi}$$

when $\beta = 0$

where

β = Angle of surcharge

c) For wet conditions

The horizontal thrust is equal to the sum of the thrust due to an equal height of water plus a thrust due to a soil pressure of equal height with reduced density by the buoyancy of water.

$$P = \frac{\Upsilon_w, H^2}{2} + 1/2\,(\Upsilon - \Upsilon_w)\,H^2 \times \frac{(1 - \sin\phi)}{(1 + \sin\phi)} \qquad ..4$$

where

Υ_w = Density of Water
Υ = Density of Soil

d) Effect of superimposed load

If a load W, such as a vehicle or a bridging load is placed on the fill within a distance H of the top of the retaining wall, the wall must be designed for an increased height of filling H_1

$$H_1 = H + \frac{W}{HD\Upsilon} \qquad ..5$$

where

D	=	Length parallel to the wall of superimposed load
W	=	Superimposed load
Υ	=	Unit weight of back fill

Thus if

W	=	a 12 ton road roller
H	=	4 m
D	=	5 m

Wt. of backfill 1600 kg/cu.m

$$H_1 = 4 + \frac{12 \times 1000}{4 \times 5 \times 1600} = 4.30 \text{ m}$$

This increased value must be used for H.

9.2.10.5. **Sliding**: The wall must have a factor of safety of two against sliding. To meet this condition, tan μ must not exceed half the coefficient of friction of the wall on the foundation material. The value of tan μ can be decreased, if this proves necessary, by sloping the foundation downward towards the back-fill (Fig. 9.1) and taking this foundation slope as 1 in q (tan μ-1/q) must be less than half the coefficient of friction.

where

μ	=	angle of resultant force on the wall to the vertical
1/q	=	foundation slope (e.g. for slope of 1 in 8 q = 8)

$$\tan \mu = \frac{Ka \ \Upsilon H^2}{2V + PB} \qquad ..6$$

where

V	=	Vertical load per metre length of wall, from the vertical component of the backfill pressure and any superimposed load.
B	=	Width of base without toe projection
P	=	Toe pressure on base B in kg/sqm.
Ka	=	$\frac{1 - \sin \phi}{1 + \sin \phi}$ for level backfill
Υ	=	Density of back fill material

9.2.10.6. **Pressure on foundation**: The pressure on foundation material at the toe of the wall must not be greater than the safe working stress. By projecting the toe, the centre of the base is brought nearer to the

resultant and the toe pressure is very much reduced. Projections on the heel increases the maximum pressures and should not be given.

The average pressure on the foundations

$$Pa = \frac{\text{total vertical force or load}}{\text{Width of base}}$$

$$= \frac{F}{B+T}$$

where

B is width of base without the projection.
T is toe projection beyond face of wall
F is total vertical force on load.

The difference in pressure at the tow and heel due to eccentricity 'e' of the resultant from the centre of the base:

$$Pe = \frac{6\,Fe}{(B+T)^2}$$

Maximum pressure at the toe Pt = Pa + Pe
Maximum pressure at the heel Ph = Pa - Pe

9.2.10.7. **Depth of foundation:** Foundations must be taken deep enough to reach solid material, and be safe from frost action, surface water and scour. Minimum depth of foundation (h) for stability is given by the following equation. However actual depth is dependent on the nature of soil and may be 0.3 m to 0.9 m

$$h = \frac{W}{A\Upsilon} \times \left(\frac{1 - \sin\phi}{1 + \sin\phi}\right)^2$$

where

W	=	Total wt. on foundation
A	=	Area of foundation
Υ	=	Wt. of unit vol. of soil
ϕ	=	Angle of repose of soil

9.2.10.8. **Practical proportions**: For average dry conditions, width of base may be taken as 0.4 H + 0.3 m (where H is the total height of wall in mtrs) and width of foundation footing as 0.5 H + 0.3 m. For saturated conditions the base width should be suitably designed and provision of drainage should be made to reduce the pressure. Top thickness of the wall is generally kept as 0.6 m, minimum depth of foundation as (0.1 H + 0.3 m) and the projection of any footing course not exceeding half the depth of the course. Back is generally vertical and front batter about 1 in 4.

9.2.10.9. In the case of loose ground, the walls are generally 0.9 m thick at the top with front batter about 1 in 3. Back may be vertical or given a batter of 1 to 5 to reduce the masonry work.

9.2.10.10. Incorrectly designed and constructed retaining wall is a great source of weakness in a hill road, and special care must be taken that specifications and designs for them are efficient. Complete retaining walls fail due to errors in construction such as:

a) Settlement of the toe, due to too shallow foundations or due to the presence of water at the toe, or no toe projection being provided to reduce the pressure on foundation.

b) Lack of proper drainage like omission of weep holes etc.

c) Carelessly placed back-fill not properly packed.

d) Insufficient bonding in masonry courses

e) Masonry courses not at right angle to the face of the wall.

9.3. Breast Walls

9.3.1. Masonry or R.C.C. structures supporting the up hill slopes along a road are termed Breast Walls. For protection against instability, slopes of cutting would have to be very flat, which are not economically practicable. At some places such slopes fail by slumping, sliding, toe failures or in the worst cases by failures far below the formation level, causing entire road to be washed away. Thus, weak spots which are chronic by way of hill slides, have to be protected by breast walls. Such walls perform the following functions:

a) They would keep the road edge defined and also protect the drain to some extent.

b) The hill slope to the extent of Breast Wall height will remain protected from slips. Any slide above this height will flow over the top of the breast wall.

c) It would not allow continuity of the flowing mass of soil and would thus facilitate the clearance of slides

d) Assistance in drainage from hill-slope through weep-holes in breast wall on to the side drain in front of the wall.

9.3.2. **Materials of construction**: Since these walls are usually provided against wet hill slopes, they have to be stronger than Retaining Walls and are usually comparatively less stable. They are usually provided in stone masonry in cement mortar though banded and dry masonry construction may be done where hill slope is not wet. Weep-holes have to be provided liberally in breast walls.

9.3.3. In very unstable situations, even stones enclosed in wire crates have been successfully tried which have the advantage of re-building in case of failure and act as flexible structures.

9.3.4. **Design:** The breast wall design has to consider:

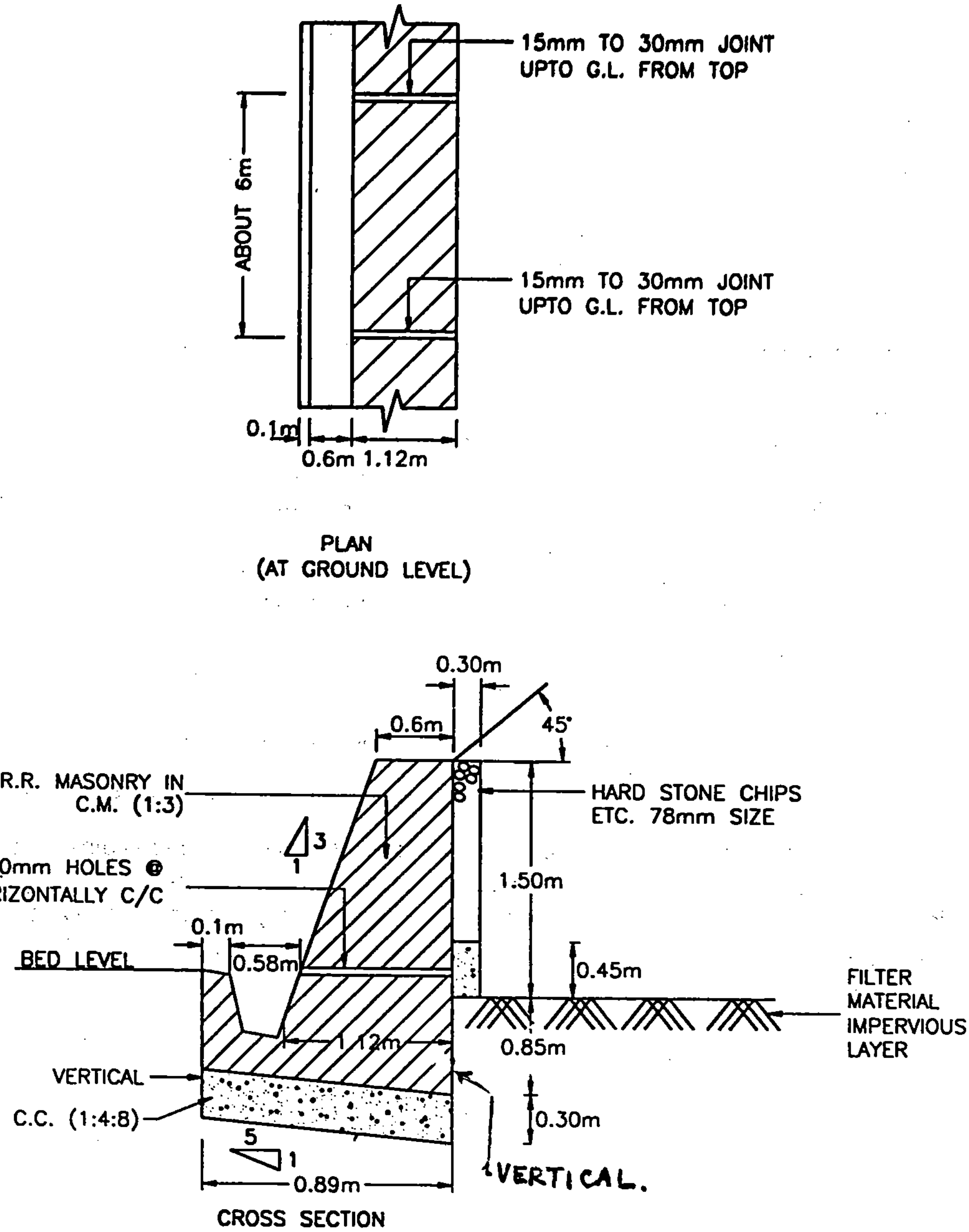
a) Of necessity, the height of these walls is kept low i.e. about 1.5 m to 3 m since they occupy lot of useable space in the Cross Section and generally the height is kept as 1.5 m.

b) Front batter is usually kept 1:3 as against 1:4 - 1:6 for retaining walls except that earth pressure is computed as a saturated coarse back fill with a 60^{0} slope of hill.

9.3.5. A typical breast wall is given in Fig. 9.4.

9.4. Parapets, Railing and Edge Stones

9.4.1. **Parapets:** For defining the edge of road and for safety of traffic, parapets are required on the valley side. They are usually made 0.45 m thick of rough dry stone masonry in lengths of 2m to 6m width 0.6m to 1m gaps. Their height is usually 0.6 m and follow the regular geometrical edge of road and not the hill edge to give a better look. In the initial stage of construction of the road they are made in dry masonry but in due course, top and end layers for 15 cm are replaced by cement masonary.



STANDARD 1.50m HIGH BREAST WALL

FIG. 9.4. TYPICAL BREAST WALL

9.4.1.1. Parapets on Retaining walls are made of stone masonary in cement, 0.45 m wide and 0.6 m high in lengths of 2 m with a gap of 0.6 to 1.0 m.

9.4.1.2. A typical sketch of a parapet wall in RR masonary is given a Fig. 9.5. Top of the parapet may be given a slope towards valley side so that these are not used as resting places by pedestrians. In selected locations these may be used as flower beds to improve appearance of the road.

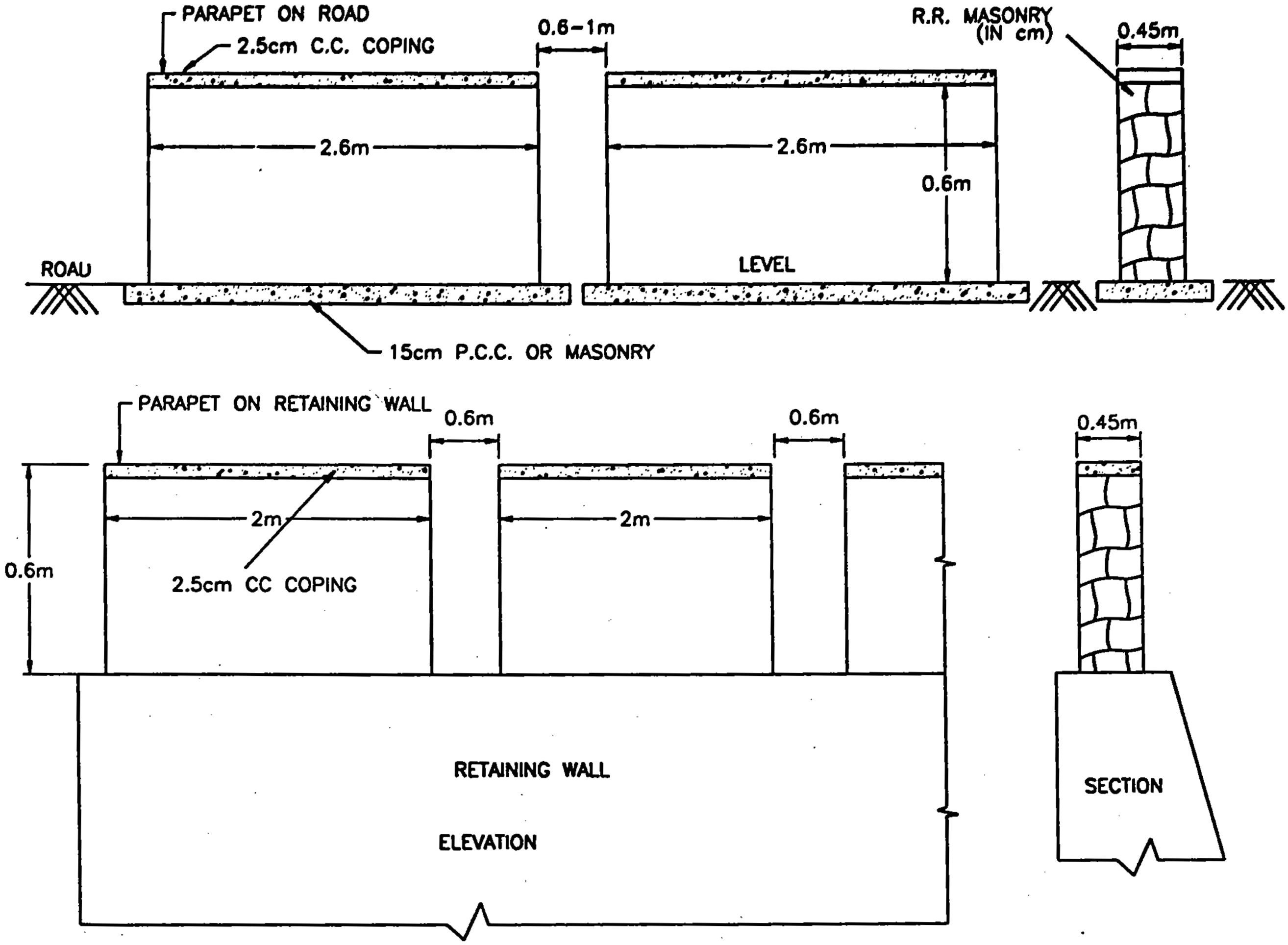


FIG. 9.5. PARAPET WALL

9.4.2. **Railings:** Railing is provided on bridges or in rocky or other stretches where full formation width, as per standards, could not be achieved. These are provided as safety measure also. Railings may be of angle iron, GI pipes rail sections, RCC posts etc. A typical sketch is given in Fig. 9.6.

9.4.3. **Edge stones/delineators**: Where the road is extra wide due to a gully or a through cut, the parapets are not required and can be safely replaced by edge stones. They are dressed stones embedded in earth and projecting about 0.3 m above the road level, duly white washed, for visibility. Ref. Fig. 9.7. On sharp bends delineators with metallic pipes and reflective paint/tape may be provided for traffic safety.

9.4.3.1. In some situations, where deep rectangular drains are provided on the hill-side, guard stones are necessary to prevent the wheel going into the deep drain. In this case they are embedded on the road side-wall of the drain as shown in Fig. 9.8.

9.4.3.2. In curves and in vulnerable locations on the valley side wire rope safety barriers may be provided.

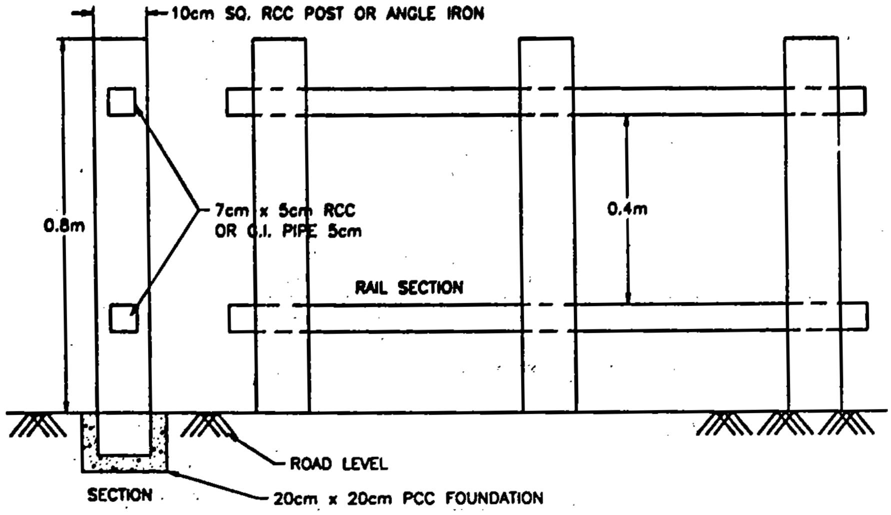


FIG. 9.6. RAILING

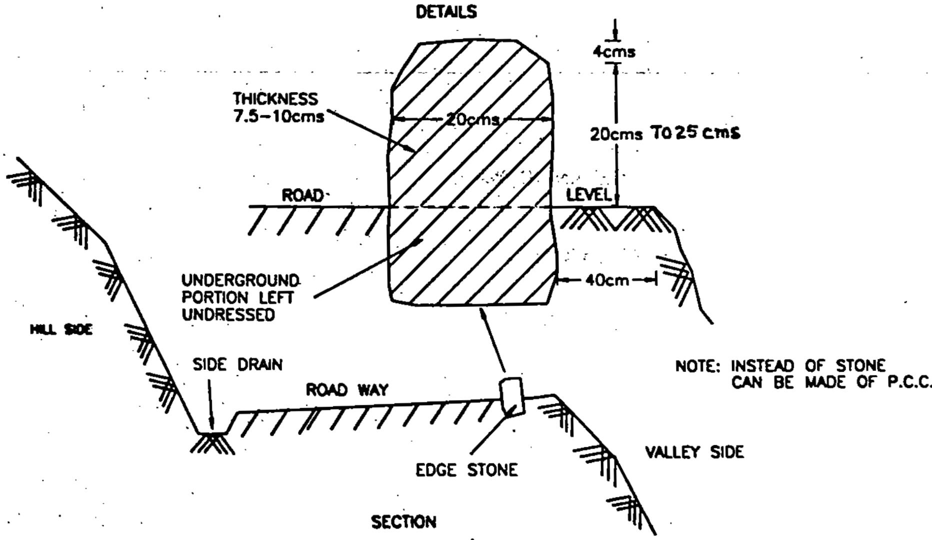


FIG. 9.7. EDGE STONE

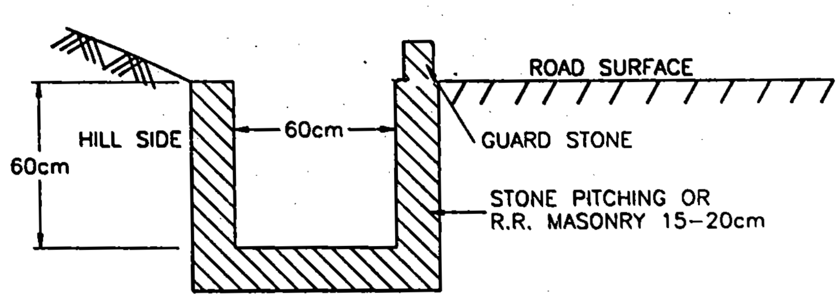


FIG. 9.8. GUARD STONE IN DEEP DRAIN

9.5. Toe and Check Walls

9.5.1. When culverts/scuppers are constructed and water falls above the retaining walls on the valley side to a considerable height, in the form of a free fall, there is considerable erosion at the toe of the retaining wall. In order to check this erosion, one or a series of toe walls are constructed in order to break the water force so that the retaining wall does not get eroded.

9.5.2. In some cases, similar structures called check walls are required in the nallah bed on the upstream side of the road to reduce the flow of debris which blocks the road.

9.5.3. Typical sections and arrangement of Toe and Check walls are given in Fig. 9.9.

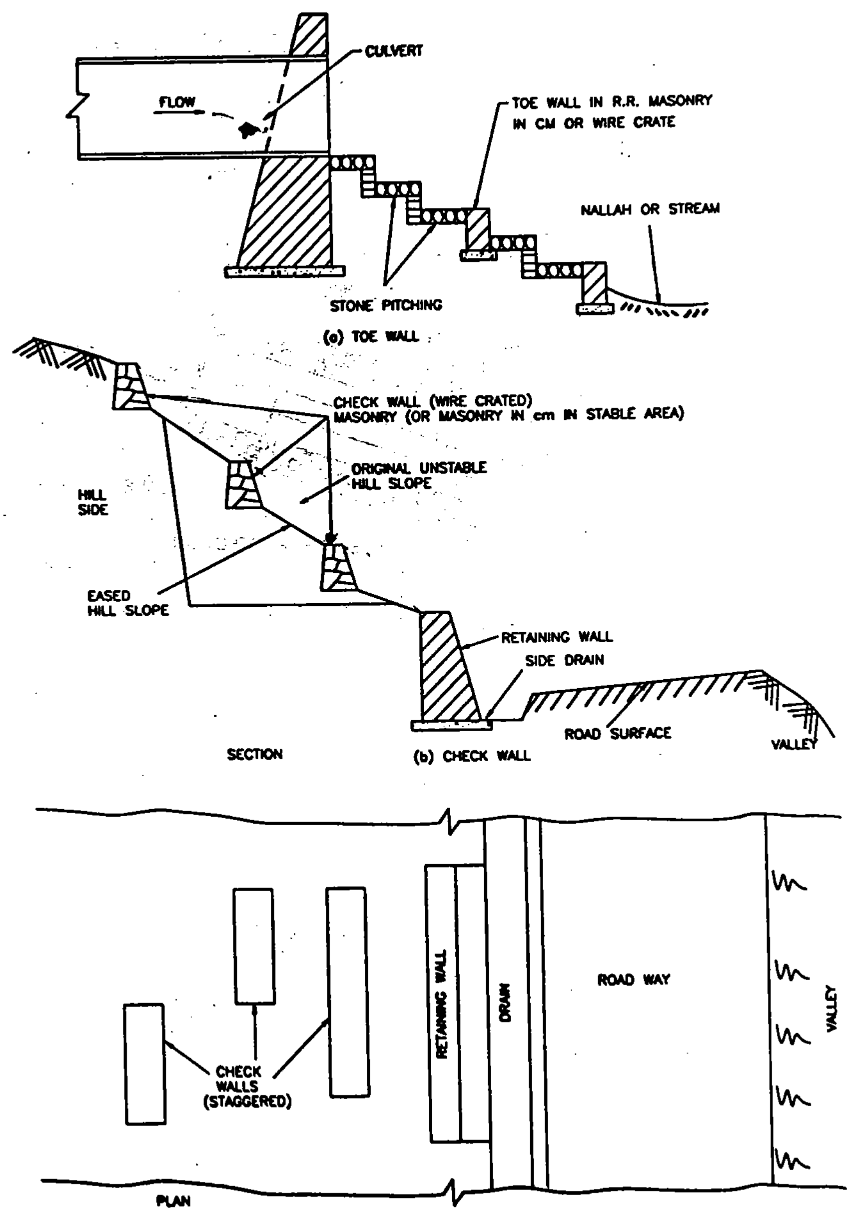
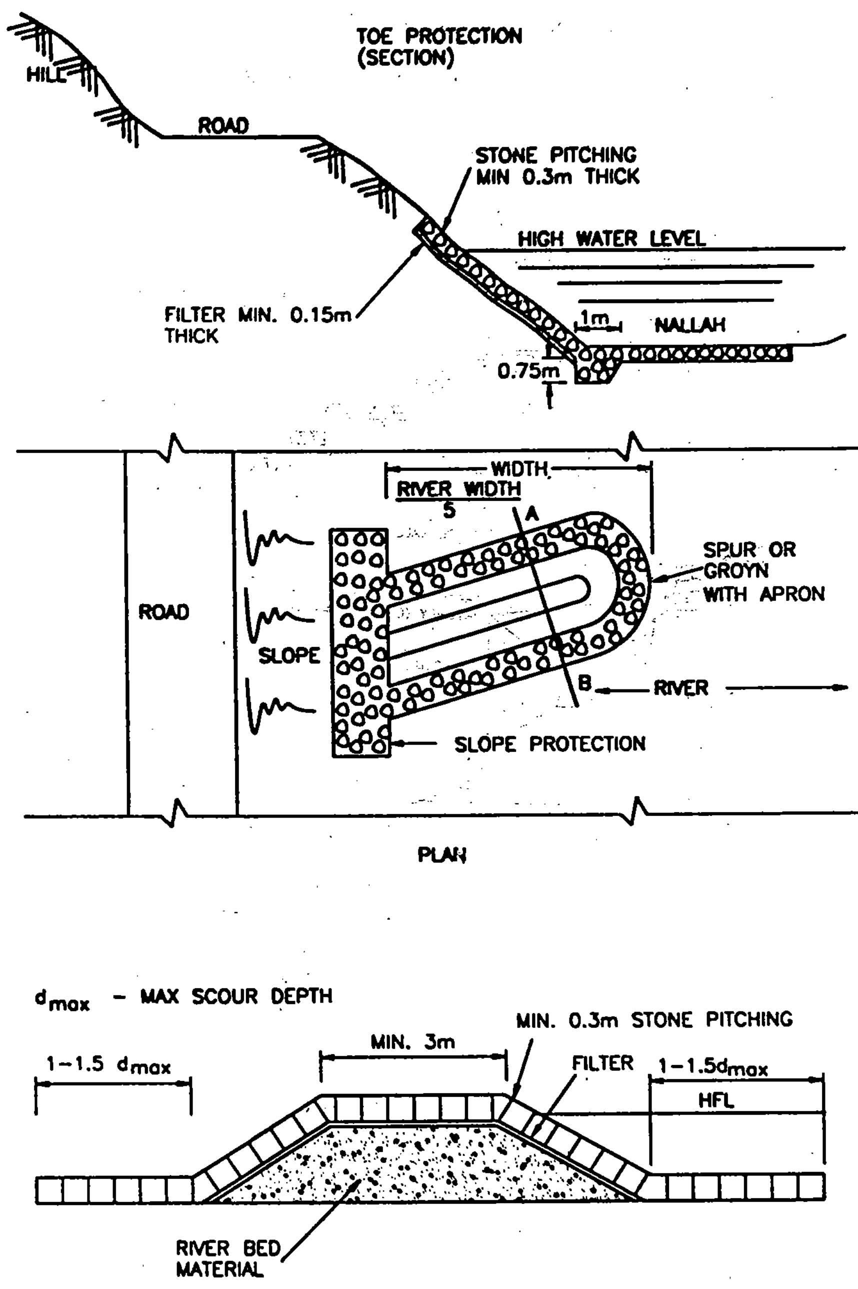


FIG. 9.9. TOE & CHECK WALLS

9.6. River Training Structures

9.6.1. As hill roads, in many cases, are aligned along river courses, river training measures like spurs or groynes, slope pitching, aprons etc. are required to be provided at the toe of down hill slope of road to prevent erosion and subsidence of road bed. Designs have to be evolved to suit site conditions as per sound engineering practice in each case. A few typical sections and arrangements are given in Fig. 9.10.



SECTION OF SPUR ON A-B

NOTE: SPUR CAN BE MADE ENTIRELY IN WIRECRATED STONE ALSO

FIG. 9.10. RIVER TRAINING WORKS

9.7. Reinforced Soil Retaining Walls

9.7.1. Reinforced soil retaining wall is a new concept. It is a composite construction material, in which the strength of fill is enhanced through addition of inextensible tensile reinforcement in form of strips, sheets, grids or geotextiles. The technique of construction is quite suitable for hilly areas mainly due to the following reasons:-

a) The fill material which consists of mainly granular material is easily available in all parts of the hilly areas from cutting of hill side during the construction of roads.

b) These involve minimum alteration in natural slopes since the emphasis is on avoiding the cutting of natural slope.

c) The land width or actual embankment width required is less.

d) This is cost effective and environment friendly.

9.7.2. Reinforced Soil Retaining Walls are flexible walls. Their main components are:-

a) Back-fill, which is granular soil.

b) Reinforcing materials - thin and wide strips or geosynthetics placed at regular intervals.

c) Facing - galvanised steel plates or precast concrete panels. In case of geotextiles, the same can be wrapped around earthwork and covered with stone masonary etc. In case of inclined wall the facing can be covered with earth and turfing.

9.7.3. Fig. 9.11 shows a typical reinforced earth retaining wall. Reinforcing ties are placed with a horizontal spacing of 'h' centre to centre and vertical spacing of 'v' centre to centre. With a conservative design, 0.5 mm thick galvanised steel plate would be enough to hold a wall about 15 m high. The use of precast slabs as a cover on the front face is also common. The slabs are grooved to fit into each other so that soil does not flow out between the joints. Panel size, configuration, surface texture and colour can be varied to provide an aesthetically pleasing finished structure. When metal plates are used, they are bolted together and reinforcing strips are placed between the plates.

9.8. Other Structures

9.8.1. In areas subject to land-slides, rock slides snow-fall, etc., special structures such as buffers, snow sheds, tunnels etc. may be needed. These have to be designed to meet specific requirements. These are discussed in subsequent chapters.

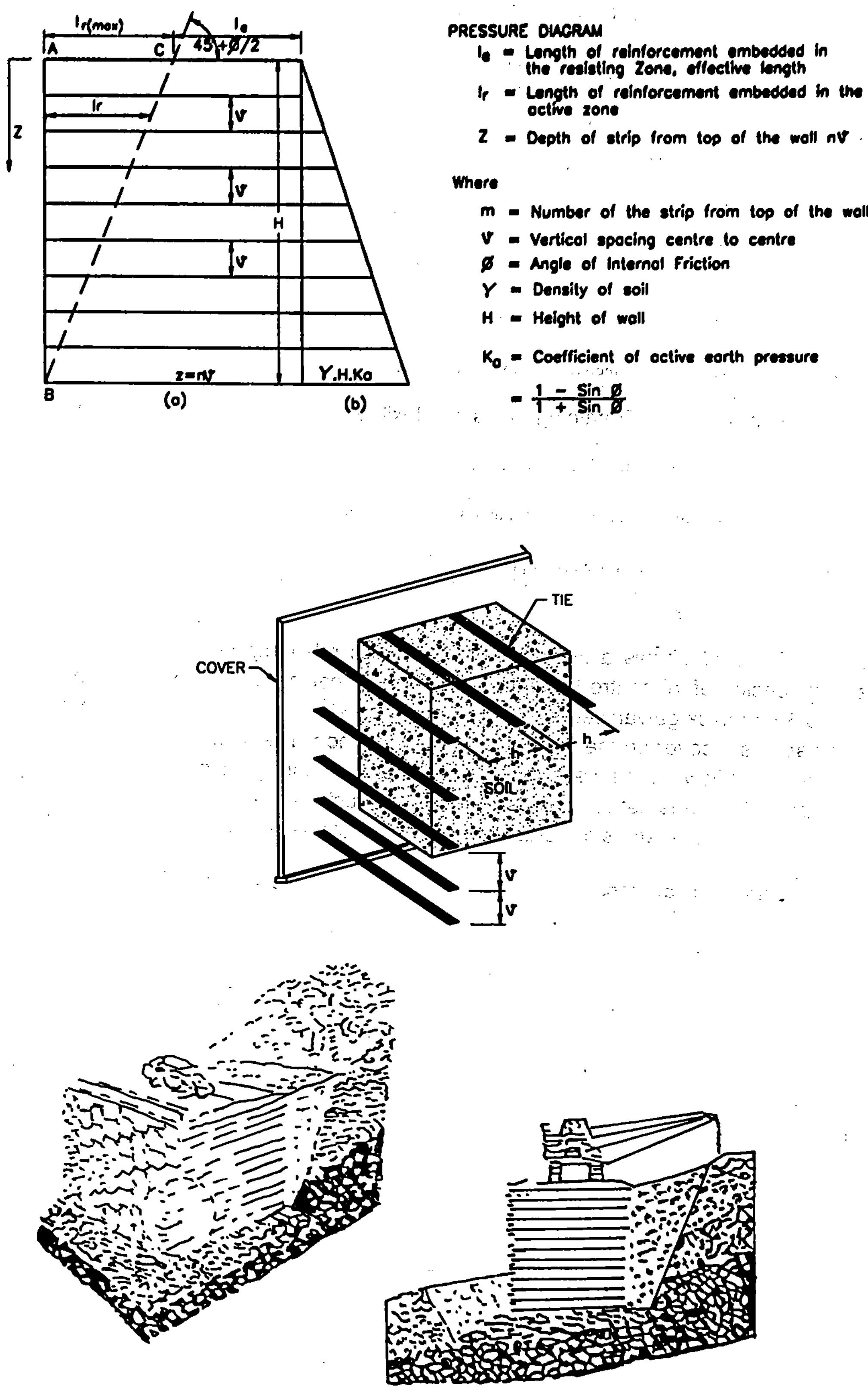


FIG. 9.11. REINFORCED EARTH RETAINNG WALL ARRANGEMEMT AND VIEWS

10. PAVEMENT DESIGN

10.1. General

10.1.1. Design of pavement for roads, whether in plains or hills follows the same basic principles like soil and traffic parameters as also climatic considerations and their effects. However, while designing pavement for hill roads, specific aspects relevant to the hill regions like terrain and topographic conditions, extremes of weather conditions, altitude effects etc have also to be duly considered and suitably incorporated in the design so that the pavement is able to perform well for the designed traffic and service life.

10.1.2. The main items that require consideration for design of pavement in hill areas, not normally met within the plains, are given below:

a) Whereas the road bed or sub-grade materials in the plains tend to be more or less homogeneous (mainly due to forming sub-grade by borrowed material) and fine grained, the road bed/sub-grades in the hilly regions are mostly mixtures of gravel, boulders, various types of rocky material etc with some fine-grained soil matrix (the material forming the hill itself becomes road bed material).

b) Hilly regions normally receive very high rainfall (reaching as high as 1200-1500 mm annually in certain areas) spread over 6 months or so with very high intensity for short duration. This results in saturated road bed for prolonged periods and creates problems of drainage of pavement, erosion and instability.

c) Large scale differences in day and night air temperatures cause thermal stresses.

d) Rarefied atmosphere at high altitude gets exposed to higher degree of solar radiation and has effect on performance characteristics of materials like bitumen which tends to become harder and brittle.

e) Some regions in high altitudes (and even at lower altitudes in Northern Himalayan ranges) receive snow fall with some areas remaining snow bound in winter. Apart from extremes of cold and problems of snow clearance, issues like frost heave, icing, repeated freezing and thawing create problems of design, composition, construction, drainage and maintenance of pavement.

f) Road construction period available in high altitude and snow fall areas is very limited and design of pavement and selection of materials for same need special consideration so that the work is done with speed in the short working season.

10.1.3. The measures to be taken in pavement design to effectively counteract the above adverse effects in hill roads are dealt at the appropriate places in this chapter.

10.2. Type of Pavement

10.2.1. Considering various aspects brought out in preceding paras, rigid pavement is not generally recommended for roads in hilly regions. In seismic areas, rigid pavement is liable to severe damages whereas flexible pavement, by its granular composition, can withstand effects of tremors better. Hence flexible pavement is normally provided on hill roads and is therefore dealt with in detail. However a brief note on rigid pavement is given for reference and understanding of the issue for consideration where site conditions, traffic etc. necessitate and permit a rigid pavement.

10.3. Composition of Road Pavement

10.3.1. A typical arrangement of a road pavement is given in Fig. 10.1.

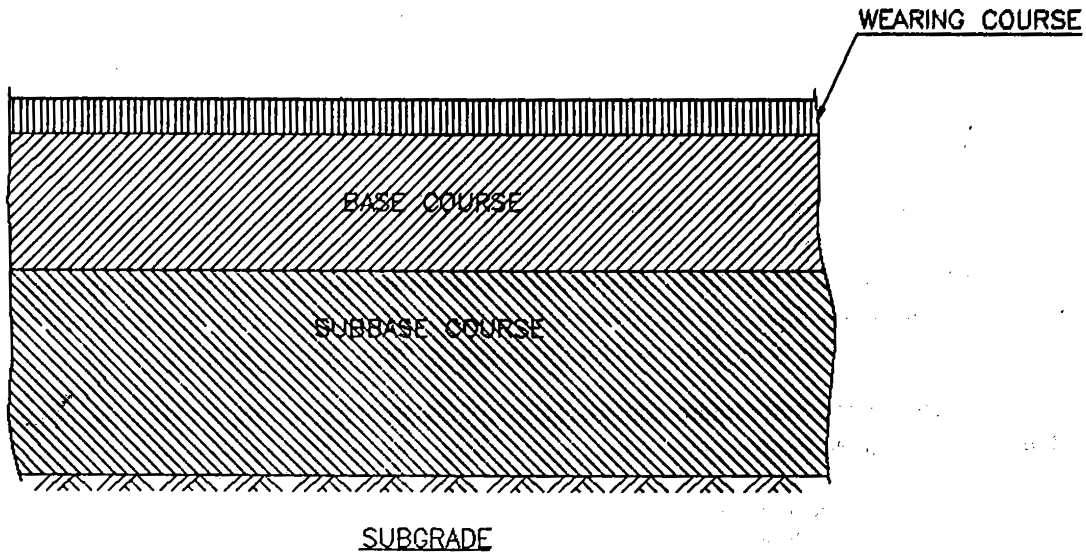


FIG.10.1. TYPICAL PAVEMENT SECTION

10.3.2. In a road the entire width on which construction activity takes place is defined as road bed which is the sub-grade. To make the road bed passable to traffic in all seasons/weather, a hard surface is laid. This surface may consist of sand, gravel, crushed rocks with or without binding material. The binding material may be bitumen, tar or cement. (Use of tar is very limited now-a-days and cement is used sparingly only.) This hard surface laid on sub-grade is the pavement. The sub-grade of weak soil is compacted or stabilised, as required, to ensure its desired strength.

10.3.3. The sub-grade which is natural soil brought to required profile and compacted to optimum density serves as foundation of the road structure and the entire load on the road is taken evenly by the sub-grade. Sub-grade is the top 50 cm of the road bed covering entire formation width of road. This sub-grade supports the road pavement.

10.3.4. A flexible pavement disperses load in a geometrical pattern as shown in Fig. 10.2.

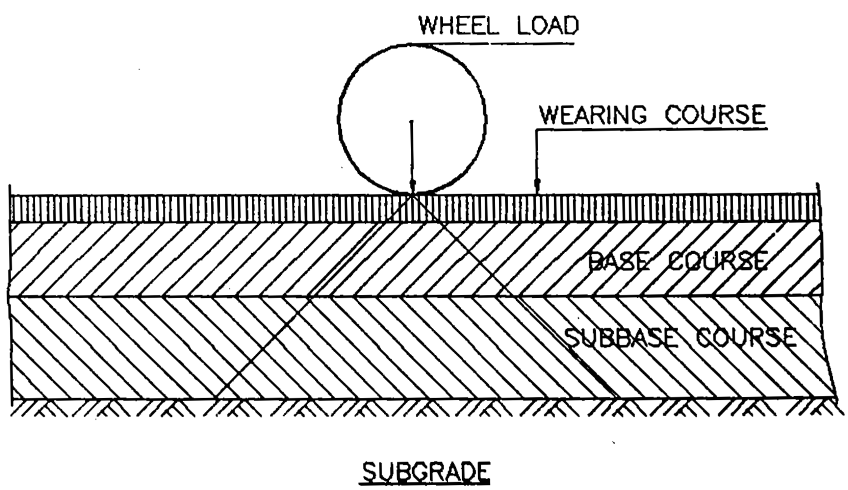


FIG.10.2. LOAD DISPERSAL IN PAVEMENT

Each lower layer has a lesser stress due to dispersion of load. Hence, in principle, the highest quality material should be nearest the load and weakest material farthest away. All granular and bitumen bound pavements are flexible. Essentially, in a flexible pavement, the strength and quality of material used may progressively increase from sub-grade to the top of the pavement, where the load of vehicles comes in contact with road surface.

10.3.5. A pavement consists of the following:-

a) **Sub-base:** This consists of a well drained material placed on the sub-grade. The sub-base may be made up of granular materials like natural sand, moorum, gravel, laterite, kanker, brick metal, crushed stone, crushed slag or combination thereof or other materials like stabilised soil which remain static under saturated conditions. Soil aggregate mixes also are suitable for use in sub-base. The sub-base may be in more than one layer and in such case nomenclature as lower sub-base and upper sub-base may be used.

b) **Base Course:** The base course consists of granular unbound or bound course placed above sub-base and transmits load and shear stress on pavement to sub-grade through sub-base. The base may be Water Bound Macadam (WBM), Wet-Mix Macadam (WMM), or any other equivalent granular construction (like Crushed Granular Aggregates or Dry Bound Macadam in water scarcity areas) or Bitumen Bound Macadam.

c) **Wearing Course or Wearing Surface:** This is the hard top crust of the pavement which comes in contact with the load. This consists of a Wearing Course only or a Wearing Course over a binder course. The function of the wearing course is to withstand the abrasive and attritive stresses due to traffic, provide good riding surface and prevent ingress of moisture to the road bed. It also prevents the base course from ravelling. At times a binder Course is provided below a wearing course. It is a bitumen bound layer between granular base course and wearing course to give better load transmission and to act as a superior bound layer, reducing over-all thickness of unbound granular base like Water Bound Macadam and adds to the structural stability of the pavement as a whole. The binder course is provided on roads with higher traffic intensity. While wearing course may be Surface Dressing, Mix-Seal, Surfacing, Open Graded Premix Carpet, Semi-Dense Bitumen Concrete or Bituminous Concrete, binder course is generally either lean Bituminous Macadam or Dense Bituminous Macadam.

d) **Shoulders or Berms:** The Shoulder or Berm is that portion of the pavement, outside the carriageway, covering the formation width (except drains and parapet, if any). The shoulder may be earthen, treated/stabilised or a paved hard shoulder. The shoulder provides lateral support to the pavement, prevents damages to the pavement edge and acts as extra space for traffic in emergencies.

10.4. Factors Governing Design of Pavement

10.4.1. Design of Pavement requires considerations of wheel load of vehicles, traffic, climate, terrain, sub-grade condition etc. Methods of pavement design normally used in the plains based on quantitative and qualitative evaluation of sub-grade materials (soils etc) for withstanding given conditions of traffic and climate also take advantage of the successful past practices and experience. This is equally applicable in the case of hill roads also duly considering aspects peculiar to hill areas as given in para 10.1.2.

10.4.2. The design procedure, as applicable to plains/rolling terrain, will apply to hilly regions in lower altitudes, high altitudes which are not snow bound, valleys and high rainfall areas. IRC: 37 "Guidelines for Design of Flexible Pavements" have generally been adopted in this manual. These guidelines are under revision. The revised guidelines when published should be adopted. However selection of specifications, composition of component layers, provision for drainage etc., have to be done to suit the special problems in such areas.

10.4.3. A pavement design may have to meet any of the following requirements:

a) New construction consisting of:

   i) Pavement on a new road

   ii) Pavement on an existing un-surfaced road which is in use already.

b) Strengthening of an existing pavement.

10.4.4. The various factor affecting design of pavement, are dealt progressively in this Chapter.

10.5. Traffic

10.5.1. For the purpose of structural design of pavement, only the number of Commercial Vehicles per Day (CVD) of laden weight of 3 tonnes or more and their axle loading are considered. However, for purpose of deciding on the lane width of road/pavement, all kinds of traffic i.e. from bullock cart and cycle to heavy vehicles are considered and converted as per norms to equivalent Passenger Car Units (PCU). To obtain realistic estimate of design traffic, due consideration should be given to the existing traffic and anticipated in case of new construction, possible changes in road net work, land use of the area served, the probable growth of traffic and design life.

10.5.2. The following guidelines be adopted for traffic estimation:-

a) Initial average traffic for any road should be based on 7 days of 24 hours classified traffic counts. In exceptional cases 3 days count could be done.

b) On new roads traffic estimation is forecast on land use, development needs and traffic on adjacent routes in the area.

c) Traffic growth may be predicted on past trends.

d) In absence of accurate data, a growth rate of traffic can be considered as 7.5% per year or more if revised by IRC.

10.5.3. The procedure for traffic census as laid down in IRC:9-1972 "Traffic Census on Non-Urban Roads" may be followed.

10.6. Design Life

10.6.1. It is considered appropriate that roads in rural areas should be designed for a life of 10-15 years but provision must be made in the design for progressive strengthening of the road. Arterial roads should normally be designed for 15 years life and others for 10 years life. Urban roads may, however, be designed for a longer life based on judgement and depending on the rate of growth of the traffic expected.

10.6.2. Very often it may not be possible to provide the ultimately needed full thickness of pavement right at the time of initial construction. In such cases stage construction techniques could be resorted to and those forms of construction chosen that could readily be strengthened as traffic increases. The initial construction stage period should not be less than 5 years.

10.7. Distribution of Traffic

10.7.1. A realistic assessment of distribution of commercial traffic by direction and by lane is necessary as it directly affects the total load application in the designs. The following distribution may be assumed for design, subject to the stipulation, that, if in a particular situation a better estimate of the distribution of traffic between the carriageway lanes is available from traffic surveys, the same should be adopted and the design made based on the traffic in the most heavily trafficked lane. The design, as evolved, will apply to the whole carriageway width:-

a) Single-lane roads (3.75 m width): Traffic tends to be more channelised on single lane roads than on two-lane roads and to allow for this concentration of load, the design should be based on the total number of commercial vehicles per day in both directions multiplied by two.

b) Intermediate width roads (5.5 m width): The design should be based on the total number of commercial vehicles per day in both directions multiplied by 1.5.

c) **Two lane single carriageway roads: The design should be based on 75 per cent of the total number of commercial vehicles in both directions.**

10.7.2. The traffic in each direction may be assumed to be half the sum in both directions when the latter only is known. Where significant difference between the streams can occur, the condition in the more heavily trafficked lane should be considered for design.

10.8. Road Capacity and Pavement Width

10.8.1. Width of carriageway and therefore the pavement width will be arrived at based on the traffic census and/or design road capacity as given in Table 4.1 under Chapter 4 "PLANNING CRITERIA". The same is reproduced as Table 10.1 below for ready reference:-

Table 10.1. Design Road Capacity (Service Volume) for Hill Roads

Sl. No.	Type of Road	Design service volume in P.C.U. per day Carriageway width	For low curvature (0-200 degrees per km)	For high curvature (above 200 degrees per km)
1.	Single lane	3.75 m	1,600	1,400
2.	Intermediate lane	5.5 m	5,200	4,500
3.	Two-lane	7 m	7,000	5,000

10.8.2. Tentative equivalency factors for conversion of different types of vehicles into equivalent Passenger Car Units (PCUs) based on their relative interference values are given in Table 10.2 below. These factors are meant for open road sections and not for intersections.

Table 10.2. PCU Factors for Various Types of Vehicles on Rural Hill Roads

Sl. No.	Vehicle of Type	Equivalency Factor
	Fast Moving Vehicles	
1.	Motor Cycle or Scooter	0.50
2.	Passenger Car, Pick-up Van or Auto Rikshaw	1.0
3.	Agricultural Tractor, Light Commercial Vehicle	1.50
4.	Truck-trailer, Agricultural Tractor-trailer	4.50
5.	Truck or Bus	3.00
	Slow Moving Vehicles	
6.	Cycle	0.50
7.	Cycle Rikshaw	2.00
8.	Hand Cart	3.00
9.	Horse Drawn Vehicle	4.00
10.	Bullock Cart	8.00 (for smaller carts 6.0)

The above data can be applied essentially for widening and strengthening of existing roads rather than for new roads under construction. However on existing unsurfaced road this data can be used for design of new pavement as long as existing traffic data is available and likely traffic growth forecast is realistically possible.

10.9. Vehicle Damage Factor (VDF)

10.9.1. The vehicle damage factor, a multiplier for converting the number of commercial vehicles of different axle loads to the number of standard axle-load repetitions, takes into account the various influencing factors of traffic mix, type of transportation, type of commodities carried etc. The tentative indicative values of vehicle damage factor based on some surveys carried out on National Highway sections as indicated in IRC: 37-1984 "Guidelines for the Design of Flexible Pavements" for hilly regions are given in Table 10.3.

Table 10.3. Indicative VDF Values for Hilly Terrain

Initial traffic intensity in terms of number of commercial vehicles/day	VDF Values (Standard axles each of 8.16 tonnes per commercial vehicle)		
	Unsurfaced	Thin bituminous surfacing	Thick bituminous surfacing
Less than 150	0.5	0.75	-
150-1500	-	1.00	1.25
More than 1500	-	1.25	1.50

10.10. Traffic Growth

10.10.1. In case no information is available regarding trend in growth of traffic during the past or likely developments in the area during the future which are likely to have major impact on the design traffic, the annual growth rate may be assumed at the rate of 7.5% and a pavement be designed for a life of 5 to 15 years as explained in paras 10.6.1 to 10.6.2. The pavement design of such roads should be reviewed in case some sudden change in traffic intensity/pattern takes place during this period. Otherwise the design traffic should be re-assessed after 5-6 years or when a renewal of wearing course is due. Strengthening can be planned along with renewal operation.

10.10.2. The following equation may be used for computation of design traffic.

$$Ns = \frac{365 \times A\,((1+r)^n - 1)}{r} \times F$$

where

Ns = The cumulative number of standard axles to be catered for in the design.
A = Initial traffic in the year of completion of construction in terms of commercial vehicles per day duly modified to account for lane distribution.
r = Annual growth rate of commercial traffic
n = Design life in years
F = Vehicle damage factor

Illustration

a) **Data (assumed)**

i.	Single lane carriageway	
ii.	Initial traffic in the year of completion of construction	750 CV/day (sum of both directions)
iii.	Growth rate	7.5% (assumed)
iv.	Design life	10 Years
v.	VDF	1

Computation

Initial traffic in design lane = 750 x 2 = 1500

$$\text{Design traffic} = \frac{365 \times 1500 \left[(1+0.075)^{10}-1\right]}{0.075} \times 1$$

$$= 77{,}45{,}530$$

$$= 7.75 \text{ msa} = \text{say } 8 \text{ msa}$$

a) **Data (assumed)**

i.	Two lane carriageway	
ii.	Initial traffic in the year of completion of construction	1000 CV/Day (sum of both directions)
iii.	Growth rate	7.5% (assumed)
iv.	Design life	10
v.	VDF	1.25

Computation

Initial traffic in design lane = 0.75 x 1000 = 750 CV/day

$$\text{Design traffic} = \frac{365 \times 750 \left[(1+0.075)^{10}-1\right] 1.25}{0.075} \times 1$$

$$= 48.40956 = 4.84 \text{ msa Say } 5 \text{ msa}$$

10.10.3. The traffic data to be used in the design of pavement is deduced as above.

10.11. Traffic Used in Design

10.11.1. The traffic used in the design is either in terms of Cumulative Standard Axle (CSA) or Commercial Vehicles per Day (CVD) as explained below:

a) **CSA Method:** This method of assessment of traffic data is in terms of CUMULATIVE STANDARD AXLE (CSA) i.e. repetitive axle loads (axle load taken as 8.16 MT) over design period and hence the design is related to life, traffic intensity, volume and repetition. This is a logical way of assessing traffic and designing a pavement to withstand a gross pre-determined repetitive axle load coming on the road. In this case, if the CSA is already reached prior to the originally designed life, a re-evaluation and strengthening can be planned assessing pavement behaviour as long as traffic data for the period is maintained. For design of pavement, certain traffic and axle load factors are considered as explained in subsequent paras.

b) **CVD Method:** In this method of estimating, traffic is considered in terms of COMMERCIAL VEHICLES PER DAY (CVD), provided the design traffic is not more than 1500 CVD. The commercial vehicles have been considered as those having laden weight of 3-tonne or more. In this method of design the traffic, in terms of CVD, is divided into certain ranges for purposes of design. The traffic range and approximate corresponding CSA are indicated below:

a) 0-15 CVD
b) 15-45 CVD - 0.5 msa
c) 45-150 CVD
d) 150-450 CVD - 0.5-2 msa
e) 450-1500 CVD - 2-5 msa against provision in IRC: 37 of 2-4 msa considering rationalisation of CVD and CSA.

The formula for predicting future traffic is given below:

$$A = P\,(1+r)^{(n+x)}$$

where

A = Number of commercial vehicles per day for design
P = Number of commercial vehicles per day at last count
r = Annual growth rate of commercial traffic
n = Number of years between the last count and the year of completion of construction
x = Design life in years

10.11.2. Where traffic is increasing rapidly it is probable that a single lane road may require to be widened to two-lane standards within a short period even otherwise and this aspect should be borne in mind when deciding the pavement thickness.

10.12. Soil Parameters (Sub-Grade Strength)

10.12.1. For design the subgrade soil strength is normally assessed in terms of the California Bearing Ratio (CBR) for use in the flexible pavement design method. The design subgrade strength depends upon the type of soil, degree of compaction, worst moisture content and the climatic conditions that the subgrade would attain during the design life of the road.

10.12.2. The conventional procedure for evaluating the sub-grade strength is by determining its laboratory CBR, an empirically determined index value representing the resistance to penetration of the subgrade soil. The subgrade soils in the hilly regions normally vary from hard rock to soft shale with intermediate types having gravel with different percentage of binder, silty gravels, silty clays, silty sands and boulders mixed with varying proportions of silty and clayey soils etc.

10.12.3. The soaked CBRs on disturbed samples are conducted on soil fractions obtained after sieving the subgrade material through a 20mm sieve and compacting it at the Proctor dry density and optimum moisture content. The CBR test is not applicable on materials having aggregates larger than 20 mm size (Ref. para 10.20.4.3). The subgrade material consisting of varying mixtures of boulders of different sizes and the fines, generally met with in the hilly regions, therefore renders the CBR evaluation method not representative.

10.12.4. The various sub-grades materials have been grouped into various strength categories and their typical CBR values given in Table 10.4.

10.12.5. The subgrade materials which are affected by frost action, tend to lose their subgrade strength. The method to be adopted for design is given in this chapter separately.

10.12.6. The CBR value is ascertained as per a standard test procedure described in IS: 2720 (Part XVI) "Methods of Test for Soils".

Table 10.4. Type of subgrade material and CBR

Category	Type of Subgrade	Strength designation (CBR etc.) range
1.	Rocky subgrade, conglomerates, slate	High strength - CBR not the criterion
2.	Gravel with binder soil less than 20%, hard slate	Soaked CBR 8-15
3.	Gravel with binder soil more than 20%, shale of medium hardness, silty sands	Soaked CBR 5-10
4.	Silty clays and soft shale	Soaked CBR 2-5

10.13. Climatic Conditions, Terrain Conditions and Other Special Problems

10.13.1. The design, specifications and selection of component materials suitably related to climate, terrain, topography and specific conditions obtainable in specific regions of hill areas are dealt in the appropriate places in this chapter. The design of pavement for high altitudes and snowfall areas are dealt elaborately under para 10.22.

10.14. Pavement Design Methods

10.14.1. Pavement design will involve any of the following:

a) New construction
b) Strengthening of an existing pavement.

The procedure outlined primarily for design of new pavement may also be applied for design of overlays/strengthening of existing pavements. However an alternate method for design of strengthening overlay, i.e. Benkleman Beam. Deflection Method is available which is discussed separately.

10.14.2. The equivalent axle load concept is the best method available for design purposes, to handle the large spectrum of axle loads actually applied to a pavement. However where data is not available to adopt the equivalent load concept, the CBR method which considers traffic in terms of commercial vehicles per day may be used provided the design traffic is not more than 1500 commercial vehicles per day.

10.14.3. The CSA method adopts superior bituminous specifications for traffic of 2-5 msa and above (equivalent to above 450-1500 CVD) and hence adoption of CSA should be limited to high traffic roads. As such stipulation of this method for traffic above 1500 CVD has been done.

10.15. Design of Pavement Based on Commercial Vehicles/Day

10.15.1. The CBR strength of soil and the design traffic has been co-related and the corresponding depth or thickness of pavement required has been worked out. This has been plotted in graphical form as curves for various traffic intensities. The commercial vehicles are those having laden weight of 3 tonnes or more. The curve is given in Fig. 10.3.

10.15.2. Thickness of Pavement: Having obtained the CBR value of the subgrade and worked out the design traffic, the total thickness of the pavement may be obtained from the curves given. The total thickness of different layers i.e. sub-base and base may be arrived at knowing CBR value of sub-base. The thickness of various layers can be arrived at by repetitive applications of CBR value of materials composing the layer. The minimum thickness of component layers are same as for CSA method given in Table 10.5. When the wearing course consists of thin bituminous layers like surface dressing or premix carpet it should not be considered for arriving at the pavement thickness.

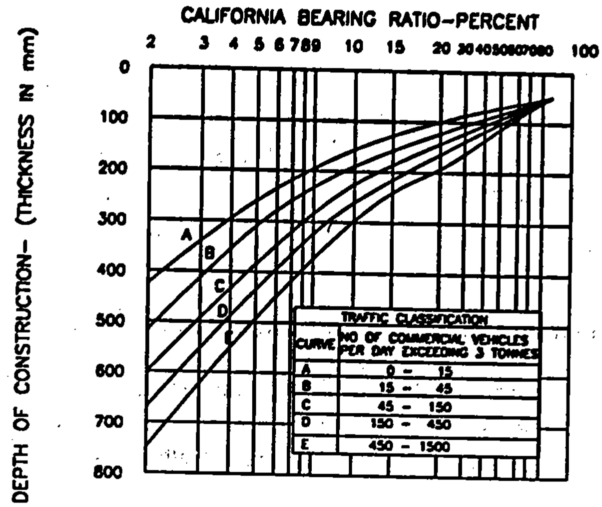


FIG. 10.3. C.B.R.CURVE FOR PAVEMENT THICKNESS (C.V.D. METHOD)

10.15.3. The minimum layer thicknesses to be adopted are given in Table 10.5.

Table 10.5. Minimum Layer Thicknesses

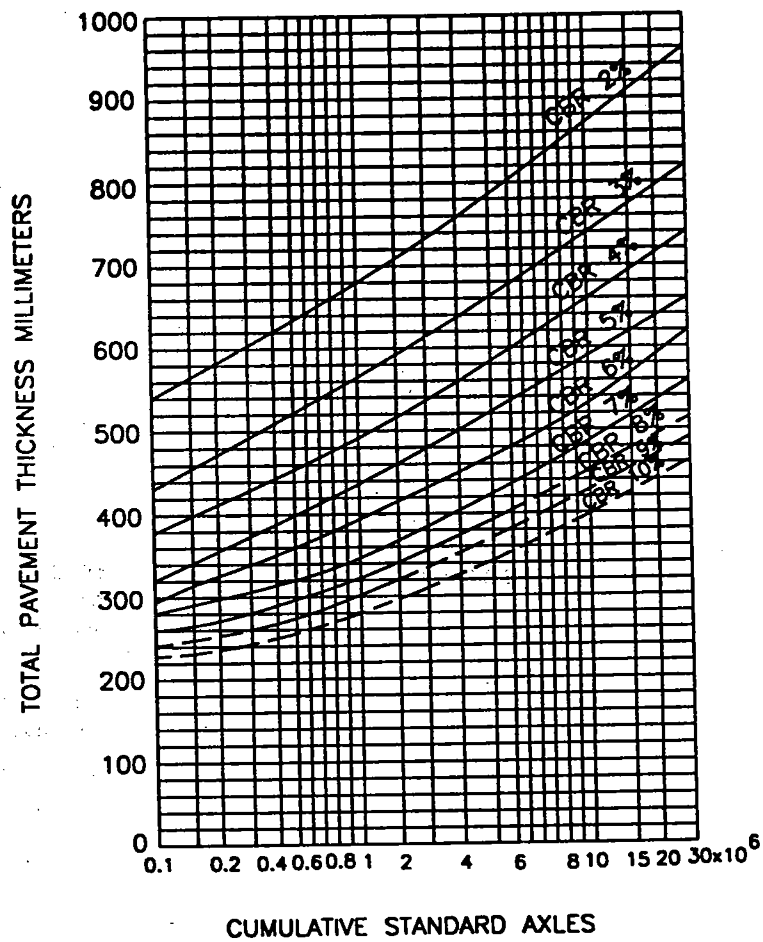
		Sub-base	Base
a)	Upto Curve C 45-150 CVD	100 mm (on sub-grade of CBR less than 20)	150 mm
b)	Curve D 150-450 CVD	150 mm (on sub-grade of CBR less than 20)	225 mm
c)	Curve E 450-1500 CVD	150 mm (on sub-grade of CBR less than 30)	250 mm

10.15.4. Certain stipulations regarding minimum CBR values for base/sub-base, treatment for low CBR values, soil sub-grades etc., as applicable, are given while dealing with sub-base, base course etc. later in this chapter.

10.16. **Design of Pavement: CSA Method**

10.16.1. The method of design is based on the Cumulative Standard Axles (8160 kg) to be carried over the design life period. The various aspects to be considered in arriving at the CSA based on traffic data, design life, VDF etc have already been explained.

10.16.2. In this method also, the CBR value is used for evaluating pavement thickness. The thickness of pavement has been plotted against CSA in the form of a curve for various CBR values from 2% to 10%. (Beyond CBR 10, no curves are drawn as the thickness arrived at will be less than minimum required to be provided). As such for CBR more than 10 the minimum thickness of layers as stipulated will have to be provided. The thickness of pavement can be read from the graph knowing CSA and CBR value of sub-grade. After having ascertained the thickness of pavement, the various layers should be adopted from the thickness combination block and composition Table. The thickness curve and thickness combination block are given in Figs. 10.4 & 10.5 respectively. The corresponding structural composition is given in Table 10.6.



PAVEMENT THICKNESS DESIGN CHART

NOTE : 1. READ TOTAL PAVEMENT THICKNESS FROM CONTINUOUS CURVES

2. USE DOTTED CURVES FOR PROPORTIONING SUB-BASE THICKNESS

FIG. 10.4. PAVEMENT THICKNESS CURVE (C.S.A. METHOD)

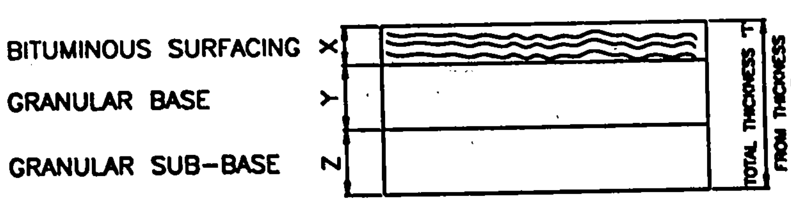


FIG.10.5. THICKNESS COMBINATION BLOCK

10.16.3. The design curves provide for CSA upto 30 msa. For traffic exceeding 30 msa, the curves will have to be suitably extra-polated. However, roads with such high traffic intensity on one lane will be very rare. However,in an eventuality of such case happening, a suitable design can be evolved by this method.

10.16.4. An illustrative example is given below:-

i.	CSA for design	10 msa
ii.	CBR of subgrade	6%

a) Thickness of pavement — 500 mm

b) Pavement thickness from combination block

i.	Surfacing	25 mm SDC/AC-Wearing Course and 75 mm DBM-Binder Course
ii.	Base	250 mm
iii.	Sub-base of material with CBR less than 30 per cent	500 - 350 = 150

Table 10.6. Structural Composition of Pavement

Cumulated standard axles million (M)	Minimum thickness of component layers compacted thickness (mm)		
	Surfacing (X)	Base (Y)	Sub-base (Z)
0-5 m	20 mm PC/2-Coat SD	150	(T-150) Minimum thickness 100 mm on subgrades of CBR less than 20%
0.5-2 m	20 mm PC/MS	225	(T-225) Minimum thickness 150 mm on subgrades of CBR less than 20%
2-5 m	20 mm PC/MS/SDC + 50 mm/75 mm BM	250	(T-300/325) Minimum thickness 150 mm on subgrades of CBR less than 30%
5-10 m	25 mm SDC/AC + 60 to 80 mm DBM	250	(T-335 to 355) -do-
10-15 m	40 mm SDC/AC + 65 to 80 mm DBM	250	(T-355 to 370) -do-
15-20 m	40 mm AC + 80 to 100 mm DBM	250	(T-370 to 390) -do-
20-30 m	40 mm AC + 100 to 150 mm DBM	250	(T-390 to 405) -do-

SD = Surface Dressing to the MOST Specification IRC/Standards
PC = Premix Carpet MOST Specification/IRC Standards
MS = Mix Seal Surfacing to the MOST Specification
SDC = Semi-dense Carpet MOST Specification
AC = Asphaltic Concrete MOST Specification
BM = Bituminous Macadam Binder Course to the MOST Specification
DBM = Dense Bituminous Macadam Binder Course

10.16.5. The Pavement Composition is given in Fig. 10.6.

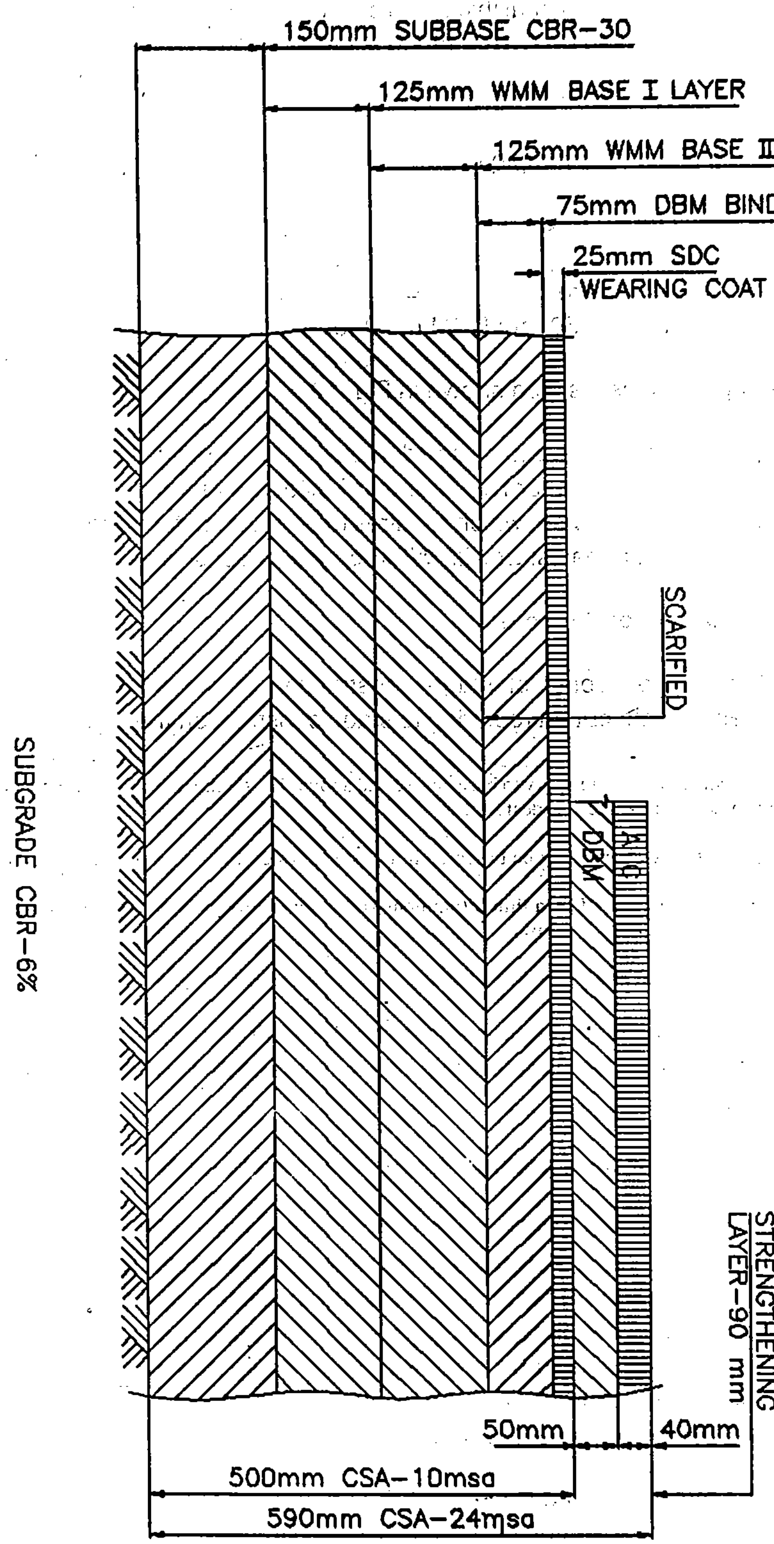


FIG. 10.6. PAVEMENT DESIGN 10 MSA AND STRENGTHENING TO 24 MSA

10.17. Design Method for Strengthening of Existing Pavement

10.17.1. The design of the pavement may be done as per CVD or CSA method depending on traffic parameters explained earlier. The additional thickness over and above existing should be added as additional layers. An illustrative example based on CSA method is given below:-

Example

Date (same as given for example in para 10.16.4 but to be strengthened to 24 msa.)

Original thickness for 10 msa	=	500 mm
Thickness for 24 msa	=	580
Additional thickness required	=	80 mm

Provided 40 mm AC over 50 mm DBM (min) for DBM

10.17.2. Strengthening to 24 msa is also shown in Fig. 10.6.

10.17.3. The strengthening layers have to be so adopted that on existing bitumen bound courses, granular unbound construction like WBM, WMM, or Dry Granular Macadam etc. do not come. If existing pavement has only a thin bituminous wearing course, which requires to be scarified for bondage, with granular unbound base like WBM below, the build up may start with WBM or similar construction.

10.18. Stage Construction of Pavement

10.18.1. In paras 10.6.2, the aspect of stage construction of pavement related to design life and development of traffic was brought out. In resorting to stage construction the following may be kept in view:-

a) Stage construction should apply to base course and above. The thickness of sub-base may be provided to the ultimate pavement section for the full design life.

b) Thickness of base course may be based on initial stage design life period chosen.

c) The base may be covered by a thin bituminous surfacing to serve as wearing course without an underlying binder course. (See para 10.18.2 below).

d) Extra pavement thickness may be added when first stage design traffic is reached.

10.18.2. If the initial stage itself warrants thick bituminous wearing course and binder course due to initial traffic and/or other consideration like climate etc., in such a case strengthening layers may compose of bituminous layers like BM, DBM etc.

10.19. Change of Pavement Composition Along the Road Length

10.19.1. The soil parameters at sub-grade change from place to place along the road. As such, pavement design and composition will also vary. CBR values and other soil characteristics have to be ascertained at every change of strata along the road. This may necessitate modification of pavement thickness at shorter intervals due to frequent changes in soil type, but generally this should be avoided. Frequent changes in crust thickness is undesirable and should be resorted to only when necessary in the interest of structural design and economy. The realistic method would be to divide the road into sectors depending on soil, terrain climatic condition etc. and design pavement for that stretch for the weakest soil.

10.20. Component Layers of Road Pavement

10.20.1. Road pavement comprises of sub-base, base and surfacing/wearing course, and rests on a subgrade.

10.20.2. Subgrade

10.20.2.1. The subgrade, whether it is in cut or fill should be well compacted to attain thickness of pavement required. Specifications prescribe use of selected materials and stiffer standards of compaction in the top 50 cm portion of roadway (usually 95-100 per cent of the standard proctor density: sometimes even higher) and this stipulation should be followed.

10.20.2.2. On a hill road, the road may be in full cutting, part cutting and part filling and in fill (embankment) at certain locations. While in the formation cutting the road bed and sub-grade will be the cut hill formation, in cut and fill method the fill is formed by placing the cut soil itself. Hence in both these cases, the compaction has to be achieved properly. In the case of formation filling the embankment has to be formed by selected borrow material but the top 50 cm i.e. sub-grade has to be such material which when compacted gives a CBR of not less than 7 per cent (Maximum dry density of atleast 1.65 gm per c.c. - Para 7.2. of IRC: 36-1970).

10.20.2.3. For pavement design, the sub-grade strength in terms of CBR of the sub-grade soil at the most critical moisture condition likely to occur in-situ is considered. The standard procedure stipulated in "IS: 2720 (Part XVI) Methods of Tests for Soils: Laboratory Determination of CBR" should be adhered to. For other aspects like dry density, moisture content, number of tests required etc. the guidelines given in IRC:37-1984 may be followed.

10.20.2.4. The pavement design is based on CBR of the sub-grade which is compacted to stipulated density as mentioned in para 10.20.2.1 above. If during construction, the field compaction is lower than stipulated, the pavement thickness may be reviewed and any extra thickness required provided by an increased thickness of sub-base.

10.20.2.5. **Salt infestation of subgrade:** In hilly regions, due to repeated freezing and thawing, water soluble salts tend to move up due to capillary action. Besides leading to hardening of bitumen due to chemical action, salts, due to change in volume on freezing and thawing, break-up the pavement in cold regions. Wherever salt concentrations in excess of 0.2% are met with, a capillary cut off in the form of a layer of coarse sand 225 mm may be provided on subgrade to check the upward movement of the moisture from below. Addition of appropriate quantities of gypsum to form non-expansive calcium salts can also be used to correct the situation. For details of recommendations for road construction in salt infested areas reference may also be made to IRC: 34-1970 "Recommendations for Road Construction in Waterlogged Areas".

10.20.2.6. **Sub-grade CBR less than 2%**: In such cases a capping layer of 150 mm thickness of coarse material with a minimum CBR of 10% may be provided over the sub-grade in addition to sub-grade requirement for 2% CBR.

10.20.2.7. **Subgrade CBR more than minimum required for sub-base**: In such a case no sub-base is required. (Min CBR of sub-base is given in para 10.20.3.4)

10.20.2.8. **Base course (WBM or WMM) directly placed on subgrade**: Where it is proposed to place WBM or WMM (as base or sub-base) directly over sub-grade without any other intervening layer, a 25 mm course of screening or coarse sand may be spread on the subgrade before WBM/WMM is taken up to serve as an inverted choke.

10.20.2.9. **Fine sand or clayey subgrade**: If the subgrade is fine sand or clay with plasticity index more than 15 and/or clay content more than 50%, a 100 mm insulating layer of screening or coarse sand should be laid on top of such subgrade, the gradation of material selected depending on whether it is intended to act as a drainage layer as well. Alternately, appropriate geo-synthetics performing functions of separation and drainage may be used over prepared sub-grade.

10.20.2.10. **Expansive soil subgrade:** If the road bed material is expansive soil like black cotton soil, a non-expansive buffer layer should be placed over the same to act as subgrade. If this is not feasible, a blanket course of at least 225 mm thickness composed of coarse/medium sand or non-plastic moorum having plasticity index less than 5 should be provided on the expensive soil sub-grade (as a sub-base in addition to sub-base required as per design) to serve as an effective intrusion barrier. This blanket should extend over the entire formation width as per Appendix-2 in IRC: 37-1984.

10.20.2.11. **Rocky subgrade:** In rocky subgrade, in order to correct surface irregularities and to make interface drainage effective, it is necessary to lay a levelling course of 100mm thick base course material over subgrade and duly compacted. This will act as levelling-cum-base course on which binder/wearing course can be laid.

10.20.3. Sub-base

10.20.3.1. The sub-base is laid on a properly prepared and compacted sub-grade. The sub-base should be a layer composed of materials like natural sand, moorum, gravel, laterite, kankar, brick metal, crushed stone, crushed slag or combination thereof like soil aggregate mixes, or any other material like stabilised soil, which remain stable under saturated conditions.

10.20.3.2. The sub-base is laid on the sub-grade suitably overlaid by screening layer, insulating layer or blanket course etc., necessary as per details given under para 10.20.2 "Subgrade"

10.20.3.3. The sub-base layer shall be any one of the following as suitable:-

a)	Granular sub-base	As per MOST specification for Road and Bridge Works (1995 revision) Clause 401
b)	Lime stabilised soil Sub-base	-do- Clause 402
c)	Cement stabilised soil sub-base	-do- Clauses 403
d)	Water bound macadam	-do- Clause 404
e)	Crushed cement concrete sub-base	-do- Clause 405
f)	Wet mix macadam	-do- Clause 406
g)	Low grade aggregate sub-base or soil aggregate mixture sub-base IRC:63-1976	
h)	Soft aggregate stabilised soil sub-base IRC:28-1967	
j)	Dry bound macadam suitably graded	A suitable grading should be worked out.

10.20.3.4. **Minimum CBR requirements of sub-base:** This is as under:-

a)	For Roads with traffic of CSA upto 2 msa (i.e. upto 450 CVD)	:	20%
b)	For Roads with traffic of CSA exceeding 2 msa (i.e. above 450 CVD)	:	30%

c)	For very low trafficked roads (say upto 15 CVD)	:	15%

d) The above will be subject to following :

i)	Where sub-base required is 300 mm or more in thickness	:	Lower portion of sub-base can have CBR 10% subject to min. 150 mm thick of either material.

10.20.3.5 **Minimum thickness of sub-base:** The minimum thickness of sub-base is as given in Table 10.5.

10.20.3.6. **Road construction materials in hilly regions:** Availability of road construction materials in hilly regions along the alignment may be limited. Techniques of properly designed soil-gravel/aggregate mix, lime established shales (if lime is locally available), and cement stabilised soil may be employed for sub-base.

10.20.3.6.1. Water availability may be a serious problem in the dry working season (even though it may be plenty all over in rainy season) and may have to be fetched from streams in valley side with considerable lift and perhaps lead also. Hence it would be advisable to use specifications, needing less water like Crushed Stone Sub-base and Dry Bound Macadam Sub-base instead of Water Bound Macadam. Wet Mix Macadam and Soil Stabilisation may not be suitable in this context.

10.20.3.7. **Specifications and standards:** The specifications and standards including maximum permissible single layer compacted thickness should be as per relevant MOST & IRC specifications & standards. The maximum single layer compacted thickness shall be as under subject to use of appropriate compaction equipment/roller.

a)	Granular sub-base	-	150 mm
b)	Stabilised sub-base	-	200 mm
c)	WBM sub-base	-	100 mm
d)	WMM sub-base	-	150 mm (may be increased to 200mm when vibratory roller is used)

10.20.4. **Base course**

10.20.4.1. The base course is laid on a well prepared and compacted sub-base (or on a sub-grade duly prepared where no sub-base is necessary) as given in paras 10.20.2 and 10.20.3. The thickness of the base course deduced from pavement design chart/table are for unbound granular bases like conventional WBM and WMM and any other equivalent construction like Bituminous penetration macadam or Built-up spray (Bituminous) Grout.

10.20.4.2. The base course layer shall be any one of the following:-

a)	Water Bound Macadam	MOST Specifications (1995 revision) Cl. 404, 406, 504, 505, 506 and 507 respectively
b)	Wet Mix Macadam	
c)	Bituminous Penetration Macadam	
d)	Built-up Spray Grout	
e)	Bituminous Macadam	
f)	Dense Bituminous Macadam	

10.20.4.3. **Minimum CBR requirements:** Base material must be of good quality so as to withstand high stress concentrations which develop immediately under the surfacing. The CBR of the material (coarse aggregate) used in base construction shall not be less than 100 per cent. Since CBR test will not be applicable as base material consists of aggregates larger than 20 mm size, the strength will have to be assessed from experience or correlation with other tests. The standards laid down for physical requirements of aggregates and screenings for bases by IRC & MOST have to be adhered to and in such cases conventional construction of properly designed WBM, WMM, etc. of adequate thickness may be assumed to satisfy CBR requirements of 100%. The coarse aggregates should consist of crushed stone, conforming to laid down standards. Screenings shall generally be of the same material as the aggregates conforming to IRC/MOST standards.

10.20.4.4. **Minimum thickness of base course:** The minimum thickness should be as given in Table 10.5. A minimum of 150 mm thick compacted base is required even for lightly trafficked roads. However, it is reiterated that where sub-grade is rocky strata, a 100 mm thick compacted layer laid as levelling course will be adequate as stated in para 10.20.2.11.

10.20.4.5. **Equivalency factor:** An equivalency factor of 1.5 for bituminous macadam and 2 for dense bituminous macadam might be adopted in design to equate the thickness of the bitumen bound base layer to that of conventional granular base layer like WBM, WMM, Dry macadam, BUSG and Penetration macadam. The surfacing layer consisting of wearing course and/or BM/DBM as provided in CSA method of design is not a part of base for this purpose.

10.20.4.6. **Road construction materials and water availability:** The aspects mentioned in paras 10.20.3.6 and 10.20.3.6.1 against sub-base apply to base course also. The choice of specifications will have to consider availability of materials. Some of the possibilities to overcome/reduce the problem are as under:-

a) in water scarce areas WBM and WMM may not be adopted and instead bituminous bound bases like BUSG, Penetration macadam provided.

b) in areas where good quality stone aggregates are hard to come by from economical leads, the requirement can be reduced by adopting Bituminous Macadam taking advantage of equivalency factor in preceding para to reduce pavement thickness.

10.20.4.7. **Specifications and standards:** The specifications and standards to be adopted should be as per MOST "Specification for Road & Bridge Works" and relevant IRC Standards. The maximum single layer compacted thickness of the base course shall be as under subject to use of appropriate compaction equipment:-

a)	WBM	75 mm for Grade 2 and 3 material and 100 mm for Grade I material
b)	WMM	
	i) 80-100 KN smooth wheel roller	100 mm
	ii) 80-100 KN (static wt.) vibratory roller	200 mm
c)	BUSG	75 mm
d)	Bituminous Penetration Macadam	75 mm
e)	BM	75 mm
f)	DBM	75 mm

10.20.5. **Bituminous surfacing**

10.20.5.1. Surfacing on a flexible pavement consists of a bituminous wearing course in all cases whether the design is based on CVD or CSA. However, where the design traffic is more than 1500 CVD (5 msa), a binder course of BM/DBM is also provided as part of surfacing as an intervening layer between the wearing course and the base course as shown in Fig. 10.5. and Table 10.6a.

10.20.5.2. The recommended types of wearing courses and binder courses for adoption related to design life and traffic are also given in Table 10.6a. When the traffic is upto 1500 CVD (5 msa) the type of wearing course be adopted as given in Table 10.6a based on equivalency of CVD and CSA given in para 10.11.1(b).

Table 10.6a. Wear Course related to base/binder course and Rainfall/Snow-fall

Sl. No.	Type of Base course	Traffic condition	Rainfall Low (L) less than 1500 mm mm	Rainfall Medium (M) 1500-3000	Rainfall High (H) is more than 3000 mm or snowfall area
1.	Granular Base WBM/WMM	Upto 150 CVD	(i) 20 mm PC with seal coat A or B (ii) 20 mm Mix Seal type A or B	(i) 20 mm PC with seal coat A or B (ii) 20 mm Mix seal type A or B	(i) 20 mm PC with liquid seal coat (Type A) (ii) 20 mm mix seal type A or B
2.	-do-	150-450 CVD and 450-1500 CVD	-do-	-do-	-do-
3.	BUSG/ Penetration Macadam	Upto 1500 CVD	(i) 20 mm PC with premix sand seal coat (ii) 20 mm Mix Seal type A or B	(i) 20 mm PC with premix sand seal coat or liquid seal coat (ii) 20 mm Mix Seal type A or B	20 mm PC with liquid seal coat
4.	BM base or Binder Course	More than 1500 CVD i.e. 5 msa to 15 msa	(i) Semi-dense carpet 25 mm (ii) -do- 40 mm (iii) 20 mm PC with liquid seal coat (iv) 20 mm mix seal type A or B	(i) Semi-dense carpet 25 mm (ii) -do- 40 mm (iii) 20 mm PC with liquid seal coat (iv) 20 mm mix seal type A or B	(i) Semi-dense carpet 25 mm (ii) -do- 40 mm (iii) 20 mm PC with liquid seal coat (iv) 20 mm mix seal type A or B
5.	Dense Bituminous Macadam	More than 1500 CVD (5 msa-15 msa)	Bituminous concrete 25 mm 40 mm	Bituminous concrete 25 mm 40 mm	Bituminouse concrete 25 mm 40 mm

10.20.5.3. The types of wearing courses available for adoption are given below:-

a) Surface dressing (IRC:23-1966)
b) 20 mm open graded premix carpet (IRC:14- 1977)
c) 20 mm mix seal surfacing (Type A or B)
d) 25 mm/40 mm Semi-dense bituminous concrete (semi-dense carpet - IRC:95-1987)
(e) 25/40 mm bituminous concrete (asphaltic concrete or dense carpet - IRC:29-1988)

MOST Specifications (1995 revision) Clause 508 to 512

10.20.5.4. As regards binder course Bituminous Macadam and Dense Bituminous Macadam are to be adopted. These are described in para 10.20.4.2 while discussing base course.

