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Ministry of Shipping, Road Transport & Highways

POCKET BOOK FOR HIGHWAY ENGINEERS

(Second Revision)

**Published by
Indian Roads Congress
New Delhi**

Pocket Book for Highway Engineers
(Second Revision)

Ministry of Shipping, Road
Transport & Highways

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Indian Roads Congress
on behalf of the Govt.
of India, Ministry of Shipping,
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FOREWORD

The first edition of this Pocket book was published in December, 1982. It was primarily intended for use as a ready reference for the highway engineers including those at the grass root level of management both in highway administration and construction industry. The publication at that time fulfilled the long felt need of the highway engineering profession in this country. It was first revised in May, 1985.

The pocket book has proved very popular with highway engineers and has generated awareness among the engineers at the grass root level. The present edition of this pocket book is being brought out after revision taking into account the feedback received from the field engineers, the changes in administrative and technical policies and procedure by the Ministry of Road Transport & Highways and includes new chapters on topics of road machinery, cement concrete pavements and environment. The section on bituminous pavements has been entirely redrafted to include the revisions carried out recently to specifications for bituminous pavements. The section on traffic and traffic control devices now includes the latest developments in the area. The chapter on pavement design is now based on the revised IRC Code for design of flexible pavements.

The pocket book is divided in eighteen sections and gives information and guidelines on all aspects of highway engineering such as preliminary project preparation, detailed project preparation, procedure for inviting tenders and approval, construction procedure and maintenance. The material is mostly drawn from the specifications of the Ministry, existing publications of IRC and the circulars/ guidelines issued by the Ministry from time to time.

The pocket book cannot be expected to cover the entire details and as such should not be considered as a substitute for the standards and specification, codes of practice etc. For convenience of reference, a classified list of IRC Publications has been appended at the end.

This pocket book has been prepared by the Indian Roads Congress. The pocket book was further got reviewed by two Chief

Engineers, namely, Shri C.C. Bhattacharya, CE(R)S&R and Shri Nirmaljit Singh, CE (PL). Shri G.S.C. Kartha and Shri Arun Kumar Sharma and Shri Satinder Pal Singh, Superintending Engineers of M/oRT&H have also made valuable contributions towards improvements in the contents of the pocket book. The contents of the pocket book were further updated by Shri S.K. Nirmal, Superintending Engineer of M/oRT&H to include latest revisions specially IRC:37, etc. I take this opportunity to acknowledge the services rendered by all these experts.

I hope this present revised edition of the pocket book will prove to be as popular as the earlier edition and continue to be useful for day to day reference for all the engineers in highway profession. The compilation of this kind of pocket book will need updating from time to time. In this context, I would welcome suggestions and feed back from the profession so that we can improve and update the pocket book in the years to come.

(C.C. Bhattacharya)
Director General (Road Development)
& Additional Secretary

New Delhi
February, 2002

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1. GENERAL INFORMATION

1. GENERAL INFORMATION

1.1. Land, Terrain and Climate

India lies entirely in the northern hemisphere. The Mainland extend between latitudes 8°4' and 37°6' north and longitudes 68°7' and 97°25' east, and measures about 3.214 km from north to south between extreme latitudes and about 2,933 km from east to west between extreme longitudes. It has a land frontier of 15,200 km and a coastline of about 6,100 km. The country has a total land area of 3,288 million sq. km.

The Mainland comprises three well-defined regions, namely, the great mountain zone, the Indo-Gangetic plains and the southern peninsula. The terrain varies from steep hills to flat plains, and there are also desert areas. Though, the climate may be broadly described as tropical monsoon type, there are areas in the bed as northern hilly region which get snow-bound for several months in a year. There is a large variation of rainfall from place to place. The area which in the past was getting the highest rainfall in the world (Cherrapunji-11,420 mm per year) is in India, but there are also arid zones getting an annual rainfall of less than 100 mm. A variety of soil types are present, from sandy soils to heavy and expansive clays. Thus, in road construction, the challenge of a large variety of physical and environmental condition is met with.

1.2. Road Classification

1.2.1. **Non-urban Roads:** Non-urban roads in the country are classified into six categories :

1) **Expressways :** The function of expressways is to cater for movement of heavy volumes of motor traffic at high speeds. They connect major points of traffic generation and are intended to serve trips of medium and long length between large residential areas, industrial or commercial concentrations, and the central business district. They are divided highways with high standards of geomatrics and full or partial control of access and provided generally with grade separation at intersections.

Parking, loading and unloading of goods and passengers and pedestrian traffic are not permitted on these highways.

2) **National Highways :** These are main highways running through the length and breadth of the country connecting major ports, highways of neighbouring countries, State capitals, large industrial and tourist centres, etc.

3) **State Highways :** These are arterial routes of a state linking district headquarters and important cities within the State and connecting them with National Highways of the neighbouring States.

4) **Major District Roads :** These are important roads within a district serving areas of production and markets, and connecting these with each other or with the main highways.

5) **Other District Roads :** These are roads serving rural areas of production and providing them with outlet to market centres, taluka/tehsil headquarters, block development headquarters or other main roads.

6) **Village Roads :** These are roads connecting villages or groups of villages with each other and to the nearest road of a higher category.

The total length of non-urban roads in the country is of the order of 2.2 million km of which about 1.06 million km are surfaced.

The total length of National Highways as on 2nd November, 1999 is 52010 km.

1.2.2. **Urban roads** : Urban roads are classified into the following five categories :

1) **Expressways :** The function of expressways is the same whether they traverse through urban areas or non-urban areas.

2) **Arterial Streets :** This system of streets, along with expressways where they exist, serves as the principal network for through traffic flows. Significant intra-urban travel, such as, between central business district and outlying residential areas or between major suburban centres takes place on this system. These streets may generally be spaced at less than 1.5 km in highly developed central business areas and at 8 km or more in sparsely developed urban fringes. The arterial streets are generally divided highways with full or partial access. Parking, loading and unloading activities are usually restricted and regulated. Pedestrians are allowed to cross only at intersections. Definition of urban roads is given in Fig. 1.

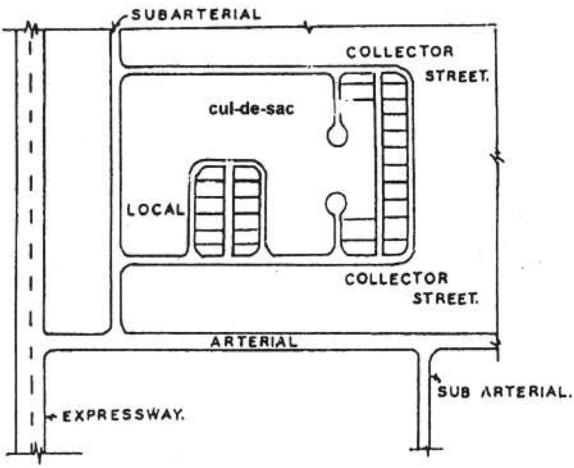


Fig. 1.1. Definition of urban roads

3) **Sub-arterial Streets:** These are functionally similar to arterial streets but with somewhat lower level of travel mobility. Their spacing may vary from about 0.5 km in the central business district to 3 - 5 km in the sub-urban fringes.

4) **Collector Streets:** The function of collector streets is to collect traffic from local streets and feed it to the arterial and sub-arterial streets or vice versa. These may be located in residential neighbourhoods, business areas and industrial areas. Normally, full access is allowed on these streets from abutting properties. There are few parking restrictions except during the peak hours.

5) **Local Streets :** These are intended primarily to provide access to abutting property and normally do not carry large volumes of traffic. Majority of trips in urban areas originate from or terminate on these streets. Local streets may be residential, commercial or industrial, depending on the predominant use of the adjoining land. They allow unrestricted parking and pedestrian movements.

2. PROJECT SURVEY AND INVESTIGATION

2. PROJECT SURVEY AND INVESTIGATION

2.1. General

One of the primary considerations in the location and design of a road is that the overall cost of transportation (i.e., the cost of initial construction, traffic operation and maintenance) is the minimum. For satisfying this consideration, detailed and accurate suveys and investigations are required. All the operations involved should be planned in advance in logical sequence, and the survey parties must be fully aware of the road. Detailed procedures for the surveys and investigation are contained in IRC:SP:19.

2.2. Alignment Surveys

2.2.1. **Reconnaissance survey :** The main objective is to examine the general character of the area for the purpose of determining the most feasible route(s) for further detailed investigations. This involves :

- study of toposheets of Survey of India. Toposheets are available in the scale of 1:2,50,000, 1:50,000 and 1:25,000. The study of the survey of India, Toposheets can be obtained from the Director, Map Publications, Survey of India, Hathibarkala Estate, Dehradun.

- study of survey sheets, maps, photographs, etc.

- aerial reconnaissance

- ground reconnaissance, to examine the routes on ground by walking or riding. Generally, information collected include length by various alternatives, bridging needs, feasibility of geometrics, existing means of communication, terrain and soil conditions, drainage conditions, climatic factors, facilities and resources, economic factors, and all other information affecting the location of the road. Based on the data collected, a report containing all the relevant information and discussing the merits and demerits of the different alternatives should be prepared. It should have a plan and profile drawn to a scale of 1:50,000. Reconnaissance survey is not required for cases involving improvement of existing roads.

2.2.2. **Preliminary survey :** This is a relatively large scale instrument survey for preparing an accurate base plan showing all the physical features affecting the highway location, a longitudinal section and cross-sections. The idea is that by a study if these supplemented by field inspections, it should be possible to fix the final centre line of the road. Scales adopted are :

i) Built-up areas and stretches in hilly terrain - 1:1,000 horizontal and 1:100 vertical.

ii) Plain and rolling terrain — 1:2,500 horizontal and 1:250 vertical.

2.2.3. **Determination of final centre line :** This involves the following operations :

i) A few alternative alignments for centre line are drawn and studied, and the best on satisfying the engineering, aesthetic and economic requirement is selected.

ii) A trial grade line is drawn taking into account the controls of road/railway/river crossings. This is studied in conjunction with the alignment and adjustment in any or both for proper co-ordination.

iii) Horizontal curves including spiral transitions and vertical curves are drawn.

iv) For improving existing roads, it is ensured that the existing alignment is used for the maximum extent possible. Similarly, the existing road levels are kept in view while fixing the grade line.

2.2.4. **Final location survey:** This is for transferring the final centre line on to the ground and for detailed levelling required for computing earthwork quantities. The centre line is staked by means of a continuous transit survey. All horizontal intersection points (H.I.P.) and intermediate points of transit (P.O.T.) on long tangents are fixed and referenced. Bench marks are fixed at 250-500 m intervals. Intervals for cross-sections should be:

Plain terrain	:	50-100 m
Rolling terrain	:	50-75 m
Built-up areas	:	50 m
Hilly terrain	:	20 m

Note : Besides these, cross-sections should also be taken at begining and end of transition curves, middle of circular curves and other critical locations.

All cross-sections should be with reference to the final centre line and should extend upto the roadland boundaries.

The important points to be considered for final selection of alignment are summarised in Table 2.1.

2.3. Soil and Material Surveys

2.3.1. Earthwork (in embankment or cutting) and materials for pavement constitute a sizeable portion of the cost of a road. Major points on which investigations are conducted pertain to:

i)	Source	:	Loaction, distance from worksite availability of haul roads, handling methods, quantities available, etc.
ii)	Suitability	:	Engineering properties and comparison with specification requirements, possibilities of improvement where the properties do not come upto mark, etc. Materials from swamps, marshes and bogs, etc. and organic soils classified as OL, OI, OH and Pt as per IS:1498

Table 2.1. Guidance on Route Selection and Highway Locations

Prefer alignment which

- is as direct as possible between points to be linked.
- streets clear of obstructions and avoids interference with industry/agriculture, places of worship, etc.
- fully integrates with the surrounding landscape.
- passes through better soil area and has good natural drainage.
- runs close to sources of embankment and pavement materials.

Keep in view

- obligatory and control points from physical, administrative, strategic and other considerations.
- the need for adopting a uniform design speed, and easy grades and curvature.
- the needs of major river crossings.
- better aesthetics of the road.

Avoid

- frequent crossing/re-crossing of railway lines and water courses.
- areas which are unstable, subject to flooding water-logging/seepage flows, etc.
- erosion/landslide prone areas.

are unsuitable for embankment construction purpose. Clay having LL and PI more than 70 and 45 respectively is also unsuitable for embankment construction. Plate 2.1 gives engineering classification of soils as per IS:1498-1970.

iii) Classification : In the case of excavation.

iv) Others : Subsoil water level, floodability of the area, and any special geological features.

2.3.2. The surveys should start with a study of all available information including soil and material maps, geological maps, published information on quarries and material sources, etc.

2.3.3. In general, approaches to railway overbridges or high level bridges will be high enough to warrant special time-consuming investigations. It is necessary that the investagation, design and construction phases of such embankments are coordinated with the construction of the bridge structure so that the bridge and the approaches are completed side by side without the need for one to wait for the other.

2.3.4. Broad outline of the investigations required for the various cases are as follows :

i) **Low embankments :** Demarcation of borrow-areas (see IRC:10) digging trial pits at 200 m intervals, and testing for properties. Also, look for using material from nearby cut areas, if any, (Refer Table 2.2.).

ii) **High embankments :** Detailed soil investigations should be carried out for designing the high embankments where stability of embankment is doubtful or settlement is expected to be large. In Coastal Marine Clay Areas, embankment of even 4 m height can cause problem, whereas, on firm foundation only settlement within the body of embankment may be of concern. Normally, for

Table 2.2. Typical table showing source of procuring earth for embankment construction

Reach	Estimated fill		Source of procurement							
	For sub-grade	For body of Em-bank-ment	For subgrade/ shoulder				For body of embankment			
			From borrow		From cutting		From borrow		From cutting	
km-km			Loc. (km)	Qty.	Loc. (km)	Qty.	Loc. (km)	Qty.	Loc. (km)	Qty.
81.0-81.2	1000	6000	-	-	81.3	1000	@	6000	-	-
81.2-81.4	400	1000	-	-	81.3	400	-	-	81.3	1000
81.4-81.6	400	2000	-	-	81.5	400	-	-	81.5	2000

Notes :
1. The quantities are in cu.m.
2. @ From adjoining borrow areas.
3. This table should be worked out after locating the borrow areas and testing the material for properties.

6-9 m heights in general cases and heights below 6 m in specific cases, discretion may be applied to decide whether detailed soil investigation is necessary and for heights more than 9 m detailed soil investigation may be carried out in all cases.

Minimum two bore holes for each approach at a distance of approximately 50 m and 120 m behind the abutment position should be taken. The depth of bore holes below the ground level should be $2^1/_2$ times the maximum height of the embankment, subject to minimum height of the embankment, subject to minimum depth of 20 m. Bore hole can be terminated at shallower depth if continuous hard strata giving N value (SPT test) in excess of 50 is encountered. One undisturbed sample may be collected for each change of strata with the help of 100 m dia and 450 thin-walled sampling tubes. No undisturbed sample may be collected from cohesionless or hard strata. Standard Penetration Test should be done immediately after the undisturbed samples have been collected. SPT should be done at 1.5 to 2 m depth interval. Undisturbed and disturbed samples collected from bore holes may be subjected to laboratory tests as per Table 2.4. Representative samples of fill materials intended to be used in the embankment should be collected and subjected to laboratory tests as per Table 2.5. It is advisable to use the services of specialists. For more information, see IRC:75, "Guidelines for the Design of High Embankments", or detailed instructions issued by the Ministry vide No. NHVI-50(21)/79 dated the 25th January, 1980.

Table 2.3. List of laboratory tests to be conducted on borehole samples

1. **Tests on undisturbed samples**

Undisturbed samples are those collected in 100 mm dia thin-walled tubes conforming to IS:2132-1972. These should be tested in the laboratory for the determination of the following soil properties:

i) Grain size analysis (as per IS:2720 (Part IV)-1975)
ii) Natural moisture content (as per IS:2720 (Part II)-1973)
iii) LL & PL (as per IS:2720 (Part V)-1970) (For soils suspected to be organic in nature, by virtue of colour, odour, texture, etc. LL on fresh as well as on oven-dry specimen may be separately found out.)
iv) Cc, Cv and Pc (preconsolidation pressure) from consolidation test (according to IS:2720 (Part XV)-1965).
v) C and Ø from unconsolidated undrained (UU) triaxial test (according to IS: 2720 (Part XI)-1971). Bulk density, void ratio and moisture content before/after UU test should also be determined.

2. **Tests on selected undisturbed samples**

Where the method of stage construction of embankment based on the effective stress method of design requires to be kept in view, selected and representative undisturbed samples should be further tested in the laboratory for the determination of the following soil properties :

C'Ø and A-factor from consolidated undrained triaxial tests with measurement of pore pressure, i.e., CU tests (according to IS: 2720 (Part XII)- 1981). Bulk density, void ratio and moisture content before/after CU test should also be determined.

3. **Tests on disturbed samples**

Samples recovered from the SPT spoon should be retained in glass jars sealed air-tight. These samples may be treated as disturbed samples and should be tested in the laboratory for the determination of following soil properties :

i) Grain size analysis (according to IS: 2720 (Part IV)-1975)

ii) Natural moisture content (as per IS:2720 (Part II)-1973)

iii) LL & PL (as per IS:2720 (Part V)-1970) (For soils suspected to be organic in nature by virtue of colour, odour, texture, etc. LL on fresh as well as on oven-dry specimens may be separately found out.)

Table 2.4. List of laboratory tests to be conducted on fill materials

---

(a) Test to be done on each sample:-

i) Grain size analysis (as per IS:2720 (Pt. IV) - 1975)

ii) Natural moisture content (as per IS:2720 (Pt. II)-1973)

iii) LL and PL (as per IS:2720 (Pt. V)-1970) (For soils suspected to be organic in nature by virtue of colour, texture, odour, etc. LL on fresh as well as on oven-dry specimens may be separately found out).

iv) Moisture-density relationship using light compaction, commonly known as Proctor test (as per IS:2720 (Pt. VIII)-1980).

(b) Strength tests on selcted samples :

On the basis of tests conducted as per (a) above, the samples may be categorised into types, each showing the same or closely similar soil characteristics. One or two samples out of each category may be judiciously selected so as to be representative and subjected to the following tests :

i) For cohesive fill material (e.g., clay or clay mixed with silt/sand.). C & Ø may be determined from unconsolidated undrained (UU) triaxial test (according to IS:2720 (Pt. XI)-1972) on specimens remoulded to 95 per cent modified Proctor density at O.M.C. plus 2 per cent.

ii) If the fill material is cohesionless, Ø may be determined from direct shear test (according to IS:2720 (Pt. XIII) 1972) on specimens remoulded to 95 per cent Ø modified Proctor density at OMC.

iii) For cohesive fill materials which may be used for forming embankments likely to be subjected to submergence and drawdown effective stress parametres C and Ø as also A-factor, may be determined from consolidated undrained test with measurement of pore pressure, i.e., CU tests (according to IS:2720 (Pt. XII-1981) on specimens remoulded to 95 per cent Ø modified Proctor density at OMC plus 2 per cent. The test specimens in the triaxial cell may be saturated by applying back pressure before shearing. This test will be in addition to that mentioned in (b) (i) above and may be carried out for selected few representative samples only.

iv) For any of the types strength tests mentioned above, the actual bulk density, void ratio and moisture content of the specimens before/after the test should be found out and recorded.

iii) **Cut sections :** Trial pits or bore holes for ascertaining the types of material to be excavated as also their quantities. At the subgrade level, check for suitability of the material, test field density and CBR, and look for seepage flows.

iv) **Landslide prone areas :** Landslide hazard zonation maps prepared by Geologist and engineers should be studied to avoid landslide prone areas. Try to avoid aligning roads along landslide vulnerable such areas. If not possible, study the past history of landslides to have a feel of the intensity and extent of the problem. Call for the services of a geologist or soil specialist for tackling the problems.

v) **Pavement design :** The investigations should be on materials, at or expected to be at subgrade level. Besides others, the tests should cover CBR values in case of flexible pavements and 'k' values in case of rigid pavement (See Tables 2.5 to 2.7).

vi) **Aggregates :** Identification of suitable quarries/material sources, testing representative samples for engineering properties and estimating the quantities available for extraction. At least 3 samples should be tested for each type of material from each source (See Table 2.8).

vii) **Manufactured items :** Identification of source of supply, distance of nearest rail-head from the work site, etc.

viii) **Water :** Identification of source, suitability and quantities available season by season.

2.4. Drainage Studies

2.4.1. **High flood level (HFL) :** Should be based on history of floods in the area dating back to some years. Collect information from inspection/local enquiry, as also from Irrigation Department. Enquire from other Departments of their plans to put new embankments in the area (this might cause increase HFL) or to provide certain

Table 2.5. Proforma for laboratory investigation data of soil for embankment construction/pavement design

State			Route		Section	
Loca-tion km	Type of soil	Sieve analysis, % passing sieve				Sand content Col. 3- Col. 6
		4.75 mm	2 mm	425 μm	75 μm	
1	2	3	4	5	6	7

Date :				Modified Proctor test IS:2720 (Pt.VIII)	
L.L.	P.L.	P.I.	PRA classification	Max. dry density gm/cc	OMC %
8	9	10	11	12	13

Deleterious constituents	Remarks
14	15

Note: For pavement design, the soil expected in the subgrade should also be tested for FDD (for existing roads/new roads in cutting), and for CBR soaked and unsoaked. For rigid pavements, 'k' value test should be conducted.

drainage measures (this might reduce HFL). Compare the HFLs so determined with those for the adjoining sections of the road or nearby railway/irrigation embankments to correct any apparent mistakes.

2.4.2. **Depth of water table:** This may be measured at open wells along the alignment or at holes specially bored for the purpose. Observations should be taken at 1 km intervals, preferably soon after withdrawal of monsoon. Any evidence of spring flow in the test holes should be recorded. In arid areas where depth of water table is more than 6 m below ground level, no measurements for water table need be made.

2.4.3. **Ponded water level :** Where water stagnates for considerable periods, e.g., irrigated fields, information about level and duration of standing water should also be collected.

Table 2.6. Approximate soaked CBR values of soils

Soil	PI	Approx. soaked CBR
Sand	-	8-25
Clayey sand	5-15	5-8
Sandy clay	15-25	4-6
Silty clay	25-40	3-5
Heavy clay	> 40	1-3

Notes 1. The values given in the Table are rough indications and not for design. Designs should be based on laboratory testing.

2. The CBR of sands depends to a great extent on degree of confinement.

Table 2.7. Proforma for record of test values of moorum/soil-gravel and similar material

State District Date of testing

Location and name of quarry	Description of material	Specimen No.	Gradation : % by wt. passing sieve					
			80 mm	40 mm	20 mm	10 mm	4.75 mm	2.36 mm
1	2	3	4	5	6	7	8	9

600 µm	425 µm	75 µm	L.L.	P.L.	P.I.	Density	OMC	Soaked CBR
10	11	12	13	14	15	16	17	18

Remarks regarding performance, qty. available access roads, etc.
19

Note: For each source, test min. 3 specimens for each type of material.

Table 2.8. Proforma for recording test values of aggregates like stone metal

State		District		Date of Testing	
Location & name of quarry	Type of rock	Speci-men@ number	L.A. * value	A.I.V.* Dry test	A.I.V.* Wet. test
1	2	3	4	5	6

Water absorption	Flakiness Index 40 mm size	Flakiness Index 20 mm size	Stripping value	Remarks regarding performance, qty. available, access roads, etc.
7	8	9	10	11

Notes 1. @ For every source, test min. 3 specimens for each type of material.

2. * Any one of the two tests may be conducted. Wet test in col. 6 is for softer aggregrate.

2.4.4. Regarding drainage studies required for various perposes are detailed in Table 2.9.

2.5. Culverts

2.5.1. **Choice of structure by type :** R.C.C. pipes or R.C.C. slab type culverts are generally used. Preference should be for the pipe type which is generally more economical, convenient and quicker in construction and is hydraulically better.

2.5.2. **Investigations :** The investigations should be for :

i) Selection of site

ii) Collection of data for design of the structure

2.5.3. **Guidance on site selection :** Generally, the road alignment will dictate the location of a culvert. Where there is a choice, the following points should be kept in view :

Table 2.9. Drainage studies

Purpose		Studies required for
1.	Fixing grade line of road	HFL, depth of water table, ponded water level, general ground level.
2.	Design of pavement	Depth of water table, rainfall intensity, type of subgrade material.
3.	Drainage of cut sections and design of sub-surface drainage system	Depth of water table, seepage flow, soil profile, permeability of strata, seepage flow head
4.	Design of surface drainage system	Study of ground contours to determine catchment contributing to side drains, surface characteristics of catchment area, location of outfall points, rainfall intensity.

i) The site should be on a straight reach sufficiently away from bends in the channel.

ii) The location should be far away from confluence of tributaries.

iii) The banks should be well defined.

iv) The site should permit square crossing as far as possible.

2.5.4. Table 2.10 lists out the data to be collected for culverts.

Table 2.10. Data to be Collected for Culverts

A. NEW CULVERTS

1. **Catchment area :** Marking the watershed on topo sheet and measuring the area, or for smaller catchments finding the watershed by compass survey, or for flat terrain by conducting a local contour survey to demarcate the watershed.

2. **Cross-sections :** Three cross-sections, one at selected site, one at upstream and one at downstream.

3. **Longitudinal section :** Should show bed levels, L.W.L. and H.F.L.

4. **Maximum H.F.L. :** Observation of marks left by flood, local enquiry and comparing with data for any nearby structure.

5. **Velocity observations :** Observed during actual flood.

6. **Trial pits :** Dug upto firm ground. Engineering characteristics of soil and safe bearing capacity at foundatioin level.

B. EXISTING CULVERTS

1. Type of structure and details of span, vent height-width of roadway, etc.

2. Load carrying capacity.

3. Condition of foundation, sub-structure and super-structure.

4. Signs of silting/scouring, blockage, overtopping, etc.

5. H.F.L., deck level, adequacy of waterway, etc.

Division	Sub-Division			Group Letter Symbol
1	2			3
COARSE-GRAINED SOILS More than half of material is larger than 75-micron IS Sieve size The smallest particle visible to the naked eye	*Gravels* More than half of coarse fraction is larger than 4.75 mm IS Sieve size	(For visual classification the 5 mm size may be used as equivalent to the 4.75 mm IS Sieve size)	Clean gravels (Little or no fines)	GW
				GP
			Gravels with fine (Appreciable amount of fines	GM
				GC
	Sands More than half of coarse fraction is smaller than 4.75 mm IS Sieve size		Clean sands (Little or no fines)	SW
				SP
			Sands with fines (Appreciable amount of fines)	SM
				SC
FINE-GRAINED SOILS More than half of material is smaller than 75-micron IS Sieve size The 75-micron IS Sieve size is about the smallest particle visible to the naked eye				
	Silts and clays with low compressibility and liquid limit less than 35			ML
				CL
				OL
	Silts and clays with medium compressibility and liquid limit greater than 35 and less than 50			MI
				CI
				OI
	Silts and clays with high compressibility and liquid limit greater than 50			MH
				CH
				OH
Highly Organic Soils				Pt
	NOTE: *Boundary classification* :			Soil p

3. GEOMETRIC DESIGN STANDARDS

3. GEOMETRIC DESIGN STANDARDS

3.1. Expressways

Table 3.1. Geometric design standards of expressways (flat terrain)

1.	Design speed (KPH)	:	120
2.	Land width (metres)	:	90 - extra to be provided where warranted
3.	Building lines (metres)	:	10 metres beyond right of way
4.	Road width (metres)		
	- For 4-lane divided carriageway	:	27
	- For 6-lane divided carriageway	:	34
	- On culverts	:	Same as for road sections
5.	Carriageway width (metres)		
	- 4-lane divided carriageway	:	2 × 7.5
	- 6-lane divided carriageway	:	2 × 11
6.	Shoulder width (metres)		
	- Treated shoulder	:	2.5
	- Untreated shoulder	:	1.0
	- Total width	:	3.5
7.	Median width (metres)	:	6
8.	Camber (per cent)		
	- Carriageway	:	2.5
	- Treated shoulder	:	3.0
	- Untreated earth shoulder	:	4.0
9.	Sight distance (metres)		
	- Safe stopping sight distance (minimum)	:	250
	- Desirable	:	500

10. Radius of horizontal curve (m)	:	Min. 700, desirable 2600 (This radius requires no superelevation and normal cross section will suffice)
11. Superelevation	:	As per formula $e = \dfrac{V^2}{225R}$ Subject to a maximum of 4 %

12. General notes on horizontal alignment
    i) Long tangent sections exceeding 6 km should be avoided.
    ii) Broken-back curves should be avoided or at least separated by 500 metres straight length.
    iii) Minimum curve length should be 150 metres for 5° deflection angle and increased at the rate of 30 m for 1° decrease thereafter.

13. Length of transition curve (metres)	:	$\dfrac{0.0215\, V^3}{CR}$ Where C=0.5 V-the design speed and R-the radius of circular curve.
14. Maximum gradient		
- Ruling	:	1 in 50
- Absolute	:	1 in 40
15. Summit and valley curves (metres)	:	To be designed for sight distance mentioned at S.No. 9 and minimum length = 0.6 V
16. Vertical profile	:	1 m clearance between HFL and subgrade
17. Clearance through road over passes	:	Vertical = 6 m Horizontal : Same normal section expressway to continue.