10.20.5.5. Selection of wearing course related to climatic and environmental considerations: The type of wearing course to be adopted are given in Table 10.6a for both CVD and CSA methods of design. However, considering traffic, environmental and climatic conditions, provision of wearing course may be suitably modified as per the guidelines given in Table 10.6a. In this table the provision of type of wearing course is related to the binder course if any and the base course. It will not be appropriate to adopt semi-dense or dense carpet on granular unbound base courses like WBM or WMM. Similarly on BM/DBM binder/base courses the wearing course should be SDC/AC unless there are some strong technical considerations to adopt lower specifications of open graded carpets.

10.20.5.5.1. Considering life and other conditions of terrain, climate and geometrics obtained in hilly region, surface dressing is not generally recommended in hill roads (though given as an alternative in Table 10.6) and this aspect has been duly considered in evolving specification in Table 10.6a.

10.20.5.5.2. Where the attritive effect of vehicles or equipment on surface is high like bus stops, roundabouts, very steep gradients, slide areas/snow clearance areas, where heavy equipments are deployed, dense asphaltic course may be provided in single or multiple layers to render surface more stable.

10.20.5.6. **Choice of bitumen**: The following aspects are brought out for adoption as required:-

a) In high rainfall areas, where open graded bituminous surface is done, an appropriate seal coat using antistripping agent of 1-1.2 per cent by weight of bitumen be used.

b) Due to wide variation of temperature in working season (may be 4°-25°C) bituminous paving work has to be carried out with cut-backs/cationic emulsions if otherwise found suitable instead of straight run bitumen. The specifications given in para 10.20.5.3 ante cover cationic emulsions also.

c) As an alternative to (b) above, the bitumen may be fluxed with kerosene for ease of workability and rapid curing.

d) Due to high incidence of water action, stripping of aggregates may be experienced in case of hydrophillic aggregates. It will be appropriate to use bitumen mixed with antistripping agents for surface courses.

e) While bitumen 80/100 grade will be suitable for most of the locations but 60/70 grades which is harder grade can also be considered as both have similar performance characteristics.

10.21. Heavy Rainfall Areas - Provisions

10.21.1. In heavy rainfall areas provision should be made for adequate drainage as brought out in Chapter on drainage and as per drainage measures given in this chapter. The following provisions also be considered as necessary:-

a) Choice of surfacing specification related to rainfall be adopted as per Table 10-6a.

b) Wherever open-graded carpet is done, a seal coat should be provided.

c) In areas where annual rainfall is higher than 300 cm the entire formation width be surfaced without leaving any gap between edge of pavement and drain/parapet.

d) If the area is subject to frost-heave in sub-soil, the crust thickness should be not less than 45 cm (if design thickness is less, the balance should be made up by additional sub-base thickness) and wearing course should not be inferior to semi dense carpet.

e) If sub-grade is salt infested, 225 mm sand blanket should be laid on sub-grade before sub-base is constructed.

10.22. Pavement for Snow Fall, High Altitude/Snow Bound Areas

10.22.1. Snow fall is met in the following two conditions:-

a) Snow fall occurs in certain areas at altitudes less than 2500 m to 3000 m where rainfall also is medium. In such areas the snow fall is such that the same can be continuously cleared on occurrence. To quote examples of such places, the Western Himalayas in Jammu & Kashmir and Eastern Himalayas come under this, where rainfall also is medium to fairly high. In these areas winter snow clearance can be resorted to keep the road open throughout the year.

b) High altitude areas above 3000 m of the Great Himalayan ranges which are distinct snow belts where intensity and periodicity is so high that the snow is allowed to accumulate in winter months and road closed in winter. The snow clearance is undertaken in summer. Here the problems of avalanche, frost, icing, etc., are encountered.

10.22.1.1. The subject of snowfall, etc., are dealt in Chapter 12 "Snow Clearance and Avalanche Treatment"

10.22.2. Pavement for areas subject to snow-fall at lower altitudes where continuous snow clearance can be done.

10.22.2.1. In such areas the normal design of flexible pavement would be generally adequate with certain specific provisions. Certain important roads including National Highways in such areas in Western Sector of Himalayas have been performing successfully. While designing/providing pavement, the following should be considered:-

a) The specification for Wearing Course be adopted as given in Table 10.6a. Thick dense carpets should be considered in preference to open-graded carpets.

b) The entire formation width may be surfaced, as suggested for high rainfall area, leaving no gap between edge of pavement and drain/parapet. In any case shoulders should be hard shoulders.

c) Since snow clearance will be done by heavy equipment, dense aspnaltic/bituminous layers in wearing course and bituminous layers in base courses would be preferable.

10.22.2.2. Maintenance and drainage of roads in such areas should be given full attention. Periodicity of renewal of surfacing may be more frequent than guidelines, as required by ground conditions.

10.22.3. Pavement for high altitudes (above 3000 m) that remain snow bound in winter

10.22.3.1. In high altitude areas which are subjected to heavy snowfall, sub-zero temperature, frost action, snow drifts and avalanche activities, design and construction of pavement require special consideration. The performance of conventional type of flexible pavements, comprising viz GSB, WBM etc, may not be found satisfactory due to factors like:

a) Frost heaving and thawing action.
b) Intensive snow and avalanche activity.
c) Icing problems
d) Damage by movement of tracked vehicles during snow clearance operations.
e) Loss of ductility of bitumen due to sub-zero temperatures.
f) Blocking of drainage system
g) Glacier and avalanche movements on the road.

The above result in excessive maintenance requirement and even destruction of pavement and allied structures. Roads in high altitude areas should be designed to retain their stability and serviceability inspite of yearly relentless cycle of freezing and thawing and occurrence of avalanches. Not much research has been done in this field nor the experiences are well documented and it becomes imperative for Engineers on ground to apply their skills judiciously based on their observations and experience.

10.22.3.2. **Climatic factors:** This is the singular most important factor which influences the design of road in high altitude areas. Factors like snow fall intensity, temperature, avalanche, snow drift, icing and frost action must be considered alongwith traffic intensity, its growth, axle load and design life. The subject of climatic factors except frost and its effects have been brought out in Chapter 12 and traffic related issues in this chapter itself which may be referred.

10.22.3.2.1. **Frost action (frost heaving and thawing):** Frost can be defined as process of freezing or deposit/covering of minute ice crystals formed from frozen water vapour. Due to the exposure of the area to sub-zero temperatures for months together the soil temperature falls below the freezing point. Due to the fall in temperature, moisture at subgrade level freezes and results in formation of ice crystals. When water freezes, it expands about 9 per cent of its original volume and is known as frost heave. In some cases water becomes super cold and remains in liquid state at temperature well below freezing point. The super cold water and ice crystals have strong affinity, with a result the water is drawn to ice crystals that are initially formed and thus continue to grow until ice lenses begin to form. The ice lenses in turn grow until frost heaving results. Fig. 10.7 illustrates ice-lens formation and frozen soil strata.

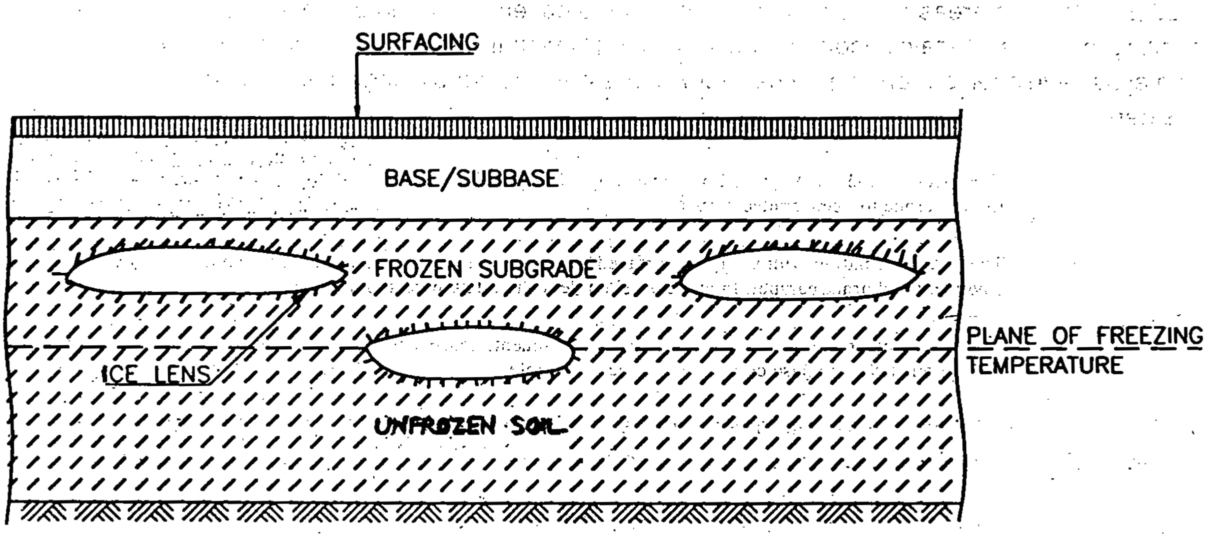


FIG. 10.7: FROZEN SOIL AND ICE LENS

10.22.3.2.1.1. After the winter when atmospheric temperature increases above the freezing point, the melting of ice lenses start. As the thermal conductivity of frozen soil is greater than unfrozen soil, the melting of ice lenses releases an excess of water within the soil, with a corresponding reduction in load supporting capacity of the subgrade and consequently pavement as a whole. Further, since restriction of vertical drainage is a characteristic of frozen ground in seasonal frost areas, the excess water released by melting of ice lenses cannot drain downward through underneath impervious frozen sub-soil. The water, therefore, tends to ooze upward and saturate subgrade/sub-base/base course, resulting in very unfavourable conditions in which not only the subgrade is in a weakened condition, but the pavement itself may be supported in part by water under traffic loading. Loss of subgrade supporting capacity can be considerable in magnitude (almost 50%) and may exists for relatively long periods of time after thawing has taken place. The weakening of sub-grade and pavement gets aggravated further during snow melting period because of wide variation in day and night

temperatures. During day time, temperature rises sometime upto 25 degrees and in night it falls even below zero degrees. Due to fall in temperature below freezing point during night, alternate thawing and freezing take place. Each time the soil freezes a loss of density results. This, in turn, results in higher potential for moisture absorption. After several cycles of freezing and thawing, a large portion of the subgrade supporting capacity is lost.

10.22.3.2.2. **Low atmospheric temperature: In high altitude areas, flexible pavements become brittle and least ductile during the period of subzero temperature when the greatest shrinkage tendency and heave occur. Brittleness of the pavement results in cracking of pavement surface. Cracks at pavement surface provide means for ingress of moisture into the base/sub-base/sub-grade. This offers a point where ravelling starts and where freezing of moisture in and immediately below the cracks add to further widen and intensify the cracks, as a result of which the life of pavement is affected adversely.**

10.22.3.3. **Frost susceptibility of soils:** From the point of view of pavement design and construction, the need is for a simple set of criteria to distinguish whether a given soil is frost susceptible or not. Such criteria, in empirical form, incorporating the principles of freezing of soils and formation of ice lenses has been evolved by Casagrande essentially based on grain size to serve as a useful guide. Casagrande concluded that :

a) Well-graded soil with 3 per cent or more soil particles less than 0.02 mm in size are highly frost susceptible.

b) Uniformly graded soils with 10 per cent or more particles less than 0.02 mm size are frost susceptible.

Elaborating the above system, soils have been divided into 4 groups F_1 to F_4 (by US Corps of Engineers) as in Table 10.7 with increasing frost - heave potential as well as increasing loss of strength on thaw.

Table 10-7. Grouping of Soils Based on Frost Susceptibility

Sl. No.	Group	Description	Characteristics
1.	F_1	Gravelly soils containing between 3 and 20 per cent finer than 0.02 mm by weight.	Least frost susceptible and least thaw weakening.
2.	F_2	Sands containing between 3 and 15 per cent finer than 0.02 mm by weight.	Increased frost-susceptibility and thaw weakening.
3.	F_3	a. Gravelly soils containing more than 20 per cent finer than 0.02 mm by weight.	
		b. Sands, except fine silty sands containing more than 15 per cent finer than 0.02 mm by weight.	Frost susceptible and high thaw weakening.
		c. Clays with plasticity indices more than 12.	
		d. Varved clays with uniform subgrade conditions.	
4.	F_4	a. All silts including silty clays.	
		b. Fine silty sands containing more than 15 per cent finer than 0.02 mm by weight.	Frost susceptible and high thaw weakening.
		c. Lean clays with plasticity Index less than 12.	
		d. Varved clays with non-uniform subgrade conditions.	

It may be surmised from above that while gravels, clean sands and highly plastic clays are not frost susceptible, silty sands, silts and lean clays are frost susceptible.

10.22.3.3.1. As regards adoption for design, while the above may be used, it would be desirable to study sub-grades met on roads and update frost susceptibility criteria in the environments existing.

10.22.3.4. **Pavement design for protection against frost action**

10.22.3.4.1. For the areas which are affected by frost action two different concepts are available for design of pavements. The concepts are, control of surface deformation by provision of sufficient pavement thickness to reduce frost penetration and design for reduced subgrade strength during the frost-melt period. Both methods of design are explained below.

a) **Limited Subgrade frost penetration**

In this method, sufficient thickness of non-frost susceptible material is used so that only limited, tolerable penetration of freezing temperature into the frost-susceptible subgrade occurs. By this means, both pavement heave and subgrade weakening are reduced sufficiently in amount as well as frequency of occurrence and duration so that their effects may be neglected. Depth of frost penetration can be worked out from the conditions developed by Aldrich as per the modified Berggren's formula given as under:-

$$Z = A \frac{\sqrt{48\,KF}}{L}$$

where

Z	=	Depth of frost penetration
K	=	Thermal conductivity (which depends upon dry density of soil and moisture content)
L	=	Volumetric heat of latent fusion
F	=	Air freezing index; degree - days
A	=	A dimensionless coefficient depending upon fusion parameter and thermal radiation

A number of charts have been developed by US Corps of Engineers based on field studies and research to arrive at depth of frost penetration in above equation. But these may not be directly applied to our conditions unless data on our situation is evolved by expert and research bodies.

b) **Reduction in subgrade strength**

This design approach is based on the reduced supporting capacity of the subgrade due to the thawing i.e. frost melting. A number of charts have been developed by US Corps of Engrs to work out the reduced subgrade strength and thickness of pavement required. But these cannot be readily extended to our conditions.

10.22.3.4.2. Both systems of assessing frost affected subgrade given in a & b above may be taken as for information. If necessary, study of sites by expert agencies in the field and site investigation will have to be done. However, an empirical method based on experience in field and performance of pavement in such areas are given in next para onwards.

10.22.3.5. **Pavement composition and layer arrangement**: Based on experience on the design and performance of various types of pavements provided in such areas (in consultation with research bodies on the subject also), the following aspects emerge:

a) the design will have to be related to the actual depth of frost penetration and severity of frost.

b) freezing conditions could develop within the pavement structure if water had a chance to ingress from above and hence has to be avoided.

c) depth of construction (Pavement) should not be less than depth of frost-penetration and should compose of non-frost susceptible materials. In any case the thickness should not be less than 45 cm.

d) Structurally strong courses like BM/DBM as against conventional granular bases like WBM or WMM will be more suitable especially if it is considered that heavy machinery and equipment are to use the road for snow clearance.

e) crushed stone base, which is a better non-frost susceptible medium will be more appropriate as it is free draining also. It may extend over full formation width.

f) Alternate designs that are not flexible may also be considered.

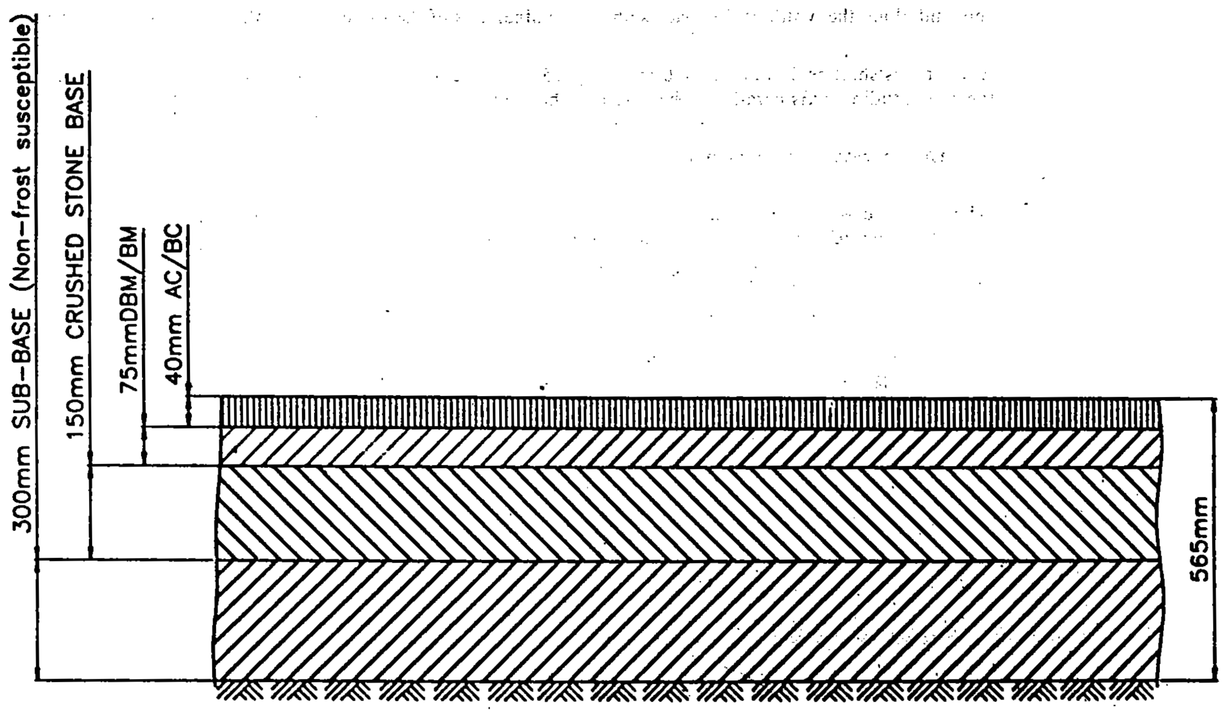
10.22.3.5.1. **Alternate specifications:** The various alternate specifications that may be adopted are as under for heavy snow accumulation/avalanches sites requiring clearance by heavy mechanical equipment:-

a) **Flexible pavement**

This may consist of a layer of Dense Bituminous Carpet, over Bituminous Macadam/Dense Bituminous Macadam, on a Crushed Stone Base Laid on Non-frost susceptible sub-base. The suggested thickness is as under: (See Fig. 10.8)

i)	Non-frost susceptible sub-base	-	300 mm
ii)	Crushed stone Base (CSB)	-	150 mm
iii)	BM/DBM	-	75 mm
iv)	Asphaltic concrete (AC/BC)	-	40 mm
			565 mm

Note:- (i) If CBR values require heigher thickness, the same may be made up by increased sub-base thickness.



SUBGRADE

FIG. 10.8. FLEXIBLE PAVEMENT HIGH ALTITUDE/SNOW BOUND AREA

(ii) If conditions warrant only lesser thickness, the thickness may be restricted to not less than 450 mm by reducing sub-base thickness.

b) Stone set pavememt

This is a semirigid type of pavement. The stone is set over a layer of lean cement concrete (1:4:8) and crushed stone base. The sub-base should be non-frost susceptible material. Fig. 10.9 illustrates arrangement. The suggested arrangement is as under:-

i)	Non-frost Susceptible Sub-base	-	300 mm
ii)	Crushed Stone Base (CSB)	-	150 mm
iii)	PCC 1:4:8	-	150 mm
iv)	Stone Set	-	150 mm
			750 mm

Note: (i) The thickness may be reduced upto 450 mm as per ground condition as in (a) above.

(ii) Specification for the work is given below:-

"Stone used shall be of the best quality, locally available granite or other variety of igneous origin rock. If in a particular locality the origin of all stones is metamorphic the stone of the variety may also be used provided it is equal to granite in toughness and uniformity of texture. Sedimentary stone shall in no case be used.

Stone sets shall be rectangular in shape, 250 mm to 300 mm long, 150 mm to 200 mm wide and 150 mm deep, with tolerance plus or minus 12 mm. Stone sets used in any one area shall be of uniform size. They shall be hammer dressed on top to the extent that maximum depression of the dressed surface from a straight edge applied across any part of the surface for testing, does not exceed 20 mm. The dressing on the sides shall be similarly carried out, so as to obtain a mortar joint not exceeding 20 mm in width. They shall be set on the base concrete over a bedding layer of cement mortar 1:3, 20 mm thick, with joints not exceeding 20 mm, in width. The joints shall be grouted with cement mortar 1:2 with an admixture of metallic hardener such as ironite, hardonate or equal and approved variety, in the proportions as recommended by the manufacturers and joints struck off as work proceeds.

Stone set shall be laid in sections not exceeding 12 m long, in herring-bone pattern, separated by two rows of stone sets laid along the width of the road, with longitudinal axis of the stone sets parallel to the length of the road.

Edge stones shall be 350 mm to 400 mm long, 150 mm to 200 mm wide and depth not less than 450 mm laid with their longitudinal axis parallel to the length of the road."

c) Precast concrete block pavement:

Where construction time is limited and road is to be kept open during the construction stage, small size high density precast concrete blocks laid on sand over crushed stone base and non-frost susceptible sub-base is suitable, Fig. 10.10 illustrates arrangement. The suggested arrangement is as under:

i)	Non-frost Susceptible Sub-base	-	300 mm
ii)	Crushed Stone Base (CSB)	-	150 mm
iii)	Sand Layer	-	30 mm
iv)	PCC Blocks	-	200 mm
			680 mm

Note:- (i) The thickness may be reduced upto 450 mm as per ground conditions as in (a) above.

(ii) Specification for the work is given below:-

"The blocks of size 225 mm length, 112 mm width and 120 - 200 mm height are recommended as shown in Fig 10.10. To ensure adequate durability under the combined action of repeated freezing, thawing and snow clearance, the blocks should have high compressive strength, not less than 500 kg/cm sq. Cement used should be high strength ordinary portland cement conforming to IS : 8112-1989. Coarse aggegates should conform to IS: 383-1970 with size not exceeding 20 mm.

Precast edge restraints are of prime importance to this type of pavement. The edge restraints prevent the blocks from migrating outwards, joints opening and interlocking being destroyed. Precast stones are laid in advance to provide edge restraint. Precast rectangular blocks of 200 mm -230 mm depth should be used for this depending on thickness.

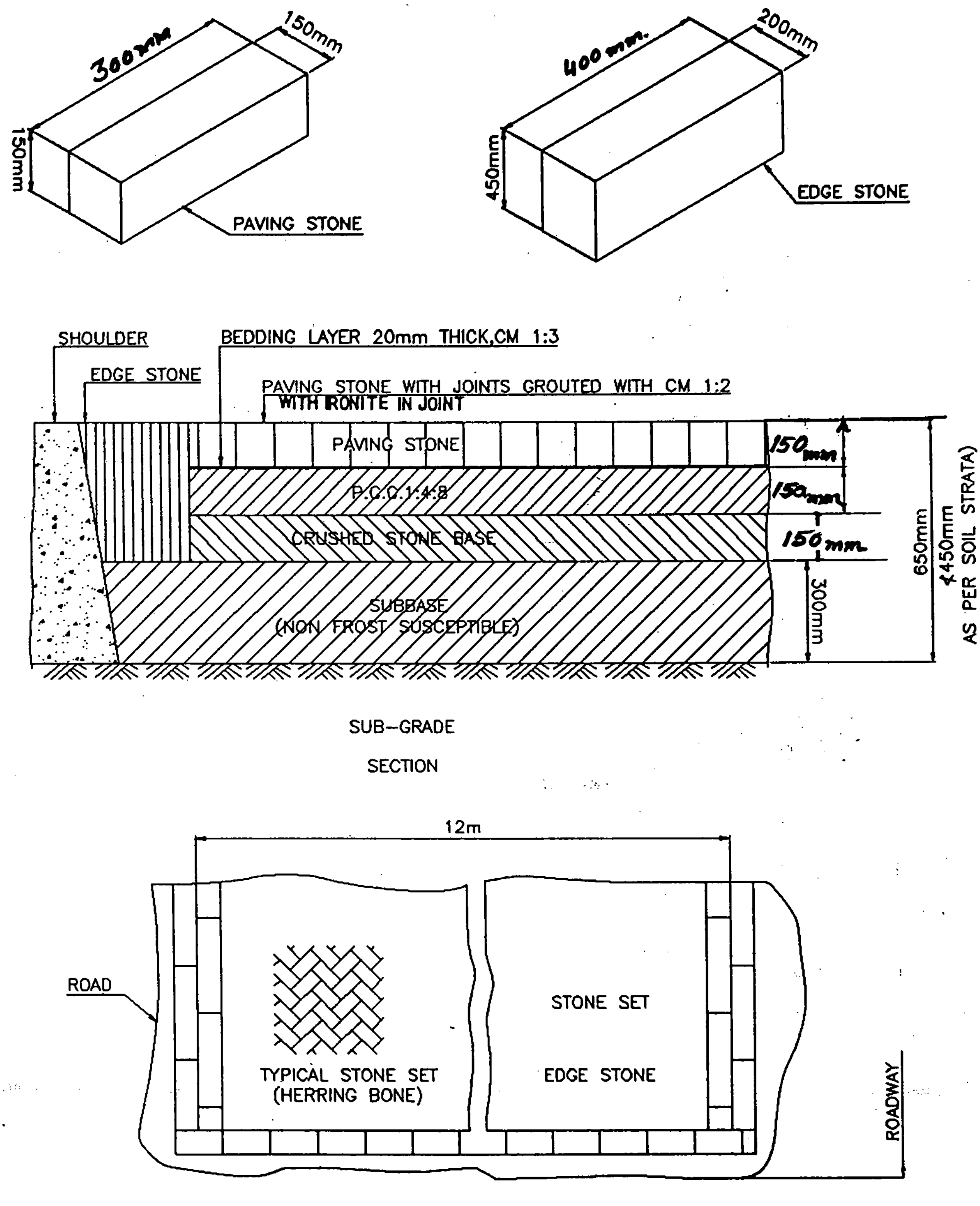
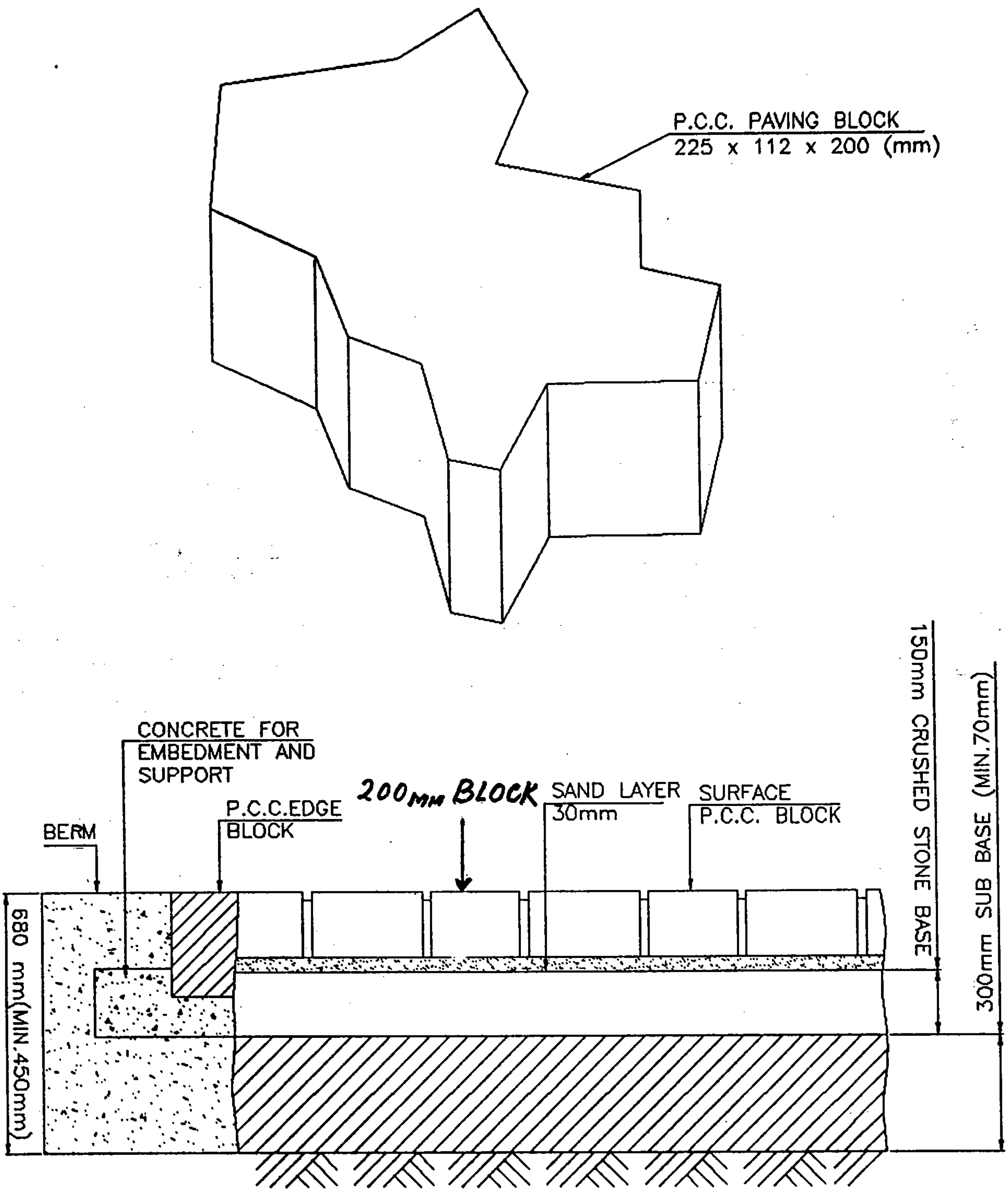


FIG. 10.9. STONE SET PAVEMENT



SECTION OF PAVEMENT

FIG. 10.10. P.C.C.BLOCK PAVEMENT

The blocks are laid manually in self repeating herring bone pattern over full width in one operation. The surface of the blocks is vibrated using plate vibrator. After the vibrations, the sand is brushed over the blocks to fill the joints using a plate vibrator. Required number of vibratory passes is best determined by field trials."

10.23. Rigid Pavement

10.23.1. Rigid pavement is not generally recommended for roads in the hilly regions due to its high initial cost, practical construction problems, unstable areas, due to high temperature fluctuations and maintenance problem because of frost and snow precipitation. Cement concrete (reinforced/unreinforced) is generally used on the hill roads at the places of causeways, bridges, culverts, tunnels, hairpin bends and also at the locations where special requirements call for this type. Because of severe cold climatic conditions, the concrete paving slabs are subjected to frost action and freeze-thaw conditions. Thus under such conditions, the maintenance of the special concrete structures poses special problems such as scaling and slipperiness, spalling of joints and cracking etc. For the design of concrete pavements, reference may be made to IRC : 58 whereas for their construction, Clause 602 of MOST Specifications for Road & Bridge Works and other relevant IRC and BS Codes may be followed.

10.24. Composite Pavement Design

10.24.1. Composite design i.e. a combination of flexible and rigid pavement (called semi-rigid) is also not normally suitable for hill areas. However, for high altitude areas that are prone to avalanche activity and remains snow bound in winter, a combined type of pavement i.e. stone-set and PCC block paved on PCC base has been suggested in para 10.22.3 to overcome the frost effect problems as a specific method suitable for such areas.

10.24.2. Semi-rigid materials such as lean cement concrete have not been suggested for hill areas for same reasons for which rigid pavement is considered not suitable.

10.25. Drainage

10.25.1. As brought out in this manual repeatedly, drainage is the most important aspect for stability of a hill road. Pavement drainage is highly crucial for effective performance. These have been dealt with in Chapters 8 "Drainage & Cross-Drainage Works" and 12 "Snow Clearance and Avalanche Treatment" also as well as touched upon in other chapters. However, considering importance of the subject, certain aspects specifically related to pavement are reiterated.

10.25.2. The performance of a pavement in hill areas can be seriously affected if adequate drainage measures to prevent accumulation of moisture in the pavement structure are not taken. Some specific additional points related to pavement drainage and composition are given below:-

a) When the traditional granular construction is provided on a relatively low permeability subgrade, the granular sub-base should be extended over the entire formation width in order to drain the pavement structural section. Fig. 10.11 depicts the arrangement.

b) Drainage of the pavement structural section can be greatly improved by providing a high permeability drainage layer (open graded material) which can be substituted on a centimetre for centimetre basis for the granular sub-base. Aggregates meeting the following criteria are regarded as very good drainage materials:

$D_{85} < 4D_{15}$
$D_2 \geq 2.5$ mm

D_{85} means the size of the sieve that allows 85 per cent by weight of the material to pass through it. Similar is the meaning of D_{15} and D_2. The drainage layer when placed on soft erodible soils should be underlain by a layer of filter material to prevent the intrusion of soil fines into the drainage layer. Fig. 10.12 depicts this arrangement. Synthetic material like non-woven geofabric can also be used in place of graded filter material.

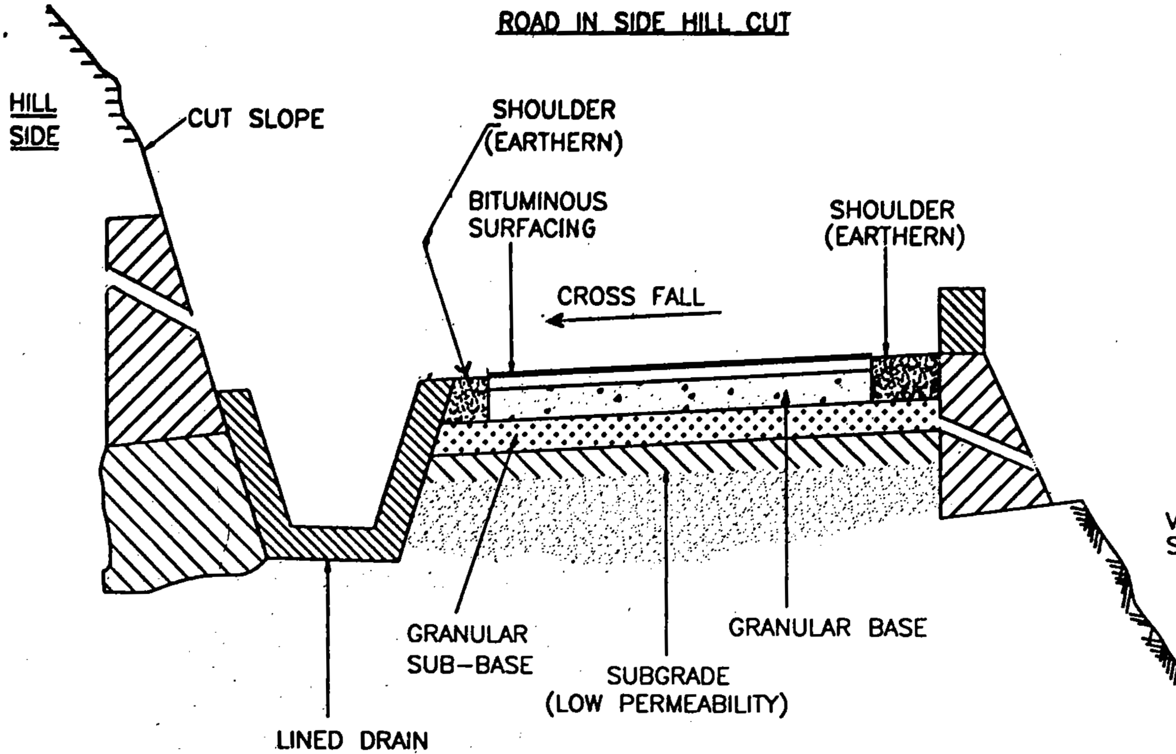


FIG. 10.11. DRAINAGE BY EXTENDED SUB-BASE

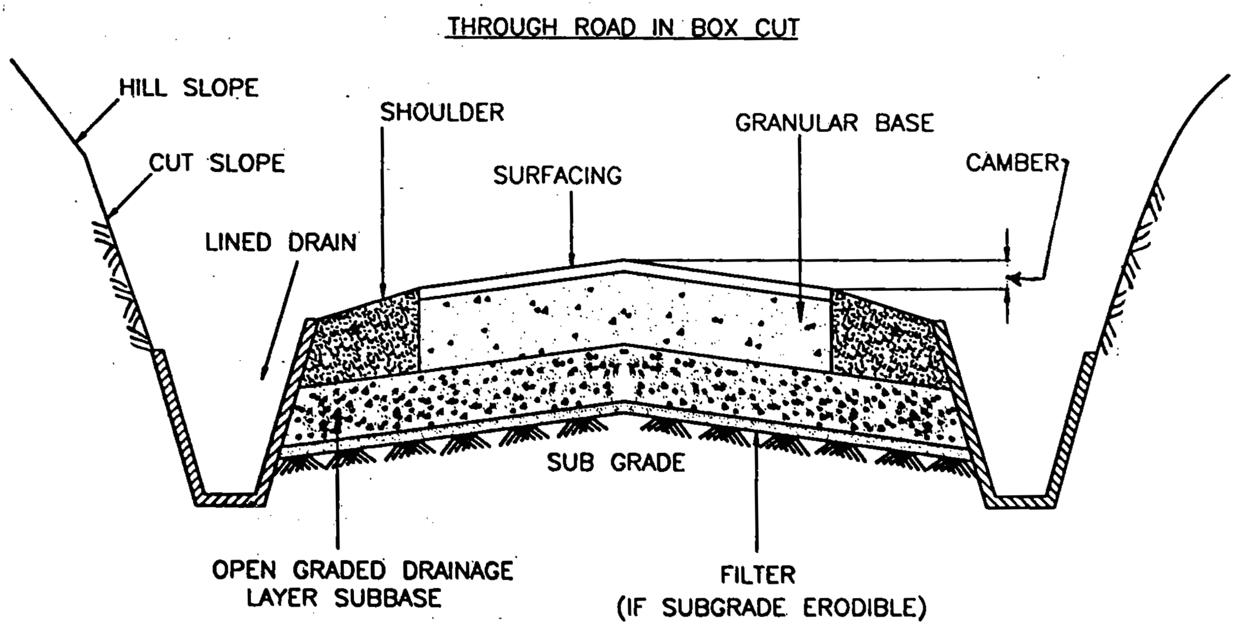


FIG. 10.12. DRAINAGE BY OPEN-GRADED SUB-BASE

c) Where large inflows are to be taken care of, an adequately designed sub-surface drainage system consisting of an open graded drainage layer with collector and outlet pipes should be provided. The system should be designed on a rational basis using seepage principles to estimate the inflow quantities and the outflow conductivity of the drainage system. It should be ensured that the outflow capabilities of the system are at least equal to the total inflow so that no free water accumulates in the pavement structural section. Fig. 10.13 indicates the arrangement.

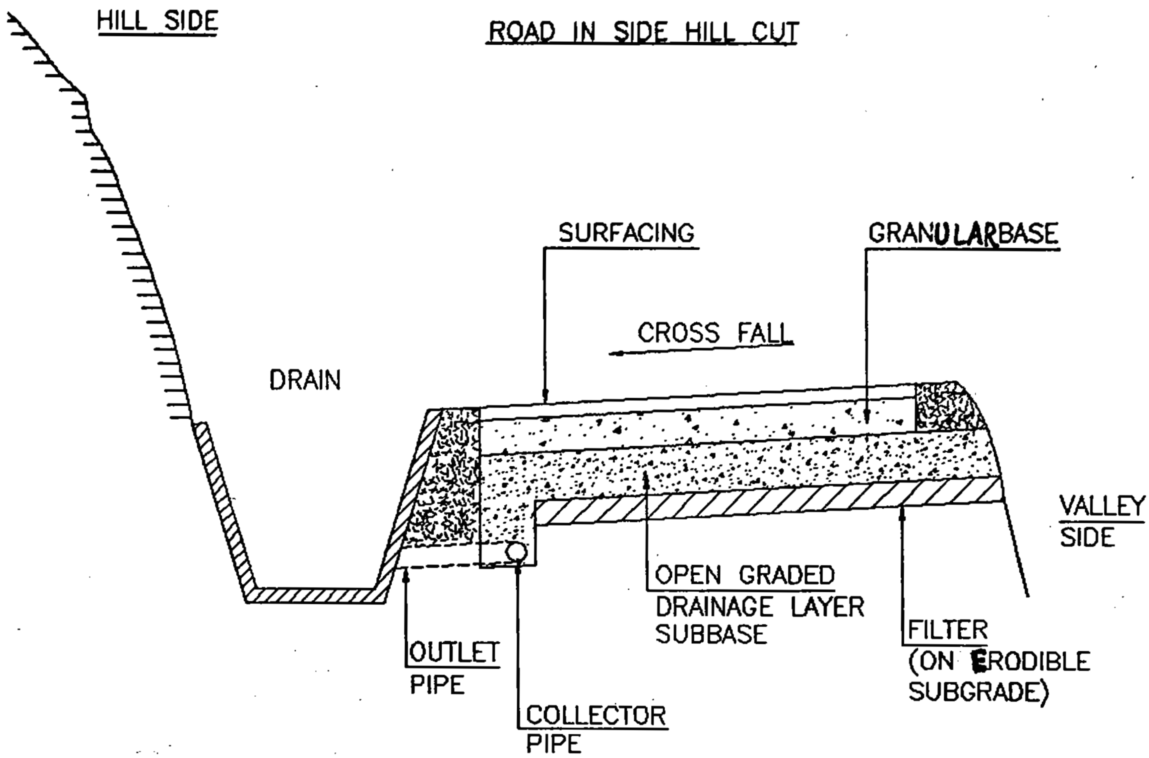


FIG. 10.13. DRAINAGE BY PIPES

d) Very often, water enters the base, sub-base or the subgrade at the junction of the verges and the bituminous surfacing. To counteract the harmful effects of this water, the shoulders should be well-shaped and, if possible, constructed of impermeable material.

e) To prevent ingress of water into the pavement through shoulders, end to end surfacing of roadway could be resorted to as stated earlier also.

10.26. Strengthening of Flexible Pavements

10.26.1. On all National Highways and other important roads where the traffic has reached 1500 CVD on a sustained basis and where the strengthening of the pavement is involved, the design of strengthening measures may be worked out by Benkleman Beam Deflection Technique. The procedure has been outlined exhaustively in IRC:81-1997 "Guidelines for Strengthening of Flexible Road Pavements Using Benkleman Beam Deflection Technique" (First Revision). The design value obtained may be compared with the design evolved for same data by CSA method of design as given in this Chapter. The strengthening measures to be adopted may be decided based on above as suitable to the ground condition.

11. SLOPE STABILITY, EROSION CONTROL AND LANDSLIDE CORRECTION

11.1. Introduction

11.1.1. A hill road is formed either by full cutting into the hill or part cut and part fill. Typical sections are given in Fig. 11.1. Stability of slopes, natural and man-made, is important for a hill road. Disturbance to slope can occur due to erosion caused by rain-fall and run-off and consequent slides. Effective erosion control measures protect slopes and prevent slides. The subject of slope stability and erosion control, therefore, become very vital for control and prevention of land slides/slips.

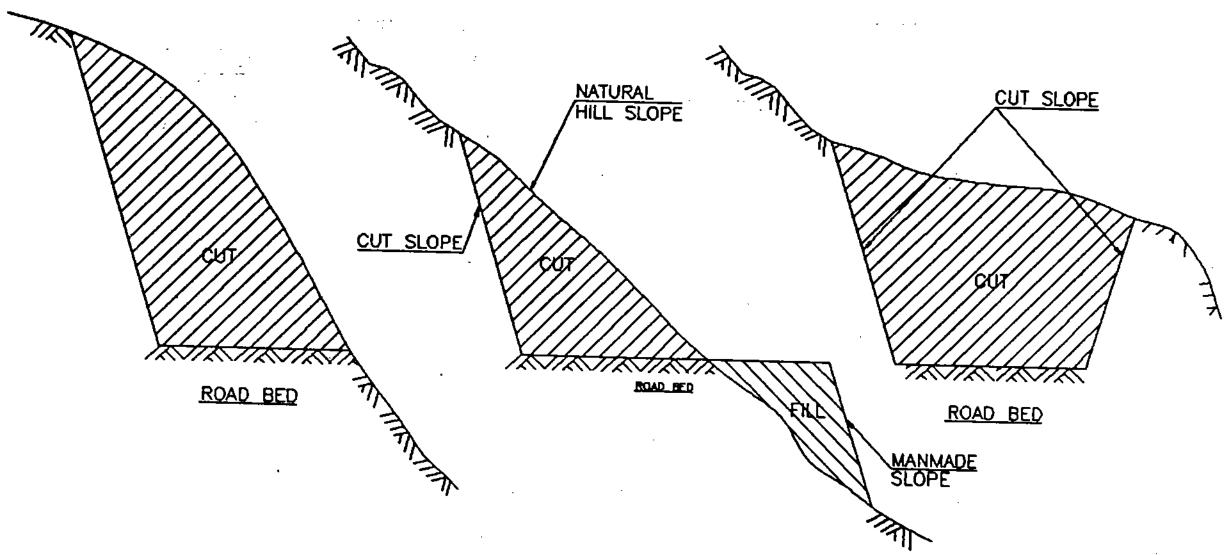


FIG. 11.1. SLOPES IN HILL ROADS NATURAL, MAN MADE, AND CUT

11.1.2. Landslide is a major hazard faced on hill roads. Study of stability of natural slopes and control of landslides thus forms an integral part of hill road design and construction.

11.1.3. A landslide may be defined as the failure of a slope mainly under the action of its own weight in which the displacement has both vertical and horizontal components of considerable magnitude. Landslide denotes downward and outward movement of slope-forming materials composed of natural rock, soil, artificial fill or a combination of these materials. The moving mass follows any one of three principal types of movements viz. falling, sliding, flowing or their combinations. The rate of movement may vary from slow to rapid.

11.2. **Classification of Slope Movement**

11.2.1. According to Ward (1945) classification of the types of slope failure is necessary for an engineer to enable him to distinguish and recognise the different phenomena for purposes of design and to take appropriate remedial or safety measure where necessary.

11.2.2. Over the years, different systems of landslide classification have been evolved based on the mode and rate of the movement, shape of the slide surface, type of material involved and a number of other factors. From the engineering-geological point of view, Terzaghi's (1950) grouping of landslides was based on the physical properties of the rocks involved. Sharpe (1938) classified sliding movements according to the material displaced and the type and rate of movement and studied the relationships between mass movements and geomorphological cycles and climatic factors. Varnes (1978) classification, establishes five principal types of mass movements and adds a sixth to accommodate landslides which combine characteristics of several principal types as given in Table 11.1. The same is summarised and explained below:

a) **Falls**

The loosened rock mass is in free fall for the greater part of the distance of movement.

b) **Topples**

The rock mass overturns about a point below its centre of gravity

c) **Slides**

i. **Rotational**

The rock mass moves about a point above its centre of gravity.

ii. **Translational**

The rock mass moves predominantly along more or less planar or gently undulating surfaces.

d) **Lateral spreads**

Lateral extension movements occur in a fractured mass.

e) **Flows**

i. **In bedrock**

These include continuous deformations and surficial and deep creep, involving extremely slow and generally non-accelerating differential movements among relatively intact units.

II. In soil

Movement occurs within a displaced mass, the form or apparent distribution of velocities of which resembles to that of a viscous fluid.

f) Complex Slides

Landslides exhibiting a combination of two or more of the five principal types of movements listed above.

Table 11.1. Classification of Slides (VARNES)

Type of Movement		Type of Material: Engineering Soils – Predominantly Fine	Type of Material: Engineering Soils – Predominantly Coarse	Type of Material: Bedrock
Falls		Earth Fall	Debris Fall	Rock Fall
Topples		Earth Topple	Debris Topple	Rock Topple
Slides Rotational	Few Units	Earth Slump	Debris Slump	Rock Slump
Translational	Many Units	Earth Block Slide	Debris Block Slide	Rock Block Slide
		Earth Slide	Debris Slide	Rock Slide
Lateral Spreads		Earth Spread	Debris Spread	Rock Spread
Flows		Earth Flow	Debris Flow	Rock Flow
		(Soil Creep)		(Deep Creep)
Complex		Combination of two or more Principal Types of Movement		

11.2.3. The workable classifications mentioned above provide some general directions for investigation and the selection of preventive or remedial measures for each established group of slope movements.

11.2.4. The main types of slides under this classification are illustrated in Fig. 11.2.

11.3. Causes of Slope Movements

11.3.1. Terzaghi (1950) summarised the processes leading to landslides in his classic paper on the mechanics of landslides. In general, the causative factors are divided into those conditions that exist in a slope such as topography, lithology and structural features, and those conditions that may produce a change, such as excavations, seismic events and variations in ground water level. The following are the important conditions that cause slopes to become unstable and factors that trigger the movements.

a) Geological Factors

The type and nature of geological formation plays a vital role in determining the degree of stability of hill slopes. The composition and the type of the rocks, orientation of bedding planes and joints, the presence of faults and folds play a dominant role in determining the degree of stability. The dip of the beds in particular is an important and controlling factor. If the dip is such that the bedding planes are inclined towards the face of the slope, stability problems are likely to arise. Frequent and open joints also lead to instability.

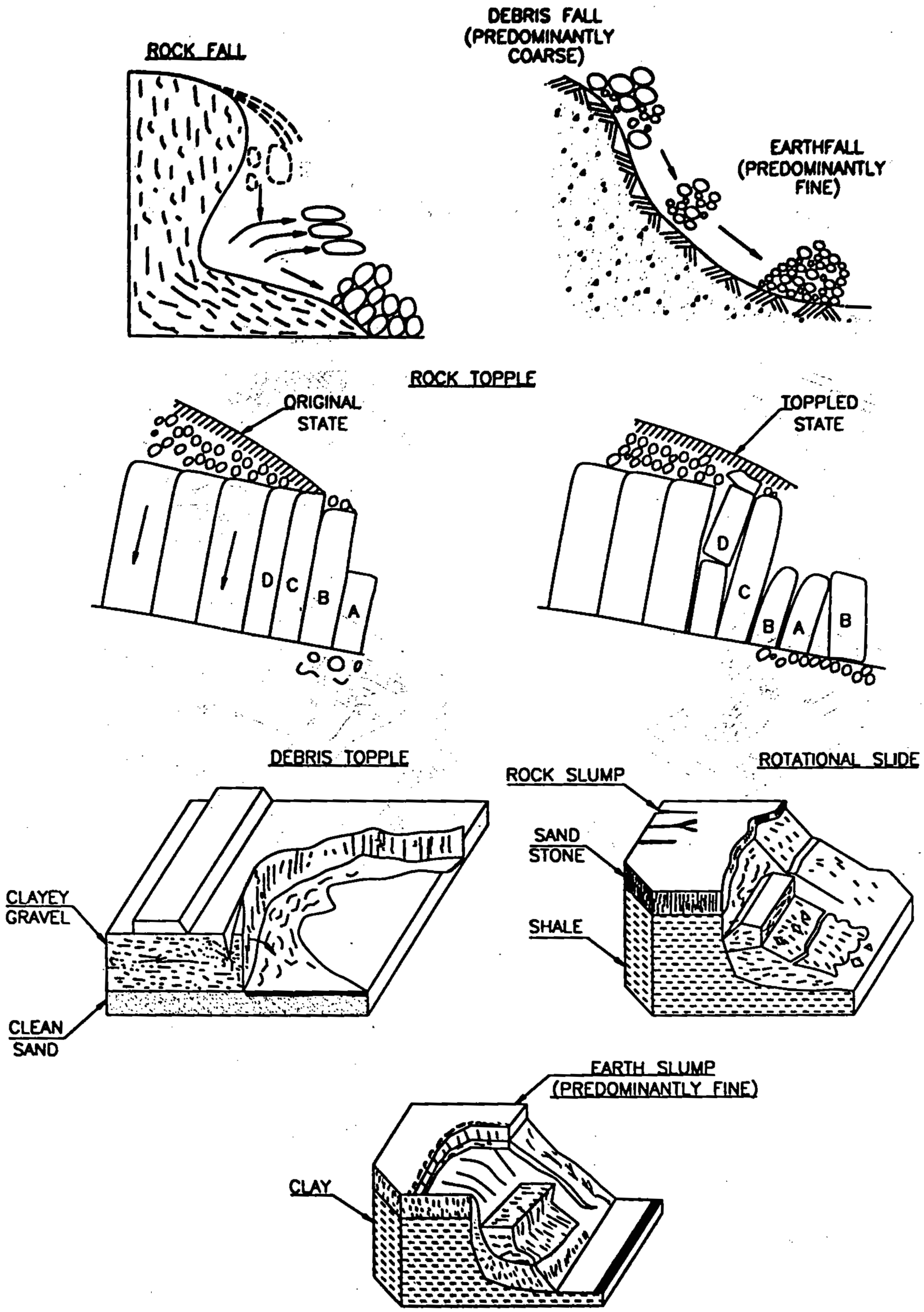


FIG.11.2. CLASSIFICATION OF SLIDES

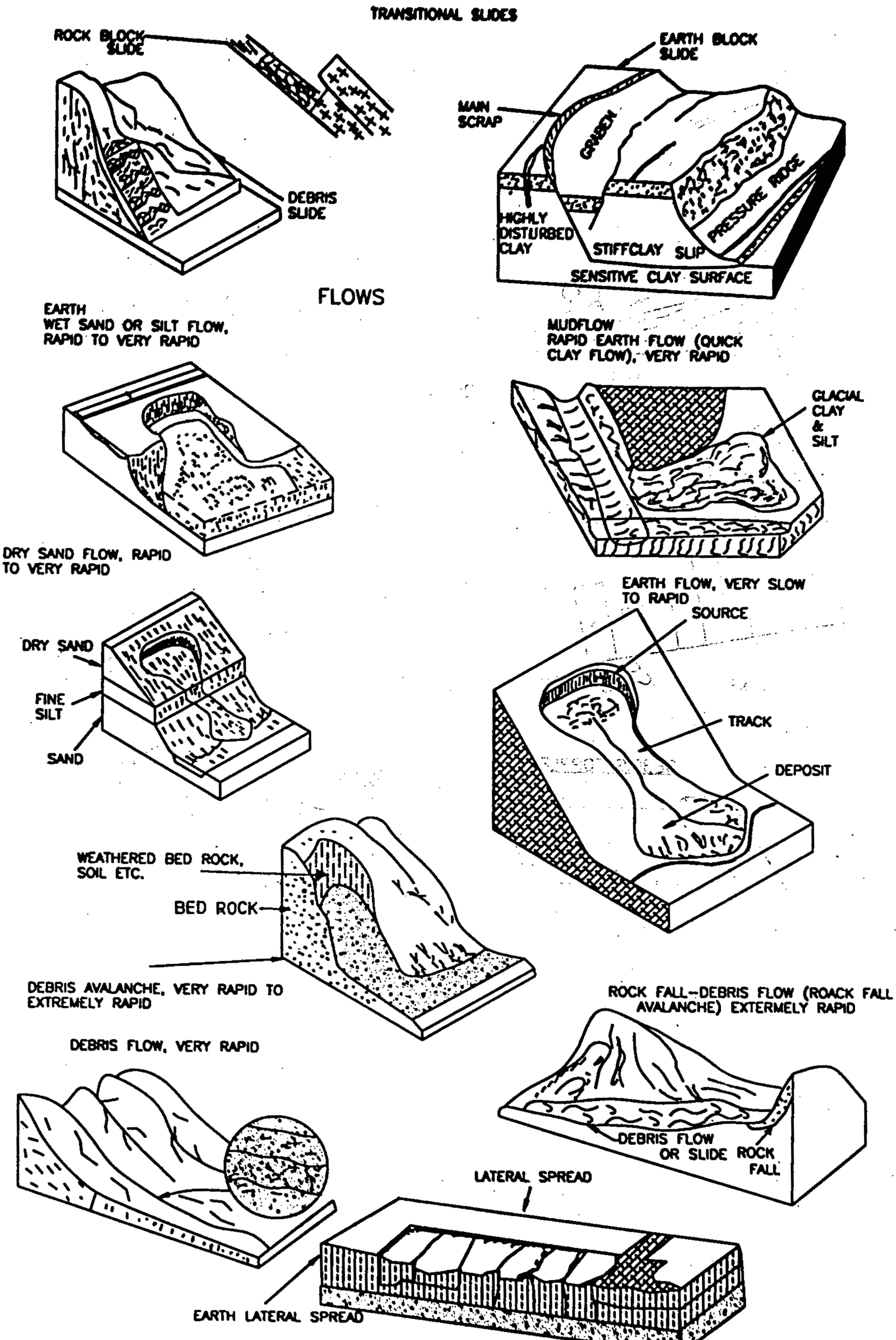


FIG.1.1.2. CLASSIFICATIONS OF SLIDES

Depending upon the orientation of bedding planes and joints with respect to the hill face, different types of instabilities can arise namely falls, slides or topples. If the slope contains many tension cracks it is an indication of distress being experienced by the slope formation. If bedding planes are filled with gouge material, stability is likely to suffer. Wherever the hill face is covered with considerable amount of debris or soil, failures may be restricted within the zone of the debris or may involve both the distressed rock as well as the overlying debris.

b) Change in the Slope Gradient

A progressive increase in the slope angle due to undermining of the foot of slope by stream erosion or by excavation may result in a landslide. The angle of slope is increased due to previous rock fall, slide, subsidence or large-scale faulting. An increase in slope gradient causes a change in the internal stress of the rock mass and equilibrium conditions may be disturbed by such increases in the stress.

c) Surcharge

The surcharge from natural causes may be due to rain, snow, accumulation of talus over-riding landslide materials, collapse of accumulated volcanic materials and vegetation etc. The surcharge may also be due to construction activity like fills and spoil heaps, weight of buildings and other structures. This produces an increase in the shear stresses and pore-water pressure in clayey soils, which result in decreased shear strength.

d) Shocks and Vibrations

Vibrations from blasting, machinery and earthquakes including minor tremors may trigger a landslide due to an increase in the shear stress and a decrease in the shear strength. In saturated fine sands and sensitive clays, vibrations may result in a sudden liquefaction of the soil.

e) Changes in the Water Content

Changes in water content can occur because of rainfall and snow melt or because of human activities such as diversion of streams, blockage of drainage, deforestation etc. In soils, rise in water table causes pore water pressure to increase and consequently the shear resistance to decrease which may eventually lead to instability.

f) Changes due to Weathering

Mechanical weathering such as softening of fissured clays, physical disintegration of granular rocks and chemical alterations such as hydration and ion exchange in clays, influence of seasonal and diurnal fluctuations of temperatures, freeze thaw cycles, generally result in the deterioration of the strength characteristics of slope forming materials, thereby increasing the risk of slope instability.

g) Influence of Developmental Activities

Increased pace of developmental activities in the hill areas have generally resulted in increased incidence of landslides. Slope cutting for roads, housing etc. and denudation of hill due to clearing of forests, mining activities etc., have had adverse effects on the stability of hill slopes. However, with adequate planning such problems can be avoided and where necessary suitable protective measures taken to preserve the hill slope stability.

11.4. Landslide Investigations

11.4.1. Investigation and study of lindslides broadly comprises of field and laboratory investigations. Both geological and geotechnical aspects, in the broad sense of the terms, need to be studied. The objective of these studies is to collect data for the evaluation of the stability of the slope, determine the conditions under which failure may occur and base the remedial measures on a rational footing.

11.4.2. **Field Investigations:** Field investigations may be divided into three stages.

a) Mapping of the area
b) Geological investigations
c) Geotechnical investigation

11.4.2.1. **Topographical mapping of the area:** The slide area should be mapped in detail. Field maps should be prepared giving the plan of the affected area and typical cross-sections, which can be used for stability analysis. If possible, the topography may be determined by aerial surveys (photogrammetry) which provides an overall view of the site features. General observations should be made concerning the condition of the slope, covering such aspects as the extent and nature of vegetation cover, surface run off characteristics, presence of springs etc. Erosion of the toe and tension cracks in the crown area may be observed in detail.

11.4.2.1.1. Topo sheets of the area should be studied as a part of the field investigation. Any signs or evidences for locating surfaces of failure should be carefully taken note of. Data concerning rainfall and intensity should be obtained as a part of field investigation.

11.4.2.2. **Geological investigations including geological and geomorphological mapping:** Geological map of the area, if available, should be studied carefully. Plan of the landslide area must be prepared incorporating geological data. Structural geological features such as bedding planes, joint planes, faults, folds, shear zones, unconformity, etc. should be studied in the field in detail and plotted on the geological map. The influence of these structural geological features on the stability of the affected slope can be evaluated with the help of stereonets, etc.

11.4.2.2.1. The rock types in the slide area should be identified and their qualities should be assessed. The minerals in the rocks and their alteration products should be taken into consideration. The investigation must carefully observe for the presence of any soft pockets or beds or interlayers. In some instances, geophysical studies may help in detecting such layers or pockets.

11.4.2.2.2. On the plan of the area already prepared or on a separate map the geomorphologial features should be marked. These include such features as elevated and depressed zones, break in slope, erosional and depositional zones, mass movement vectors, etc.

11.4.2.3. **Geotechnical investigation:** Geotechnical investigations shall be carried out with the objective of determining the nature and strength characteristics of the material comprising the slope. If the slope is predominantly made up of soil or a mixture of soil and rock, disturbed and undisturbed samples should be collected at a few locations covering the affected area. Disturbed samples may be made use of for determining the index properties, grain size analysis etc. Undisturbed samples may be collected from open pits or from boreholes, using appropriate type of sampling tubes. In debris covered slopes, as is very often the case in land slides affected areas of Himalayas, undisturbed samples of good quality can be collected only from open pits. Good quality undisturbed samples are a basic requiroment for reliable evaluation of shear strength parameters.

11.4.2.3.1. The depth and seasonal fluctuations of water table also form an important component of data required for landslide investigations. This information may be obtained from local enquiries, observations in wells that may be present or by noting the presence of springs, etc. Sometimes, it may be desirable to make a borehole and instal a piezometer, to observe the water level over a cycle of seasons.

11.4.2.4. Geological and geomorphological maps of one major land-slide in Garhwal Himalayas are illustrated in Figs. 11.3 and 11.4.

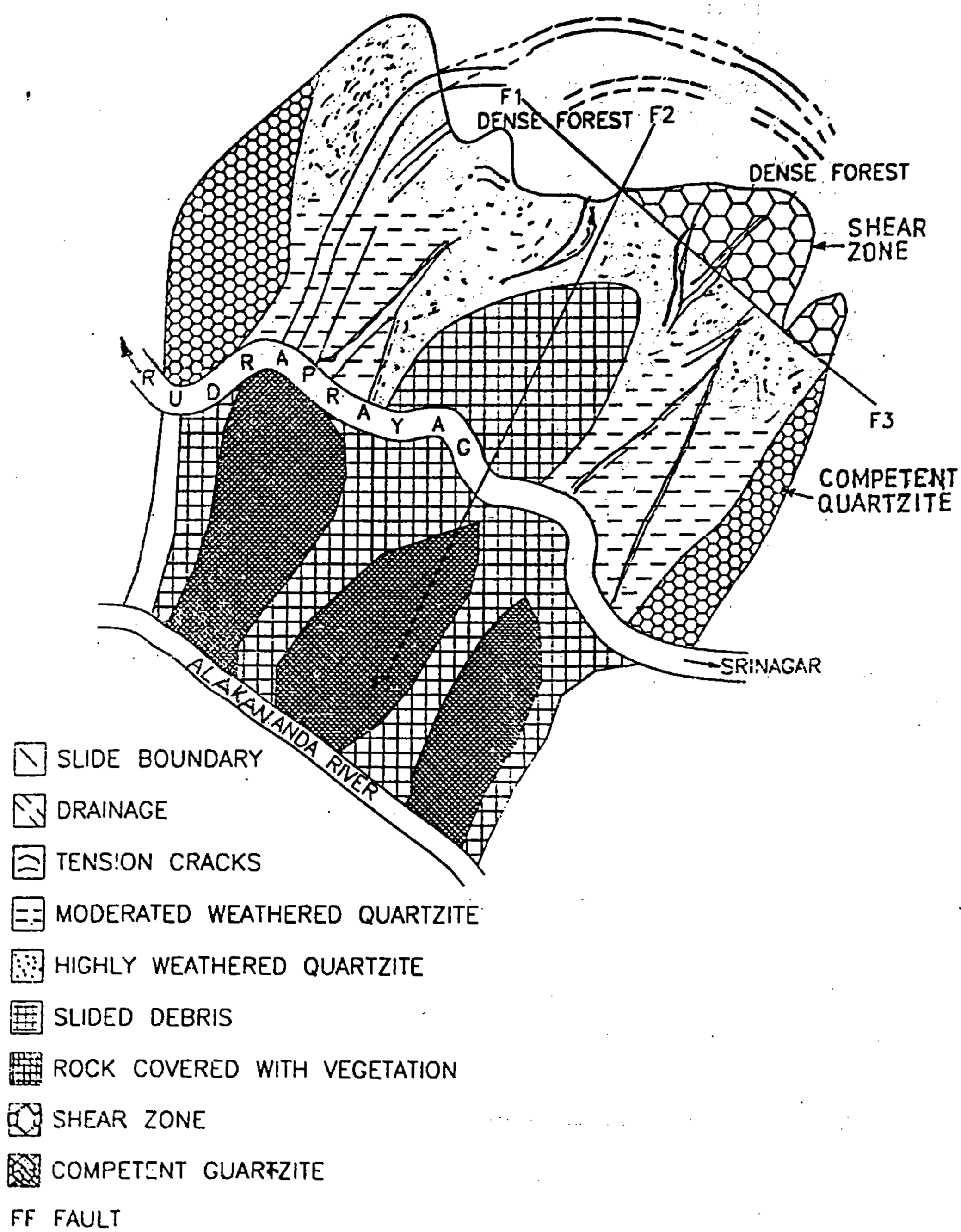


FIG. 11.3 GEOLOGICAL MAP OF KALIASAUR SLIDE (GARHWAL HIMALAYAS)

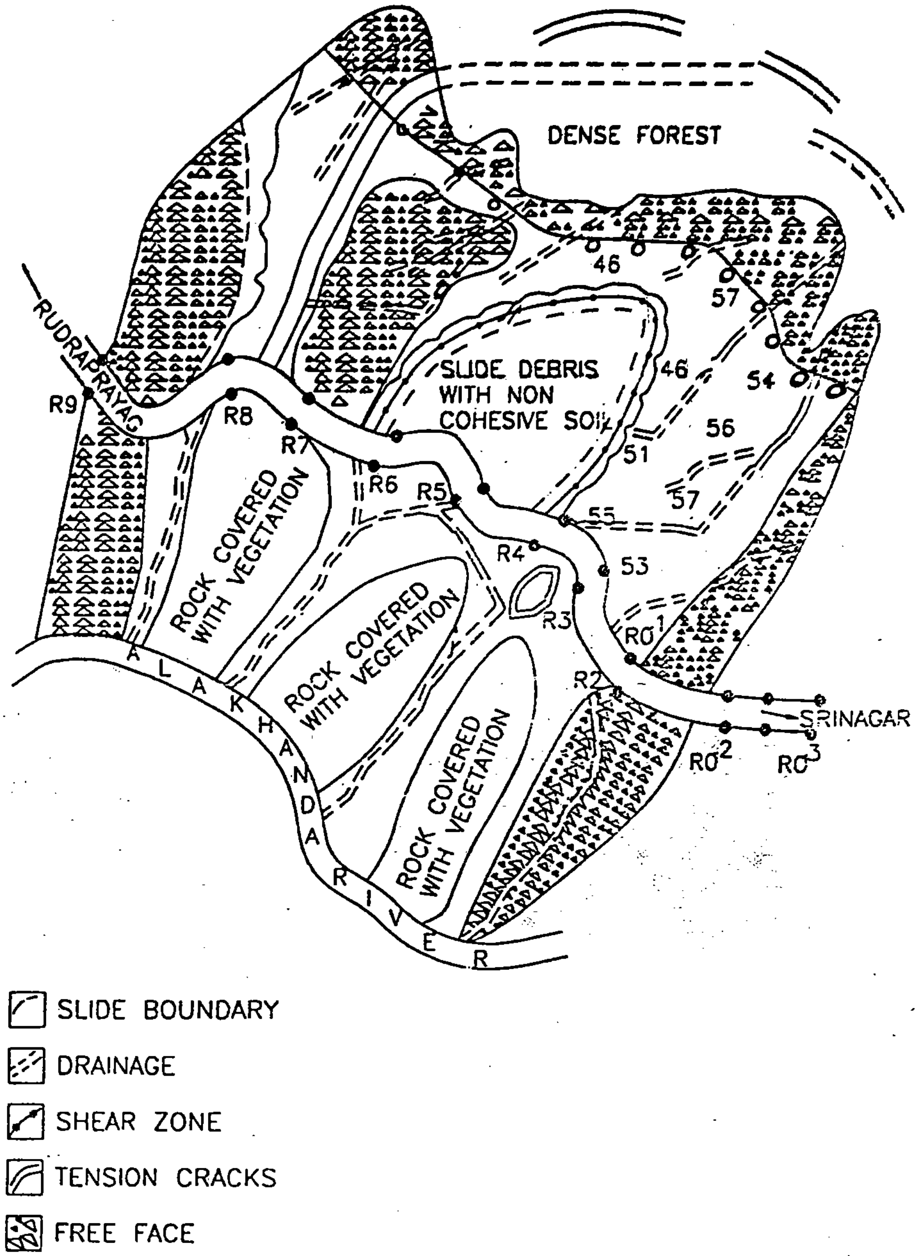


FIG. 11.4 GEOMORPHOLOGICAL MAP OF KALIASAUR SLIDE LANDSLIDE
(GARHWAL HIMALAYAS)

11.4.2. Laboratory Investigations: The following represents some of the basic tests that need to be carried out on the soil and rock samples collected from the slide area.

a) Determination of index properties in case of soil samples.

b) Determination of shear characteristics of slope material by appropriate type of shear tests. If the material is by and large fine-grained, triaxial shear test may be suitable. If sample contains relatively high content of gravel or rock fragments, direct shear test could be conducted more easily on such samples. The size of the samples used for testing would depend upon its granular composition. The shear strength parameters should be determined using a test procedure compatible with the method of analysis.

c) Rock sample should be examined to find out the nature of rock, extent of weathering, presence of any weak inter layer etc. If suitable samples are obtained, strength of rock samples may also be determined.

11.4.4. The above data are used for stability analysis and formulation of corrective measures.

11.5. Stability Analysis

11.5.1. **Stability analysis of predominantly soil slopes**: Slopes often fail by rotation as the mass slides along a curved surface. The geometry of the failure surface is predicted on many factors such as the presence of weak layers or seams, strength properties of slope forming materials, the height and inclination of slope etc. The first sign of an imminent failure of slope is usually an outward or upward bulging near the toe and development of cracks near the crest of the slope, the failure plane being approximately arc of a circle. Though in actual practice the failure plane may be a complex surface, in most stability analysis cases a cylindrical rupture surface is assumed to simplify computation. The analysis consists of drawing trial circles and calculating the factor of safety of each circle. Analysis may be done either by considering the stability of the slope en-mass or by dividing the strip mass into many vertical slices and considering equilibrium of each slice i.e. the Equilibrium Method.

11.5.1.1. Typical sketch of slope failure, slip circle, vertical slices etc. are illustrated in Fig. 11.5.

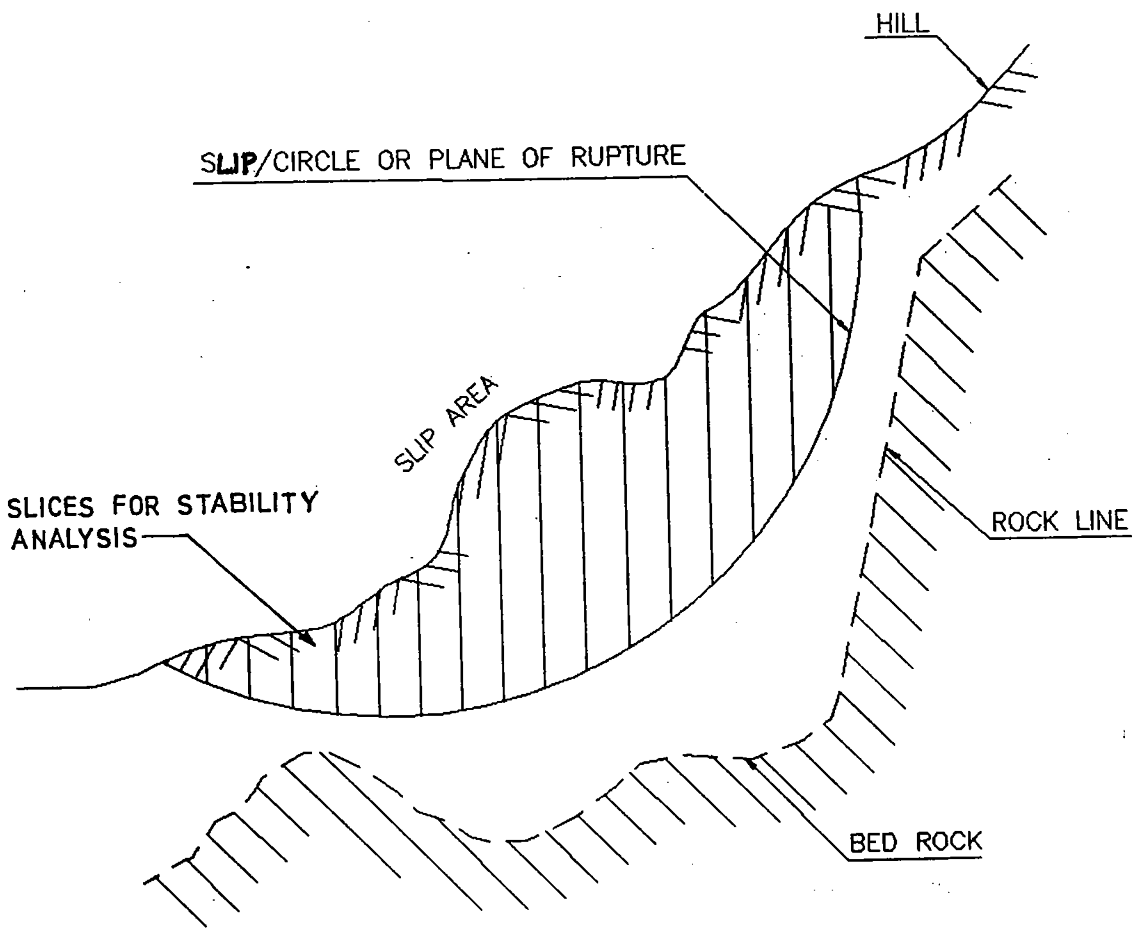
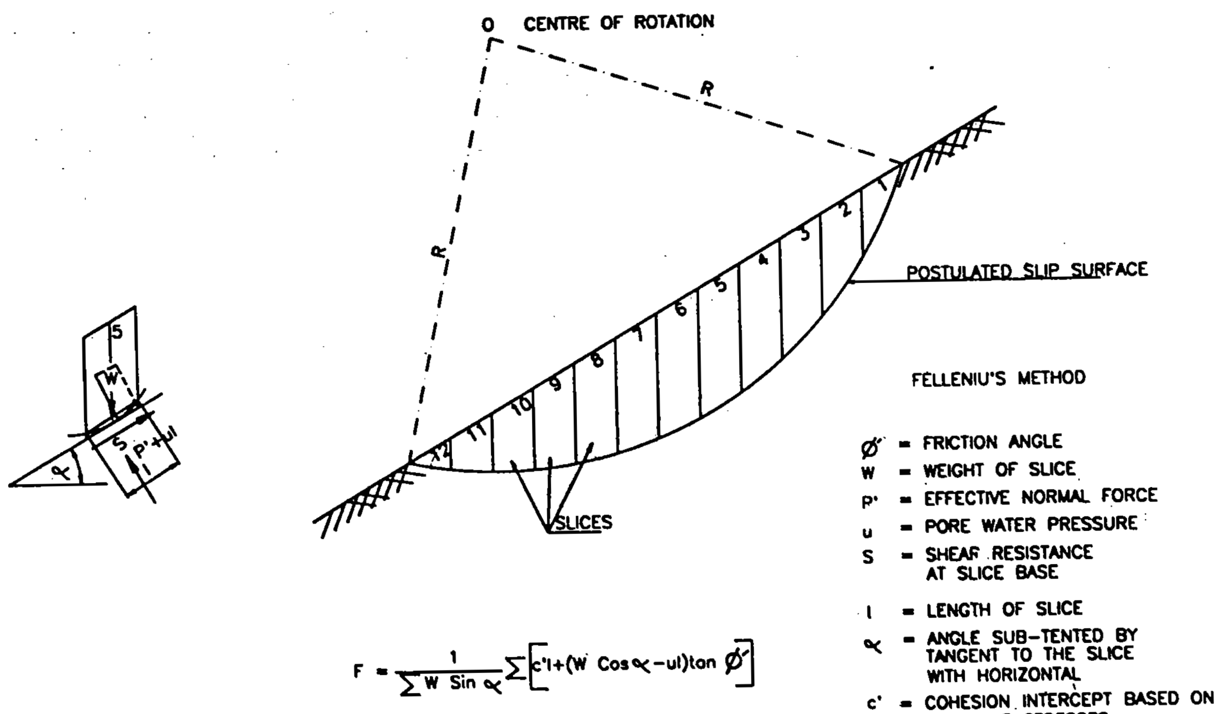


FIG.11.5. UNSTABLE SLOPE,SLIP CIRCLE AND SLICES FOR ANALYSIS

11.5.1.2. Method of analysis of stability is given in detail in IRC:75-1979 "Guidelines for the Design of High Embankments" which may be referred. Though IRC: 75-1979 deals with man made slope i.e. Embankments, the method of analysis given is equally applicable to natural hill slopes including cut-slopes.

11.5.2. **Methods of stability analysis:** The slope stability can be analysed by slip circle analysis or by deformation (stress) analysis. The latter method is rather complex. As such the equilibrium method of stability of slices is common and simple.

11.5.2.1. **Limit equilibrium methods:** In all limit equilibrium methods of analysis shearing forces tending to disturb the equilibrium are quantitatively evaluated and compared with the available shear strength. This process enables the calculation of a factor of safety. At the out-set, continuous failure surfaces that are kinematically acceptable are assumed and calculations are made for several such surfaces. The slip surface for which the factor of safety is minimum is called the critical slip surface. Common methods of calculating factor of safety assuming circular failure surfaces are Fellenius method (Swedish slip circle method) and Bishop's method. A sketch showing analysis by Fellenius Method is given in Fig 11.6. For details IRC:75-1979, as stated, may be referred.



$$F = \frac{1}{\sum W \sin \alpha} \sum \left[c'l + (W \cos \alpha - ul) \tan \phi' \right]$$

FIG.11.6. SLIP CIRCLE ANALYSIS

11.5.3. **Stability analysis for predominantly rock slopes:** Where the hillside formation is made up of jointed rock mass, failures are governed by the relative orientation of the discontinuities within the rock mass with respect to slope of the hill face. Different types of spherical projections can be used to determine which mechanism of failure of the rock masses are kinematically possible. The results of such analysis form the basis for choosing appropriate method of analysis for evaluating the factor of safety against sliding.

11.5.3.1. The interactions of joints and bedding planes with reference to a given plane are normally evaluated by resorting to spherical projections and by use of stereonets. With the help of such stereonets, it will be possible to identify if sliding is likely to occur on a single plane or along two planes or over a set of stepped joints etc. Reference may be made to Goodman (1980) "Introduction to Rock Mechanics" for details concerning the application of stereonet projection methods for evaluating stability of rock slopes.

11.5.3.2. In certain situations sliding in a slope made up of rock mass can also be analysed by slip circle analysis, discussed in the previous section. Some of such conditions are:

i) The rock mass on hill face is highly fractured and has randomly oriented joints.

ii) The rock mass has low strength and its strength characteristics approach that of soil.

iii) Faults or pre-shear planes or other discontinuities may exist, which may induce failure along non-linear slope surface.

11.5.3.3. Notwithstanding the above, the geological and geomorphological study of the rocky area and devising corrective measures would normally be adequate for meeting most requirements of rocky slopes on hill roads.

11.6. Corrective Measures and Design Considerations

11.6.1. A variety of remedial, corrective or control methods are practiced to protect hill slopes from instability. These are briefly discussed under three broad categories.

a) Avoid or eliminate the problem itself.

b) Reduce the forces tending to cause movement i.e. the driving forces.

c) Increase the forces resisting the movement

11.6.2. Avoid the problem: The problem may be avoided or eliminated by one of the following methods:

a) **Change of alignment:** During reconnaissance, potential stability problems such as poor surface drainage, seepage zones on existing natural slopes, hillside creep and old landslides should be carefully noted. Early recognition of known troublesome areas helps studies for choice of alternate alignments. It is often more practicable to avoid a potential landslide by changing the alignment of a proposed highway initially than resorting to elaborate remedial measures. In some places, it may be possible to choose the opposite side of valley or hill where the bedding planes of the rock dip away from the cut slope rather than dip towards the cut.

b) **Removal of materials:** If relocation and realignment of a proposed highway is not possible, either complete or partial removal of the unstable material should be among the alternative considerations. The removal of potentially unstable material can vary from simple stripping of a surface layer by few metres to depths as great as 50 m. Economics as well as the relative risk of slope stability play an important role in the selection of final course of action. This is illustrated in Fig. 11.7.

c) **Bridging:** In some case when removal of steep, long and narrow unstable slope is too costly then the alternative solution is bridging. A land bridge or a structure founded on piles placed well below the unstable foundation materials is constructed, spanning the unstable area. A sketch illustrating this is given in Fig. 11.8.

d) **Tunnelling:** An unstable alignment can also be avoided by resorting to tunnelling, if the rocks at a suitable depth are found to be stable. Both tunnelling and bridging are capital intensive solutions and have not so far been widely

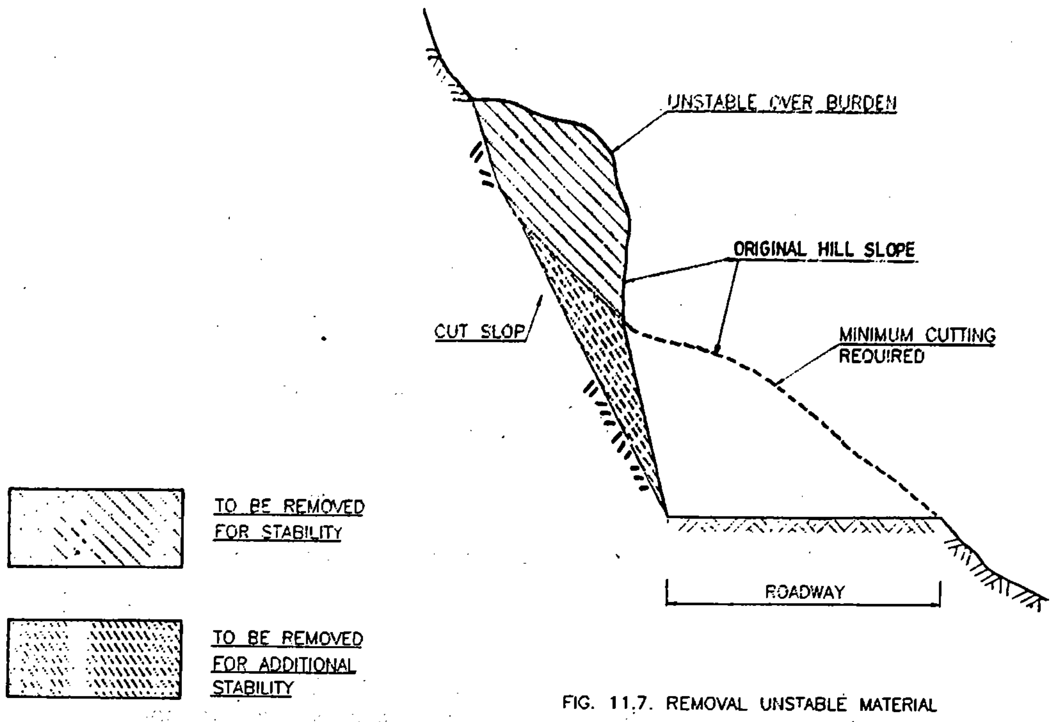


FIG. 11.7. REMOVAL UNSTABLE MATERIAL

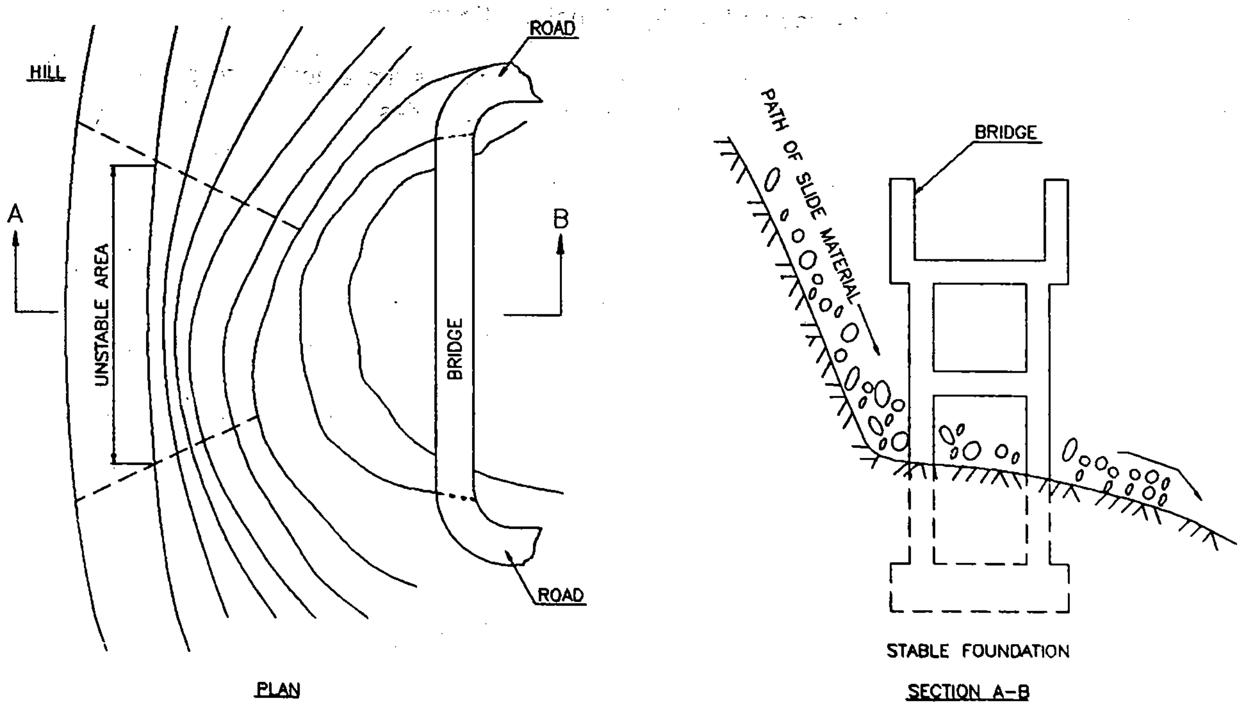


FIG.11.8. BRIDGING UNSTABLE AREA

used in India. However due to increasing demands of safe, and uninterrupted traffic movements in hill areas, these solutions may have to be resorted to. An illustrative sketch is given in Fig. 11.9.