18. Design standards for inter-change elements.

i) Speed, sight distance and radius	Design speed (KPH)	Radius (m)	Stopping sight distance (m)
Desirable	80	230	130
Minimum	60	130	80

(The direct ramps/diagonal connection should be designed for the desirable design speed and the design speed of loops may be near the minimum)

ii) Maximum grade (per cent) : Desirable - 4
Absolute - 6

iii) Summit and valley curves (metres) : To be designed as per stopping sight distances formulae and minimum length = 0.6V

iv) Cross-section elements : a) Carriageway
Desirable - 2-Lanes
Minimum - Intermediate lane
b) Shoulder: 2 metres each

v) Length of speed change lanes (m)

	Ramp/loop speed	
	80 KPH	60 KPH
Acceleration lane	300	400
Deceleration lane	130	150

Note : An Expressway is a divided arterial highway intended for through traffic with full control of access and generally provided with grade separations at intersections. No slow moving traffic or pedestrians will be permitted on expressways.

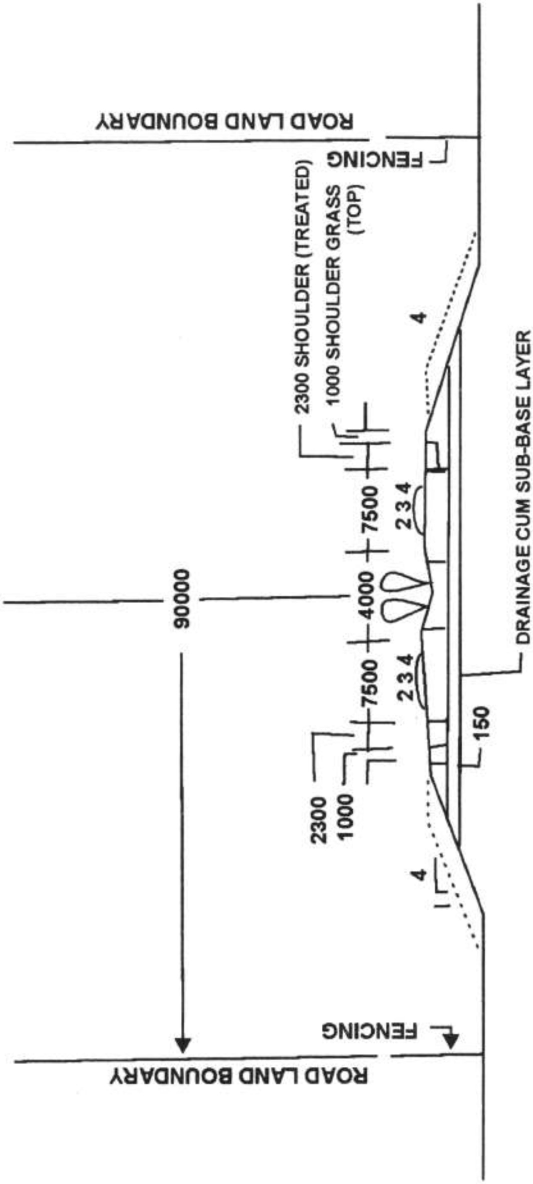


Fig. 3.1. Typical cross-section of expressway

Notes: 1. All dimensions are in mm. 2. Dotted lines indicate future extension

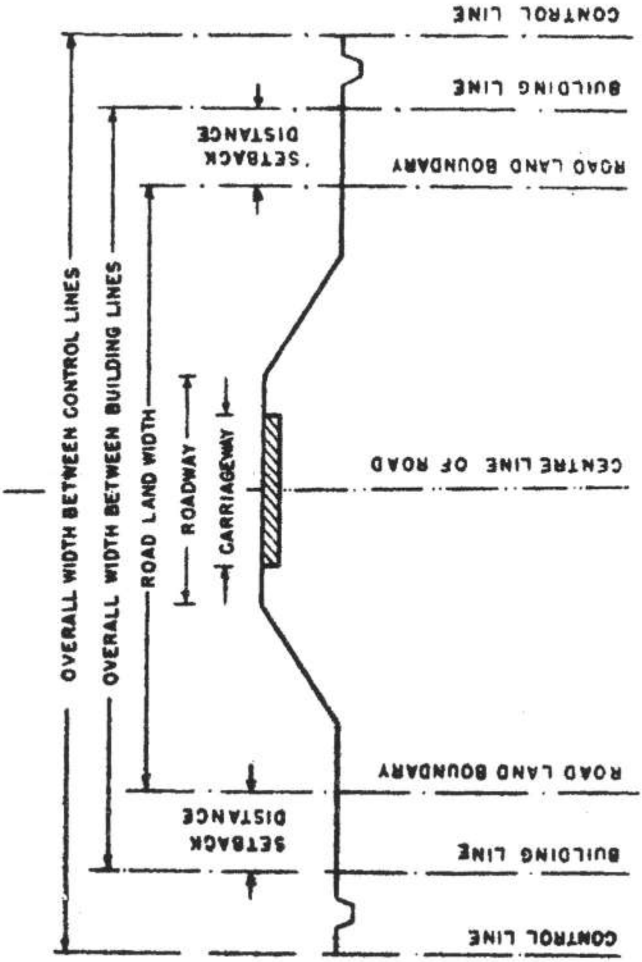


Fig. 3.2. Road land boundary, building lines and control lines

Table 3.2. Terrain classification

Terrain classification	Per cent cross slope of the country
Plain	0-10
Rolling	>10-25
Mountainous	>25-60
Steep	>60

Table 3.3. Design speeds km/h

Road class	Plain	Rolling	Mountainous	Steep
1. NH&SH				
Ruling	100	80	50	40
Minimum	80	65	40	30
2. MDR				
Ruling	80	65	40	30
Minimum	65	50	30	20
3. ODR				
Ruling	65	50	30	25
Minimum	50	40	25	20
4. VR				
Ruling	50	40	25	25
Minimum	40	35	20	20

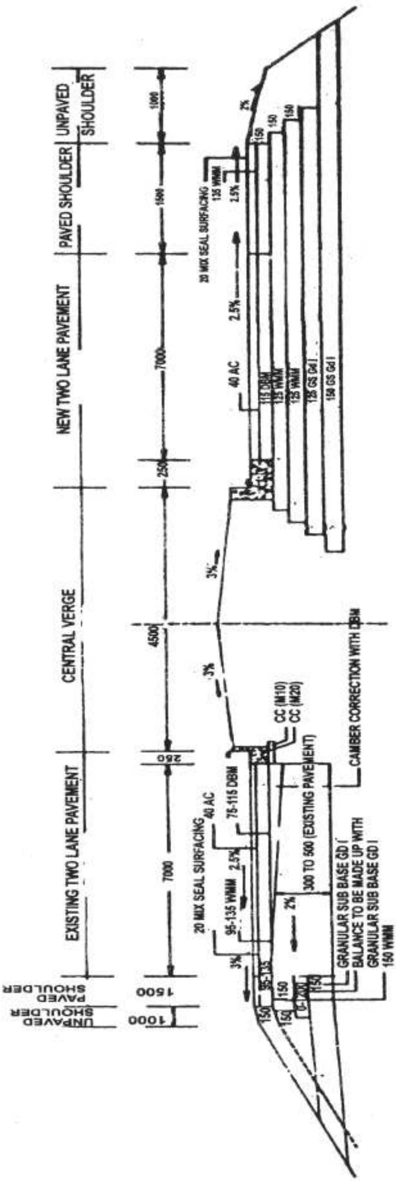
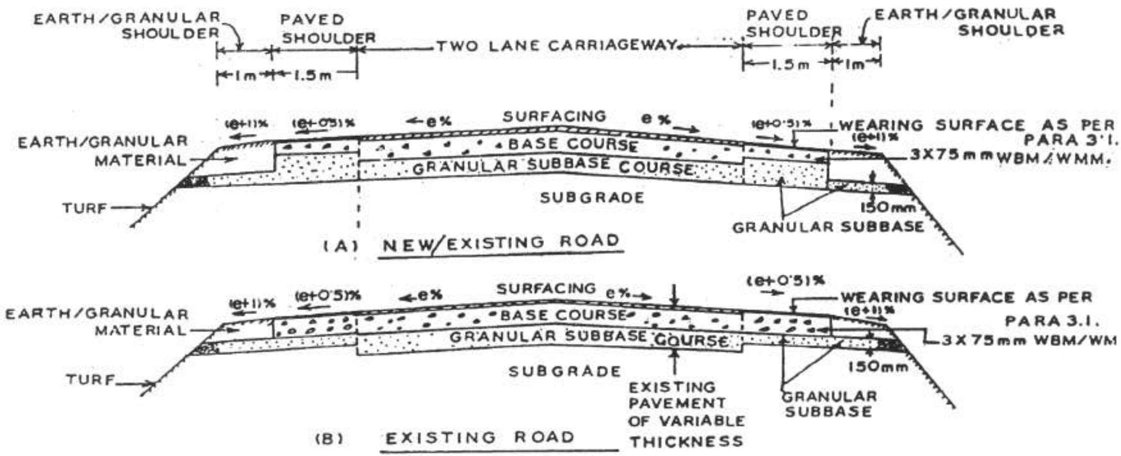


Fig. 3.3. Typical cross-section of a 4-lane divided highway



NOTATION
e = CROSS FALL (CAMBER) OF PAVEMENT
WBM = WATER BOUND MACADAM.
WMM = WET MIX MACADAM.

Notes : 1. (e+1)% crossfall shall not be less than 2.5 to 3% on granular shoulder and 3 to 4% on earth shoulder - steaper values shall be used for rainfall exceeding 150 cm per year

2. On superelevated sections the shoulder, should have same crossfall as the pavement

Fig. 3.4. Typical cross-sections of two-lane road in plain/rolling terrain with paved shoulder

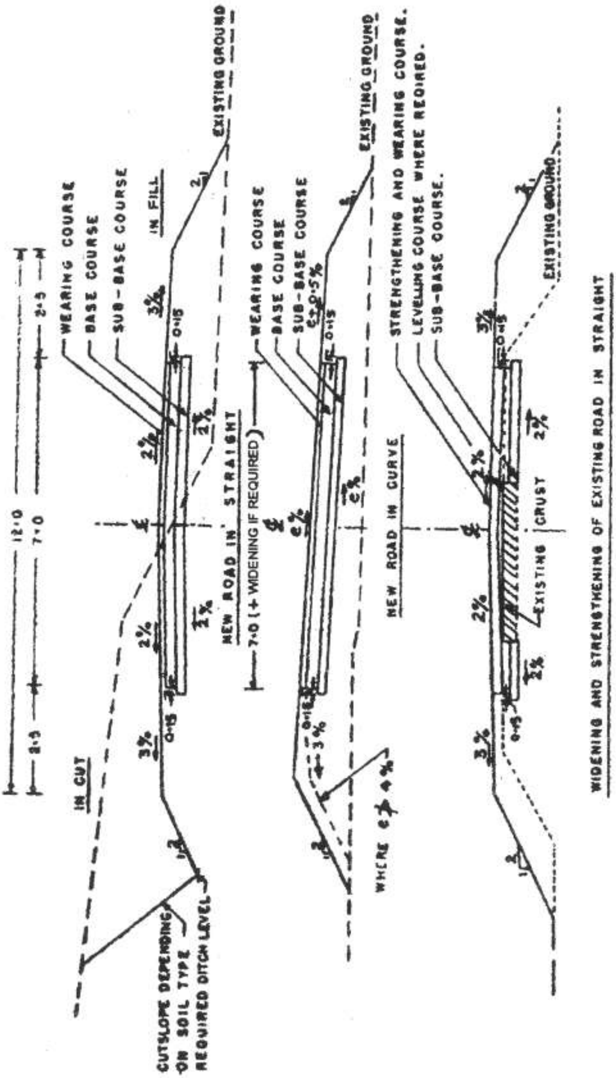


Fig. 3.5. Typical cross-sections for two-lane road in plain/rolling terrain

Table 3.4. Widths in plain (for National and State Highways)

Item		Plain and rolling terrain		Mountainous and steep terrain	
		Open areas	Built-up areas	Open areas	Built-up areas
1.	Land width (metre)				
	Normal	45	30	24	20
	Range	30-60	30-60		
2.	Building lines (overall width, metres)	80	Distance between building line and road boundary (set-back) should be 3-6 metres		
3.	Control lines (overall width, metres)	150			
4.	Roadway width (metres)	Single-lane Two-lane	- 12.0* - 12.0		6.25** 8.80**

Notes :

1. For other road categories, see IRC:73.

2. * Reduce to 9 m for SHs having remote possibility of widening to 2-lanes.

3. ** Widths are exclusive of parapets (0.6 m) and side drains (0.6 m). In hard rock stretches and unstable locations, the roadway width may be reduced by 0.8 m on two-lane roads and 0.4 m in other cases. However, where such stretches occur in continuous long length on single-lane roads, reduction in roadway width should not be effected unless requisite passing places are provided.

4. Passing places where provided should be based on actual needs, generally at the rate of 2-3 per km. These should be 3.75 m wide, 30 m long on the inside edge (i.e., towards the carriageway side) and 20 m long on the farther side.

5. On horizontal curves in mountainous and steep terrain, increase roadway equal to extra widening of carriageway.

6. For multi-lane highways, the roadway should provide for the requisite number of traffic lanes plus shoulders and median. The shoulder width should in general be 2.5 m. Desirable median width for rural highways is 5 m while the absolute minimum is 1.2 m.

Table 3.5. Width at highway structures and clearances

1.	Clear width of roadway between kerbs at bridges		
	Single-lane bridge	:	4.25 m
	Two-lane bridge	:	7.5 m
	Multi-lane bridge	:	3.5 m per lane plus 0.5 m for each carriageway
2.	Roadway width at culverts	:	Same as the roadway width at approaches (see Table 3.6)
3.	Minimum width of footpath	:	1.5 m
4.	Width of median		
	Normal	:	5 m
	Minimum	:	1.2 m
5.	Lateral clearance at underpasses		
	Desirably the full roadway width of the approaches should be carried through the underpass. See IRC:54 for more details.		
6.	Vertical clearance at underpasses		
	Rural areas	:	5 m min.
	Urban areas	:	5.5 m min.
7.	Vertical clearance for railway traction (broad gauge)		
	Electric traction	:	5.87 m min.
	Non-electric traction	:	4.875 m min.
8.	Vertical clearance for power/telecommunication lines		
	Lines carrying low voltage upto 110 V	:	5.5 m min.
	Electric power lines upto 650 V	:	6.0 m min.
	Electric power lines > 650 V	:	6.5 m min.

Table 3.6. Width of carriageway

Description	Width (m)
Single-lane *	3.75
Intermediate**	5.5
Two-lanes without raised kerbs	7.0
Two-lanes with raised kerbs	7.5
Multi-lane width per lane	3.5

Notes : * On village roads, the width may be restricted to 3 m.
** This may be adopted instead of regular two-lanes except on important trunk routes.

Table 3.7. Extra width of pavement on horizontal curves

Radius of curve (m)	Extra width (m)	
	Single-lane	Two-lanes
Upto 20	0.9	1.5
21-40	0.6	1.5
41-60	0.6	1.2
61-100	Nil	0.9
101-300	Nil	0.6
above 300	Nil	Nil

Table 3.8. Pavement crossfall/camber

	Surface type	Crossfall (per cent)
1.	High type BT or CC	1.7 - 2.0
2.	Thin BT	2.0 - 2.5
3.	WBM, gravel	2.5 - 3.0
4.	Earth	3.0 - 4.0

Notes : 1. Use steeper values in Table for high rainfall areas (>1,500 mm/year) and vice-versa.

2. For earth shoulders, adopt crossfall 0.5 per cent steeper than that for pavement but not less than 3 per cent.

3. On superelevated sections, the shoulders should normally have the same crossfall as the pavement.

4. Sections in straight :

Undivided roads	—	Crowned in middle
Divided with raised	—	Unidirectional
Median	—	Crossfall

Table 3.9. Maximum permissible superelevation

Plain/rolling terrain and snow bound hill roads	7 per cent
Hill roads not affected by snow	10 per cent

Table 3.10. Sight distance, radius of horizontal curves

Speed km/h	Sight distance (metre)			Radius of horizontal curve (metre)		
	Stopp-ing	Inter-mediate	Over-taking	Plain & rolling terrain	Hilly	
					Not affected by snow	Snow bound
20	20	40			14	15
25	25	50			20	23
30	30	60			30	33
35	40	80		45	40	45
40	45	90	165	60	50	60
50	60	120	235	90	80	90
65	90	180	340	155	-	-
80	120	240	470	230	-	-
100	180	360	640	360	-	-

Notes : 1. Values in the Table are minimum. Use higher values where feasible.

2. Stopping sight distance is the absolute minimum for design. See IRC:73 for more details.

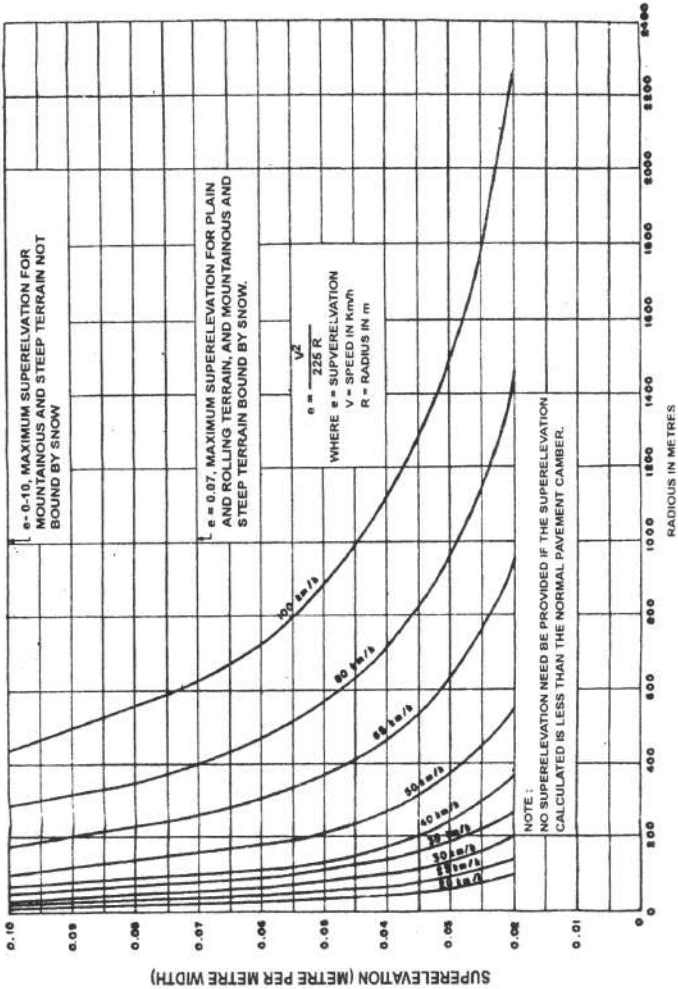


Fig. 3.6. Superelevation rates for various design speeds

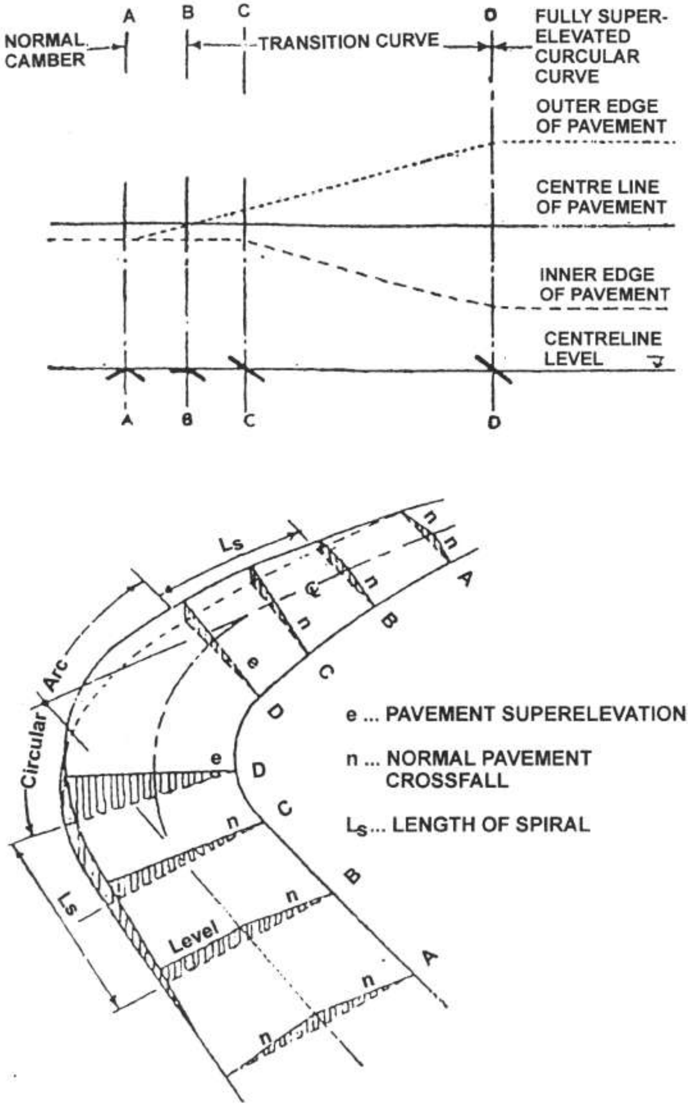


Fig. 3.7. Method of attaining superelevation

Table 3.11. Gradients

Terrain	Gradient (per cent)		
	Ruling	Limiting	Exceptional
1. Plain/rolling	3.3	5	6.7
2. Mountainous, and steep terrain having elevation more than 3,000 m above MSL	5	6	7
3. Steep terrain upto 3,000 m elevation	6	7	8

Notes : 1. Generally, use ruling gradient for design. In special situations, such as, isolated overbridges in plain terrain or roads carrying substantial slow traffic, use a flatter gradient of 2 per cent.

2. Exceptional gradient should not exceed 100 m at a stretch. Successive stretches of exceptional gradient must be separated by a minimum length of 100 m having gentler gradient

3. The rise in elevation over a length of 2 km should not exceed 100 m in mountainous terrain and 120 m in steep terrain.

4. For kerbed sections, minimum gradient for drainage should be 0.5 per cent when drain is lined and 1 per cent if unlined.

5. Maximum gradient at hari-pin bend is 2.5 per cent.

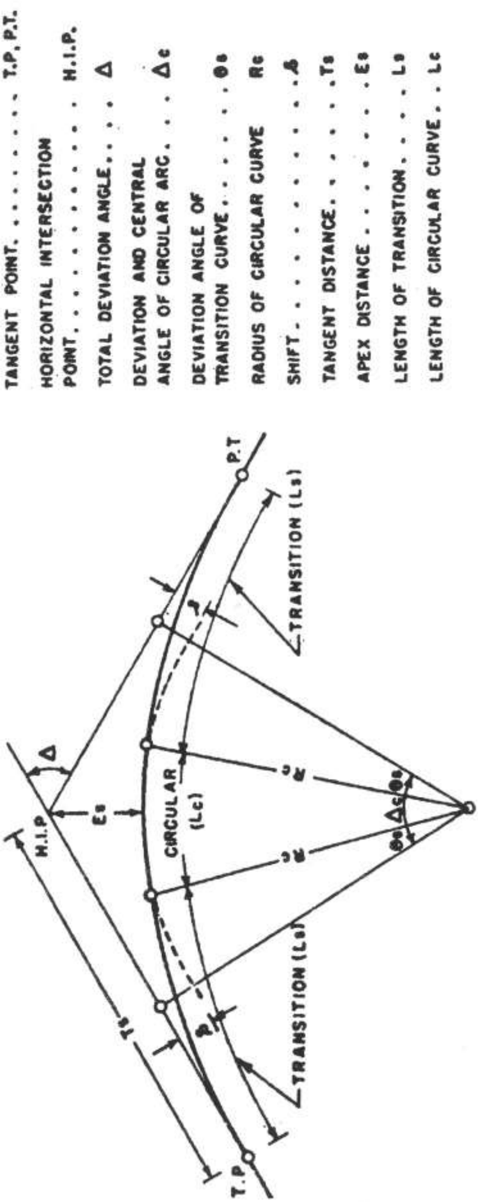


Fig. 3.8. Elements of a combined circular and transition curve

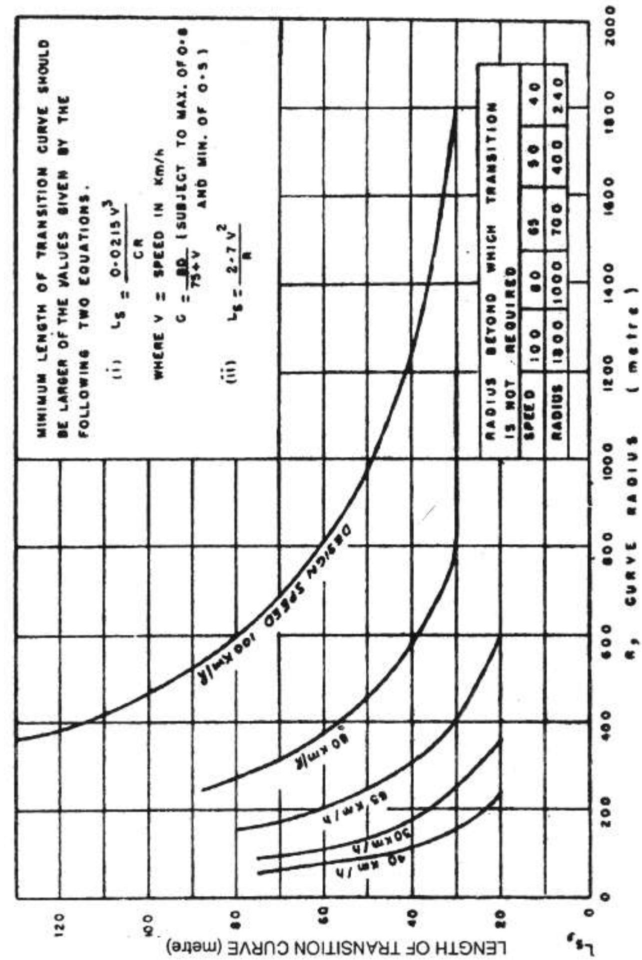


Fig. 3.9. Length of transition curve for roads in plain/rolling terrain

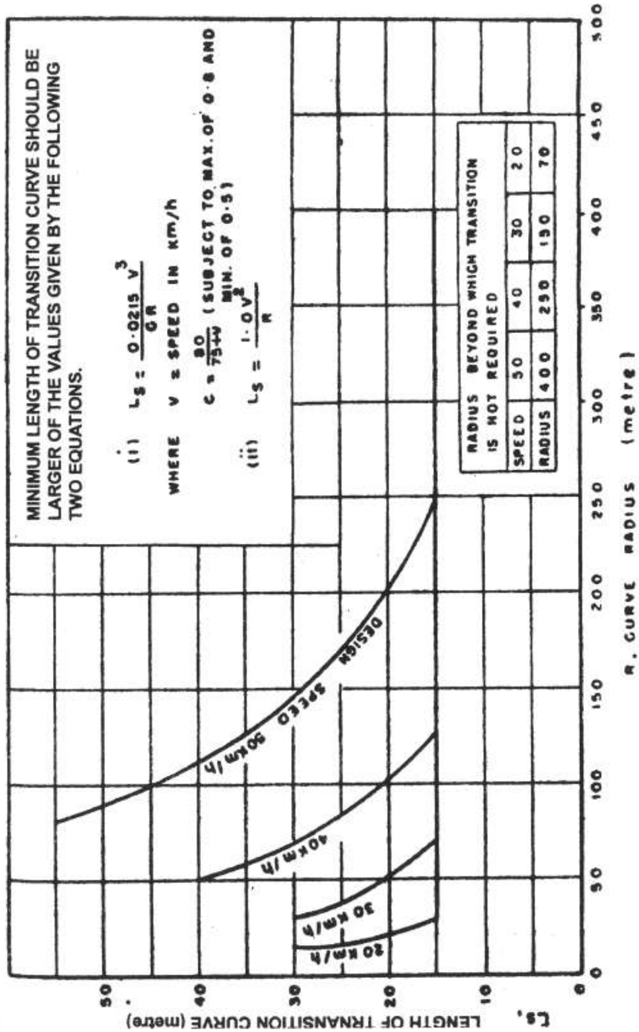


Fig. 3.10. Length of transition curve for roads in mountainous and steep terrain

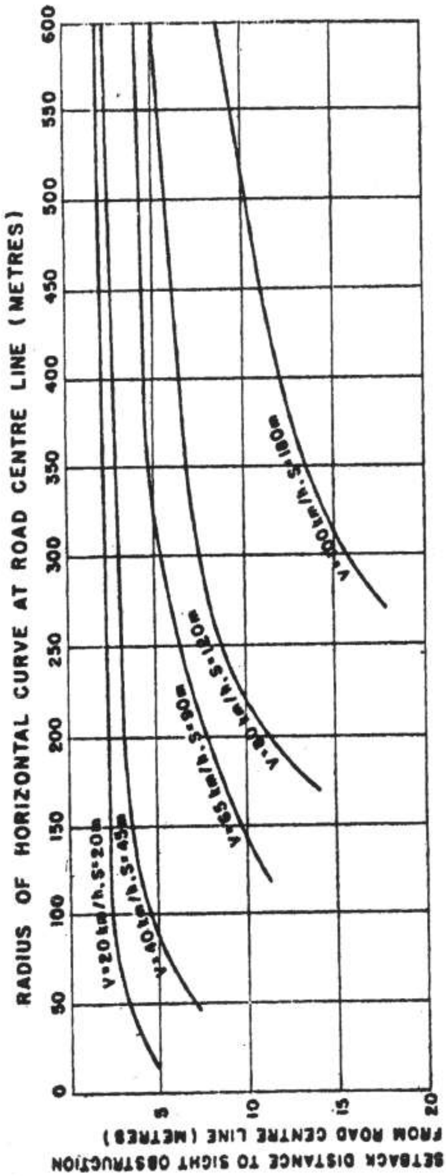


Fig. 3.11. Minimum set-back distance at horizontal curves for safe stopping sight distance