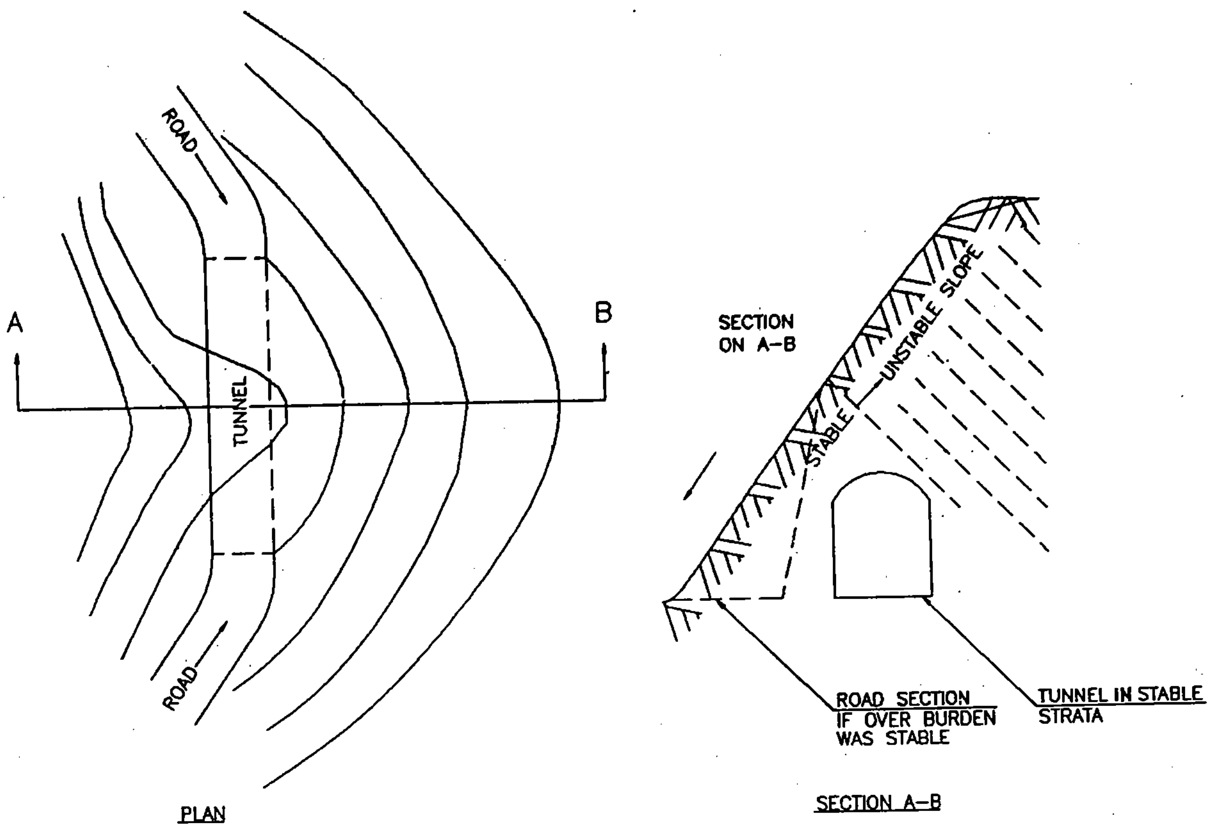


FIG. 11.9. TUNNEL TO AVOID UNSTABLE SLOPE

11.6.3. **Reduce the driving forces:** The driving forces comprise of the component weight of the soil, superimposed loads and water. The simplest approach to reduce such forces, is to reduce the mass involved. There are three methods by which the driving forces can be reduced as described hereafter.

a) **Change the line or grade:** Line or grade changes are generally done to reduce the driving forces. Shifting the highway alignment away from the toe of the slide area eliminates the need to provide toe support. Where necessary, a buttress may be placed to support the sliding mass in the form of a retaining, breast or toe wall. A sketch of buttress is given in Fig. 11.10.

b) **Surface Drainage:**

(i) Drainage not only reduces the weight of the mass tending to slide but also increases the strength of the slope-forming material. A high degree of surface erosion and development of excess pore pressure within the slope, due to the absence of proper drainage facility are the two principal causes of slope instability. It is, therefore, natural that the improvement of the drainage facilities in the area is given high priority.

(ii) Mere provision of contour drains, culverts and drainage chutes does not help if it is not ensured that the catchment would effectively feed them and that the drainage system is firmly founded. A broken or dislocated surface drain may sometime cause damage to the slope more than the lack of any drainage. Surface drains should be located very carefully after the topography of the ground is studied. It has been observed in practice that poor location of surface drains results in their serving no purpose, since no water would be collected by them. On the other hand, the run-off by-passes the drains and continues to damage

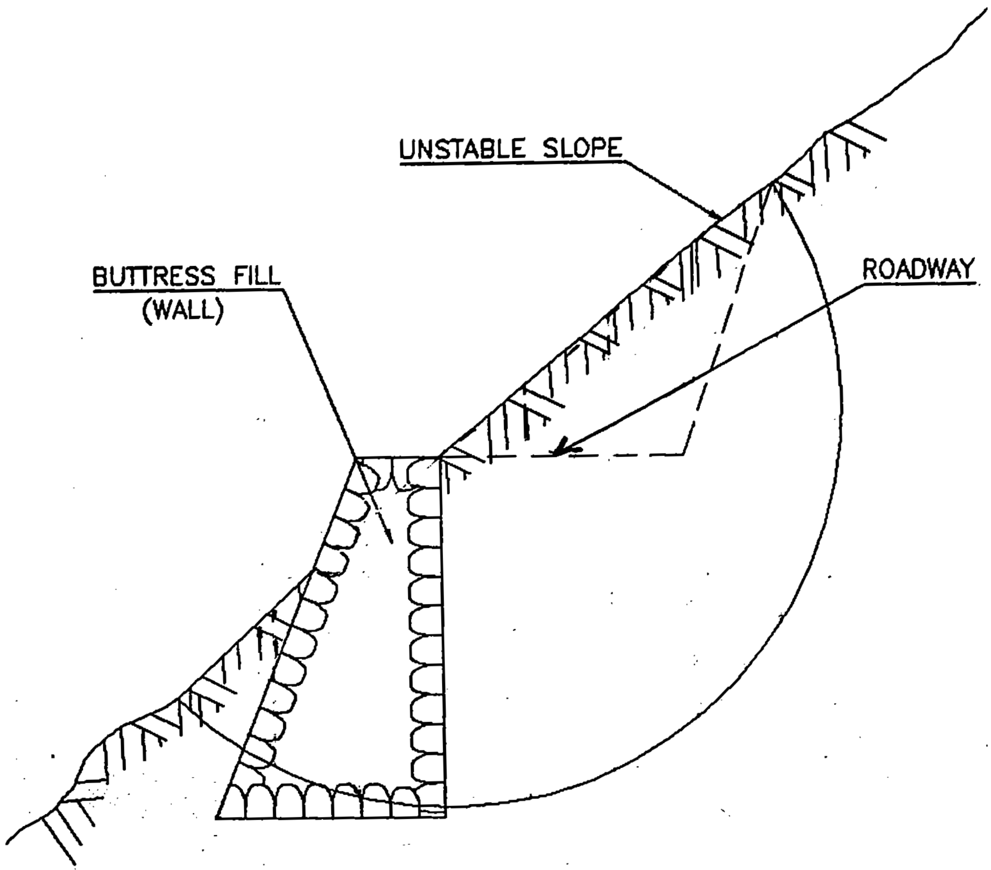


FIG. 11.10. BUTTRESS FILL (WALL)
(SERVING AS RETAINING WALL)

the slopes. A number of rows of inter-connecting lined catch-water drains should be constructed on the slope to collect the surface run off which should in turn be brought to culverts at a lower level to be led through chutes to natural water-courses. Lined road side drains should also be built. The different types of drains and drainage works are described in Chapter 8 "Drainage and Cross-Drainage".

(iii) To prevent intrusion of direct rainfall in the loose mantle of earth along the slopes, a vegetative cover should be provided. Sealing of tension cracks on the surface of the slope in any type of landslide will prove beneficial since it prevents the ingress of surface water into the slide mass. (Methods of sealing of tension cracks and provision of vegetative cover are dealt separately later).

(iv) Methods of surface drainage should also include the following where required:-

a) reshaping of the slopes
b) construction of paved ditches
c) installation of drain pipes and
d) paving or bituminous treatment of slopes.

All precautions should be taken to prevent the surface run-off from entering a potentially unstable area. Proper surface drainage measures are a good investment compared to any other type of preventive treatment. Provision of surface drains along the outer periphery of the potentially unstable area is particularly desirable. Surface drains serve to intercept the run-off from higher ground above the scarp, and divert it away from the slide surface. If surface drains are likely to be clogged by debris from above, a drain pipe should be placed to ensure that the water is not trapped inside the area. The bed of the drain should be sloped such that it drains off the water quickly or else it should be sealed with an impermeable material.

(v) **The surface drains must be provided with impervious paving and have a uniform gradient to prevent deposition of material silt on the bottom of the drain. Surface drainage may also be used in conjunction with other types of treatment such as seeding of sodding, rip-rap, etc. as illustrated in Fig. 11.11.**

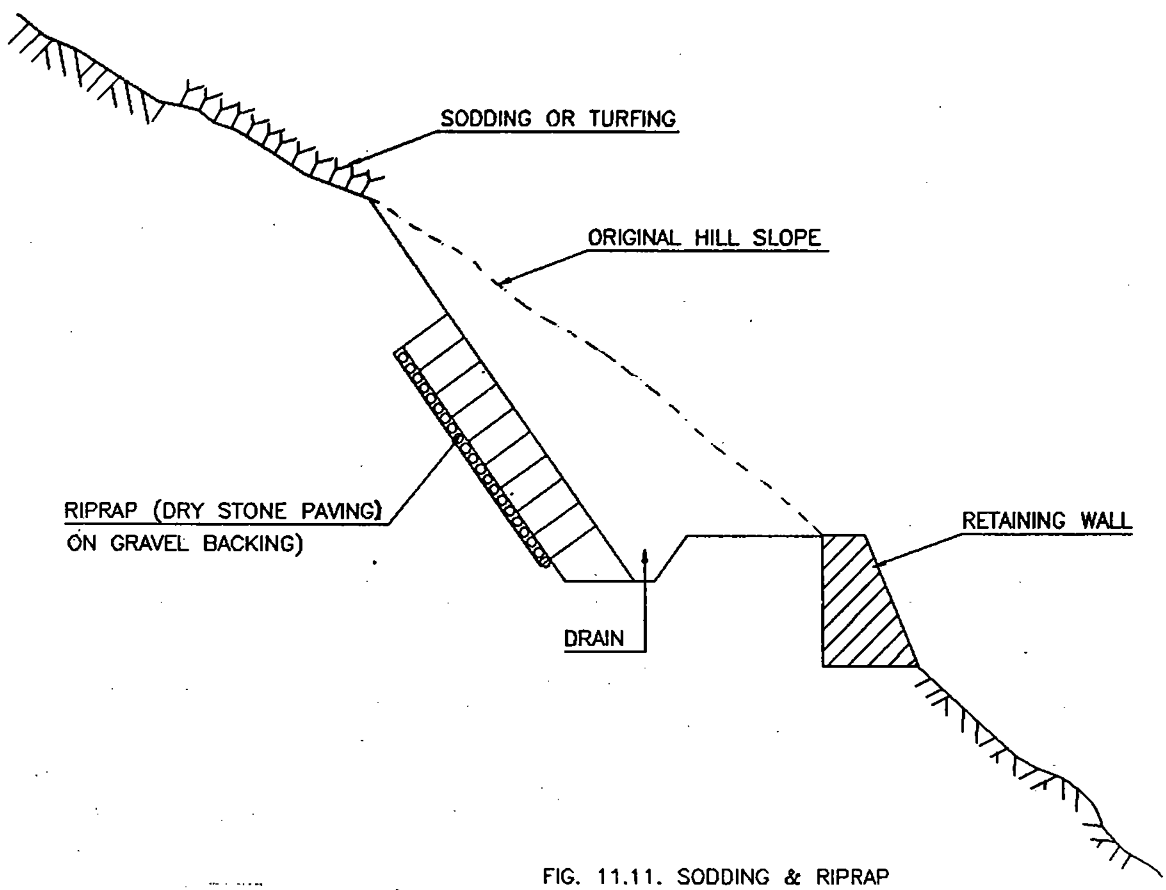


FIG. 11.11. SODDING & RIPRAP

c) **Sub-surface drainage:** Removal of sub-surface water tends to produce a more stable condition in several ways such as:-

i) Seepage forces are reduced
ii) Shear strength is increased
iii) There is reduction in excess hydrostatic pressure
iv) Driving forces are reduced.

The removal of water within a slope by sub-surface drainage is usually costly and difficult. Methods generally used to accomplish sub-surface drainage are the installation of horizontal drains, deep trench drains, vertical drainage wells and drainage tunnels. Sub-surface drainage has been dealt in Chapter 8 "Drainage and Cross-Drainage" also. However, drains related to slope stability not covered earlier are described below:-

(i) Horizontal drains may be used in slopes where steady seepage of water is encountered. They provide channels for drainage of sub-surface water either from the sliding mass or from its source in the adjacent area. It has been observed that installation of such horizontal drains is very effective in lowering the ground water level and thus stabilising the slopes. A typical sketch and arrangement of horizontal drain is given in Fig. 11.12.

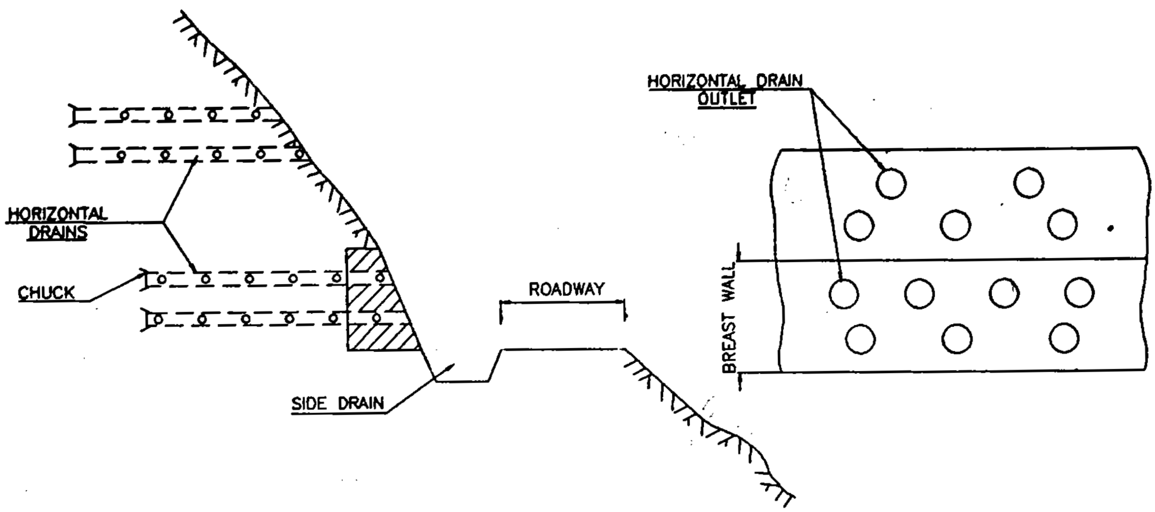


FIG.. 11.12. HORIZONTAL DRAIN

(ab) Horizontal drains enable an overall improvement of the stability of the slopes by reduction in the level of the water table. Reducion in water table results in decreased pore water pressure at the base of the slide surface. The relation between the factor of safety and pore water pressure is shown in Fig. 11.6 where in the porewater pressue is expressed in terms of a non-dimensional parameter. As may be seen from the figure, reduction in pore water pressure results in a direct increase in the factor of safety. The relationship can be worked out easily, for a given slope. In general, the disposition of horizontal drains should be so arranged that the desired decrease in piezometric levels occur.

(ac) Practical experiences concerning the installation of horizontal drains indicate the following:

1) Horizontal drains can be used in a wide variety of soil types including weathered and fragmented rocks.

2) For Horizontal drains, perforated or slotted rigid PVC pipes with internal diameters of 38 mm to 50 mm and in lengths of 3 m to 6 m can be used. Perforations or slots are made on the upper two thirds of the pipes.

3) These pipes are installed at an outward inclination with the horizontal. A special chuck may have to be attached at the end of each pipe to prevent its slip out from the drill hole.

4) Sub-surface drainage by horizontal drains represents a more effective solution compared to the prohibitive cost of adopting other conventional corrective measures, in situations where excess hydrostatic pressure is the main cause of slope failure.

5) Adequate geological and geotechnical studies should be conducted to locate the water table, determine the material properties and evaluate the benefits from horizontal drain installation.

6) In critical slopes, the horizontal drain may be placed behind retaining structures like breast walls and the discharge allowed to collect by draining across the wall into side drains.

(ii) Deep Trench Drains

(aa) Deep trench drains can also be used for the purpose of sub-surface drainage. A typical sketch is given in Fig. 11.13. These are generally limited, by practical consideration, to those locations where water can be intercepted at depths less than 5 to 6 m. Such effective drains consist of a permeable gravel core, surrounded by a filter fabric like geotextile to prevent clogging. These can be adjusted to varying conditions of soil and groundwater. The gravel size is either 16-32 mm or 36-70 mm to ensure a sufficiently high void ratio. The average amount of material needed per metre of drain length is about 1 m^3 of gravel and 5 m^2 filter fabric.

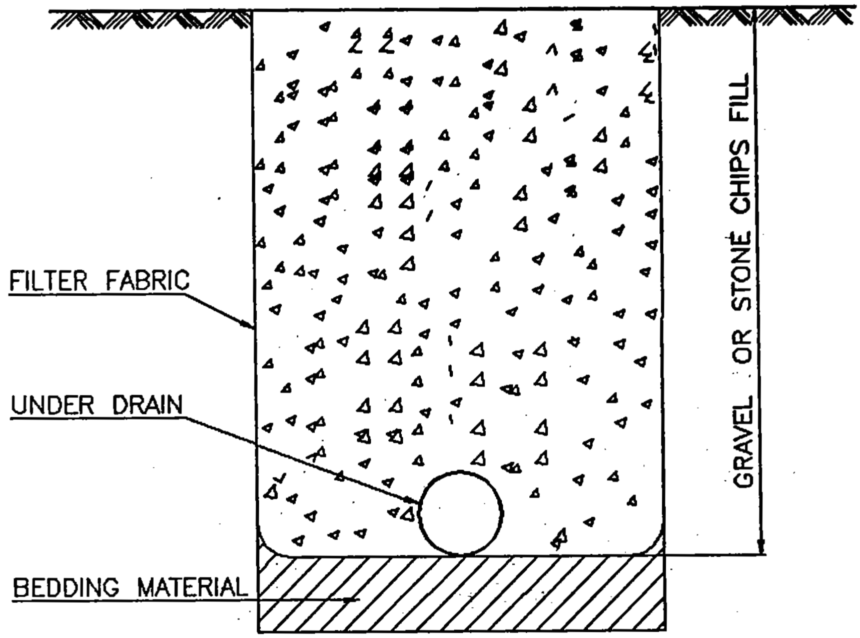


FIG. 11.13. DEEP TRENCH DRAIN

(ab) In addition to the above, a lined surface drain may also be constructed for the upper part of the trench drain serving purpose of catch water drain, which will cater both surface drainage as well as subsurface drainage. Such drains are connected to the nearest natural water course or chutes. The method is illustrated in Fig. 11.14.

(ac) The individual trench drains have to be made in short sections 5 m to 10 m long. After the trench is excavated the filter fabric is spread out, trench is filled with gravel upto the top water bearing layer and then the fabric is overlapped. Control shafts at the junction of drains are installed in order to ckeck the time dependent flow of water in the individual drains. Pipes may be required to feed the water into the control shafts, at some locations.

(d) Reduction of weight

(i) If relocation or realignment of a proposed highway is not possible, either complete or partial removal of the unstable material should be among the alternative design considerations. This method will contribute to increase sability of the soil mass beneath a slope. The main methods used for prevention or correction are removal of head of the slide, lowering of the grade line, flattening or benching of slopes and complete removal of all unstable material. The required quantity of material to be removed must be carefully estimated by stability analysis, using laboratory and field data. Removal of head of a slide aims at unloading or taking away a relatively large quantity of material from the head of a landslide, thereby reducing the activating force. The method is illustrated in Fig. 11.15.

(ii) Slope flattening and benching reduces the driving forces on a potential or existing slide. Slopes constructed with benches or berms are considered preferable to equivalent uniform straight slopes. Benching produces increased stability by dividing the long slope into segments of smaller slopes connected by benches. The width of benches should be adequate to enable the slope segments to act independently. Benches are useful in controlling instability if they are properly designed and provided with paved drains. Slope flattening by benches is illustrated in Fig. 11.16.

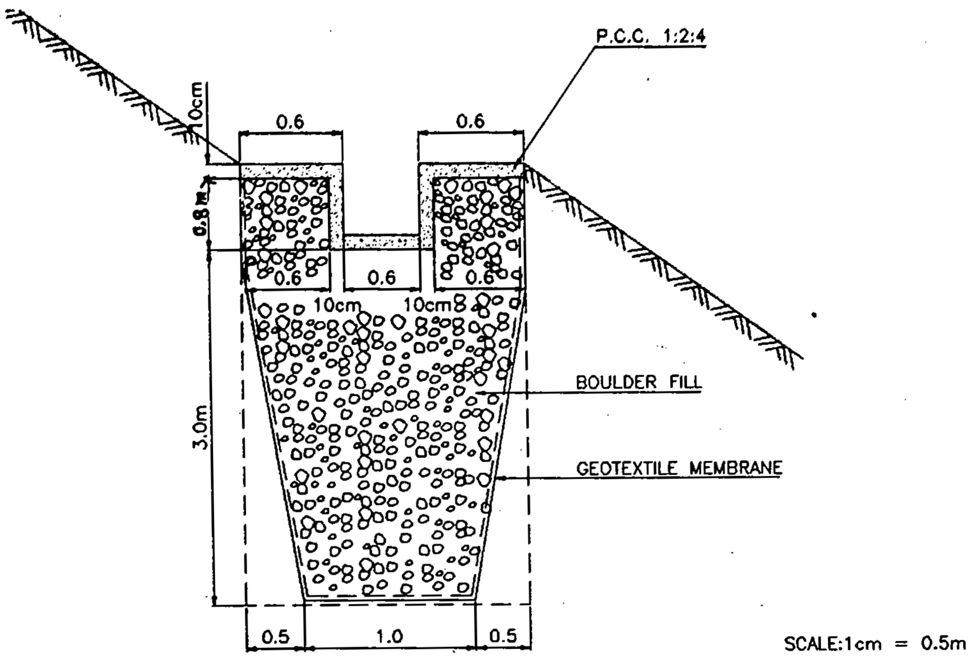
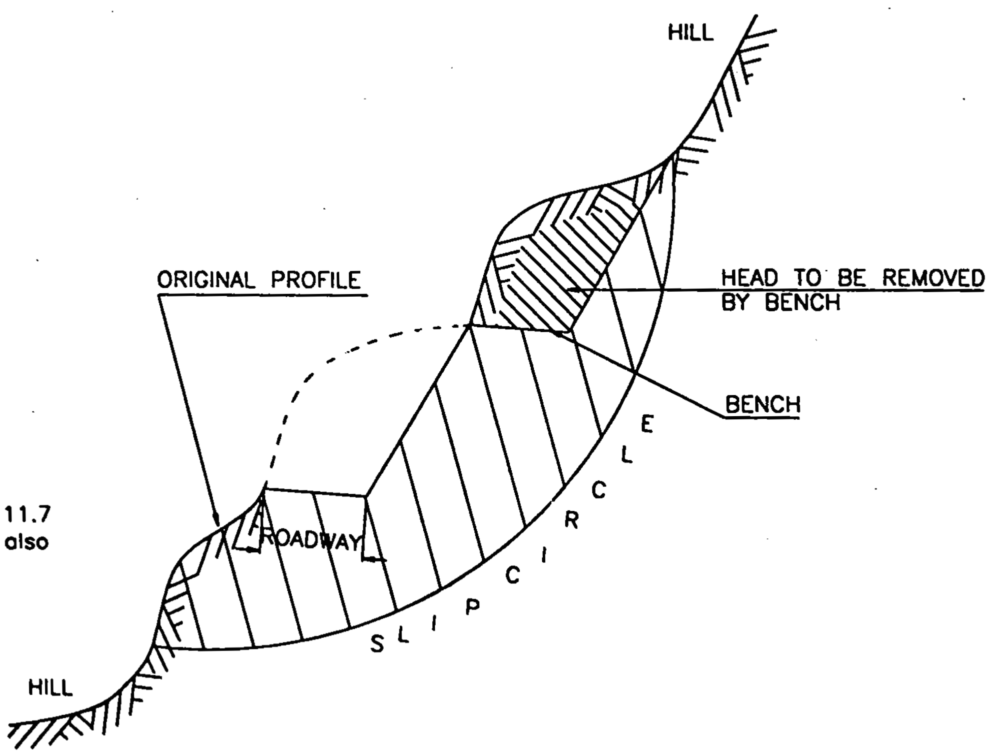


FIG. 11.14 CROSS SECTION OF TRENCH CUM SURFACE DRAIN



NOTE:
Refer Figs. 11.7 and 11.16 also

FIG 11.15. REDUCTION OF WEIGHT

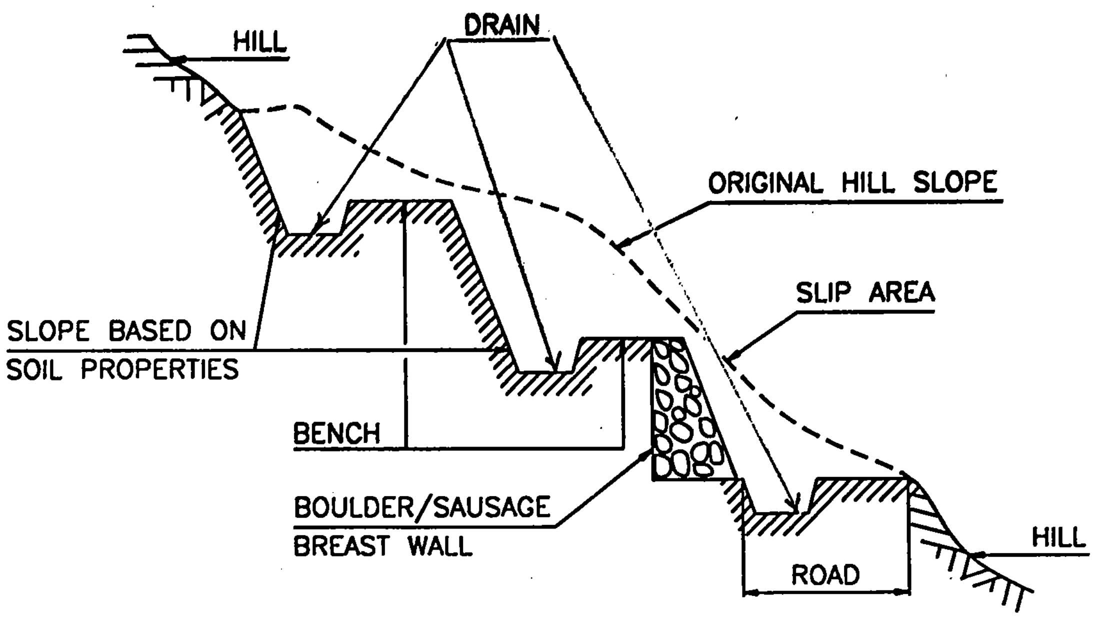


FIG 11.16. BENCHING

11.6.4. **Increase the resisting forces:** There are many methods available to increase the resisting forces of a slide surface. These methods can be grouped according to two basic principles. Restraining structures such as counterweight fills, buttresses, pile system and anchor system are the methods which apply a resisting force at the toe of the sliding mass. Other methods such as sub-surface drainage, slope treatment, slope stabilisation, etc. are essentially methods for increasing the strength of the material in the failure zone. These are described below:-

a) **Counterweight fills and their design:**

(i) Counterweight fills provide sufficient dead weight near the toe of the unstable slope to prevent the movement. These provide an additional resisting component thereby increasing the factor of safety against failure. The counterweight fill should be placed on a stable foundation layer with adequate depth. These must be designed to resist the driving forces, i.e. overturning, shearing and sliding at or below the base. Stability analysis can be carried out using standard procedures available. It must also be ensured that the counterweight fill itself is stable during as well as after the construction.

(ii) In general, cuts and fills have better effects in correcting deep seated slides where the steep slip surface falls near the crown. However, it is suggested that whenever the modification of slope profile resorting to cutting or filling, is contemplated an analysis of its effect on the factor of safety of the slope be carried out. Fig. 11.17, illustrates counter-weight fill on cut and fill method to increase stability factor.

b) **Use of Reinforced Earth Fills**

(i) The concept of reinforced earth has been developed and propagated by Vidal (1966). Earth retaining structures with vertical faces can be built using this concept. One of the major applications has been its use in building fills on side long ground and as counterweight fills to improve slope stability. As initially developed, for strengthening the soil mass horizontal metal strips of galvanized mild steel, aluminium and stainless steel were used as reinforcements. With the advent of geosynthetics, geofabrics and geogrids having high tensile strength, these are now used as reinforcement in the reinforced earth systems. As in the case of any gravity structure the internal as well as external stability must be ensured by proper analysis and design, of reinforced earth wall.

(ii) Reinforced earth fills require granular fills since good frictional resistance is required for developing the reinforcing effect. Fig. 11.18 shows the use of reinforced earth wall for controlling and improving the stability of the earth fill slopes. Reinforced Earth Retaining Wall is explained in Chapter 9 "Structures and Protective Works" also.

(iii) Reinforced earth walls have been constructed from as early as 1974 in many countries. The alternative would have been the construction of high retaining structures or viaducts which are costlier. The general behaviour of reinforced earth walls was found to be satisfactory, even under conditions where the hill slopes experienced movements. This is attributed to the good deformability of reinforced earth. In such situations rigid structures would suffer damages.

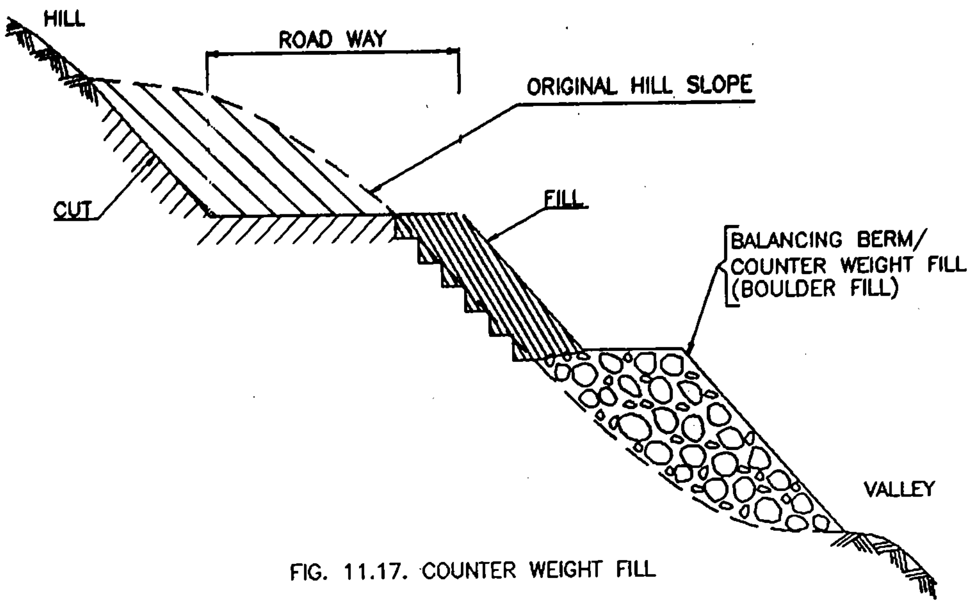


FIG. 11.17. COUNTER WEIGHT FILL

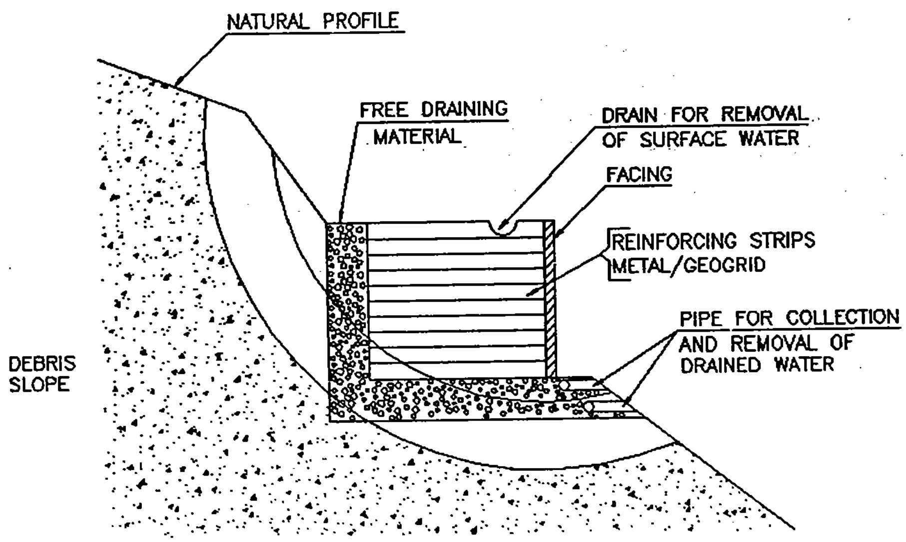


FIG. 11.18. REINFORCED EARTH WALL

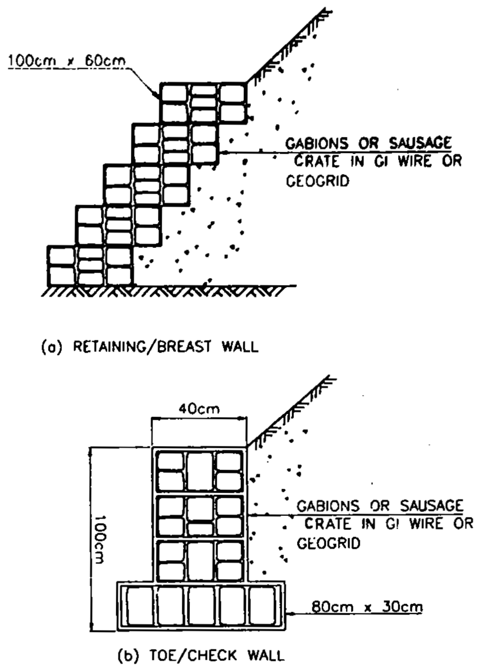
c) **Sausage walls**

(i) Sausage walls are made by forming sausages of Galvanized Iron or steel wire netting of 4 mm dia having 10 cm square or hexagonal openings and filling the sausages with hard local boulders/stones and wrapping the wire-net at the top. The process is carried out in-situ i.e. at the location where the sausage-walls are to be installed on the slide. Over the past 25 years, sausage walls have been used extensively on the Himalayan slopes. Unlike walls made of stone masonry, the sausage walls have the advantage of being able to withstand large deformations without cracking and are flexible. Further, because of the open structure, they allow free drainage of water.

(ii) One drawback that has been observed occasionally is that falling boulders may cut or break the wire mesh, thereby leading to the possibility of stones falling out of the sausage crates. However, with adequate attention, such damages can be rectified and the intergrity of the sausage walls maintained. If high humidity and other adverse climatic conditions prevail, rusting of wire may occur damaging the sausage casings.

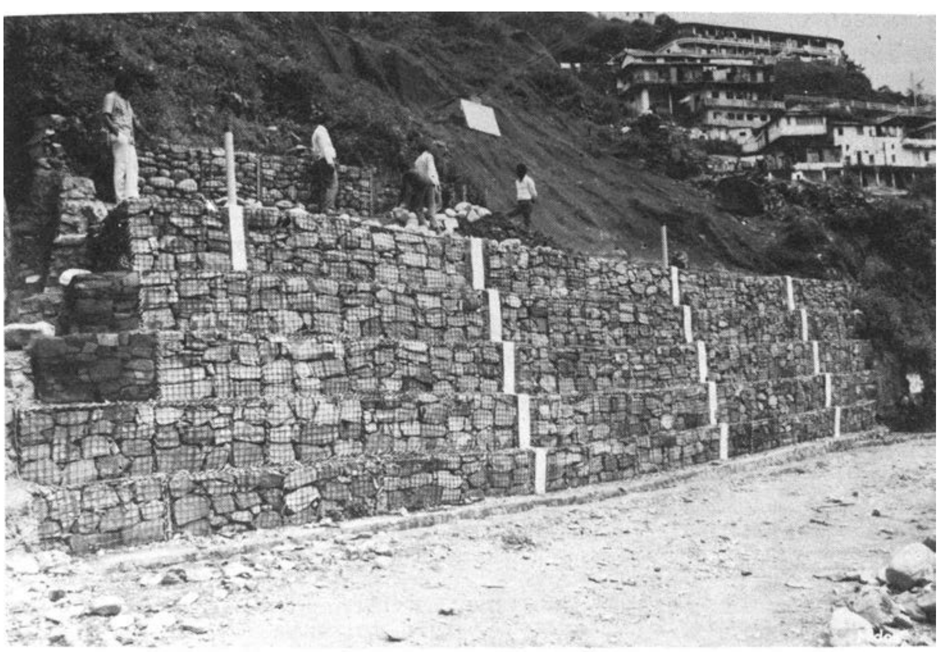
(iii) Of late, sausage walls (more commonly termed as gabions) are assembled from perforated geogrids. Geogrids, which are made of polypropylene, have high resistance to impact and weathering besides possessing good strength and elongation characteristics.

(iv) A row of sausage walls may be placed at the toe of the slide so that these serve to improve the stability of the slopes by their dead weight. It is a common practice to use sausage walls to serve as breast walls as well as in the middle of running slopes where they serve as check-walls. In such applications sausage walls help to retard the flow of water and reduce the surface erosion of the slope, to a certain extent. Fig. 11.19 illustrates sausage walls of various types.



VIEW OF GEOGRID GABION WALL

FIG 11.19. SAUSAGE WALLS



View of 16 m Wall Using Geogrids

d) **Restraining Structures:**

(i) Different types of restraining structures are used to protect slopes from moving. Retaining/Breast walls of masonry or concrete are such examples. Timber, metal, or concrete crib walls are also used as restraining structures. These structures have been dealt in detail in Chapter 9 "Structures and Protective Works". In Fig. 11.19 retaining/breast walls in sausage have also been shown. Restraining structure are often used where due to the limitation of space it is not possible to flatten the slopes.

(ii) **Crib Walls**

Crib walls can be used as restraining structures and may be made of reinforced concrete or steel members. The vertical posts are connected by horizontal members and allow free drainage. These are suitable for small slides that are not deep seated. An arrangement is illustrated in Fig. 11.20.

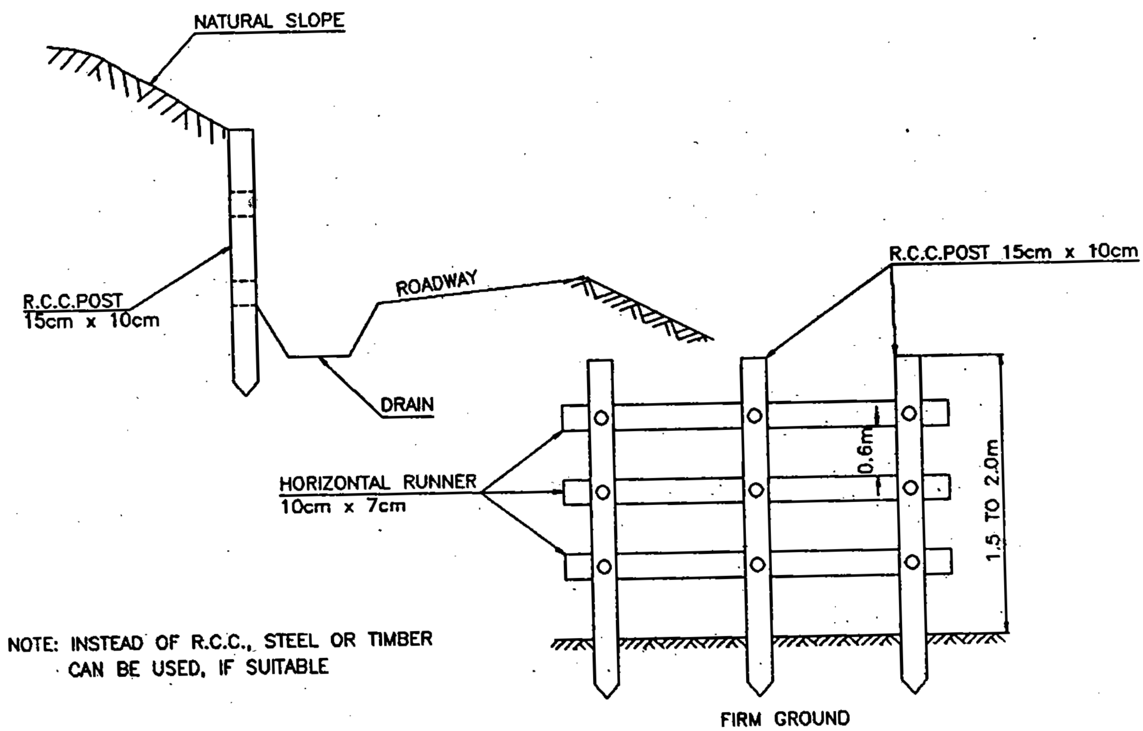


FIG. 11.20. R.C.C. CRIB WALL

(iii) **Timber piles**

Can be used for stabilisation of small and relatively shallow potential slides. For stabilising the slope, the piles, preferably of hard wood, are driven vertically into the slope with the help of monkey hammer, operated manually or by any other suitable means. The size, spacing and number of rows of the piles may depend upon the local requirements. In a slide area, the piles may be driven into the body of the slide so that the same are anchored into firm strata beneath. Such groups of piles/rows can be repeated on top and toe in shallow failure areas of the slide, if necessary.

The piles should not be driven into soils which are susceptible to liquefaction. The longevity of the wooden pile may be increased by treating them with protective agents such as creosote oil. Such a treatment is essential if the area is infected with insects like white ants, etc.

Timber is a forest produce and extraction of piles denudes forest and may cause environmental de-gradation. As such, this practice may be followed only where timber pile availability is plenty and regular system exists for re-plantation and where forest is not adversely affected.

e) **Improving the strength characteristics of slope soil**

The strength properties of a slope material can be improved by various chemical and physico-chemical methods such as stabilization using lime, lime slurry injection, electro-osmotic hardening or thermal hardening. However, the use of such methods for slope stabilisation is adopted only rarely.

11.7. Control of Erosion of Hill Slopes

11.7.1. Hill slopes are subject to erosion from flowing water leading to the foot of hill slopes. Cutting of forests increases the erosion potential. The debris carried away by the flowing water may damage the slopes downhill and choke the streams. It has also been found that, erosion, if unchecked, tends to produce mass movements in the shape of landslides. Thus the slope degradation by surface erosion has a multiplier effect. It is more economical to control the damage at the initial stage itself i.e. when it is existing as surface erosion.

11.7.2. Majority of slope stability problems in hill areas have their origin in cumulative erosion of hill slopes. It has been repeatedly observed that the combination of rainfall, soil type and slope conditions in these areas favour the occurrence of shallow erosion type of landslides. Plantation of grass and shrubs to restore the vegetative cover has been found to be successful in arresting this type of mass movements. The presence of vegetative cover is beneficial to the stability of slope in a number of ways as enumerated below :

a) Surface erosion will be controlled. If some remains unchecked, there is a high probability that the erosion may extend deeper and wider and eventually endanger the stability of the slope.

b) Infiltration of water into the slope will be controlled, thereby reducing the build-up of pore pressure. Decrease in factor of safety is directly proportional to the increase in pore pressure.

11.7.3. Growth of vegetative cover and the spread of root-network to an approximate depth of 0.5 to 1.0 m depth help to improve the overall stability of the slope as brought out by field experiments carried out on different hill slopes for erosion control. Certain methods are described below

a) **Asphalt mulch treatment:**

(i) Field trials have indicated that the asphalt mulch technique is effective in controlling erosion of hill-slopes by providing suitable vegetative turfing. For this treatment, the proposed slope area is prepared into vast seed beds by levelling of the top, regrading or reshaping and finally raking the top soil about 2 cm thick. If the soil is infertile or slightly acidic, calcium ammonium nitrate is applied at the rate of 50 kg. per 1000 sq.m. in solution. The root slips or locally available grasses are dibbled 15 to 20 cm apart, root to root and row to row. An asphalt emulsion (mulch) of a specified grade is then spread by a suitable sprayer. The optimum rate of application of the emulsion is 0.9 litre per sq.m i.e. just a thick film.

(ii) The asphaltic film gradually disintegrates and its place is taken by a carpet of green vegetation and the deep rooted species of grasses, clovers, etc. The advantages of this technique are:

(aa) Susceptibility to erosion is cut down.

(ab) The moisture content as well as the nutrients in the soil mantle are conserved.

(ac) The soil temperature is raised by absorbing light rays, promoting the emergence and growth of tiny saplings.

(iii) This method, if done just before the monsoons, the increased moisture content due to rains automatically helps in the growth of saplings.

b) **Slope treatment by jute/coir netting**

(i) Field trials have shown that jute/coir netting are promising techniques for erosion control especially where problem is of surficial nature. The slopes are initially demarcated, graded, fenced and fertilised as in the case of asphalt mulch technique cited above. The levelling of the area in this case must be uniform so that the netting laid is flush with the ground, permitting water to flow over the matting. Initially seeding at the rate of 5 kg per acre or dibbling of the root slips of locally available grasses 15 cm apart row to row and plant to plant is done. After that light compaction of seeds and root slips is done by tamping.

(ii) Thereafter, jute or coir netting with 1.27 cm to 2.54 cm opening size and in widths of 1.0 m to 1.22 m is laid on the prepared ground surface. The widths of netting are secured against displacement by an overlap of 5 cm to 8 cm and pegged down with staples of 3 mm GI wire, 30 cm to 60 cm apart. The top and bottom ends of the nettings are fixed in slots of 30 cm deep fully stretched. Subsequently another dose of light fertilizer and seeding is given.

11.7.3.1. The main advantages of this techniques are:-

a) The net provides innumerable miniature check dams thus absorbing the impact and kinetic energy of the falling rain drops and water flow.

b) The soil, seed and slips are kept in-situ without being dislodged and are protected by getting the full benefit of moisture. The technique is simple to use and inexpensive and thus merits widespread use to improve the stability as well as the ecology of slopes that have been denuded by either mass wasting process such as landslides or due to man made cause such as clearing of existing forest. A view of this method is shown in Fig. 11.21.

Slope Covering with Grass through the Net

Fig. 11.21

11.7.4. Bally benching: Bally benching is used for control of surface erosion on slide areas as well as for arresting shallow movement of the top mantle of slide mass. This technique can also be used effectively in preventing the deepening of gullies/chutes, caused by the eroding action of flowing water. During rains, the surface flow generally results in gully formation on slopes. Such gullies, if allowed to deepen, induce instability in the slide slopes which eventually fall/slide down and help the gullies to widen. Latter this phenomena can result into a potential landslide. Barrier/bench system helps in densification of soil material surrounding the ballies thereby increasing the strength of the slope, prevents the shallow movement of the loose mantle and retards the speed of surface water responsible for gully formation. Typical arrangement is shown in

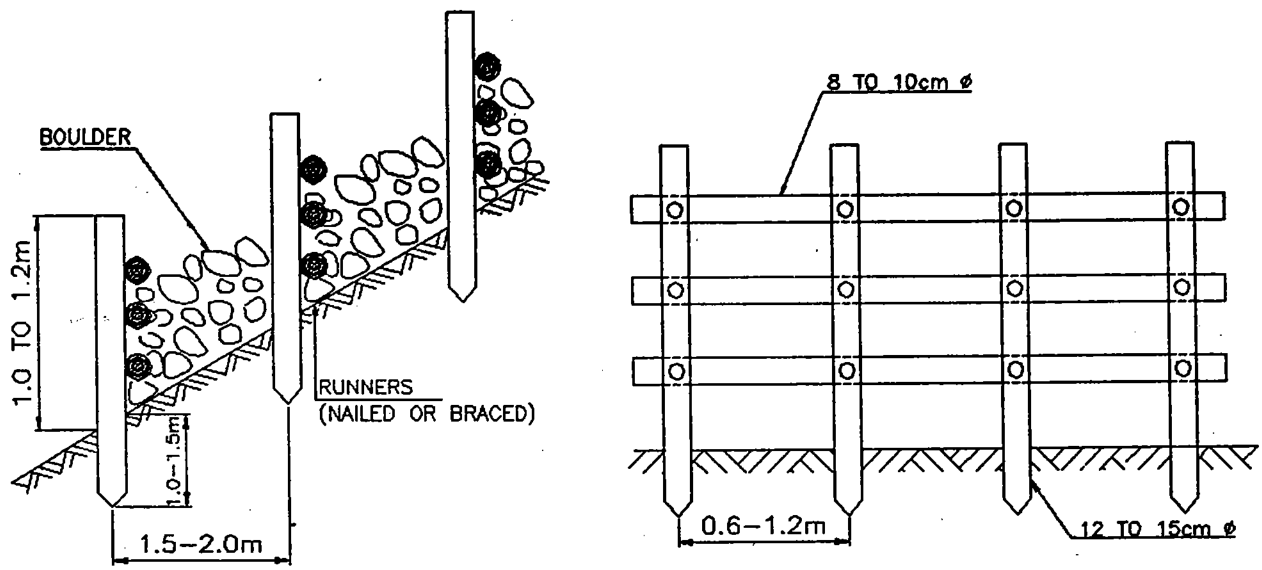


FIG. 11.22. BALLY BENCHING

11.7.5. Sealing of tension cracks: Tension cracks are usually present in all slopes affected by instability. These are produced due to the strains caused by the incipient mass movements and are thus indicators of impending instability. Cracks have been observed with widths ranging from a few millimeterers to as much as 100 cm or more. These open cracks serve as a direct path for the infiltration of surface run-off water, enabling it to reach deep into the slope mass, thereby further decreasing the factor of safety of the slope. It is, therefore, important to seal the tension cracks effectively to prevent any ingress of water.

11.7.5.1. The procedure adopted in sealing the tension cracks is that a trench of about minimum 50 cm depth and 50 cm width should be cut all along the length of the cracks. The excavated material should be mixed with water to make up to the optimum moisture content for filling the trench. At first the deeper parts of the cracks should be filled up by rolling and tamping thoroughly with crow bars. The filling of the trench should be done by spreading the wet soil at O.M.C. in layers of 15 cm and compacting by hand rammers.

11.7.5.2. The top layer should be finished such that the original shape/gradient of the slope is retained to the maximum possible expert. The filled up surface over the tension crack should then be made water proof by evenly spraying it with bituminous cutback of following composition viz. Bitumen (1.0 kg), Kerosene (0.6 kg) and Paraffin Wax (0.01 kg). The bitumen should be first heated to about 110°C and removed away from the flame and other two components added. The mixture may be sprayed with a garden sprayer, at an average rate of 0.2 kg per sq. metre.

11.7.5.3. Sealing of tension cracks should be considered as a regular maintenance measure and not as a one time remedial measure. The slopes should be inspected before the onset of monsoons and tension cracks sealed. As may be seen from above, sealing of tension cracks is an inexpensive measure and the returns in form of improved slope stability are very high as observed at a number of slide locations in practice.

11.8. Rock Slope Protection

11.8.1. Hill slopes composed of rocks are prone to generate rock fall and rock slide hazards. Falling rocks, especially, are highly dangerous to life and property because of the large momentum they acquire in motion. The volume of rock affected by instability may range from isolated boulders to enormous volumes involved in rock slides. It has been a common experience that long after the construction has been completed, rock fall or slide incidence can occur.

11.8.2. **Cutting of slopes in rock:** The quality of rock which is commonly designated by qualitative index or RQD can be of help to the engineers in qualitatively assessing the overall stability of slope. The relation between RQD (Kraatx, 1964) and the description of rock quality is given in Table 11.2.

Table 11.2. RQD Vs Description of Rock

IS 12070-1987 RMR Rock Mass Rating	RQD (per cent)	Description of rock quality
0-20	0-25	Very poor
21-40	25-50	Poor
41-60	50-75	Fair
61-80	75-90	Good
81-100	90-100	Excellent

$$RQD = \frac{Lc}{La} \times 100 \text{ where}$$

Lc = Total length of intact pieces > 100 mm long
La = Total length of core advance

If the hill slope under consideration has no major fault planes or shear zones nearby, RQD can have a significant influence on the stability. In general, a tendency exists for adoption of experience based rule of thumb procedures when dealing with stability of rock slopes.

However, it would lead to safer and economical rock slopes if proper design methods are adopted to evaluate the stability of rock slopes as well. Rough guide for the slopes or cuts in rock is given in Table 11.3. However in adopting this table, caution must be exercised and such factors as the influence of dip in relation to the inclination of the slope face, the nature of joints etc. must be kept specially in mind.

11.8.3. Review of methods of rock slope protection: A number of methods are available for the control of rock slope instability. Some of the methods by which rock slides can be controlled for protection from rockfall hazard are listed below:

(a) Shortcreting of slopes
(b) Grouting
(c) Provision of rock collecting trenches
(d) Benching of slopes
(e) Provision of rockfall fences, fixed or swinging type
(f) Provision of protection sheds, tunnels or covered galleries
(g) Provision of rock bolts and anchors
(h) Covering the slope with coir-netting or geogrids

Table 11.3 Slopes for Bed Rocks Cuts

Rock type	Range of permissible slope (Horizontal : Vertical)
Sedimentary Rocks	
Massive sand stones and limestones	1/4 : 1 to 1/2 : 1
Inter bedded sand stones, shales and limestone	1/2 : 1 to 3/4 : 1
Massive clay stone and slit stone	3/4 : 1 to 1 : 1
Igneous Rocks	
Granites, Trap, Basalt and Lava	1/4 : 1 to 1/2 : 1
Metamorphic Rocks	
Gneiss, Schist and Marble Slate	1/4 : 1 to 1/2 : 1
Slate	1/2 : 1 to 3/4 : 1

11.8.3.1. The above methods may be used either singly or in combination and are described below:-

a) **Shotcreting**

Shotcrete consists of cement mortar with aggregate upto 20 mm size, and is applied to the surface by an air jet. Thickness of layer deposited varies from 70 mm to 100 mm. Prior to the application of shotcrete, the slope could be thoroughly scaled of loose rock pieces. The process requires special machinery and trained personnel. Sometimes a steel mesh is bolted to the slope face before shotcreting is done. It is desirable to insert pipes into the rock slope to provide drainage and avoid build-up of pore pressure after shotcreting is done on the slope.

b) **Grouting**

Grouting is used to improve weathered slopes from which rocks or boulders may be falling. Proper type of cement grout and safe injection pressure have to be determined carefully. Stringent quality control has to be exercised on mix proportions, water content, grout pressure, etc., during the grouting operation. Grouting is a costly remedial measure and is recommended for use only in exceptional situations.

c) **Collecting trenches and fences**

By providing suitably placed benches or ditches that intersect the trajectory of the falling rocks, the roadway and other structures can be protected from the rockfall hazard. Yet another method is to provide a protective fence. The location and height of the fence can also be determined on the basis of the possible trajectories of falling rocks. Such fences are of two types i.e. fixed and swinging. In some instances instead of fences gabion walls or sand bags are provided on the slope or on a bench or ditch to retain or stop the moving boulders or attenuate their momentum. An outstanding example on the use of rack-fence in India is the swinging fence across Khooni Nallah bridge rock-fall area in J&K on NHIA. A view of the same is given in Chapter 16 Fig. 16.5.

11.8.4. **Rockfall control using geogrids:** Rockfall hazard can be mitigated by use of geogrids. In this technique, the susceptible slope is covered with a geogrid mesh. To fix the geogrids on the slope, stable part of the slope area not forming a source of rockfall, has to be first identified and located. This area will normally be situated some distance beyond the periphery of the slope affected by instability. At their end, the geogrids are rigidly fixed by suitable anchors. In general, the fixing procedure involves a trench to be made on the stable part of the slope and iron bolts are fixed in the trench which is then filled with cement concrete. The geogrid roll is fixed to the iron bolts with help of clamps and nuts. The geogrid is then rolled down the slope ensuring that the roll generally follows the contours of the slope. The remaining edges of the geogrid are then fixed by driving 'T' roads into the slope so as to maintain good contact between the geogrid and the rock slope. Geogrids are manufactured from selected polymers by a special process that aligns the molecular chains of the polymers and thereby produces material of high tensile strength and high resistance to natural ambient conditions.

11.8.5. **Rock bolts and prestressed anchors:** Rock bolts and anchors are used to strengthen, reinforce or tie together unstable blocks or beds of rocks.

11.8.5.1. The use of rock bolts is normally confined to keep in place shallow layers of rock. The bolts exert a compressive force so that relaxation, exfoliation and elastic rebound of rock layers are prevented. The design is based on the shear resistance along the discontinuities identified for improvement. If the surface layers of rock are in a weathered state, the bolt head is likely to experience a loss in tension. Under such conditions, the rock face under each bolt head must be protected by fixing wire mesh set in shotcrete. Normally the design load does not exceed 60% of ultimate strength of bolts.

11.8.5.2. Prestressed anchors are used when it is required to stabilise a rock slope against the possibility of deep seated failure. High tensile steel tendons or cables are commonly used to provide the prestressing force. However, before grouting fixed end of anchor, it is necessary to grout fissures in the rock. The procedure therefore should be, making the boreholes, water pressure test and if the borehole stands water pressure, grouting the fixed end of anchors. Otherwise, grouting the borehole and reboring and grouting the fixed end of anchors thereafter. After the grout has set reinforcing cable is stretched to impart a calculated magnitude of prestressing force to the rock mass and then the cable is fixed to the anchor plate. Prestressed anchor is an expensive remedial measure and is used only where there is no other alternative. Prestressed anchors have been used to improve the stability of rock slopes beneath Khooni nallah bridge [mentioned in para 11.8.3.1 (c) above] and to improve the stability of hill slope in Shimla area in Himachal Pradesh.

11.9. Instrumentation and Monitoring

11.9.1. Field instrumentation and monitoring is a requirement for detecting signs of impending instability as well as post-slide movements. Observational data on vertical and lateral surface and sub-surface movements, and piezometric pressures within the unstable slopes are necessary for evaluation of stability and design of control measures.

11.9.2. The instrumentation programme should be planned to provide the basic information of the following aspects:

a) Monitoring of the build-up and dissipation of pore water pressure at different points in the slide area, specially around the failure plane.

b) Measurement of sub-surface movements and

c) Measurement of surface movements.

Fig. 11.23 gives layout of instrumentation for monitoring a slope. The section gives a brief outline only of the instruments.

11.9.2.1. **Monitoring of pore water pressure:** Monitoring pore pressure is essential for effective stress analysis of the slide prone area. Pore pressure measurements are required specially around the failure plans for control measures to be adopted as well as for mitigating potential slides. Piezometers are installed for this purpose.

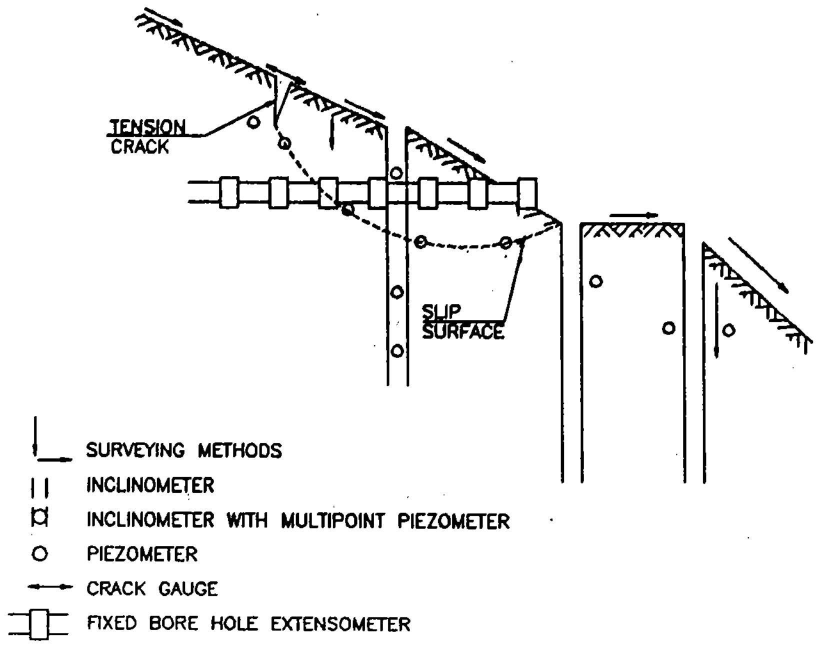


FIG. 11.23. TYPICAL LAYOUT OF INSTRUMENTS FOR MONITORING A SLOPE

11.9.2.1.1. A number of piezometers are available for this purpose. These piezometers are broadly classified into three categories.

a) Hydraulic piezometer
b) Pneumatic piezometer and
c) Electrical piezometer.

11.9.2.2. **Monitoring of subsurface movements:** Analysis of a slide gives an indication of probable failure arc. Normally, the sliding surface can not be observed visually nor it is apparent from surface measurements. The knowledge of actual deep seated failure plane is of use in back calculation of factor of safety and for properly understanding the mechanism of sliding. The data is also of utility in designing remedial measures, such as restraining structures. Inclinometers enable quantitative measurement of lateral movement of slopes. The instrument not only gives the lateral movement but also reveals the direction of movement and rate of lateral movement.

11.9.2.3. **Monitoring of surface movements**

11.9.2.3.1. Surface movements may be horizontal or vertical. Horizontal movements are measured with surveying methods. This primarily involves distance measurements. Vertical movements are measured with settlement gauges. To measure the subsidence or horizontal surface movement pegs or surface markers are fixed at a number of predetermined points on the surface. Their vertical and horizontal positions are monitored periodically with the help of a theodolite. With the advent of Electronic Distance Measuring Devices, called EDM devices, the same can be used for monitoring surface movements. All the measurements are taken from a fixed observation post or permanent bench marks which are installed at a place not likely to have any disturbance and is located away from the zone of slide.

11.9.2.3.2. Apart from the general surveying methods, photo-grammetric methods, surface extensometers, rock gauges, covergence gauge of various types using mechanical, electrical or electronic gadgets are also used in monitoring surface movements.

11.9.2.3.3. Surface vertical movements are also measured with platform gauges, extensometers, hydraulic settlement gauges mercury settlement/heave and magnetic settlement/heave gauges. Some inclinometers are also combined with extensometer for monitoring vertical settlements. Surface measurements of inclination or rotation is monitored with tilt meters. This also contains a gravity sensing transducer which may be mechanical, electrical or electronic.

11.9.2.4. **Warning devices:** The main aim of instrumentation is to provide timely warning against incipient instability of a slope. The installation of warning devices on hill slopes helps the detection of an impending slope movement and thereby provides time for taking precautionary measures to prevent any loss of life and property due to landslide.

11.9.2.4.1. Some warning devices are mainly simple slide fences with alarm buzzers. Inclinometers, extensometers and piezometers can be coupled with alarm buzzers. These instruments are pre-calibrated to sound alarm signals at a predetermined rate of movement or increase in a particular parameter.

11.10. Proforma for Data Collection

11.10.1. A systematic collection of data helps in proper study of landslide problem thereby leading to a correct identification of landslide mechanism and choice of appropriate remedial measures. Use of standardised proforma for data recording also helps in setting up a data bank of landslides and interchange of information between experts belonging to different disciplines concerned with landslide studies. The correction of landslides continues to be as much of an art as a science. Properly recorded and analysed case histories are of unique value in evaluation of the range of applicability of various theoretical models used in the analysis. Further, stability and efficacy of remedial measures can also be determined with the help of such recorded case histories.

11.10.2. A proforma for collection of data regarding landslides is given below.

PROFORMA FOR COLLECTION OF DATA REGARDING LANDSLIDE OCCURRENCE AND CLEARANCE

1.1. Location
- i. Name of the Road:
- ii. National Highway No.:
- or State Highway No:
- or Other roads:
  Name of the Category No.:

1.2. Location of the Slide:
- i. Name of the place:
- ii. at Km from:
- iii. Name, if any, by which the slide is commonly referred to

2.0. Data to be collected regarding the slide when it is active:
- a. Date of sliding:
- b. No. of times sliding has taken place in the year:
- c. Duration for which road was blocked by the slide No. of days/hours
- d. Damages to propety or persons caused by the slide:
- e. Quantity of material cleared:
- f. Method of clearance; Manual/or by machine and the time taken for clearing:
- g. Cost of clearance operation:
- h. Were any permanent stabilising measures executed since last sliding and if so, their efficacy:

i. Is the slide preceded by rainfall or snowfall?

j. Is extent of area participating: in sliding

   i. confined to uphill slide of road only
   ii. confined to downhill side of road only
   iii. Covers both:

k. Is the cause of slide due to man made causes such as back-cutting, etc.:

l. Does the slide appear to be a surficial one or a deep seated one:

3.0. Standard information/data to be collected about the slide:

3.1. Prepare a sketch of the slide area covering the slopes both uphill and downhill of the road and include the following information

a) Length of slide from crown to: toe, indicating separately the length affected both above the road and below the road

b) Width of the slide (parallel to the road):

c) Maximum depth (Normal to the slide)

d) General description of the slide area giving condition of the slopes, presence of erosion gullies, presence of water springs, tension cracks etc.

Note: The sketch and the associated data should be updated after each major sliding/movement

3.2. **Geological Data**

a) Nature of rock

Indicate whether the slide material is predominantly rock or soil, decomposed rock or disintegrated rock or a mixture of both

b) Type of rock and formation

i. Indicate the type of rocks met within the formation

ii. Indicate whether there is any inter-bedding involving especially slide susceptible formation such as shales or sandstones

c) Dip and strike

Indicate the dip and strikes of the rock formation and note whether they are favourable or unfavourable for slide formation with reference to the location of the road at the particular stretch

d) Weathering

Indicate whether the rock is subject to weathering or other degrading process due to natural or man made causes

3.3. **Geotechnical data**

a) Nature of the soil

i. Give the classification of soil (or soil fraction of the mantle material) and identification data according to standard soil mechanics procedure

ii. Is there any pre-consolidated clay or shale met with?

b) Alteration of forces acting

i. Has there been any increases in the load due to construction of embankments or structures or accumulation of slide material? :

ii. Has any construction work been carried out that adversely influences the stability, such as under-cutting the toe etc.?

iii. Has the slope been subject to vibrating action of either construction equipment or due to earthquakes or due to blasting?

c) Action of Water

i. Has any water or seepage been noticed at the joint planes or along the slide surface or in clay strata?

ii. Give a brief description of the drainage conditions prevailling in the slide area.

iii. Are there any sources of water flow nearby, such as a lake or reservoir or a river etc.?

3.4. Causes of slide

Landslides are normally caused by a number of factors rather than a single factor. Indicate which in your opinion are the predominant causes, and give, if possible, the order of their relative predominance.

a) Geological Causes

i. Weathered rock, disintegrated and/or decomposed rock, due to various reasons like temperature changes, frost effects, other natural or man made causes, etc.

ii. Joint planes dipping unfavourably

b) Geotechnical Causes

i. Increase in load causing sliding due to any construction or accumulation of slide material or snow.

ii. Reduction in resisting forces caused by excavation at toe.

iii. Increase in water content of clayey layers due to rainfall or seepage, bad drainage, sudden draw-down, rise in water level in lake upstream.

iv. Interbeds of clay or shale or micaceous matter that are susceptible of being softened by the action of water.

3.5. Classification of slide:

Give the classification of the slide according to the Varness system of classification.

3.6. Remedial measures:

a) Has the slide area been studied for evolving remedial measures?

b) If so, by which organisation?

c) Give a summary of the major recommendations

d) Were any/all of the remedial measures implemented? If so, detail them

e) What is the degree of success met with in stabilizing the slide area?

3.7. Recommendations:

a) Comment on future action you suggest

b) Likely behaviour in future

3.8. Any other aspects

a) Comments on any other aspects not covered above

11.11. Simple Guidelines on Prevention and Correction of Landslides

11.11.1. In general, landslides represent a complex phenomenon. Factors such as the composition of the slope viz. the mixture of soil and rock debris, jointed nature of rockbeds with varying thickness of beds and spacing of joints, presence of inter-bedding, shear and fault planes, weaker gauge material, etc., contribute to this inhomogeneity. The built-in stresses arising from the past tectonic history are not susceptible of rational estimation but affect the slope stability profoundly both in the short term as well as in the long term. Prime causative factors such as rainfall have a highly random distribution in terms of intensity, duration and temporal as well as spatial incidence of slides. To these complexities has to be added the effect of developmental works in hill areas on the stability of slopes. Thus, the prediction, analysis and correction of landslides is rendered a truly challenging task.

11.11.2. It thus follows that considerable amount of field survey, boring, sampling and testing is required for carrying out a reliable analysis of the stability of slopes on which to base the remedial measures. An observational procedure of monitoring the surface movements, normally forms an integral part of systematic landslide studies. However, given the various constraints of time and money, such elaborate procedures are resorted to in case of landslides of major significance where a combination of remedial measures is essential. Simple, easy to use guidelines are sought for the practicing engineer to deal with routine type of slope stability problems.

11.11.3. The incidence of landslides along a given road may be minimised by adopting some precautionary measures. In case of relatively small landslides, remedial measures can be undertaken on the basis of their suitability for the particular slide as judged from past experience as to whether or not the particular remedial measures provided were satisfactory in the area.

11.11.4. Precautionary surveys:

a) A majority of landslides are induced by rainfall or due to surface erosion. Thus, good drainage of the slope assumes great importance. The slope stretches prone to slide or those with known history of instability should be checked carefully before the onset of monsoon, paying particular attention to the following factors.

b) The engineer should observe and note such visible features as bulge in the pavements or at the toe of the slope, broken pipes, tilting of trees, distress in buildings, which are indicative of ground movements that may eventually lead to a landslide.

c) Such inspections should not be confined merely to the road width but should encompass the uphill and downhill slopes as well. A trained observer can obtain a great deal of information on the various factors affecting the stability of the slope.

d) Condition of surface drains such as catch water drains, chutes, etc., and any signs of chocking of these drains or cracking of the bed, if observed, should be repaired immediately.

e) Choked culverts and road side drains should be cleared of any debris.

f) Tension cracks are tell-tale signs of impending instability. Water seeping through the tension cracks has the effect of increasing the instability of the slope. All slide prone areas should be inspected periodically for the presence of tension cracks and the same should be sealed following the procedure described earlier. This should be treated as routine maintenance measure and helps to substantially reduce the incidence of slope instability.

g) Denuded slopes are more susceptible for eventual mass movements. It is highly desirable that a slope regeneration programme be adopted to promote the vegetative growth on eroded slopes. A suitable method, from among these discussed in the earlier sections, may be adopted for the purpose.

h) Where earth fills with high retaining walls exist, it should be ensured that the backfill used is having good drainage characteristics. The earth pressure exerted by a saturated fill is nearly double that in the unsaturated state. Weep holes or other drains should be cleared.

i) In case of deep seated complex or recurring slides, it is essential that a thorough stability analysis, including an evaluation of the response of the slope to changes in significant parameters, such as piezometric levels, shear strength parameters, etc., should be carried out. It is desirable that an expert organisation is consulted for this purpose.

11.12. Illustrations

11.12.1. The following sketches, views and figures are given:-

a) View of two landslides in Garhwal Himalayas - Figs. 11.24 & 11.25.

b) Control measures marked on plan of one slide - Fig. 11.26.

Panoramic View of Mussoorie Slide

Panoramic View of Kaliasaur Slide

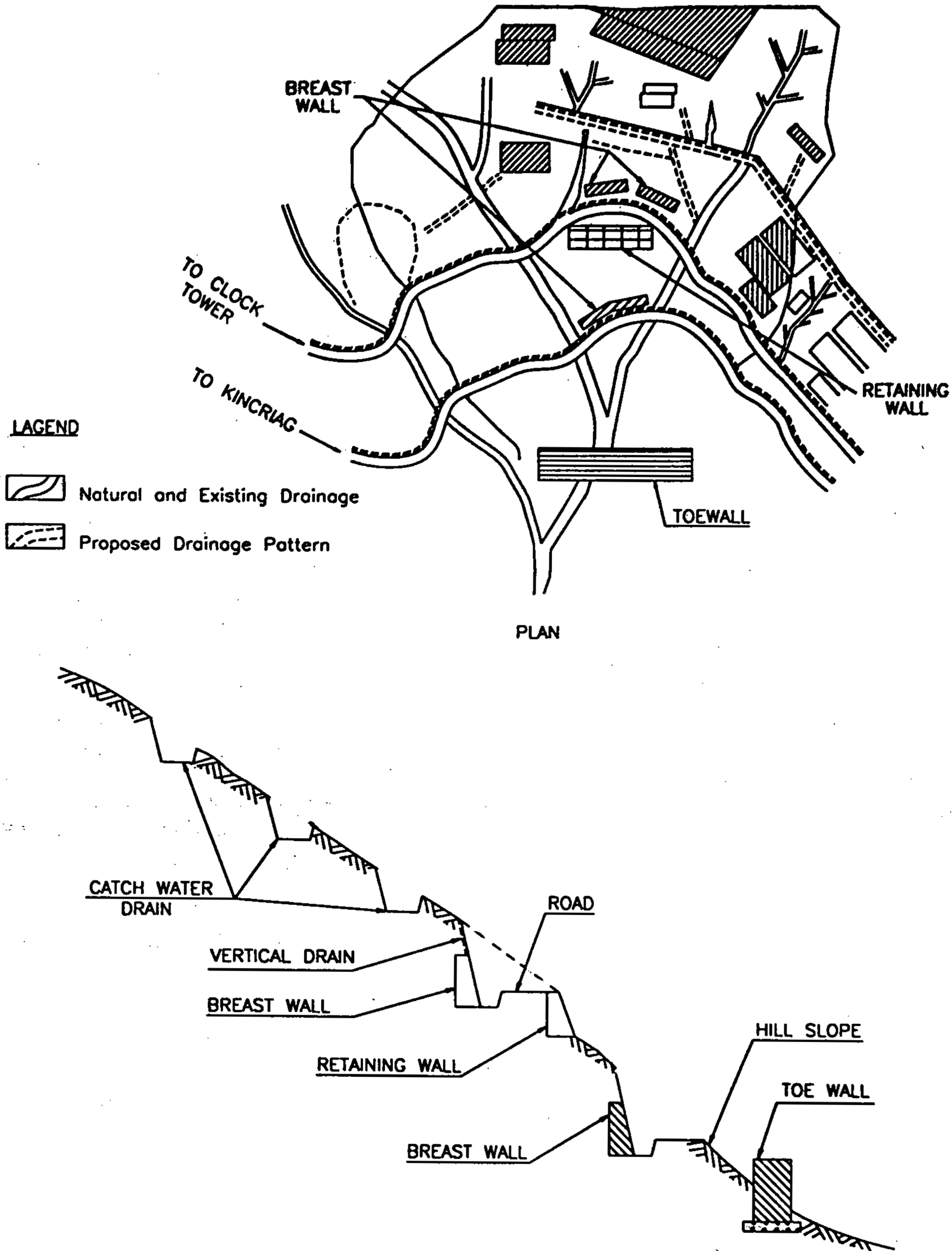


FIG. 11.26. CONTROL MEASURES FOR A SLIDE
(SECTION AND PLAN)

11.13. Final Analysis

11.13.1. The performance of a hill road is directly proportional to degree of stability of slopes on which it has been built.

12. SNOW CLEARANCE AND AVALANCHE TREATMENT

12.1. Introduction

12.1.1. A large number of roads have now been constructed in the Himalayas, especially in high altitude area. Many of these roads run over high passes, having altitudes above 3000 M and through snow belts and avalanche prone slopes. Large stretches of these roads normally remain closed for six to seven months in a year due to heavy snow fall during winter months and consequent accumulation/compaction of snow at low temperatures, snow drift and avalanches. Keeping these roads open to traffic for longer periods during the year is of vital importance not only for strategic reasons, but also for the welfare of the people living in these areas. The prevailing environmental condition in these areas necessitate specialised methods of snow clearance of roads and avalanche control to minimise the road closure period.

12.1.2. Studies pertaining to snow, ice and related manifestations are only about 20 years old in India and the Snow and Avalanches Study Establishment (SASE) is engaged in research and development in the field. Keeping a road open in snow bound high altitude in winter as against closing for winter months would depend on road user requirements and practicability of keeping the road open in winter coupled with the financial outlay involved.

12.1.3. In this Chapter it is aimed to outline the most practicable procedures and solutions to problems concerning snow clearance based on experience gained in the last 30 years on roads in the Himalayan region.

12.2. Terrain, Geology and Climatic Conditions

12.2.1. **Terrain and geology:** These roads run at altitudes ranging between 2500 m to 5000 m. Most of these roads are above the tree line and in very scantily populated areas. Only grass and rhododendrons grow along these roads. The soil in the area is mostly of glacial origin and consist of metamorphosed, stratified and schistose rock formation which distingegrate under extreme weather conditions. The portion covered with fluvio-glacial materials are very unstable and prone to slide.

12.2.2. **Climatic conditions:** Rainfall is very heavy and goes upto 500 cm in the Eastern Himalayas, even in high altitude snow fall areas, whereas in Western Sector it ranges from 150-250 cm in lower ranges but scanty in higher altitudes. The winter temperature, depending upon the altitude and the place could be as low as -35°C (The temperature goes down to minus 50° in certain areas). In summer the day temperature may be as high as 30°C. Velocities of wind exceeding 80 km/h are common, especially near the high passes. The chilling effect of the wind in winter could be devasting and during this period snow clearance operation is near impossible. A chill temperature chart would help as a guideline for working conditions during the worst spell.

12.3. Properties of Snow and Its Effects on Snow Clearance

12.3.1. **Snow pattern:** The snowfall season begins with the onset of winter transition and as such the first snowfall in the higher altitudes of the Himalayas may occur some time towards the end of September. However, these events may be sporadic till the end of October and also snow melt may take place rather rapidly in autumn as the land surface has stored sufficient heat during the preceding summer season. Subsequently mid-latitude storms and their extension equator-wards, with the advance of the winter season, results in accumulation of the snow in depth as well as in extending it towards the greater Himalayas and even on its lower ranges. Thus, by January-February, during the peak of the winter season (this period constitutes the heavy snowfall period), snow accumulation is expected to be maximum.

12.3.1.1. Snow melt, atleast in the lower Himalayan ranges and in the latitude belt 30^{o}-40^{o} N, may begin from April and within about 4-8 weeks (May-June) almost all the snow may melt away with the advance of summer season. Thus, in July-August snow is expected to remain only on high mountain ranges near and above what is called the "permanent snow line".

12.3.1.2. Snowfall occurs in spells or storms spread generally over a period of four months, duration of individual storms varying from one to seven days. The intensity of snowfall in individual storms has a greater effect on snow clearance operations than the total snowfall. High intensities of snowfall above 3 to 4 cm/hour are quite common in the Western Himalayas.

12.3.2. **Type of snow**: Snow is a mixture of ice, water and air. It may be classified physically as crystalline, granular, powdery pallet snow or mixtures. Crystalline snow has good internal cohesion. Freshly deposited snow is a highly porous permeable aggregate of ice grains. Snow type is drier in western sector than in eastern sector. Fresh snow in a powdery and granular condition, is easy to clear but if the snow is allowed to accumulate, it gets compacted and hardened over a period of time rendering subsequent snow clearance difficult. The lower layers get hardened and dense, become icy smooth and very difficult to clear. Snow hardens as the temperature drops.

12.3.3. **Density**: The density of fresh snowfall is not affected by wind and is quite low, the values ranging between 0.04 to 0.14 gm per cubic centimetre. Maximum packing and settlement takes place within the first 24 hrs resulting in the loose snow attaining density of 0.15 gm per cubic centimetre. On further accumulation and time lapse the density of snow may rise upto 0.45 gm per cubic centimetre due to densification of the snow cover. The accumulation may result in standing snow of 8 to 10 mts on the road surface and exceeding 30 metres at avalanche sites.

12.3.4. **Snow drift**: In addition to the thick blanket of snow due to direct precipitation, the high velocity winds activate deposition of large quantity of snow on the road from the adjacent slopes due to snow drift. This constitutes a major hazard in snow clearance efforts.

12.3.5. **Icing**: The snow melt water on the pavement freezes at night when temperature drops below freezing point. Thus the water freezes in the form of thin ice layers which are glass smooth and form a potential traffic hazard. Icings are irregular sheets of ice built up on the pavement by thin films of water which flows out on the surface and freezes when exposed to sub-zero temperatures. It is very important that the road alignments in areas prone to icing are so chosen as to minimise the recurring problem of icing in relation to the pavement.

12.3.6. **Avalanche**: Avalanche is a hurtling mass of snow (speed has been clocked upto 90 m/sec or 320 km/hour) with ice and debris, descending along a mountain slope with tremendous momentum. Avalanches are caused due to:

a) Wind
b) Vibration and earth tremors
c) Rise in temperature at the end of Winter
d) Gravity
e) Heavy snow storm and geomorphological features of terrain
f) Even a falling branch, a hopping animal or a passing plane can trigger an avalanche

12.3.6.1. Avalanche prone areas in Himalayas exist at very high altitudes and extend to hundreds of Kms. Grassy slopes are considered most dangerous for avalanche occurrence. The intensity of an avalanche event is adequately described when following parameters are known by direct or indirect method:-

a. The area and extent of the avalanche, particularly the run out zone.

b. **Distribution of impact pressures and forces likely to be exerted upon obstacles along the road.**

c. **Types of avalanches likely to reach various locations on the road.**

d. **The frequency of avalanche occurrence along the road**

12.3.6.2. **Terrain and avalanches formation:** Terrain plays a very important role in avalanche formation. Steepness, exposition or orientation and shape and type of the surface of the slope contribute a great deal towards avalanche formation. The relation between slope and avalanche formation is given in Fig. 12.1.

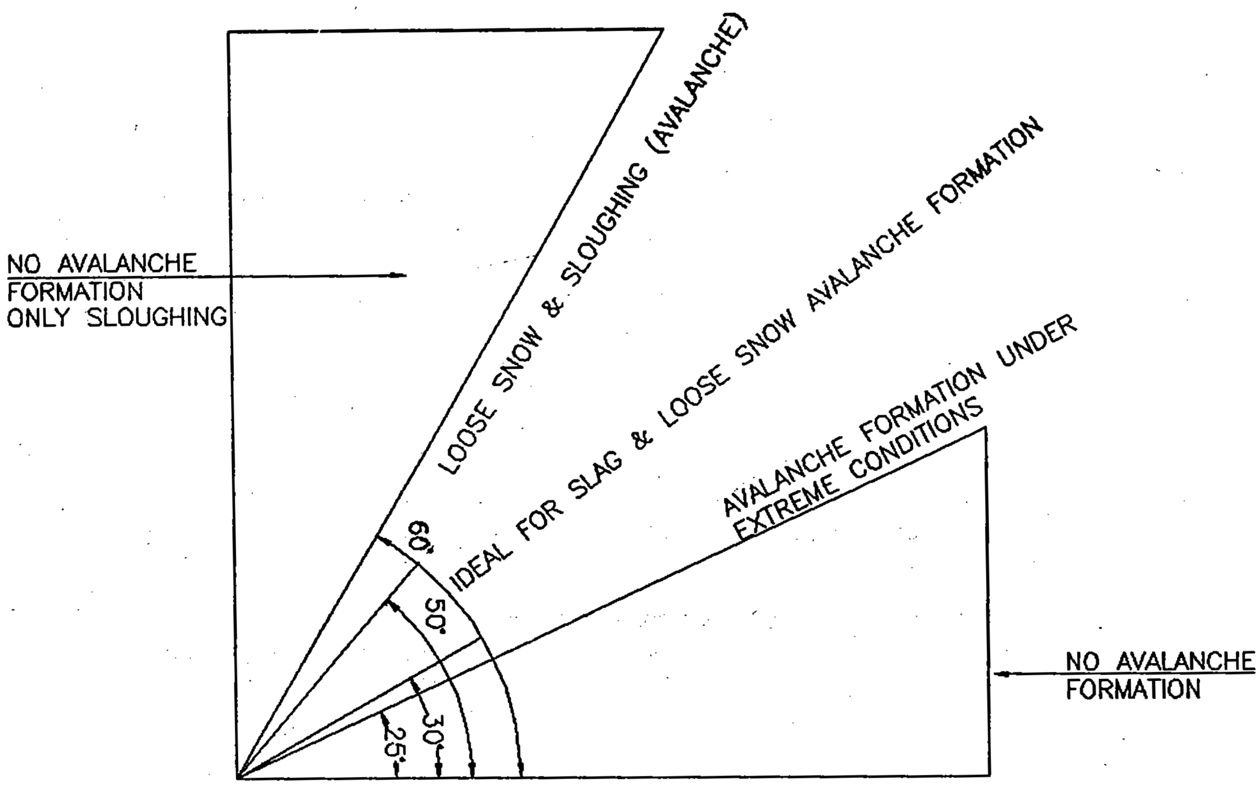


FIG. 12.1. SLOPE AND AVALANCHE FORMATION

12.3.6.3. **Type of avalanches:** Snow avalanches are broadly classified into two categories i.e. loose snow and packed snow or slab avalanches. Criteria, nomenclature and characteristics are given in Fig. 12.2.

12.3.6.4. Loose snow avalanche originates at a point and fan out expanding both in width and depth. Such an avalanche occurs usually during or immediately after a storm and does not pose serious problems unless it is damp or wet. Avalanches of packed snow result in the release of a cohesive slab with a wide fracture line. These avalanches are dangerous. Slab avalanches may originate either at the surface or along a weak layer below. A fast moving dry snow soft slab avalanche many a time turn out to be an air-borne powder avalanche with an airwave moving several metres ahead of the slide at somewhat higher level, leaving in its wake vast destruction. When the snow conditions are critical, slopes of 30^0 to 45^0 give rise to dangerous avalanches. The speed range of large avalanches is:

a) Wet snow avalanches - 10 to 30 m/sec
b) Dry snow avalanches - 20 to 30 m/sec and even reaching upto 70 m/sec. In case of stormy weather conditions.

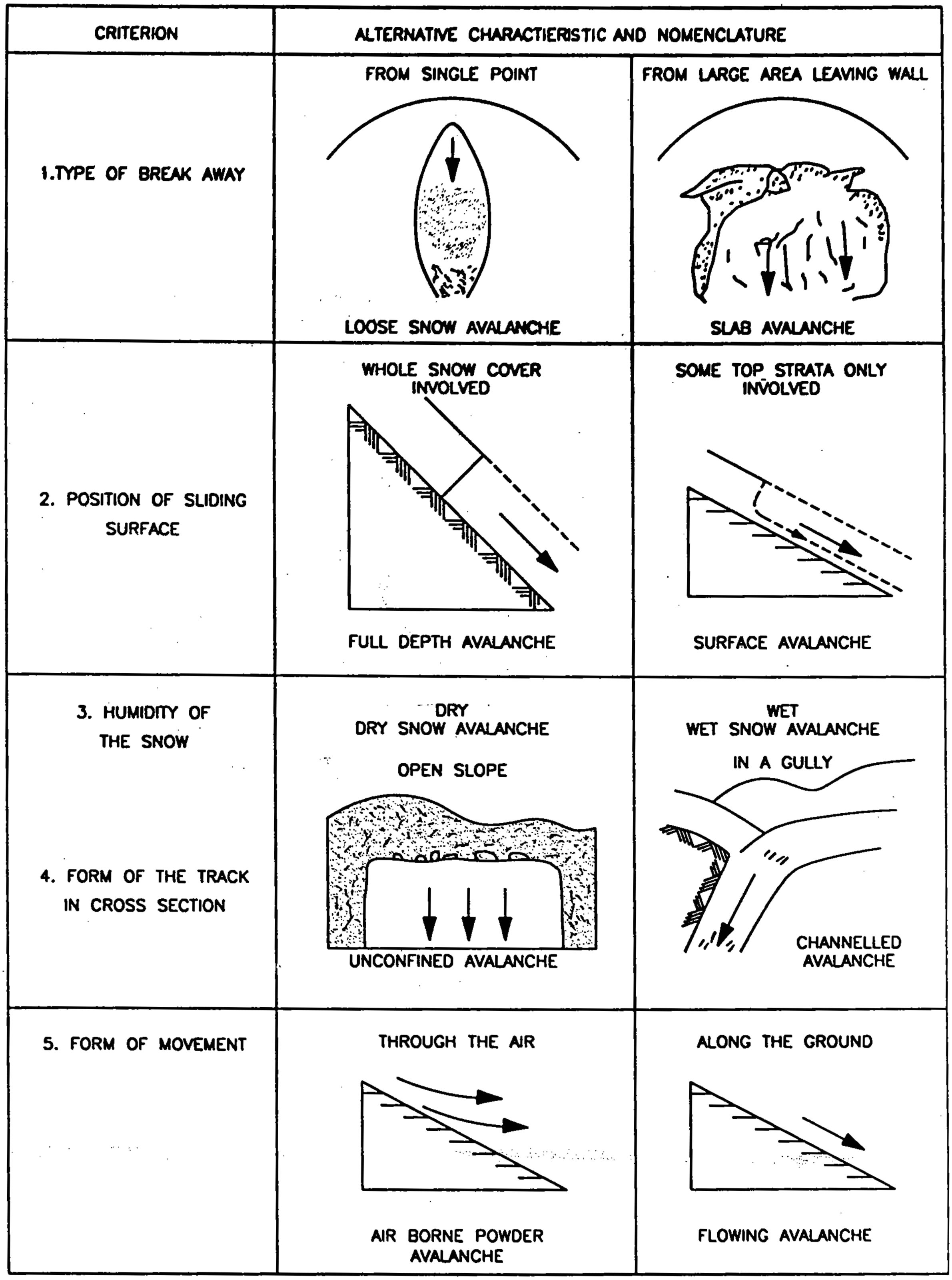


FIG.12.2 TYPES OF AVALANCHES

12.3.6.5. During spring, ambient temperatures go up and the intense solar radiation converts a large portion of snow pack into wet cohesionless mass resulting in wet snow avalanches. Avalanches affect all the major roads in the high altitudes. The avalanches activity is most pronounced in the months of January, February and March and continues even upto April in very high altitude of more than 5000 m.

12.3.6.6. **Zones of avalanches:** An avalanche has the following three well defined zones as shown in Fig. 12.3.

a) Formation zone or starting zone: The slope of an avalanche formation zone is generally more than 30^0. Steeper slopes more than 60^0 do not help in accumulation of snow and therefore chances of avalanche occurrence becomes minimum. Only frequent sloughing keeps on taking place which are of minor nature compared to the devastating avalanches.

b) Middle Zone or Avalanche Path: The part of an avalanche track below the formation zone and above the run out zone is known as Middle zone or avalanche path. The slope of this path is generally more than 12^0.

c. Run Out Zone: The lowest part of an avalanche area, where the snow mass of a moving avalanche come to a halt because of the decrease of slope or a natural obstacle, is known as the run out zone. The zone is marked by the debris carried by avalanche waves. The slope of a run out zone is generally less than 12^o.

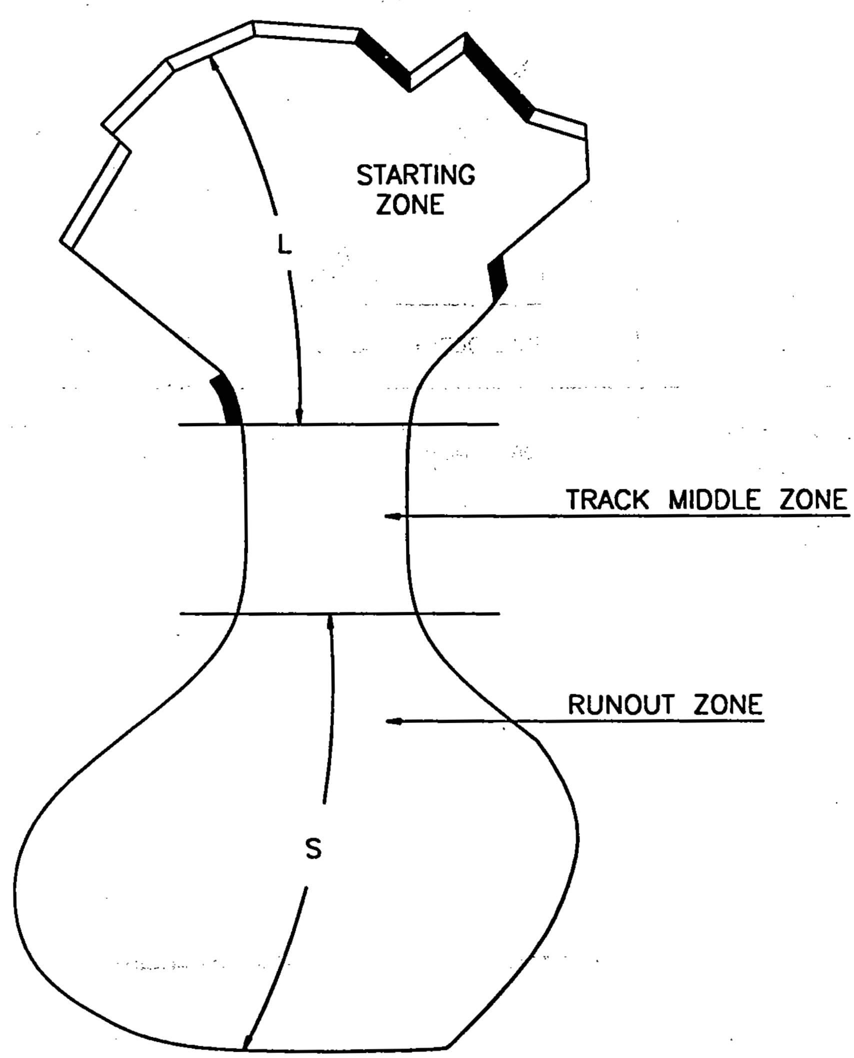


FIG. 12.3. ZONES OF AVALANCHES

12.3.6.7. The basic issues to be examined for the sake of cost effectiveness of avalanche control along a highway are:

a. The type of avalanches that occur,

b. The magnitude, frequency, density and extent of deposition of both routine and climax time occurrences,

c. The path taken by the avalanche,

d. Its velocity and destructive force,

e. Type of damage likely to road structures,

f. The return period of climax avalanche,

g. Its history and local knowledge,

h. Wheather situation warrants costly methods of structural control or will avalanche forecasting and artificial triggering suffice,

12.3.6.8. **Spring thaw:** High altitude roads in heavy snowfall areas experience a major drainage problem during spring thaw. The snow melt water flows with tremendous velocity over the pavement, causing its erosion covered on either side by snow accumulated on berms during snow clearance operations. The water released by thawing collects in the centre of the pavement and the road itself acts as a drain. At times this running snow melt water freezes on the pavement and causes skidding. Thaw water penetrates through the potholes and crevices in the pavement. When subsequent freezing occurs, this thaw also freezes and expands causing damage to the pavement. This alternative cycle of road thawing and freezing is one of the major causes of damage to the pavement in snow bound areas.

12.3.6.8.1. Pavement can be protected by using superior specifications like bituminous macadam and repairing all potholes and crevices prior to winter snowfall. Damages to berms can be minimised by periodical application of hygroscopic chemical like calcium chloride (Salt) or light oils. The rate of application can be between 0.25 kg to 1 kg of calcium chloride per sq. mt. But this is a very expensive proposition. The best solution is to dispose of the thaw water by making temporary cross drains.

12.3.7. **Glaciers:** A glacier is an ice sheet that has spread out from a central mass and covering a large area. Glacier moves slowly in a continuous stream down a valley under its own weight. The problem posed by glacier is compulsion to align roads over glaciers that have settled rather than snow clearance operations. Adequate protective measures are needed where road netotiates glaciers.

12.4. Design Parameters

12.4.1. **General:** Snow removal and avalanche control should be one of the factors to be considered in the planning stage of the highway. The alignment selected should be free of these problems as far as possible. Designs to mitigate snow problems should provide for higher road levels, wider right of way, gentle slopes, careful designation of borrow pit locations and proper selection and placing of roadside plants. Special considerations should be given to the design of adequate drainage system.

12.4.1.1. Grades in flat stretches should be kept above the general elevation of the adjacent land. If all grades are constructed 0.5 - 1.0 m higher than the land on either side of the highway, practically no snow will drift on to the carriageway portion of the road; even wet packing snow will tend to clear off the surface of such grades.

12.4.1.2. A narrow right of way is a snow hazard. Vegetation, buildings, fences and other structures cause serious snow drifting on the road unless the right of way is wide enough so that these drifts run out before they reach the carriageway potion of the road.

12.5. Advance Planning Action for Snow Clearance

12.5.1. **General:** Meticulous advance planning and preparations are required to be done with the greatest care so that snow clearance operations do not get hampered and delays are minimised.

12.5.1.1. Careful and detailed planning for the use of labour and equipments during snow storms and avalanche activity is necessary for successful results. The experience, ability and dependability of all men, types and adaptability of all available equipments and finally the type and relative importance of the roads to be cleared during the storm must be considered. The plan should assign adequate equipment, well-manned, to the most important specific sections of the road without overlooking the other sectors on the road and keeping in view the vagaries of the snow storm. During snow clearance season the men should be kept alert at all times and should be ready to undertake snow clearance immediately on occurrence.

12.5.2. **Snow markers:** The function of snow marker is to indicate the location of the road and depth of snow to the snow clearance team. A snow marker is a 80 mm dia 3 to 5 m long G I Pipe, graduated at 0.25 m intervals, filled with concrete and erected on the Valley side with proper foundation. It is essential to check all the snow markers before the closure of road. A typical sketch of Snow Marker is shown in Fig. 12.4.

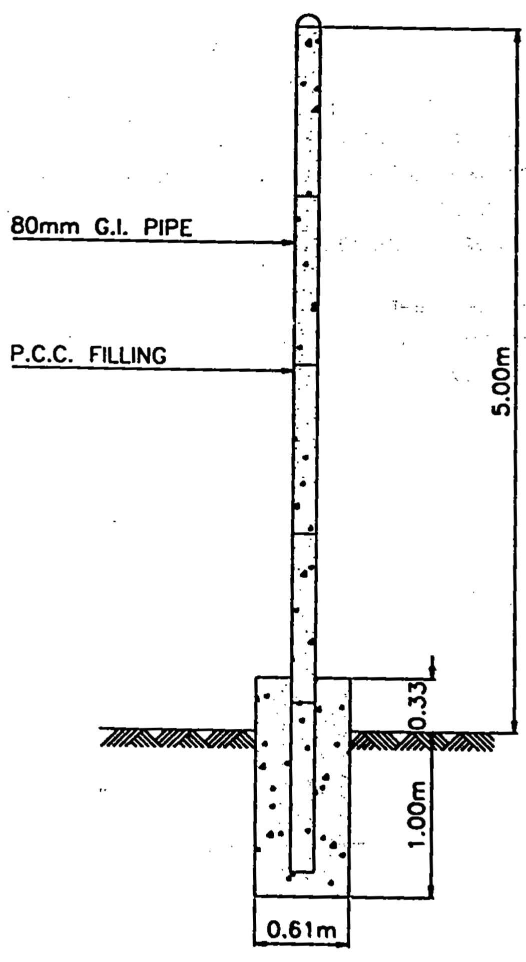


FIG. 12.4. SNOW MARKER

12.5.3. **Equipment:** It is absolutely essential that appropriate type of equipments for snow clearance are positioned at the appropriate locations and their mechanical conditions checked before they are positioned at site. The equipments should be in perfect working condition. The locations where these equipments are required to be positioned should be so selected that they are safe, secure and clearly away from avalanche prone areas. Adequate stock of spares and a team of well trained mechanics for the periodical maintenance of the equipment both during the idle period as well as during the operation should be positioned at centrally located camps in the sector, close to the location of the equipment. Adequate quantity of the right type of fuel and starting aids should also be stocked in the respective camps.

12.5.4. **Manpower:** The main aspects to be borne in mind regarding man power are:

a) The men should be physically robust and mentally alert; preferably of a lower age group.

b) Adequate number of men to work with the equipment and for essential administrative duties should be positioned at appropriate locations well before on set of winter.

c) Suitable shelter with heating and warming arrangements, adequate food, clothing and medicines, etc., should be available at the various camps before deployment of the men.

d) Proper inter-communication by wireless set between the sectors and HQ should be ensured.

e) Suitable rescue/recovery posts should be established.

f) Air sorties for mail, evacuation of casulties, supply of rations, spares and conveyance of personnel should be made available as a routine/ on call service so that personnel have high morale.

g) Essential recreational facilities should be provided.

h) The men should be acclimatised to work in high altitude and snow fall areas, and should be given adequate winter and snow clothing and trained to take precautions against likely adverse effects on them.

12.6. Snow Clearance Equipment

12.6.1. **General:** There is almost 10% decrease in efficiency of mechanical equipment for every 1000 m above mean sea level. Clearance machinery now in service in the country, is mostly imported equipment, mainly of German, Swiss and Canadian origin. There is a need to indigenise at least certain assemblies.

12.6.1.1. **Effects of cold on mechanical equipments and counter measures:** Metal under very low temperature will develop brittleness and the stressed parts and welds tend to fracture under impact. The adverse effect of this brittleness is particularly on blades and cutting edges of dozers, bucket fingers of loaders and external moving parts and snow cutters. Cold also causes loosening of many parts such as master pins, cap screws and nuts etc. Rubber hoses, fan belts, hydraulic pipes, tyres, etc. are liable to harden and crack at low temperatures. Seals also harden causing stiff operation and failure leading to leakages. Insulation of electric cable may fail. Springs develop fatigue and lose tension. Wheeled machines become immobilized by soft snow of more than 30 cm and hence tracked machines are more suitable. Suitable shelters should be provided to machines. All plants should have heated cabins for efficient operation. The efficiency of the plant operator under exposed conditions may be as low as 35% whereas in a closed well heated cabin it could be as high as 75%. Snow clearance equipment can be broadly classified as snow removal machine and spreading machines. Snow removal machines can be further classified as blade ploughs and rotary ploughs.

12.6.2. **Crawler tractor (blade plough):** For heavy snow clearance operations, the blade plough dozer is the most suitable equipment. Its advantages are:

a) It can tackle any depth of snow.

b) It is a tracked dozer and, therefore, can transmit considerable tractive force without slipping on snow.

c) It has good menoeuvrability and turning radius specially suitable for restricted location.

d) Presence of rock pieces and boulders in the snow does not damage or affect its performance and it is specially suitable for clearance avalanche debris.

e) It can tackle hard snow except frozen icy smooth surfaces where it tends to slip.

f) Its output varies from 1000-2000 tonne per day depending upon the varying site conditions.

12.6.2.1. Its disadvantage is that its track damages the pavement if sufficient precautions are not taken during snow clearance. Normally 15 cm to 25 cm snow is left uncleared below its track to avoid damage to the pavement. The residual snow can be cleared manually.

12.6.3. **Rotary snow plough or cutter**: This is a versatile snow clearance equipment.

Its advantages are:

a) It can tackle upto 3 metres of standing snow.

b) Its output is nearly 1000 MT per hour on soft snow.

c) It has good mobility and can be moved to the site quickly.

d) Being mounted on pneumatic wheels, it does not damage the pavement.

e) The rotary head can be adjusted so that it does not leave more than 5-10 cm snow on the surface.

Its disadvantages are :

a) It tends to slip on ice even with non-skid chain.

b) It can only be used in conjunction with dozer on heavy snow clearance.

c) Can damage the wearing course if not properly operated.

12.6.4. Wheeled Dozers (Blade Plough): Wheeled dozers are useful for fresh light snow clearance.

12.6.5. **Non-rotary snow plough**: Non-rotary snow plough with different types of blades attached to a separate prime mover or to the normal vehicles and snow sweepers are used for clearance operations in fresh snow with light precipitation.

12.6.6. **Drag scrapers**: A triangular metal frame of sides about 2.5 M long with rubber padding dragged by a load carrier vehicle can be used for clearing residual snow on the road after clearance by snow cutters, with a reasonable degree of success.

12.6.7. **Spreading machines**: These machines are used for spreading gritting materials and deicing salts/chemicals on the roads.

12.6.8. **Space heater**: These are designed to blow a hot blast of air. Before starting engines in sub-zero temperatures hot blast of air is blown on engines so as to loosen the bearings for easy starting. It is also useful for changing engine oil in winter under low temperatures and for repairing machines in winter.

12.6.9. **Slave starter**: These are used for charging batteries which frequently get discharged due to very low temperatures. It can charge upto ten, 12V batteries at a time.

12.7. Snow Clearance Operation

12.7.1. **General:** Snow Clearance Operation can be broadly classified into two types viz:

a) Continuous snow clearance in winter and part of summer which involves clearance of snow as and when it occurs is called winter snow clearance.

b) **Summer snow clearance which commences when the snow precipitation is over and the total accumulated snow of the season is tackled in one operation.**

12.7.2. **Continuous snow clearance**: It is easy to clear freshly fallen snow by an appropriate equipment like snow cutter upto a depth of less than 1 m provided there are no repeated snowfall, thereby giving adequate time for clearing all the fresh snow before the occurrence of the next snowfall. Roads below 3000 m falling in the snow belt can be kept open by continuous snow clearance using appropriate equipment.

12.7.3. Light dry snow is of little concern, but wet snow with heavy winds is a problem which results in dangerous conditions if not properly tackled. Wet snow under traffic, packed on the pavements and particularly if followed by a drop in temperature, can create very dangerous conditions. The best method of preventing the packing of wet snow is to have a large fleet of light, high speed, straight blade snow ploughs available. These ploughs should be started with the storm and kept working till the storm ends and the pavements are clear or until the snow gets so deep that snow ploughs cannot handle the situation.

12.7.4. **Packed snow and icing problems:** Packed snow forms when fresh snow is not cleared immediately and the ploughs cannot keep ahead of the storm. Curves, hill sections, highway intersections and icing prone stretches, should be covered with a chemically treated abrasive material like sand or small chips. If the traffic is sufficiently heavy to warrant it, the entire road should be treated with abrasives. This type of work should be continuous during winter months. Application of abrasive material either alone or in combination with calcium or sodium chloride should be undertaken for treating icy pavements. The pavement should be treated whenever slippery conditions exists. The treatment procedure is given in para 12.10.

12.7.5. **Summer snow clearance**: In higher reaches of the great Himalayan ranges which are distinct snow belts, specially in the Western Himalayas, the intensity and periodicity of snowfall combined with avalanche activity and icing problems make it almost impossible to undertake snow clearance operations continuously. The snow, perforce, will have to be allowed to accumulate during winter months and in such cases the road sector has to be closed during winter months. The compacted snow on the road at places will be of the order of 10 to 12 m and at major avalanche sites this may exceed 30 m.

12.7.6. **Organisation**: Despite the fact that summer snow clearance operation is mostly based on machines, adequate manpower is essential for various allied tasks like deicing, maintenance of the cleared road, cutting of rolled down trees, blasting of boulders brought by avalanches, launching of equipment bridges, carriage of stores, etc.

12.7.7. **Sequence of summer snow clearance operation:** Because the entire road is covered under a thick blanket of snow, it is a difficult job to trace the road alignment, though the snow markers erected specifically for this purpose do help. At times the snow markers get burried or unrooted. At many places, huge avalanches occur making it difficult to locate the road. If the snow clearance operation is commenced without locating the road this can lead to disaster. Therefore, it is of utmost importance to identify and mark the road alignment. Firstly, the road alignment should be marked with the help of prismatic compass and levelling instruments based on survey charts of the road. The help of snow marker should also be taken. The recce party with prismatic compass, levelling instrument and rolls of magnetic bearing charts mark the road alignment, with pegs/local material followed by tracked dozers.

12.7.7.1. Once the road alignment is identified and marked by the reconnaissance party, a dozer should be deployed first to make a break through for the snow cutter and other tractor to follow the leading crawler tractor cuts the snow and makes the path for itself. The distance between tractors is kept 50 to 200 m depending upon site conditions. Where hard snow is encountered, it should be tackled by the crawler tractor. In this manner except for last 5 to 10 cm, the snow clearance is done by a combination of dozers and snow cutter. The remaining 5 to 10 cm of snow on the road surface should not be cleared by the crawler tractors to minimise damage to surface. This should be cleared by motor grader or manually or allowed to melt away. One snow cutter and a crawler tractor should follow in the rear to widen the cleared portion and also to clear any snow drift or avalanche which may occur.

12.7.8. **Clearance of overhanging snow**: Whenever deep box cuts of snow are involved, the snow should initially be cut in a half tunnel pattern and subsequently these masses of overhanging and unsupported snow should be removed. Resorting to blasting is not desirable as this may trigger avalanche.

12.7.9. **Precautions**: When snow clearance operation is in progress the following precautions should be taken to ensure safety of men and machines.

a) All men and machines should be deployed in a dispersed manner to guard against avalanches. At the end of the day, the machines should be parked at places free of likely avalanches.

b) A sentry with a whistle should be detailed and located at a vantage point to give early warning of avalanches.

c) All machines parked for the night should be covered with tarpaulines and other protective measures taken.

d) During snow clearance operation an ambulance along with nursing assistant and first aid, should be available at site.

e) All workers should wear sun goggles as protection of eyes against glare of sun-shine

f) Adding anti-freeze chemicals to radiator water, use of winter grade diesel, draining radiators in the night are some methods to keep vehicles/equipments in running order.

12.7.10. **Communications**: It is necessary that parties engaged in snow clearance are in communication with their main camp and the main camp in turn is in contact with their HQ. For this, short range walkie-talkie, wireless sets for local contacts and wireless radio sets for long range communications are essential.

12.8. Road Maintenance Subsequent to Snow Clearance

12.8.1. After snow clearance, enormous maintenance efforts are required to make the road traffic-worthy. Road maintenance parties should follow immediately behind the snow clearance teams. The damage done by snow and avalanches to the drainage system should be restored on highest priority. The most important and immediate problem is the control of snow melt water on the road surface. A party should be detailed to control this water by diverting it to flow across the road at suitable intervals and also to clear the existing drains and culverts. The maintenance team should repair the following damages:

a) All drains and culverts

b) Pothole repairs

c) Repair of damaged protective works like retaining wall, etc.

d) Km stone and road signs should be repaired or replaced as necessary.

e) Road formation should be repaired where damaged by avalanches.

f) After the snow clearance on the road, the snow on hill slopes melt and may cause slides. Also the rivers flooded with snow melt water can cause toe erosion. Machines should be kept ready at vulnerable points to tackle these expeditiously.

12.9. Avalanche Control

12.9.1. **General**: To tackle the problem of avalanche control appropriately, a fairly accurate knowledge and data is necessary of the type of avalanche frequency at the location, its magnitude and intensity, extent of spread and the return period of the climax avalanche, which is the avalanche that causes maximum damage and havoc.

12.9.2. In absence of adequate information and data available on past avalanche activity, recourse may be taken to indirect evidence as under.

a) Air photo interpretation of avalanche slopes

b) Study of forest on avalanche prone slopes

c) Obtaining information of avalanche occurrence/accidents.

12.9.3. Avalanche Forecasting: Avalanche forecasting is basically dependent on the direct evidence method, indirect evidence method, the statistical approach or a combination of these. In the Western Himalayas, SASE issues a higher danger forecast on avalanches on radio based on the data collected by their observatories located near formation zones on important roads. Maximum avalanches occur in months of February and March in Western Himalayas. It is necessary to stop all snow clearance efforts once the warning is issued, to avoid loss of lives and damage to equipments.

12.9.4. **Control structures:** Corresponding to their nature and mode of action, three different type of structures can be distinguished. Structures in the formation zone which prevent avalanches, structures in the avalanche path which deflect the avalanches and structures in the run out zone which reduce the damaging effect of the avalanches. Formation zone control is most effective and permanent solution to the avalanche control problem but requires heavy expenditure and long time for construction. Avalanche control using structural methods involves long term study, proper designs and deployment of huge resources for construction. Avalanches can be controlled by the following structures:

a) Stopping structures like snow bridges, snow rakes, snow fences, avalanche fences, terraces and snow nets.

b) Drift control measures like appropriate highway design, planting trees and structures like inclined roofs, wind baffles and snow fences.

c) Deflecting structures like gallery, guide and diversion walls.

12.9.4.1. **Structures in the formation zone**: The various types of alavanche control measures used in the formation zone are supporting structures which are normal to the slopes, like steps or terraces where the support surface is close to the horizontal and act as earthen dams as the retaining barriers in the formation zone. While steps and terraces give protection in limiting the glide and creep, they do not render enough protection in stabilising the newly fallen snow and retaining it.

12.9.4.2. Above the tree line permanent structures could be set up in materials like steel, concrete, etc., having long life. Below the tree line where the structures are surrounded by forest, the construction could be of timber (keeping however, environmental aspects in view).

12.9.4.3. The types of stopping structures are:

a) **Snow bridge**: should be made of round timber, aluminium, steel tubes with I sections or prestressed concrete. Refer Fig. 12.5.

b) **Snow rakes**: usually made of rounded timber or aluminium, Refer Fig. 12.6.

c) **Snow nets**: the net used can either be of wire ropes or nylon rope, Refer Fig. 12.7.

d) **Avalanche fence**: usually made of timber, Fig. 12.8.

e) **Terraces**: Refer Fig.12.9

12.9.4.4. In addition to the above structures, drift control structures should also be put up in the formation zone. These structures make use of wind force and prevent formation of great mounds of snow and cornices. Generally these are used in conjunction with the supporting structures. The type of drift structures in use are:

a) **Jet roof**: Put on a ridge to prevent formation of cornices and is constructed of rounded timber. Refer Fig. 12.10.

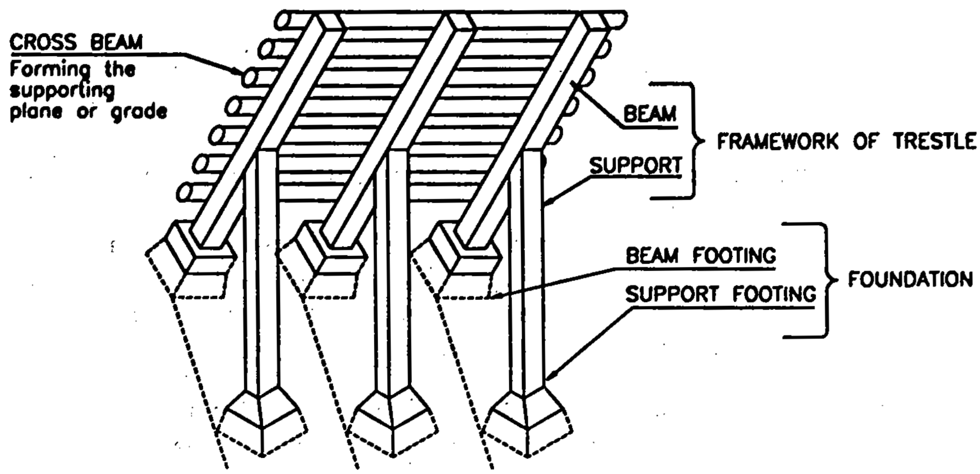


FIG.12.5. SNOW BRIDGE

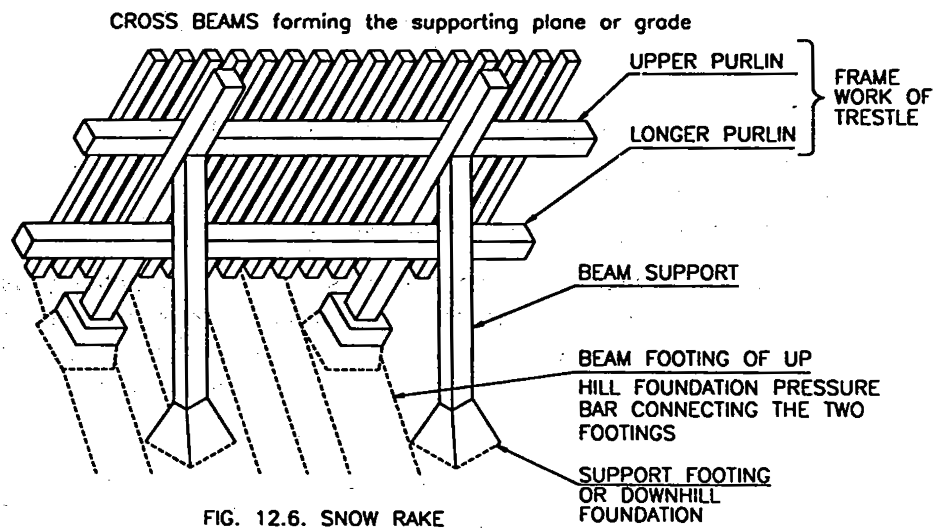


FIG. 12.6. SNOW RAKE

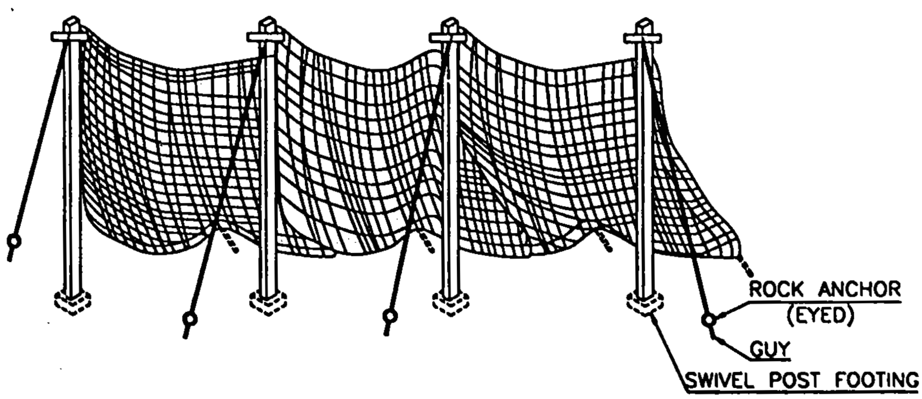


FIG. 12.7. SNOW NETS

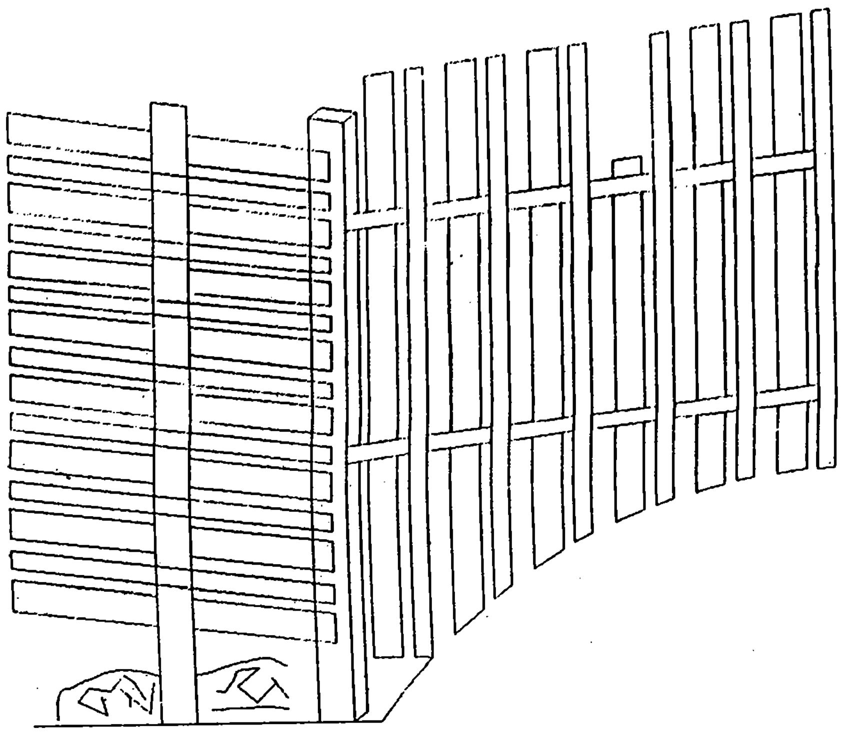


FIG. 12.8. AVALANCHE FENCE

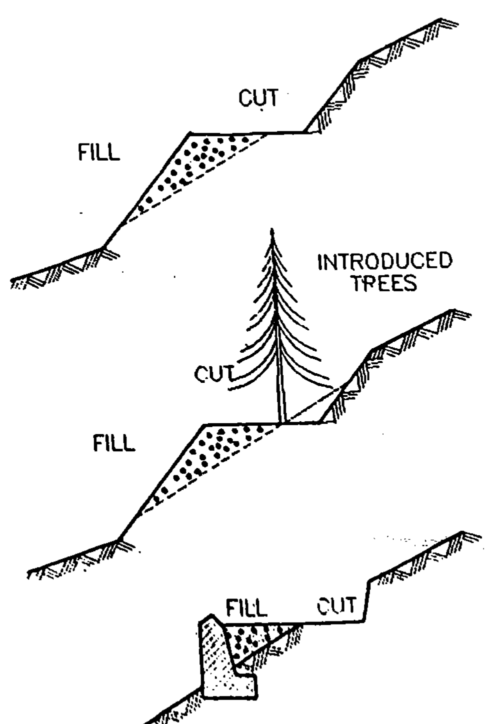


FIG. 12.9. TERRACES

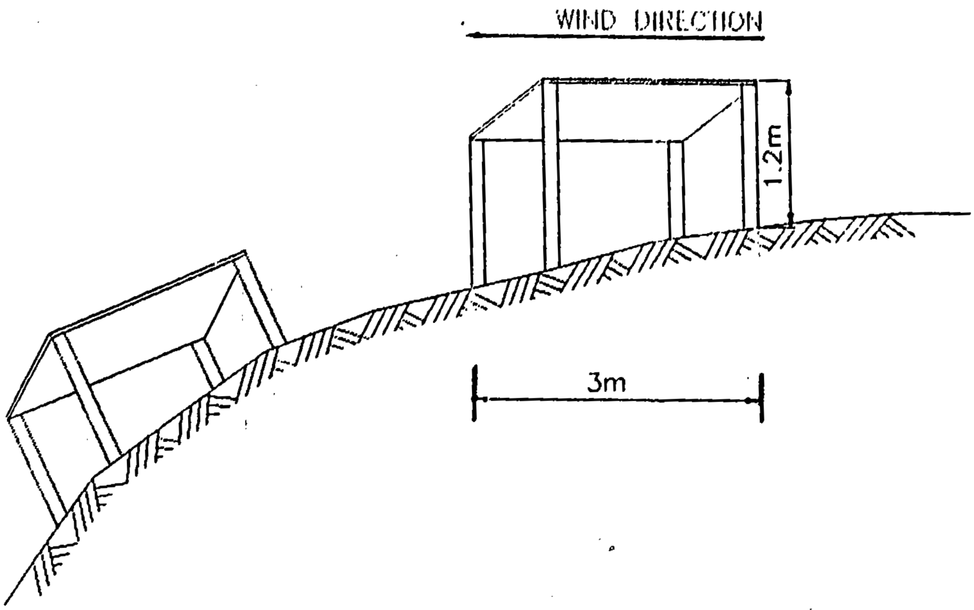


FIG. 12.10. JET PROOF

b) **Wind Baffle**: This prevents cornice and may be made of timber or steel, pipes, sheets etc. A typical arrangement is given in Fig. 12.11.

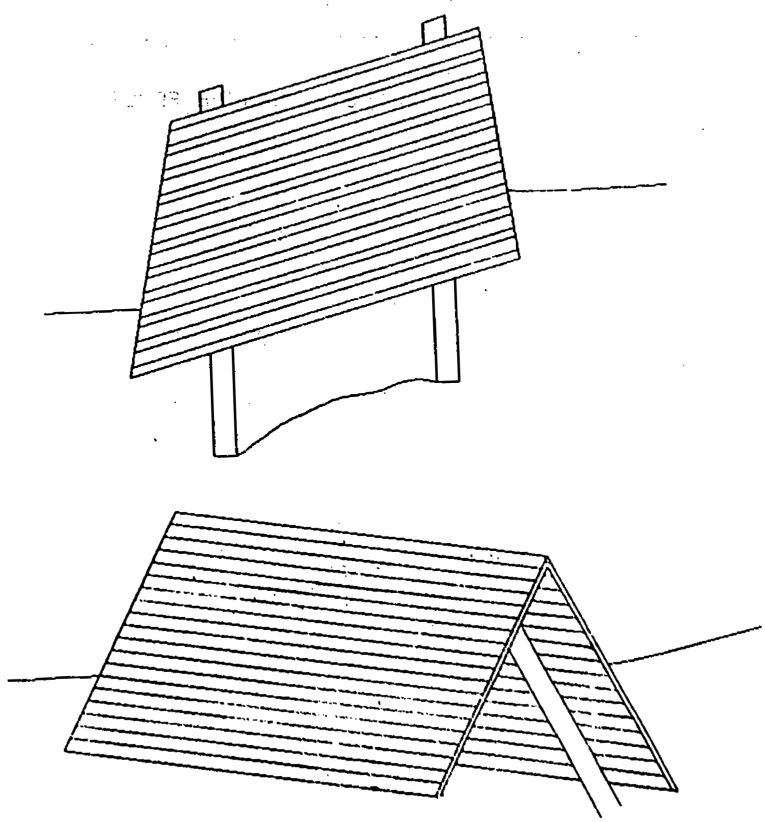


FIG. 12.11. WIND BAFFLE

c) **Snow fence:** Snow fences prevent drifting of snow on to the road and can be made of timber, concrete steel, etc. Two typical types of fences are shown in Figs. 12.12 and 12.13.

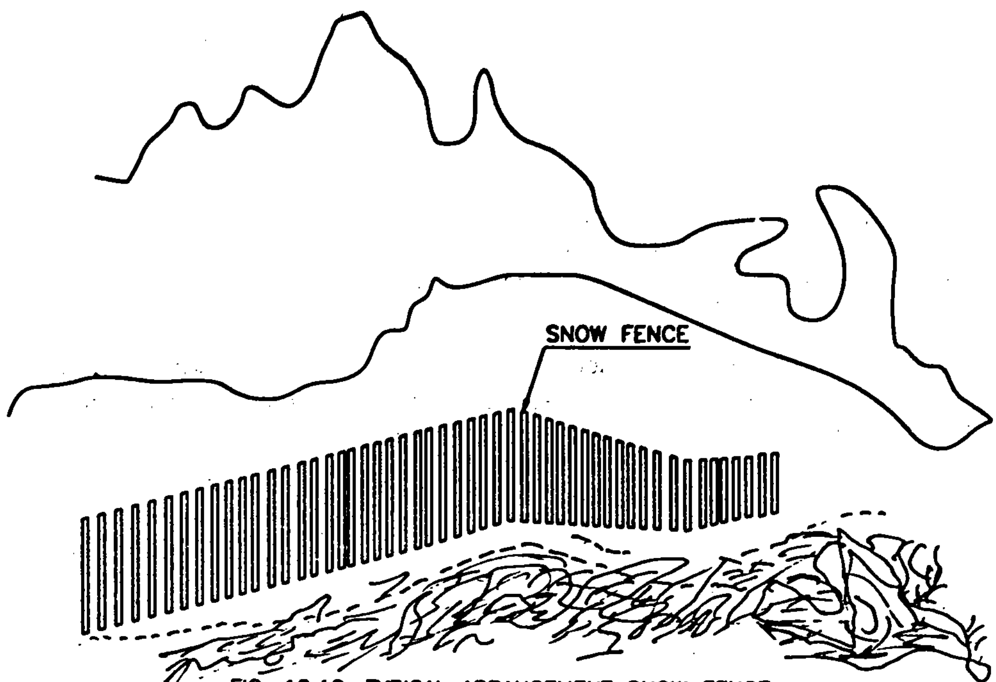


FIG. 12.12. TYPICAL ARRANGEMENT SNOW FENCE

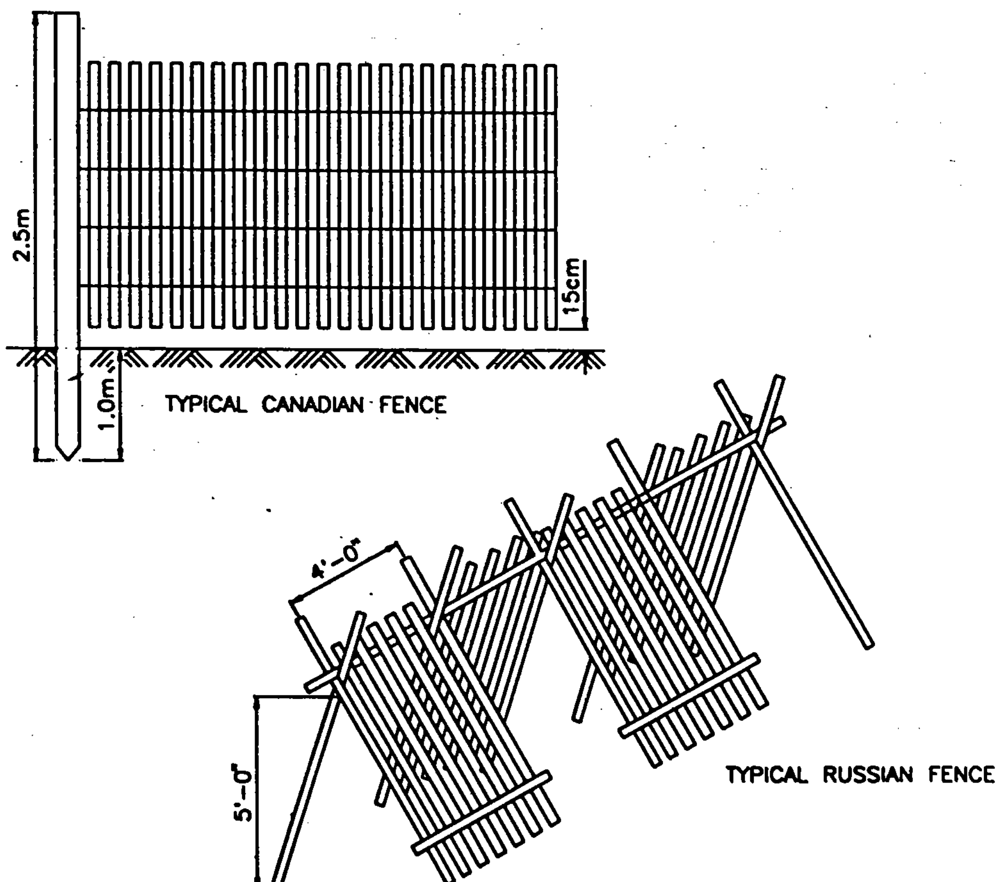


FIG. 12.13. SNOW FENCE

12.9.4.5. **Structures in avalanche path:** To protect the important installations in the avalanche path, deflecting structures are used. These structures are designed to change the direction of the moving avalanche and deflect it away from the object to be protected. The deflecting structures are:

a) **Gallery:** Used for protection of highways, it runs through the terrain like a narrow band. The avalanches are either conducted over the gallery or they are partially deposited on the roof. Refer Fig 12.14.

b) **Guide walls:** These are built above a gallery in order to limit width of a flowing avalanche to the length of the gallery. This is also shown in Fig. 12.14.

c) **Diversion dams:** These are made of earth or concrete with stone pitching and are meant to divert the flow of an avalanche in the desired direction. Refer Fig. 12.15.

d) **Avalanche ramp:** This is made of earth to allow avalanche to pass over. Refer Fig. 12.16.

e) **Avalanche wedge:** These are used for breaking the speed of avalanche and thus to protect structures. Refer Fig. 12.17.

12.9.4.6. Guiding and diversionary structures are massive in nature to withstand impact of avalanche moving at full speed. These are useful only in special cases where ground contours, curves or other natural obstacles tend to divert the avalanche out of its original path.

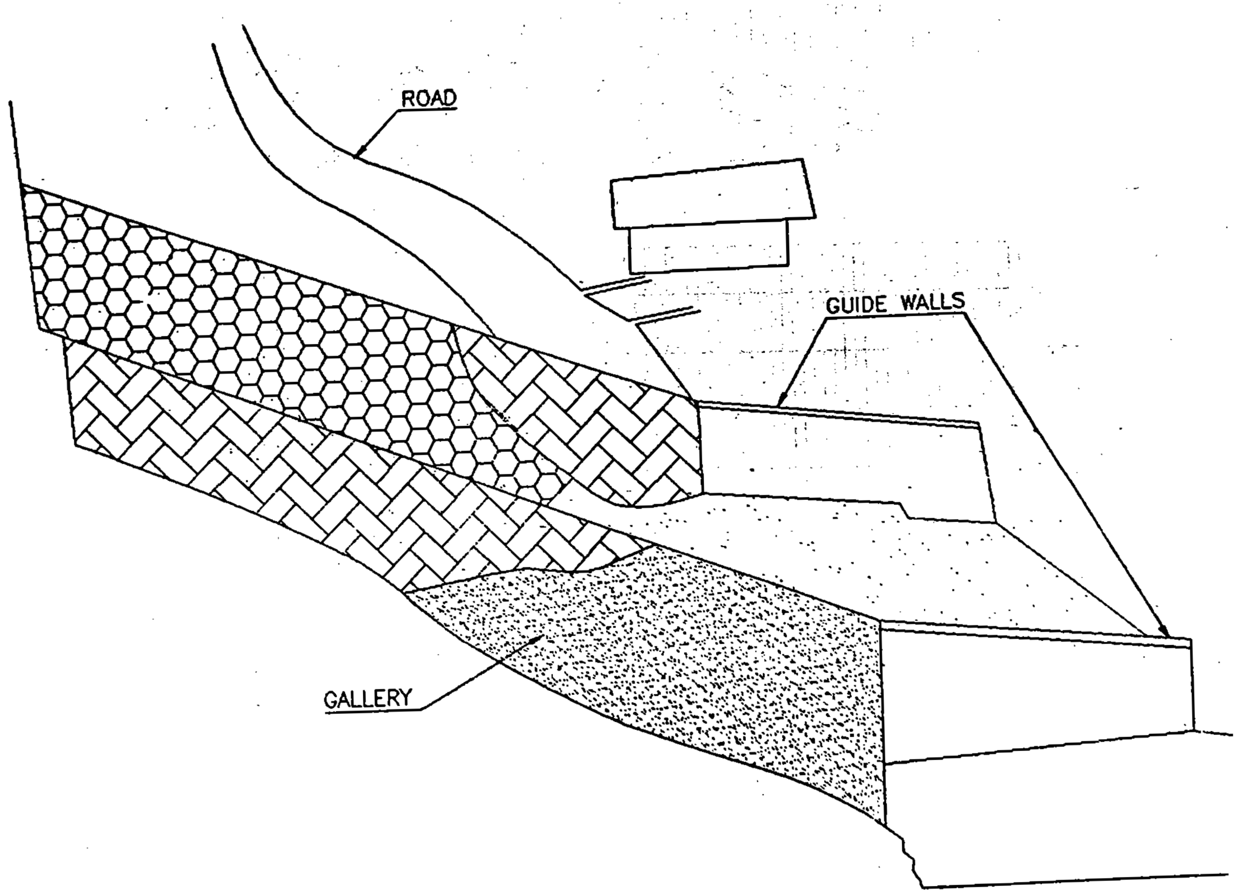


FIG. 12.14. GALLERY AND GUIDE WALLS

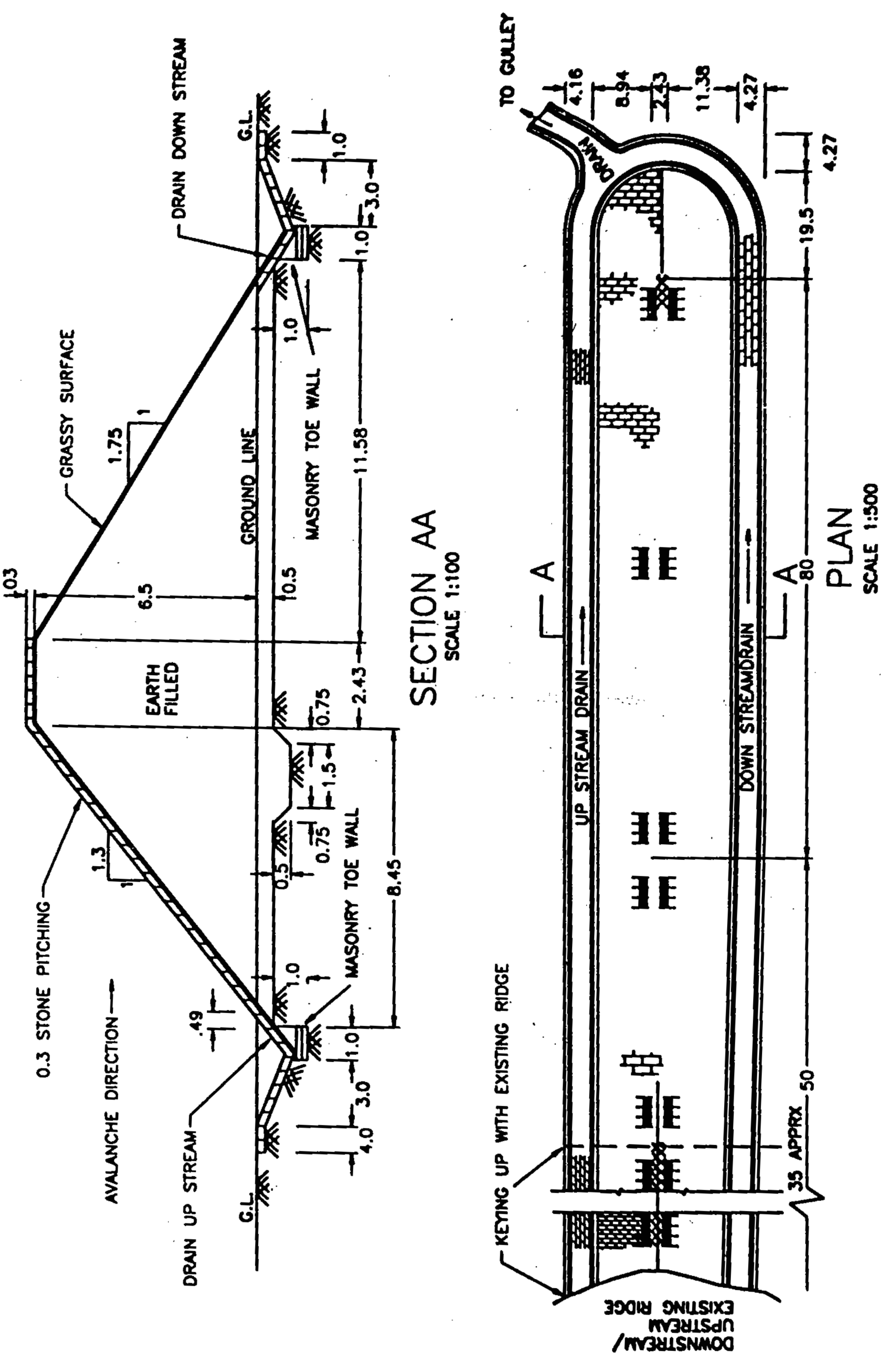


FIG. 12.15. TYPICAL LAYOUT EARTH FILLING AND DIVERSION DAM

NOTES
1. DIMENSIONS IN METRES.
2. STONE PITCHING 0.3 THICK TO BE DONE ON UPSTREAM SLOPE 4. DRAIN UP/DOWNSTREAM
3. SODDING TO BE DONE WITH SHRUBS ON DOWNSTREAM SLOPE

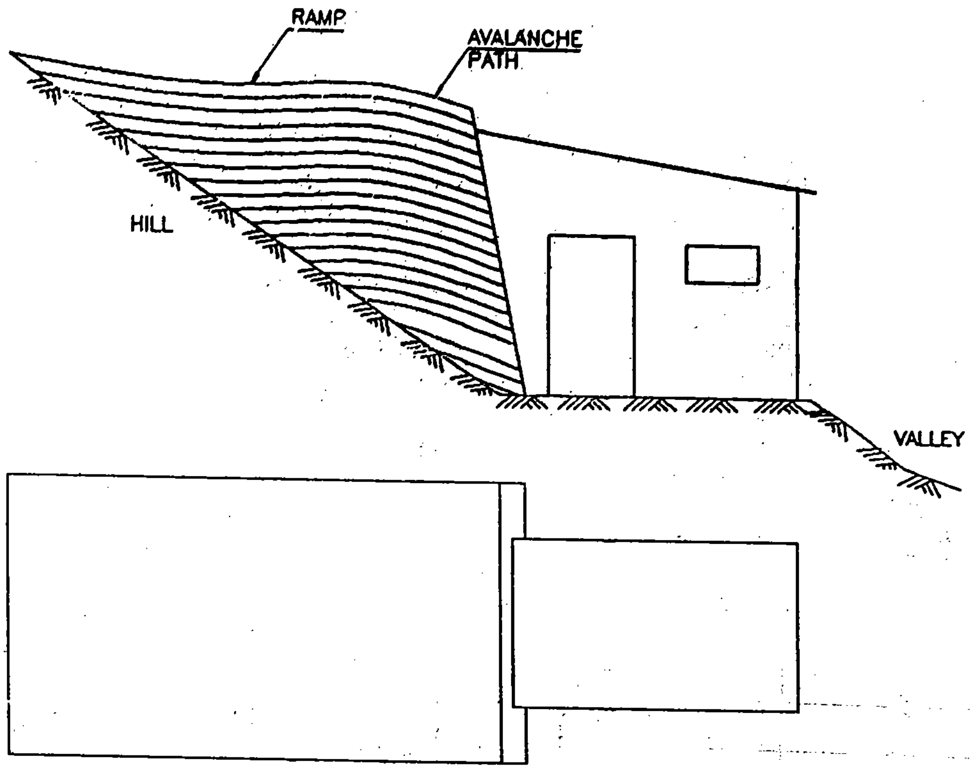


FIG. 12.16. AVALANCHE RAMP

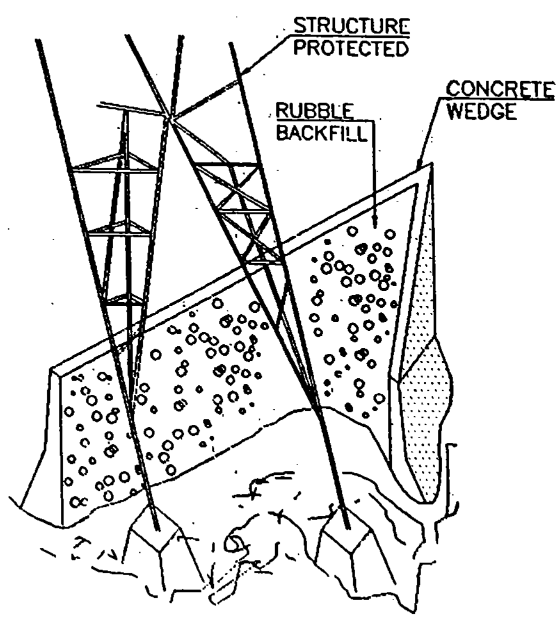


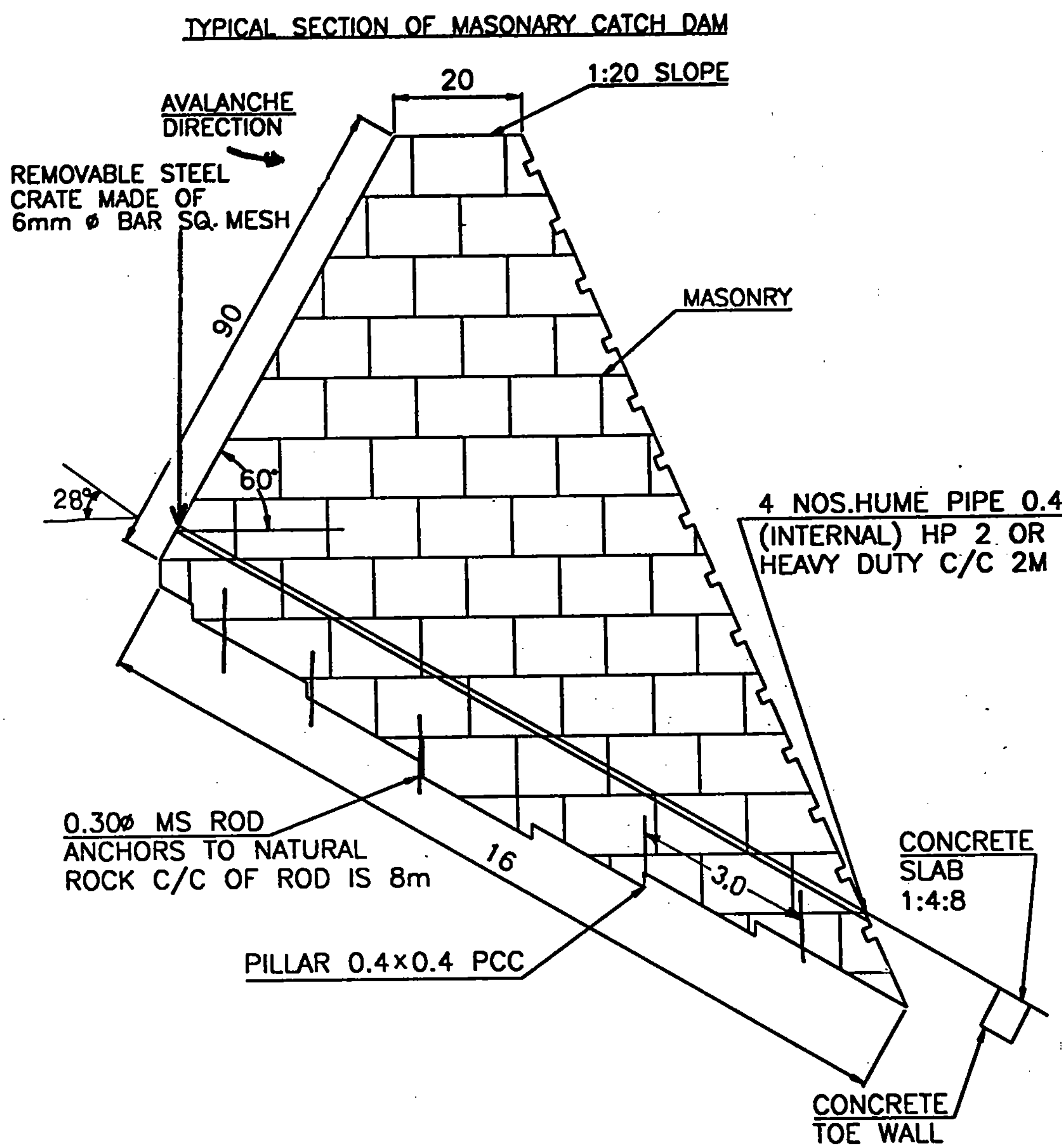
FIG. 12.17. AVALANCHE WEDGE

12.9.4.7. **Structures in run out zone:** These structures are massive in construction and are used to shorten the run out zone or give a direct protection to an installation. These obstruct the force of the moving avalancnes. These structures are:-

a) Masonry catch dams - Refer Fig. 12.18

b) Retaining walls

c) Wedges and mounds. Refer Fig. 12.19



NOTES

1. WEEP HOLES 10cm x 10cm WITH 1:3 CEMENT MORTAR.
2. SLOPE 1:2 C/C 1.9m HORIZONTALLY STAGGERED WITH VERTICAL INTERVAL 1.5m

FIG. 12.18. MASONRY CATCH DAM

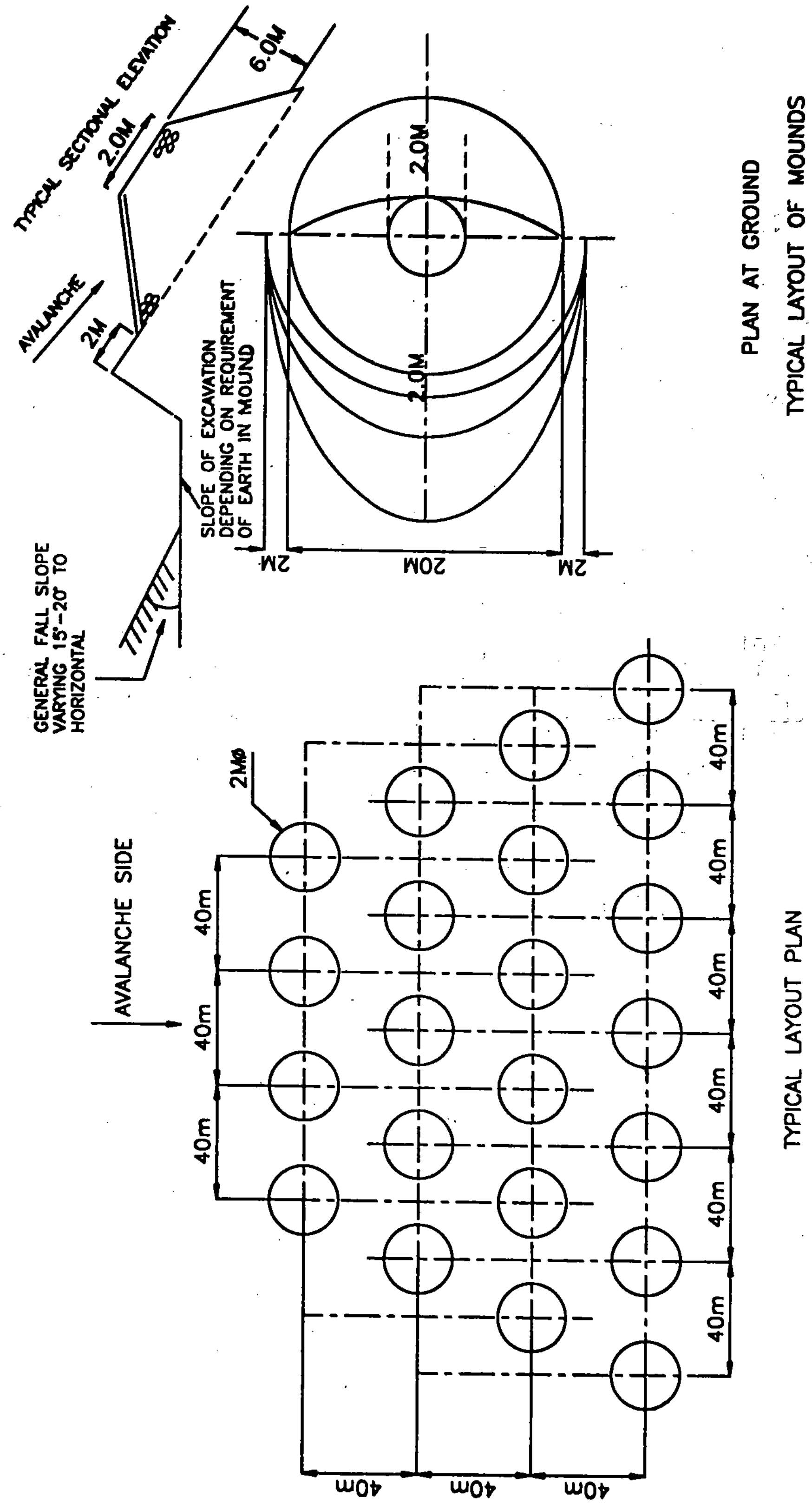


FIG. 12.19. WEDGE & MOUNDS

12.10. Treatment of Icy Pavements

12.10.1. General

12.10.1.1. Treatment of icy pavements is given in 12.7.4. In some cases calcium or sodium chloride is applied without abrasives. The pavement should be treated wherever slippery conditions exist and for as long a period as necessary.

12.10.2. Equipment

12.10.2.1. A truck equipped with a special cinder or aggregate bed having a conveyor belt at the bottom for feeding the abrasive material to a spinner type spreader at the rear, all powered by the power take off of the truck, has proved to be the fastest and most economical spreader. When the conveyor type truck bed is not available, then any 2 to 5 ton truck with a dump bed can be used and spreading can be done manually.

12.10.3. Chemicals

12.10.3.1. Calcium chloride and sodium chloride are the most suitable chemicals and these should conform to the relevant IS specifications.

12.10.4. Abrasives

12.10.4.1. Local availability and unit cost determines the type of abrasive to be used. The following abrasives are most commonly used:

a) Sand - Sand containing excess of fines does not provide good traction and coarse material is likely to whip off and therefore these are not effective in combating the skid hazard. Sand for ice control should be clean, hard, sharp and free from loam clay or frozen lumps, with 100% passing a 10 mm sieve and not more than 30% passing 300 micron sieve.

b) Washed stone screenings - Stone screenings from which the fines have been removed by washing produces a good abrasive. Its gradation should be the same as for sand given above.

12.10.4.2. **Treatment with abrasives**: Abrasives should be treated to prevent freezing before application and as an aid to anchoring the material in the ice or packed snow so that it will not be blown off the road. Heating the abrasive does not work. Treatment with sodium or calcium chloride is the best method of preparing abrasives for tackling icy pavements. On heavily trafficked roads untreated abrasives whip off the road and even moderate winds will sweep the material from the surface.

12.10.4.3. **Application of abrasives**: Before treating a road with abrasives or chemicals to prevent skidding on icy surfaces, the snow or loose ice should be removed as completely as possible by a blade grader. An application of 0.4 kg treated sand or screenings per sq.m. will give a good cover and should make the road non-skid if it is uniformly distributed. When traffic or wind has whipped off the abrasive material it should be recovered, especially on steep grades, curves and intersections.

12.10.5. Treatment with dry calcium and sodium chloride

12.10.5.1. When abrasives are placed in storage they should be treated with chloride, the quantity depending on the moisture content of the abrasive and the temperature.

12.10.6. Brine spray method

12.10.6.1. A convenient method of applying calcium chloride to the abrasive material to obtain quick and uniform dispersal of the chemical is by spraying with brine. The brine should be made up of 1 kg of flake calcium chloride to 2 lt of water.

12.10.7. Treatment of concrete pavement

12.10.7.1. Calcium or Sodium Chloride treatment should be applied as sparingly as possible to concrete pavement. This is because repeated freezing and thawing of concrete in contact with these salts may make it susceptible to surface pitting or scaling. The concrete pavements that have been given protective surface treatments or those made from entrained concrete are generally not susceptible to damage from ice control chemicals.

12.11. Present State of Art

12.11.1. Snow clearance is not a common theme other than to highway engineers directly involved in it. However the subject is important and will gain essentiality in future with need to open more areas in remote high altitudes. The data therefore needs regular upgradation.

13. ROAD CONSTRUCTION TOOLS, PLANTS AND EQUIPMENTS

13.1. General

13.1.1. On account of availability of cheap and abundant labour, only labour intensive methods have so far been largely used for road construction in the country except for hill and remote areas in the Himalayan region. Complete mechanisation of road construction was not considered necessary. Mechanisation is confined to situations requiring high productivity, high standard of quality and superior quality surface finish. Almost all road construction activities can be carried out manually except obligatory items like transportation of materials, rolling and other such items but mechanised means can accelerate speed and improve quality.

13.1.2. Construction of roads in hills are machine based with an appropriate mixture of labour due to the following main factors:-

a) Non-availability of adequate local labour
b) Difficult terrain/remote areas
c) Severe climatic conditions
d) Non-availability of infrastructure to sustain labour.

13.1.3. In most of the hilly areas, labour has to be imported from plains due to paucity of local labour. Such labour takes long time to acclimatise and their output is also comparatively lower. Thus use of labour intensive methods in hilly areas is often not economical and takes longer duration. The terrain in hilly areas is generally difficult. The construction of roads in some areas requires extensive blasting and the roads have to be carved through very steep and vertical rock faces. Thus exclusive dependence on manual labour for work in hilly areas has safety hazards. Due to severe climatic conditions in most of the hilly areas, the fair weather period available for work is also low. Some of the hilly areas have heavy rainfall or snow-fall for major part of the year. Since the time available for work is very limited, mechanisation is rather a necessity to achieve high productivity during the available short time.

13.1.4. Production of road construction machinery in the country is presently confined to only some selected machines and manufacture of most of these machines is of recent origin. Some of the machines, though indigenously available, cannot be used in hilly areas due to constraints like narrow width, sharp bends, steep gradients and severe climatic conditions. A suitable blend of machines and manual labour, depending upon local conditions and nature of activity, is generally considered most appropriate for hill road construction. The proportion is decided keeping in view the output norms of men and machines and fair weather period available for construction activity in different hilly areas. The average output norms for labour and machines for major construction activities are given in Appendices 9 and 10. The norms vary inter-alia with the terrain, climatic conditions and skill of labour. In case of machines, output norms further vary with make, model and mechanical conditions of machines and degree of complementing/balancing resources available. These norms are only a rough guide for altitudes upto 2100 meters.

13.1.5. For works at altitudes exceeding 2100 mtrs a reduction factor has to be applied as efficiency gets reduced due to high altitude effect. Considering loss of output of men and machines above 2100 mtrs altitude the extra efforts required upto 5700 m altitude is given in Table 13.1.

Table 13.1. Extra Efforts Required in respect of Men and Machinery for altitudes above 2100 m

Altitude in metres above MSL	Extra Efforts in % against MSL Personnel	Machines
2100-2400	7	3
2401-2700	15	6
2701-3000	25	9
3001-3300	32	12
3301-3600	48	15
3601-3900	66	18
3901-4200	86	21
4201-4500	108	24
4501-4800	132	27
4801-5100	156	30
5101-5400	180	33
5401-5700	204	36

13.1.6. The fair weather full working periods for heavy snowfall/rainfall areas in hilly region are generally assumed as follows:

a) Heavy snow fall areas - 6 months in a year (May to October)

b) Heavy rain fall areas - 7 months in a year (October to April)

13.1.7. The weather in most of the areas follows a cycle. Thus fair weather period also varies from year to year. The length of fair weather periods shown above is only the average period.

13.2. Construction Methods and Tools

13.2.1. Road construction work is divided into the following major phases:

a) Road alignment
b) Formation cutting/embankment
c) Protective and drainage works
d) Pavement works

13.2.2. The tools, appliances and equipment required for different construction activities/phases may be classified under the following sub-heads depending upon the method of construction adopted:-

a) Manual Method
b) Mechanised Method

Most of the tools and appliances used by manual labour for various phases of construction are conventional tools and appliances and common to all the activities/phases of construction. Special tools, appliances and equipment are also used for special construction activities like bituminous work and construction of concrete road, etc. Some machines/equipments like dozers, compressors, crushers, pay leaders and load carriers are also similarly common to most of the construction activities where mechanised methods are adopted.

13.2.3. **The following tools, appliances and equipment are generally required for manual and mechanized methods:**

A. Manual Method

A. Road Alignment - Recce survey and trace cut, layout

i. Abney level/quick setting level
ii. Ghat tracer :
iii. Prismatic Compass & Theodolite, where required : Distomat if available
iv. Dumpy level with staff :
v. Altimeter
vi. Measuring chain with arrows/tape
vii. Ranging roads, flags, pegs and nails
viii. Sharp knife
ix. Pick axes, crow bars, shovels and spades
x. Felling axes, sledges and Dahs
xi. Rope and mason's thread
xii. Tools for making machans
xiii. Oxygen kit

B. Formation cutting/embankment

Jungle clearance

i. Hand Saws, Felling axes and dahs
ii. Anchor bars and rope
iii. Flags and measuring tape

Excavation/Embankment

i. Pick axes, crow bars, shovels and spades
ii. Cane baskets and wheel barrows
iii. Sledges and chisels
iv. Rammers and compactors
v. Flags and rope
vi. Water cans, empty drums for storage of water and hose pipe
vii. Sheep foot roller with prime mover
viii. Template, straight edge 3 metres long and Engineer's sprit level
ix. Mason's thread and other tools as required for surface dressing or making camber.

Tools for making scaffoldiing

Blasting tools

i.	Auger/Crow bar/ Jumping bar	-	Made of steel for drilling holes in rocks
ii.	Stemming rod -		made of wood to charge and stem the holes for blasting
iii.	Scraper	-	Made of brass to clean the holes
iv.	Pricker	-	Made of brass, aluminium or wood to prick the cartridge prior to inserting detonator or detonating fuse.
v.	Crimper	-	Made of non-ferrous, non-sparking material for crimping the detonator to fuse.

C. Protective and drainage work

Layout and construction

i. Measuring boxes, water measures and sieves
ii. Spades and shovels
iii. Mortar pans, cane baskets and wheel barrows
iv. Iron rammers and wooden tampers
v. Dressing hammers and chisels
vi. Mason's tools including trowel, float, spirit level, straight edge and thread etc.
vii. GI buckets - 6 to 12 litres
viii. Empty drum or GI storage tank 200 litres capacity
ix. GI sheet for mixing mortar/concrete
x. Vibrator and concrete mixer
xi. Tools for making scaffolding

Curing

i. Hessain cloth and polythene sheets
ii. Buckets, cans and hose pipe
iii. Empty drums or water storage tanks 200 litres capacity

D. Pavement work

Picking up or removing old pavement

i. Pick axes, crow bars, hammers and chisels

Laying out

i. Pegs, nails, rope, measuring tape, chalk and angle iron
ii. Wooden strips of required dimensions for edge support

Cleaning the surface

i. Wire brushes
ii. Coir brushes
iii. Brooms and old gunny bags

Handling and spreading materials

i. Baskets lines with gunny cloth and wheel barrows
ii. Bucket GI-6 to 12 litres capacity
iii. Empty drums or GI storage tank-200 litres capacity
iv. Heating trays, wheel barrows
v. Hammer and cutter for opening bitumen drums
vi. 15 to 30 litres capacity containers for measuring aggregate
vii. Shovels and spades
viii. Rakers with small and long handle
ix. Spring balance 10 and 25 Kg
x. Bitumen boiler
xi. Chain pulley arrangement for lifting drums
xii. Tractor or other arrangement to pull the bitumen boiler (Road Roller may also be able to do this)

Checking profile and quality control

i. Thermometer dial type range 0^{o} - 250^{o}C

ii. Thermometer, mercury in glass-range 0° - $250^{\circ}C$
iii. Straight edge - 3 metres
iv. Camber board/template
v. Depth gauge

Special tools for pavement surfacing
i. Manually operated sprayers
ii. Road rollers - 3 wheeled smooth, tandem, vibratory & pneumatic as per specification of component layers of pavement

13.2.3.1. **Concrete roads:** Since in practice, the construction of concrete road is generally semi-mechanised, the list of tools, appliances and equipment, as required for semi-mechanised construction, is as follows:-

Subgrade/ sub-base correction and compaction
i. Pick axes, shovels, spades and wheel barrows
ii. Scratch templates
iii. Bulk head
iv. Vibratory roller
v. Water sprinkling device - water lorries, water carriers or watering cans
vi. 8/10 tonne three - wheeled roller, pneumatic roller

Fixing form work and concrete mixing
i. Form work and iron stakes
ii. Shovels and spades
iii. Sieving screens
iv. Weigh batcher/aggregate measuring boxes
v. Water pump
vi. Water measure
vii. Concrete mixers
viii. Cane baskets/pan mortars
ix. Water storage arrangement and GI buckets

Transportation, laying and compaction of concrete
i. Wheel barrows/iron pans
ii. Wooden bridges
iii. Mild steel sections for making joint grove
iv. Edging tools - Edging tool and double edging tool
v. Canvas belt
vi. Long handled broom
vii. Graduated wedge gauge and straight edge
viii. Diamond cutter - for making saw cut joints
ix. Grinder - for grinding local high spots
x. Concrete Vibrator or Form Vibrator with accessary arrangement to operate them.

Curing
i. Hessain cloth on polythene sheeting
ii. Water tank and GI buckets

Cleaning and sealing of joints
i. Iron raker
ii. Coir brushes
iii. Cycle pump for air blowing
iv. Kerosene stove
v. Thermometer
vi. Transferring pot
vii. Painter brush
viii. Pouring kettle and scraper

B. Mechanised Method

13.2.4. On major projects, the work of bulky and repetitive nature can be done more economically and efficiently by well-designed machines. The use of machines also greatly reduces logistic problems. Practically every operation in construction of roads can be performed by different types of equipment, but under any given set of conditions only a particular type of machine would be most effective. Thus selection of machines for any particular phase of construction requires detailed study about brands, models and specifications of the various equipment available and their suitability for particular phase of construction. IRC publication "Handbook on Road Construction Machinery" of MOST may be referred for further details.

13.2.4.1. A list of plant and equipment commonly required for different phases of mechanised construction are as follows:-

A. Formation cut/embankment

Jungle clearance

i. Crawler tractor with bulldozer attachment
ii. Power saw
iii. Tractor mounted winch
iv. Rooters

Formation cutting, excavation/embankment

i. Scraper, tractor/motorised or towed
ii. Crawler tractor with bulldozer/angle dozer/ripper attachment and wheel dozer.
iii. Excavator with shovel/drag-line attachment
iv. Pay loader - (Front end loader)
v. Disc harrow
vi. Rotary tillers
vii. Water lorries
viii. Water pump
ix. Motor grader
x. Compactor - Sheep foot with prime mover, Vibratory roller and smooth wheel roller (8/10 tonne capacity).

Blasting

i. Air compressor
ii. Wagon drill
iii. Jack hammer with accessories
iv. Exploder with shot firing cable
v. Ohm-meter
vi. Winch for suspending scaffolding

B. Protective and drainage works

i. Excavator
ii. Back hoe ripper with prime mover/tractor
iii. Concrete mixer
iv. Tripod pulley block/crane
v. Truck mounted mixers
vi. Vibrators Internal and screed type
vii. Fork lift
viii. Water lorries
ix. Bar bending machine
x. Water pump
xi. Load Carriers (Dumper/Tipper & Trucks)

C. Flexible pavement - (Pavement with bituminous surfacing)

Crushing of aggregate

i. Stone crusher

ii. Granulators
iii. Air compressor
iv. Jack hammer with accessories
v. Blasting accessories
vi. Tractor with dozer attachment, wheel dozer
vii. Pay loader (front end loader)
viii. Load carriers (Dumper/Tipper & Trucks)
ix. Generator

Laying base/sub-base courses

i. Grader
ii. Water bowser with water sprinkling system
iii. Disc harrow/rotary tillers
iv. Paver finisher
v. Compactors - 3 wheeled smooth roller 8/10 tonne capacity and vibratory roller
vi. Mixer for wet-mix macadam
vii. Power compactor for compacting narrow widths
viii. Load Carriers

Bitumen Work

Bituminous heating and handling equipment

i. Bitumen tanker (in case of bulk supply arrangement)
ii. Bitumen boiler
iii. Mastic cooker (in case of mastic asphalt)

Bitumen spraying and mixing equipment

i. Bitumen pressure distributor
ii. Gritter
iii. Hot mix or cold mixing plant of appropriate capacity with all accessories as laid down in IRC: SP-24
iv. Dumper/Tippers and Trucks

Spreading and laying bituminous courses

i. Paver finisher

D. Rolling equipment and pavement marking equipment

i. Three wheeled roller, 8/12 tonne
ii. Tandem roller
iii. Vibratory roller
iv. Pneumatic tyre roller
v. Pavement marker

E. Tools for checking surface evenness and density/compaction

i. Profilometer
ii. Density meter

13.2.4.2. The surface unevenness and compaction are generally checked with camber board/template, straight edge, depth gauge and density measuring kit. Recently unevenness indicator and nuclear density meters have also been introduced for exercising quality control.

F. Rigid pavement - Cement concrete roads

Preparation/compaction sub-grade

i. Motor grader
ii. Compactor - 8/10 tonne steel wheeled roller, vibratory roller, tandem roller
iii. Water bowser/water lorry with water sprinkling arrangement
iv. Hydraulic hammer
v. Hydraulic concrete cutter for cutting/dressing the concrete pavements neatly etc.