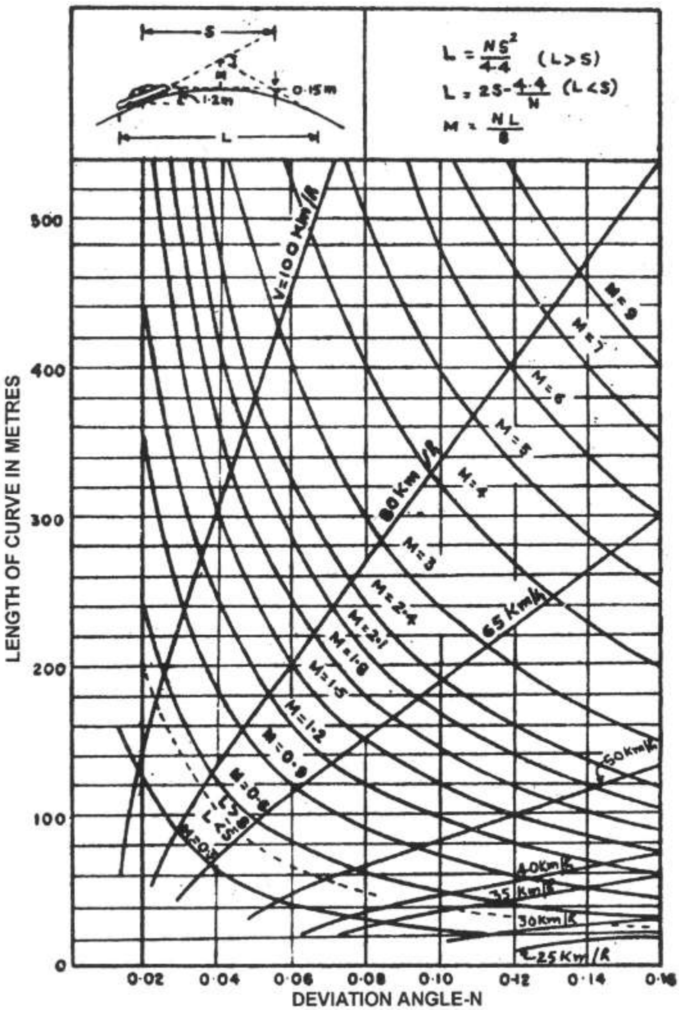


Fig. 3.12. Length of summit curve for stopping sight distance

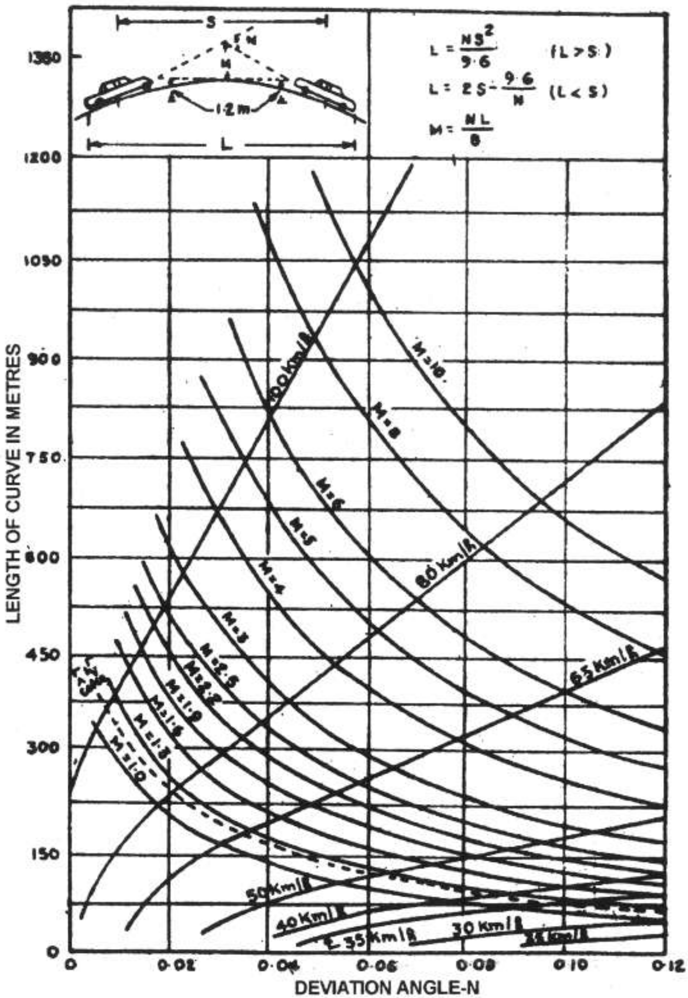


Fig. 3.13. Length of summit curve for intermediate sight distance

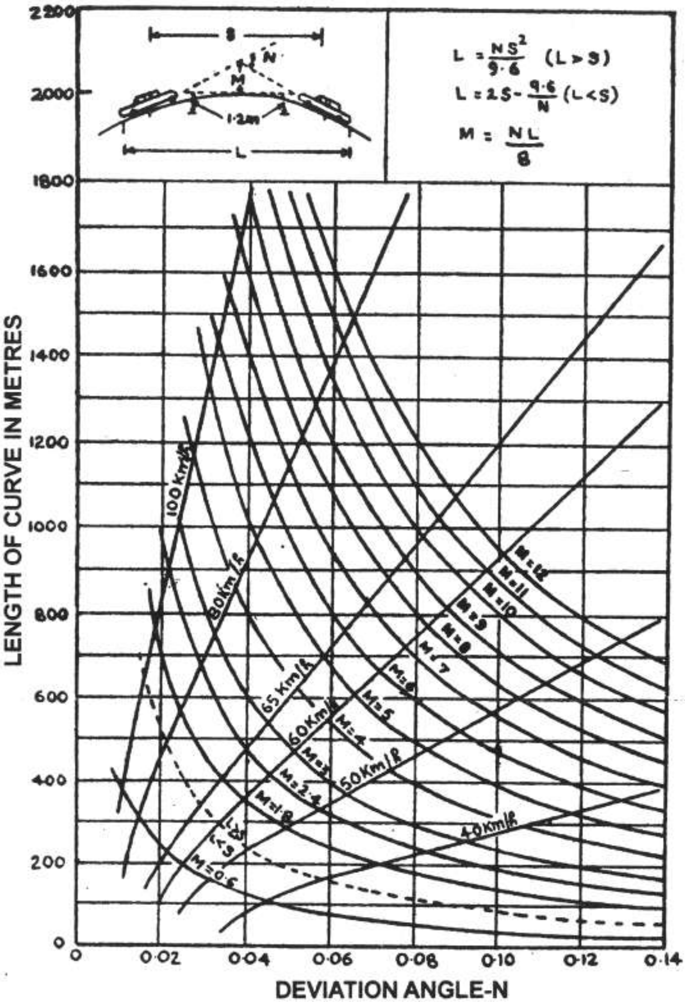


Fig. 3.14. Length of summit curve for overtaking sight distance

Table 3.12. Vertical curves

	Summit curve	Valley curve
(a)	For stopping sight distance	
	$L = \dfrac{NS^2}{4.4}$ (L > S)	$L = \dfrac{NS^2}{1.5 + 0.035S}$ (L > S)
	$L = 2S - \dfrac{4.4}{N}$ (L > S)	$L = 2S - \dfrac{1.5 + 0.035S}{N}$ (L > S)
(b)	For intermediate or overtaking sight distance	
	$L = \dfrac{NS2}{9.6}$ (L > S)	S = Sight distance L = Length of Curve
	$L = 2S - \dfrac{9.6}{N}$ (L < S)	N = Deviation angle

Notes : 1. For summit curves, overtaking sight distance should be the general criterion. Where not fesible, intermediate sight distance should be adopted as the next best. Safe stopping sight distance is the absolute minimum.

2. For valley curves, safe stopping sight distance should be adopted.

Table 3.13. Minimum length of vertical curve

Design speed (km/h)	Provide curve for grade change (%) exceeding	Min. length (metre)
Upto 35	1.5	15
40	1.2	20
50	1.0	30
65	0.8	40
80	0.6	50
100	0.5	60

Notes on alignment co-ordination :

1. Vertical and horizontal curves should coincide. If not possible, the horizontal curve should be somewhat longer than the vertical curve.

2. Sharp horizontal curves should be avoided at or near apex of pronounced summit/valley curves.

3. Grade and curvature should be in proper balance. Flat horizontal curves at the expense of steep or long grades, or sharp curvature with flat grades should be avoided.

4. Broken-back curves (two curves in the same direction with short tangent in-between) both in alignment and profile should be replaced by a single curve.

4. TRAFFIC AND TRAFFIC CONTROL DEVICES

4. TRAFFIC AND TRAFFIC CONTROL DEVICES

4.1. Traffic Surveys

4.1.1. **General :** Information on traffic is necessary for any highway project, since it would form the basis for design of pavement, fixing the number of traffic lanes, economic appraisal, etc. The operations vary from simple traffic counts to detailed traffic, and transportation studies. For major new or improvement works, it is necessary to carry out economic analysis, for which purpose studies on speeds, delays, journey time, vehicle operating cost, cost of accidents, etc., would also be called for.

4.1.2. **Equivalency factors for vehicles :** One of the fundamental measures of traffic on a road system is the volume of traffic using the road in a given interval of time. It is also termed as traffic flow and is expressed in vehicle per hour or vehicle per day. When the traffic is composed of different types of vehicles, it is normal practice to convert the volume into equivalent passenger car units (PCUs), by using equivalency factors as given in Table 4.1 for rural roads. Equivalency factors in respect of urban roads are given in Table 4.2.

4.1.3. **Traffic counts :** Count of traffic is the basic traffic study required in connection with improvements to existing roads. The points to be kept in view while organising traffic counts on existing non-urban roads are enumerated below :

(1) Traffic census should be done twice in a year; once during the peak season of harvesting and marketing and the other during the off-season. Each time, the counts should be made round the clock for seven consecutive days.

(2) The proforma to be adopted should confirm to MIS/DS/5A as given in Table 4.3. Instructions to fill-up the proforma are given in Table 4.4.

(3) Traffic census should not generally encompass abnormal conditions of traffic like a fair or exhibition. In such cases, the count in the area should be postponed by a few days till normalcy returns.

Table 4.1. Equivalency factors for various types of vehicles on rural roads

S.No.	Vehicle Type	Equivalency factor
	Fast Vehicles	
1.	Motor-cycle or Scooter	0.50
2.	Passenger car, Pick-up van or Auto-rickshaw	1.00
3.	Agricultural tractor, light commercial vehicle	1.50
4.	Truck or Bus	3.00
5.	Truck-trailer, Agricultural tractor-trailer	4.50
	Slow Vehicles	
6.	Cycle	0.50
7.	Cycle-rickshaw	2.00
8.	Hand cart	3.00
9.	Horse-drawn vehicle	4.00
10.	Bullock cart*	8.00

*For small bullock carts, a value of 6 will be appropriate.

Table 4.2. Equivalency factors for various types of vehicles on urban roads

S.No.	Vehicle Type	Equivalent PCU factors Percentage composition of vehicle type in traffic stream	
		5%	10% and above
	Fast Vehicles		
1.	Two-wheelers - Motor Cycle or Scooter, etc.	0.5	0.75
2.	Passanger car, Pick-up Van	1.0	1.0
3.	Auto-rickshaw	1.2	2.0
4.	Light commercial vehicle	1.4	2.0
5.	Truck or Bus	2.2	3.7
6.	Agricultural tractor - trailer	4.0	5.0
	Slow Vehicles		
7.	Cycle	0.4	0.5
8.	Cycle-rickshaw	0.5	2.0
9.	Horse-drawn vehicles	1.5	2.0
10.	Hand cart	2.0	3.0

Table 4.3. Traffic census data

1. Name of the State
2. National Highway Number
3. Link Number
4. Location of Count Station
   (a) Kilometrage of Count Station:
   (b) Name of Nearest Town
   (c) Distance of Count Station from the nearest town
5. Count Station Number
6. State code (see ***Annexure***)
7. Month and Year of Census
8. Duration of Census in days
9. Average daily traffic in number of vehicles (Sum of both the directions)

A - Power Driven Vehicles
   a) Cars/Jeep/Taxies/Vans/Three-wheelers
   b) Buses, Mini Buses
   c) Two Axled Trucks, Mini Trucks
   d) Multi-axled vehicles including articulated vehicles and truck trailer combinations with more than two axles
   e) Motor Cycles, Mopeds and other power driven two-wheelers

B - Slow Moving Vehicles
   a) Bicycles, Cycle-rickshaws and other manpowered passenger vehicles
   b) Animal Drawn Vehicles

C - Other Vehicles not included in any of the categories mentioned above, e.g., Agriculture Tractors, Tractor-Trailer Combination, etc.

Annexure to Table 4.3.