Preparation of concrete mix and laying

i. Weigh batch plant of suitable capacity
ii. Trucks/dumpers/tippers
iii. Mixer mounted on truck
iv. Water bowser/water lorry
v. Cement silo
vi. Concrete laying train
vii. Joint sealing machine
viii. Joint cutting machine
ix. Fork-lift for shifting at work site.
x. Water pump
xi. Concrete vibrators - internal type and screed type.
xii. Generator
xiii. Sub form paver

13.2.5. Tools and appliances for safety during construction. These are common to all activities and are listed below:

a) Road barriers
b) Diversion boards
c) Caution boards
d) Red flags
e) Red lamps
f) Field tent and accessories
g) Gum boots
h) Gloves
i) Goggles
j) First aid box
k) Oxygen kit for high altitude work

13.2.6. Apart from the tools, appliances and equipment required for construction, it will be necessary to set up well equipped laboratory for carrying out quality control and acceptance checks as per guidelines in IRC:SP-11 "Quality Control for Construction of Roads and Runways".

13.2.7. The list of equipment for various phases of construction in the preceding paras is by no means exhaustive. The list, however, includes the items which will generally be needed. Where no machine is available for any particular activity, the machine/equipment could be supplemented by manual labour, on as required basis, to ensure proper execution of such activities and quality control. In addition, some ancillary tools will also be required for all phases of construction for taking measurement, marking distances, storage of water and providing repair cover to the machine/equipment, etc.

13.2.8. The basic features of the various major equipments listed in the preceeding paras, have been briefly described in MOST "Hand Book on Road Construction Machinery" published by Indian Roads Congress, IRC publications like IRC:72-1978 "Recommended Practice for Use and Upkeep of Equipment, Tools and Appliances for Bituminous Pavement Construction" and IRC:43-1972 "Recommended Practice for Tools, Equipment and Appliances for Concrete Pavement Construction".

13.2.9. All the equipments should conform to the relevant ISI standards. Where no ISI standards are available the equipments shall conform to the approved quality to ensure satisfactory performance.

13.3. Selection of Machines

13.3.1. The following major equipments are generally required for construction of various phases of hill roads:

i.	Crawler tractor mounted with Bulldozer/angle dozer 80-100 HP and 180-192 HP	Formation cutting

ii.	Scraper : 130-160 HP	-	Formation cutting/embankment
iii.	Motor grader : 125-190 Hp	-	Subgrade preparation/correction of surface profile
iv.	Excavator : 100-120 HP	-	Formation cutting/side slope cutting/protective drainage works
v.	Compressor : 7-10 m^3/m	-	Blasting work/quarry operation
vi.	Road roller : 8-10 tonne capacity/Vibratory roller/Pneumatic roller	-	Compaction
vii.	Stone crusher with/without granulator : 30-50 tonne or Portable stone crusher 10-20 tonne capacity	-	Crushing of stone aggregates
viii.	Hot mix plant : 30-40 tonne capacity	-	Bituminous work
ix.	Concrete mixer 0.3/0.2 m	-	Concrete work
x.	Weigh batch plant : 0.5 cu.m	-	Concrete work
xi.	Front end loader bucket : 1.5-2 cu.m	-	Loading of Vehicles
xii.	Generator set : 2KVA, 11.5 KVA, 30 KVA	-	For Power supply
xiii.	Vehicles : 7-10 tonne capacity (Dumpers/Tippers/Trucks)	-	Transportation of resources

13.4. Output Factors of Earth Moving Equipment

13.4.1. Good organisation is always necessary to maintain output. The following factors are generally taken into consideration when planning deployment of equipment to obtain optimum output.

a. **Tractors mounted with dozer attachments**

The economical limit of haul, with the blade, is about 100 metres. It can be increased to about 120 metres when dozing down hill. Increased output is achieved by:-

i. Dozing down hill, whenever possible

ii. Using highest possible gear, especially when operating reverse.

iii. Slot dozing i.e. dozing in one path so that the windrows formed by the spillage from the slides of blade would reduce further spillage.

b. **Grader**

The grader is designed for accurate shaping and finishing of earth work. It should not be used for digging or transporting earth in bulk. Motor grader is self propelled and has pneumatic tyres; it can, therefore, travel on road without causing damage at high speed. It is suitable for light cuts in comparatively easy material. In wet soil condition, its tractive resistance is poor.

c. **Mechanical Excavator**

The output of mechanical excavator depends on the provision of adequate earth carrying transport, except when excavated material can be side-cast.

i. The number of haulage vehicles, that an excavator can feed with, is given by the following expression.

$$\frac{\text{Excavator output per hour}}{\text{Vehicle carrying capacity per hour}}$$

Vehicle carrying capacity per hour is made up of effective load per trip multiplied by number of trips per hour, the latter being loading time plus travelling time (haul and return) plus unloading time plus turning and manoeuvering time.

ii. The use of vehicle of same capacity saves time in loading as the number of buckets to a full load is soon established.

iii. The excavator swing, when loading, should be restricted to 90°.

d. **Scrapers**

The economical range of tractor scraper is about 300 metres, one-way haul. The motorised scraper is designed for longer hauls. Its deployment on short haul is wasteful and a bad practice. Optimum output is achieved by:-

i. Making maximum use of down grades for cutting and full haul. Downgrades should be created or increased when possible.

ii. Loading towards the fill or dumping area only, unless it conflicts with movement of vehicles. This reduces the low gear haul distance.

iii. Ensuring that heaped load is obtained; a push dozer may be needed to achieve this.

iv. Planning cuts to form intermediate ridges so as to permit saddle loading by following scraper.

v. Planning work to avoid unnecessary turns, gear changes and travelling in highest possible gear.

vi. Using ripper, if the ground is hard. Using push dozer, if it is soft and wet.

13.4.2. General factors affecting output

13.4.2.1. The following factors affect output of machines:-

a) Work must be planned to avoid interference between machines e.g. between digging plant or grader and haulage vehicles.

b) Haulage and working routes must be planned and well maintained and traffic control arranged.

c) Mutual assistance, e.g. push dozer and scrapers, must be organized.

d) Working down-grades increases output and upgrades reduces same.

e) Time spent on proper servicing is less than time lost through breakdowns due to neglect.

f) Output figure is generally based on an 8 hour shift. On longer shifts, hourly output will fall owing to fatigue of the operators.

g) Night work reduces output. With moonlight or artificial illumination, output is unlikely to exceed 80% of day light figures.

h) Slight moisture in sandy soil increases output by preventing dust and heaped loads. Wet soils form a slurry and can reduce output. Mud may bog down tractors and reduce output considerably. Frost may require rooting or blasting and subsequent thaw may bring the work to stand-still.

i) Drainage is of vital importance. Formation work grading must always maintain the correct cross section. Before closing down the work in the evening, ruts and potholes should be smoothed out and temoporary drainage ditches provided, where necessary.

13.4.3. **Balanced output**: The effective output of a machine is often dependent either upon the material made available to it by other piece of equipment or upon the rate of removal of the material which it itself produces. For example, material such as shale may have to be ripped with a ripper or blasted with explosives before it can be broken. If it is then loaded by a power shovel into dumpers or trucks for transport to a distant site, the overall output will depend not only upon the capacity of the power shovel but also upon the rate of loosening and number of haulage vehicles deployed. In any individual operation, therefore, it is important to ensure that a properly balanced set of equipment and labour is provided.

13.4.3.1. The principles of balanced output must, as far as possible, be applied throughout the chain of operations, to avoid wastage of inputs.

13.5. Optimum Output

13.5.1. Correct selection of equipment and tools, correct techniques of operation, balanced set of equipment and regular maintenance can give optimum and economical outputs from construction machinery.

14. MAINTENANCE OF HILL ROADS

14.1. General

14.1.1. A road is designed and constructed to cater to needs of the road user i.e. comfortable and safe passage on it at the design speed without a hold-up. Thus the road user and vehicle which compose the traffic is the most important consideration as soon as a road is opened to traffic. All facilities and amenities will have to be provided to ensure smooth traffic consisting of a well-maintained road with information on its condition, warnings and caution, way-side amenities, etc. This has to be ensured and assured on a regular and sustained basis which needs an effective and planned maintenance programme and its efficient implementation. On hill roads all above aspects become more pronounced due to terrain, topographic and climatic conditions of hill/mountain regions.

14.1.2. Maintenance of hill roads involves a variety of operations from planning, programming and scheduling to actual implementation on ground. The aim should be to keep the road surface and appurtenances in good order and extend life of the road assets to maximum possible and minimise hold-ups to traffic. This will include identification of defects and remedial measures and involves launching an effective management system. In broad terms, maintenance activity will include normal maintenance, periodic renewal, special repairs, emergent repairs, slide/snow clearance operations and preparation of a plan of timely upgradation based on traffic data.

14.2. Basic Maintenance Objectives and Policies

14.2.1. The basic objectives of maintenance function are to maintain and operate the highway system in a manner such that comfort/safety are afforded to public, investment, aesthetics and compatibility of road system including environment are preserved and resources are used economically. Each of these objectives is elaborated in following paras.

14.2.2. **Service to travelling public**: The road system should be maintained adequately at all times within the fiscal constraints to ensure safe and convenient travel considering the density and nature of traffic being served. Emergent conditions may develop from time to time adversely affecting safe and convenient travel which should be attended to promptly. Persons dealing with maintenance of traffic should be on call at all times and be ready to be of service in effective use of the roads.

14.2.3. **Preservation of investment**: It is the objective, as far as possible, to maintain all roads, bridges and appurtenances in originally constructed or subsequently improved condition, and perform works of such conclusive and restorative nature to ensure that the investment of public funds in each road is preserved.

14.2.4. **Preventive maintenance**: Maintenance of a clearly preventive nature (as opposed to waiting until correction is required) shall be performed by operating units. Planned work of a restorative nature (maintenance, replacements or reconstruction) which will be done in a reasonable length of time, shall be the only reason for deferring routine maintenance.

14.2.5. **Environmental considerations**: Maintenance operations should be performed in such a manner as to preserve or enhance the compatibility of the road system with environment. The maintenance of roadside shall be directed towards the preservation or enhancement of the natural beauty of the road land.

14.2.6. **Consistency of maintenance service:** All roads providing similar service will require similar maintenance care based on needs and requirements of particular region and road.

14.2.7. **Economy of operation and performance improvement:** It is the objective to constantly devote efforts towards improving the performance of the maintenance organisation through a process of research and analysis, management improvement and training, investigative research in the field of maintenance, equipment, materials and technology and regular communication with operating personnel to incorporate improvements as developed.

14.3. Performance of a Hill Road - Governing Factors

14.3.1. The performance of a hill road vis-a-vis traffic comfort is dependent mainly on the following:-

a) **Road geometrics**
   - Road and carriageway width, radii of curves, widening at curves, gradients, summit and valley curves, sight distance, super-elevation/camber/cross-fall etc.

b) Efficiency of drainage
c) Riding surface and its conditions
d) Unstable areas, slide-prone areas and areas susceptible to erosion.
e) Information system/signs
f) Climatic conditions

The above factors have therefore a prominent place of consideration in the maintenance efforts for the road.

14.4. Components of Maintenance Activities

14.4.1. Periodic Maintenance activities on hill roads will consist of the following:-

a) Routine maintenance and upkeep of road component as under:-

   i. Road pavement and shoulders including repairs of potholes, ruts etc.

   ii. Drainage system consisting of side drains, catch-water drains, sub-surface drains.

   iii. Culverts, bridges, causeways etc.

   iv. Structures like retaining walls, breast walls, parapets, railings, toe walls, check walls, river training structures, etc.

   v. Km. stones, road signs, boundary pillars, etc. including replacement when required.

   vi. Roadside accommodation like rest houses, inspection bungalows, residential and office/storage accomodation, gang huts, etc.

   vii. Roadside arboriculture, including development of scenic spots.

b) Clearance of land-slides/slips caused by rains or other natural causes.

c) Snow clearance to keep road open to traffic.

d) Providing adequate information, warning, etc. to the road user on the road condition.

e) Collection of traffic data for forecasting future trends to plan upgrading the pavement composition and if so necessary, the road standards.

14.4.2. Special repairs/flood damage repairs

Repairs of damages caused by floods, rains or other natural calamities that are beyond scope of ordinary repairs/routine maintenance come under this category and are normally executed as original job

Funds for these works may be from additional maintenance grant or capital works grant as decided by approving authority.

14.4.3. Emergent repairs

On hill roads, it may often become necessary to take up on immediate basis work of emergent nature like rebuilding structures, construction of bridges in replacement of washed away bridges, cutting a new formation in place of breached/washed off road stretch, diversions, etc., to restore traffic or to warn off danger to life/property. Such works may have to be commenced by field executive in anticipation of formal sanctions based on urgency as these works do not come under purview of normal maintenance or grant therefor. However this work is considered under 'Maintenance' as this is a work to ensure continued traffic ability of the road and special maintenance grant is allotted for this purpose.

14.4.4. Periodic renewal

This refers to periodic renewal of wearing course of the carriageway based on guidelines on life cycle and specifications adopted for the road. (In the case of gravelled or metalled or earthen roads, the renewal of the top layer is not normally done periodically but repairs carried out regularly under ordinary repairs. Where quantum of work is high due to damages by natural causes, these are treated as special repairs).

14.5. Planning and Financing

14.5.1. Inventory of road

14.5.1.1. The first step to planning of maintenance operation and for deciding required finance is evaluation of the existing road in terms of its physical condition, structural capacity and surface profile (roughness), etc. For this purpose, basic road inventory containing all details of the existing road should be available. The following details are required to have a complete inventory.

14.5.1.2. **District map**: District Map on the scale of 1:50,000 should be available with the following details shown in Fig. 14.1.

a) Classification/Category - width of roads
b) Location of streams and C D works
c) Type of surfaces
d) Lane width of road
e) Traffic intensity and volume
f) Urban limits

14.5.1.3. **Strip maps**: Strip maps where required of a particular section of the road must have the following details as given in Fig. 14.2.

a) Kilometrage, altitude, road geometrics viz. road width, steep gradients, if any, culverts with brief particulars, crossings, etc.

b) Availability of materials and location of quarries.

c) Availability of T & P, existence of stores and departmental workshops, gang huts, etc.

d) Any other features such as sections which require special attention to substandard geometrics, e.g. inadequate sight distance, horizontal or vertical alignment, narrow width, inadequate superelevation, weak bridges, etc.

e) Broad soil types, hill slopes and terrain data.

f) Unstable/slide - prone area, snow/avalanche/glacier area

LEGEND

1. W.B.M. ROADS	W.B.M.	MAJOR BRIDGE
2. SURFACE PAINTING ONE COAT	S.D.(S)	REFERENCE NO.
3. SURFACE PAINTING TWO COATS	S.D.(D)	
4. OPEN GRADED CARPET	P.C.	SUB-STANDARD
5. MIX-SEAL SURFACING	M.S.S.	ALIGNMENT
6. SEMI DENSE CARPET	S.D.C.	
7. ASPHALTIC CONCRETE	A.C.	LANE WIDTH
8. CEMENT CONCRETE	C.C.	L = SINGLE LANE
		D = DOUBLE LANE

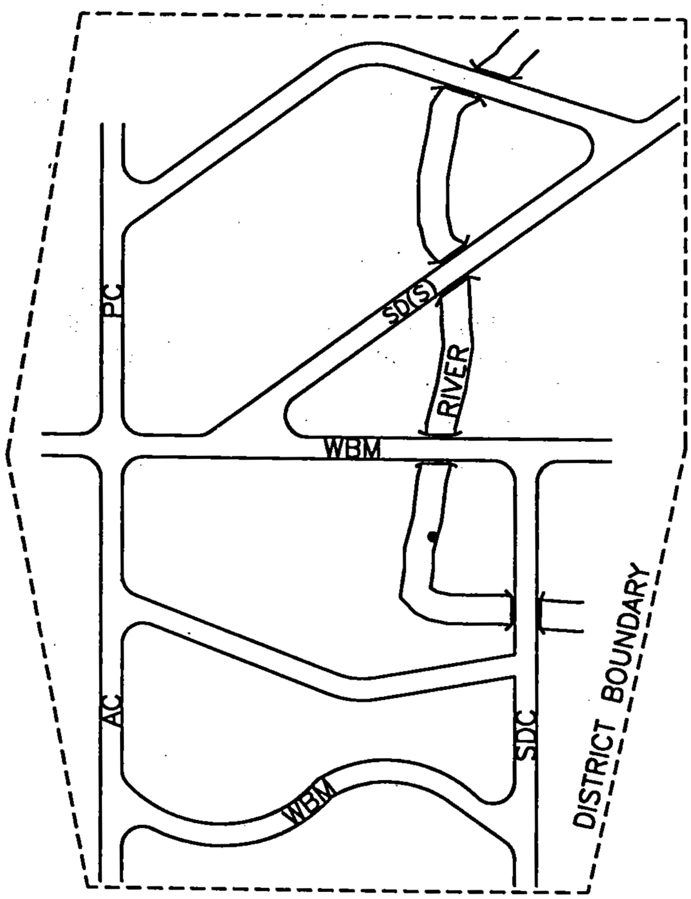


FIG. 14.1. DISTRICT MAP SHOWING ROADS

14.5.1.4. **Surface history:** Surface history of the road should be compiled in the format given in Appendix 11. It should contain the summary of information available in the road register maintained on the prescribed lines. The information should be as accurate as possible and collected from the available records. This will help in deciding when renewal coat due with its period in a particular stretch of road.

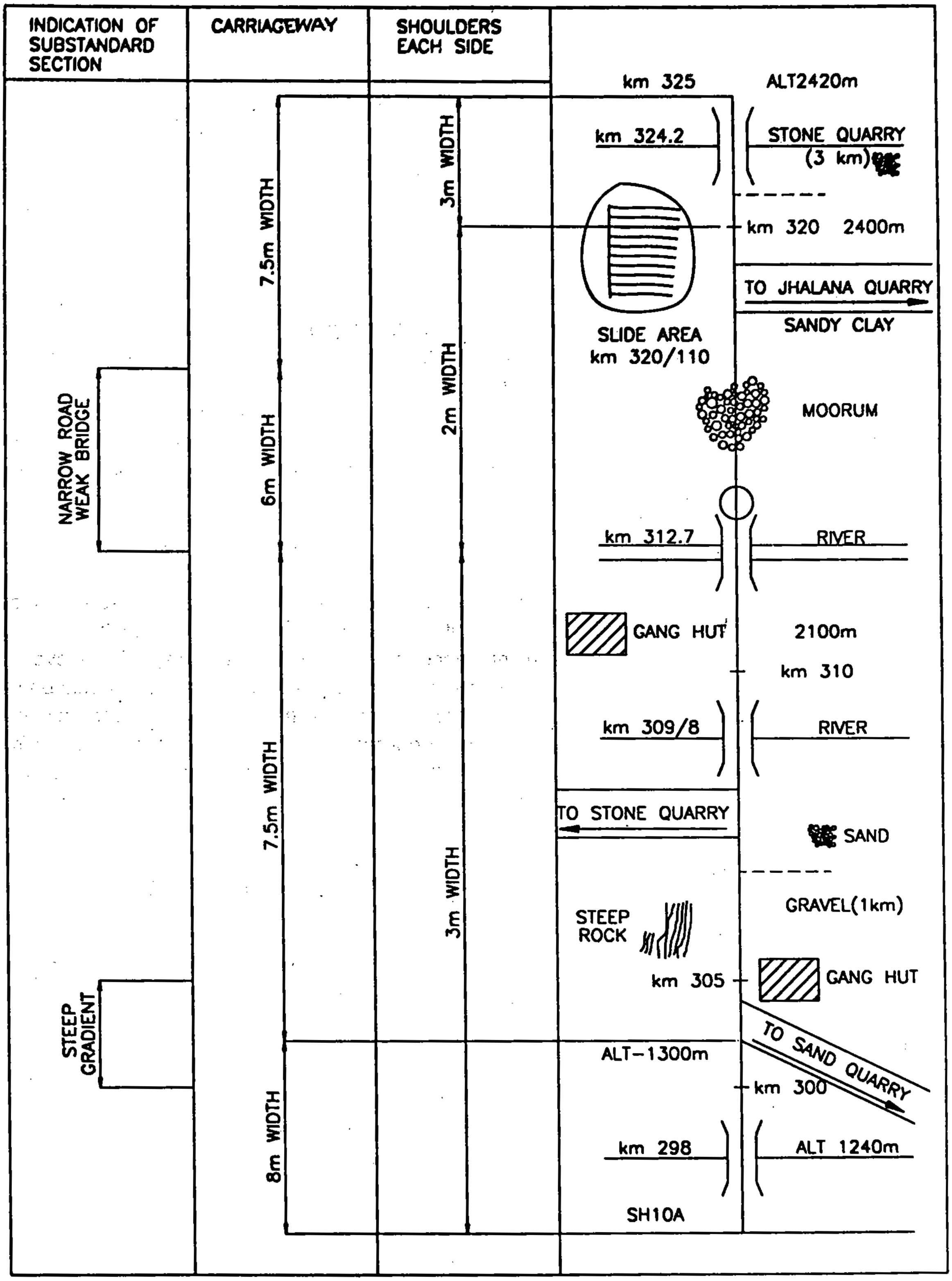


FIG. 14.2. STRIP CHART (ROAD INVENTORY CHART)

14.5.2. Condition survey

14.5.2.1. When all the inventory of the road is available, condition survey can be carried out:

a) By visual inspection
b) By mechanical evaluation

Condition survey by visual inspection/assessment of the pavement cover the type, magnitude and location of the deficiency or distress. Necessary information about the routine maintenance can be had by simply going along the road and comparing past and present state and arriving at the likely causes of distress.

14.5.2.2. Pavement surface evaluation based on surface condition (cracking, patching), riding quality (i.e. road roughness) and skid resistance would form basis for taking periodic maintenance decisions. Condition survey at fixed frequency is necessary for determining periodic renewal requirements, long term maintenance strategy and need for upgradation. For this purpose, the condition survey should be conducted for each stretch of the road as frequently as the situation warrants. Generally, the condition survey is carried out from a vehicle travelling at a slow speed supplemented by inspection of more critical spots on foot. The data collected should be recorded methodically kilometre-wise. It is desirable that these condition surveys be carried out by the Junior Engineer/Assistant Engineer. While carrying out inspections, the check list of items given in Appendix - 12 should be kept in mind. The findings of condition survey should be recorded in a suitable format.

14.5.3. Programming and planning

14.5.3.1. Based on the condition evaluation, the causes for the various defects observed should be examined in detail and a decision taken whether to initiate a particular maintenance activity, or to go in for more detailed investigations to determine the maintenance/rehabilitation needs precisely. Whenever distress on the pavement has reached the stage which affects the smooth operation of traffic, it should be rectified straightway. For other defects like cracking, ravelling etc., the optimal strategy should be determined having regard to the various factors involved and a decision taken whether to go in for measures like seal/renewal coat or to strengthen/reconstruct the pavement. If the latter appears necessary, further investigations about structural deficiencies must be taken up. In other words, the planning of the various maintenance operations should be co-ordinated and looked upon as a total system rather than each activity being considered in isolation. The criteria for maintenance priorities/rehabilitation needs would be as per the guidelines given under the heading "Maintenance Criteria" in paras 14.7 and 14.7.1 to 14.7.2.1.

14.5.3.2. Once the overall maintenance plan has been drawn up, attention should be given to the proper organisation and management of the whole programme including deployment of various resources i.e. men, materials and equipment, in an efficient manner. For each maintenance activity, the work at site should be carefully controlled so that the optimum output and quality are achieved.

14.5.3.3. **Annual calender of road maintenance activities**: The planning and programming of various major maintenance activities throughout the year should be done in advance keeping in view the climatic conditions and periods available for carrying out different activities. This calendar will help in planning the activities at the appropriate time.

14.5.4. Scales of maintenance

14.5.4.1. Roads in hills are subject to vagaries of weather like heavy rain-fall, floods, land-slides, snowfall, breaches, etc. blocking road and compelling closure of road at times inspite of the desirable principle that a road is available for traffic all the time. Though the resources and financial outlay required for uninterrupted road availability may be dispropotionately huge, (and even then an assurance of uninterrupted availability cannot be ensured at all times on a hill road) it is a practice to classify roads under different scales of maintenance depending on their importance. Certain norms/guidelines for maintenance of hill roads have been laid down by a Committee appointed by MOST, which may be followed to the extent the availability of funds permits.

14.5.4.2. Roads in snow bound areas are so classified depending on intensity, quantum, and period of snow fall i.e. roads planned to be kept open throughout the year and those kept open only in summer months (i.e. closed in winter).

14.5.5. Financing

14.5.5.1. Adequate finances have to be arranged on an annual basis for all activities of maintenance as under:

a) Ordinary repairs/routine maintenance and data collection are financed out of annual maintenance grants.

b) Periodical renewals are met out of separate sanction or grants under maintenance head or as works financed as original/capital work.

c) Special repairs/flood damage repairs and emergent repairs are met out of separate grants under original/capital works or special maintenance grant as decided by approving authority.

d) Clearance of snow in winter or summer or both, which can not be done under normal maintenance, need a separate grant under maintenance head.

14.5.5.2. The inspection should be done as frequently as possible by engineers at various levels as required of them.

14.5.5.3. As the traffic worthiness and safety on hill roads depend on efficient maintenance, efforts should be made to get finance to an approved scale per Km per year for ordinary repairs, and maintenance, annual grants for snow clearance, assessed annual amounts for special repair and anticipated emergent repairs through annual budget so that finances do not hinder road availability of desired standard to the user.

14.6. Inspection

14.6.1. Inspection should be carried out not only to check the condition of works but also for planning future strategies. Senior officers should make it a point to note and communicate instructions to the subordinates. While on inspection, the senior officer should go through the notes of junior colleagues and make suitable suggestions so that inspections are meaningful. Items required to be inspected are listed in the check list given at Appendix 12.

14.6.2. **Identification of defects**: It is important to identify and locate the defects of surface, shoulders, side drains and cross drainage during the inspection of the road by various officers. Reference should be made to IRC: 82 "Code of Practice for Maintenance of Bituminous Surfaces of Highways" to help in identifying the various surface defects such as bleeding, streaking, cracking, ravelling, edge subsidence, edge fretting, rutting, shoving, potholes etc. Common defects and deficiencies of shoulders, side drains, cross drainage works, etc., have been indicated in a separate para 14.8.6 under the heading "Maintenance of Drains, Cross Drainage Works, Shoulders and Slopes". A suitable procedure showed be evolved for inspection and planning.

14.7. Maintenance Criteria

14.7.1. Once the inspection of road for condition survey has been carried out and its findings available, the priorities for the required maintenance operations are required to be fixed. These priorities are to be assigned judiciously looking to the urgency of the work. The urgency is governed by factors like

a) Safe and unobstructed flow of traffic

b) Preservation of the assets in the form of roadway and its appurtenance and

c) Preventive maintenance to avoid any further deterioration.

14.7.1.1. Guidance regarding assignment of priorities is given in Table 14.1, which indicates the priorities for various operations broadly on the following principles.

a) Urgent for jobs requiring top priority

b) Special for jobs which are in next order of priority

c) Recurrent for jobs which occur recurrently and are next to special in order of priority and

d) Routine - for jobs which are to be attended to in a routine manner.

Table 14.1. Priorities for Maintenance

Feature 1		Criteria 2	Action 3	Priority 4
A. Features concerned with safety of traffic				
1.	Landslides/slips	Any type of slip or slides blocking the road and affecting flow of traffic.	Steps to be taken as given in Chapter 17 "Traffic Management". Slide to be cleared on top priority.	Urgent
2.	Snow-fall/Avalanche	Road affected by snow-fall or avalanche activity, compelling suspension of traffic.	To be cleared as per policy on road-open period in winter season for the road	Urgent
3.	Major breaches in the roadway	Any type of breach which endangers safety of traffic and causes obstruction to flow of traffic.	Steps to be taken as given in Chapter 17 "Traffic Management"	Urgent
4.	Minor cuts, ruts or blockades	Cuts or blockades which do not completely obstruct the traffic but endanger safety of traffic.	Blockades to be removed and the cuts repaired.	Urgent
5.	Branches of trees of height less than 4.5 m over the roadway.	Any kind	Get them cut in order of lower ones first	Special Attention
B. Carriageway and crust conditions				
1.	Cracking not accompanied by rutting	a) Cracking in local areas equal to or less than 25 per cent of the total area.	a) Local sealing or filling of the cracks.	Routine
		b) Cracking in large areas exceeding 25 per cent of the total area	b) Binder @ 1.5 kg/m^2 of bitumen emulsion or of 1 kg/m^2 of cutback for local sealing.	Special Attention
			c) Chippings (6-10 mm) for local surfacing repairs. Needs surfacing after local sealing	

Feature 1		Criteria 2	Action 3	Priority 4
2.	Stripping	a) In local areas exceeding 25 per cent of the total area	Apply local sealing	Routine
		b) In long areas exceeding 25 per cent of total area	Apply surface dressing	Special Attention
3.	Bleeding	a) In local areas not exceeding 25 per cent of total area	Spread and roll over 6 mm size aggregate, heated to 60°C	Routine
		b) In local areas exceeding 25 per cent of total area	Apply surface dressing	Special Attention
4.	Rutting	a) Less than 50 mm accompanied by cracking of less than or equal to 10 m/m^2	Apply coat @ 0.5 kg/m^2 and fill bituminous mix using a rake and leaving an excess thickiness of about one third the depth of rut. Compact till surface is level and do local sealing of cracks.	Routine
		b) Less than 50 mm accompanied by cracking more than 10 m/m^2	-do-	Special Attention
		c) More than 50 mm accompanied by cracking more than 10 m/m^2	With surface dressing over cracks. Overlay required	Work of original nature
5.	Potholes	Potholes as soon as they occur	Local restoration by patching	Special Attention
6.	Reflection cracks	a) Widely spaced cracks	Seals	Recurrent
		b) Closely spaced cracks	Apply surface dressing	Special Attention
7.	Edge subsidence and rutting	Any extent	Patch road edge and repair shoulder	Recurrent
8.	Defective camber	Any extent	Check and correct by reconstructing to proper camber profile	Special Attention
9.	Undulations	Any extent	Investigate the cause and rectify	Special Attention
10.	Loss of material from unpaved road	Any extent	Do regravelling	-do-
C. Shoulders, side drains, catch water drains, etc.				
1.	Deformation or scour of shoulders	Any extent	Fill, compact and bring its surface to desired camber	Routine
2.	Silting of drains	-do-	Clean out the drains	Routine
3.	Damage or scouring of drains	-do-	Reconstruct to adequate shape and size	Special Attention
D. Cross drainage works - causeways, culverts/minor bridges, equipment bridges				
1.	Causeways			
	a) Potholes in paved surface	Any extent	Repair by filling	Special Attention

Feature 1	Criteria 2	Action 3	Priority 4
b) Erosion at inlet/outlet	-do-	Repair	-do-
c) Guide posts/Flood gauge missing	-do-	Repairs/Replace	-do-
2. Culverts			
a) Silting	Any extent	Desilting	-do-
b) Erosion at inlet/outlet	-do-	Repair	-do-
c) Settlement cracks	-do-	-do-	-do-
3. Equipment Brs.			
a) Damage	-do-	-do-	Urgent
E. Major bridges			
1. Damage to substructure including foundation	Any extent	Investigation and repairs	As per bridge maintenance and repair policy
2. Damage to superstructure including roadway	Any extent	Investigation and repairs	As per bridge maintenance and repair policy
F. Structures like retaining walls, breast walls, river training structures etc.			
1. Damaged structures	Any extent	Repair	Urgent
2. Collapsed structures	-do-	Rebuilding	Urgent
G. Other works			
1. Road furniture and warning signs dirty or corroded or damaged/missing	Any extent	Clean and repair/replace	Routine
2. Missing road signs	Any extent	Fix new one	Special Attention

In case the road is breached or blocked action as given in Chapter 17 'Traffic management' should be taken.

14.7.2. **Criteria for renewal:** The wearing course will need renewal periodically either as redoing the worn-off or distressed wearing course or to upgrade the same to superior specifications to cater to the increased traffic needs. The following criteria may be adopted in this regard:-

a) Normally, the wearing surface will have a life cycle under design traffic conditions, weather conditions, etc. Based on inspection and surveys of the condition of the surface, over a period of time and considering traffic/climatic conditions, normal life cycle for surface course should be arrived at, which can act as a guide. The rough life cycle for hill roads, is given, Table 14.2 as a guide.

b) While the life cycle given above is a guide, there will be instances where the condition may not warrant renewal even if stipulated life has been achieved and may be deferred. There may also be cases where renewal may be required before stipulated life. In such instances renewal showed be done at that time to prevent deterioration of the pavement and hazards to traffic.

c) When a road is due for renewal, it would be logical and rational to evaluate traffic volume and conditions and plan up-gradation of specifications of wearing course. The guidelines for assessment of traffic and need for upgradation are given in Chapter 4 "Planning Criteria". If upgradation is necessary, design and specifications should be as per Chapter 10 "Pavement Design" for Hill Roads in respect of composition and specifications.

Table 14.2. Life Cycle in Years for Different Renewal Treatment

Type of Treatment	S.H./M.D.R.				O.D.R./V.R.	
	Traffic upto 450 CVD		Traffic more than 450 CVD		Traffic upto 450 CVD	
	B.T.	W.B.M.	B.T.	W.B.M.	B.T.	W.B.M.
S.D.C	-	-	6	-	-	-
P.C.	6	-	5	-	6	-
S.D.	5	-	4	-	5	-
MR	-	5	-	4	-	5

SDC - 25 mm Semi-dense carpet
PC - 25 MM Premix carpet with seal coat
SD - One coat surface dressing with precoated chips
MR - 75 mm (compacted) metal renewal i.e. 100 mm loose

14.7.2.1. It must always be borne in mind that if timely renewals and/or upgradations are neglected, the road condition is bound to deteriorate not only resulting in inconvenience to traffic but also in compromising safety and possible avoidable additional finances to restore normalcy.

14.8. Execution of Maintenance Operation

14.8.1. Safety of labour and road user during maintenance

14.8.1.1. **Principles:** In the implementation of maintenance operations, the road user and personnel involved in the work should not be exposed to hazards. Besides, delay and inconvenience to the traffic should be reduced to the minimum. Road user, even when fully aware that maintenance is for his ultimate good and safety, does not take it kindly if it is not done in a proper manner.

14.8.1.2. Traffic hazards and inconvenience can be minimised by use of temporary road signs and controlling/guiding of the traffic. While keeping in mind the positioning of road signs, the standard signs in good and clear condition should be displayed in a proper and standard layout, so as to give the drivers sufficient time to understand and react to the information on the sign. The signs to be used should be as per IRC:67-1977 "Code of Practice for Road Signs". A few of these are shown in Fig. 14.3.

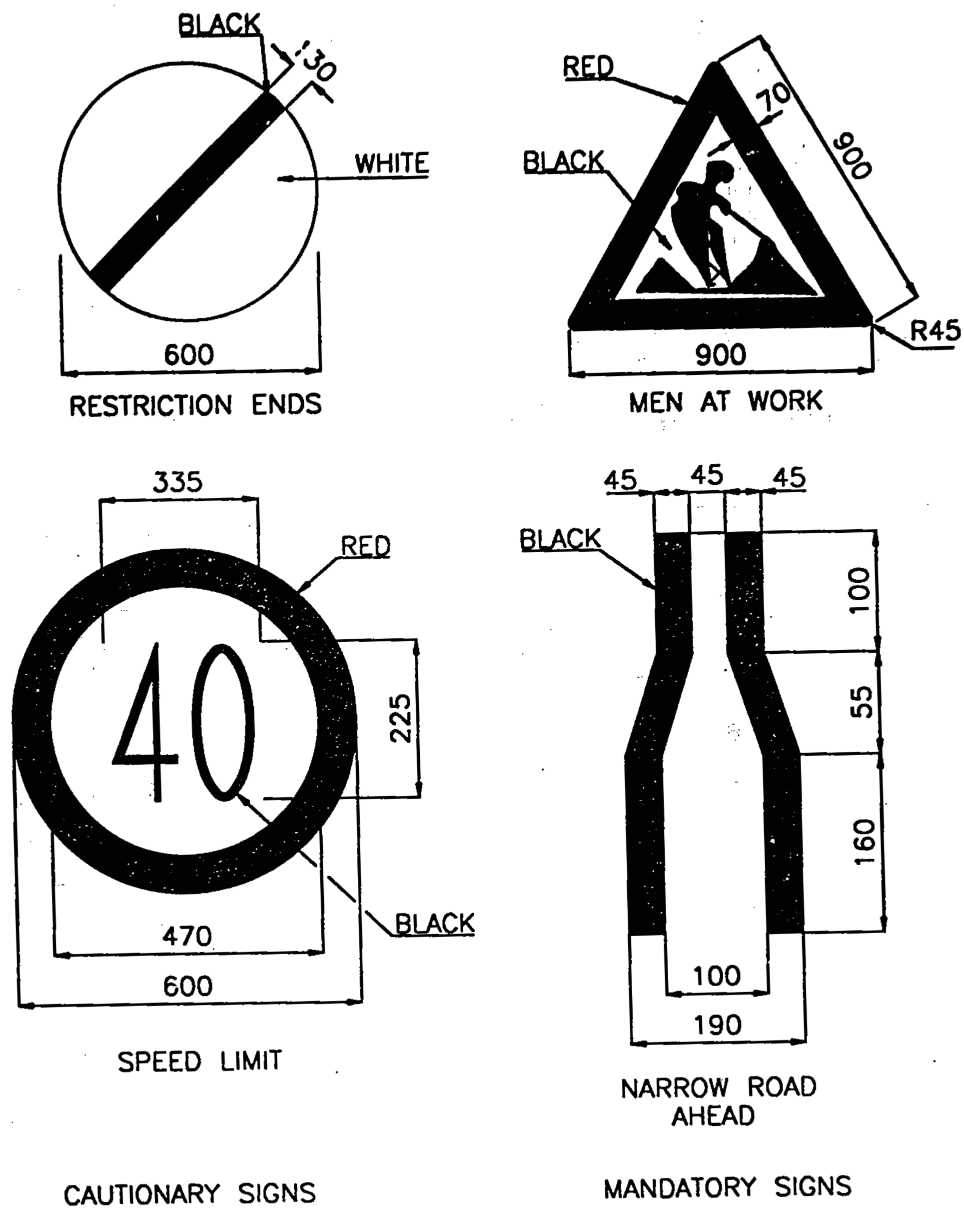


FIG. 14.3. A FEW ROAD SIGNS

14.8.1.3. Maintenance operations at a time should be confined to small lengths, say 30 m, half the pavement width, leaving the other half for use by traffic. However, sometimes this may not be possible, and in such a case, maintenance work can be divided in the following four categories from the point of view of safety and traffic control:

a) Repairing the edges of the carriageway, shoulders, cleaning out drains, cutting grass etc, where carriageway is not affected.

b) Repairing the carriageway restricting the traffic.

c) While working on the centre line such as centre line marking/painting necessitating the traffic to use restricted width on either side.

d) Total closure of the road necessitating use of diversion due to widening/reconstruction of an existing CD work or construction of a new structure or due to breach or damage to existing road or CD works or due to land-slides.

14.8.1.4. Procedure for various categories are given in succeeding paragraphs.

14.8.1.5. **Works on edges and shoulders:** The positioning of the cautionary signs for this category are illustrated in Fig. 14.4. Before starting the work, all warning signs should be installed in the following manner. "MEN AT WORK" should be placed 200 m before approaching the work area and "RESTRICTION ENDS" sign should be displayed 200 m beyond the work area. When the work is completed, these signs should be removed in the reverse order.

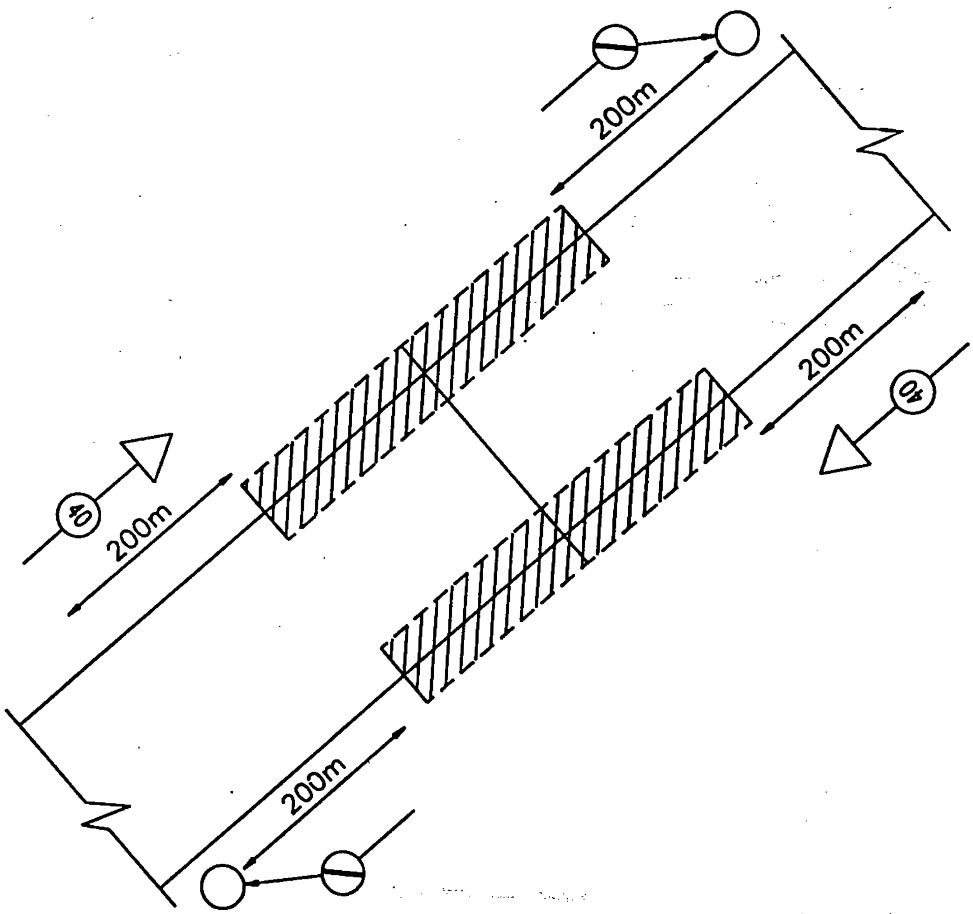


FIG. 14.4. ARRANGEMENT OF SIGNS FOR WORK ON EDGE AND SHOULDERS

14.8.1.6. Restricting the traffic: At times, the traffic is to be restricted only due to repairs being carried out such as major patch repairs, etc. The position of various cautionary and warning signs are illustrated in Fig 14.5 which are to be installed before start of the work in the following sequence:

i. "MEN AT WORK" sign to be put up 200 m before approaching of work site.

ii. "NARROW ROAD AHEAD" should be at 100 m ahead of work area.

iii. "KEEP LEFT/RIGHT" sign to be placed at the commencement point of work and next to the barriers on either end of the work area.

iv. "BARRIERS" should be placed on both sides of the work area.

v. DRUMS painted white and black should be placed at 10 m intervals for guiding the traffic. In the approaches these are to be kept in a tapered manner.

vi. "RESTRICTION ENDS" sign should be installed 200 m beyond the work area.

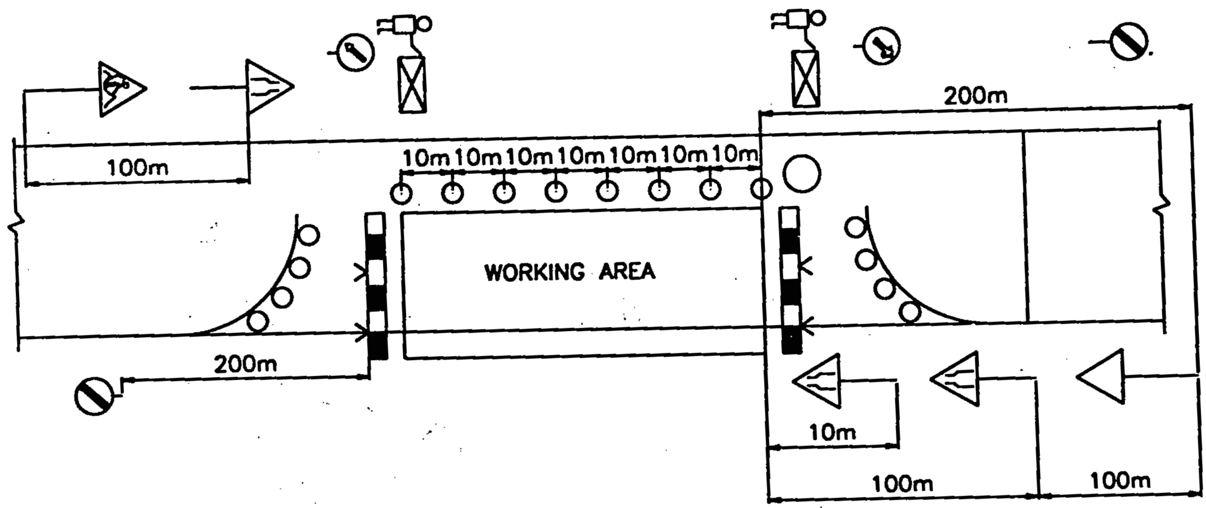


FIG. 14.5. ARRANGEMENTS OF SIGNS FOR CLOSURE OF ONE LANE

14.8.1.6.1. In addition to the above a watchman should be present at the barrier to control the traffic at all times. Police assistance may also be sought for in case of need. Necessary lighting arrangements may be made during night with flashing lights when required. The barricade should be lighted with red warning lamps at night which should stay lit from sun set to sun rise. In addition, alternate black and white diagonal strips should be marked on these for effective advance warning, preferably with reflectorised paint.

14.8.1.6.2. Signs, lights, barriers and other traffic control devices should be kept maintained in a satisfactory condition till such time the traffic is restored and allowed to follow its normal path.

14.8.1.7. **Working in the centre line of carriageway:** On hill roads work on centre line of single lane roads like marking should, preferably be done in the nights or early mornings, when traffic is very low as diverting traffic to half-width may not be practicable in all cases. The procedure laid down below may be followed in two-lane roads and at locations in single lane roads where passing traffic on half-width is possible:-

"The traffic should use available half-width. Cautionary and warning signs should be installed as given in preceding paras 14.8.1.6.1 and 14.8.1.6.2 as per sequence given therein."

14.8.1.7.1. The positioning of signs etc. as above is given in Fig. 14.6.

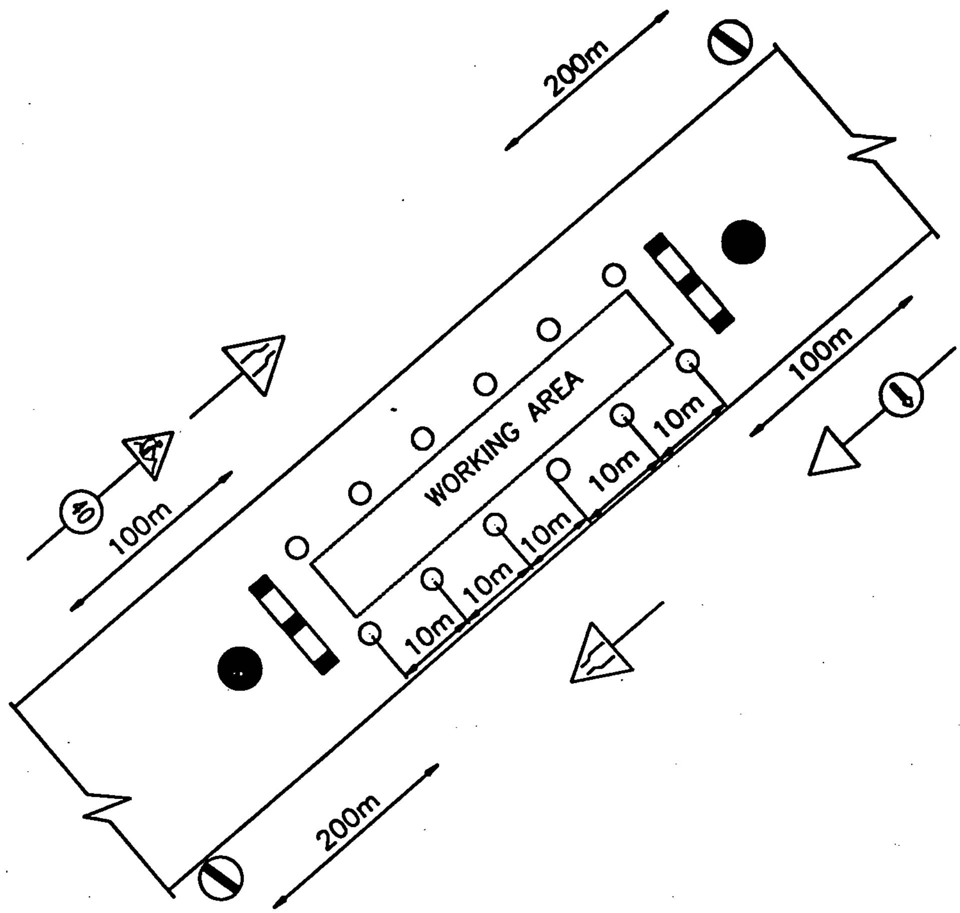


FIG. 14.6. ARRANGEMENT OF SIGNS FOR WORKING IN CENTRE OF CARRIAGEWAY

14.8.1.8. **Diversions:** In the interest of safety and convenience of traffic, appropriate measures must be taken whenever traffic on any section of a highway is to be diverted to another route, or made to sever from its normal path into another. Basic principles to be kept in mind are:

i. that the traffic must be guided properly where it is required to follow an alternate facility,

ii. given a clear warning of any hazards that may be present ahead.

14.8.1.8.1. The typical situations arising in above are:-

a) Arrangement when traffic is suspended on a section of the road closed due to breach or damage.

b) Arrangement when traffic in part of carriageway is blocked due to land-slides or repair/reconstruction of cross-drainage works, etc., when traffic is allowed one way on part width or through a local diversion.

The above are dealt with in detail in Chapter 17 "Traffic Management" paras 17.2., 17.3 which may be referred.

14.8.1.9. **General:** It will probably not be possible to provide all the safety requirements recommended for small works due to paucity of funds and limitation of resources. Hence, the engineer must take his own decisions regarding display of adequate cautionary signs depending upon the traffic on the road. However, for important roads, these systems must be adopted. The following further precautions must be taken:

a) For safety of workmen

i. Workmen must be trained in use of tools and plant.

ii. Gum boots, spectacles, etc. must be given to persons using bitumen.

iii. First aid training and kits should be provided.

iv. Helmets, goggles, etc. as required for the type of work engaged on should be provided.

b) For safety of road user

i. As far as possible, the materials, equipment and machinery should be collected/installed/parked in places sufficiently away from the berms in the available road land. Only in unavoidable cases, the same shall be allowed to be collected/installed/parked near the edge of the berms. In any case, no material should be collected nor any equipment/machinery installed/parked cn berms near and in the curves.

ii. Caution sign boards should be maintained at all the required and desired places.

iii. Machinery should be parked at appropriate places with red flags and red lights on.

iv. Minimum quantity of materials required for one operation should be collected so that it does not hinder the road user.

14.8.2. Symptoms, causes and treatment of surface defects

14.8.2.1. The types of defects in bituminous surfacing are grouped under four categories as under:

a) Surface Defects

These include fatty surfaces, smooth surfaces, streaking and hungry surfaces. These are associated with the surfacing layers and may be due to excessive or deficient quantities of bitumen in these layers.

b) Cracks

These can be broadly classified as hair-line cracks, alligator cracks, longitudinal cracks, edge cracks, shrinkage cracks and reflection cracks. A common defect in bituminous surface is the formation of cracks. The crack pattern can, in many cases, indicate the cause of the defect. As soon as cracks are observed, it is necessary to study the pattern in detail so as to arrive at the cause. Immediate remedial action should be taken there after because of the danger of ingress of water through the cracks and of the formation of pot holes and ravelling. Cracks can hardly be observed from moving vehicles and inspection on foot is always essential.

c) Deformation

Under this are grouped slippage, rutting, corrugations, shallow depressions, settlements, and upheavals. Any change in the shape of the pavement from its original shape is a deformation. It may be associated with slippage, rutting, etc. The treatment measures aim at the removal of the cause, and bringing it to original level by fill material or by removing the entire affected part and replacing it with new material.

d) Disintegration

This covers stripping, loss of aggregates, ravelling, formation of potholes and edge breaking. These are some defects, which if not rectified immediately result in the disintegration of the pavement into small loose fragments and necessitate complete rebuilding of the pavement.

14.8.2.2. The details of various types of defects and their treatment are given in Table 14.3 and broad specifications for sealing and patching materials in Table 14.4:

Table 14.3. Symptoms, Causes and Treatment of Defects in Bituminous Surfacings

Sl. No.	Type of Distress	Symptoms	Probable Causes	Possible type of Treatment
A. Surface Defects				
1.	Fatty surface	Collection of binder on the surface	Excessive binder in premix, spray or tack coat, loss of cover aggregates; excessively heavy axle loads	Sand blinding, open graded premix, liquid seal coat; burning of excess binder; removal of affected area
2.	Smooth surface	Slippery	Polishing of aggregates under traffic or excessive binder.	Resurfacing with surface dressing or premix carpet.
3.	Streaking	Presence of alternate lean and heavy lines of bitumen	Non-uniform application of bitumen or at a low temperature.	Application of a new surface
4.	Hungry surface	Loss of aggregates or presence of fine cracks	Use of less bitumen or absorptive aggregates.	Slurry seal or fog seal
B. Cracks				
1.	Hair line crack	Short and fine cracks at close intervals on the surface.	Insufficient bitumen, excessive filler or improper compaction.	The treatment will depend on whether pavement is structurally sound or unsound. Where the pavement is structurally sound, the crack should be filled with a low viscosity binder or a slurry seal or fog seal depending on the width of cracks. Unsound cracked pavements will need strengthening or rehabilitation treatment.
2.	Alligator crack	Inter-connected cracks forming a series of small blocks	Weak pavement, unstable conditions of sub-grade or lower layers, excessive overloads or brittleness of binder.	-do-
3.	Longitudinal crack	Cracks in a straight line along the road	Poor drainage, shoulder settlement, weak joint between adjoining pavement layers or differential frost heave.	-do-
4.	Edge crack	Crack near and parallel to pavement edge.	Lack of support from shoulder, poor drainage, frost heave, or inadequate pavement width.	-do-

Sl. No.	Type of Distress	Symptoms	Probable Causes	Possible type of Treatment
5.	Shrinkage crack	Cracks in transverse directions or inter-connectd cracks forming a series of large blocks.	Shrinkage of bituminous layer with age.	-do-
6.	Reflection crack	Sympathetic cracks over joints and cracks in the pavement underneath.	Due to joints and cracks in the pavement layer underneath.	-do-
C. Deformation				
1.	Slippage	Formation of crescent shaped cracks pointing in the direction of the thrust of wheels	Unusual thrust of wheels in a direction, lack or failure of bond between surface and lower pavement courses.	Removal of the surface layer in the affected area and replacement with fresh material.
2.	Rutting	Longitudinal depression in the wheel tracks	Heavy channelised traffic, inadequate compaction of pavement layers, poor stability of pavement material, or heavy bullock cart traffic.	Filling the depressions with premix material.
3.	Corrugations	Formation of regular undulations.	Lack of stability in the mix, oscillations set up by vehicle springs, faulty laying of surface course.	Scarification and relaying of surfacing, or cutting of high spots and filling low spots.
4.	Shoving	Localised bulging of pavement surface along with crescent shaped cracks	Unstable mix, lack of bond between layers, or heavy start - stop type movements and those involving negotiation of curves and graidents.	Removing the material to firm base and relaying a stable mix.
5.	Shallow depression	Localised shallow depressions.	Presence of inadequately compacted pockets.	Filling with premix materials.
6.	Settlement & upheaval	Large deformation of pavement	Poor compaction of fills, poor drainage, inadequate pavement, or frost heave.	Where fill is weak, the defective fill should be excavated and redone. Where inadequate pavement is the cause, the pavement should be strengthened.
D. Disintegration				
1.	Stripping	Separation of bitumen from aggregate in the presence of moisture.	Use of hydrophilic aggregate, inadequate mix composition, continuous contact with water, poor bond between aggregate and bitumen at the time of construction, poor compaction etc.	Spreading and compacting heated sand over the affected area in the case of surface dressing; replacement with fresh bituminous mix with added anti-stripping agent in other cases.

Sl. No.	Type of Distress	Symptoms	Probable Causes	Possible type of Treatment
2.	Loss of aggregate	Rough surface with loss of aggregate in some portions	Ageing and hardening of binder, stripping, poor bond between binder and aggregate, insufficient binder, brittleness of binder etc.	Application of liquid seal, fog seal, or slurry seal depending on the extent of damage.
3.	Ravelling	Failure of binder to hold the aggregate shown up by pock marks or eroded areas on the surface	Poor compaction, poor bond between binder and aggregate, insufficient binder, brittleness of binder etc.	Application of cut-back covered with coarse sand, or slurry seal, or a premix renewal coat.
4.	Pothole	Appearance of bowl shaped holes, usually after rain.	Ingress of water into the pavement, lack of bond between the surfacing and WBM base, insufficient bitumen content, etc.	Filling potholes with premix material, or penetration patching.
5.	Edge breaking	Irregular breakage of pavement edges	Water infiltration, poor lateral support from shoulders, inadequate strength of pavement edges etc.	Cutting the affected area to regular sections and rebuilding with simultaneous attention paid to the proper construction of shoulders.

Table 14.4. Broad Specifications for Sealing and Patching Materials for Repairing Defects (Refer IRC:82-1982)

Sl.No.	Treatment	Binder	Aggregate	Specification in brief
1.	**Seal**			
	a) Liquid seal	Penetration grade, cut-back or emulsion Rapid Setting	6.3 mm size	Spray binder uniformly at 9.8 kg/10 sq.m. spread aggregate over it at 0.09 cu.m/10 sq.m and roll.
	b) Fog seal	Slow setting emulsion diluted with equal amount of water	-	Spray binder at 0.5-1 litre/sq.m. Allow traffic after seal sets. If considered necessary by the Engineer, apply tack coat with diluted emulsion at 2.5-3.5 kg/10 sq.m.

Sl.No.	Treatment	Binder	Aggregate	Specification in brief
	c) Slurry seal	Slow setting emulsion	Well graded material between 4.75 mm and 75 micron	Apply slurry mix consisting of 18-20% emulsion and 10-12% water by weight of aggregate at the rate coverage of 200 sq.m. per tonne giving a thickness of 2 to 5 mm. No rolling is required.
2.	**Patching**			
	a) Sand premix	Penetration grade, or cut-back (Rapid or Medium curring)	Fine grit 1.7 mm to 180 micron	Apply tack coat at 7.5 kg per 10 sq.m. Spread mix consisting of 0.06 cu.m. of grit and 6.8 kg of binder per 10 sq.m. and roll.
	b) Open graded premix	Paving grade, RC or MC cut-back, Medium setting emulsion	12.5 mm and 10 mm size aggregate	Apply tack coat, prepare the mix as per IRC:14 spread and roll. Where cut-back is the binder, the premix should be prepared at least 3 days in advance of use. The final surface should be provided with seal coat.
	c) Dense-graded premix	Paving grade bitumen	Well-graded as per IRC:29	Apply tack coat prepare and spread the mix as per IRC:29 and compact
	d) Penetration patching	Penetration grade, RC or MC cut-back	Coarse and key aggregate as per IRC:20	Apply tack coat, spread coarse aggregate and dry roll; apply binder and key aggregate and roll as per IRC:20. For patching 15-75 mm thickness, use BUSG as per IRC:47.

Notes :
- i. The area to be treated should be thoroughly cleaned prior to application of the remedial treatment.
- ii. If it is a pothole the edges of the hole should be square and cut to solid material with vertical edges.
- iii. The treatment area should be dry unless the binder is an emulsion.
- iv. The areas where fresh material is applied should be finished in line with the adjoining pavement.
- v. For more details on the construction procedure, reference should be made to IRC:82.

14.8.3. Productivity of maintenance labour

14.8.3.1. As maintenance of hill roads requires deployment of considerable labour, by the very nature of maintenance activities (even if machines are also deployed), the efficiency of maintenance efforts and consequent road condition will depend, to a great extent, on the output/productivity of labour. The necessity to get optimum outputs from labour, mostly employed as part of maintenance gangs, by all the means like appropriate tools, correct distribution and assignment of tasks, and allocation of duties cannot but be emphasised.

14.8.3.2. **Clear directions**: The directions and allocation of duties to supervisory staff on maintenance should be unambiguously specific and clear so that they effectively co-ordinate the maintenance tasks and ensure optimum outputs from labour.

14.8.3.3. **Task norms of gangmen:** The gangmen must fully know the tasks they are to carry out and the expected output. There should be regular checking whether the tasks assigned and output achieved are as per norms. Gang books shall be maintained indicating work assigned to the gang and work done by the gang during a month.

14.8.3.4. **Gang beats:** The gang should be made responsible for a particular section of the road depending upon the nature of works in that reach and the mobility of the labour. Normal beat of gang on hill roads is from 5 to 10 km Storing materials, tools and plant should be at a central location for quick and proper access.

14.8.3.5. **Mobile gang system:** Mobile system of gangs in the place of the conventional labour gangs, who are practically immobile and have little or no equipments, will go a long way in streamlining the routine maintenance work. In this system, the labourers instead of moving individually on foot move about collectively in groups of 10 or more in a truck equipped with necessary basic tools for routine maintenance work. In addition to the required equipments, the truck may carry premixed stock-piled patching material. Such groups, because of their mobility, are capable of looking after sections of road from 30-50 km with much greater ease and efficiency than the dispersed gang labourers. Despite its initial cost, it is advantageous in the long run. The headquarters of one or more mobile gangs should be fixed at a convenient location on the road side where the necessary store sheds for tools/plant and construction materials could be available together with rest shed.

14.8.3.6. **Proper tools and plant**: Proper tools and plant having multi-purpose use increase efficiency of the labour. Tractors with trailers, disc-harrows, wheel barrows, small mechanical rammers can do multi jobs. Use of tar-patcher, motorized equipment for preparing cut back by using kerosene, folding wooden camber boards, etc., are small equipments which add to the efficiency of labour and quality of work.

14.8.3.7. **Training**: Right type of person should be employed for every type of work. Whereas female labour can be good transporters for small loads, only skilled male labour should be employed for work like bituminous construction. Regular training regarding works to be carried out, use of tools, plant and materials, etc. should be imparted to these workers.

14.8.4. Material procurement

14.8.4.1. Material that is used for maintenance of bituminous paved surface is bitumen and aggregate. As the riding quality of the road depends on the surface condition, it is essential that bitumen and aggregates are stored at sites on the road for speedy repairs. For this, procurement can be divided into different operations.

14.8.4.2. **Control procurement of binders:** The materials that are procured and stored centrally are bitumen, cut-backs and emulsions. These bituminous products should be procured and stored centrally in each section for use in the work. The quantity required should be calculated from the repair programme approved which will also decide the time scheduling of procurement.

14.8.4.3. **Aggregate:** The aggregate for renewal work should be collected at site of work only when it is required to be used. Aggregates for patch work can be collected at the time of starting the work after calculating actual requirement and also can be procured before critical season (such as rains) and stored in every kilometre on a specially prepared platform preferably by the side of each kilometre stone. A judicious decision in this respect has to be taken by the engineer-in-charge depending upon likely work and availability of materials at short notice.

14.8.5. Technology for maintenance

14.8.5.1. The spectrum of technologies available for maintenance of hill roads ranges from labour based to machine/equipment based and combination of labour and machines (intermediate) although the relative proportions can differ substantially. While the socio-econimic conditions in India indicate labour based maintenance to provide employment to a large number of people, it may be necessary to use equipment to achieve specified quality and in the interest of speedy achievement of the end product.

14.8.5.2. Even the labour based methods have to use certain items of obligatory equipment on maintenance (except probably on light vehicle roads, Bridle roads/paths) such as compaction equipment (Rollers), vehicles for transportation, earthmoving equipment for landslide clearance, compressors and drills for blasting or quarry operation, bitumen heaters and distributors, etc. For snow clearance operations, bulldozers and special snow clearance equipment will also be needed. Machinery becomes an obligatory requirement as it will not be possible to get all the maintenance activities on a hill road executed purely by manual labour considering magnitude of the task, necessity to clear road blocks and slides without delay and for quality outputs. Hence policy should be made out grading the roads for purposes of maintenance as "Labour Based," "Machine Based" and combination to a pre-determined proportion and scales worked out as given under para 14.5.4 'Scale of Maintenance" paras 14.5.4.1 to 14.5.4.2 ante. The machinery required for each road depending on its priority, behaviour and climatic conditions should be decided and allotted.

14.8.5.3. Use of works animals, where available, are also very useful and cost effective in maintenance activities. It may be possible to use agricultural equipment like tractors, trailers, etc. for grading, haulage, digging, etc.

14.8.6. Maintenance of drains, cross-drainage works, shoulders and slopes

14.8.6.1. Drainage

14.8.6.1.1. The objective is to ensure that drainage elements remain free of obstruction and retain their intended cross sections and grades. They must function properly so that surface and sub-surface water can drain freely and quickly away from the road or under the road. Water is the worst enemy of any road and on a hill road drainage is the most important aspect for stability. Uncontrolled drainage can:-

- Erode soil and therefore road bed
- Weaken pavement
- Cause landslides
- Destroy shoulders and slopes
- Wash out culverts and even bridges.

14.8.6.1.2. The maintenance activities on the drainage system are given below:

a) **Side drains, catch water drains, sub-soil drains (dealt as Drains)**

i. Routine Activities
- Reshape/regrade/deepen
- Clearing and cleaning
- Erosion repair

ii. Perodical Activities
- Provision of lateral ditches (turn out)

b) **Culverts**

i. Routine Activities
- Clearing and cleaning including catchpits
- Repair to cracks
- Erosion repair
- Repair to protection works

ii. Periodical Activities
- Repair of invert
- Repair of walls, aprons etc.

c) **Causeways**

i. Routine Activities
- Minor surface repair
- Replacing guide posts
- Replacing flood gauges
- Repairing protection works

ii. Periodical Activities
- Repairs of floor
- Repairs of head walls
- Repairs of apron

14.8.6.1.3. **Inspection**: Inspection of drainage system is an year round task. Structure must be examined in dry season when little or no water is flowing so that structural damage cracks, settlement, erosion, etc., can be seen better, identified and repaired well as, waterway cleared of debris. The functioning of drainage system during the rainy season should also be inspected. Special emphasis must be given to inspection of drainage works during thaw period at end of winter in snow bound area to identify crucial places and their clearance on priority to avoid damage to roads. If surface and ground water drains freely as intended, the system can be deemed satisfactory, otherwise there is something wrong and needs to be repaired.

For Example :

- If a culvert outlet discharge is small when the inlet is at full head or submerged, the culvert is not functioning or is damaged/cracked in flooring/abutments
- Where the carriageway does not have an adequate camber or cross fall, the surface water will pond on the surface and accelerate the formation of ruts, potholes and unintended ditches.
- Where drains have little or no scope or inadequate turn outs, silting will occur and cause ponding of water and weakening of pavement.

14.8.6.1.4. Inspection check list: These are given below:

a) Drains
- Drain cross section destroyed
- Ponding in drain
- Erosion

b) Causeways
- Potholes in paved surface
- Cracks in paved surface
- Guide posts missing
- Flood gauge missing/tilted
- Damage to curtain wall/appron.

c) **Culverts**

- **Silting, sanding, blockage by debris or frozen water**
- **Erosion at inlet and outlet**
- **Settlement cracks**
- **Damage to flooring and parapets**

14.8.6.1.5. Defects, causes, effects and remedies

These are listed below:

a. **Drains**

i. **Defect ponding**

Cause and effect - Cross section too small or grade improper. The shoulder material becomes soft and can easily erode. The pavement can also be flooded and thus weakened.

Activity - Enlarge cross section or regrade drain

ii. **Defect silting**

Cause and Effect - Invert slope is too flat, the water cannot flow at sufficient velocity. If neglected the drain will get blocked.

Activity - Deepen drains (desilting) giving proper grades and/or provide lateral drains (turn outs)

iii. Defect - Uneven drain invert varying cross section

Cause and Effect - Blockade by debris, and vegetation; if neglected cross section is reduced and water cannot flow as intended.

Activity - Cleaning, Clearing, repairing.

iv. Defect - invert and sides of drains are eroded

Cause and Effects - Invert slope is too steep. If neglected, water flows at too high a velocity and starts carrying away the soil. The drain becomes deeper (ravine). The sides then cave in, the shoulder or even part of carriageway can get washed away.

Activity - Reinforce drain slopes and invert regarding/realigning drains, Provision of drain checks.

b) Culverts

i. Defect - silting, sanding, blockage by debris

Cause and Effect - Invert slope too flat.

- Culvert constructed too low, and hence material from stream bed gets deposited in the culvert.

- Vegetation and flooding debris carried by water have got lodged in the culvert. If neglected, the intended waterway opening will be so reduced that flood water cannot flow. It will back up or pond on the upstream side of culvert and may eventually overflow the road formation. The road is in danger of being washed away.

Activity - Cleaning and clearing. If flooding debris is a problem, the provision of debris rack should be considered.

ii. Defect - erosion of stream bed at culvert outlet

Cause and Effect - The culvert invert has been constructed on too steep a grade so that water flows too fast.

- **If neglected, the stream bed is eroded and a pool or ravine develops. The culvert downstream head wall and wing walls and even a section of the culvert and road formation can collapse into the pool or ravine.**

Activity - **Erosion repair and provision of toe wall or pitching of stream bed.**

iii. Defect - settlement cracks

Cause and Effect - **Settlement of soil below culvert**

- **Minor damage - if the settlement is minor, only light cracking will result in head walls, wing walls and main structure. This will hardly affect the functioning of the structure.**

- **Major damage - if the settlement is average, it will cause large relative movement of culvert body so that formation soil will enter through the cracks and block the culvert, or that the culvert may collapse.**

Activity - **Crack repair for minor damage. Sealing cracks with clay/bituminous mulch to extend life of culvert and reconstruct in the event of collapse.**

c) Causeways

The surface of causeways is endangered by washouts and slush movement caused by water current. Routine maintenance in this case can only by regarded as temporary measure. The activities include masonry repair, placing of stone crates; and erosion protection of causeway openings.

i. Defect - cracks in paved surface

Cause and Effect - Settlement of slab. If neglected, the cracks in concrete slab spread and widen especially during the following flood season.

Activity - Minor surface repair (sealing cracks)

ii. Defect - guide posts/flood gauges are missing or damaged

Cause and Effect - Accident, vandalism, flood damage. If neglected, when the pavement becomes submerged during flood and the edge of pavement cannot be seen, vehicles can accidentally drive into deep water.

Activity - Replacing guide posts.

14.8.6.2. Maintenance of slopes

14.8.6.2.1. A hill road is formed by cutting slopes or forming slopes and stability of the road is dependent on slope stability itself. It is therefore essential that the slopes are maintained to designed standards/specifications and corrective action taken, whenever the slope is disturbed. Typical cross-section given in Fig. 14.7 shows the road and the slopes on hill and valley side and certain correction measures.

14.8.6.2.2. The subject of slope stability has been dealt in Chapter 11 "Slope Stability, Erosion Control and Landslide Correction" and also in this Chapter under heading "Landslides" para 14.8.10.2.

14.8.6.2.3. **Causes of instability of slopes**: Slopes may become unstable due to drainage water and accompanying erosion, slides breaches etc., or may be triggered by other causes like earthquakes/tremors, floods in streams/rivers downstream of slopes etc.

14.8.6.2.4. **Remedies**: Irrespective of the cause, the efforts in maintenance should be to ensure that the original slope is maintained and stability retained. This can be done by regular dressing of slopes, ensuring vegetation is not denuded, by turfing/growing plants and if necessary by structures like retaining walls, breast walls, toe/check walls etc.

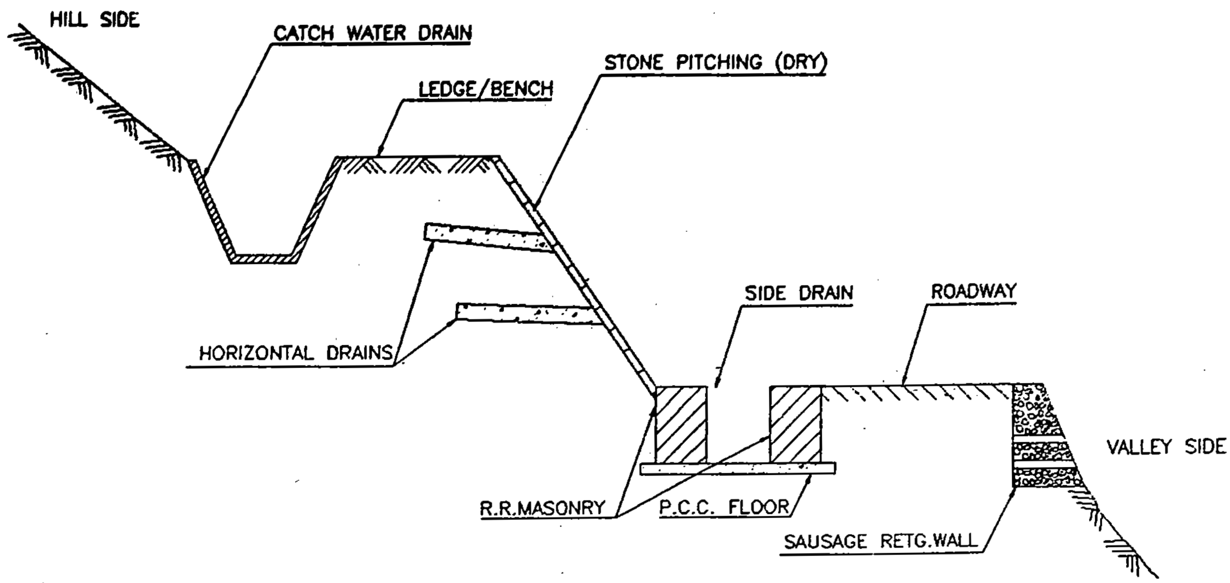


FIG. 14.7. ROAD SECTION WITH HILL AND VALLEY SLOPES AND PROTECTION/CORRECTION WORKS

14.8.6.2.5. Slope stability coupled with controlled drainage can go a long way in maintaining a more or less, hill road free of slope failure.

14.8.6.3. Maintenance of shoulders (berms)

14.8.6.3.1. Shoulders provide lateral support to the pavement. They are used for parking vehicles in case of single lane roads, provide room for passing vehicles where carriageway width is insufficient and also comes in handy for the parking of disabled vehicles at locations where passing places are not nearby. These at times serve as a track for slow moving vehicles. Properly maintained shoulders also help the drainage of surface water quickly to the side drains. Improper maintenance of shoulders will cause drainage water to flow along the edge of the pavement resulting in caving and thereby penetration of moisture to the subgrade.

14.8.6.3.2. In order to perform the functions stated above satisfactorily it is necessary that the surface of the shoulders are hard enough to resist the abrasive action of vehicles and the disrupting influences of the elements of nature.

14.8.6.3.3. The shoulder surface should always slope uniformly (as per standards) from the edge of the pavement so that any water falling on the road surface or shoulders is speedily drained off. Paved or hard shoulder reduces the problem considerably.

14.8.6.3.4. The work of maintenance of earth shoulders consists of periodically replacing earth or moorum carried away from the shoulders, to remove ruts and restore the slope to the designed level. This work is generally heavy during and after the rains.

14.8.7. Maintenance of structures

14.8.7.1. Structures like retaining/breast walls, toe/check walls, parapets, railings, etc on the road have to be maintained always in a good state so that they perform their designed role. To achieve this, regular inspection/checks to identify any damages/inadequacies should be carried out as brought out earlier in this chapter and repairs promptly carried out.

14.8.7.2. All repairs have to be completed before rainy season and any damages in rains temporarily repaired immediately must be permanently restored as soon after the rainy season, as possible.

14.8.8. Maintenance/repair of bridges

14.8.8.1. All bridges must be maintained and periodical repairs and protection works carried out as per normal laid down practice.

14.8.9. Maintenance of road furniture

14.8.9.1. **Traffic signs:** Traffic signs are the principal means of conveying information about the road to drivers and as the road network becomes more extensive the number of traffic signs increases. As traffic flow increases, an increasing effort on their maintenance is needed. Signs which are clean and in good condition can be easily seen and understood and inspire confidence that their message is accurate and reliable. Damaged or missing signs should, for the same reasons, be replaced promptly, and temporary signs should be removed upon completion of the maintenance works to which they are related. The provision and care of signs is very cheap and cost effective. Signs should be inspected, cleaned and repaired if necessary at least twice a year. It is worth keeping records of traffic signs. They should be included in an inventory and transferred to a signs register in which details of inspections, repairs and replacements are recorded. It is useful if their location is also recorded in strip map.

14.8.9.2. **Railings:** Guard-rails and parapet rails are provided to protect road users; to prevent vehicles from running over high embankments or valley side and parapet rails on bridges to safeguard pedestrians and vehicles. They should be repaired promptly, if damaged and kept clean and repainted regularly so as to maintain their visibility.

14.8.9.3. **Kilometre stones:** These provide both drivers and the maintenance organisation with the basic reference for the location of any point on the road. Kilometre stones should be kept clean and repainted regularly and vegetation around these should be cleared so that they can easily be read from a moving vehicle.

14.8.9.4. Marker stones - Each Bridge Culvert and other structures should be serially numbered within the Kilometre in which it is located thus: 80/2 is the second culvert or bridge in Km 80. These numbers should be marked on parapets/structures or Separate marker stone placed firmly near the structure and used as references in the culvert and bridge registers. The painting of markers should be maintained properly for easy identification.

14.8.9.5. **Delineators:** These are usually provided only on high bank or on bends. They should be kept clean and colour washed/painted regularly. Reflectors may also be fitted on them if they are properly fixed. Vegetation around the delineators should be cleared so that they can be easily seen from a distance.

14.8.10. Special problems and techniques for maintenance of roads in heavy rainfall areas

14.8.10.1. **General:** In heavy rainfall areas in hilly terrain, the major problems faced in maintaining the roads are landslides, drainage and soil erosion, apart from frequent damages to road pavement. The remedial measures to be adopted for these are discussed in succeeding paras.

14.8.10.2. **Landslide problem:** The subject of land slides have been discussed in detail in Chapter 11 "Slope Stability, Erosion Control and Landslides Correction". Landslide constitutes by far the most serious problem in maintenance of roads in hilly terrain subjected to heavy rainfall. The remedial measures for control/minimising the problems are briefly reiterated below:

a) The side slopes of the hill should be maintained to proper angle so that they are stable.

b) Minimum deforestation should only be done on the hill face above the road as this cause disturbances to the stability of hill slopes.

c) All potential landslide/disturbed slopes should be identified and suitable treatment should be provided e.g. terraced benches, afforestation, turfing/plantation of shrubs/bushes, alongwith asphalt mulch treatment of jute/coir netting etc.

d) Indiscriminate blasting in hill slopes causes destabilisation and this should be avoided as far as possible.

e) Jhoom cultivation in hill slopes above the road constitue potential factors for destabilising hill slope and this should be discouraged.

f) Apart from the treatment of disturbed hill slopes, protective structures in the form of retaining walls, check walls, breast walls, toe walls, etc. help in stabilising hill slopes and contain the landslides.

g) The immediate action required on occurrence of a landslide is to clear the same quickly by deploying adequate machinery like dozers/excavators/payloaders. It will be good to keep the machines at/near vulnerable slide areas/stretches, available on call at short notice.

14.8.10.3. **Drainage problem:** Most of the maintenance problems in hill roads on heavy rainfall areas starts from improper drainage. It is therefore, very essential to provide adequate system for ensuring easy and prompt drainage of rain water or of molten snow flowing to the road from the upper catchment areas. This subject has been dealt in detail at appropriate places in this manual. Uncontrolled drainage is a major cause of landslide. Following steps should be taken to ensure effective drainage:

a) Surface/Subsurface water should be led to natural water courses below road through cross drainage structures. In particular, intercepting or catch water drains provided above the cut slopes for speedy and safe disposal of rain water should be kept in good repair condition and cleared of obstructions. Side drains should be maintained to their capacity for ensuring effective drainage even when partially blocked/choked due to debris, growth of plants, etc. The drains should have gentle gradients and side slopes to enable carrying the flow without erosion. Drains should be lined/cement pointed where erosion is anticipated due to poor or weak soil and in subsidence areas.

b) Where the side drains are likely to be choked with sliding materials, they should be covered temporarily during rainy season with closely placed wooden ballies or punctured bitumen barrel sheets where feasible, in order to ensure uninterrupted drainage.

c) At the upstream side of the culvert, the catch pit provided should be kept clean.

d) Drains, catch pits, etc., should be cleared of all debris and repaired, where necessary, before the onset of the rainy season.

e) In order to avoid rain water flowing across the road surface, when side drains are blocked in part length due to landslides/erosion of hill slopes, temporary drains with guidebunds should be provided by the side of the choked drain in order to channelise water to the unaffected portion of road side drain.

f) Weep holes of retaining walls and breast walls should be cleared and all vegetative growth/chokage should be removed before onset of monsoon.

14.8.10.4. **Soil erosion problems:** Measures should be taken to ensure that erosion of soil from hill slopes both above and below the road formation is kept to the minimum, as this eventually leads to landslide/chokage of drains and natural water courses. Some of the erosion control measures are indicated below:

a) It should be ensured that the cross drainage structures discharging water on the valley side do not cause erosion even when flowing for a long period. Necessary channel training and erosion control works like paving/pitching of the channel and out fall points, drop walls, apron etc. below the outlet of cross drainage structures should be properly maintained.

b) Vegetative cover should be established on cut/fill slopes through any of the techniques described in IRC:56 "Recommended Practice for Treatment of Embankment Slopes for Erosion Control". The activity of establishing vegetation on barren slopes should be treated as part of the regular maintenance activities on roads.

14.8.10.5. **Repairs to damages of pavement**: Repairs to damages of pavement like potholes and depression form another important maintenance task. Such repairs should be done to regular shape and should match the existing surface to correct level and grade. Paras 14.7 "Maintenance Criteria" and 14.8.2 "Symptoms, causes and treatment of surface defects" may be referred.

14.8.11. Miscellaneous repairs/maintenance

14.8.11.1. Vegetative growth from roadside berms and from hill slopes for a height of atleast 2 m above the road level should be trimmed regularly.

14.8.12. Special problems and techniques for maintenance of road in high altitude and snow fall areas

14.8.12.1. The main problems in maintenance of roads in high altitude areas are of drainage caused by rapid melting of snow during spring, extreme cold climate during winter and consequent restrictions in working. Loss of efficiency of men and machines in the rarefied atmosphere is also a major problem.

14.8.12.2. **Drainage problems**: There is scanty rainfall in most of the high altitude areas (except in certain high altitude areas of Eastern Himalayas where rainfall also is fairly high) and most of the precipitation consists of snow. The drainage problems are mostly due to thawing of snow and ice. Temperature rise during the day results in rapid melting of snow with the advent of spring.

14.8.12.2.1. The streams in the region have heavy floods during spring. Large amount of debris and ice carried in such streams results in more drainage problems. Since the soil surface is invariably frozen at the end of winter, there is no absorption of moisture by the soil and the run off coefficient is sometimes as high as 100 per cent. Flash floods also sometimes occur in the streams due to breaking of glacier dams and cloud bursts. The major factors responsible for drainage problems in these regions include temperature, humidity, snowfall and consequent run-off, nature of soil and catchment area, etc.

14.8.12.3. **Problems of snowfall**: The problems due to snow and avalanche on hill roads is dealt elaborately in Chapter 12 "Snow Clearance and Avalanche Treatment". But the important aspects related to maintenance of hill roads are reiterated here.

14.8.12.3.1 Heavy snowfall combined with severe cold climate causes numerous problems for the maintenance of roads at high altitudes. The problems faced are as under:

a) Slow seepage

In stretches subjected to heavy snowfall melting of snow results in slow seepage into sub-soil and subgrade causing subsidence of subgrade over long lengths. Slow seepage from the accumulated snow above road formation also destabilises the hill slopes above the road formation resulting in landslides.

b) Snow avalanches

Often huge accumulation of snow comes down the slope at great speed and brings boulders and debris. Such avalanches along the re-entrants cause considerable damage to road formation, pavement and permanent structures, apart from the potential danger to traffic, life and property.

c) Drainage problems during snow clearance

During heavy snowfall large stretches of road are affected. For the quick opening of the road communication, the normal practice is to clear minimum road width required for passing of vehicles for one way traffic, in the first instance. The restricted width of road acts as drain for melting snow and causes slow seepage of water in road crust and subgrade and often causes damages to road crust/settlement of subgrade.

d) Effect of Frost

Freezing of water behind the retaining wall causes cracks in the structure due to increases in volume of back fill. Formation of ice pockets in some stretches also causes heaving of subgrade and crust.

e) Icing problems

Where a thin layer of snow has remained on pavement for some time, it becomes more dense and compact due to drop in temperature caused by cold wind blowing on the surface during winter months and also hardening effect of moving traffic. The top layer of snow on road is rapidly coated with an ice glaze, which is very hard, slippery and extremely dangerous for traffic due to the skidding effect of vehicles. This thin layer of ice poses great problems for removal as it is hard and adhere tenaciously to paved surface.

f) Restricted efficiency of men and machines

Efficiency of men and machinery decreases at high altitudes due to lack of oxygen, low atmospheric pressure and severe climatic conditions. Working hours are also restricted. Working season for constructing works involving cement and bitumen is normally limited between middle of May to middle of November. The loss of efficiency of men and machines above 2100 m altitude are given in Table 13.1 under Chapter 13 "Road Construction Tools, Plants and Equipment".

14.8.12.4. **Remedial measures:** The remedial measures for above are given as under:

a) Melting effects of snowfall

i. Quick removal of snow from whole formation by using wheel dozers, motor graders and special rotary cutter type snow clearance machines.

ii. Clearing of roadside drains promptly.

iii. If restricted width of road has been opened due to compulsion of providing prompt road communication by clearing snow, then cross drains must be opened on either side of the road at intervals to guide melted snow water to valley sides or roadside drains.

b) Snow avalanches

Potential snow avalanche zone must be identified and camping, movement of traffic, etc. must not be permitted in such avalanche prone areas during the snowfall season. Effect of snow avalanches can be controlled/maintained by provision of following.

i. Stopping structures like snow bridges, snow rakes, snow fences, avalanches fences, terraces and snow nets.

ii. Drift control structures like inclined roofs, wind baffles and snow fences.

iii. Deflecting structures like gallery construction, guide and diversion walls.

c) Effect of frost/icing

Efficient drainage of water is to be ensured from back face of retaining/breast walls through weep holes, etc. Surface water on road formation and drain should not be allowed to stand but drained out quickly so that the same does not seep through to the subgrade. Common salt/urea can be sprinkled on ice/frost on critical stretches to cause deicing and avoid skidding and slipping of vehicles.

14.8.12.5. Problems in maintenance of machinery: In high altitude areas, the work is mainly equipment oriented. The maintenance of equipment and machinery requires planning as various types of snow clearance machinery and vehicles are involved and repairs have to be carried out on an emergency basis. Temperature prevailing in most of the snow clearance detachments/locations can be much below subzero level. Proper precautions for men engaged on repairs/maintenance of the equipment have, therefore, to be ensured. Apart from providing the man with adequate snow clothing, the repair workshop shed should also be kept warm by use of heaters. Some of the preventive maintenance measures for the equipment are:

a) Radiators are drained or wrapped up after working hours.
b) Batteries are removed and kept in heated/covered rooms

c) Subzero diesel is used as primary oil.
d) Close and proper check on appropriate lubricants is ensured.

14.8.12.5.1. Problems of providing the required spares for equipment, plant and vehicles for snow clearance efforts also need close attention and advance planning for ensuring timely procurement and placement at appropriate places. This is particularly so for snow clearance equipment which are of foreign make as procurement of spares for repairs of FIP assembly,hydraulic pump assembly, impellers, outer blade, etc., involves long range advance planning, in view of the long lead time involved for materialisation.

14.9. **Organising Maintenance Operations in the Field**

14.9.1. In the preceding paragraphs the aspects of maintenance from objective to execution has been dealt with. To ensure effective maintenance, it is essential that organisation deployed on maintenance task under the engineer-in-charge of maintenance is armed with a systematic operational procedure and step-by-step methodology. Such a system should be evolved for each road or group of roads depending on the ground, terrain, topographic, climatic and traffic conditions and user requirements.

14.10. **Monitoring**

14.10.1. An efficient system of monitoring the maintenance task should be evolved so that the performance is studied for upgradation of technology in rendering better service to the road user and traffic.

14.11. **Training in Maintenance Operation and Management**

14.11.1. Training of all the personnel involved in maintenance is an integral part of the maintenance function. Such training, as may be required by the operating and maintenance personnel to achieve better performance, can be classified as below:

a) Training of engineering subordinates
b) Training of gangmen/mate

14.11.2. **Training of engineering subordinates**: The engineering subordinates are expected to perform all the necessary management tasks even without formal management orientation or training. The supervisor learns about type maintenance work on precedent practice and a new supervisor/engineer handles the job in the same manner as the person before him. Techniques which may or may not have worked in the past are tried again. Supervisors/engineers must be provided with the opportunity to attend maintenance management and operations training. The areas to be covered during the training should be:

1. Identification of defects
2. Planning maintenance operations effectively
3. Crew scheduling and control to achieve higher productivity at low cost consistent with quality.
4. Problems of crew supervision-communicating and coordinating
5. Preparing road inventory
6. Management by objectives
7. Repair methods

14.11.3. **Training of gangmen/mates**: The training of maintenance gangmen in two areas is very essential as under.

a) Safety aspects
b) Repair methods

14.11.3.1. The training in safety aspects will include:

a) training of flag-men
b) use and lay out of temporary traffic signs for repair works
c) safety oriented handling and parking of machinery and equipment

d) safety in slide areas
e) safety in snow fall conditions

14.11.3.2. The training in repair methods will include:

a) slide clearance
b) snow clearance
c) drain maintenance
d) proper patching methods
e) proper grading of shoulders
f) maintenance of drainage structures
g) crack sealing
h) painting and maintenance of the traffic signs and warnings
i) equipment maintenance

14.12. Formats for Various Data

14.12.1. Ministry of Surface Transport "Manual for Maintenance of Roads" may be referred for details of certain formats for recording field data, duties of subordinate staff, etc., engaged for maintenance.

15. ROADSIDE AMENITIES

15.1. The Need

15.1.1. The provision of roadside amenities in hill roads contribute to a large extent in ensuring safety besides making the journey convenient and pleasant. The type of amenity, its location and its frequency depends on many factors which include classification of highway, traffic volume, type of vehicles, steepness of grades, road geometrics, terrain and environment. Main amenities which need consideration are scenic overlook, fuel stations, servicing areas, recovery posts, water points, lay-byes, walkways in tunnels and on bridges, rest areas, restaurants, shelters against rain/snow at bus stops, emergency telephones, traffic aid posts, tourist information centres, guide maps and facilities at check posts/border posts. In view of the safety aspects involved, it is of paramount importance that the need for amenities and their provision should be incorporated into the regular planning, design, construction and maintenance/improvement practices followed in hill roads. The requirement of each of the amenities is discussed in subsequent paras.

15.2. Scenic Overlooks

15.2.1. It is quite natural for a traveller to be attracted by a sight of natural beauty or some other point of interest. This results in distraction and haphazard parking at such location causing bottlenecks and accidents. It is, therefore, advisable to provide a separate laybye at such locations for parking and combine these with rest areas wherever possible. Sign posts should also be posted to inform the user of its location. The design of laybye should be adequate to cater to the volume of traffic expected to stop at the location. Typical design of laybyes are given in Fig. 15.1.

15.3. Fuel Stations, Service Stations, Watering Points and First-Aid Posts

15.3.1. Driving on hill roads is strenuous both for the driver and the vehicle. Invariably the engines generate more heat in continuous climbs and low gears and drivers often stop to feed water at natural water courses. At such locations extra widening or separate laybye should be provided. Besides this, oil consumption increases and wear on brakes etc. also gets pronounced. As such, arrangements for refuelling, oil check, water and air pressure check and normal repair and servicing become essential facilities required for vehicles. The study group on wayside amenities of the Ministry of Surface Transport has recommended that small repair and service stations should be set up at distances of about 80 km in hilly areas and also at the terminals on a route. This recommendation should be followed as far as possible. IRC:12-1983 provides guidance on fuel filling stations and service stations. These should be adopted with necessary changes to suit hill roads.

15.3.2. As hill roads give rise to larger incidence of accidents, FIRST AID posts at fairly frequent intervals to render relief to accident victims is essential. These may conveniently be combined with fuel stations, service stations etc.

15.4. Rest Areas/Rest Houses/Rest Laybyes

15.4.1. Research in road safety has shown that a major cause of fatal accident is fatigue and/or driver falling asleep at the wheel. To avoid such occurrences, it is desirable to provide rest areas at every 3 hours driving time distance. The facilities to be provided would depend on the volume of traffic. On low density traffic routes, where higher type of development is not feasible, parking spaces, toilets and minimum shelter with table/benches can be provided. Since, in hilly areas, not much land is available, these areas could be

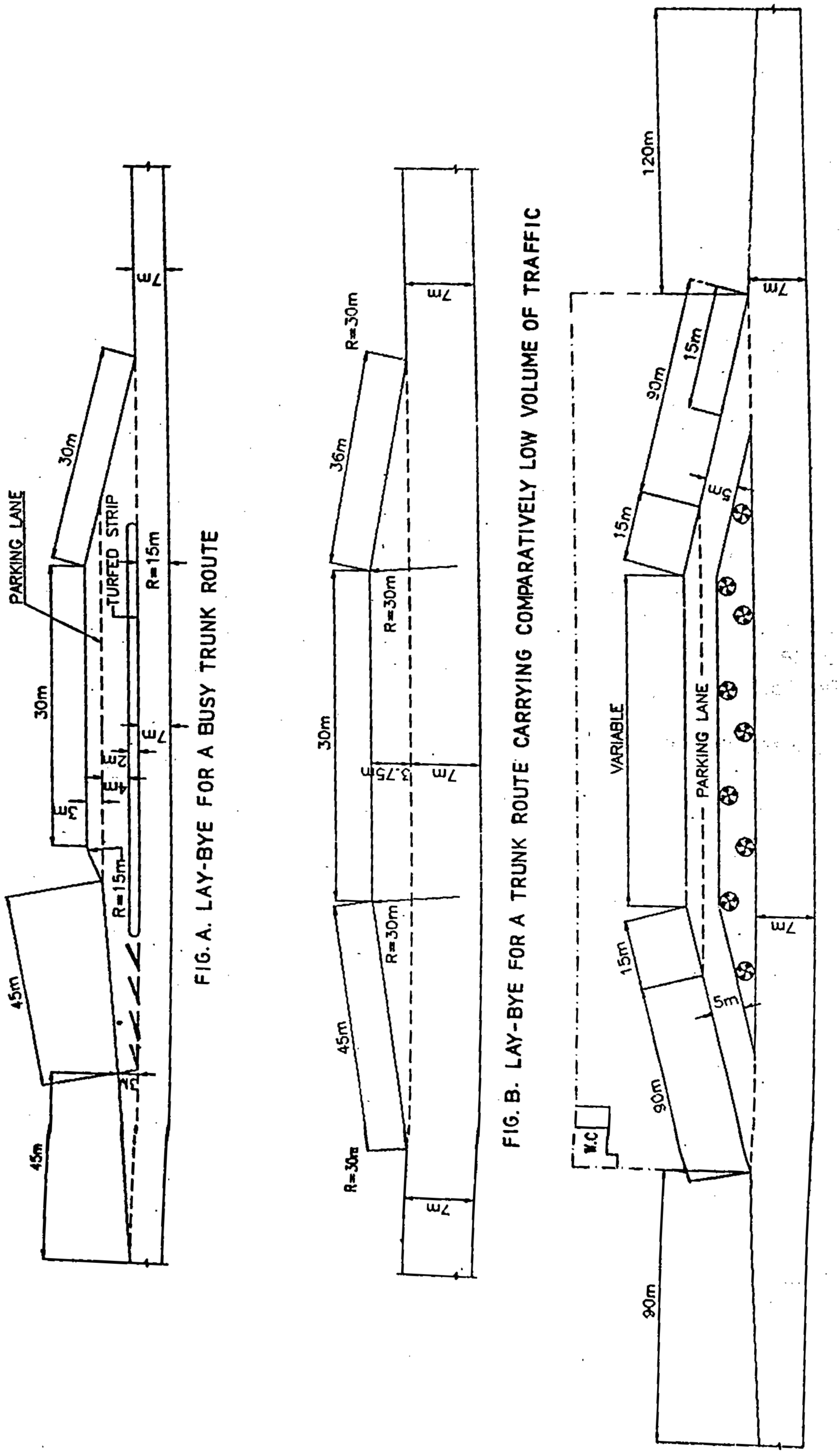


FIG. A. LAY-BYE FOR A BUSY TRUNK ROUTE

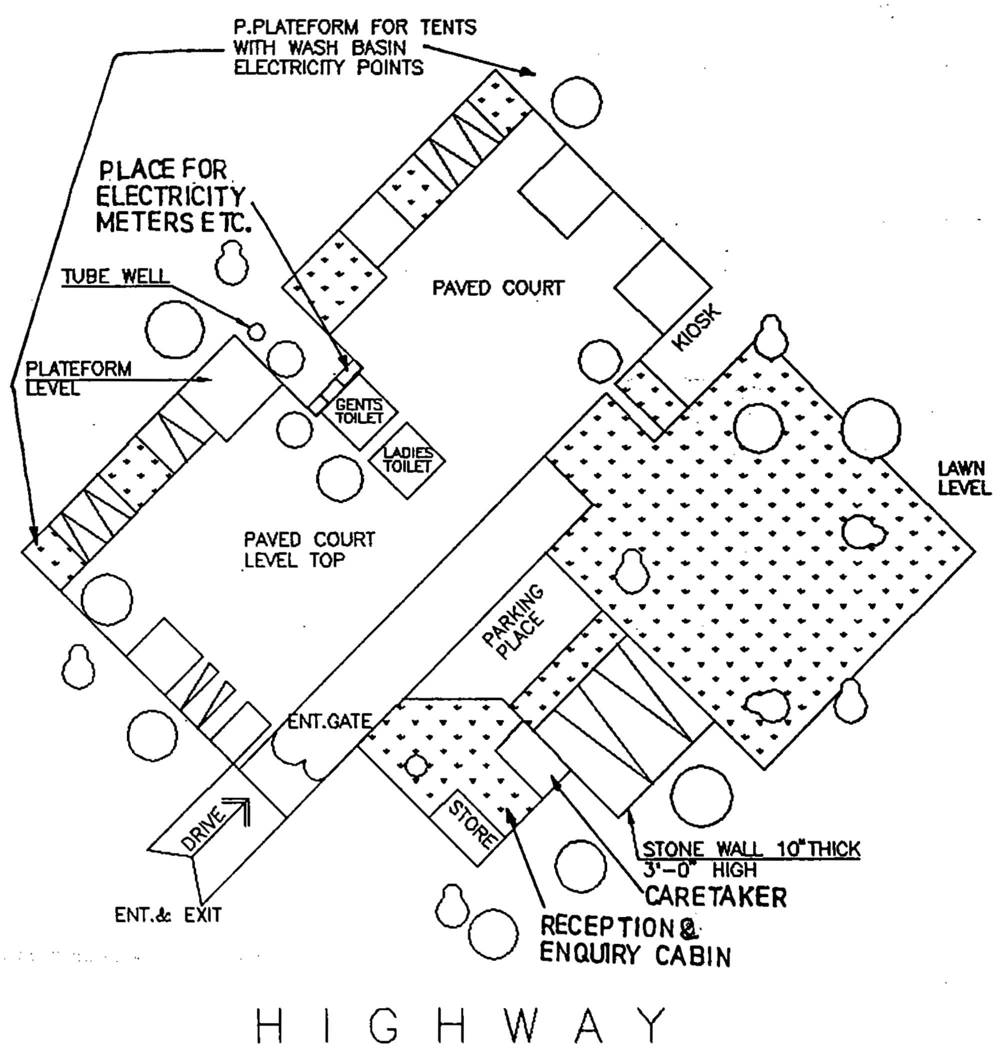
FIG. B. LAY-BYE FOR A TRUNK ROUTE CARRYING COMPARATIVELY LOW VOLUME OF TRAFFIC

FIG. C. LAY-BYE DESIGN FOR A SCENIC LOOKOUT

FIG. 15.1

combined with scenic overlooks. The ideal roadside rest areas should have fully equipped shelter, concrete tables, drinking water facilities either by pumping from adjoining river or tapped from nearby perennial sources, telephone, toilets, waste receptacles and area lighting. Self draining soakage pit system of disposal which require minimum attention is desirable. Arrangement for coffee, tea and cold drinks should be made at these locations and special care exercised to exclude alcohol and other drugs which compromise driving ability of driver and safety.

15.4.2. In providing such facilities, great care should be taken to maintain cleanliness and tackle the problem of disposal of rubbish litter etc. and in provision of sanitary facilities. The main requirement at such places is that there should not be any contamination of ground water, surface water or surface soil and that the excreta should not be accessible to flies or animals and the area should remain free from odours or unsightly conditions. At the same time, the disposal method should be simple and inexpensive in construction and operation. Figs. 15.2 and 15.3 show typical plans for such areas. These would need modification according to site slopes and conditions.



HIGHWAY DEVELOPMENT PLAN
TYPICAL TOURIST CAMPING GROUND
LAY-OUT PLAN
FIG. 15.2.

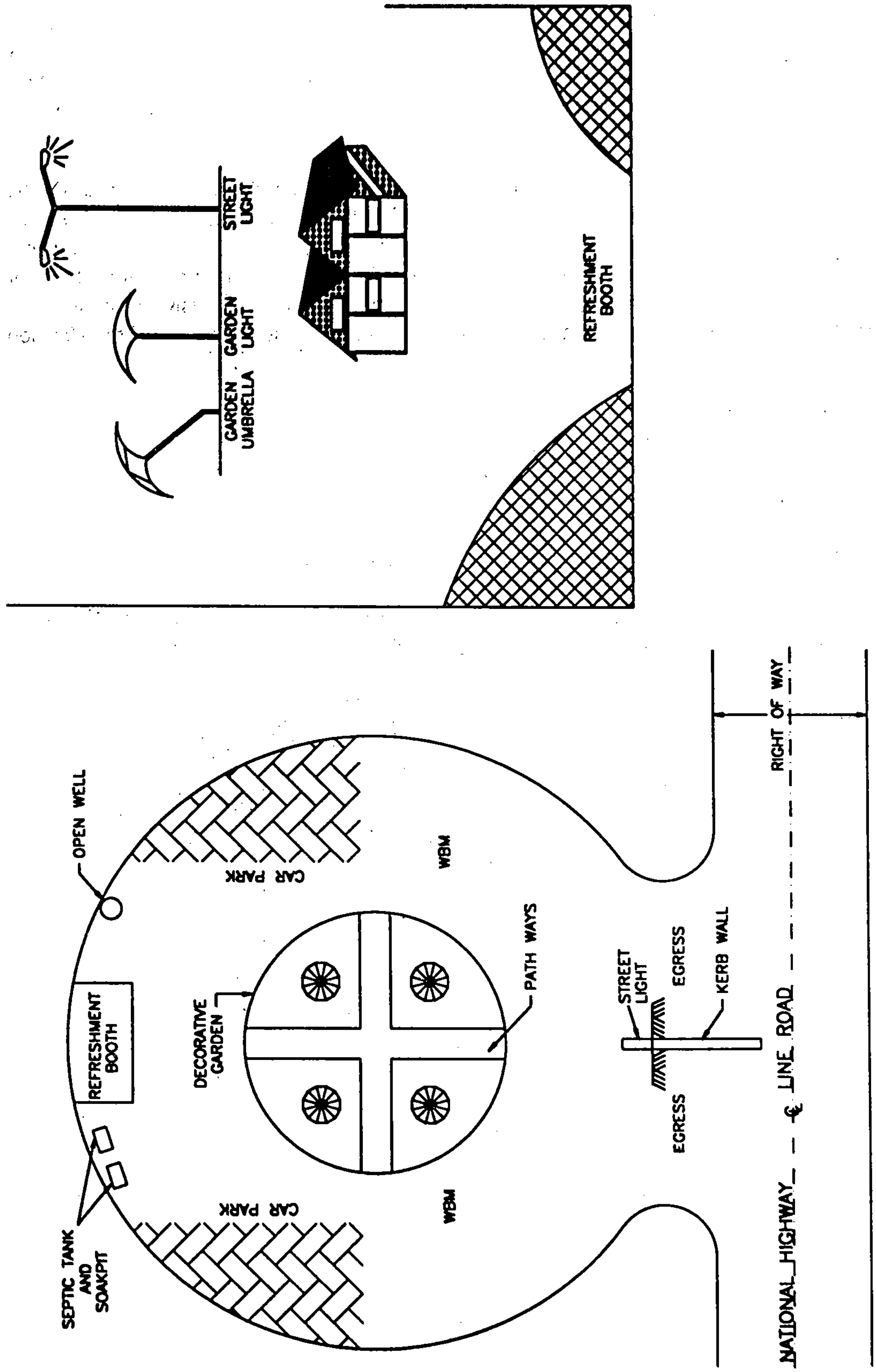
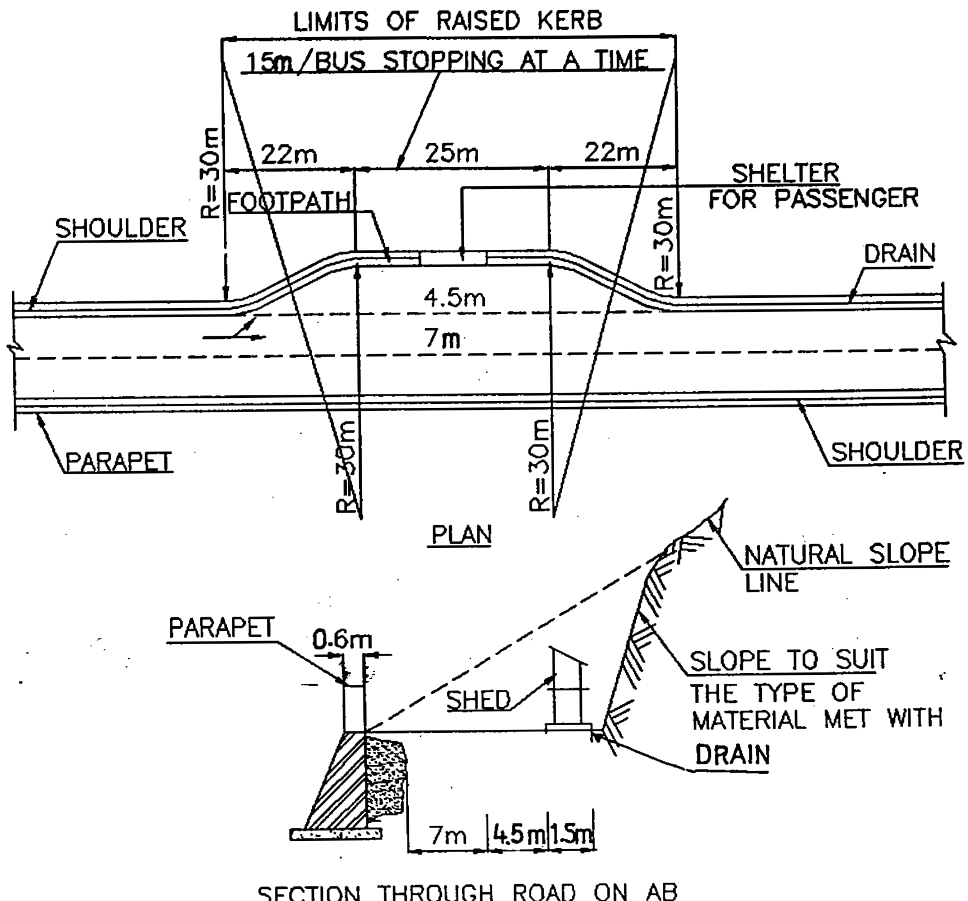


FIG.15.5.3. HIGHWAY DEVELOPMENT PLAN
(AMENITIES – TYPICAL WAYSIDE – RESTAURANT)

15.4.3. In hilly areas, there are several locations, where buses make short stop-overs for alighting/getting down of passengers. These should be provided with a lay-bye with a suitable shed for waiting passengers. A typical design is shown in Fig. 15.4. The bus stop should normally be located where the road is straight on both sides, the gradient is level or as flat as possible and the visibility is reasonable (not less than 50 m). It is advisable to choose locations where it is possible to widen the roadway economically for accommodating lay-byes, passenger shelter etc. The hill slopes should be properly dressed and suitably protected to avoid slips. Water should be drained away from the lay-bye area. Suitable signs should also be provided at and in advance of such locations.



NOTES:-

1. ADEQUATE FACILITIES FOR EFFICIENT DRAINAGE OF THE BUS STOP AREA INCLUDING LAY-BYES SHOULD BE ENSURED.
2. PAVEMENT MARKINGS SHOULD BE PROVIDED AS INDICATED ON THE DRAWING.THE WORD BUS SHOULD BE WRITTEN ON THE PAVEMENT AT THE ENTRY TO THE BUS WAY FOR DETAILED GUIDANCE SEE IRC:35.
3. IN THE BUS STOP AREA THE SHOULDER ON BUS STOP SIDE SHOULD BE RAISED TO FROM FOOTPATHS AS MARKED ON THE DRAWING.THE JUNCTION BETWEEN SHOULDER AND FOOTPATH SHOULD BE SUITABLY TRANSITIONED BY A RAMP.
4. FOR DETAILED GUIDANCE ABOUT LOCATION,LAYOUT, DESIGN ETC.OF BUS STOPS REF.IRC:80-1981

FIG. 15.4. LAYOUT OF PICK-UP BUS STOP LAY-BYE IN HILLY AREAS

15.4.4. In all these developments emphasis should also be laid on aesthetics, environment protection and blending of the facility with the landscape. Land for this purpose should be acquired at the time of land acquisition for the road itself.

15.5. Traffic Aid Posts/Emergency Telephone

15.5.1. A major problem in hill roads is the absence of suitable communication and assistance to aid the stranded and damaged vehicles and passengers in case of accident or brake down. It is suggested that a system of ground traffic aid post with telephone/wireless communication be provided along all highways. The traffic aid post should be fully equipped with mobile traffic patrol cars, recovery vehicles/cranes, First Aid kit etc.

15.6. Information Signs

15.6.1. One of the most important amenity to a traveller is availability of adequate travelling information. Adequate number of road signs in accordance with IRC:67-1977-"Code of Practice of Road Signs" should be provided on all roads. In order to enhance the visibility, all road signs should be made from retro- reflective sheeting as per guidelines circulated vide Ministry of Surface Transport letter No. RW/NH-33023/31/88-DO III dated 2.5.1994. Also information sign boards to indicate the road condition i.e. Road open/closed, expected time of opening etc should be displayed at suitable locations, preferably sectorwise. Weather information along the route also be added as this is vital for travelling public. At check posts additional amenities by way of tourist information, road maps etc. should also be provided. Similar information, in printed form should also be made available at roadside fuel stations and restaurants. Sign posting should be in English and other regional languages in accordance with the practice being followed on National Highways.

15.7. Truck Terminals/Parking Complexes

15.7.1. A major cause of increase in accidents is also the non-availability of adequate resting places for truck drivers and crew. To take care of this requirement, truck parking complexes should be set up at convenient locations at a distance of about 150 km on selected major arterial routes and such complexes should have facilities for parking, refuelling, carrying out of repairs, supply of spare parts, canteen, board and lodge etc.

15.8. Eating Places

15.8.1. A major problem in hill roads is absence of clean and suitable eating places and the encroachment by small establishments on to the road. To solve the problem, suitable locations along the highway should be developed and leased to the operators at low cost. Such places should be kept well away from the right of way and should be provided with off-road parking facilities. Control should be exercised on them to improve the hygiene with the cooperation of local bodies and health authorities.

15.9. Coordination in Planning Amenities

15.9.1. Roadside amenities should be developed in coordination with other related departments like the Department of Tourism, State Transport Undertakings, Automobile Association, Transport Operators and ascertaining views of public through local Non-Governmental Organisations. Private sector participation for development of scenic spots, water points, shelters at but stop etc. with permission for display of their advertisements as per approved pattern could be considered so as to meet the cost of these amenities.

16. SAFETY ON HILL ROADS

16.1. General

16.1.1. The concern for safety on hill roads is an essential part of highway engineering. This involves decisions on administration, design, construction, maintenance and operation including traffic management. The objective is to set standards which will produce desired degree of mobility and reduce accident risk.

16.1.2. It must always be borne in mind, that safety on a hill road is directly proportional to adherence of laid down geometric standards, specifications and traffic rules and any compromise on this, for economic or other considerations, will only result in a road of sub-standard safety norms. It is always good to build a road to laid down standards rather than attempt improvements after building sub-standard roads and experiencing safety hazards. Improvements will always have limitations and unless re-built, cannot be a substitute for a newly constructed good road.

16.2. Causes of Accidents

16.2.1. Driving in hills, especially in adverse and inclement weather conditions, is a very complex, difficult and tiring task. Accidents occur at places where the rythm of motion changes unexpectedly for a driver. Such happenings are not infrequent on hill roads due to the following:-

a) Travelling over sharp curves of sub-normal radius in conditions of inadequate sight distance needs frequent deceleration and acceleration.

b) Curves have to be negotiated in varying speeds due to varying degrees of curvature and applying brake when entering a curve and accelerating at the exit.

c) Alternating entry from major valley into a side-valley, crossing of streams by narrow bridges, causeways, etc.

d) Steep grades and alternating UP and DOWN grades and negotiation of high altitudes.

16.2.2. Considering the above, the aim of the highway engineer should be to duly consider the usual driving errors and response of the vehicles and design a highway which will eliminate such errors and reduce stress on the drivers. A well - designed and constructed road will always be less prone to accidents and will add to safety.

16.3. Safety on Hill Roads

16.3.1. Safety on roads in hills, like in the plains, is dependent on the same factors i.e. Driver, Vehicle, Road and Environmental Conditions..However, environmental factors affect a hill road very much due to severity of climatic and terrain conditions like torrential rains and consequent slides (mud flow, rock fall rolling boulders., etc.), snow fall, snow drifts, avalanche/glacier activity icing problems, fog chilly winds, blizzards, etc. Measures to improve safety on hill roads follow the usual pattern of Engineering, Enforcement and Education measures. However, while dealing with engineering measures in detail, as relevant to this manual, others are proposed to be touched upon only.

16.3.2. Road condition plays a very significant part in road safety. Studies based on wide spread scientific research, involving analysis of road accidents, examination of interaction between vehicles, different road conditions and driver reaction to highway situations, has established a clear relationship between road condition and safety.

16.3.3. There are elements of roadway that have a direct effect on safety which include cross-section, vertical and horizontal alignments, access control, system of lay-out, inter-section design, pavement surface, illumination, road signs and barriers. The effect of these in combination and not individually determines the level of safety.

16.4. Engineering Measures

16.4.1. Engineering measures to improve safety in hill roads can be classified into four aspects as under:-

a) Geometric design measures which ensures adequate width, curve radii, easy grades and sight distance.

b) Engineering design measures to deal with specific and exclusive conditions in hills. This includes design and provision of good drainage system, protection like parapets, railings, snow fences, snow shelters, rolling boulder buffer (netting), etc.

c) Traffic control devices like signs, signals, pavement markings, delineators, advance public warning system etc.

d) Maintenance response and safety monitoring.

16.5. Enforcement Measures

16.5.1. There are laws enforcing traffic and vehicle discipline to be adhered to by all road users and drivers. Strict enforcement of these by the appropriate authorities and deterrent action on violations can enhance safety level. Some of these are mentioned below:-

a) Condition of the vehicle: The vehicle must be in a mechanically fit condition to operate on hill roads.

b) Condition of driver: The driver should be physically and mentally capable and alert to operate in the hills and undergo rigors of climate and toughness of terrain met with. Drunken driving should be checked.

c) Overloading: Overloading of vehicles (load carriers and passengers) has to be strictly prohibited. The practice of passengers travelling on bus top as also on heavily loaded truck or overcrowding in driver's cabin which has to be curbed.

16.6. Education Measures

16.6.1. Consciousness among the users about the road condition and necessity to adopt safety measures should be imparted by appropriate awareness system like pamphlets, mass media publicity, etc. Important aspects like "DON'T MIX DRINK & DRIVING", "IT TAKES CARE FROM TWO DRIVERS TO AVOID AN ACCIDENT" and SAFE DRIVING TECHNIQUES" etc. can be imparted by training measures by traffic control and enforcing authorities. Private sector participation for erection of such slogan boards with their advertisement as per approved pattern on the reverse of board may be considered

16.7. Safety Analysis

16.7.1. For evolving safety measures on existing road system, it is necessary to collect data on accident and conduct safety analysis. These can be done with the aid of the following:-

a) Preparation of 'Accident Spot Maps' wherein location, types, severity, seasonal incidence, pedestrain involvement, night incidence etc. of accident is marked.

b) Preparation of "Accident Report Form" as per IRC:53-1982 "Roade Accident Forms A_1 and 4"

c) Detailed study of accident spots based on either number of accidents or accident rates, indicating geometry, road width, obstruction etc.

d) Collision diagram indicating type and nature of collision of vehicles, pedestrains involved etc.

e) Traffic volume

By analysing the above data as per normal traffic engineering practice, suitable remedial measures can be evolved.

16.8. Geometric Deficiency

16.8.1. Geometric deficiencies cover inadequacies in sight distance, horizontal curves, vertical curves, pavement widths, gradients, setback distances/vision berms, camber, super elevation, passing places and lateral/vertical clearance. Deficiency in any of these compromises safety, the extent depending on the severity of the inadequacy.

16.8.2. Safety on individual horizontal curves: This can be improved by following methods:

a) realigning the road to build up the requisite radius.

b) increasing super-elavation to cater to higher speeds on curve (but not more than maximum permissible as per standards).

c) improving sight distance by batter benching or vision berms.

d) provision of adequate road signs and markings.

e) blind curves and hairpin bends may be made 2-lane. Detailed measures are given in para 16.8.2.1.

f) ensuring that extra width at curve is invariably provided as per standards.

g) providing parapets and/or railings at dangerous locations.

16.8.2.1. **Narrow/sharp curves and zigs**: A common type of deficiency in hill roads is the existence of narrow and sharp curves/zigs with inadequate sight distance. This leads to frequent head-on collision. At such locations following measures may be taken:

a) A double solid centre line should be painted to prohibit overtaking in accordance with IRC: 35-1970 "Code of Practice for Road Markings". Cat eyes should be provided along the centre line for visibility at night. Parapet walls, guard stones or railings along the valley side should be provided at all sharp curves. (The hill roads are designed for intermediate sight distance and hence this can be enforced).

b) 'OVERTAKING PROHIBITED', 'COMPULSORY SOUND HORN' signs and 'speed limits' shall be posted on each side of the curve in accordance with the provision of IRC: 67-1977 "Code of Practice for Road Signs". Retro-reflective sheeting may be used on all signs to improve its visibility.

c) Adequate widening, transition curves and sight distance should be provided, if feasible, as a long term measure in accordance with standards.

d) All blind curves must have two lanes which should be divided by fixing stone or concrete studs as brought out earlier also.

16.8.3. **Vertical curves and grades:** In hill areas steep grades contribute to a large extent to accidents. This may be due to factors like insufficient sight distances, low capacity, interference to traffic on ascending grade, and vehicles whose brakes have failed.

16.8.3.1. Insufficient sight distance along L-section of a road due to small radius of convex vertical curve is one of the main causes of head-on collision accident in hill roads.

In such locations, improvements in three stages are possible as under:

a) Widening of lanes and marking of a continuous centre line and/or providing cat eyes prohibiting overtaking as shown in Fig. 16.1. This is effective for traffic volumes upto 500 vehicles/day on two-lane roads

b) Provision of a dividing stand at least 1 m wide starting at a point which is within clear sight distance as shown in Fig. 16.2. This is suitable for traffic volume from 500 to 1500 vehicles/day on two lane road.

c) Increasing the radius of vertical curve by cutting the protruding crests so as to conform to the speed and curve radii requirements as shown in Fig. 16.3. This is the solution on single lane roads, which most of the hill roads are.

Note: Hill Roads are not normally designed for overtaking sight distance and hence by enforcing traffic discipline, the problem can be reduced to a great extent.

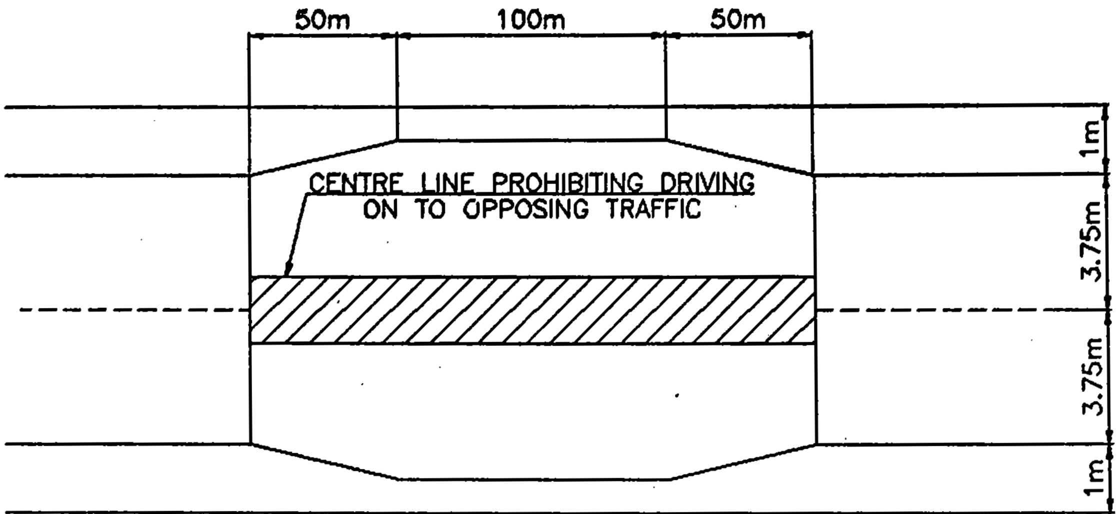


FIG.16.1. WIDENING ROADWAY

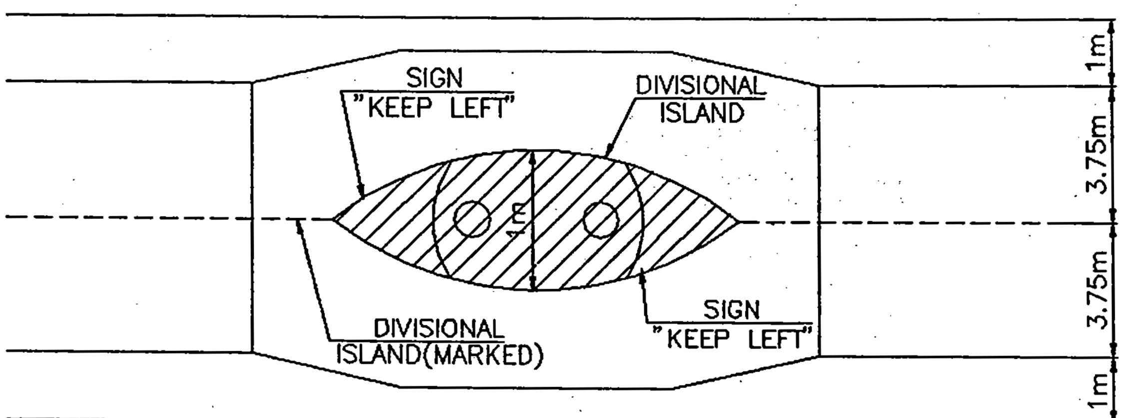


FIG.16.2. DIVISIONAL STAND (ISLAND)

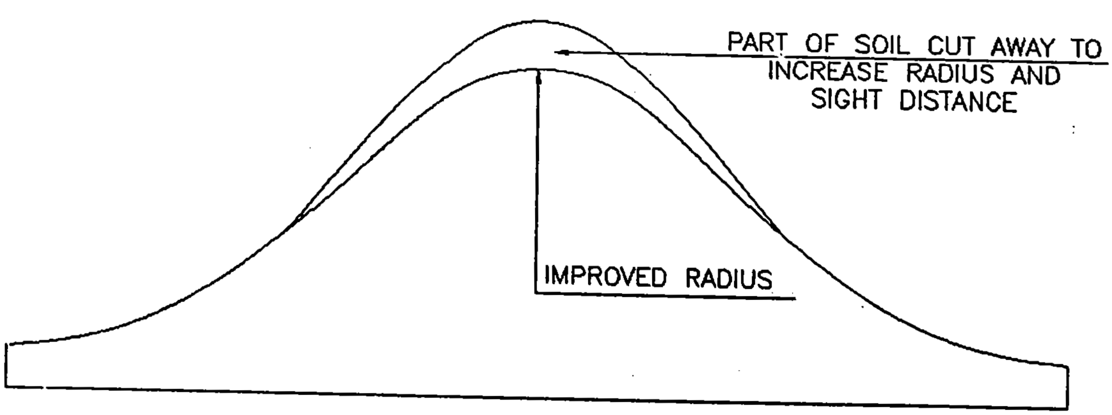


FIG. 16.3. INCREASING RADIUS OF VERTICAL CURVE

16.8.4. **Bridge approaches:** Another serious accident prone location in hill road is existence of bridge with curved approach combined with down gradient. Such locations are common sites of topping over of vehicle over the bridge. Such siting of bridges should be avoided and bridge structure should follow the general flow of the alignment. However, short term measures to improve safety are to increase visibility, use of reflective cautionary signs, use of speed control measures and strong guard rails to deflect out of control vehicles. Delineators in approach to bridge should also be provided as per IRC: 79-1981 "Recommended Practice for Road Delineators".

16.9. Problem of High Altitude/Snow Fall Areas

16.9.1. A common problem in high altitude and snowfall areas is of snow drifts and avalanches. This requires a detailed study of the phenomenon and identification of sections prone to this. Having identified the area, first a warning system has to be developed and then long term engineering measures planned. The engineering measures available are snow fences, construction of snow-sheds to allow passage of snow drifts over the road and construction of tunnels etc.

If these phenomenon are noticed at the survey stage itself, the road design can locate the road alignment and structures suitably and incorporate suitable protection measures right in the beginning. Snow markers showing depth of snow in metres should be placed on both sides of road for guidance. These are dealt with in detail in Chapter 12 "Snow Clearance and Avalanche Treatment".

16.9.2. Views of three snow/avalanche protection structures are given in Fig. 16.4.

16.10. Rock Fall, Shooting Boulders, Unstable Areas etc.

16.10.1. A common cause of accidents in some locations in hill roads is shooting boulders or rock fall. This is basically due to unstable upper slope. Some of the measures to improve safety of such locations are listed below and may be applied selectively depending on the situation. (The subject of stability has been dealt in Chapter 11 "Slope Stability and Erosion Control and Landslides Correction").

a) Stabilise the upper slope by improving drainage, other erosion control measure and treatment of exposed rock face.
b) Planting of upper slopes with a belt of trees to stop the boulders short of the road.
c) Providing extra wide hill side shoulders with deep drain to catch these falling debris and carry away as the water flows.
d) Provide a shelter similar to snow shelter to allow the boulder to go over the road.
e) Provide deflection walls and buffer zone to divert boulders and impound them.
f) Design a wire net screen buffer to catch the boulders and subsequently dispose them off suitably.
g) Post appropriate warning signs to caution the traffic.

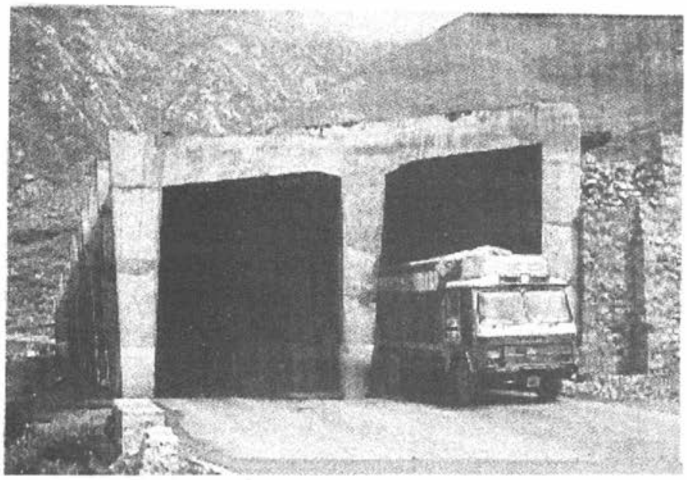
16.10.2. A view of a buffer-net constructed on one important hill road is given in Fig 16.5.

16.10.3. Slides, flow of excessive water and slope materials on roads is a common factor endangering safety on roads in hills during rainy season. Major slides block the road and smaller slides make the roads slushy and slippery. Water overflowing drain erodes the berms, jeopardising safety. A combination of catch-water drains, chutes, catch pits with cross drains and adequate camber can channelise the drainage and improve safety on roads as discussed in the relevant chapters earlier.

16.11. Vehicles Rolling into Valley

16.11.1. Vehicles rolling off the road into the valley is also a major safety problem. In areas prone to this type of accidents i.e. blind curves, sharp curves and deep vertical cuts, strong parapet walls capable of

TIMBER AVALANCHE DEFENCE MEASURE OF 'FIFTIES



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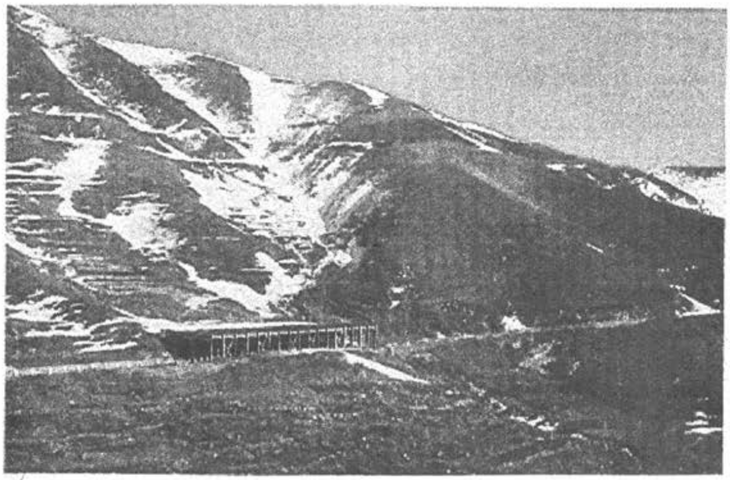

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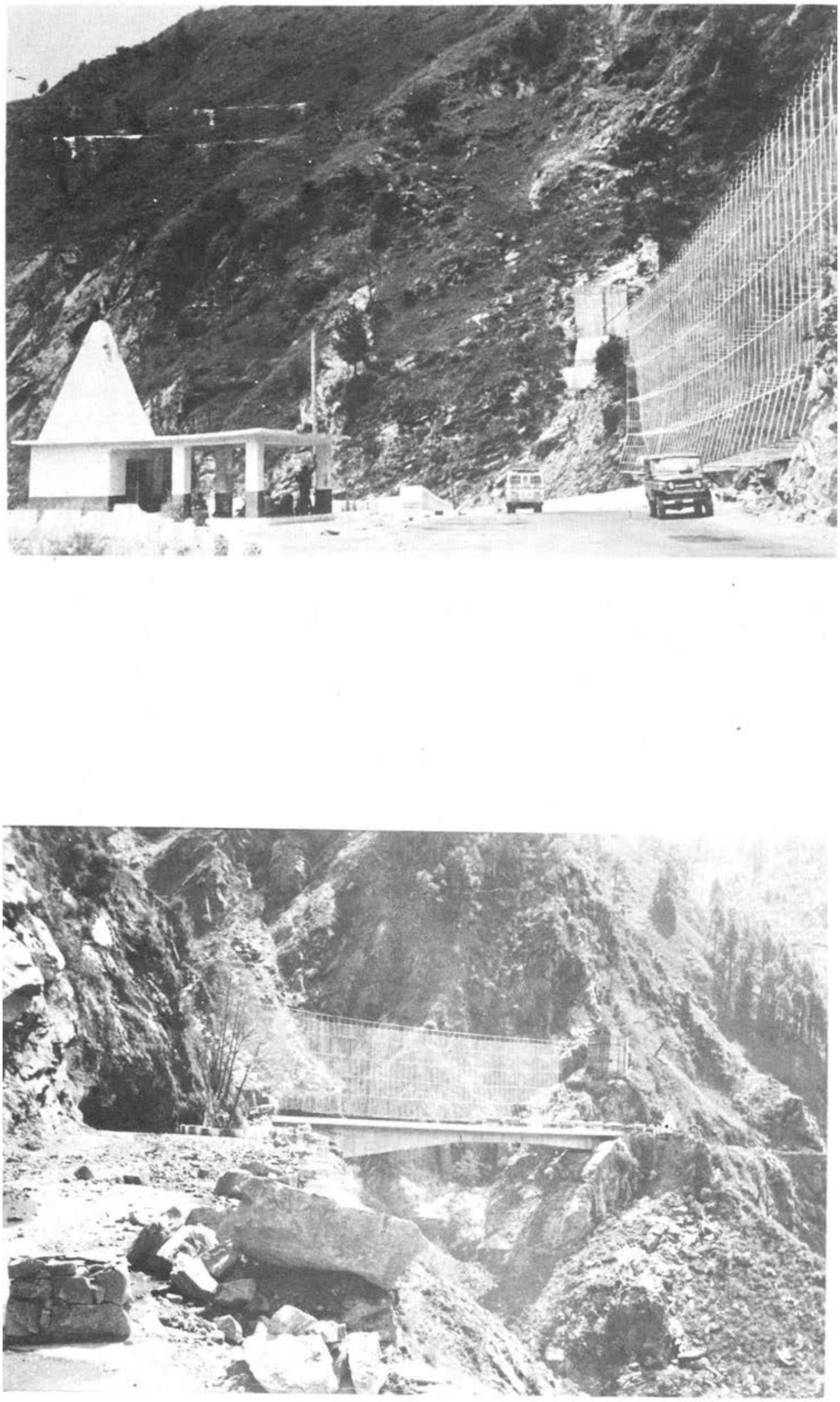


Fig. 16.5

restraining the vehicles back or guard rails/cables fixed to deep piles or strong pillars should be provided at suitable intervals. These can only act as caution and the proper solution is improvement of geometrics and educating drivers on safety.

16.12. Low Visibility

16.12.1. In sections of roads subjected to serious visibility reduction due to fog, rain, low clouds and on sharp curves, road delineators should be provided in accordance with IRC:79-1981 'Recommended Practice for Road Delineators'. All delineators should, as far as possible, use retro-reflective sheeting. The firm edge of the road should be marked with stone of approximately uniform size and should be white washed. At dangerous points, parapets should be constructed.

16.13. Icing Areas

16.13.1. In many locations of hill roads in high altitude areas water over the road surfaces freezes into ice lenses which make the roadway slippery causing accidents by skidding. In such locations following measures should be adopted:-

a) Instal warning signs of 'SLIPPERY ROAD' (as per IRC:67-1977) and provide additional informatory signs advising use of tyre chains and impose speed limits.

b) Improve drainage by providing steep hill side cross fall draining water towards hill side. This measure will also help to some extent prevent skidding/running of vehicles to valley side.

c) Provide impact resistance guard railing or parapet wall on the valley side.

d) Use deicing chemicals.

16.13.2. The problem of snow and ice has been dealt in Chapter 12. "Snow Clearance and Avalanche Treatment".

16.14. Miscellaneous

16.14.1. Road side trees, poles, projecting rocks, parapets are also a source of accidents. These should be painted in accordance with Clause 13.3 of IRC: 35 "Code of Practice for Road Marking" to reduce hazard and to provide delineation. All stone/tree hindrances, in case these cannot be removed should be white washed. White washing is necessary for safe night driving. A band of reflective sheeting should also be used to improve night visibility.

16.15. Construction Sites

16.15.1. Construction sites on hill roads also pose a safety hazard unless suitable precautionary measures are taken. Road signs such as 'DEAD SLOW' 'WORK IN PROGRESS' should be placed well in advance of work sites to warn the road users of the danger ahead. While working on deep foundations the area leading to the work site must be heavily barricaded and lighted at night prevent any errant vehicle falling in.

16.16. Ribbon Development

16.16.1. Ribbon Development along highways in the form of encroachments, proliferation of eating places, roadside vehicle repair shops etc. is a growing menace and seriously impairs safe movement of vehicles. Measures to control this involves removal of encroachments, provision of railings on road boundary, provision of separate laybyes, parking places and making way-side amenities available off the road at convenient places. Cautionary signs and speed barriers should be provided in approaches to such areas to reduce risk of accidents.

16.17. Traffic Management

16.17.1. This has been dealt elaborately in Chapter 17 "Traffic Management".

16.18. Gate System for UP and DOWN Traffic

16.18.1. To reduce accidents on heavily trafficked single lane road sectors, gate timings system for UP and DOWN traffic can be introduced to control traffic so that vehicles in opposite directions do not use the road simultaneously. This has been dealt in detail in Chapter 17 "Traffic Management".

16.19. Sum Up

16.19.1. Keeping all above in view, safety can be improved by following in combination:

a) providing geometric standards of roads as per specifications

b) adequate warning, cautionary and information signs

c) regular maintenance of road

d) adequate drainage system

e) construction of protective structure for traffic like parapets, railings, snow sheds, boulder net, etc

f) appropriate road markings

g) enforcement of traffic discipline, traffic rules/regulations

h) introduction of gate system of traffic on crucial road sectors

16.19.2. The efforts should be to ensure safe and comfortable travel at design speed for the road user in hilly regions.

17. TRAFFIC MANAGEMENT

17.1. General

17.1.1. In hill roads there are several typical situations in which traffic management becomes essential. Traffic management can be classified into two categories. One which requires traffic management due to closure, mishap, etc. The second where traffic is required to be regulated to improve operation and safety.

17.1.2. The following belong to first category:

a) Closure due to landslide, snowfall, blizzard, etc.

b) Protection of places of road repair.

c) Operation of certain section as one way lanes.

d) Weather warning

17.1.3. The second category comprises the following:

a) Speed restrictions.

b) Restriction on parking.

c) Use of traffic control devices/Signs like Speed Signs, Curve Warning Signs, Central line marking, No passing signs, Warning about land slide/Rockfall areas etc.

d) Time restrictions or gate system for up and down traffic, where required.

17.2. Arrangement when Traffic is Suspended

17.2.1. In the event of traffic being suspended on a section of hill road, the following traffic arrangement should be made:-

a) If the duration of suspension is such as to necessitate diversion of traffic to another route, guidance about this should be provided at the appropriate road inter-section, on either side of the damaged section, where it would be possible for the through traffic to alter its course. This should be done with the help of suitable warning signs put up in a pair, one just close to the intersection and the other 30 to 60 meters away depending on vehicle speeds at the site. In addition, a prominent 'ROAD CLOSED' sign should be fixed on the far side of the intersection blocking half the width of the carriageway. Word message on the signs may be in more than one language according to needs of the road users. To regulate traffic at the points of re-routing, police help may also be requisitioned. Together with this, Press and other Mass media should be used to notify the public about road closure and alternative routing for the through traffic. A typical information board may be as under:-

i) When road is closed
_______________ road closed at km ____________________
at _____________ hrs on __________ Due to ____________________
to be opened on

ii) When road is opened
_______________ road at km ____________________
since opened for traffic.

b) Similar boards should be erected at the junction where the traffic is to take a diverted route requesting to follow diversion.

c) Strong inviolable barriers should be erected in the immediate vicinity of the damaged section on both sides so that traffic can have no chance of going through imprudently. Besides, regulatory signs announcing that the road ahead is closed should be installed on the approaches; one sign at 10 m from the barrier and the other 30 to 60 metres further away. These should be supplemented by a 'ROAD CLOSED' sign affixed to the barrier in prominent position. Word messages on the sign may be in more than one language as dictated by needs of the road users.

d) The barricades should be protected by red warning lamps at night which should stay lit from sunset to sunrise. In addition, alternate black and white diagonal strips should be marked on these for effective advance warning. Preferably, reflectorised paint/sheets should be used for this purpose.

e) A watchman should be present at the barrier at all times. Whenever the barrier is to be temporarily opened for construction traffic in connection with repairs to the damaged section, a responsible person must be present at the site for supervising traffic arrangements and explaining the hazard ahead to adamant drivers. The construction traffic may be allowed through a small opening (about 3 m wide) at the extreme edge of the roadway, normally kept blocked with a double row of painted bitumen drums or barrier frames which should be removed only for permitting the construction vehicles to pass each time and put back in position immediately thereafter.

f) Signs, lights, barriers and other traffic control devices should be kept maintained in a satisfactory condition till such time the traffic is restored and allowed to follow its normal path.

g) Typical arrangements according to the above plan are illustrated in Fig. 17.1. It should be suitably modified for each location to ensure adequate visibility and sight distance on curves etc.

17.3. Arrangements when Part of Carriageway is Blocked and Leading to One Way Operation

17.3.1. Blockage of part carriageway on account of landslides, or repair or construction of cross-drainage works is a common occurrence in hill roads. In such cases the following general guidelines should be kept in mind:

a) Traffic may be passed either over part width of the structure or a temporary diversion, depending on site conditions, intensity and volume of traffic, preferably on economic considerations and other related matters. The former method should be employed as far as possible specially when the work could be conveniently carried out in half width at a time and there are no undue problems in channelling the traffic through the available road width. In both cases, the work should be so planned that widening/reconstruction of the cross-drainage facility is over in the shortest time possible following properly conceived construction schedules. This will be facilitated if all the materials and other equipments are collected at site in advance before the work actually commences.

b) One-way traffic operation should be established whenever the traffic is to be allowed over part width of a structure. This should be done with the help of flagmen, positioned on opposite sides, who should be on duty during all hours. For regulation of traffic, the flagmen should be equipped with red/green flags and lanterns/lights or reversible stop/go sign boards. Where possible short range radio transmitters may be used for communication if the blocked stretch is long.

c) Where for any reason traffic cannot be allowed over part width of a structure, a temporary diversion should be constructed. The width and paving specifications for the diversion should be decided on factors like the period for which diversion will be in use, intensity and volume of traffic and climatic conditions. Attention must also be given to the avoidance of dust nuisance. On both ends, the diversion should be joined to the main carriageway with smooth transition, with visibility requirements fully taken care of.

d) At the point where traffic is to deviate from its normal path (whether on temporary diversion of part width of the carriageway), the channel for traffic should be clearly marked with the aid of pavement markings and painted drums or a similar device. At night the passage should be delineated with lanterns or other suitable light source. To enhance night visibility, reflectorised paint or sheeting may be used for the painting of markings and drums. Power operated flashing lights may be used where needed and feasible.

e) Strong barriers of suitable design should be erected on either side of the portion of carriageway closed to traffic, both when the traffic is to be turned to a diversion road or channelled on to part width of the structure. For protection of traffic, red lanterns or warning lights of similar type should be mounted on the barriers at night and kept lit throughout from sunset to sunrise. Besides, barricades should be painted with alternate black and white markings, for which reflectorised paint/sheets should be preferred to improve their night visibility.

f) On both sides, suitable regulatory/warning signs should be installed for the guidance of road users. Word message on the signs may be in more than one language as necessary. On each approach at least two signs should be put-up, one close to the point where transition of carriageway begins and the other 30-60 m away. Signs may be placed in the following order. "MEN AT WORK" sign at 60 m from work area, "NARROW ROAD AHEAD" at 30 m from work area, "KEEP LEFT" at start of work area and "RESTRICTION ENDS" at 30 m beyond the area.

g) Signs, lights, barriers and other traffic control devices, as also the temporary diversion, should be kept well-maintained till such time the traffic is again able to follow its normal path.

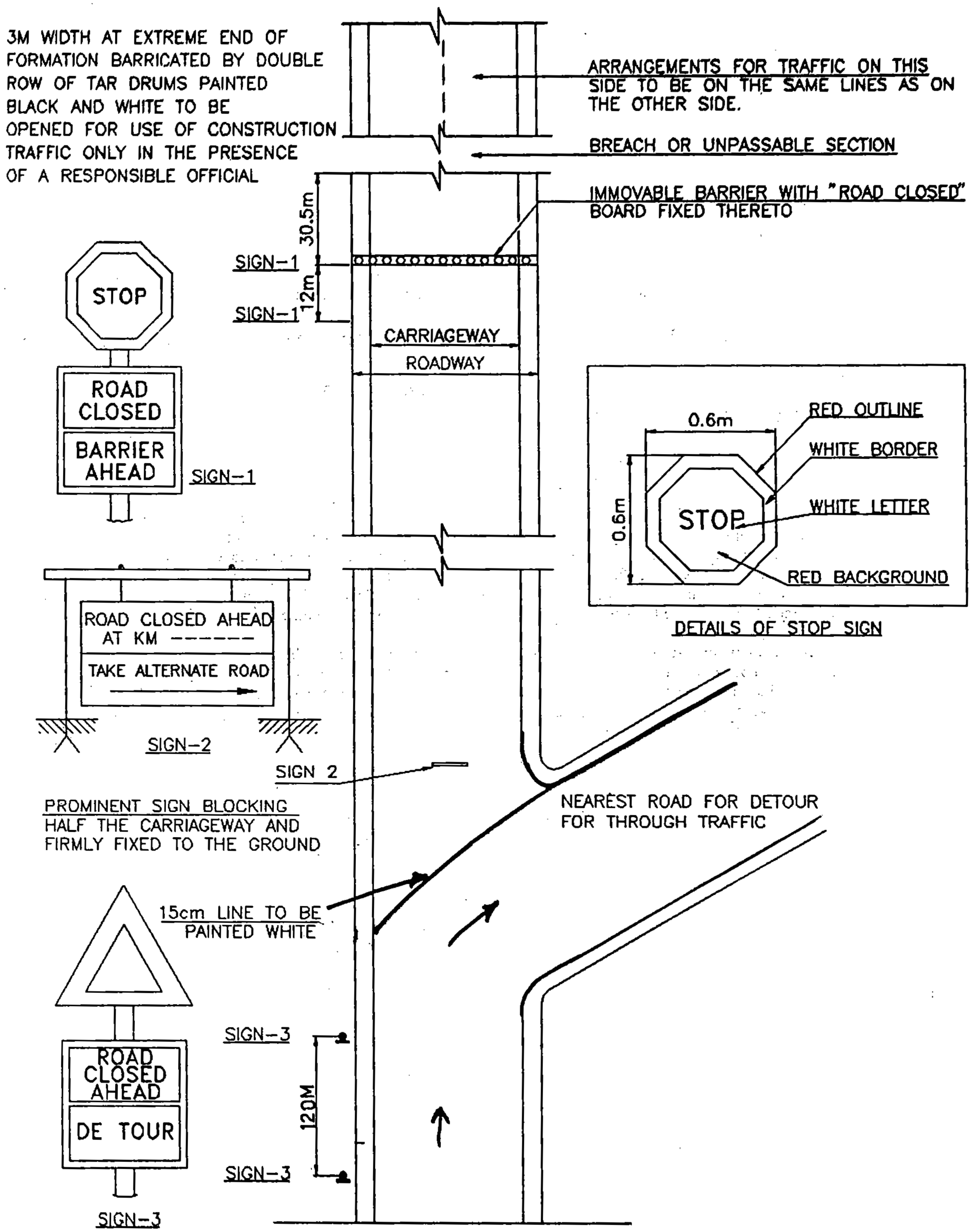


FIG. 17.1. ARRANGEMENTS FOR TRAFFIC WHEN A SECTION OF THE ROAD IS CLOSED DUE TO BREACH OR DAMAGE

h) **Typical arrangements for the two cases where traffic may be passed (i) over part width of a structure or (ii) over a temporary diversion, are illustrated, in Figs. 17.2 and 17.3 respectively.**

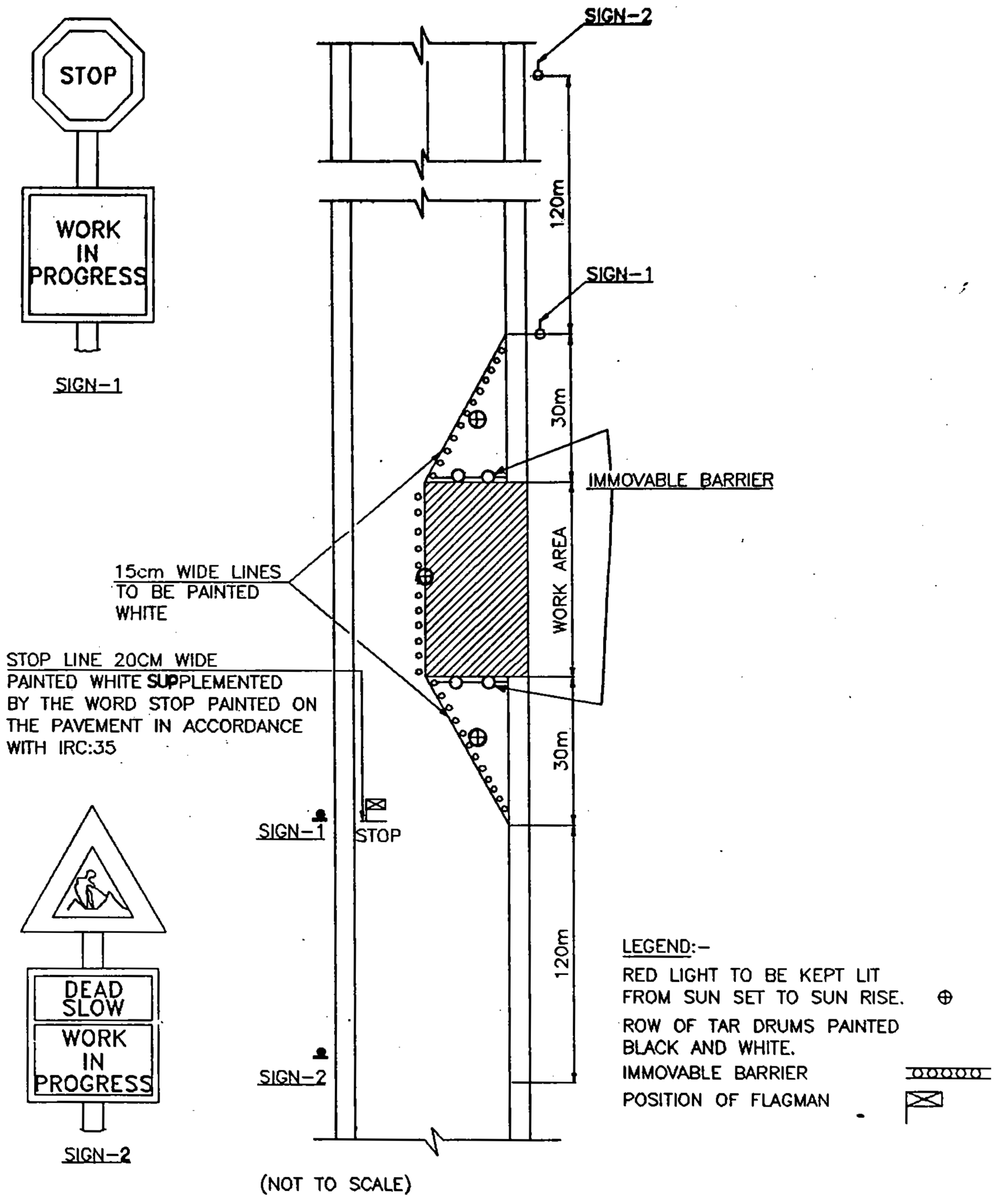


FIG. 17.2. ARRANGEMENTS DURING RECONSTRUCTION OF CROSS DRAINAGE STRUCTURES WHERE TRAFFIC CAN BE PASSED OVER PART WIDTH OF STRUCTURE

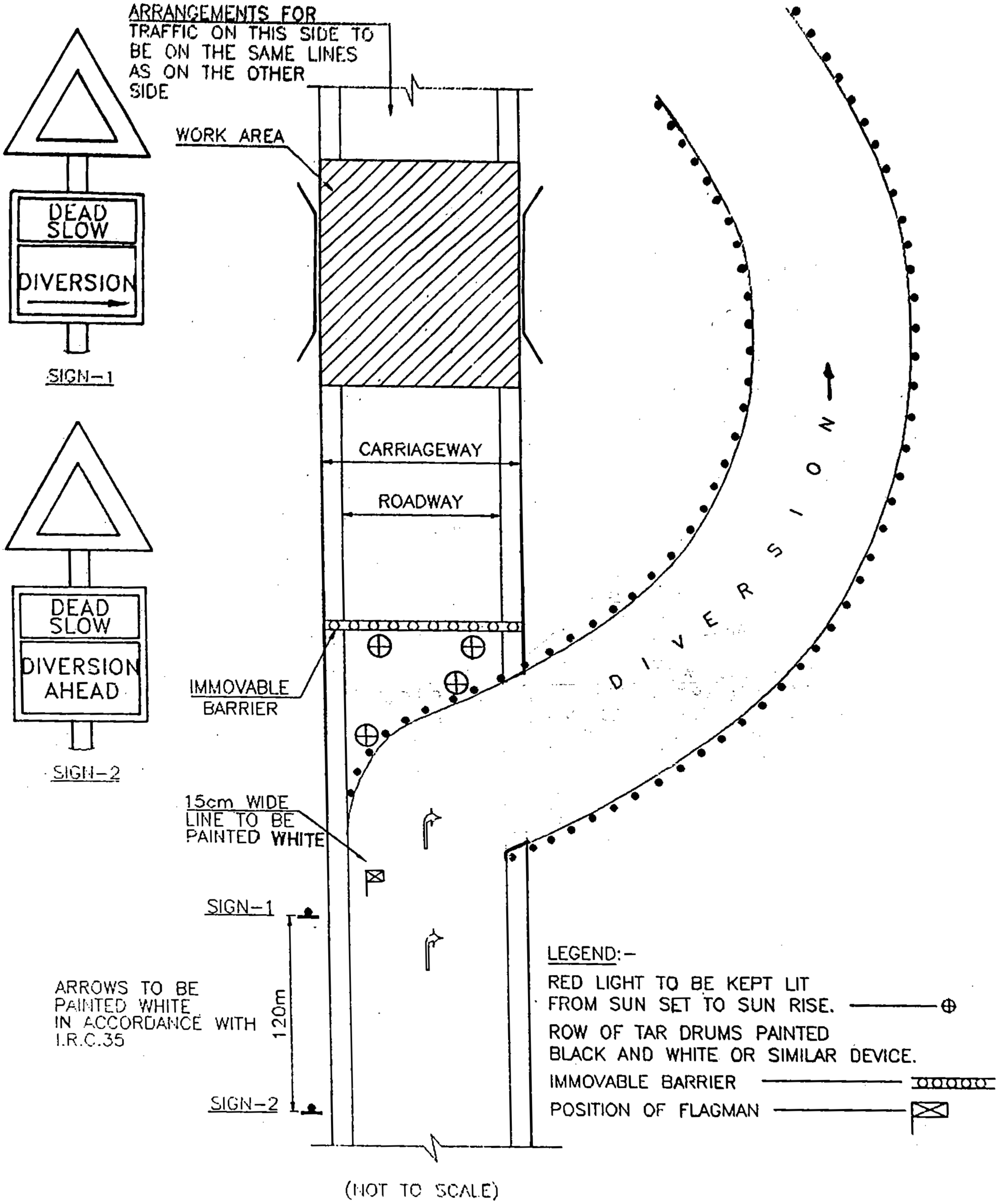


FIG. 17.3. ARRANGEMENTS DURING RECONSTRUCTION OF CROSS DURING DRAINAGE STRUCTURES WHERE TRAFFIC IS TO BE PASSED OVER A DIVERSION

17.4. **Large Weather Warning Signs**

17.4.1. At the start of sections subject to closure under bad weather conditions and at other frequently travelled sections, large changeable message informatory signs should be installed to provide warning and/or information to users of conditions expected on the route. The sign should also be used to inform public of sections which are closed due to blizzard, landslides etc.

17.5. **Other Traffic Signs and Markings**

17.5.1. An important element of traffic management in hill roads is proper traffic signing and marking. In general, to be effective, the signs/markings should only be installed where needed, convey a clear simple warning, command respect and attention of road user and give adequate time for proper response. It is, therefore, very important not to allow unauthorised and unnecessary signs on roads. Some of the signs and markings normally required in hill road are given in succeeding paras. As fog is a problem in many such roads use of luminous paints/strips may be used for sign boards.

17.5.2. **Speed limit signs:** In hill roads, speed regulations and speed limits are necessary to supplement motorist's judgement in determining speed that are reasonable and proper for particular weather and roadway conditions. Speed limits should be imposed to reduce accidents and improve traffic flow. However, if the speed limits are unreasonable, the limit will be disobeyed and loose much of its value. The speed limit signs should conform to IRC: 67-1977 "Code of Practice for Road Signs". The speed limit should be determined on the basis of, where applicable, proper engineering and traffic data, i.e., prevailing wind speeds, physical features of road, accident experience, traffic characteristics and traffic control.

17.5.3. **Curve warning signs:** On sharp curves i.e., curves that permit less speed than the general operating speed of the highway, curve sign should be provided and advisory speed plate added below it.

17.5.4. **No parking and no standing/stopping sign:** Safety, comfort and convenience of road users, demands a proper and effective regulation of parking on hill roads, due to inadequacy of wide areas for parking on roadside and steep slopes. Parking restriction should be placed after a careful study of the traffic patterns and engineering requirements. The signs for controlling parking should conform to IRC: 67-1977 "Code of Practice for Road Signs" and should be accompanied by suitable kerb or carriageway marking as indicated in IRC: 35-1970 "Code of Practice for Road Markings".

17.5.5. **Centre line and no passing marking/signs:** In accident prone location and sharp curves where head-on collisions are common, centre line marking should be provided as indicated in IRC: 35-1970 "Code of Practice for Road Markings". On blind curves in single lane roads the width may be made two lane and lanes divided by studs/cats eye.

17.5.5.1. No-passing sign and painting of strips as per IRC: 35-1970 mentioned in preceding paras, should be adopted where the passing sight distance is restricted, and volume of traffic is high.

17.5.5.2. Other useful signs for regulating traffic on hill roads which are given in IRC: 67-1977 "Code of Practice for Road Signs" and should be posted are "FALLING ROCKS", "LOOSE GRAVEL", "STEEP ASCENT", "STEEP DESCENT", "NARROW BRIDGE", "NARROW ROAD AHEAD", "ROAD WIDENS AHEAD", "DANGEROUS DIP", "HUMP", "HAIRPIN BEND", "REVERSE BEND", "CURVE" AND compulsory "SOUND HORNS".

17.6. **Traffic Regulation In Winter**

17.6.1. Traffic accidents rate is much higher on roads with ice and snow. To reduce these accidents, the following measures are recommended:

a) Provide information to road user in advance to reduce the element of surprise as far as possible.

b) Impose lower speed limits.

c) Surveillance of traffic and road conditions.

17.7. Gate System or Restricted Time for UP and DOWN Traffic

17.7.1. On a number of important hill roads there is seasonal heavy traffic due to tourist or pilgrimage season etc. when the vehicles using road shows manifold increase over the normal period. To ensure that such increased traffic does not result in congestion and traffic bottlenecks, possible danger and safety to road users and vehicles and to avoid accidents, a gate system may be introduced in the affected Sector.

Traffic is allowed at fixed timings so that UP and DOWN traffic do not use the stretch simultaneously. However, to ensure that the travelling public is not put to inconvenience and to reduce delays, central vehicle crossing grounds could be created in between the stretch so that the Up and Down traffic converge on to the crossing ground and proceed further to the destination. The gates and crossing grounds function as traffic control points properly manned with telephone, radio sets etc. for traffic control and convenience to road users. Such system has been found to function efficiently not only in thickly trafficked corridors but also in stretches where road passes through difficult terrain conditions like snow fall areas, high mountain passes, etc. A typical arrangement is given in Fig. 17.4.

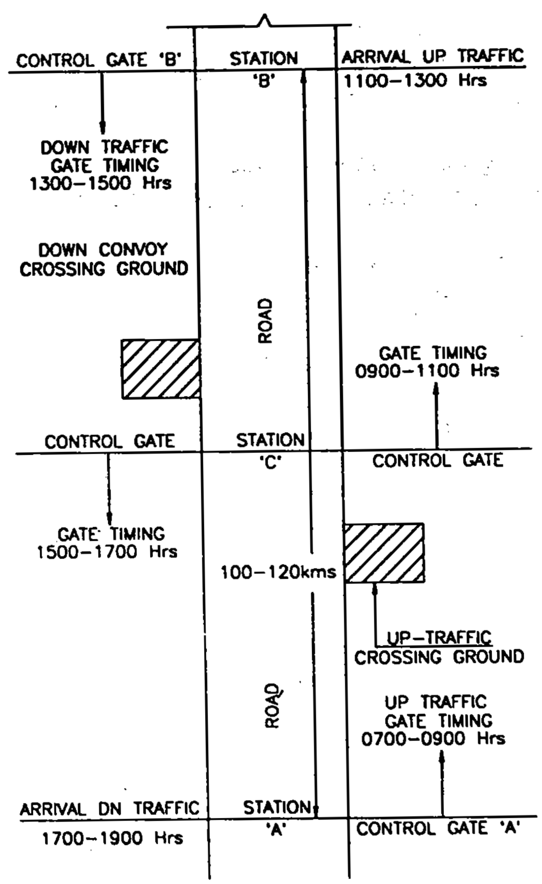


FIG.17.4. GATE SYSTEM STATION A TO B

17.8. Weather Information System

17.8.1. On important roads specially in snow bound areas it is essential to develop a 'Road weather information system' which should contain several field stations and a central unit. Field stations should be equipped with sensors to determine the temperature of road surface, humidity, wind speed, and its direction, condition of road surface (wet, dry, slippery) and information about weather (precipitation). Inclement weather is hazardous on hill roads and more so in high altitudes. The change of weather is also faster and sudden. Sensitive barometer may be utilised to forecast change likely in weather. Drop in pressure indicates approaching inclement weather. The siting of field station should be preceded by a detailed climate survey to ensure best possible sites. The field stations should be linked to a central station by telephone and/or radio control sets. The Central unit should be equipped with computer to record and analyse the data and a communication system to transit data and warnings to public and field maintenance units. Road users can be informed over the radio and at restaurants/eating places along the routes.

17.8.2. The information centre should also have cooperative connections with transport firms plying on the road who provide feedback on actual site conditions. Use of TV monitors and weather radar can also be made if funds permit. Radar is very useful as it gives advance warning of the approaching bad weather. The success of the system depends on quick response from snow and ice clearing maintenance teams and on ability to regulate traffic at start of safe sections identified by earlier studies.

18. ROCK BLASTING

18.1. General

18.1.1. Blasting of rock disturbs the stability of nearby hill side to a great extent. This also results in immediate and delayed landslides and slip zones causing considerable damage to property. For road construction in hills, rock blasting may be inescapable but it should be avoided to the maximum extent. There should not be tendency to resort to rock blasting only for immediate economy in cost and expediency of construction work. Rock blasting preferably should be done for hard rocks and also where road cutting cannot be done manually by shovels, crow-bars and dozers. For restricting rock blasting to the barest minimum the following guidelines must be strictly followed.

18.2. Guidelines

18.2.1. All the staff involved in rock blasting work, right from the Engineer to the skilled worker must be given necessary training and consciousness regarding grave adverse ecological effects as well as danger to life and property due to rock blasting so that they do rock blasting only when unavoidable and do it in the proper manner consciously. The manufacturers of explosives normally arrange training courses for users on request.

18.2.2. Rock blasting must be properly planned and controlled. Rock blasting work for a project must be planned in detail at the stage of preparation of estimates. The blasting work must be carried out under the direct supervision of a Junior Engineer or trained Supervisor. Daily account must be maintained of rock blasting to be done, explosives planned/expected to be used and actually used under the direct control of the Engineer and wherever there is any anticipated deviation in quantities from that planned it should be checked. Only just sufficient quantity of explosive should be issued in the morning for the days work and consumption justification should be scrutinised at the close of day's work.

18.2.3. For blasting, holes should be drilled along the Line of Least Resistance to avoid developing of cleavage planes/cracks and opening up fissures etc. The depth of holes should be minimum. Minimum numbers of holes should be blasted at a time. In case of large scale blasting to be done by electric detonators, delay detonators should be used in order to disperse shock waves.

18.2.4. On hill roads blasted material and debris rolling down should be avoided where these are likely to result in destabilisation of hillside or cause soil erosion. Subject to cost effectiveness, the debris should be moved to selected safer places where these are not likely to be washed away. These should be kept in such form as are likely to stabilise later.

18.3. Necessity of Rock Blasting

18.3.1. Since hilly regions in the country have predominance of rock varieties in some areas, blasting is rather a necessity in road construction activities. Blasting is required for rock excavation in hill sides, through cutting and quarrying. Blasting of ledge or half tunnel across a cliff face may also, sometimes, be necessary. Before deciding the exact alignment of the road and method of cutting, the dip of the rock must be carefully examined to ensure that the completed road would be stable. Particular care should be taken to detect faults, which often provide planes of potential slips which may be dangerous.

18.4. Explosives and Accessories

18.4.1. The choice of explosives and accessories depends upon the nature of strata and its characteristics.

18.4.2. An explosive is a substance or a mixture of substances, which for the purpose of transport, handling and storage is in stable equilibrium. The equilibrium is upset, if subjected to severe shock resulting in violent release of energy in the form of shock waves accompanied by extremely rapid conversion of the explosives into a large volume of gases at high temperature and pressure. The necessary shock is provided by means of a detonator or detonating fuse. The explosives are normally Nitroglycerine based, though Ammonium Nitrate based explosives are also available. For road construction, nitroglycerine based gelatine is used. These are known by trade/brand names and terms "gelatine" or "special gelatine" of various strengths or power are commonly used and understood.

18.4.3. Properties of explosives

18.4.3.1. Power

The most important property of an explosive is its strength or power. Blasting gelatine, the most powerful of all commercial explosives, is taken as the standard and the power of all other explosives are measured in relation to the power of blasting gelatine, indicated as percentages.

18.4.3.2. **Velocity of detonation:** Detonation of an explosive is the rate which the detonating wave travels through a column of explosives and is of considerable importance since shock energy of detonation increases rapidly with velocity. High velocity explosives are preferred for special purposes such as plaster shooting and underwater work. Low velocity explosives are most suitable where excessive shattering is to be avoided.

18.4.3.3. **Density:** The density is important when selecting an explosive for a particular use. With a high density explosive the energy of the shot is concentrated, a desirable feature in tunnelling whereas a low density explosive distributes energy along the shot hole.

18.4.3.4. **Water resistance:** Explosives differ widely in resistance to water and moisture penetration. While some explosives deteriorate rapidly under wet conditions, others are designed to withstand water for considerable periods. If blasting is to be done under wet conditions, a water resistant explosive should preferably be selected.

18.4.3.5. **Sensitivity:** An explosive must not be sensitive to normal handling, shock and fraction, but it must remain sufficiently sensitive to be satisfactorily detonated and capable of propagating satisfactorily, cartridge to cartridge even over short gaps, such as may occur in practice.

18.4.3.6. **Fume characteristics:** Explosives when used under stipulated ventilation conditions should liberate minimum of harmful gases in the process of detonation.

18.4.3.7. **Thermal stability:** Explosive combination should be such as to be stable under all normal conditions of transportation, handling and usage. This is extremely important as use of explosive itself depends on this characteristic.

18.4.4. Explosives in common use

18.4.4.1. The details of some explosives most commonly used in road construction are given in Table 18.1.

Table 18.1. Explosives in Common Use

Name of explosives	Velocity of detonation (confined) metres/ sec	Normal density gms/cc	Nature of rock to be blasted
Blasting gelatine 90%	5000	1.40	Quartzite, very hard granite
Blasting gelatine 80%	5000	1.40	Hard rock formation
Blasting gelatine 60%	5000	1.40	Medium, hard and soft rock
Slurry explosive 80%	3400-4000	1.15 to 1.25	Hard rock formation

18.4.4.2. The explosives are supplied in cylindrical cartridges of diameter varying from 25-32 mm and length 200-250 mm, the weight of a cartridge being 130-220 gm depending on size.

18.4.5. **Detonator**

18.4.5.1. High explosives are by themselves not very sensitive and need some form of intense local shock to initiate them. This shock is produced by a detonator. Extremely sensitive composition are loaded in small quantities into copper or aluminium tubes to form detonators and in this form, they are used to prime charges on high explosives. It is the spark or SPIT from a safety fuse, which causes the detonator to explode. A variety of detonators are used for blasting.

18.4.5.2. **Plain detonators:** Plain detonator for use with safety fuse, consists of a small aluminium tube closed at one end. It contain a base charge of PETN (PENTA ERYTHRTOL TETRANITRATE) and a priming charge of ASA composition (lead azide, lead styphnate and aluminium powder) in an aluminium tube. This standard tube is known as a No. 6 detonator and is commonly used. Super plain detonators No. 8 strength are also used for specific purposes.

18.4.5.3. **Ordinary electric detonators:** An ordinary or instantaneous electric detonator is essentially a plain detonator plus a fuse head coupled to a pair of leading wires and is triggered by electric current.

18.4.5.4. **Delay detonators:** Many blasting operations call for a series of shots to be fired in a pre-determined sequence, which can be achieved by the use of short delay denoters. This detonator consists basically of an electric detonator with appropriate delay element interposed between the fusehead and the priming charge. There are eleven detonators in this range, numbered 0 to 10 (the number of delay detonators of certain manufacturers has been increased to 16, numbered 0 - 15) with nominal delay intervals of 25 milli seconds (increased in later numbers) between consecutive numbers having leading wires of 24 SWG, PVC coated.

18.4.5.5. Sketch of various types of detonators and fuse head is given in Fig. 18.1.

18.4.6. **Detonating fuse:** Detonating fuse is a simple and safe device for initiating cap sensitive commercial explosives particularly suitable for simultaneous firing of multiple charges and for the mass initiation of large charges. It consists of a core of PETN with covering of textile and plastic. It is initiated by a No. 6 detonator and detonates at a velocity of approximately 6500 m/sec.