Details of State Code for Reporting Traffic Data

S. No.	Name of States	State Code	
1.	Andhra Pradesh	AP	01
2.	Arunanchal Pradesh	AR	24
3.	Assam	AS	02
4.	Bihar	BR	03
5.	Chandigarh	CH	25
6.	Delhi	DL	27
7.	Goa	GO	28
8.	Gujarat	GJ	04
9.	Haryana	HR	05
10.	Himachal Pradesh	HP	06
11.	Jammu & Kashmir	JK	07
12.	Karnataka	KN	08
13.	Kerala	KR	09
14.	Madhya Pradesh	MP	10
15.	Maharashtra	MH	11
16.	Manipur	MN	12
17.	Meghalaya	MG	13
18.	Mizoram	MZ	30
19.	Nagaland	NG	14
20.	Orissa	OR	15
21.	Punjab	PN	16
22.	Rajasthan	RJ	17
23.	Sikkim	SK	18
24.	Tamil Nadu	TN	19
25.	Tripura	TR	20
26.	Uttar Pradesh	UP	21
27.	West Bengal	WB	22
28.	Pondicherry	PO	31
29.	Chattisgarh	-	-
30.	Uttaranchal	-	-
31.	Jharkhand	-	-

Table 4.4. Instruction sheet for filling-up proforma MIS/DS/5A of traffic census data

1	2	3	4
1.	Name of the State		
2.	National Highway Number	Three digit number, e.g. N.H. No. 1A as N.H. No. 8 as N.H. No. 45 as	 0 1 A 0 0 8 0 4 5
3.	Link Numbers (as communicated separately to the State PWDs)	Four digit number indicating the link number on which the count station is located, e.g. Link No. 1002 as	 1 0 0 2
4(a).	Kilometrage of Count Station and distance from the nearest town	Six digit number first four representing kilometre and last two representing Chainage, e.g.: Km. 407/105 as Km. 3/048 as	 0 4 0 7 1 5 0 0 0 3 0 5
4(b).	Name of the nearest town	Twelve letters. Where the name is longer it may be abbreviated as per local usage. Blank column should be kept to the right, e.g., Lucknow	 L U C K N O W
5.	Count Station Number	Three digits, e.g. Station No. 5 as Station No. 109 as	 0 0 5 1 0 9
6.	State Code : (As per ***Annexure*** to Table 4.3)	Two digits, e.g. Haryana as	 0 5
7.	Month and year of census. The month and year in which the most of the days of census	Four digits, e.g., Nov., 1992 as May, 1992 as	 1 1 9 2 0 5 9 2

	fall, e.g., a 7 days' census commencing on 30th December, 1992 should be taken as Census for January, 1993.		
8.	Duration of Census: Number of days for which counts have been taken.	Single digit, e.g., 7 days' census	7
9.	Traffic intensity :	Five digits, e.g., 507 vehicles	0 0 5 0 7
		Count not taken	9 9 9 9 9
		Zero vehicles	0 0 0 0 0

(4) A 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 such section. The limits of the sections could generally be the important towns along the road or major roads intersecting or taking off from the highway in question.

(5) The census sites should be fixed well away from all urbanised developements and villages. In particular, sites within zone of influence of towns where there may be regular flow of commuter traffic must be avoided. If need be, additional stations could be fixed for these zones.

(6) Every subsequent census should be taken at the same locations. New stations could, of course, be added as and when needed.

(7) For the purpose of traffic counts, a day may be divided into 3 shifts of 8 hours each and separate enumerators with a supervisor be assigned for each shift.

(8) Recording should be done for each direction of travel separately. For this, the staff should be divided into two parties for every shift. Each type of vehicle, e.g., car, truck, bus, etc., should be counted separately.

(9) In each hourly column, the traffic should be recorded by making tally marks in five dash system (vertical strokes for the first four vehicles followed by an oblique stroke for the fifth vehicle so as to depict a total of five). Hourly totals should be made at the end of the shift.

(10) An index map indicating the location of the census site should be attached to the traffic summary sheet.

(11) The highest peak hour traffic in a day for fast as well as slow vehicles may be highlighted in summary sheets by drawing a firm line in red around the figures in appropriate column.

(12) The system of expressing traffic in terms of tonnes/day has already been dispensed with.

4.1.4. **Traffic studies :** Traffic surveys/studies are of different types and the type survey required depends upon the purpose as given in Table 4.5.

Table 4.5. Traffic surveys/studies

	Purpose	Type of Survey
1.	Improving existing roads	Seven-day traffic counts. Past records to be analysed for trends in growth.
2.	New network of extensive improvement of existing network	Traffic and transportation studies
3.	Bypass construction	Origin-destination (O-D) surveys; speed and delay studies.
4.	Replacing railway level crossing	Seven-day continuous count and data on number and duration of gate closures.
5.	Improvement of road junctions	Peak-hour counts on all arms giving its compositional and directional distribution.
6.	All cases	Analysis of accident records.

Note : All traffic volumes/intensities should be expressed in numbers by vehicle type and not in tonnes.

4.1.5. **Origin and destination surveys :** When planning a new road, carrying out extensive improvements to an existing road or when a bypass is contemplated, simple census cannot serve the purpose and it may be necessary to collect information about the origin and destination of traffic passing through the area in which the road is located. The origin and destination data should cover all road likely to be affected by the proposed scheme.

Depending upon the size of the town, accuracy required, etc. the survey can be carried out by one of the following methods :

i) Registration plate method

ii) Tag and disc method

iii) Roadside interview method

4.1.5.1. **Registration plate method :** In this method recording of registration number of vehicles and time of entry and exit of the inbound and outbound vehicles are noted down by the observers posted separately at each survey point. The method has the advantage that it does not cause any inconvenience to the traffic and is suitable for small towns. However, it is not possible to collect data regarding the purpose of trip, details of stopping delays to thorough traffic by this method.

4.1.5.2. **Tag and disc method :** In 'Tag and Disc Mehtod' the vehicles entering the town are stopped at the survey points and tags with entries, such as, time of entry, place of entry and type of vehicle are tied to the front of the vehicles by the observer. Sometimes instead of tags, discs are distributed to the drivers. The tag/discs are collected by the observers posted at the exit points. The method is useful where the traffic is heavy and moves continuously. However, the method gives only information in respect of entry and exit points and time spent within the town.

4.1.5.3. **Roadside interview method :** In this method inbound vehicles are stopped at the survey points and information on time of interview, type of vehicle, registration number, etc. are noted down by the observer. Then the observer puts questions in a polite manner about origin, destination, purpose of trip, number and purpose of halts within the town and also the route followed inside the town.

4.1.5.4. Only a proportion of the drivers, systematically sampled is interviwed. Generally, the survey should be for a peroid of two/ three days and should cover about 20 per cent of vehicles. (For furthur details refer IRC:102).

4.1.6. **Traffic projection :** Traffic counts and O-D surveys would provide information on present traffic (or possible diverted traffic in case of new roads). For design purposes, the traffic should be projected for the future horizon year which may be 10-20 years for major routes and 5-10 years for less important roads. The growth factor can be assessed on the basis of observed traffic trends in the recent years and other economic indicators. In the absence of any reliable data, a compound growth rate of 7.5 per cent per annum may be assumed.

4.2. Capacity and Design Service Volumes for Different Categories of Roads

Important Definitions

1. Capacity is defined as the maximum hourly volume (Vehicles per hour) at which vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under the prevailing roadway, traffic and control conditions.

2. Design service volume is defined as the maximum hourly volume at which vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under the prevailing roadway, traffic and control conditions while maintaining a designated level-of-service.

3. Level-of-Service (LOS) is defined as a qulitative measure describing operational conditions within a traffic stream and their perception by drivers/passengers.

Level-of-Service definition generally describes these conditions in terms of factors, such as, speed and travel time, freedom to manoeuvre, traffic interruptions, comfort, convenience and safety. Six levels*-of-service are recognized commonly, designated from 'A to F' with Level-of-Service 'A' representing the best operating condition, i.e., free flow and Level-of-Service 'F' the worst, i.e., forced or break-down flow.

* For details refer IRC:106 - "Guidelines for Capacity of Urban Roads in Plain Areas" and IRC:64 - "Guidelines for Capacity of Roads in Rural Areas".

Roads in Rural Areas

4.2.1. Recommended design service volume for single-lane, intermediate-lane and two-lane roads in rural areas are given in Tables 4.6, 4.7 and 4.8 respectively.

Table 4.6. Recommended design service volumes for single lane roads

S.No.	Terrain	Curvature (Degrees per kilometre)	Suggested Design Service Volume in PCU/day
1.	Plain	Low (0-50)	2000
		High (above 51)	1900
2.	Rolling	Low (0-100)	1800
		High (above 101)	1700
3.	Hilly	Low (0-200)	1600
		High (above 201)	1400

4.2.2. The values in Table 4.6 are applicable for 3.75 m wide black-topped pavements with good quality shoulders, such as, moorum shoulders of minimum 1.0 m width on either side. When the pavement is not black-topped the design service volume will be lower by 20-30 per cent. In locations where low quality earthen shoulders are available (such as, earthen shoulders made of plastic soil), the design service volume should be taken as 50 per cent of the given values in Table 4.6.

Table 4.7. Recommended design service for intermediate-lane roads

S.No.	Terrain	Curvature (Degrees per kilometre)	Design Service volume in PCU/day
1.	Plain	Low (0-50)	6,000
		High (above 51)	5,800
2.	Rolling	Low (0-100)	5,700
		High (above 101)	5,600
3.	Hilly	Low (0-200)	5,200
		High (above 201)	4,500

Table 4.8. Recommended design service volumes for two-lane roads

S.No.	Terrain	Curvature (Degrees per km.)	Design Service in Volume in PCU/day
1.	Plain	Low (0-50)	15,000
		High (above 51)	12,500
2.	Rolling	Low (0-100)	11,000
		High (above 101)	10,000
3.	Hilly	Low (0-200)	7,000
		High (above 201)	5,000

4.2.3. The values in Table 4.7 are applicable for 5.5 m wide black-topped pavements with good usable shoulders on either side.

4.2.4. The values recommended above are based on the assumptions that the road has 7 m wide carriageway and good earthen shoulders are available. The capacity figures relate to peak hour traffic in the range of 8-10 per cent and LOS 'B'.

4.2.5. The capacity of two-lane roads can be increased by providing paved and surfaced shoulders of at least 1.5 metre width on either side. Provision of paved shoulder 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 values given in Table 4.8.

4.2.6. Where shoulder width or carriageway width on a two-lane roads are restricted, there will be a certain reduction in capacity. Table 4.9 gives the recommended reduction factors on this account over the capacity values given in Table 4.8.

Table 4.9. Capacity reduction factors suggested for substandard lane and shoulder width on two-lane roads

Usable* shoulder width (m)	3.50 m lane	3.25 m lane	3.00 m lane
≥1.8	1.00	0.92	0.84
1.2	0.92	0.85	0.77
0.6	0.81	0.75	0.68
0	0.70	0.64	0.58

* Usable shoulder width refers to well-maintained earth/moorum/ gravel shoulders which can safely permit occasional passage of vehicles.

4.2.7. Sufficient information about the capacity of multi-lane roads under the mixed traffic conditions is not yet available. Capacity on dual carriageway roads can also be affected by factors, like, kerb shyness on the median side, vehicle parking, etc. Tentatively, a value of 35,000 PCUs can be adopted for four-lane divided carriageways located in plain terrain. It is assumed for this purpose that reasonable good earthen shoulders exist on the outer side, and a minimum 3.0 m wide central verge exists. In case well designed paved shoulders of 1.5 m width are provided, the capacity value of four-lane dual roads can be taken upto 40,000 PCUs.

Roads in Urban Areas

4.2.8. Design service volumes for urban roads in plain areas for different pavement widths are given in Table 4.10.

Table 4.10. Recommended design service volume (PCUs per hour)

Sr. No.	Type of Carriageway	Total design service volumes for different categories of urban roads		
		Arterial*	Sub-Arterial**	Collector***
1.	2-Lane (one-way)	2400	1900	1400
2.	2-Lane (two-way)	1500	1200	900
3.	3-Lane (one-way)	3600	2900	2200
4.	4-Lane Undivided (two-way)	3000	2400	1800
5.	4-Lane Divided (two-way)	3600	2900	-
6.	6-Lane Undivided (two-way)	4800	3800	-
7.	6-Lane Divided (two-way)	5400	4300	-
8.	8-Lane Divided (two-way)	7200	-	-

* Roads with no frontage access, no standing vehicles, very little cross traffic.

** Roads with frontage access but no standing vehicles and high capacity intersections.

*** Roads with free frontage access, praked vehicles and heavy cross traffic.

4.3. Traffic Signs

4.3.1. Complete details of the signs including guidelines on their erection are contained in IRC:67 "Code of Practice for Road Signs". Brief particulars of the sign system are given below :

4.3.2. Classification of signs

Manadatory/Regulatory : These inform the road users of laws and regulations. Violation is a legal offence.

Cautionary/Warning	:	Warn road users of the existence of certain hazardous conditions.
Informatory	:	For information and guidance of road users.

4.3.3. **Sizes of signs** : The recommended sizes for the traffic signs are shown in Table 4.11. Two sizes of mandatory and cautionary signs have been prescribed. The normal size is to be used for main roads in rural areas, and the smaller size for less important roads in rural areas and roads in urban areas. On expressways, bigger than normal sizes may be used.

Table 4.11. Sizes for traffic signs

Sign	Height/Diameter/Side Normal sized cm	 Small sized cm
Mandatory		
Stop sign	90	60
Give way	90 (side)	60
Others (circular)	90 (dia)	60 (dia)
Warning		
Triangular	90 (side)	60 (side)
Informatory		
Rectangular	80 x 60	60

4.3.4. **Retro-reflective signs** : As far as possible retro-reflective signs made of Engineering Grade Sheeting or of High Intensity Grade Sheeting with encapsulated lens as per Ministry's Specification may be used.

4.3.5. **Shape** : For mandatory signs, the general shape is circular except for STOP (Octagonal) and GIVE WAY (inverted triangle). The warning signs have the shape of equilateral triangle with apex pointing upwards, red border and black symbols on white background. The informatory signs are generally rectangular in shape.

4.3.6. **Colour** : Colour of signs should be as shown on detailed drawings, IRC:67. The reverse should be painted grey. The sign posts (except for level crossing signs) should be painted in 25 cm wide bands alternately black and white.

4.3.7. **Urban locations** : In urban locations, the warning signs should be located at about 50 metre away from the points of hazard. Distance may be increased or decreased to suit site conditions. The siting of signs may be made as indicated in Table 4.12

4.3.8. **Mandatory/regulatory signs :** Some of the mandatory signs are shown in Fig. 4.1.

4.3.9. **Cautionary/warning signs :** A few of the Cautionary/ Warning signs are shown in Fig. 4.2. (a, b and c).

4.3.10. **Informatory signs :** A few of the Informatory signs are shown in Fig. 4.3.

Table 4.12. Siting of signs

	Kerbed roads	Unkerbed roads
Min. lateral clearance from carriageway edge	60 cm	2 - 3 m
Min. vertical clearance	2 m above kerb	1.5 m above pavement crown

4.3.11. **Guidelines on use of retro-reflective sheetings for road signs**

4.3.11.1. Retro-reflective sheetings of high intensity grade shall be used for :

i) All road signs on 4-lane National Highway Sections and two-lane sections which are to be widened to four-lanes.

ii) Mandatory/regulatory and cautionary/warning signs on two-lane National Highway section.

iii) All overhead signs.