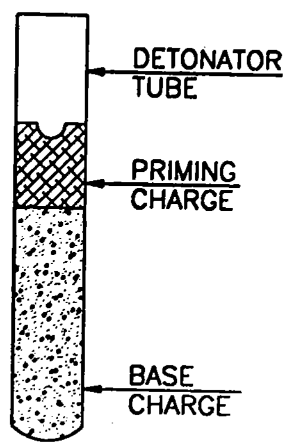


FIG. (a) PLAIN DETONATOR

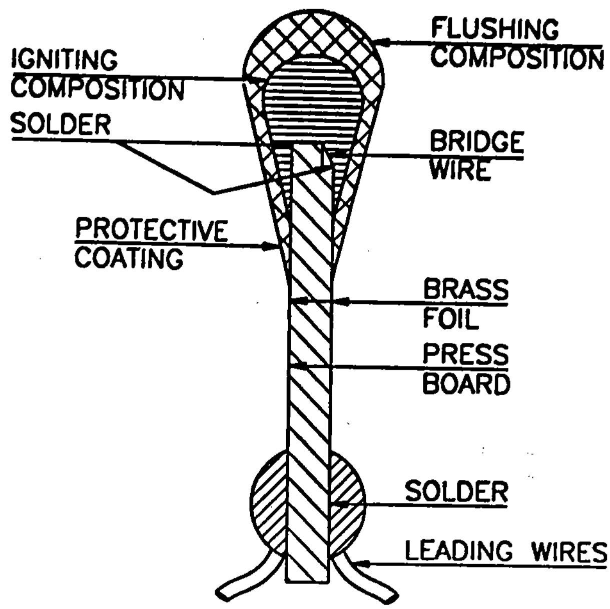


FIG. (b) ELECTRIC FUSE HEAD

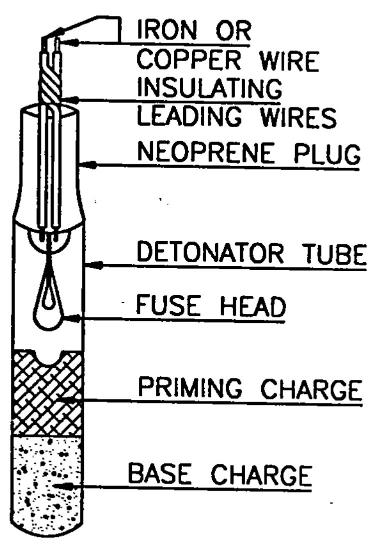


FIG. (c) SECTIONED ELECTRIC DETONATOR

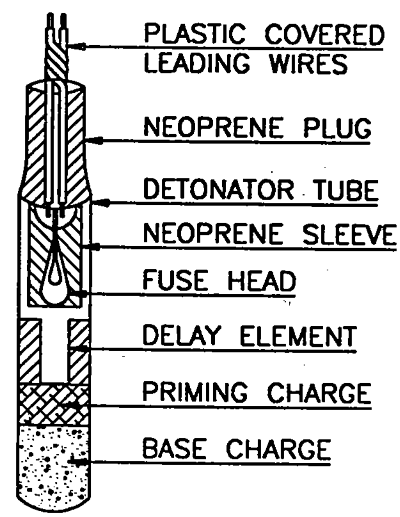


FIG. (d) SECTIONED DELAY DETONATOR

FIG.18.1. DETONATORS

18.4.7. **Safety fuse:** Safety Fuse consists of a thin core of specially prepared black powder wrapped in layers of textile yarn and waterproof coating. The burning speed of safety fuse is controlled and is 100 to 120 seconds per metre.

18.4.8. **Exploder:** When explosives are to be initiated electrically a portable exploder for generating electricity is used. The exploders being manufactured in the country, have a range of 50 shots to 200 shots at a time. An exploder, is generally built on a metal chassis contained in a waterproof 'bakelite' case. It comprises of a dynamo which is operated by turning a handle. The A.C. Voltage generated by the dynamo is stepped up by a transformer rectifier and used to charge a condenser to a potential of not less than 1,200 volts. When the firing button is pressed the condenser is discharged through the electric circuit firing the shots.

18.5. Transportation of Explosives

18.5.1. All the relevant central, state and local laws and rules and regulations framed thereunder shall be complied. Loading, unloading and handling of explosives shall be supervised by qualified personnel. At the time of loading or unloading of explosives, no electrical switch should be operated.

18.5.2. **Containers** - For carrying small quantity (upto 5 kg of explosives) specially designed insulated containers may be used. These containers shall be constructed of finished wood not less than 50 mm thick or plastic material not less than 6 mm thick or pressed fibre not less than 10 mm thick. Metal components, including nails, bolts, screws, etc., shall not be used in the construction of the containers, which shall be waterproof and provided with lids. The containers shall be provided with suitable non-conductive carrying device, such as rubber, leather or canvas handle or strap.

18.5.3. **Vehicles** - The vehicles used for transporting explosive shall be driven only by an experienced driver who is physically fit and is familiar with the precautions to be taken while carrying the explosives in his vehicle. All vehicles used for transporting explosives shall be maintained in good working condition and all systems of same must be checked before starting move of vehicle. The vehicles should preferably be enclosed type with locking arrangements and body-work leak-proof.

18.5.3.1. In open body vehicle the floor of the vehicle carrying explosive shall be leak proof. The sides and ends shall be of sufficient height to prevent the explosive from falling off the vehicles.

18.5.3.1.1. The interior of the body shall not have any exposed metal parts, except those of copper, brass and other non-sparking metals and shall preferably be lined with wood.

18.5.3.1.2. The chassis of the vehicles shall be well sprung. The tyre pressure shall be maintained as per the requirement of the Indian Explosives Regulations.

18.5.3.2. All electrical wiring and equipment of vehicles shall be adequately insulated and protected against mechanical damage to prevent short circuiting.

18.5.3.3. Two carbon dioxide fire extinguishers, each of not less than 3 kg capacity, conforming to IS: 2878-1986, shall be carried on each vehicle. The extinguishers shall be securely mounted on the vehicles in such a manner that they can be readily removed for use in an emergency.

18.5.3.4. A motor vehicle carrying explosives shall not be refuelled except in emergencies and even then only when the motor has been stopped and other precautions have been taken to prevent accidents.

18.5.3.5. The quantity carried, in any single vehicle should not exceed 75% of its rated capacity or 3600 kgs, whichever is less.

18.5.4. Safety Precautions in Transportation: Safety precautions outlined below shall be observed for transportation of explosives.

18.5.4.1. No metals except approved metal truck bodies shall be allowed to come in contact with cases of explosives. Metal, flammable or corrosive substances shall not be transported with explosives. As far as possible, transportation of any other material alongwith explosives shall be prohibited.

18.5.4.2. Smoking shall be prohibited in the vehicle carrying explosives and in its vicinity upto a distance of 30 m.

18.5.4.3. No unauthorised person shall be allowed in the vehicle carrying explosives.

18.5.4.4. Explosives and detonators of blasting caps shall not be permitted to be transported in the same vehicle.

18.5.4.5. Detonators and other explosives for blasting shall be transported to the site of work in the original containers or in securely locked separate non-metallic container and shall not be carried loose or mixed with other materials.

18.5.4.6. Care shall be taken while loading and unloading of explosives, like inside of vehicle body must be free from grit, oil rags etc., unloading should not be done near exhaust of pipe, explosive protected from rain/prolonged exposure to sun, engine of vehicle switched off and no refuelling permitted while unloading etc. The filled containers shall not be handled roughly or dropped.

18.5.4.7. Drivers shall not leave the vehicles unattended while transporting explosives.

18.5.4.8. The speed of the vehicle shall not exceed 25 km/h on rough roads and 40 km/h elsewhere.

18.5.4.9. Vehicles, transporting explosives shall not be taken into a garage, repair shop or parked in congested areas, public parking or similar places.

18.5.4.10. Explosives shall not be transported in trailers. Further, any trailer shall not be attached to a motor truck or vehicle when it is being used in transporting explosives.

18.5.4.11. Explosives shall not be transported on public highways during darkness, except in emergencies and even then only when the approval of the concerned authorities has been obtained. Such vehicles shall be fitted with adequate warning lights on both ends, while operating in darkness.

18.5.4.12. Explosives shall not be transferred from one vehicle to another on public highways, except in cases of emergency.

18.5.4.13. When explosives are carried in a convoy, the distance between any two vehicles will not be less than 75 metres.

18.6. Storage of Explosives

18.6.1. Storage of explosives is regulated by Indian Explosives Act 1884 and provision there under should be strictly observed, unless exempted under section 14 of the Act.

18.6.2. Explosives shall be stored only in a magazine, which is clean, dry, well ventilated, well illuminated where electricity is available, reasonably cool, correctly located (more than 100 mtrs from living accommodation) and protected against lightening if explosive is one ton or more in accordance with Indian Electricity Act and Indian Explosives Act. The magazine should be located on well drained sloping ground and away from built-up area/highway but approachable with all-weather road. In case of new storage accommodation for explosive, the local inspector of explosive or other licencing authority should be consulted and care should be taken to ensure that the statutory distances from other buildings and property are observed.

18.6.3. All major dumps as well as dumps in disturbed area having explosive of 3 ton or more should be fenced with double fencing of barbed wire. Similarly all precautions of security must also be taken for safe storage of explosives.

18.6.4. Explosive cases should not be stacked in more than five tiers and should be stacked in such a way that ends of the cases showing the date of manufacture are visible, which will facilitate use of stock early.

18.6.5. Explosives upto 4 kgs should be kept in a securely locked container away from fire and detonators/capped fuses should be kept in separate containers. While storing explosive upto 20-25 kgs a small store/magazine should be built. In case of storage for large quantity, following guidelines be followed.

18.6.5.1. Building should be specially constructed for this purpose situated away from residential/industrial area and highway.

18.6.5.2. About 2.42 sqm floor area should be considered for each ton of explosive. While stacking cases, each stack should not have more than 5 tiers and a working space of 1.22 m must be left between two stacks.

18.6.5.3. Where quantity of explosive exceeds 20 tonne a separate building for storage of detonators must be built and for leser quantity detonators can be stored in an annexe, which is built as integral part of main building but has a substantial partition with an air space between them. As a rough guide a double partition of 2 cm each with 45 cm air space between them will suffice the purpose of storing 10,000 detonators.

18.6.6. Blasting caps, electric blasting caps or primers shall not be stored in the same box or room with other explosives in big dumps. However, in small dumps sand bag revetments of appropriate thicknesses and hight will be used to segregate different zones of explosives.

18.6.7. Explosives, fuse or fuse lighters shall not be stored in a damp or wet place or near oil, gasoline, or near radiators, steam pipes or other sources of heat.

18.6.8. Smoking and use of matches, naked lights and readily flammable articles or open fire/flame shall be prohibited with in the fenced area around it. Similarly explosives should be kept away from electric contact, fuse boxes and switches.

18.6.9. An area upto a distance of not less than 50 m on all sides of a magazine shall be maintained free of all vegetation, debris and combustibles.

18.6.10. Metals, metallic objects and metal tools that are capable of producing sparks shall not be stored or used inside or in the immediate vicinity of the magazine.

18.6.11. Boxes of explosives shall not be thrown down or dragged along the floor and may be stacked on wooden trestles.

18.6.12. Package containing explosives shall not be allowed to remain in the sun.

18.6.13. Empty boxes, packing materials or any combustible material shall not be stored inside or in the vicinity of the magazine.

18.6.14. Adequate quantity of water and fire fighting equipment shall be provided near/in the magazine. Guards shall be properly trained in handling such equipment.

18.6.15. Signboards reading "DANGER-HIGH EXPLOSIVES", "PROTECTED AREA" "NO SMOKING" etc. shall be prominently displayed in front of the magazine.

18.6.16. Well trained preferably armed guards shall be posted to guard the magazine.

18.6.17. The following shall be hung up in the lobby of the magazine:

a) A copy of explosive rules
b) A statement showing the stock in the magazine, and
c) Certificate showing the last date of testing of the lightening conductor

18.6.18. Magazine shoes, without nails, shall be kept at all times in the magazine and a wooden tub or cement trough, approximately 300 mm high and 450 mm in diameter, filled with water shall be fixed near the door of the magazine. Persons entering the magazine shall put on the magazine shoes provided for the purpose and be careful is not to allow the magazine shoes to touch the ground outside clear floor. Persons with bare feet shall, before entering the magazine, dip their feet in water and then step direct from the tub on to the clean floor.

18.6.19. For continued blasting operations the magazine shall be located at a safe distance near the work site and actual requirement of explosives for each blast may be drawn and transported to the site and left-overs, if any, must be immediately returned to the magazine. Where the blasting operations extend to several scattered sites and/or one for a short duration, portable magazines shall be used. Each such magazine shall be located at a safe distance from the work site, enclosed in a fence and properly guarded.

18.7. Methods of Blasting

18.7.1. High explosives are initiated by plain detonators in conjunction with safety fuse, by ordinary electric detonators, delay detonators or by detonating fuse.

18.7.2. Blasting with safety fuse

18.7.2.1. A cartridge of explosives containing a detonator is known as a 'primer' cartridge. Only one primer is required in any one shothole, irrespective of the number of other cartridges used therein. Where gelatine explosive is used, primer cartridge is generally the top cartridge.

18.7.2.2. Preparing the 'Primer' Cartridge: All the saw-dust should be shaken out of the detonator. The safety fuse should be cut straight across with a sharp clean knife. The newly cut fuse should be pushed into the detonator holding it away and the detonator crimped securely to the fuse with a crimper, ensuring not to crimp the detonator tube on the part which contains the detonating composition. The length of crimp should be 3 mm to 6 mm from the open end of the tube. The cartridge should be opened at one end and a hole made with a pricker. The detonator should be pushed in until it is burried, the open end closed and the paper tied round the fuse with a piece of string. The other end of safety fuse should be cut at an angle or scarp for easy lighting.

18.7.2.3. Method described above is illustrated in Fig. 18.2.

18.7.2.4. Charging and Firing: Following accessories are required:-

a)	Stemming rod:	Made of wood (not metal) to charge and stem the hole.
b)	Scraper:	Made of brass (no other metal) to clean the holes.
c)	Pricker:	Made of brass, aluminium or wood to prick the cartridge prior to inserting the detonator or detonating fuse.
d)	Crimper:	Made of non-ferrous non-sparking material for crimping the detonator to the fuse.

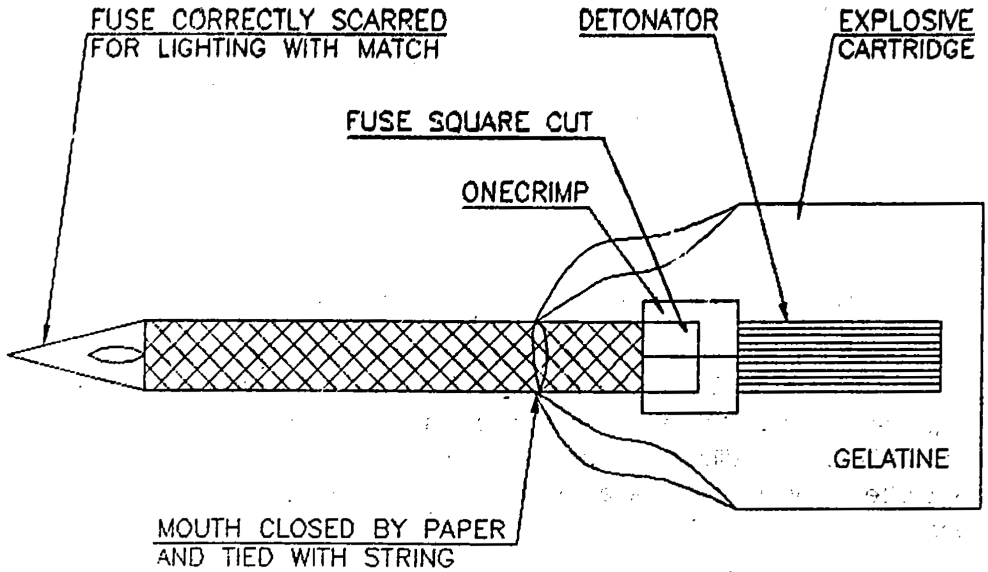


FIG. 18.2. FIXING DETONATOR, SAFETY FUSE AND EXPLOSIVE CARTRIDGE

18.7.2.5. The holes are drilled in rock with Jack hammer operated with the help of a compressor. The holes are generally 20 mm to 40 mm dia and 1 to 3 m deep. The holes can be drilled vertical, horizontal or at any angle. The holes should be cleaned first with compressed air or scraper. The diameter of the hole should be at least 3 mm more than the cartridge diameter. The primer cartridge should be made. Sufficiently long fuses should be used to enable men to get clear after lighting the fuse. If a total of say, three cartridges are required in a hole, then two cartridges should be inserted followed by the primer. The 'primer' cartridge is always the last. The base of the detonator should point towards the full length of the charge. The cartridges should be pushed in one by one with a wooden stemming rod.

18.7.2.6. After charging, the hole should be stemmed with sand or a mixture of sand and clay. The first few inches of stemming should be tamped gently with the wooden rod increasing the pressure as the shotholes get filled. Stemming material should be free from sharp particles. The fuse should not be damaged or pulled while stemming. It should be ensured that all personnel have taken shelter before going to light the fuse. After lighting the fuse with a flame, moving to a place of safety away atleast 100 metres from the direction of the blast from the shot holes is essential.

18.7.3. **Electric shot-firing**

18.7.3.1. This method of initiation is safer than blasting with safety fuse since the blaster is definitely out of the way of danger at the time of the blast. Electric shot firing allows upto 200 shots to be fired at a time and with this method the possibilities of misfires are also remote.

18.7.3.2. **Preparing the primer cartridge**: The detonator leading wires should be straightened. A hole should be made with the pricker in one end of the cartridge. (For plain detonators the cartridge end is opened, but with electric detonator this is not necessary). The detonator should be inserted inside the hole until it is burried. The wires are then hitched round the cartridge to prevent the detonator from being withdrawn.

18.7.3.3. **Charging and firing**: For firing a single shot, the procedure is very simple. The hole should be charged with the requisite number of cartridges, inserting the primer last. After the hole has been stemmed, the bare ends of the detonator lead wires should be connected to the firing cable. Moving to the firing station, the other end of the cable should be connected to the exploder and fired. Finally the firing key should be removed and the cable from the exploder disconnected.

18.7.3.4. For firing two or more shots at a time, the lead wires are connected in a series circuit. The series circuit is made by connecting one wire from each detonator to one wire of the succeeding detonator and so on, thus forming a continuous circuit. The free wires at either end are then connected to the shot firing cable and the circuit tested with an ohmmeter prior to firing.

18.7.3.5. In damp conditions, each joint should be insulated to prevent current leakages which might cause misfires and also as a safeguard against stray currents.

18.7.3.6. While blasting with safety fuse, the shots in a round do not go off simultaneously. There is usually a short interval between each shot. With electric shot firing, however, all the shots in a round explode simultaneously and only one shot is heard.

18.7.4. **Blasting with delay detonators**

18.7.4.1. Short delay detonators are more suitable for blasting in road construction, excavations and quarrying.

18.7.4.2. **Charging and firing:** The primer cartridge is prepared in exactly the same way as with an ordinary electric detonator. With ordinary electric detonators, the 'Primer' is inserted into the shothole last. With delay detonators however, the primer is inserted first, followed by other cartridges. The base of the detonator should point towards the mouth of the hole. The wires should be connected up in series. It does not matter whether the leadwire of a No. 1 delay is connected with that of a No. 7 or a No. 2 delay; as long as the series circuit is properly made, the detonators will explode at the appropriate intervals.

18.7.4.3. **Advantages of short-delay blasting:** The technique of short-deley blasting offers a number of advantages over simultaneous blasting, particularly in reducing ground vibrations and improving fragmentation as given below.

a) **Reducing of ground vibration:** In blasting for road construction in unstable rock formations, care should be taken to avoid excessive vibrations. Short delay detonators could also be used when blasting in the vicinity of buildings and structures. The magniture of the vibrations produced by 5 kg of explosives fired by ordinary detonators is more than that resulting from 75 kg fired with a combination of No. 0 to No. 10 short delay detonators.

b) **Multi-row firing:** Firing with ordinary detonators, only one row of holes can be fired satisfactorily at a time. To fire several rows, some form of delay is necessary. With delay detonators, the second row fires after the first row has been broken and the third row comes into action after the first two rows have been displaced and so on.

c) **Less boulders:** Very few boulders are produced with short delay blasting.

d) **Less back break:** With instantaneous blasting by ordinary detention the area behind the shotholes is likely to be badly cracked. These cracks may cause the roadside wall to collapse at a later date. By using short delay detonators, back break or back cracking can be reduced.

18.7.5. **Blasting with detonating fuse**

18.7.5.1. Detonating fuse is the simplest and safest accessory for initiating explosive charges. It is not normally economical to use detonating fuse in short jack hammer holes. In certain cases however, where speed is essential, the time required for charging and blasting can be considerably reduced with the use of detonating fuse. A large number of shots connected with detonating fuse can be initiated by a single detonator, thus eliminating the length and complicated procedure of electrical connections or of lighting fuses. The process of blasting with detonating fuse is comparatively costly and its use may not be economical in some cases.

18.7.5.2. **Preparing the primer cartridge:** A suitable hole should be made with a pricker through the primer cartridge, longitudinally in the case of special gelatines. A piece of detonating fuse of suitable length should then be threaded through the cartridge and the projecting end secured to it by a knot or by taping it to the side of the cartridge so that it cannot be pulled out. The methods for this are illustrated in Fig. 18.3.

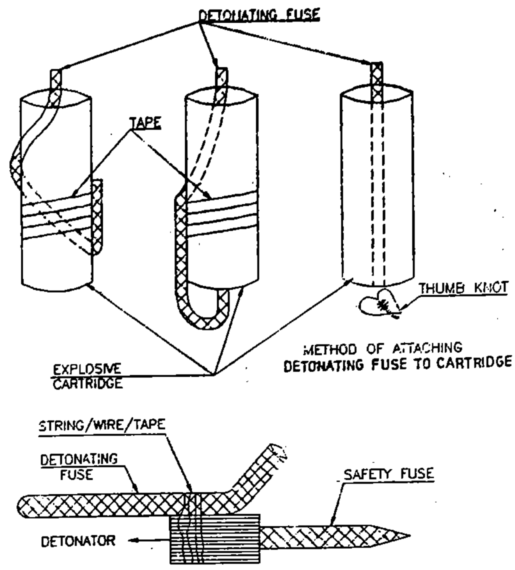


FIG. 18.3 BLASTING WITH DETONATING FUSE

18.7.5.3. **Connecting and initiation detonating fuse**: For charging the holes, the procedure is similar to that adopted for blasting with plain or electric detonators. When the holes have been stemmed, about 15 to 25 cm of detonating fuse should remain outside each hole. A long piece of detonating fuse known as a main line or trunk line should then be laid alongside the holes and the short pieces of detonating fuse connected to the main line. An 'L' joint or a clove-hitch joint can be used for connecting branch lines to the main line. This can be initiated by all types of detonators. The detonator secured to one end of the main line by adhesive tape, should point towards the charges.

18.8. Blasting Technique

18.8.1. The design of an efficient blast depends upon the relationship between the diameter and depth of hole, spacing, burden etc. In order to ensure that each cartridge of explosives does maximum work for given working conditions, systematic trials are essential to arrive at the best blasting technique. However, some important general principles are given hereunder.

18.8.2. **Drilling**: It is necessary to have a free face of the rock forming a 'bench' for ensuring effective utilisation of explosives. This is done by developing a free face first and then drilling rows of shotholes, parallel to the free face, 1.5 to 1.7 metres deep and blasting them. The holes in the middle two rows are inclined so as to form a wedge as illustrated in the Fig. 18.4. These inclined holes are blasted first, followed by other holes, fired in sequence. The resulting excavation is about 1.5 metres deep and can be deepened further using similar blasting pattern.

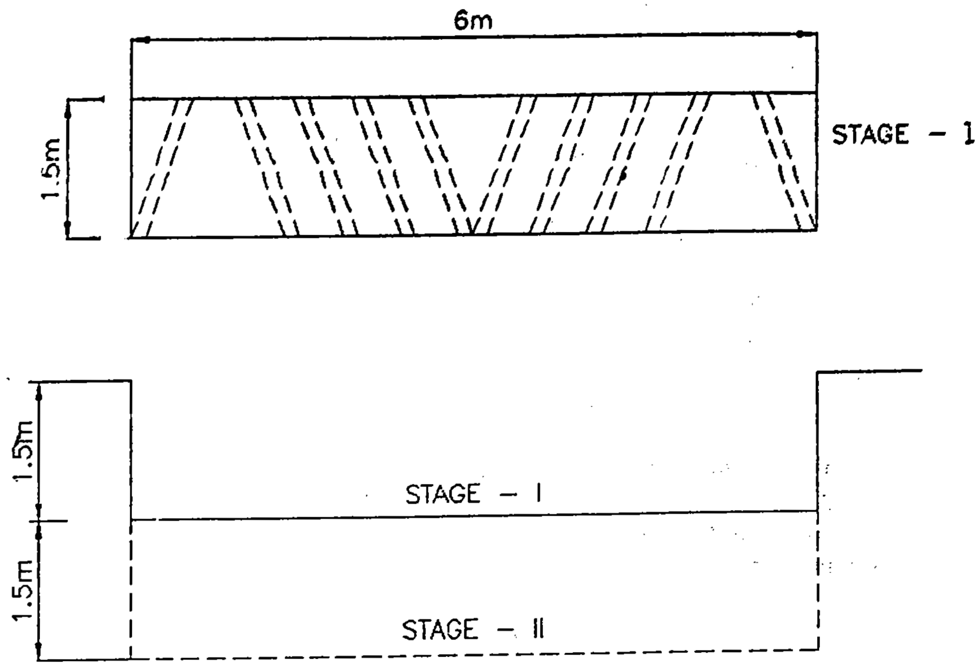


FIG. 18.4. DRILLING IN STAGES

18.8.3. **Burden:** This is the most critical parameter in benching. 'Burden' is the perpendicular distance from shot hole to the nearest free face of the rock in the direction in which the displacement is most likely to occur. Its actual value will depend upon a combination of variables including rock characteristics, the nature of explosive and the diameter of explosive etc.

18.8.4. **Depth of holes:** The depth of a drill hole depends upon type of drilling equipment and loading method adopted. In case of manual loading the bench height should not exceed 2-3 metres and depth of hole should be kept 3-4 metres, while using jack hammers. As a rule, the depth of hole should never be less than the 'Burden'. In practice holes are drilled to a depth varying from 1.5-2.5 times the 'Burden'. While deciding the depth of drill holes it must be borne in mind that depth of stemming should not be less than the 'Burden'; otherwise Line of Least Resistance will be established in the direction of stemming and blasting may not be much effective.

18.8.4.1. In general, a few deep bore holes are more efficient than large number of shallow ones as the amount of material detached is proportional to the cube of the depth of the charge. Also the vertical holes are easy to drill and normally give best results. They should be so placed that the Line of Least Resistance is horizontal.

18.8.5. **Spacing of holes:** The spacing between holes is dependent upon the nature of rock, degree of fragmentation required and the method of firing. Where holes are fired singly or with large intervals, the spacing may be twice the 'Burden'. However, where shotholes are fired simultaneously, which is the most common practice, spacing should not exceed 1.5 times the 'Burden'. In very hard and tough rocks, the spacing may have to be less than the 'Burden'. The optimum spacing between drilled holes should be determined by trials.

Example:-	Drill Hole Diameter	-	32 mm
	Depth of hole	-	2 m
	Burden	-	1 to 1.2 m
	Spacing	-	1 to 1.5 m

18.9. **Calculation for Blasting and Volume of Rock Blasted**

18.9.1. **Volume of rock blasted**: The volume of rock blasted is proportional to the depth and spacing of drill holes and burden and is given by the formula:

Volume of rock blasted per hole (Cum) = Depth (m) x Burden (m) x Spacing (m)

18.9.1.1. For jack hammer holes it is not necessary to calculate the volume per individual hole. The total volume to be blasted may be calculated as follows:-

Total volume of rock (Cum) = Average depth (m) x Total length of face (m) x Average burden (m)

18.9.2. **Blasting ratio**: The volume of rock broken by a unit weight of explosive is known as "Blasting Ratio". This ratio is usually expressed in "Cum of rock broken per Kg of explosives". For blasting with gelatine 80%, the following ratios may be adopted:-

Very Hard Rock	-	1 kg explosive for 3 Cum of rock
Medium Rock	-	1 kg explosive for 4 Cum of rock

18.9.3. **Quantity of explosives required**: The quantity of explosives required per hole or per blast can be worked out as follows:-

$$\text{Quantity of explosives (kg)} - \frac{\text{Volume of rock (cu.m.)}}{\text{Blasting ratio (cu.m.)}}$$

Example 1: Ten jack hammer holes are expected to break 20 cu. m (solid) of medium hard rock. What will be the charge per hole?
Volume of rock - 20 cu.m.
Blasting Ratio - 4 cu.m. per kg.
Therefore, total charge in 10 holes - 20/4 = 5 kg
Therefore, charge in each hole = 5/10 = 1/2 kg

Example 2: 32 mm dia drill holes is 2 m deep, with 1.5 m Burden and 1.5 m spacing in Hard Rock.
Volume of Rock = 2 x 1.5 x 1.5 = 4.5 cu.m. per hole
Blasting Ratio = 3 Total charge = 4.5/3 = 1.5 kg explosive

18.10. Secondary Blasting

18.10.1. Secondary blasting sometimes becomes necessary in the following cases.

a) To break oversize boulders produced during the primary blast to suitable size.

b) To break oversize boulders in land slides causing road blockades.

18.10.2. There are two basic methods of secondary blasting viz. Pop Shooting and Plaster Shooting.

18.10.3. **Pop shooting**: Pop shooting consists of drilling a hole just close to the centre of the boulder to be broken so that the charge is centrally situated and depth of hole a little more than half the thickness of the boulder. A hole is drilled either manually with the help of a cold chisel or with a hand drill or compressor drill as the situation may permit.

18.10.3.1. The charge varies with the size of the boulder, but for average conditions, a boulder of size 1.4 m x 1.4 m x 1 m requires a charge of 140 gm i.e. one cartridge of blasting gelatine 80% for every two cu.m. of the boulder. The shots can be fired by safety fuse alone or in conjunction with detonating fuse.

18.10.3.2. Machines/equipment etc. deployed on the road near the site should be withdrawn to safer distances, since there is considerable scatter of rock when firing pop shots.

18.10.4. **Plaster shooting (mud capping)**: Plaster shooting also known as 'Pressure Blasting' provides a ready means of breaking even large boulders in circumstances where drilling is difficult due to expediency, or due to non-availability of drilling tools/equipment at sites such as isolated landslides. A charge of one or more cartridges is primed with a detonator and safety fuse, and laid on the surface of the boulder. It is then covered with a shovel-full of plastic clay which is pressed into position by hand. It should be in good contact with the surface around the explosive charge.

18.10.4.1. In plaster shooting, the charge used is about four times that required for pop shooting, primarily depending upon the thickness of the boulder. Table 18.2 gives a guide to the quantity of explosive required for different boulder thicknesses although it will vary with the type of rock blasted. Best results in plaster shooting are obtained when the rock is of a hard and brittle nature.

Table 18.2. Quantity of Explosives Required for Plaster Shooting

Thickness of Boulder (cm)	Charge in gm
Upto 40	100
40-70	200
70-90	300
90-110	400
110-140	400-700

18.11. Blasting Methods for Different Road Construction Activities

18.11.1. New roads: The most convenient method is to drill vertical holes in several parallel rows across the roadside face of hill to obtain 'benching'. A series of benches can be established to achieve the full height of the cutting. The height of the benches will vary depending upon the type of the drilling equipment available and with jack hammers it rarely exceeds 3 metres. For fast advance of the benches, multi-row firing is often useful. The method is illustrated in Fig. 18.5.

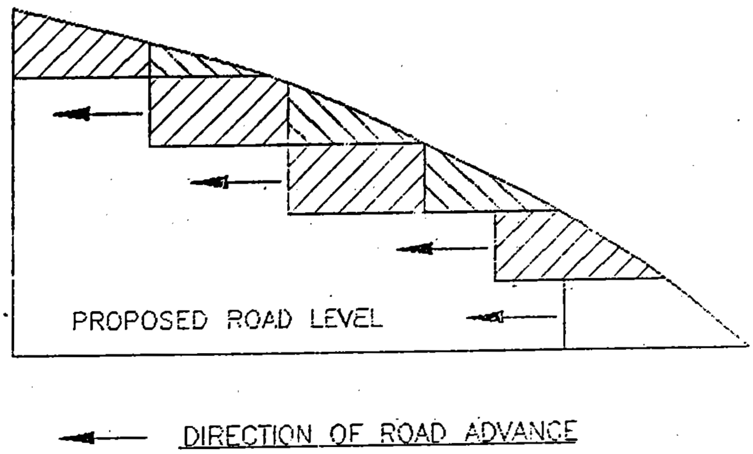


FIG. 18.5. ROCK EXCAVATION BY BENCHING

18.11.1.1. Cuttings: There are two general types of cuts, a side hill cut where the excavation is made on the side of the hill leaving a wall on one side only and a through cut, where the excavation is made through a hill leaving a wall on both sides. The procedure is described below:-

a) **Side Hill Cuts:** The first operation is the removal of soft over-burden. This is carried out in advance of the rock excavation, to facilitate drilling of the rock. When the rock has been exposed, a free face is established across the width of the cutting. This is done by two or more parallel rows of vertical holes and charging and firing them simultaneously. Once the free face has been established, the work proceeds by blasting successive rows of holes drilled parallel to it. For deep cuttings, the desired level of road can be reached by excavating in several lifts.

b) **Through cut:** In case of through cut, a long cut can be opened up along the centre line on either side depending on the slope of the surface. This face is then worked as a quarry and pushed back laterally to the slope line. This method can be repeated on successive lifts until the cut becomes too narrow. After that, the through cut is worked in the normal manner, that is, with the shots extending to the full width.

18.11.2. Half-tunnelling: Half tunnels are made where the strata is particularly strong and where construction of an open road would entail prohibitive amount of rock excavation. The width and height of half-tunnels (and full tunnels) should also consider future requirements of widening etc. as hill cutting later on will be very inconvenient and too costly. The half tunnel should be 7 m or more wide and 5-6 m high. Jack hammer drills fitted with air legs are most suitable for drilling the horizontal holes required for half-tunnelling. For drilling holes in the upper section of the cave, a portable staging with several platforms will be necessary. Alternatively, where the half tunnels are not very high, the upper holes can be drilled by standing on the debris produced by an earlier blast. Horizontal holes drilled parallel to the hill-side should be 1.6 to 2 m deep and fired with short delay detonators. A typical half tunnel face showing hole placement and distribution of short delay detonators is illustrated in Fig. 18.6.

18.11.3. Tunnelling (full) / drifting: A variety of drilling patterns are adopted in tunnelling work. The usual procedure is to fire several shots to break out a preliminary cavity known as 'cut', in the centre of the cross section. This is further widened by means of easer shots and final trimmer shots are fired to bring the tunnel

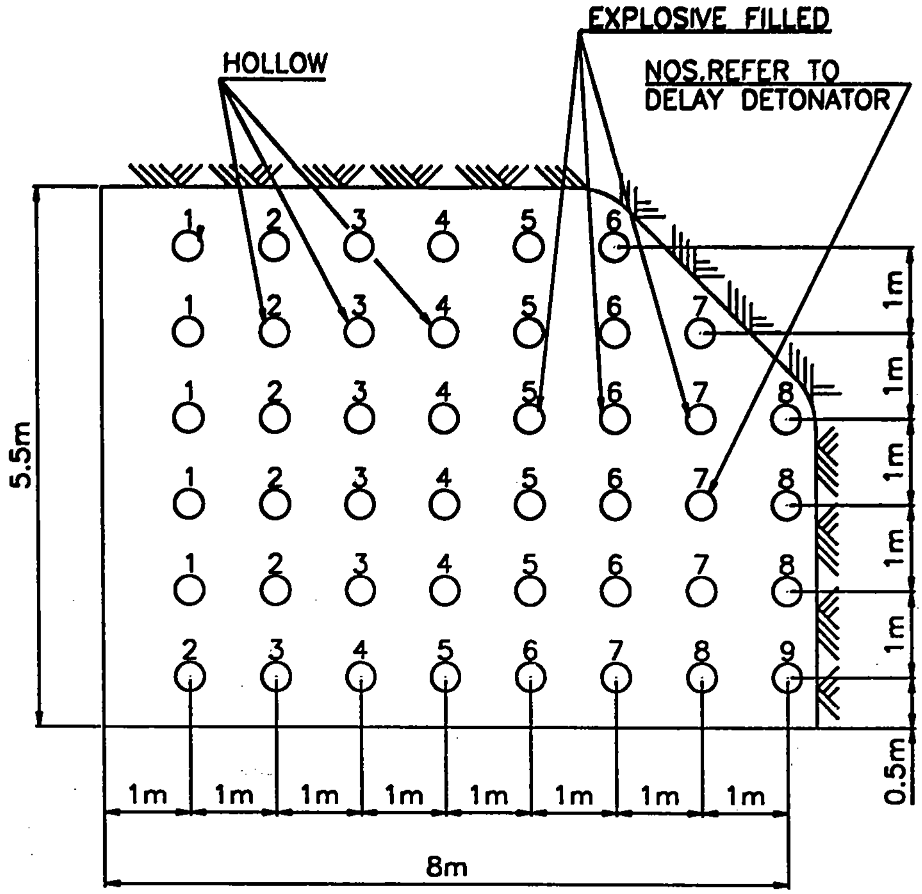


FIG. 18.6. SECTION OF HALF TUNNEL FACE

to the required finished size. The type of cuts commonly used include pyramid cut, drag cut and burn cut depending upon the nature of rock. These are described below:-

a) **Pyramid cut:** A typical arrangement is given in Fig. 18.7. Due to the inclination of the holes, the depth of the cut is generally restricted to half the width of the drift.

b) **Wedge cut:** A typical system is given in Fig. 18.8. The holes are inclined at an angle not less than 45^0 towards the centre and almost meeting at the back of the cut. In large tunnels a double wedge cut is often used i.e. a small wedge followed by a larger one.

Note: Both pyramid and wedge cuts are suitable for uniform bedded hard rocks. Explosives consumption is less than for other types of cut, but the depth of pull is restricted by the width of the drift.

c) **Drag cut:** This is mainly used in small drifts. A typical system is given in Fig. 18.9. Wherever possible holes are inclined to the cleavage so that strata breaks along these planes. 'D' is not more than H/2 & 'h' is not more than H/3, where D is depth of hole, H is height of cut and h is height of bottom most hole from ground level.

d) **Burn cut:** Typical arrangement is given in Fig. 18.10. While it is difficult to drill more than half the width of the tunnel with a, b and c above due to angle of drill hole, with the burn cut, advances equal to width of tunnel can be obtained. Burn cut patterns comprise a number of parallel holes of the same diameter, closely spaced, some of which are heavily charged and the remainder left empty to provide a free face.

18.11.3.1. It is necessary to have a series of charges firing at intervals. This is achieved either by using delay detonators if fired electrically or plastic cord, if fired with safety fuse. Generally special blasting gelatines are best suited for this work. Consumption of gelatine varies from 0.7 - 0.25 kg/cu.m of rock broken depending upon the nature of rock and size of excavation.

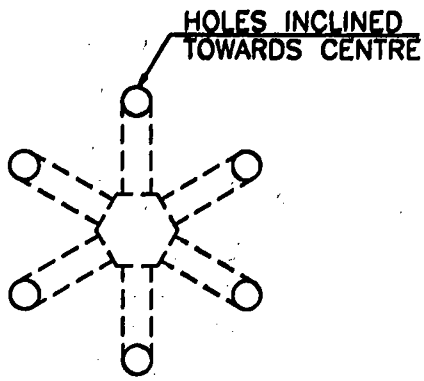


FIG. 18.7. PYRAMID CUT

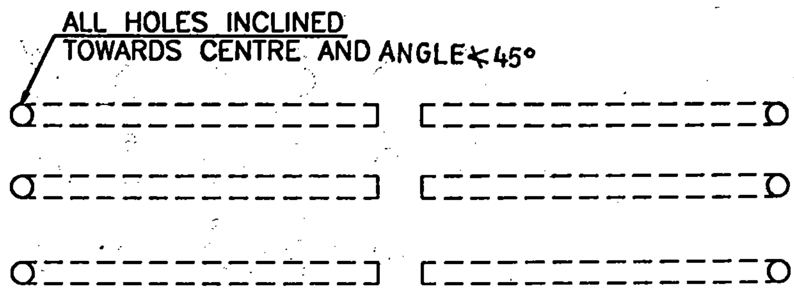
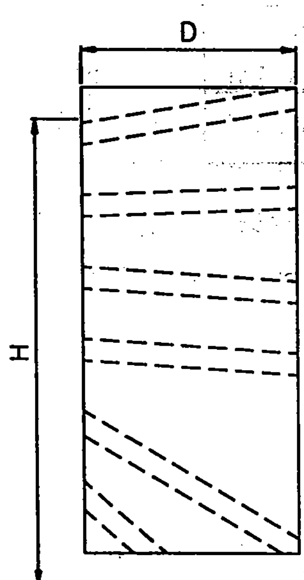
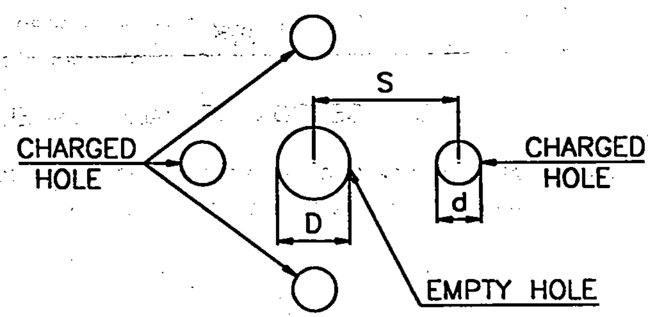


FIG.18.8. WEDGE CUT



D = $\ngtr$H/2
h = $\ngtr$H/3

FIG. 18.9. DRAG CUT



EXAMPLE

D = 60mm
d = 32mm
S = 112mm

FIG. 18.10. BURN CUT

18.11.3.2. To expedite progress on a long stretch of half tunnel or tunnel, approach tunnels may be driven at intermediate points, at right angles to the direction of the centre line of proposed road. This will allow extra tunnel faces to be opened up. Once the faces have advanced away from the tunnel the compressor and other equipment can be stored in the bye-end.

18.11.4. **Excavation of rock foundations:** Excavation of foundations for bridges, piers etc. forms an important part of the road building projects.

18.11.4.1. First a small pit should be formed by blasting and this can be later enlarged and deepened to the desired limits of excavation. Several pairs of inclined holes shoud be drilled in the form of a wedge. These holes should be drilled 0.9 to 1.2 m deep at 75 cm centre to centre and each hole should be charged with two or three 25 mm x 20 cm cartridges of blasting gelatine 80% strength.

18.11.4.2. For excavation in low lying areas and river beds the depth of water normally ranges from 3 to 90 cm. Drilling in shallow water is rather difficult and the holes often get filled up with sand and dirt. The depth of holes, therefore, should not be more than 0.9 m. A number of holes should be drilled 0.9 m deep with 6 m spacings and each hole should be charged with blasting gelatine 80% strength at a ratio of approximately 1.5 cu.m per kg.

18.11.4.3. Detonating fuse may be used for under water blasting and the cartridges should be taped on a thin strip of wood or bamboo. If electric detonators are used then all joints should be properly insulated and kept out of water.

18.11.5. Well-sinking

Since conditions in sinking are normally wet, it is important to use high density, water resistant, gelatinous explosives. The principle in sinking is same as in tunnelling. An initial cavity is created by blasting a ring of holes inclined towards the centre as to form an inverted pyramid. The subsequent ring of 'easers' and 'simper' holes which are succeedingly less inclined than the preceding holes, fire into this cavity. The charge ratio is about 0.45 - 2 kg/cu.m solid rock broken.

18.11.6. Maintenance of roads

Hill roads are sometimes blocked by slips/landslides and also by large boulders sliding down hill. Smaller pieces can be bulldozed away but the large ones often require to be blasted. Both pop shooting and plaster shooting can be applied to break up large boulders.

18.12. Machinery Required for Rock Blasting on Roads

18.12.1. Air compressors of 4 to 6 cu.m/min. capacity are generally used. The accessories required with a compressor are as follows:

a) Jack Hammer - 1 to 3 Nos depending on capacity of the compressors
b) Line lubricator - 1 to 3 Nos
c) Air hose pipe - 100 m
d) Hose pipe couplings - 8 No as required
e) Drill rods (i) 1 m - 6 Nos
f) (ii) - 1.5 m - 6 Nos
g) Grinder for sharpening - 1 No
h) Essential spare parts for jack hammer

18.13. Record of Drilling/Blasting

18.13.1. Record of drilling and blasting may be maintained in the format given in Table 18.3.

Table 18.3. Record of Drilling and Blasting

Date .... Location .... Rock ....

Hole No.	Hole Dia (mm)	Height of Face (m)	Depth of Hole (m)	Burden (m)	Spacing (m)	Volume of Solid Rock per Hole (cu.m)	Charge per Hole (kg)	Charge Ratio	Detonating Fuse (m)	Detonators (Mention type wise) (Nos)	Remarks

18.14. Blasting in Adverse Weather Conditions

18.14.1. Special measures have to be adopted when blasting in unfavourable weather conditions.

18.14.1.1. **In very cold weather:** Low - freezing type explosives can be stored and used upto 0^0C or even at lower temperatures if the exposure is of short duration. Prolonged exposure to lower temperatures may, however, cause the explosives to freeze. On freezing, explosives lose their plasticity and become hard. In frozen state, some types of explosives are very sensitive and liable to premature explosion.

18.14.1.1.1. All types of detonators and detonating fuse remain unaffected by low temperatures. The outer coating of safety fuse will freeze in sub-zero temperature conditions.

18.14.1.1.2. **Precaution to be taken to prevent explosives from freezing:** The following precautions should be taken:-

a) Store all explosives in well constructed magazines until required for use.

b) Stack cases of explosives on wooden trestles clear off the ground.

c) Cover cases of explosives with tarpauline when awaiting use in the field.

d) Use up the contents of the case quickly once it has been opened.

e) Return all unused explosives to a magazine at the end of the day.

f) Explosives should not be left exposed in the open for longer than is absolutely necessary.

g) As a general rule, explosives should be issued from a magazine on a 'first-in first-out' basis.

18.14.1.1.3. **Precautions to be taken with frozen explosives:** The precaution to be taken are:-

a) Frozen explosives should not be used for blasting.

b) Pricker should not be forced into a frozen cartridge of explosive.

c) Attempt to soften a frozen cartridge of explosives by pressing it in the hand or rolling it on the ground should not be resorted to.

d) Attempt to thaw frozen explosives by heating them over an open fire should not be done.

e) Frozen explosives should be thawed by placing them in the sun.

18.14.1.1.4. **Precautions to be taken with frozen safety fuse:** The outer coating of safety fuse is likely to crack if it is stored and uncoiled in very cold weather. Moisture or water may enter through these cracks and affect the black-powder core.

18.14.1.2. **In wet weather:** Blasting gelatine is water resistant and can be kept submerged in water for atleast 24 hours. Ordinary detonators and safety fuse can be used in wet holes provided the crimps have been treated with cap sealing compound.

18.14.1.2.1. Blasting with safety fuse cannot be practised when it is actually raining. Electric shot firing may be carried on provided all the joints have been properly insulated.

18.14.1.2.2. The most suitable method, of course, is to use detonating fuse for blasting in very wet weather. If the holes contain water, a knot should be tied in the fuse in such a way that about 8-10 cm of fuse extend beyond the knot. A cap sealing compound may be required when holes are likely to contain water. The junction between the fuse and detonator should be properly coated with this compound.

18.14.1.3. During thunderstorms: Blasting should be stopped and all men must leave the blasting site, when an electric storm is approaching. An electrical shot firing circuit, if struck by lightening may detonate despite all precautions. Lightening several kms away may produce electrical charges sufficient to fire electric detonatcrs. In case the storm is not severe, then the charges primed with detonating fuse can be initiated by plain detonator and safety fuse.

18.14.1.4. **In foggy weather:** Shot firing should be suspended during dense fog. Due to poor visibility it becomes difficult to ensure that the danger area has been cleared of men and animals.

18.14.1.4.1. In foggy weather it takes a long time for the fumes to clear and workers should not return to the work site until the smoke and fumes have disappeared.

18.14.1.5. **In high wind:** In high wind, as difficulty may be experienced in lighting fuses with ordinary matches, special matches and lighting devices available for this purpose should be used.

18.15. Fly Rocks

18.15.1. Fragments of rock always fly as a result of blasts. These fragments should not be allowed to fly dangerously when blasting near villages or buildings etc. Fly rock can be prevented by placing blasting mats on top of the area being fired. These are heavy large mats in various sizes and can be made from 2 to 4 cm manila rope or old steel wire rope or old rubber tyres etc. These mats catch or arrest the fly rock. Holes should be some what under-charged in order to avoid fly rock. Only two or three shot holes should be fired at a time, with minimum quantity of explosive just to crack/break the rock.

18.16. Misfires

18.16.1. In case the proper method of blasting is used, the occurrence of misfire will be very rare. Occasionally, however, the shot firer may encounter a misfired shot and it is important that he should know how to deal with it. It is a general practice to wait for 30 minutes, when blasting with plain detonators, before returning to blasting site and 5 minutes when using electric detonators or delay detonators.

18.16.2. **Cause of misfires:** These are explained below along with precautions for their prevention:

a) With safety fuse and plain detonators:

Cause	How to prevent
1. Black powder core becoming damp	Store fuse in cool, dry place. Use waterproof fuse in wet holes.
2. Cracking of fuse by uncoiling in very cold weather. Moisture can enter through these cracks.	Warm frozen fuse at 20^{o} to 25^{o} for eight hours before uncoiling.
3. Water entering detonator	Crimp tightly. Use cap sealing compound. Dip the joint in the compound and allow it to dry before making up the primer. Do not use grease for water proofing.
4. Fuse damaged during stemming	Use fine material for stemming and stem gently using a wooden rod.
5. End of fuse may have absorbed moisture	Use freshly cut fuse only.

6. Fuse cut at an angle may double back inside a detonator.	Cut fuse straight across section with a sharp knife.
7. Air gap between detonating compaction and fuse and saw dust or dirt inside detonator.	Remove all saw dust and dirt from detonators. Make sure that the end of the fuse is in close contact with the detonating compaction.
8. Fuse and detonator may have been pulled out of the primer	Fix fuse securely and test by pulling during stemming.
9. Fuse may have come out of detonator	Use a proper crimper. Do not crip with tooth or ordinary pliers.
10. Fuse may not have lighted.	Be sure that each fuse is burning before lighting the next fuse.
11. Damp detonator	Store detonators in a dry place. Do not blow into a detonator to remove sawdust.

b) With Electric Detonators:

1. Detonator damaged, or lead wire corroded due to damp.	Store in a dry, well ventilated place
2. Broken lead wire	Do not pull or jerk lead wires
3. Detonator pulled out of primer	Stem gently
4. Poor connection causes partial misfire in round	Make clean, firm joints and keep them dry.
5. Faulty exploder or faulty operation of exploder	Check exploder regularly and see that it is capable of firing the required number of shots. Keep exploder dry. Use full force when turning the key
6. Insulation scraping off causing short circuit.	Avoid sharp particles in stemming and stem gently
7. Lead wire touching rails, pipes etc. Cause earth leakage and short circuit	Keep wire of blasting circuit away from metal objects
8. Bare joints lying in water or on wet ground	Insulate all joints and keep them above wet ground
9. Wrong wires connected with each other	Make proper series connection and check with ohmmeter
10. Cut off with delay detonators	Place primer cartridge at the back or bottom of the hole when using delay detonators.
11. Faulty cable	Check cable regularly with ohmmeter

18.16.3. **Detecting of misfired shots:** While blasting with safety fuse it is easy to locate the misfired shot by simple visual examination. When firing electrically, however, the procedure described below has to be adopted to find the faulty shot.

18.16.3.1. Where the electric detonators are connected in series, the first step is to divide the circuit at the face in half, connecting one half to the shot firing cable and testing it from the firing point, all men having been withdrawn from blasting site. This procedure will indicate in which half of the circuit, the defect lies. The defective half of the circuit is again halved, the test repeated and the faulty quarter of the circuit discovered. By further repetition of this method, the faulty shot will be finally located. The remaining shots can be fired after taping the leading wires from the defective shot to a suitable marker. A search should be made afterwards for undetonated cartridges and detonator, assuming that the misfired hole has been dislodged during the blast.

18.16.4. **Dealing with misfired shots:** Where a misfire occurs with safety fuse, the exposed fuse should be examined after a lapse of thirty minutes. If a sufficient length of sound fuse is found projecting from the hole, then it should be relighted. Where the fuse has burnt to a point inside the stemmed hole, the procedure given below should be adopted. This procedure will also apply to misfires with electric detonator.

18.16.4.1. **Recovering the charge by removal of stemming:** Attempts should be made to remove the stemming by blowing out with compressed air or flushing out with water. The air blast or water should be introduced through rubber or non-ferrous metal pipe. No tools should be used for digging out stemming since there is the risk of detonation of the charge by friction or shock. After the stemming has been removed, it may be possible to withdraw remaining cartridges in the shot hole.

18.16.4.2. **Displacement of charge by relieving holes:** If it is not possible to fire the charge by inserting a fresh primer, then a relieving hole, not more than 90 cm deep should be drilled parallel to and atleast 45 cm away from the misfired shot. After firing the relieving shot, the debris must be carefully searched and the undetonated cartridges and detonator recovered.

18.16.4.3. **Misfired shot containing detonating fuse:** With charge in large diameter holes primed with detonating fuse, the stemming should be removed to expose a short length of detonating fuse. A primer should then be secured to the fuse and fired. This will most likely detonate the misfired charge. If, however, the fuse cannot be exposed, then relieving holes, not more than 38 mm diameter and 90 cm depth should be drilled and blasted in such a way that the rock is benched away from around the misfire.

18.17. DO'S and DON'Ts with Explosives

18.17.1. In earlier paragraphs detailed notes have been given on the correct method of handling of explosives, accessories and blasting techniques. DO's and DON'Ts on the use of explosives, considering safety is given in Appendix 13.

18.18. Caution

18.18.1. Explosives and accessories are sensitive materials and hence blasting operation has inherent risk and danger unless the entire operation is handled with security and safety as prime factor. Utmost care and caution should be exercised in handling and use of explosives and laid down procedures strictly adhered to.

19. ECOLOGY AND ENVIRONMENT

19.1. General

19.1.1. Development in terms of environment consequent to the realisation that the environment was deteriorating and earth's resources were fast depleting threatening man's survival on earth itself has given rise to serious universal thought on preservation of environment and maintenance of a balanced eco-system.

19.1.2. "Development without destruction" in pursuance of the national priority to create a balance between ecology and development is of utmost importance. While constructing roads for the development and prosperity of the nation, it has to be ensured that the eco-system is not disturbed and a harmonious, balance struck between road development and environment.

19.2. Definitions and Introduction

19.2.1. Environment includes water, air, land and all items forming part of surroundings whereas ecology is the relationship between organisms i.e. human beings, living creatures, plants, micro-organisms, etc. Thus environment will include ecological resources also. Eco-system is the ecological community living together with its physical environment considered as a unit. Disturbance to any of the component factors in a unit environment is likely to upset the ecological balance and lead to destruction. Hence maintenance of ecological balance is of prime concern.

19.2.2. Certain important aspects of environmental degradation that can result in ecological imbalance are given below:-

a) Anything that affects quality of air that we breathe adversely affects general well being of all living creatures, i.e. human, animal and plant life.

b) ozone layer surrounding earth acts as protective filter against harmful rays reaching the earth and any disturbance to this layer tampers with life supporting system and therefore harmful to healthy life.

c) Emission of green house gases i.e. carbon dioxide, nitrous oxide, methane, etc. by human activities and industrialisation leading to destruction of patches of ozone layer and consequent global warming, could destroy crop patterns, cause skin diseases, raise water level in oceans and resultant flooding, etc.

d) Forests are repositories of the earth's bio-diversity and the millions of species that exist in the forests are natural wealth and is greatly responsible for preservation of the Eco-system. The forests have, therefore, to be preserved even if certain of the forest wealth/resources require to be exploited for development and industrialisation.

e) Pollution of water sources and affecting quality and supply of fresh water sources can affect life and health of living organisms including human beings.

f) Climatic changes with disastrous consequences on account of items mentioned above.

g) Rapid industrialisation, population growth, denuding forest cover, creation of habitation in virgin areas, and development projects affecting not only natural resources, but also people and destruction of naturally stable hills, rivers, lakes, and items of art, culture and heritage.

It may be seen from above that any development activity can result in disturbance to the eco-system unless effective measures are taken to ensure that adverse effects are inevitable minimum and adequate mitigation measures are also taken.

19.2.3. In the post-independence period, massive and large development projects were undertaken for development and economic upliftment in all spheres viz. communications including roads, irrigation, flood control, housing, industries etc. These were mostly launched on technical and economic feasibility and on socio-economic considerations. Impact or adverse effect on environment was not a guiding consideration. This obviously had detrimental effect on the eco-system. This issue has received world wide concern and attention since the recent past. The Earth Summit in Rio de Janeiro in Jun., '92, in which India was an active participant and ratification of Global Bio-diversity convention on 29 December, 1993 are indicators of our grave concern in the matter. For developing countries like India, the crucial issue is development for uplifting living standards of the people as against environmental protection. It cannot be denied that environmental problems are due to inadequacy of development and development project itself is a tool for preservation of environment as long as effective protection measures are taken.

19.3. Hill Roads and Environment

19.3.1. All road or highway projects have necessarily to come up on land and hence have an impact on physical and natural resources such as water, air, soil, vegetation, forests, noise levels, etc. as under depending on location of the highway project.

19.3.2. The roads in hilly regions are aligned in forest and mountain areas. In most of these areas survival itself is a fight against nature but the region by themselves are endowed with gifts of nature and environmentally and ecologically fascinating. These areas are treasure houses of flora and fauna, important as tourist and health resorts, pilgrim centers, adventure sports area, habited by under privileged brethren of our land whose advancement and merger into mainstream of national life depends on good road communication. At the same time, these areas are ideal for development schemes also like hydel projects, flood control etc.

19.3.3. The regions are mostly in unstable terrain conditions subject to extremes of climate and are prone to land-slides, flooding, snowfall, snow drifts, glaciers/avalanche activity and so on which have adverse effect on road system. However, the road system is itself an encroachment on surroundings, disturbing natural state, when this is coupled with adverse conditions situation worsens. As a balanced eco-system is essential for survival of all living species it becomes imperative that when hill roads are developed preservation of environment and ecological balance is a part of the project.

19.4. Impact of Highway Projects on Environment

19.4.1. Highway projects have impact on the physical resources such as drainage, surface water quality, air quality, soils and noise levels. Improper cross drainage can cause swamps on either side of the road embankment possibly leading to increased flood water levels. Water quality can be affected during construction and operation of the highway by run-off of wastes. Pollution can occur through accidents causing spills of transported materials. The air quality can be affected by emission during construction from mobile sources such as vehicles involved in construction activities as also from fixed sources such as stationary construction equipments like stone crushers and hot mix plants. During the operation phase, air quality can be affected by vehicular exhaust. Air pollutants of primary concern include suspended particle matter, nitrogen oxides, carbon monoxide, hydrocarbons and lead. Air pollution impact will be more appreciable in urban and industrial areas.

19.4.2. The possible positive and negative impacts (beneficial and adverse/detrimental) to the environment resulting from a proposed highway project in hills are given in Table 19.1.

19.5. Guidelines for Highway Projects on Environmental Issues

19.5.1. The Ministry of Environment and Forests, Government of India have outlined "Environmental Guidelines" for highway projects. The environmental parameters, associated with highway projects are given in Table 19.2.

Table 19.1. Beneficial and Negative Impacts of Hill Road Projects

Beneficial Impact	Adverse Impact
- Socio-economic upliftment of people	- Landslides, erosion and sediment discharge.
- Employment opportunity - Education and health care - Income from Tourists & Taxes - Enhancement of rural development through better transportation facilities - Transporting, processing and marketing agricultural products	- Poor drainage resulting in damage leading to flooding and degradation of water sources. - Formation of new gullies. - Denuding of forest cover - Increase in concentration of run off causing water pollution.
- Opening up new industries and opportunity for new occupation - Approach to quick services and safety	- Clearing of road side vegetation for firewood, grazing, cultivation and ubranisation.
- Improved quality of life	- Increase in traffic litter, noise and dust pollution.
- Better habitat and housing	
- Feeling of security and social equality.	- Air quality affected by vehicle exhaust and spills of toxic and hazardous chemicals from couriers using road for transportation of such materials.
	- Transfer of vector diseases.
	- Disturbance to flora and fauna.
	- Effect on wild life through loss of habitat and encroachment.

Table 19.2. Environmental Parameters for Highway Projects

1.	Surface Water Quality	14.	Industries
2.	Air Quality	15.	Habitat
3.	Seismology/Geology	16.	Resettlement
4.	Hydrology and Drainage	17.	Archeological/Historic Significance sites
5.	Soils	18.	Public/Private Institutions of repute
6.	Erosion (Landslides, snow slides/drift, etc.)	19.	Religious sites/places
7.	Land Quality and Land Use	20.	Architectural sites
8.	Fisheries and Aquaculture	21.	Public health
9.	Forests	22.	Socio-economic aspects
10.	Terrain and Topography	23.	Agriculture and farming
11.	Terrestrial Wild life		
12.	Noise		
13.	Aesthetics		

19.5.2. The guidelines prescribe the following procedure for assessing highway projects environmentally.

a) **Environmental Impact Assessment (EIA)**

This is a procedure for bringing out the potential effects of human activities on environmental systems, identifying positive and negative effects resulting from the construction of projects considering various alternative sites or options and drawing out a list of parameters relevant to the project.

b) **Environmental Impact Statement (EIS)**

The environmental impact assessment is to be followed by Environmental Impact Statement. The basic objective of the EIS is to identify, predict and evaluate the likely impacts of a given activity and then prepare necessary action plans to eliminate or mitigate the adverse impacts as a part of the overall environment management plan. EIS should cover the following:

i. A brief discussion of the project.

ii. Description of the existing environment.

iii. Likely impacts of the proposed project both adverse and beneficial; reversible, short/long term impacts.

iv. Mitigation, protection and enhancement measures.

v. Consideration of alternatives.

vi. Effect of no - change alternative.

These steps are necessary to predict the likely adverse consequence which will result not only in avoidable loss of natural resources but also additional expenditure. To cite an instance, absence of catchment area treatment may lead to loss of fertile top soil, flash floods and reduction of live storage of reservoirs. The adverse consequences result in loss of national assets such as land, water, forests and a vast variety of plants and animals.

c) **Environment Management Plan (EMP)**

The Environment Management Plan is an implementation plan for carrying out mitigation, protection and enhancement measures as are recommended by the EIS. The EMP gives details as to how these measures should be operated, the resources required and the schedule for implementation.

19.6. Mitigation Measures

19.6.1. Keeping in view the importance of environmental aspects, it is imperative that mitigation measures are incorporated at the planning stage itself which may even involve changing the vertical and horizontal alignments. Sufficient information needs to be elicited at the planning stage in regard to environmental characteristics of the project viz. delineation of national parks, recreation areas, land use, details of forest lands, proposals for rehabilitation of displaced persons, compensation for loss of forest areas, details of land fill/embankments, proposals for protection and renewal of forests, balancing of cut and fill and site clearance etc.

19.6.2. Mitigation measures for fixed source emission could include location of all stationary equipment as far away as practicable from the work site to allow dispersion of emitted pollutants and stabilisation of areas prone to dust emission by spreading water. Mitigation measures for noise during construction could include spelling out permissible standards for noise for construction equipment in the contract specifications and restricting the hours of construction at sensitive areas such as schools and hospitals.

19.6.3. Mitigation measures for mobile sources could include performing construction activities during non-peak hours to avoid street closures, use of low emission (diesel) vehicles, setting limits of maximum allowable emission periodic checks for emission control, use of dust covers over the beds of trucks during transportation.

19.6.4. Mitigation measures for unstable hill slopes, landslide - prone areas etc could be appropriate stabilisation measures, protective/control structures and even alternate route selection etc.

19.6.5. Mitigation measures during operation phase could include construction of buffer strips on either side, planting of tree belts, construction of noise barriers, noise insulation of public building such as schools,

hospitals etc, improvement of equipment and vehicle design, rerouting of heavy traffic and changing speed limits.

19.7. Environmental Monitoring

19.7.1. Monitoring of the impacts and measures taken, especially air, noise, water, effectiveness of control measures, etc. is a requirement to ensure that the situation does not deteriorate.

19.8. Management Considerations

19.8.1. While implementing hill road projects certain aspects of construction and maintenance should be kept in mind for implementation as a part of the project covering project proposals, construction techniques, maintenance system, etc. Some important aspects are given as under :-

a) Important points on which attention is required during planning and construction and moniture of hill roads. — Appendix - 14

b) Check list of points about erosion control on the construction of roads in hilly areas. — Appendix - 15

19.9. Requirements of the Ministry of Environment

19.9.1. The Ministry of Environment and Forests notified rules relating to environmental clearance requirements in January, 1992 which envisaged state level clearance upto 5 km length for all roads in the Himalayas or involving forest lands and Central level clearance for lengths beyond 5 km. However, these rules were revised in January, 1993. The revised rules envisage the following given in Table 19.3.

Table 19.3. Guidelines for environmental clearance

	Name of the Project	Clearance at State level
1.	Tarred roads (Bitumen surfaced) in Himalayas and forest land	Upto 5 km length
2.	National Highways	Upto 5 km length
3.	State Highways	
	a) Involving forest land	Upto 5 km length
	b) Not involving forest land	All lengths

Clearance for projects above these threshold levels is to be obtained at the Central Government level. As these policies are subject to change, the latest and the current policy will have to be adopted.

19.10. Legislation on Environmental Issues

19.10.1. To ensure control on use of forest area for development projects and to ensure protection of environment while implementing such projects the following enactments have been done by Govt. of India.

a)	Forest (Conservation) Act	1980 (as amended from time to time)
b)	Forest (Conservation) Rule	1981 (as amended from time to time)
c)	Environment (Protection) Act	1986

The provisions in the above Ordinance/Act (as per current amendments, if any) as well as Rules framed there-under should be kept in view while planning and implementing road projects and making Environmental Impact Assessment. These are very relevant to hill roads due to the terrain and topography of the regions where hill roads are planned.

19.10.2. The Forest (conservation) Rules, 1981 have been amended vide Forest (conservation) Amendment Rules 1992 and the current provision of rule 4 are as under :-

a) Every State Government of other authority seeking the prior approval under section 2 shall send its proposal to the central Government in the form appended to these rules. Provided that all proposals involving clearing of naturally grown trees in forest land or portion thereof for the purpose of using it for reafforestation shall be sent in the form of Working Plan/Management Plan.

2) Every proposal referred to in sub-rule (1) shall be sent to the following address, namely :-

Secretary to the Government of India,
Ministry of Environment and Forests,
Paryavaran Bhavan, C.G.O. Complex, Lodi Road,
New Delhi - 110003

Provided that all proposals involving forest land upto twenty hectares and proposals involving clearing of naturally grown trees in forest land or portion thereof for the purpose of using it for reafforestation shall be sent to the Chief Conservator of Forests/Conservator of Forests of the concerned Regional Office of the Ministry of Environment and Forests.

b) In rule 5 of the said rules for sub rule (1) the following sub-rule shall be substituted. namely :-

1) "The Central Government shall refer every proposal received by it under sub-rule (1) of rule 4 of the committee for its advice thereon if the area of the forest land involved is more than twenty hectares.

Provided that proposals involving clearing of naturally grown trees in forest land or portion thereof for the purpose of using it for reafforestation shall not be referred to the Committee for its advice."

For the annexure appended to the said rules, the form shall be as per format given at Appendix-16.

19.11. Conclusion

19.11.1. As environmental clearance has become an inescapable part of preparation of highway projects, it is essential that all highway engineers are familiar with the requirements of the Ministry of Environment and Forests. The mitigation measures required for environmental management should be well understood and provided for as specific items in the cost estimates. If sufficient and detailed attention is not paid to this, it is quite likely that the clearance of highway projects will get badly delayed affecting development.

20. PREPARATION AND PRESENTATION OF PROJECT DOCUMENTS

20.1. General

20.1.1. The project data collected during the survey, trace cut and investigation together with the proposals worked out on that basis should be presented in proper form for full appreciation by the appropriate authority. This should be divided in three parts under the following headings which when read together will constitute the complete project documents :

a) The Project Report
b) Estimate
c) Drawings

20.1.2. Details to be presented in each part are brought out in subsequent paragraphs for guidance. It should, however, be understood that the extent of detailing an individual aspect would depend upon the size of the concerned project and its scope e.g. whether new construction or improvements to an existing road.

20.1.3. Special features to hill area like Reserved Forests, wild life sanctuaries etc. should also be collected and find a place in the Project Report.

20.2. Project Report

20.2.1. The Project Report is one of the most important parts of the project document and should give a precise account of the different features for easy understanding and appreciation of the proposals. The information provided may be conveniently dealt with under the following heads:

a) Preliminary
b) Road features
c) Road design and specifications
d) Drainage facilities including cross drainage structures
e) Materials, labour and equipment
f) Rates
g) Construction programming
h) Miscellaneous

20.2.2. Preferably the design calculations etc. with regard to the above items should be attached as appendices.

20.2.3. Preliminary

20.2.3.1. This should cover :

a) **Name of the work and its broad scope** : Information here should give a general idea of the scheme as a whole.

b) **Authority and plan provision:** Reference to the order of the competent authority calling for the project and the provision of the work in the relevant development plan, should be given.

c) **History, geography, climate etc** : This should cover the following :

i. Previous history of the road and its present condition (in the case of existing roads) or development history of the project as regards economic activity, population served, available transport facilities etc. (in the case of new roads). Highlight aspects such as susceptibility of the area to floods, waterlogging etc.

ii. **The general topographical and geological features of the area.**

iii. **Rainfall snowfall, and their annual average intensity and distribution during the year, range of temperature during summer and winter months, etc.**

iv. **Maximum intensity of rain/snow in one hour.**

d) **Necessity: Indicate the necessity for the project and the circumstances which have made its execution urgent.**

e) **Method of execution: Discuss technology proposed for construction, whether labour based, machine based or combination.**

20.2.4. Road features

20.2.4.1. Description under this head should inter-alia cover :-

a) Route selection

Considerations governing the route selection and the effect of the proposed route on the overall transportation pattern of the area with respect to other facilities like railways, inland waterways etc. (in the case of new roads) alongwith the merits and demerits of alternative routes investigated and reasons for selecting the proposed route should be brought out.

b) The general alignment of the road and its details, section by section, with reference to topographical and geological features, obligatory points such as bridge sites, important population centres, existing or prospective industrial centres, etc., has to be brought out. It should also discuss points of general importance like high banks, heavy cuttings, nature of gradients, radii of curves, sight distance, nature of soil along the alignment etc.

c) Environmental and Ecological Aspects

The effect on Environment and Ecology due to the proposed road project should be briefly brought out. The subject is covered under Chapter 19 "Ecology and Environment" and the main aspects of Environmental Impact Assessment done for the project should be touched upon. If Environmental clearance from Government has been obtained, the same should be mentioned; if not obtained the present stage and details should be given. If no environmental clearance is required or proposed to be obtained, it should be clearly brought out indicating reasons thereof.

d) Roadland, roadway, carriageway and other cross-sectional elements

The proposals regarding right-of-way, acquisition of structures alongside roadway, carriageway width, etc., should be discussed. In the case of existing roads, the cross-sectional elements with the widths existing may be brought out.

e) Traffic

The type of traffic survey conducted for various sections, the data collected and the likely future growth has to be explained. The design traffic figures, separately for each element of the project, e.g. width of carriageway, pavement intersections, railway crossings etc. should be touched upon. For existing roads, the accident data with special reference to the known accident prone locations may be elaborated.

20.2.5. Road design and specification

a) Road design

This should cover the special features of road design e.g. fixation of grade line vis-a-vis HFL/Water table, high embankments, treatment of cut sections, design of road junctions, removal of geometric deficiencies in the case of existing roads, remedial measures for landslide prone locations etc. Design calculations should be attached where necessary. Any deviations from the prescribed standards should be discussed with reasons for the same.

b) Pavement design

The soil investigation data for pavement design should be presented in a tabular form. The methodology of collecting these data should be discussed and the pavement design proposals with respect to the alternatives considered brought out.

c) **Protective works (other than cross-drainage works)**

The proposals for retaining walls, breast walls, pitching, parapet walls, railing etc. should be brought out and design calculation attached.

d) **Specifications**

Reference to the standard specifications in accordance with which the works are proposed to be executed should be highlighted. Any modifications proposed or special specifications suggested should be brought out.

20.2.6. Drainage facilities including cross-drainage structures

a) The investigations carried out for designing the drainage measures and the salient points in respect of H.F.L., water table, ponded water level, seepage flows etc., should be highlighted.

b) Details of surface/sub-surface drainage measures proposed e.g. longitudinal side drains, catch-water drains, longitudinal/transverse sub-drains, blanket courses etc., be given. Design calculations/drawings as necessary may be attached.

c) Highlight, if any, special measures are proposed to check soil erosion and assist soil conservation. Slide-prone and unstable areas and measures proposed may be discussed.

d) The proposals regarding small cross-drainage structures i.e. culverts and minor bridges (upto 20 mtrs span should be explained. Details of the proposed structures may be given in a tabular form with cross reference to the standard designs adopted or the detailed drawings enclosed. The table should also indicate special features of each structure like design HFL, deck level, waterway, etc supported by waterway calculations.

e) Details of major bridges involved and proposed for bridging should be brought out. If temporary bridges are proposed in the initial construction stage, the estimate should include same. Replacement of temporary bridges by permanent bridges at a later date can be a separate project later.

f) In case of improvements to existing roads, the crossdrainage structures proposed to be improved/widened/reconstructed with details of improvement and justification should be listed out.

g) Wether the structures to be built are proposed as per standard designs should be stated. If so, give reference to the relevant drawings. Otherwise, design calculations and drawings should be attached.

20.2.7. Materials, labour and equipment

a) Materials

The results of the soil and materials survey with reference to various sections of the road, bringing out clearly the sources from which the materials are to be obtained and their suitability for use in the works should be presented. Borrow area charts, quarry charts, approximate likely yield, results of tests on material, etc., may be attached. Facilities for transport of materials, and how these are to be provided should be discussed.

b) Labour

The requirements of labour for the work, whether it is to be imported, skilled labour needed, housing facilities, etc., should be discussed in the report.

c) Equipment

List the total equipment required for the project, the equipment already available with the department and additional equipment required to be procured, etc., should be stated in the report.

20.2.8. Rates

a) Reference to the schedule of Rates adopted and the year of its publications should be mentioned. Whether the Schedule is current or any correction have to be applied has to be indicated.

b) The items for which suitable rates are not available in the Schedule should be based on analysis of rates which should be attached to the estimate.

20.2.9. Construction programming

a) Whether the work is proposed to be executed departmentally or through contract, period proposed for completion of the project and the constraints which might possibly upset this schedule should be mentioned.

b) Construction schedule should be drawn up either in the form of a bar chart or on the basis of Critical Path Method (CPM). For details of the latter, reference may be made to IRC Special Publication 14 "A Manual for the Application of the Critical Path Method for Highway Projects in India".

20.2.10. Miscellaneous

20.2.10.1. Mention about the miscellaneous items of work like the following should be made:

a) Rest houses and temporary work sheds
b) Diversions and haul roads;
c) Arrangements for water supply and other site amenities;
d) Traffic control devices e.g. signs, pavement markings, guard stones, kilometre stones etc.
e) Roadside plantations, turfing, landscaping, wayside amenities etc.
f) Tourist facility items such as parking/scenic laybyes.
g) Environmental protection measures

20.3. Estimate

20.3.1. The Project Estimate should give a clear picture of the financial commitments involved and should be realistic. This is possible only if the items of work are carefully listed, the quantities determined to a reasonable degree of accuracy and the rates provided on a realistic basis.

20.3.2. The estimate should consist of:

a) General abstract of cost

This should give the total cost of the scheme with a general break-up under major heads of items with further sub-divisions as necessary), e.g. land acquisition, site clearance, hill cutting under various types of excavation and filling, sub-bases and bases, bituminous work/cement concrete pavement, cross-drainage and other miscellaneous structures, miscellaneous items, percentage charges for contingencies, work charged establishment, quality control etc.

b) Detailed estimates for each major head:

This should consist of

i) Abstract of cost indicating quantities, rates and amount of each item of work.

ii) Estimate of quantities

iii) Analysis of rates for items not covered by the relevant schedule of rates; and

iv) Quarry/material source charts.

20.3.3. Where a project work is proposed to be executed in stages, the estimate should be prepared for each stage separately.

20.3.4. The matter presented should follow a logical sequence.

20.4. Drawings

20.4.1. General Project drawings should depict the proposed works in relation to the existing features, besides other information necessary for easy and accurate translation of the proposals in the field. For easy understanding and interpretation, it is desirable that the drawings should follow a uniform practice with regard to size, scales and the details to be incorporated.

20.4.2. **Drawing size:** Drawings should be of adequate size to accommodate a reasonable length of the road or a structural unit in full detail. At the same time, these should not be inconveniently large to necessitate several folds. From this angle it is recommended that preferably the size may be 594 mm x 420 mm, corresponding to the size A2 of IS: 696-1960. Drawings of this size could be stitched in a folder with flexible covers so that the folio can be rolled for convenient handling. On one sheet of this size, it will be possible to accommodate the plan and L-section of one km length of the road with sufficient overlap on either side, if drawn to the horizontal scale of 1:2500. A wide margin of 40 mm may be kept on the left hand side of the drawing to facilitate stitching into a folio. Chapter 5 "Survey and Alignment" may be referred regarding map preparation.

20.4.3. **Component parts of highway project drawings:-** The drawings usually required for a road project include the following:-

a) Locality Map-cum-Site plan

This is combination of a key map and index map drawn on a single sheet. This will be the first sheet in folio of drawings for a particular section of the road. However, where the length of a section is substantial, it may become necessary to separate out the locality map and the site plan, the former being accommodated in one sheet and the later on a series of sheets. The locality map (same as key map) should show the location of the road with respect to important towns and industrial centres and the existing means of communication in the neighbourhood so as to give a bird's eye-view of the proposed work. The map may be to a scale of 1:2,50,000 which is one of the common scales used in Survey of India maps. The site plan (same as index map) should show the project road and its immediate neighbourhood covering the important physical features such as hills, rivers, tanks, railway links etc. It may be to a scale of 1:50,000 and should show the kilometrage from the beginning to end.

The sheet containing the locality map-cum-site plan should have a legend to explain the abbreviations and symbols used in subsequent drawing sheets.

b) Land acquisition plan

These should be prepared on existing village maps or settlement maps giving the details of property boundaries and their survey numbers. A scale in the range of 1:2000 to 1:8000 depending on available maps will be suitable. If for any reasons detailed land acquisition plans are not possible then rough plan should be prepared. Inter-alia the plans should show the final centre line of the road, the right-of-way limits, buildings, walls, monuments, trees etc. affected by the road alignment, type of land i.e. irrigated, wet, dry, barren, forest etc., and the nature of crops.

c) Plan and longitudinal section

Plan and longitudinal section for one km length of the road should be shown on a single drawing sheet as far as possible. The plan should be at the top and the longitudinal section at the bottom. Common scale adopted is 1:2500 for the horizontal, and 1:250 for the vertical which may be changed suitably.

The plan, among other things, should show the final centre line of the right-of-way limits, roadway of the existing road where applicable, existing structures, drainage courses, intersecting roads, railway lines, electric and telephone lines/cables, location of cross drainage structures, design details of horizontal curves, bench marks, position of POT, HIPs, location of cross sections, contours, north direction etc. The longitudinal section should show the profiles of the proposed road, the general ground and the existing road where applicable. In addition, it should show details such as the gradients, location and set-out data for vertical curves, super-elevation, details of horizontal alignment, the design HFL, location of drainage crossings and intersecting roads, pavement design features, continuous chainage etc.

The manner of presenting the details on the plan and longitudinal section drawings is illustrated in Plate 8.

d) Detailed cross-sections

The cross-sections should be presented serially along the continuous chainage. These should show the ground levels existing road levels where applicable, and the proposed road levels. The area of cut and/or fill involved should be indicated as also the type and thickness of the different pavement courses. The cross section should extend, preferably on each side of centre line as under:

i)	Straight reaches and easy curves	-	15 m
ii)	Sharp curves	-	25m
iii)	HP bends	-	50 m

e) Drawings for cross drainage structures

In a highway project, a large number of small cross drainage structures will be required. Unless there is a special problem, it should normally be convenient to adopt standard designs for these. If a standard design is not used for any reason, a separate drawing should be prepared for each cross drainage structure. However protective structures on downstream side of culverts to drain outflow of water may vary from culvert to culvert and as such, wherever such provision is required, a separate drawing should be prepared for same. A convenient scale is 1:50. These will include culverts and minor bridges also.

f) **Major bridges**

Drawings for major bridges should be included where feasible. However, it is a normal practice to provide for temporary bridges in the initial stages and frame separate report/estimate for major bridges based on adequate field data and subsoil investigation

g) **Drawings for retaining walls and other structures**

These drawings should clearly show the foundation and structural details as also the materials proposed to be used. The scale chosen should be large enough to show all the details comprehensively.

20.5. Check List

The various items that should be incorporated in a Project Report are shown in the form of a check list in Appendix 17 for guidance. This is intended to serve as a ready reference to ensure that all the items have been included and to give an opportunity to the engineer preparing the project to review his work and to state why some items have been left out.

Appendix-1
(Para 4.2.2.refers)

TRAFFIC CENSUS
FIELD DATA SHEET

DATE AND DAY OF WEEK :- ____________

DIRECTION OF TRAFFIC UP/DOWN FROM ____________ TO ____________

ROAD CLASSIFICATION :- ____________
KILOMETRAGE/MILEAGE:- ____________
ROUTE NO. (IF ANY) :- ____________
DISTRICT ____________ STATE ____________

TYPE OF VEHICLES / HOUR OF COUNT	CARS, JEEPS, VANS THREE WHEELERS ETC.	BUSES	TRUCKS	MOTOR CYCLES AND SCOOTERS	ANIMAL DRAWN VEHICLES **	CYCLES	OTHERS (Specify)	REMARKS, INCLUDING WEATHER CONDITIONS
1	2	3	4	5	6	7	8	9
FROM.....HRS* TO......HRS								
HOURLY TOTAL								
FROM.....HRS* TO.......HRS								
HOURLY TOTAL								
FROM.....HRS* TO.......HRS								
HOURLY TOTAL								
FROM......HRS* TO........HRS								
HOURLY TOTAL								

NOTES:-

1. RECORD TRAFFIC VOLUME IN COLUMNS 2 TO 8 BY MAKING TALLIES IN THE FORM OF VERTICAL STROKES FOR FIRST FOUR VEHICLES AND DRAWING AN OBLIQUE STROKE FOR EVERY 5TH AS SHOWN WITHIN BRACKETS(~~IIII~~).
2. SOME ROADS CARRY APPRECIABLE VOLUME OF OTHER TRAFFIC LIKE CYCLE-RICKSHAWS. RECORD THE VOLUME OF SUCH VEHICLES IN COLUMN 8 AFTER SPECIFYING THE VEHICLE TYPE.

* THE HOUR OF COUNT SHOULD BE ENTERED BEFORE THE START OF ENUMERATION. PM HOURS SHOULD BE RECORDED AFTER ADDING 12 TO THE ACTUAL HOUR, FOR EXAMPLE 2 PM SHOULD BE RECORDED AS 14·00 HRS.

** IF FELT NECESSARY BY HIGHWAY AUTHORITY, THIS COLUMN COULD BE SUB-DIVIDED INTO TWO FOR RECORDING THE VOLUME OF "PNEUMATIC-TYRED" AND "IRON-TYRED" VEHICLES SEPARATELY.

NAME AND SIGNATURE OF ENUMERATOR WITH DATE ____________

NAME AND SIGNATURE OF SUPERVISOR WITH DATE ____________

Appendix-2
(Para 4.2.2. refers)

TRAFFIC CENSUS
DAILY TRAFFIC SUMMARY

FROM ________ HRS. ON* ____________ TO ____________ HRS ON* ____________

DIRECTION OF TRAFFIC:- FROM ________ TO ____________ (UP)

FROM ________ TO ____________ (DOWN)

ROAD CLASSIFICATION :- ____________

KILOMETRAGE/MILEAGE :- ____________

ROUTE NO. (IF ANY) :- ____________

DISTRICT:- ____________ STATE ____________

COUNT HOUR	FAST VEHICLES											SLOW VEHICLES										REMARKS
	CARS, JEEPS, VANS, THREE WHEELERS ETC.		BUSES		TRUCKS		MOTOR CYCLES AND SCOOTERS		TOTAL FAST			ANIMAL DRAWN VEHICLES		CYCLES		OTHERS (SPECIFY)		TOTAL SLOW			
	UP	DOWN	UP	DOWN	UP	DOWN	UP	DOWN	UP	DOWN	TOTAL COL. 10 & 11	UP	DOWN	UP	DOWN	UP	DOWN	UP	DOWN	TOTAL COL. 19 & 20	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
0600 - 0700																					
0700 - 0800																					
0800 - 0900																					
0900 - 1000																					
1000 - 1100																					
1100 - 1200																					
1200 - 1300																					
1300 - 1400																					
1400 - 1500																					
1500 - 1600																					
1600 - 1700																					
1700 - 1800																					
1800 - 1900																					
1900 - 2000																					
2000 - 2100																					
2100 - 2200																					
2200 - 2300																					
2300 - 2400																					
0000 - 0100																					
0100 - 0200																					
0200 - 0300																					
0300 - 0400																					
0400 - 0500																					
0500 - 0600																					
TOTAL																					
TOTAL UP & DOWN PER VEHICLE TYPE																					

* ENTER DATE AND DAY OF WEEK

NAME AND SIGNATURE OF SUPERVISOR WITH DATE

Appendix-3
(Para 5.3.2 refers)

GUIDING PRINCIPLES OF ROUTE SELECTION AND LOCATION APPLICABLE TO HILL ROADS

1. The alignment should be as direct as possible between the obligatory and control points to be linked. A direct highway link results in economy in construction, maintenance and operation.

2. The location should result in minimum interference to agriculture and industry. It should steer clear of obstructions such as cemetries, burning ghats, places of worship, archaeological and historical monuments, and public facilities like hospitals, schools, play grounds etc.

3. Where the proposed location interferes with utility services like overhead transmission lines, water supply lines, etc. decision of changing the highway alignment or shifting the utility services should be based on a study of the relative economics and feasibility.

4. As far as possible, frequent crossing and re-crossing of railway lines, canals, water courses, ridges, etc. should be avoided.

5. The alignment should avoid large scale cutting and filling, and follow the profile of the land as far as possible. Use of tunnels to avoid deep cuts should be considered where feasible and economical. If the road has to be in cutting, the location and the grade line should permit the adoption of half cut and half fill type of cross-section which involves least disturbance to the natural ground subject, however, to considerations of economy and road stability being satisfied.

OBLIGATORY POINTS

6. The obligatory points to be connected from administrative, strategic or other considerations should be ascertained and taken into account while finalising the highway alignment. Similarly, control points like mountain passes, saddles, river crossing, etc., should be kept in view when deciding the alignment.

7. When crossing mountain ranges, the highway should preferably cross the ridges at their lowest elevation. In certain cases it may be more expedient to negotiate high mountain ranges through tunnels. This decision should be taken after considering the relative economics or the strategic requirements.

GRADE AND CURVATURES

8. The route should enable ruling gradient to be attained in most of its length.

9. As far as possible, the alignment should permit adoption of a uniform design speed and easy curvature in the entire length.

10. The route should avoid the introduction of hair-pin bends, as far as possible and their location, particularly in valleys avoided. The bends should be located on stable and flat hill slopes. Also, a series of hair-pin bends on the same face of the hill should be avoided.

11. Needless rise and fall must be avoided where the general purpose of the route is to gain elevation from a lower to a higher point. Also, deep cuts involving destabilisation of natural hill slope should be avoided.

RIVER CROSSING

12. It is preferable that crossings of major rivers (waterway exceeding 60 m) should be at right angles to the river flow with highway alignment subordinated to considerations of the bridge siting. Crossings of medium/minor streams may also sometimes govern the choice of alignment in the case of hill roads due to foundation problems, though their positions will be determined generally by requirements of the highway proper and the crossings could be even skew or on curve if necessary.

13. As far as possible, efforts should be made to locate bridges where:-

(i) The river is straight both on the upstream and downstream side.

(ii) The location is sufficiently away from confluence of tributaries.

(iii) The channel is well-defined and narrow

(iv) The banks are high, rocky/firm and well defined above the HFL.

AREAS TO BE AVOIDED

14. As far as possible, attempt should be to avoid the following areas:-

(i) Unstable hill features and areas having perennial/potential landslide or settlement problems.

(ii) Areas subject to seepage/flow from springs, hydel channels, sub-terranean channels etc.

(iii) Steep hill sides.

(iv) Locations involving unnecessary and expensive destruction of wooded areas.

MISCELLANEOUS

15. Location along a river valley has the inherent advantage of comparatively gentle gradients, proximity of inhibited villages, and easy supply of water for construction purpose. But this solution is beset with disadvantages such as need for a large number of cross-drainage structures and protective works against toe erosion. These pros and cons should be kept in view while making initial selection of the alignment.

16. The location should be such that the highway is fully integrated with the surrounding landscape of the area. It would be desirable to study the environmental impact of the highway and ensure that the adverse effects are kept to the minimum.

17. An alignment likely to receive plenty of sun light should receive preference over the one which will be in shade.

Appendix-4
(Para 5.3.7 refers)

POINTS ON WHICH DATA MAY BE COLLECTED DURING GROUND RECONNAISSANCE

1. Details of route vis-a-vis topography of the area.

2. Length of the road

3. Bridging requirements- number, length.

4. Geometrics:

   (a) Gradients
   (b) Curves, hair-pin bends, etc.

5. Existing means of communication-mule path, jeep track, etc.

6. Right-of way, bringing out constraints on account of built-up area, monuments and other structures.

7. Terrain and soil conditions:

   7.1 Geology of the area.
   7.2 Nature of the soil.
   7.3 Road length passing through:

      (i) mountainous terrain.
      (ii) steep terrain
      (iii) rocky stretches with indication of the length in loose rock stretches.
      (iv) area subject to avalanches and snow drifts
      (v) slip-prone areas.

   7.4 Cliffs and gorges
   7.5 Drainage characteristics of the area including susceptibility to flooding.
   7.6 General elevation of the road indicating maximum and minimum heights negotiated by main ascents and descents.
   7.7 Total number of ascents and descents.
   7.8 Vegetation - extent and type

8. Climatic conditions:

   8.1 Temperature - monthly maximum and minimum readings
   8.2 Rainfall data - average annual, peak intensities, monthly distribution (to the extent available)
   8.3 Snowfall data - average annual, peak intensities, monthly distribution (to the extent available) avalanches etc.
   8.4 Wind direction and velocities

8.5 Fog conditions

8.6 Exposure to sun

8.7 Unusual weather conditions like cloud bursts, etc.

9. Facilities/Resources

9.1 Landing ground

9.2 Dropping zones

9.3 Food stuffs

9.4 Labour - local availability or need for import

9.5 Construction materials (timber, bamboo, sand, stone, shingle, etc.) extent of their availability and leads involved.

10. Value of land - agriculture land, irrigated land, built-up land, forest land, etc.

11. Approximate construction cost.

12. Access points, indicating possibility of induction of equipment.

13. Period required for construction.

14. Strategic considerations.

15. Recreational potential

16. Important villages, towns and marketing centres to be connected.

17. Economic factors:

(i) Population served by the alignment.

(ii) Agricultural and economic potential of the area.

18. Other major developmental projects being taken up in the area e.g. hydro-electric projects

19. Miscellaneous such as camping sites, law and order problems, royalty charges, availability of contractors for collection and carriage of construction materials, working period available for construction work etc.

Appendix-5
(Para 5.3.11(g) refers)

SAMPLE
FORM FOR GROUND RECCE OFFICER
FORTNIGHTLY REPORT

NAME OF ROAD ______________
PERIOD OF REPORT ______________
RECCE OFFICER ______________

SHEET NO. B2 LAP
LENGTH OF STRIP COVERED 2.5 KM

NAME OF THE VILLAGE/ PLACE IF ANY OTHERWISE INDICATE SADDLE OR VALLEY	KILO-METERAGE AND ALTITUDE	TYPE OF SOIL	VEGETATION	X MINOR/ MAJOR BRIDGES/ OBST-ACLES	CROSS SLOPE	GRADIENT	ALTITUDE	XX DETILS OF LOCAL POPULATION	MEANS OF COMMUNICATION	QUARRY SITES	PROBABLE AND EXISTING LG.DZ. HELIPAD AND CAMP SITES	XXX REMARKS
a.	b.	c.	d.	e.	f.	g.	h.	i.	j.	k.	l.	m.
SADDLE	GR-s 17467 2.50 (Alt 1140) M	HARD ROCK	HEAVY JUNGLE WITH BIG TREES		75"-0'	1:25	1:40 JUNCTION OF MULE PATH AND STREAM	NIL	NO TRACK VILLAGE TRACK PASS:200' ABOVE THE ALIGNMENT			2.50 — 1. PEOPLE SUFFER FROM GOITRE 2. MEN & WOMEN LOOK HEALTHY 3. WORKING SEASON SAME AS PER NEFA 4. MOSTLY THE LAND NOT OWNED CULTIVATED LAND IN VILLAGE REQUEST ACQUISITION POSSIBLE RATE RS. 10.5 PER ACRE.
		BOULDER MIXED SOIL	OPEN MIXED JUNGLE		65"-2'	1:30				STONE 2 MILLION CU FT	NIL	2.00
	2.00	ORD SOIL	SHRUB AND BUSHES	60' GR S 701690 20'	20"-40'	1:25						
TURINI RIVER VALLEY	1.0 1.500 (Alt.1001 M)						899' ON KAMLA NADI	GR-S1906.9 VILLAGE JAIANING POPULATION 100 NO LABOUR TUESDAY WEEKLY MARKET	VILLAGE TRACK NEAR BY NOT MULE ABLE		PROBABLE DZ CAMP SITE HELIPAD	1.50
	0.500	SOFT ROCK MINOR LAND SLIDES POSSIBLE	DENSE MIXED JUNGLE		70"-00'	1:35	973' SADDLE	NIL	VILLAGE TRACK PASS 100' BELOW ALIGNMENT	NIL	GOOD STRETCH OF LAND FOR LANDING	1..
SEILING	0.00 GR-S 145630 (Alt 1834 M)	ORD. SOIL	SHRUB AND BUSHES	250' GR S 19593	35"-40'	1:40	550" BRIDGE SITE ON STOM RIVER	GR-S 159645 VILLAGE POAK POPULATION 150:50 LABOUR	VILLAGE TRACK NEAR BY	SAND 1 MILLION CUB.FT	NIL	0.50 0.00

X IN CASE OF MAJOR BRIDGE, FORM OF BRIDGE RECCE REPORT WILL BE FILLED

XX DETAILS OF LOCAL LABOUR, MARKETING CENTRE AND ANY OTHER SUITABLE INFORMATION WHICH WILL HELP IN PLANNING.

XXX HERE THE RECCE OFFICER MUST STATE THE FOLLOWING WHEREVER APPLICABLE

1. PREVALENT DISEASES
2. HOSTILE ACTIVITIES IF ANY
3. CONSTRUCTION EQPT & PLANT CROSSING PLACE
4. WORKING SEASON
5. TYPE OF OWNERSHIP OF LAND
6. RAINFALL AND OTHER METEOROLOGICAL DATA
7. ANIMALS AND BIRDS AVAILABLE
8. TYPE OF TREES
9. TYPE OF FLOWERS.

Appendix-6
(Para 5.3.12 refers)

GENERAL POINTS FOR COMPARISON OF ROUTES

No.	Details	Route No.1	Route No.2	Route No.3	Route No.4	Remarks
(a)	(b)	(c)	(d)	(e)	(f)	(g)
1.	Annual Rainfall Data					
2.	Weather Condition and Period of Working Season					
3.	Length of Strip					
4.	Nature of Soil					
5.	Camp Sites					
6.	Landing Grounds					
7.	Dropping Zones					
8.	Existing Means of Inter Communication					
9.	Right of Way					
10.	Gradients					
11.	Length of Gentle Slopes					
12.	Length of Forests Affected					
13.	Length of Cliffs					
14.	Length of Rocks					
15.	Length of Agriculture Land					
16.	Length of Loose Rocks/Avalanche					
17.	Length of Land Slides					
18.	Length of Unstable Areas					
19.	Length of Heavy Clearing					
20.	Length of Steep Slopes					
21.	Length of Marshy Area					
22.	Availability of Road Construction Materials					
23.	No. and Width of Rivers/Nallahs to be Bridged					
24.	No. of Hairpin Bends					

No.	Details	Route No.1	Route No.2	Route No.3	Route No.4	Remarks
(a)	(b)	(c)	(d)	(e)	(f)	(g)
25.	No. of Villages					
26.	Availability of Labour					
27.	Hostile Activities if any					
28.	Total Length of Bridges					
29.	Important Town and Marketing Centres Connected					
30.	Maximum Altitude Crossed Enroute					
31.	Any Other Information					
32.	Approximate Cost of Construction					
33.	Maintenance Problems if any					

Appendix-7
(Para 5.5.7 refers)

AERIAL SURVEY, PHOTOGRAMMETRY, REMOTE SENSING

AERIAL SURVEY

1. A comprehensive view of the terrain through which the highway is to pass is an essential requirement for the engineers to appreciate and integrate the natural and cultural features of the terrain that influence the geometric design and economic considerations in highway planning. Field methods of route surveying being limited by nature cannot provide this facility in adequate measure particularly in the hilly region. Aerial Survey is therefore the answer to meet such requirements.

2. Topographic maps made from the aerial photographs and the regional photomosaics with stereoscopic prints duly correlated with the ground control stations provide a comprehensive three dimensional view of the natural and cultural environment between the terminal points. During aerial survey the recording by film of segments of land surface is done, which consists of taking individual perspective views (contact prints) overlapping one another by predetermined percentage along the line of survey. Two different views of all the images on the ground obtained thereof can be studied with stereoscopic instruments to observe the three dimensions of length, width and height. The approximate scale of the perspective view obtained is related to the elevation of the camera stations above the grounds and the focal length of the camera in use and may be determined by one of the established formulae in vogue.

3. After aerial recording and production of air photographs the next step in the survey is the air photo interpretations (if aerial photographs are readily available for the area, study can be done straight away). It consists of the following techniques:-

(a) Photo reading
(b) Photo interpretation
(c) Photogrammetry

4. Photo reading is a method to examine stereoscopic aerial photographs by means of a stereoscope to recognize the images portrayed. It is an inference and qualitative technique.

5. Photo interpretation is the technique of obtaining required informations from the photographs and determining their effect upon a particular problem by logic and reasoning. It is also an inference technique but being a specialised art requires broad technical knowledge in several sciences combined with deductive and inductive reasoning ability.

6. Photogrammetry is a science of making vertical and horizontal measurement from photographs and is thus a measuring technique.

7. Photo reading and photo interpretation studies follow the same procedures to secure information. The primary difference between the two is in limitation of background of the person who makes the study.

8. All photo studies should start with the preparation of a mosaic consisting of alternate prints in each photographic flight line. This mosaic is most easily assembled by stapling individual photographs to a fibre board and matching overlap and sidelap areas of adjacent pictures. The mosaic provides a regional view of a large segment of the terrain. This regional view will show changes in natural and cultural features that are significant to the particular study. All rivers and streams can be located and their shape observed.

All transportation systems can be seen and any adjustment in alignment may be indicative of strong topographic differences. On the mosaic the major land forms of valleys, plains and mountains may be distinct. All important features may be marked by the use of blue or orange china marking pencils.

9. The regional mosaic analysis is then followed by a detailed stereoscopic examination using a lens stereoscope and the appropriate airphotos that match in overlap of prints that form the mosaic. The stereoscopic examination is made to determine all factors for the photo reading or photo interpretation analysis. All unidentified features of importance to the study are also marked and access roads are selected so that ground control can be obtained by field reconnaissance. The final step in the procedure is the preparation of a photo map or a line map by use of photogrammetric techniques.

10. Photo interpretation technique, including photo study duly supplemented by photogrammetry can be very effectively adopted in collecting following information of the region.

(a) Cultural features like residential, commercial and industrial buildings, existing roads and railways, land use and habitations pattern etc.

(b) Natural features like rivers, lakes, valleys, plains, mountains, ridges forests etc.

(c) Watersheds for approximate estimation of quantity of storm water that will flow through a culvert at a point in the watershed.

(d) Types and nature of soils and rocks.

11. Aerial surveys with associated photo interpretation technique can thus be profitably adopted during the following stages of Highway Engineering Investigations:-

(a) Reconnaissance Survey
(b) Preliminary Survey
(c) Final location Survey

It can also be used for determining various economical routes of access to construction sites for transporting equipment and materials.

12. Aerial survey is a valuable technique that can be used by the highway design engineers for terrain evaluation. However, many of the features shown on aerial photographs cannot be evaluated by these techniques alone and must be supplemented by well planned field surveys.

PHOTOGRAMMETRY

13. Photogrammetry is the Science or Art of obtaining reliable measurements by means of metric photography. The distinction of the metric photograph over the ordinary photograph is that the former enables the engineer to mathematically and physically recover the effective geometric point of convergence of the rays which formed the photograph.

14. The photogrammetric system may be defined as coordinated chain of instruments and associated methods for procurement, recording, storage, reduction and presentation of metric data based on the photograph. The photogrammetric system consists of following operations:-

(a) Data acquisition operation
(b) Data reduction operation

15. Data Acquisition Operation is concerned with the procurement of raw data/raw information in the form of suitable photograph. The aim of the system is to obtain photographic negatives of the specified object with sufficient accuracy and completeness of data for intended use. The basic instrument of the data acquisition system is the photogrammetric camera. The supporting auxiliary equipment necessary to conduct the data acquisition phase are platform for the camera, exposures point selection devices and laboratory

processing equipment for the film. Platform for camera may be an aircraft or satellite. The function of the camera is to create and record a perspective projection of the object photographed. Two photographs taken of the same object from two different camera positions enables a photographer to achieve spatial intersections of rays for determining a point uniquely in space.

16. Data reduction operation is concerned in coverting the photographic data into final data form as per requirement of the user, for example, reducing the angular data of the aerial photograph in combination with ground control data to produce a topographic map. The basic instrument of the data reduction operation are the stereo plotter and transformation printer. The function of the stereo plotter is to create and measure a three dimensional model of the object photographed.

17. If the final data form is to be digital, stereo comparator may be the basic instrument for data reduction operation. Normally the data processing is done with electronic computer.

18. Achieving good results from photogrammetry depends to a great deal on the skill and experience of the camera operator and stereo plotter and also on the experience of Engineer responsible for designing the system and supervision of operations.

REMOTE SENSING

19. Remote sensing is the modern scientific method of acquiring data or information on natural and cultural features of a terrain of interest from measurements made at a distance without coming in physical contact with the object. It may in fact be described as extended photo interpretation method. Broadly the remote sensing device consists of following components:-

(a) Sensors for acquiring data
(b) Platform for mounting sensors
(c) Arrangement for synthesis of images taken in different wave lengths band
(d) Data Processing Equipment

Two most useful forms of remote sensing are:-

(a) Aerial photographs
(b) Satellite imageries

20. Aerial photographs are used for detailed study of the local areas of interest whereas satellite imageries provide overall view of the region.

21. Some of the sophisticated sensors in use include

(a) Mappers
(b) Side looking airborne radars
(c) Microwave radicometers

Such sensors have high flying aircraft or manned/unmanned satellites or spacecrafts as platform which provide ideal vantage points for observations and recording.

Appendix-8
(Para 5.5.7 refers)

GEOLOGICAL SURVEY AND CONSIDERATIONS

1. Geology is the science to study the composition and arrangements of the elements of the earth's crust. In terms of geologic time and study the earth's crust is not a stable mass but its shape and configuration have constantly undergone changes not only because of erosive actions of climate, wind, water, ice and snow but also because of major tectonic movements caused due to internal stresses and strains, Mountains and valleys have thus been formed. Further the intense sub-terranean heat has modified and changed the condition of many of the constituent materials. Consequently the rock formations of the earth are folded, tilted, cracked and displaced. The survey and study of these structural features are of considerable significance to the highway engineer and must be understood to facilitate intelligent interpretation of surface and subsurface conditions of planning, designing and construction of the highway and its structural components, particularly in the hilly regions.

2. A detailed study of geological, pedological and geomorphological maps, as required and aerial photographs, if available, showing physiographic features of the terrain under investigation has to be made by the engineers who verify the suitability of the region for highway construction. The information gathered from such study have to be supplemented with further information collected during field survey. The following structural features and subsurface condition of the area of interest need detailed investigation during the field survey :-

(a) Types of rocks and soils and land form in the area of interest
(b) Hardness of rock
(c) Dip and strike of the rock
(d) Folding or bending of rock
(e) Joints or fracture of the rock
(f) Faulting of fracture zone of the rock

3. It is advantageous to associate a geologist or geotechnical engineer with the study and field survey to assist the highway engineer in the scientific evaluation of the terrain and selecting the best possible and stable road alignment free from following geological hazards to the possible extent :-

(a) Vertical and horizontal movement of the land mass that cause land slides.

(b) Cracks, fissures and weak planes in the rock that activate and trigger slides and avalanches.

(c) Sources of water seepage which disturb stability of hill slopes.

4. Apart from helping in selection of stable alignment , geological survey assists the highway engineer in locating

(a) Safe camp sites for the workers

(b) Appropriate quarries for stone and sand for the construction work

(c) Perennial water sources both for human consumption and construction purposes.

Appendix-9
(Para 13.1.4 refers)

AVERAGE OUTPUT NORMS OF LABOUR

Sl. No.	Item of work	Output	
1.	Excavation in mixed soil	$2.27m^3$	per labour per day
2.	Excavation in soft rock	$1.06m^3$	per labour per day
3.	Excavation in hard rock by blasting	$1.87m^3$	per labour per day
4.	Collection of quarry stone	$2.24m^3$	per labour per day
5.	Collection of shingle	$1.13m^3$	per labour per day
6.	Hand breaking of stone to 50 mm size	$0.42m^3$	per labour per day
7.	Hand breaking of stone to 40 mm size	$0.364m^3$	per labour per day
8.	Hand breaking of stone to 20 mm size	$0.196m^3$	per labour per day
9.	22 cm soling or GSB hand packed, watered etc.	$6.10m^2$	per labour per day
10.	15 cm soling or GSB hand packed watered etc.	$7.70m^2$	per labour per day
11.	WBM 11 cm spread, rolled, blinded etc.	$10.30m^2$	per labour per day
12.	WBM 7.5 cm spread, rolled blinded etc.	$15.40m^2$	per labour per day
13.	Laying 2.5 cm premix carpet	$7.00m^2$	per labour per day
14.	Laying 2 cm premix carpet	$7.70m^2$	per labour per day
15.	One coat surface dressing	$15m^2$	per labour per day
16.	Two coat surface dressing	$10m^2$	per labour per day
17.	RR masonry dry wall	$0.92m^3$/mason with 1.8 labour days	
18.	RR masonry in cement mortar	$0.92m^3$/mason with 2 labour	
19.	Back filling of retaining/breast wall	$1.89m^3$/labour	
20.	1.2 cm plaster in cm (1:6)	$10.52m^2$/mason with 3/4 labour day	
21.	2.5 cm plaster in cm (1:6)	$6.6m^2$/mason with 2/3 labour day	
22.	Ruled pointing on stone work with cm (1:3)	$11.52m^2$/mason with 3/4 labour day	

Sl. No.	Item of work	Output
23.	Edging with rubble stone 15x20 cm	27m/mason with 2 labour days
24.	RCC (1:2:4) or (1:3:6) in slabs mixed in concrete mixer but excluding centering and shuttering	$7m^3$/day with 17.5 labour and 1/2 concrete mixer day
25.	Bending, placing and binding MS bars upto 12 mm dia	91 kg/Blacksmith with 1 labour/day
26.	Bending, placing and binding MS bars beyond 12 mm dia	137 kg/Blacksmith with 1 labour/day
27.	Cutting, placing and binding TOR steel rods including providing hooks etc.	500 kg/Blacksmith with 7.5 labour/day
28.	Centering and shuttering including strutting and propping	$5.3m^3$/Carpenter with 1.1 labour/day

Appendix-10
(Para 13.1.4 refers)

AVERAGE OUTPUT NORMS OF MACHINES

Sl. No.	Item of work	Output
1.	Excavation in mixed soil	$43.28m^3$/dozer II/hour (dozer II 80-100 HP)
2.	Excavation in soft rock	$28.32m^3$/dozer II/hour (dozer II 80-100 HP)
3.	Excavation in hard rock by blasting	$28.32m^3$/dozer II/hour (dozer II 80-100 HP)
4.	Drilling in hard rock with compressor 6-7 m^3/min with 2 jack hammers	3m/compressor/day
5.	Crushing stone metal 50 mm size graded down to 12 mm	$4.25m^3$/crusher/hour or $34m^3$/crusher day
6.	Crushing stone metal 40 mm size	$3.25m^3$/crusher/hour or $26m^3$/crusher/day
7.	Crushing stone metal 20 mm size	$2.13m^3$/crusher/hour or $17m^3$/crusher/day
8.	Compaction of subgrade	$231.25m^2$/road roller/hour or $1850m^2$/road roller/day
9.	Compaction of 22 cm sub-base	$65m^2$/road roller/hour or $520m^2$/road roller/day
10.	Compaction of 15 cm sub-base	$100m^2$/road roller/hour or $800m^2$/road roller/day
11.	Compaction of 10 cm WBM	$31m^2$/road roller/hour or $248m^2$/road roller/day
12.	Compaction of 7.5 cm WBM	$46.5m^2$/road roller/hour or $372m^2$/road roller/day
13.	One coat surface dressing	$96.75m^2$/road roller/hour or $774m^2$/road roller/day
14.	Two coat surface dressing	$69.75m^2$/road roller/hour or $558m^2$/road roller/day
15.	Rolling of 2.5 cm premix carpet including sand seal coat	$75m^2$/road roller/hour or $600m^2$/road roller/day
16.	Rolling of 2 cm premix carpet including sand seal coat	$93m^2$/road roller/hour or $744m^2$/road roller/day
17.	Carrying capacity of vehicle for stone chips and sand upto 4 km lead	7 trips/veh/day ($2.25m^3$/trip)
18.	Carrying capacity of boulder/stone/ ballast upto 4 km lead	8 trip/veh/day ($2.25m^3$/trip)

SURFACE HISTORY OF ROAD

APPENDIX-11
(PARA14:5.1.4 REFERS)

NAME OF ROAD ----------- km 1/0 TO 20/0
KILOMETERS ------------- ORIGINAL CONSTRUCTION

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	REMARKS
1970-71																						20mm
1971-72																						150mm
1972-73																						150mm
1973-74																						
1974-75																						OVERLAY
1975-76																						EARTH ON DRAIN
1976-77			(K)																			
1977-78																						
1978-79																						
1979-80																						
1980-81																						
1981-82																						
1982-83																						

THIS INFORMATION CAN BE PICKED UP FROM THE ROAD REGISTER

PREMIX BITUMEN CARPET

G.S.B. SUB-BASE

W.B.M.

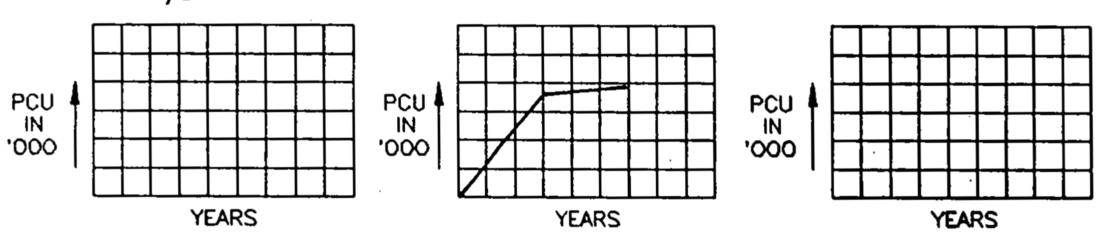
RENEWALS

1975																						
1976																						
1977																						
1978																						BM
1979																						
1980																						
1981																						
1982																						
1983																						

BITUMINOUS MACADAM

DRAINS (KUTCHA)
(PUCCA)

TRAFFIC/DAILY



STATION --------- km   10 --------- kms   --------- km

SURFACE DRESSING

Appendix - 12
(Para 14.5.2.2. and 14.6.1 refers)

Check list of points to be examined during inspection for Maintenance of Hill Roads (at level of Assistant Engineers/Junior Engineers/Supervisors)

1. Safety aspects

   a) Safety precautions at slides/slips, breaches, blockades
   b) Deep cuts on road
   c) Damaged culverts/bridges
   d) Horizontal and vertical clearance of power lines crossing the road.
   e) Branches of trees with low height obstructing vertical clearance

2. Land-slide/unstable areas

   a) Behaviour of the slide whether dormant, active or unstable areas likely to become active, any movements observed
   b) Effectiveness of control measures already done
   c) Functioning of drainage arrangement
   d) Condition of protective/control structures and their effectiveness

3. Snow-fall/damages

   a) Advance action required for snow clearance
   b) Condition of snow/avalanche control structures-repairs required
   c) Additional control measures required
   d) Snow fall pattern

4. Road profile and section

   a) Condition of slopes on hill and valley side
   b) Requirement of retaining/protective structures to retain/correct slope
   c) Easing of slopes required

5. Carriageway and crust conditions

   a) Magnitude and location of potholes
   b) Condition of edges
   c) Magnitude and location of undulations
   d) Location of crust failures alongwith their causes
   e) Condition of camber/cross-fall/super elevation, whether affected by subsidence, etc.

6. Shoulders (Berms) and Embankment

   a) Width of berm adequate as per specification or not
   b) Cross slope of berms - check if correct.
   c) Check if slide-slopes are intact and not eroded.
   d) Berms are properly dressed or not
   e) Turfing, if exists, is it properly cut and maintained.

7. Drainage (Side, Catch Water, etc.)

   a) Cross sectional area adequate or not
   b) Blockage/damage to drains
   c) Flow in drain and disposal of discharge
   d) Bed slopes, lining etc - are they in good order or to be rectified

8. **Culverts/scuppers/minor bridges**

   a) Damages, if any
   b) Free flowing or is there any blockage
   c) Silting of catch-pits
   d) Damages to head walls, parapets, etc., if any

9. Protection works (Retaining walls, breast walls, parapets, aprons, etc.)

   a) General condition
   b) Any damages/cracks
   c) Weep-holes - effective functioning
   d) Apron, revetment, pitching - properly maintained or not.

10. Road furniture

   a) KM stones, boundary stones exists in proper condition.
   b) Traffic sign correctly located and maintained.
   c) Painting and numbering of culverts, bridges and structures.

11. Roadside arboriculture

   a) Check if numbering of trees is done or not
   b) Disposal of dead trees
   c) Register of trees maintained
   d) Planting of new trees being done or not as required
   e) Location & condition of drums/parapet wall/guardstones on curves.

12. Road Geometrics

   a. Sight distance and obstructions, if any
   b. Improvements required in horizontal curves, like layout, extra width etc.
   c. Vertical Curves - Check visibility and obstruction, if any
   d. Passing places - are they in good shape and being used as expected - is its location correct.

13. Roadside Material:

   Whether aggregates, bitumen, required for maintenance are available at sites located at regular intervals and are stacked properly.

14. Encroachment:

   Encroachments, if any to be checked and action for their removal.

Appendix - 13
(Para 18.17.1 refers)

DO's & DON'Ts on the Use of Explosives

a) General

	i.	Don't	smoke or have matches, naked light, etc. while storing, transporting, or using explosives.
2.2	ii.	Do	store explosives in dry, clean and well ventilated magazines.
2.4	iii.	Don't	keep explosives and detonators in the same box or the same magazine. Separate persons should carry explosives and detonators while transporting these to the blasting site.

b) While Using

2.8	i.	Don't	use tools made of iron or steel for opening cases. Use hard wood or brass implements.
2.10	ii.	Don't	leave explosives lying in the hot sun.
3.3	iii.	Do	replace the cover of the case after the required quantity has been taken out.
3.4	iv.	Don't	carry explosives in your pockets.
3.5	v.	Don't	make up primers near large stacks of explosives
3.6	vi.	Don't	insert anything but a fuse inside a detonator
3.1	vii.	Don't	handle or be near explosives during an electric storm. All persons should retire to a place of safety.
3.10	viii.	Don't	use damaged or deteriorated explosives and accessories.
3.7	ix.	Don't	break explosives cartridge

c) While Drilling and Charging

	i.	Don't	start drilling until you have made sure that the rock face contains no unfired explosives. Never drill into explosives
	ii	Do	check condition of shot hole with stemming rod before inserting detonating fuse.
	iii.	Don't	force detonating fuse into a hole.
	iv.	Don't	keep large unwanted stocks of explosive near the shot holes
	v.	Do	cut detonating fuse from the reel immediately after the primer has reached the bottom of the hole.
3.9	vi	Don't	try to soften cartridge or hardened explosive by hitting or by rolling on the ground.

d) While Stemming

	i.	Don't	use metallic rods for stemming. Use only wooden rods. The end of the rod should be kept square by sawing off the pointed end periodically.
	ii.	Don't	apply pressure directly on the primer cartridge. Always put a few cm of stemming after the primer is in position inside the hole.
	iii.	Don't	use sharp particles in the stemming
	iv.	Don't	damage fuse, lead wires or detonating fuse while stemming.

e) While Firing with Safety Fuse

	i.	Don't	use short fuse. The minimum length should be 1.2 m and make sure you have time to reach a place of safety before the explosive detonates.
	ii.	Do	use only approved crimpers for securing detonators on to fuse.
	iii.	Do	use fuse lighters. If matches have to be used slit the end of fuse, hold the match head in the slit and rub the side of an empty match box against the match-head.
	iv.	Don't	use explosive cartridges for lightening fuse. It is extremely dangerous.

f) While Firing Electrically

i.	Don't	use electric detonators during dust storms or near any other source of large static charges.
ii.	Do	keep the firing circuit insulated from the ground, bare wires, rails, pipes or any other paths of stray currents.
iii.	Do	test the firing circuit with an Ohmmeter or circuit tester from the firing points.
iv	Do	make sure that all joints are firm, clean and dry.
v.	Do	keep lead wires short-circuited until ready for firing.

g) Before and After Firing

i.	Don't	fire until you have made sure that all surplus explosives have been removed and all persons, vehicles and equipment are at a safe distance.
ii.	Don't	return to the blasting site soon after misfire. Wait five minutes when firing electrically or wait 30 minutes if firing with safety fuse.
iii.	Do	handle misfires with care.

Appendix 14
(Para 19.8.1 refers)

IMPORTANT POINTS ON WHICH ATTENTION IS REQUIRED DURING PLANNING, CONSTRUCTION AND MAINTENANCE OF HILL ROADS

1. Any road construction activity in the Hilly region should be based on a Master Plan of the district and should be integrated with existing roads as far as possible.

2. It may not be possible to give road connections to all villages. The concept of giving connection to a cluster of villages though an all-weather motorable road is more practicable. The other villages could be connected to the roadhead through bridle paths, bridle bridges, foot tracks or light vehicle roads as feasible.

3. All road construction activities should be coordinated through a single agency both at the central and the state level.

4. Roads to be constructed by all agencies should generally conform to the design standards and specification laid down by IRC for similar category of roads.

5. Adequate attention must be paid while selecting road alignment, that landslide/erosion prone areas are avoided as far as possible. While selecting the road alignment the advice of geotechnical engineers and geologists, forest and soil conservation experts should be taken right from the start.

6. During the process of road construction, cut and fill method should be resorted to in order to cause minimum disturbance.

7. Heavy rock blasting should be avoided and controlled blasting should be resorted to by using a low explosive charge. Blasting should be adequately supervised by technical personnel. Selection of blasting holes should be so done as to avoid large scale disturbance to the rock face, developing cleavage planes/cracks and opening up fissures etc.

8. Spoil from cut/blasted rock should not be thrown haphazardly along the valley slopes as these are likely to cause heavy siltation/chokage of water channels/streams and damage agricultural lands. These should be preserved by stocking at selected location along roadside for future use.

9. Cut slopes should be rendered stable in the construction stage itself by cutting at the correct angle and benching etc. including slope stabilising structures like drains, breast walls, pitching etc. Wherever considered appropriate on the basis of a technical study conducted for the purpose, funds should be provided in the project estimates for the treatment of the unstable areas both above road level and below road formation. Steps should be taken to stabilise the existing roads within a fixed time frame.

10. All cut/denuded slopes should be treated with vegetative turfing.

11. Deforestation during the construction of road should be kept to the minimum and should be done only in consultation with Forest Authorities. Any cutting of trees must be replaced by planting 3 to 4 times the number so that atleast an equal number survives.

12. Drainage of water from roadside should be given adequate attention and an effective system of drainage should be constructed to lead the run-off to natural water courses. In particular, suitable intercepting and catch water drains should be provided above the cut slopes for the speedy and safe disposal of water. It should be ensured that water is not drained into villages

and cultivated land. Location of cross drains and culverts should be so chosen as to avoid erosion of the outlet. Adequate erosion control works like drop walls, apron etc. at out-fall points alongwith pitching/paving of the channel should be undertaken.

13. To minimise the adverse effects of cattle grazing proper check should be exercised and the concept of rotational grazing should be implemented. 'Jhoom' cultivation, impounding water very near and above the hill roads for terraced paddy cultivation and fish rearing must be avoided.

14. The use of horizontal drains represents the most promising method of correcting flow types of landslides. Efforts should be made to instal horizontal drains at selected locations with a view to gaining first-hand experience of their functioning and in order to develop their use.

15. The main approach to the control of rock-fall should be to contain the rock-fall or to deflect the falling rock away from the road pavement and towards the cliff.

16. To the extent feasible, roads should be aligned away from streams and torrents except where these are to be crossed. Since the greatest damage always occurs along water courses, special attention is necessary to create protection belts of forests on both sides.

17. Excavated material should not be thrown haphazardly but dumped duly dressed in a suitable form at suitable places where it cannot get easily washed away by rain and such spoil deposits may be duly turfed or provided some vegetative cover towards the same purpose.

18. Strip forests with suitable site conditions for minimum distance of 30 m on either side of the road should be provided. These should be raised and maintained by forest authorities. No felling except of dead or dying trees should be permitted in this area.

19. A mountainous road, when located along a river valley, has the inherent advantage of gentle gradients, proximity to in-habited village, and general convenience of construction and operation of the facility. However, this solution has the disadvantage of larger outlay on cross drainage and protective works as well as problem of erosion. All these factors should be carefully considered before making final selection.

20. The alignment should involve least number of hairpin bends. Where unavoidable, these should be located on stable and less steep slopes.

21. While locating roads in high mountain ranges, it may be expedient and economical in some cases to construct tunnels to shorten the length of the alignment.

22. As far as possible, mountain ridges should be crossed at their lower elevation.

23. In hilly country, a location subject to sunlight should get preference over a location in the shade. In snowfall area roads should run, as far as possible on southern face of hill to get sun light for maximum period in winter.

24. Areas liable to snow drift should be avoided.

25. Prompt removal of debris blocking the road because of landslides or other reasons.

26. Eroded areas should be promptly made up and provided with vegetative cover.

27. Drains, catch pits etc, should be cleared of all debris and repaired where necessary before the onset of the rainy season.

Appendix-15
(Para 19.8.1 refers)

CHECK LIST OF POINTS ABOUT EROSION CONTROL ON THE CONSTRUCTION OF ROADS IN HILLY AREAS

(Refer IRC: 104, Appendix 2)

1. Does the road construction project estimate provide for the necessary measures against soil erosion.

2. Have soil maps and aerial photographs studies and investigations been made to locate areas or sections with high erosion potential.

3. Has erosion potential been considered for each alignment.

4. Have geological maps been studied or local geological department consulted to avoid unstable strata.

5. Does the selected alignment follow the lie of the land and avoid large scale cutting.

6. Has use of tunnels to avoid deep cuts been investigated.

7. Is the road alignment suspect to damage/erosion by streams and torrents.

8. Is consultation/coordination with other departments like forest department necessary. If so, have they been consulted.

9. How will adjacent and nearby streams, ponds and lakes be affected by project construction.

10. Does the road cross section involve a lot of disturbance to the natural ground.

11. Are the design cut slopes stable for the type of strata.

12. Are slope stabilising structures like breast walls, pitching etc. required.

13. Does the cut hill face require any special treatment to prevent slips.

14. Has the area for clearing and grubbing been clearly demarcated.

15. Has a work schedule been worked out for the different construction operations.

16. What erosion control works are required before clearing and other works are started.

17. Are any temporary erosion control measures required between successive construction stages.

18. Have sediment traps, benches, catch water drains, side drains, ditch paving, slope protection works and other erosion control items been identified on the plans and provided in the proposals.

19. Have the location and alignment of culverts been fixed with due consideration to erosion at outlets and siltation at inlets.

20. Have the necessary erosion control measures been taken at the out falls of culverts.

21. Has the proper disposal of surplus excavated material been thought of and provided for.

22. What action has been taken to establish vegetative cover to cut/fill sloes and plantings on the disturbed roadside land.

23. Are the existing drainage facilities maintained in good order.

24. Do any of the design measures require modification in the light of field conditions.

Appendix 16
(Para 19.10. 2 refers)

FORM FOR SEEKING PRIOR APPROVAL UNDER SECTION 2 OF THE PROPOSALS BY THE STATE GOVERNMENTS AND OTHER AUTHORITIES

(see rule 4)

1. **Project details :-**

   (i) Short narrative of the proposal and project/scheme for which the forest land is required.

   (ii) Map showing the required forest area, boundary of adjoining forest and item wise break-up of the required forest area for different purposes (to be authenticated by an officer not below the rank of Deputy Conservator of Forests)...............................

   (iii) Total Cost of the project. ....

   (iv) Justification for locating the project in the forest area giving alternatives examined and reasons for their rejection ....

   (v) Financial and social benefits........................

   (vi) Total population benefitted..........................

   (vii) Employment generated ....

2. **Location of the project/scheme :-**

   (i) State/Union Territory ....
   (ii) District.......................
   (iii) Forest Division, Forest Block, Compartment, etc..........................

3. **Item-wise break-up of the total land required for the project/scheme alongwith its existing land use.......**

4. **Details of forest land involved :-**

   (i) Legal status of the forest (namely, reserve, protected/unclassed, etc.)................................

   (ii) Details of flora and fauna existing in the area ....

   (iii) Density of vegetation ....

   (iv) Species-wise and diameter class-wise abstract of trees ....

   (v) Vulnerability of the forest area to erosion. Whether it forms a part of seriously eroded area or not.....................

   (vi) Whether it forms a part of National Park, Wildlife Sanctuary, Nature Reserve, Biosphere Reserve, etc; and if so, details of the area involved. (Specific comments of the chief wildlife warden to be annexed)......................

(vii) Item-wise break-up of the forest land required for the project/scheme for different purposes............................

(viii) Rare/endangered species of flora and fauna found in the area ....

(ix) Whether it is a habitat for migrating fauna or forms a breeding ground for them ....

(x) Any other significance of the area relevant to the proposal ....

5. **Details of displacement of people due to the project :-**

(i) Total number of families involved in displacement ....

(ii) Number of scheduled caste/scheduled tribes families involved in displacement ....

(iii) Detailed rehabilitation plan ....

6. **Details of compensatory afforestation scheme :-**

(i) Details of non-forest area/degraded forest area identified for compensatory afforestation, its distance from adjoining forests, number of patches, size of each patch ....

(ii) Map showing non-forest/degraded forest area identified for compensatory afforestation and adjoining forest boundaries ....

(iii) Detailed compensatory afforestation scheme including species to be planted, implementing agency, time schedule, cost structure, etc...........

(iv) Total financial outlay for compensatory afforestation scheme ....

(v) Certificates from competent authority regarding suitability of area identified for compensatory afforestation for afforestation and from management point of view. (To be signed by an officer not below the rank of Deputy Conservator of Forests) ....

(vi) Certificate from the Chief Secretary regarding non-availability of the non-forest land for compensatory afforestation (if applicable) ....

7. **Details regarding transmission lines (only for 'transmission line' proposals):-**

(i) Total length of the transmission line ....

(ii) Length passing through forest area ....

(iii) Right of way ....

(iv) Number of towers to be erected ....

(v) Number of towers to be erected in forest area ....

(vi) Height of transmission towers ....

8. **Details of irrigation/hydel projects (only for irrigation/hydel projects):-**

(i) Total catchment area ....

(ii) Total command area ....

(iii) Full reservoir Level ....

(iv) High flood level ....

(v) Minimum drawal level ....

(vi) Break-up of area falling in catchment area of the project (forest land, cultivated land, pasture land, human cultivation and others)......................

(vii) Area of submergence at high flood level ....

(viii) Area of submergence at full reservoir level ....

(ix) Area of submergence 2 meter below full reservoir level.......................

(x) Area of submergence at 4 meter below full reservoir level (for medium and major projects only)

(xi) Area of submergence at minimum drawal level ....

(xii) Detailed catchment area treatment plan ....

(xiii) Total financial outlay and details regarding availability of funds for catchment area treatment plan ....

9. **Details regarding road/railway line (only for roads/railway lines proposals)**

(i) Length and width of the strip ....
required and forest area required...........

(ii) Total length of the road ....

(iii) Length of the road already constructed ....

(iv) Length of the road passing through the forest ....

10. **Details regarding mining proposals (only for mining proposals):-**

(i) Total mining lease area and forest area required ....

(ii) Period of mining lease proposed ....

(iii) Estimated reserve of each mineral/ore in the forest area and in the non-forest area..........................

(iv) Annual estimated production of mineral/ore ....

(v) **Nature of mining operations (open cast/underground)............................**

(vi) **Phased reclamation plan ....**

(vii) **Gradient of the area where mining would be undertaken ....**

(viii) Copy of the lease deed (to be attached only for renewal purposes).........................

(ix) Number of labourers to be employed................

(x) Area of forest land required for ....

(a) Mining.......................

(b) Storing mineral/ore......................

(c) Dumping of overburden...................

(d) Storing tools and machinery..................

(e) Construction of building, power stations, workshops, etc...................

(f) Township/housing colony...................

(g) Construction of road/ropeway/railway lines............

(h) Full land use plan of forest area required...................

(xi) Reasons why any of the activities referred to in (a) to (h) above under the project for which forest land has been asked for cannot be undertaken/located outside forest area.............

(xii) The extent of damage likely to be caused and the number of trees affected on account of mining and related activities ....

(xiii) Distance of the mining area from perennial water courses, national and state highways, national parks, sanctuaries and biosphere reserves ....

(xiv) Procedure for stocking of the top soil for reuse ....

(xv) Extent of subsistence expected in underground mining operations and its impact on water, forest and other vegetation ....

11. Cost benefit analysis.........................

12. Whether clearance from environmental angle is required (Yes/No)......................

If, yes. whether, requisite details for the same have been furnished (Yes/No)......................

13. Whether any work in violation of the Act has been carried out (Yes/No).........................

If yes.

(i) Details of the same including date of commencement..................

(ii) **Officers responsible for violation of the Act......................**

(iii) **Action taken/being taken against erring officers......................**

(iv) **Whether work in violation of the Act is still in progress......................**

14. Any other information ....

15. Details of certificates/documents enclosed........................

16. Detailed opinion of the chief conservator of forests/head of the forest department concerned covering the following aspects, namely :-

(i) cut-turn of timber, fuelwood and other forest produce from the forest land involved ;

(ii) whether the district is self-sufficient in timber and fuelwood ; and

(iii) the effect of the proposal on

(a) fuelwood supply to rural population ;

(b) economy and livelihood of the tribal and backward communities

(iv) Specific recommendations of the chief conservator of forest/head of the forest department for acceptance or otherwise of the proposal with reasons thereof.

Certified that all other alternatives for the purpose have been explored and the demand for the required area is the minimum demand for forest land.

Signature of the authorised officer
of the State/Government/Authority

N.B.1 While furnishing details of flora and fauna, the species should be described by their scientific names.

N.B.2 If the space provided above is not sufficient to specify any information. Please attach separate details/documents.

Foot Note

The principal rules were notified vide number G.S.R. 719 dated the 20th July, 1981 and subsequently amended vide

(1) G.S.R. 14, dated the 28th December, 1987
(2) G.S.R. 6.10 (D), dated the 26th June, 1989

Appendix 17
(Para 20.5 refers)

CHECK LIST OF ITEMS FOR A HIGHWAY PROJECT REPORT

1. Project Report

1.1 Preliminary

i) Name of work and its scope
ii) Authority and plan provisions
iii) History, geography, climate, etc.
iv) Necessity

1.2 Road Features

i) Route selection
ii) Alignment
iii) Environmental factors
iv) Cross-sectional elements
v) Traffic

1.3 Road Design Specification

i) Road design
ii) Pavement design
iii) Protective works
iv) Specifications

1.4 Drainage Facilities including Cross-Drainage Structures

i) General drainage conditions, HFL water-table, seepage flows, rainfall, snowfall, run off
ii) Surface drainage, catch water drains, longitudinal side drains
iii) Sub-surface drainage, blanket courses, sub-drains
iv) Cross-drainage structures

1.5 Materials, Labour and Equipment

i) Sources of construction materials, transport arrangements
ii) Labour availability, amenities
iii) Equipment

1.6 Rates

i) Schedule of rates
ii) Rate justification

1.7 Construction Programming

i) Working season
ii) Schedule of completing the work

1.8 Miscellaneous

i) Rest houses, temporary quarters
ii) Diversions and haul roads
iii) Site amenities
iv) Traffic control devices
v) Roadside plantations, turfing, landscaping

2. Estimate

2.1 General Abstract of Cost

2.2 Detailed Estimate for each Major Head of Item

i) Abstract of cost
ii) Estimates of quantities
iii) Analysis of rates
iv) Quarry/material source charts

3. Project Drawings

i) Locality map-cum-site plan
ii) Land acquisition plans
iii) Plan and longitudinal sections
iv) Typical cross-sections cross-section sheet
v) Detailed cross-sections
vi) Drawings for cross-sections drawings for cross-drainage structures
vii) Road junction drawings
viii) Drawings for retaining walls and other starting walls and other structures.

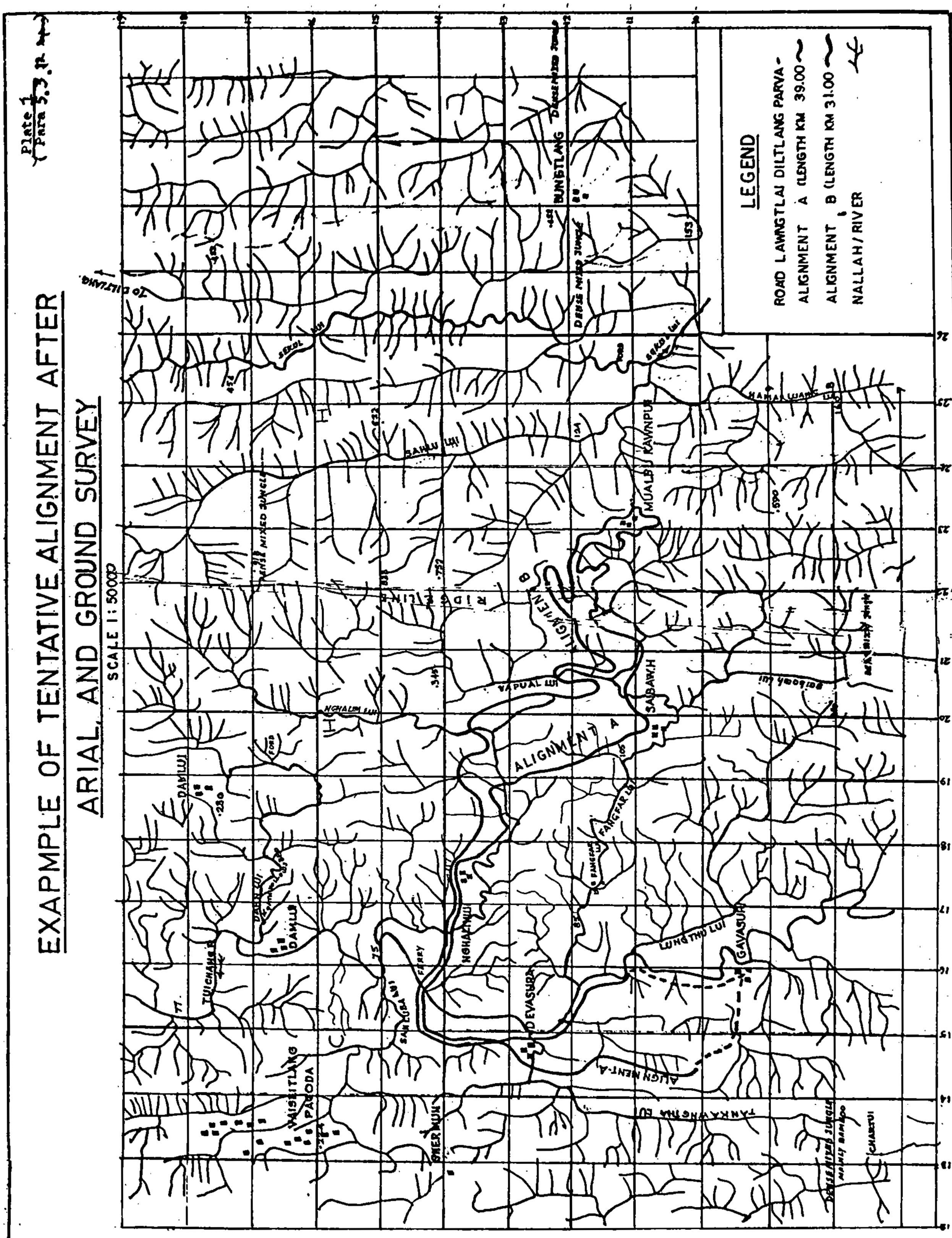


Plate 1
(Para 5.3 pt...)
EXAPMPLE OF TENTATIVE ALIGNMENT AFTER
ARIAL AND GROUND SURVEY
SCALE 1:50000
LEGEND
ROAD LAWNGTLAI DILTLANG PARVA -
ALIGNMENT A (LENGTH KM 39.00
ALIGNMENT B (LENGTH KM 31.00
NALLAH/RIVER
To DILTLANG
BUNGTLANG
DENSE MIXED JUNGLE
SEKOL LUI
RIDGE LINE
ALIGNMENT B
MUALBU
KAWNPUR
VAPUAL LUI
SAIBAWH
ALIGNMENT A
NGHALIM LUI
FANGFAR LUI
DAWLUI
DAWLUI
TUICHANG R
LUNGTHO LUI
GAVASURA
DEVASURA
FERRY
NGHAITHULI
SAIKUBA
VAISEITLANG
PAGODA
SHERKUN
ALIGNMENT-A
TANKAWNGNHA LUI
CHARTUI

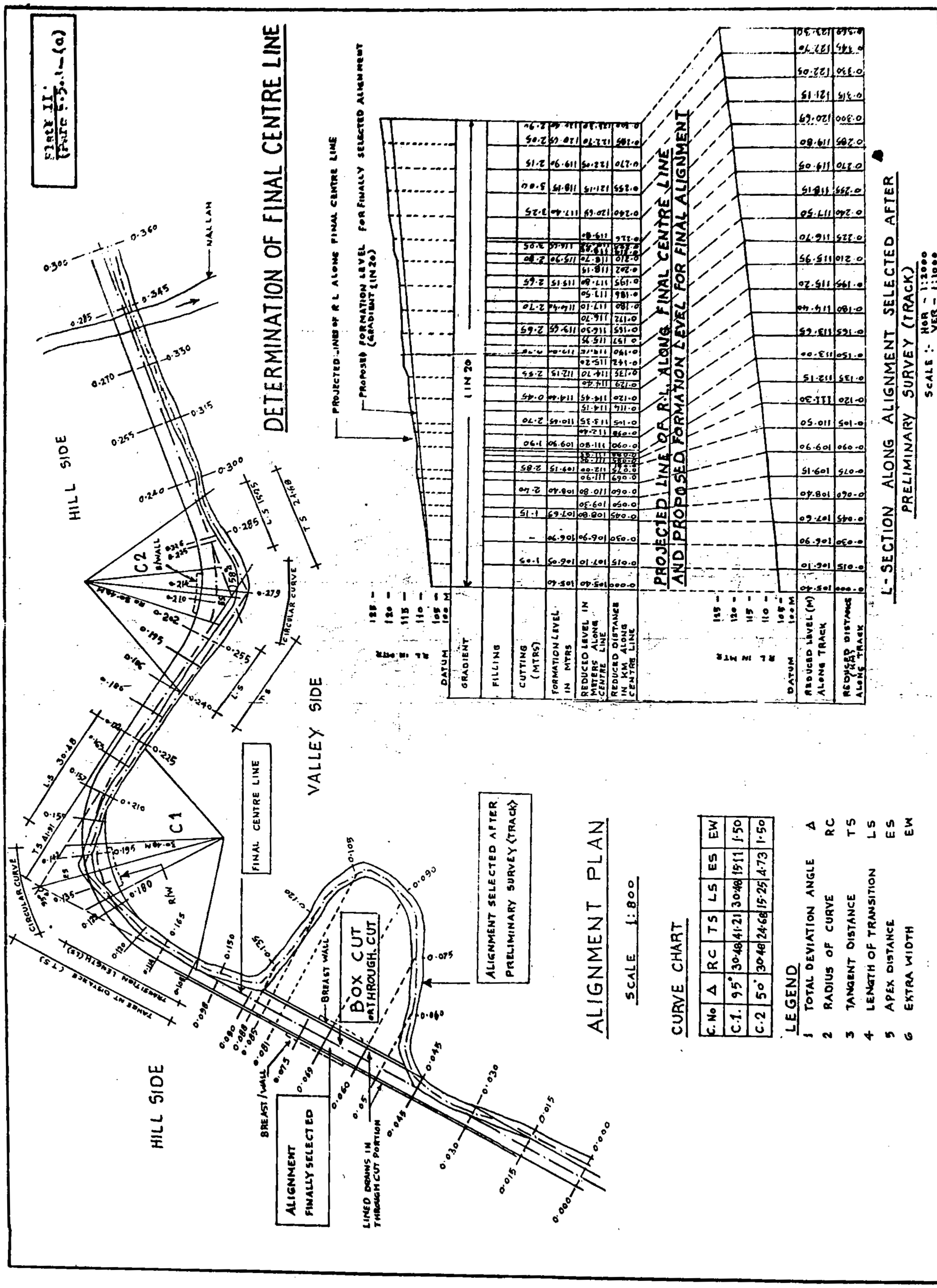
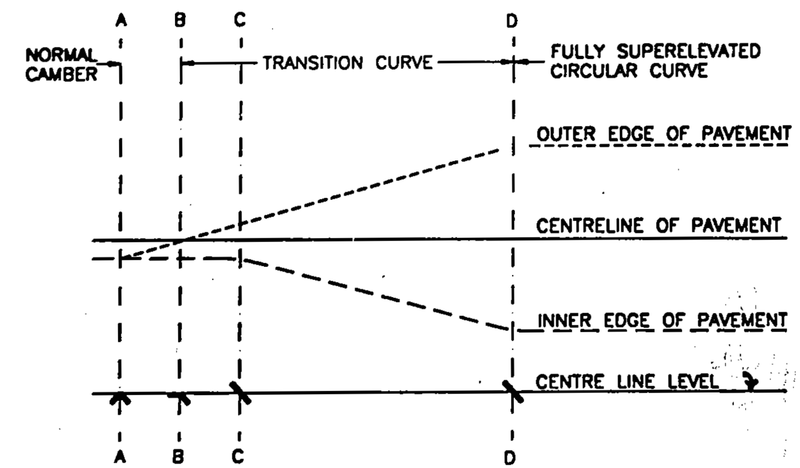
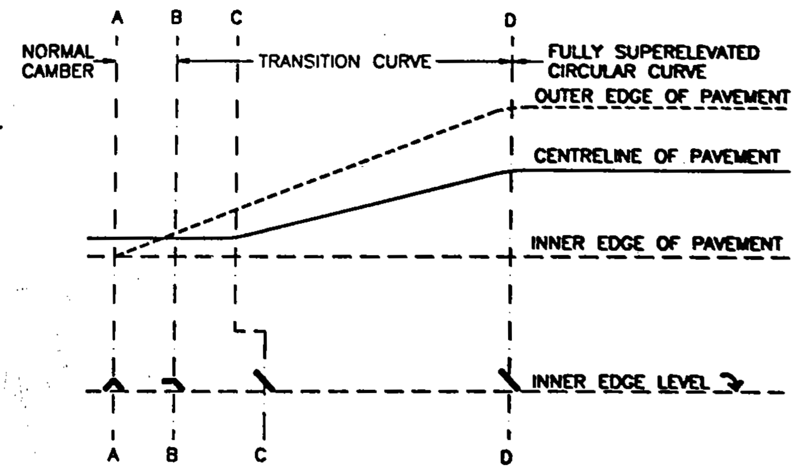

DETERMINATION OF FINAL CENTRE LINE
ALIGNMENT PLAN
SCALE 1:800
HILL SIDE
VALLEY SIDE
HILL SIDE
NALLAH
FINAL CENTRE LINE
ALIGNMENT SELECTED AFTER PRELIMINARY SURVEY (TRACK)
ALIGNMENT FINALLY SELECTED
BOX CUT OR THROUGH CUT
BREAST WALL
LINED DRAINS IN THROUGH CUT PORTION
CIRCULAR CURVE
C1
C2
CURVE CHART
C. No | Δ | RC | TS | LS | ES | EW
C.1 | 95° | 30.48 | 41.21 | 30.48 | 15.11 | 1.50
C.2 | 50° | 30.48 | 24.68 | 15.25 | 4.73 | 1.50
LEGEND
1 TOTAL DEVIATION ANGLE Δ
2 RADIUS OF CURVE RC
3 TANGENT DISTANCE TS
4 LENGTH OF TRANSITION LS
5 APEX DISTANCE ES
6 EXTRA WIDTH EW
PROJECTED LINE OF R.L ALONG FINAL CENTRE LINE AND PROPOSED FORMATION LEVEL FOR FINAL ALIGNMENT
L-SECTION ALONG ALIGNMENT SELECTED AFTER PRELIMINARY SURVEY (TRACK)
SCALE :- HOR - 1:2000 VER - 1:1000
DATUM
GRADIENT
FILLING
CUTTING (MTRS)
FORMATION LEVEL IN MTRS
REDUCED LEVEL IN METERS ALONG CENTRE LINE
REDUCED DISTANCE IN KM ALONG CENTRE LINE
REDUCED LEVEL (M) ALONG TRACK
REDUCED DISTANCE (KM) ALONG TRACK
1 IN 20

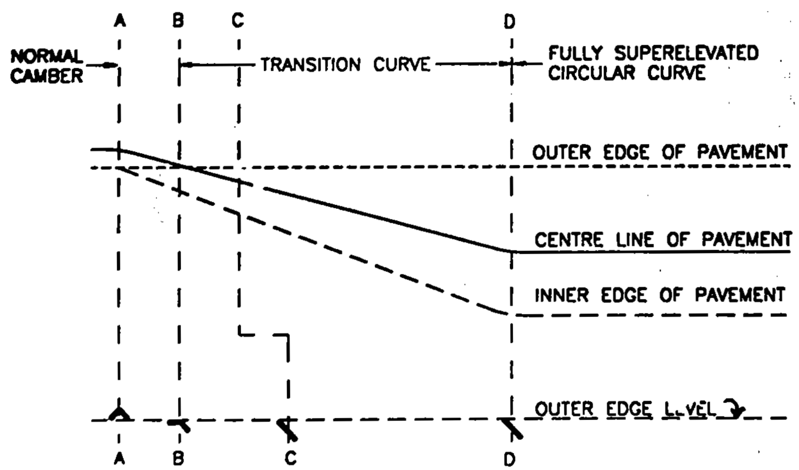
PLATE-3
(PARA 6.8.2.7 REFER)



(a) PAVEMENT REVOLVED ABOUT CENTRE LINE



(b) PAVEMENT REVOLVED ABOUT INNER EDGE



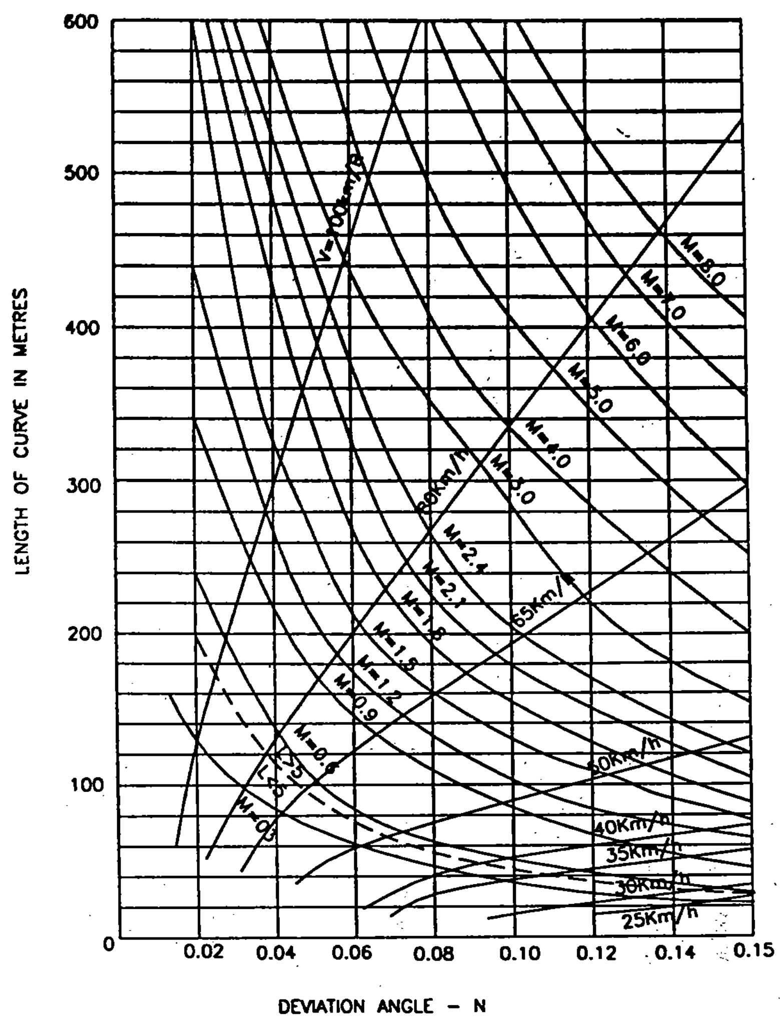
(d) PAVEMENT REVOLVED ABOUT OUTER EDGE

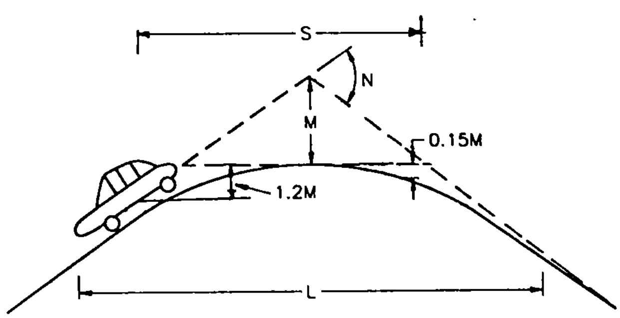
LEGEND
CROSS SECTION AT AA–NORMAL CAMBER
CROSS SECTION AT BB–ADVERSE CAMBER REMOVED
CROSS SECTION AT CC–SUPERELEVATION EQUAL TO CAMBER
CROSS SECTION AT DD–FULL SUPERELEVATION ACHIEVED

NOTE :
THE RATE OF CHANGE OF SUPERELEVATION (LOGITUDINAL SLOPE OF EDGE COMPARED TO CENTRE LINE) SHOULD BE MINIMUM 1 IN 150 FOR ROADS IN PLAIN AND ROLLING TERRAIN AND 1 IN 60 IN MOUNTAINOUS AND STEEP TERRAIN THE ACTUAL RATE USED WILL DETERMINE THE DISTANCES AB, BC AND CD.

SCHEMATIC DIAGRAMS SHOWING DIFFERENT METHODS OF ATTAINING SUPERELEVATION

PLATE – 4
(PARA 6.9.4.2 REFERS)





$$L = \frac{NS^2}{4.4} \quad (L>S)$$

$$L = 2S - \frac{4.4}{N} \quad (L<S)$$

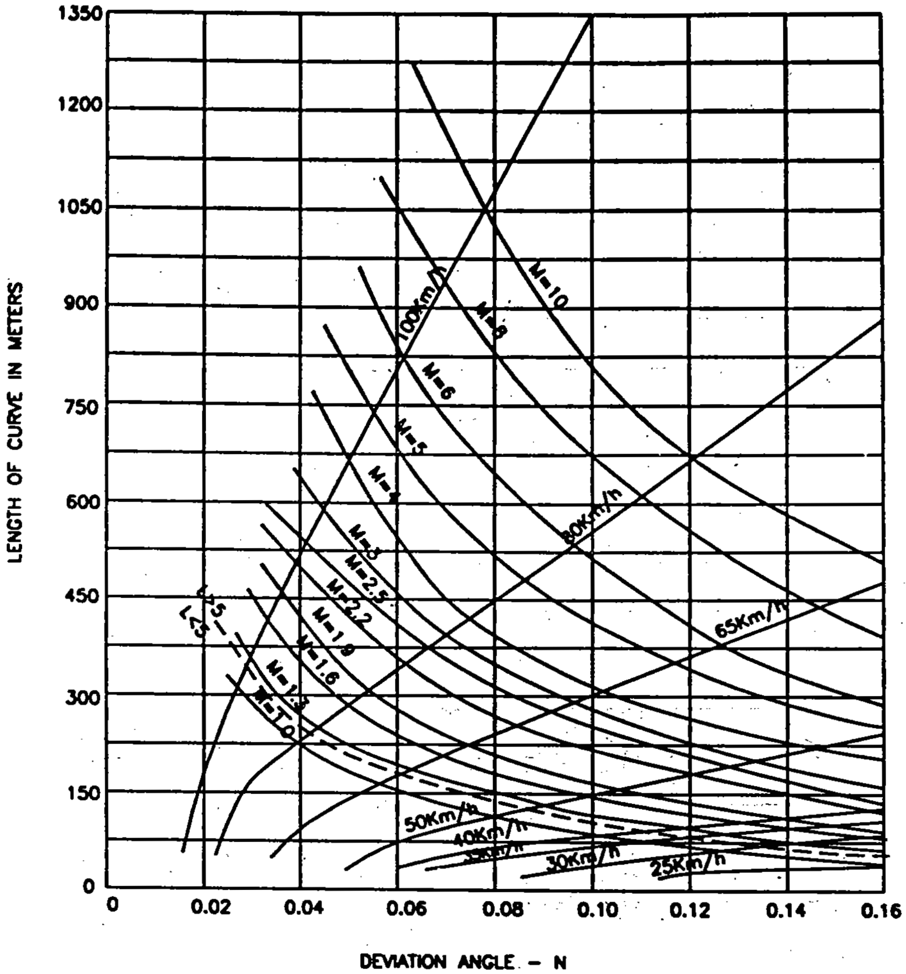
$$M = \frac{NL}{8}$$

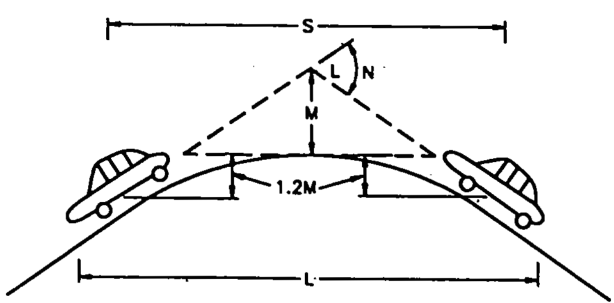
WHERE L = LENGTH OF SUMMIT CURVE
S = STOPPING SIGHT DISTANCE
N = DEVIATION ANGLE
M = ORDINATE TO SUMMIT CURVE FROM THE INTERSECTION POINT OF GRADE LINES

NOTE : – FOR MINIMUM LENGTH OF CURVE SEE TABLE 6-12

LENGTH OF SUMMIT CURVE FOR STOPPING SIGHT DISTANCE

PLATE – 5
(PARA 6.9.4.2 REFERS)





$$L = \frac{NS^2}{9.6} \quad (L>S)$$

$$L = 2S - \frac{9.6}{N} \quad (L<S)$$

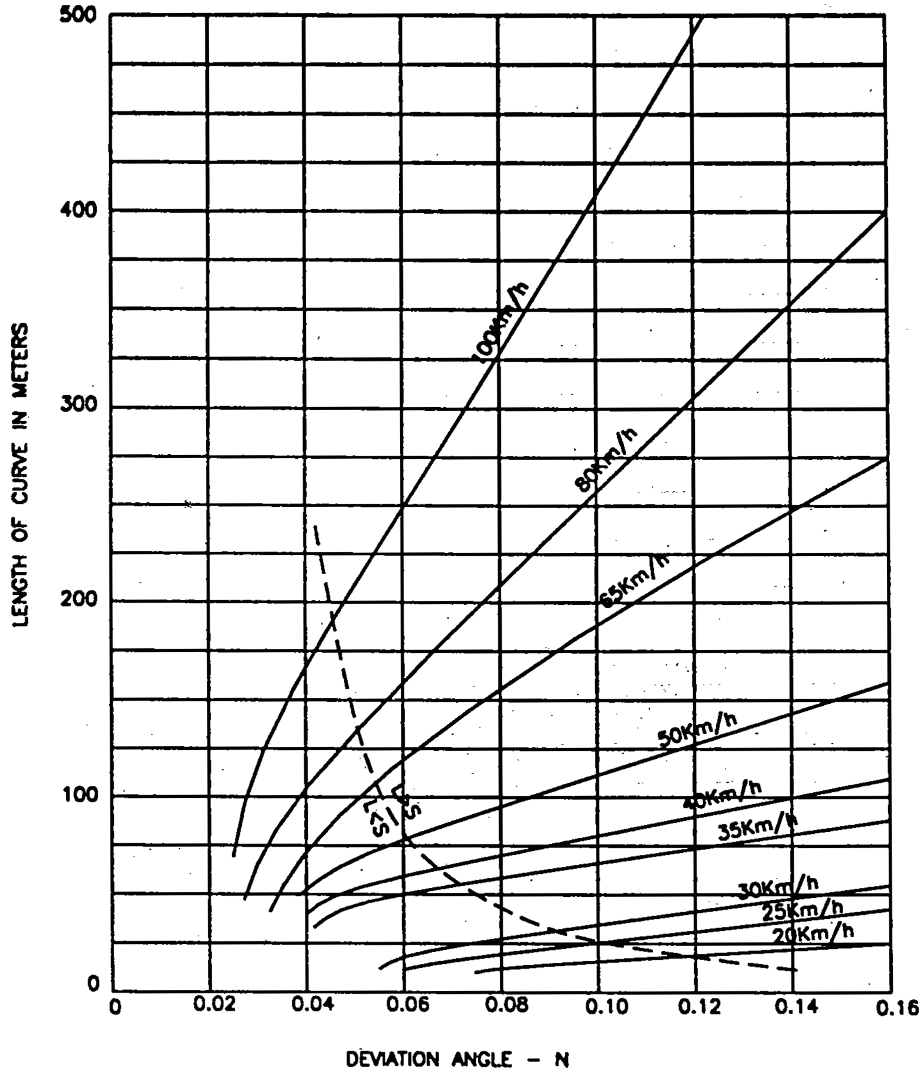
$$M = \frac{NL}{8}$$

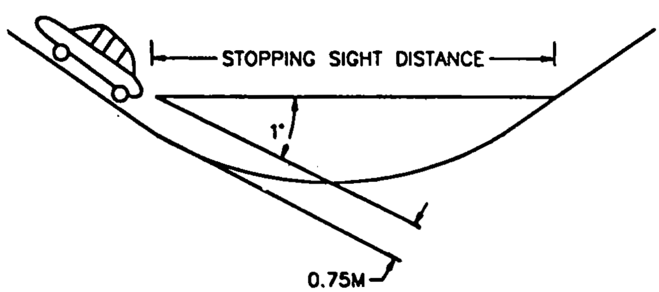
WHERE L = LENGTH OF SUMMIT CURVE
S = INTERMEDIATE SIGHT DISTANCE
N = DEVIATION ANGLE
M = ORDINATE TO SUMMIT CURVE FROM THE INTERSECTION POINT OF GRADE LINES

NOTE : – FOR MINIMUM LENGTH OF CURVE SEE TABLE 6-12

LENGTH OF SUMMIT CURVE FOR INTERMEDIATE SIGHT DISTANCE

PLATE -6
(PARA 6.9.5.2 RREFRS)





$$L = \frac{NS^2}{1.50+0.035\ S} \quad (L>S)$$

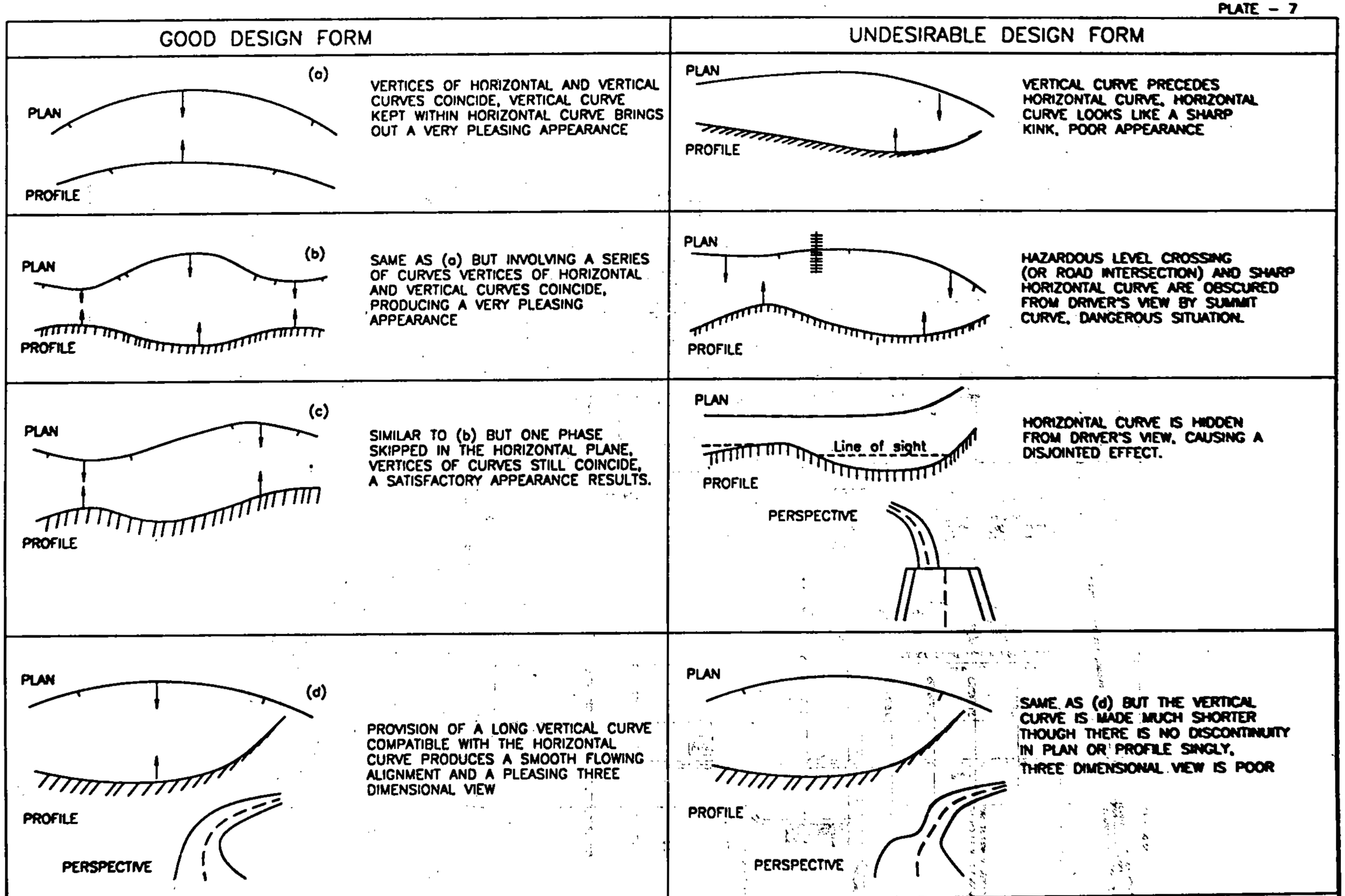
$$L = 2S - \frac{1.50+0.035\ S}{N} \quad (L<S)$$

WHERE L = LENGTH OF CURVE
S = STOPPING SIGHT DISTANCE
N = DEVIATION ANGLE

NOTE : – FOR MINIMUM LENGTH OF CURVE SEE TABLE 6–12

LENGTH OF VELLEY CURVE

PLATE – 7



SKETCHES SHOWING GOOD AND BAD ALIGNMENT COORDINATION (PARA 6.12.5 REFERS)

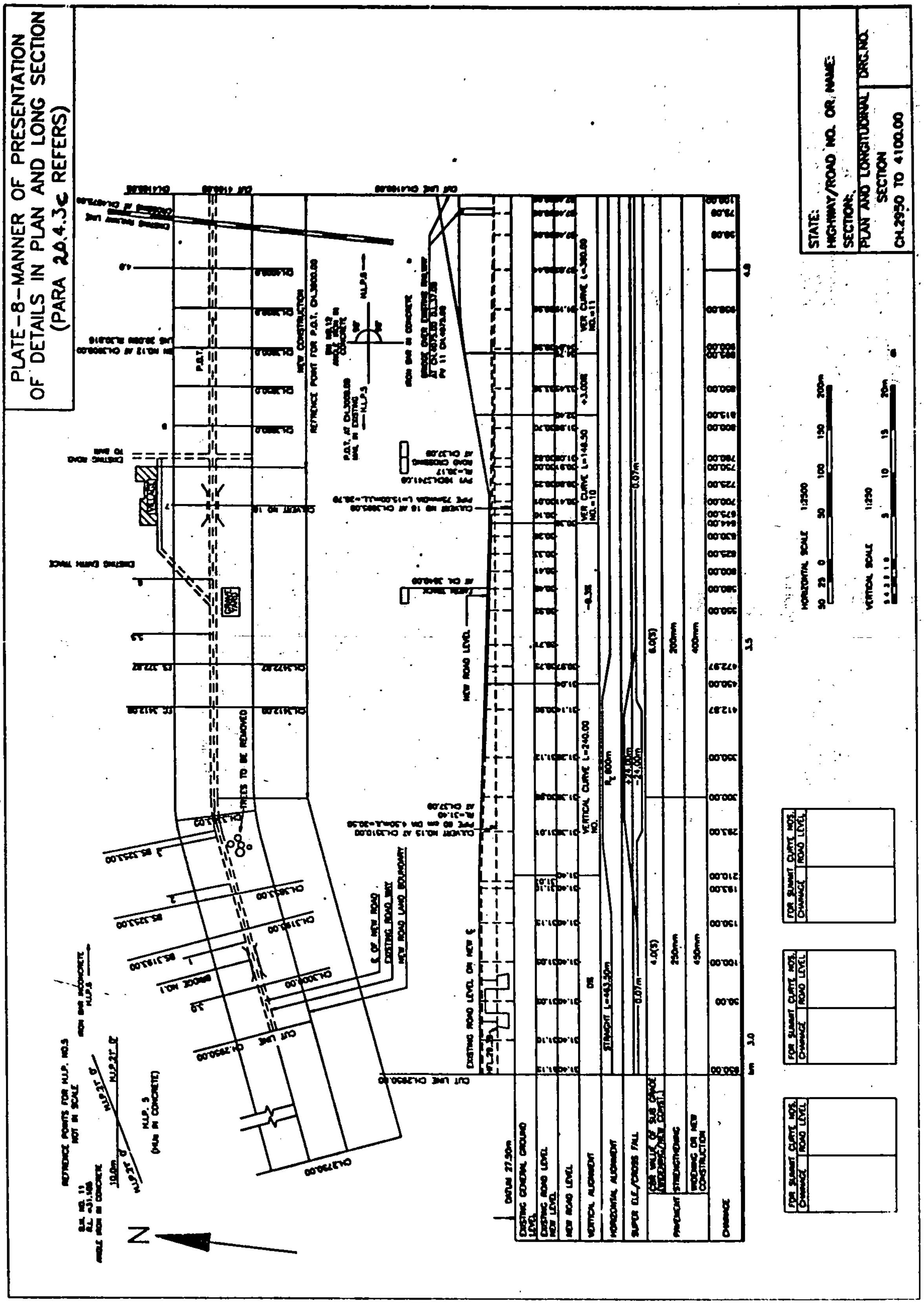


PLATE-8-MANNER OF PRESENTATION OF DETAILS IN PLAN AND LONG SECTION (PARA 20.4.3c REFERS)
STATE:
HIGHWAY/ROAD NO. OR NAME:
SECTION:
PLAN AND LONGITUDINAL SECTION
CH.2950 TO 4100.00
DRG.NO.
HORIZONTAL SCALE 1:2500
VERTICAL SCALE 1:250
DATUM 27.30m
EXISTING GENERAL GROUND LEVEL
EXISTING ROAD LEVEL
NEW ROAD LEVEL
VERTICAL ALIGNMENT
HORIZONTAL ALIGNMENT
SUPER ELE./CROSS FALL
PAVEMENT
STRENGTHENING
WIDENING OR NEW CONSTRUCTION
CHAINAGE
TREES TO BE REMOVED
NEW CONSTRUCTION
EXISTING ROAD LEVEL ON NEW ℄
NEW ROAD LEVEL