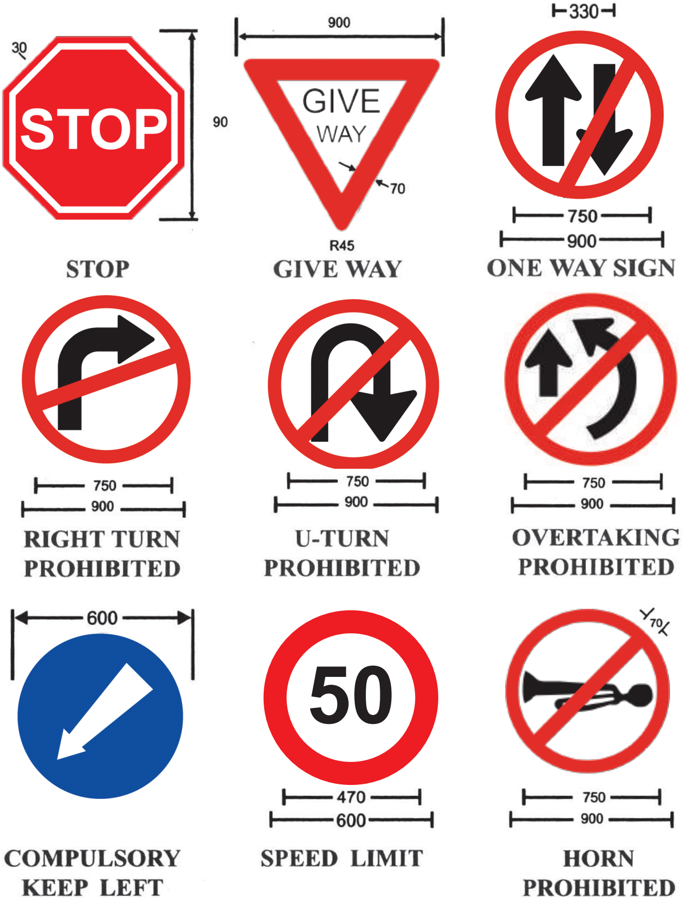


Fig. 4.1. Some of the mandatory/regulatory signs

4.3.11.2. Retro reflective sheetings of 'engineering grade' shall be used for informatory signs for two-lane Natioanl Highway sections.

4.3.12. **Colour scheme**

4.3.12.1. Colour scheme for manadatory/regulatory and cautionary warning signs shall be conform to IRC:67 “Code of Practice for Road Signs”.

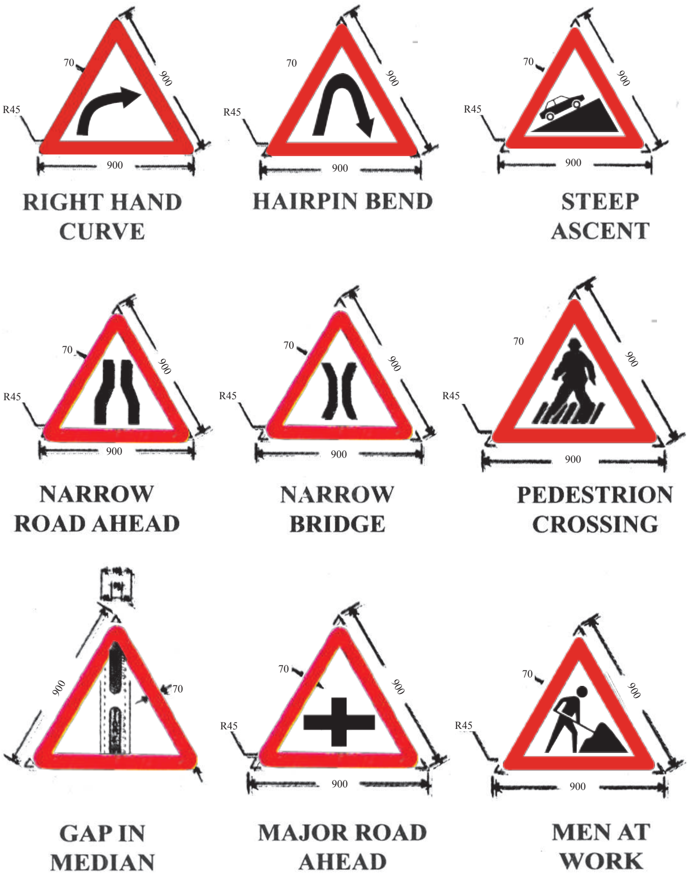
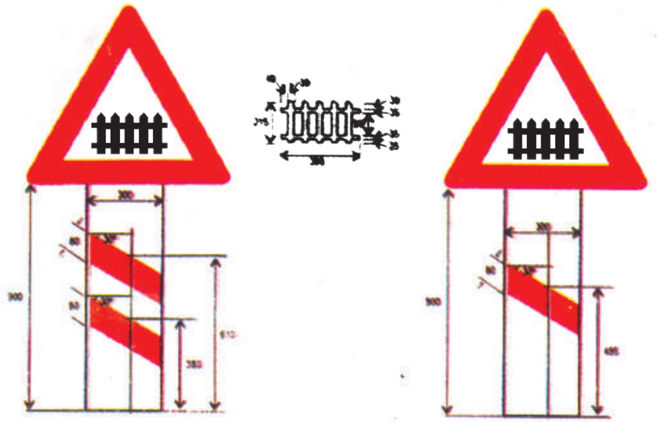


Fig. 4.2. (a) Some of the cautionary signs

4.3.12.2. Direction, destination and place identifications signs have been green background, white messages and borders.

4.3.12.3. Colour scheme for facility information signs and parking signs shall be as per IRC:67.

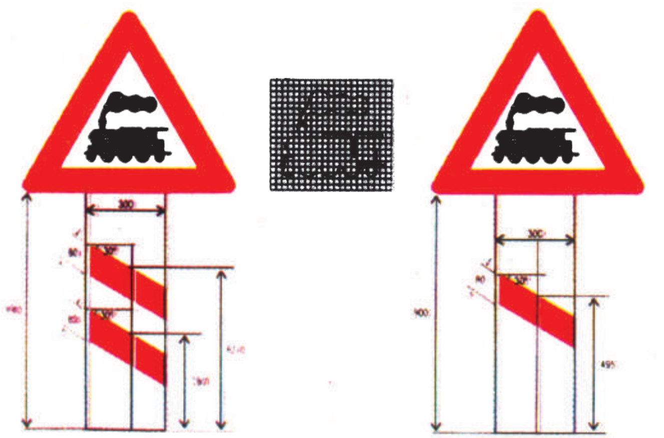
4.3.13. Private participations in provision of retro-reflective road signs.



200 METRES

50-100 METRES IN PLAIN & ROLLING TERRAIN AND 30-60 METRES IN HILLY TERRAIN

Fig. 4.2. (b) Guarded railway crossing
(For each crossing, both signs are to be at distances indicated above)



200 METRES

50-100 METRES IN PLAIN & ROLLING TERRAIN AND 30-60 METRES IN HILLY TERRAIN

Fig. 4.2. (c) Unguarded railway crossing
(For each crossing, both signs are to be at distances indicated above)

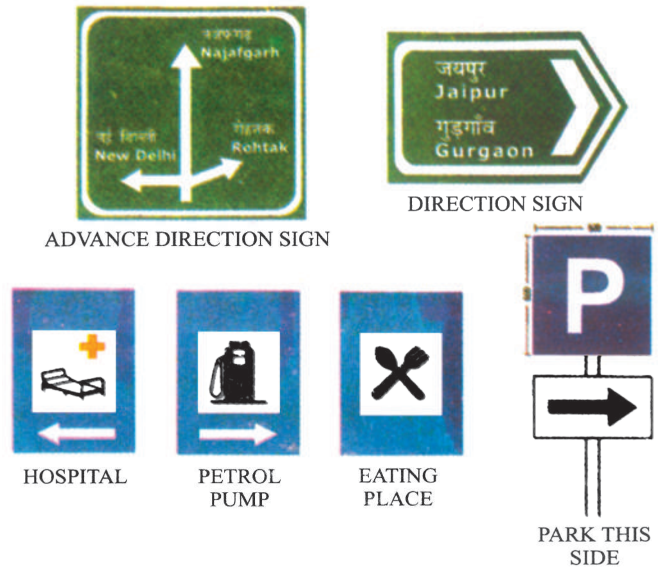


Fig. 4.3. Some of the informatory signs

4.3.13.1. As per Ministry's policy circular issued vide letter No. RW/NH-33023/31/88/DO.III dated 22-03-96, 19-03-97 and 9-02-98, privately sponsored retro-reflective signs can be allowed in selected locations, provided that the advertisement display is regulated by restricting it to the name and logo only of the firms and without unduly affecting the aesthetics of the highway and attentions of the drivers. General guidelines and technical specifications to be followed for such privately sponsored road signs are given in Ministry's circulars.

4.4. Road Markings

4.4.1. Markings on the carriageway and on the objects within and adjacent to the roadway are used as a means of guiding and controlling the traffic. They promote road safety and ensure smooth flow of traffic into the required paths of travel. Complete details of the Road Markings and guidelines for their usage are contained in IRC:35 "Code of Practice for Road Markings" and Ministry's "Specifications for Road and Bridge Works (Fourth Revision)".

4.4.2. **Types of carriageway marking lines**

4.4.2.1. A broken longitudinal line is used for indicating the centre line on two and three-lane roads and for lane marking on multi-lane roads. Drivers may cross these at their discretion, if traffic permits.

4.4.2.2. Longitudinal solid lines are used as guiding or regulating lines and are not meant to be crossed by the driver except for entry or exit from a premises or a side road or to avoid a stationary obstruction.

4.4.2.3. Double solid lines indicate maximum restriction and arenot to be crossed except in emergent usage.

4.4.2.4. In a combination of broken and solid lines, a solid line may be crossed, with discretion, if the broken line of the combination is nearer to the direction of travel. Vehicles from opposite directions arenot permitted to cross the solid lines.

4.4.2.5. Solid lines either parallel to the intersecting roadway or at right angles to the direction of approaching traffic mark the position of a stop line before the road junction. Stop line indicates the position beyond which the vehicles should not proceed when required to stop by the traffic police, traffic signals or other traffic control devices. Stop lines shall not be used unless traffic control by anyone ofthese means exist.

4.4.3. **Material and Colour**

4.4.3.1. The material commonly employed for pavement, kerb and object marking is paint. Reflectorised paint have better night visibility and last longer and, therefore, not applied thermoplastic paints instead of ordinary paints, wherever feasible may be used. For specifications on road marking materials including thermoplastic paints, reference may be made to Clause 803 of the Ministry's "specification for Road and Bridge Works".

4.4.3.2. The commonly used colour for road markings are yellow, white and black. The usage of these is summarised in Table 4.13.

Table 4.13. Colour of road markings as per Indian practice

Colour of road markings		Uses
i)	White	All carriagway markings except those intended for parking restrictions, obstruction approach, no overtaking zone and continuous centre line. Objects adjacent to carriageway, such as, guard rails, guard stones or drums and trees. Trees shall be painted solid white upto a height of 1.25 m above the road level with a 300 mm band in black paint in the middle of this height for enhanced visibility that are not likely to be hit unless a vehicle runs pff the carriageway.
ii)	Yellow	i) Markings intended for parking restrictions. ii) Continuous centre and barrier line markings.
iii)	Alternating black and yellow strips	Markings on obstructions in the carriageway
iv)	Alternating white, black and stripes	Markings on kerbs and objects adjacent to carriageway (e.g., subway piers and abutments culvert head walls, poles)

4.4.4. **Centre lines and lane lining:** A centre line marking is employed for separating traffic in opposite directions, whereas, lane lines divide wide carriageway into separate lanes on either side of the centre line to regulate traffic into proper lanes and curb the meandering tendency of the drivers, thereby promoting safety and ensuring maximum capacity. Figs. 4.4. to 4.7 show the recommended practice of centre lines and lane lines.

4.4.5. **No overtaking zones:** No overtaking zones on horizontal and vertical curves are marked in Figs, 4.8 (a) and 4.8 (b) respectively. Barrier distance on no overtaking zone is given in Table 4.14.

Table 4.14. Barrier line distance on no-overtaking zone

85th percentile speed (kmph)	Intermediate sight distance	Barrier line distance (m)
Upto 45	120	75
46-55	150	100
56-65	180	120
66-75	210	145
76-85	240	170
86-95	270	190
96-105	300	215
More than 105	300	240

4.4.6. **Intersections, carriageway transitions, transition of median width, obstructions, road rail level crossings, parking spaces, but stops, kerb, speed breakers**: Figs. 4.9 to 4.32 show the road markings for the above mentioned situations.

4.5. Road Delineators

4.5.1. The role of delineators is to provide visual assistance to drivers about alignment of the road ahead, especially at night. Reflectors are used on the delineators for better night visibility. Delineators are classified under three types :

i) **Roadway Indicators** : These are intended to delineate the edges of the roadway so as to guide drivers about the alignment ahead, particularly where it might be confusing for some reason. As a general rule, delineators posts should be erected at the edge of usable shoulder, and in the case of kerbed sections at a distance of 0.6 m to 1.5 m from the kerb face on hill roads, these may be placed either on the parapet or at the edge of the shoulder. Roadway indicators have been shown in Fig. 4.33.

ii) **Hazard Markers** : These are to define obstruction, like, guard-rails and abutments adjacent to the carriageway, for instance at culverts and bridges which are narrower than the roadway sideth at approaches. Hazard markers are shown in Fig. 4.34.

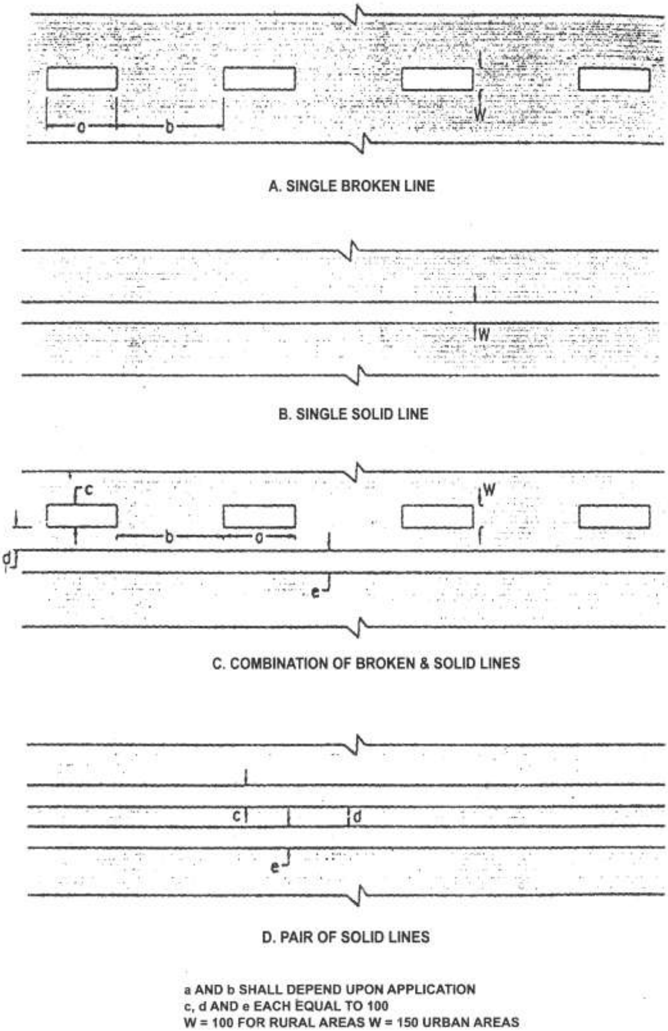


Fig. 4.4. Recommended size of longitudinal marking

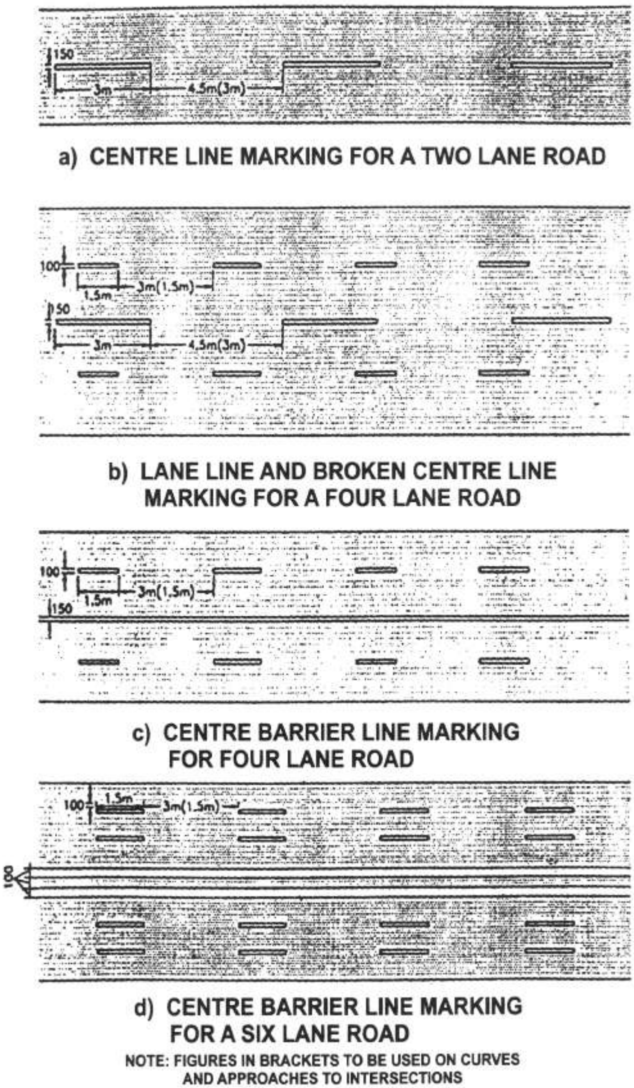


Fig. 4.5. Centre line and lane line marking for urban areas

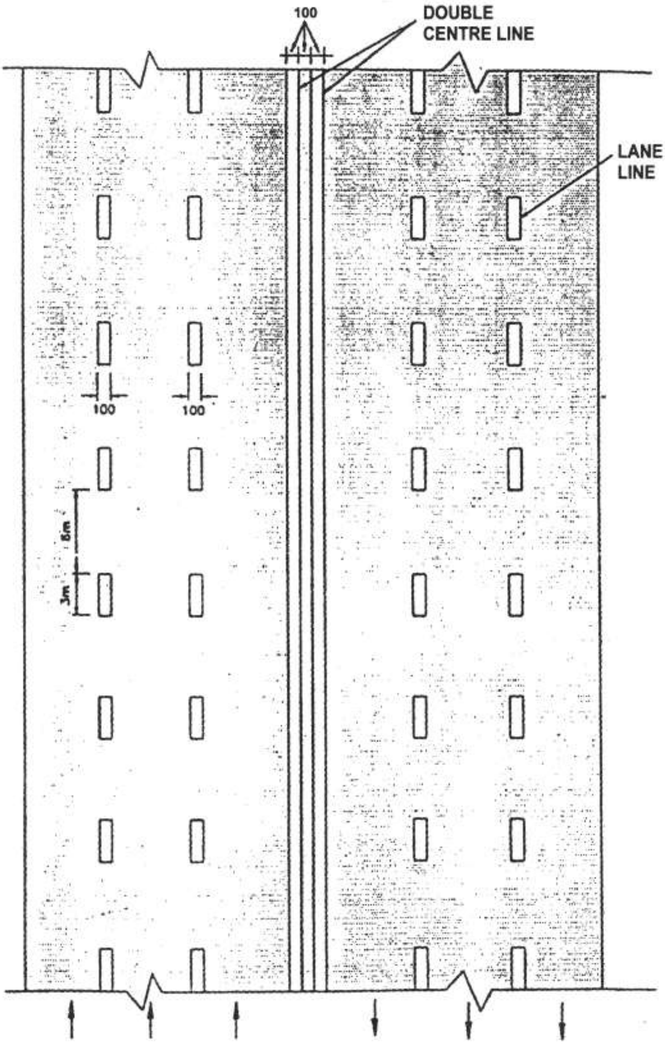


Fig. 4.6. Lane lines on a six-lane rural road straight stretch

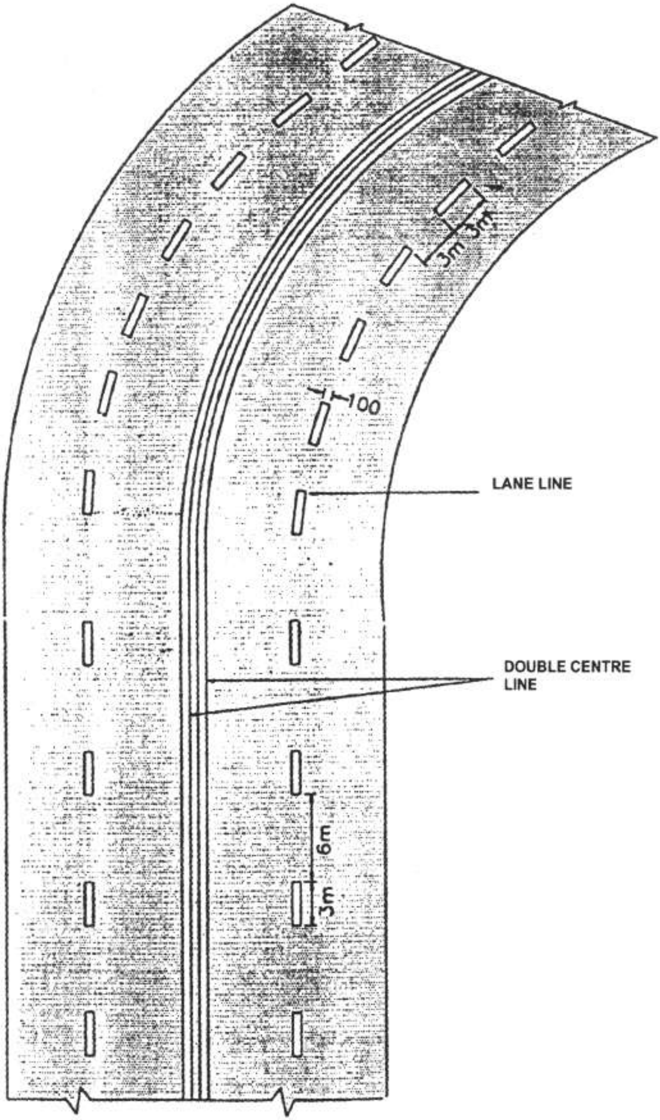
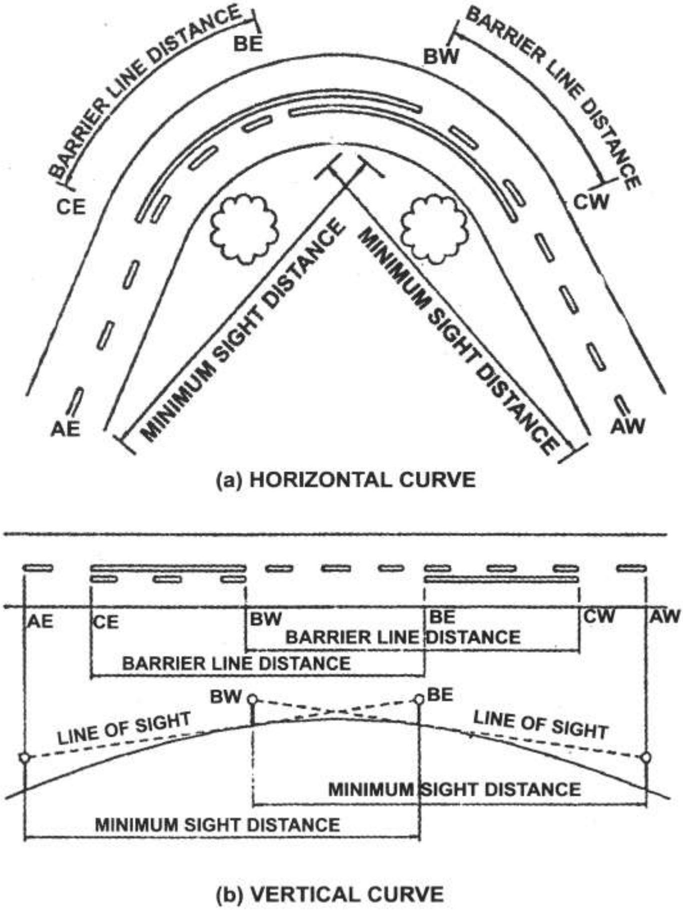


Fig. 4.7. Centre line and lane markings at curves on NH and SH in rural areas



AE-BE REPRESENT THE PORTION WHERE THE SIGHT DISTANCE STARTS FALLING BELLOW THE MINIMUM]PERMISSIBLE LIMITS.
AW-BW REPRESENT THE PORTION WHERE THE SIGHT DISTANCE IS REGAINED.
BARRIER DISTANCE AS PER TABLE 4.14

Fig. 4.8. Method of locating no-overtaking zones on isolated curves

iii) **Object Markers** : These are used to indicate hazards and obstructions within the vehicle flow path, for example channelising islands close to intersections. Typical designs of object markers are shown in Fig. 4.35.

4.5.2. Details regarding design, application and placement, installation and maintenance of road delineators have been included in IRC:79 "Recommended Practice for Road Delineators".

4.6. Reflective Pavement Markers

4.6.1. Road pavement markers of road studs are being increasingly used on the roads for lane marking and delineation for night, time visibility. Ministry has vide letter No.RW/NH-33023/10/97-DO.III dated 11-06-97 circulated tentative specifications for these pavement markers. These specifications prescribe a two year warranty for satisfactory infield performance of the finished road markers.

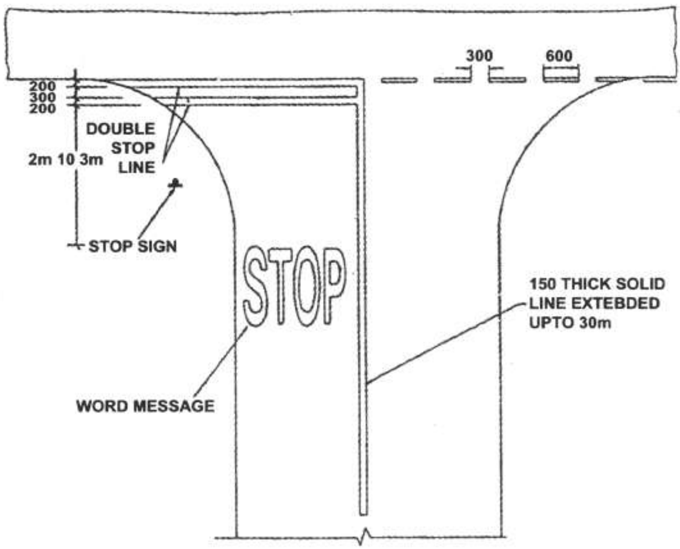


Fig. 4.9. Stop line markings for use with stop sign

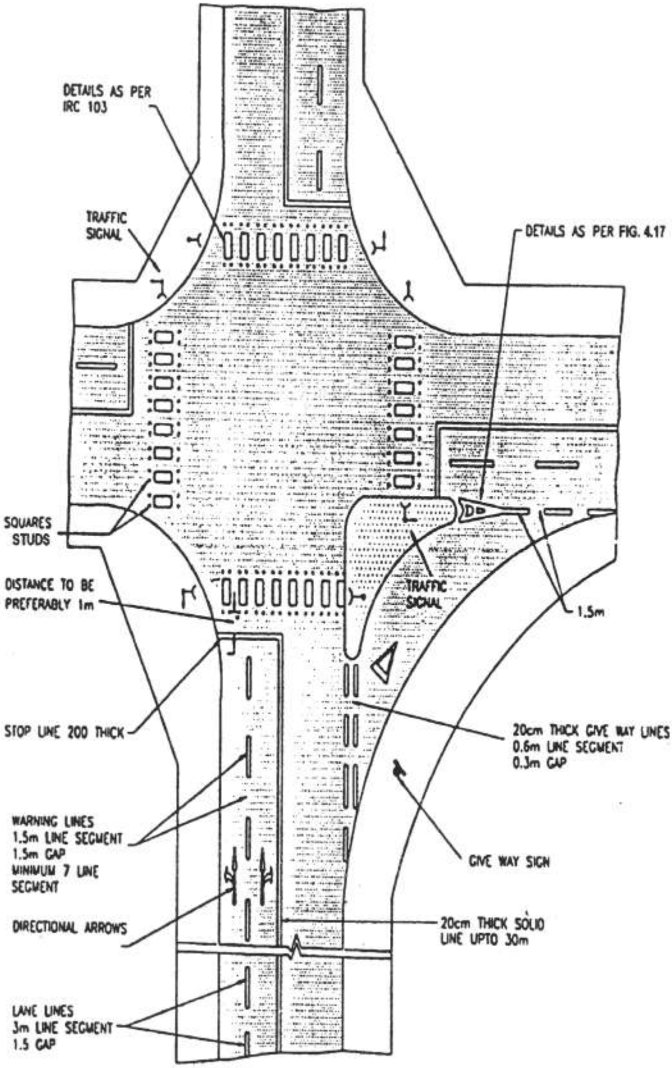
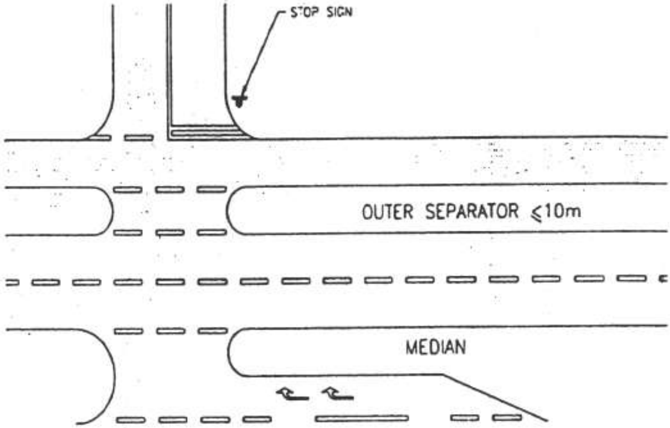
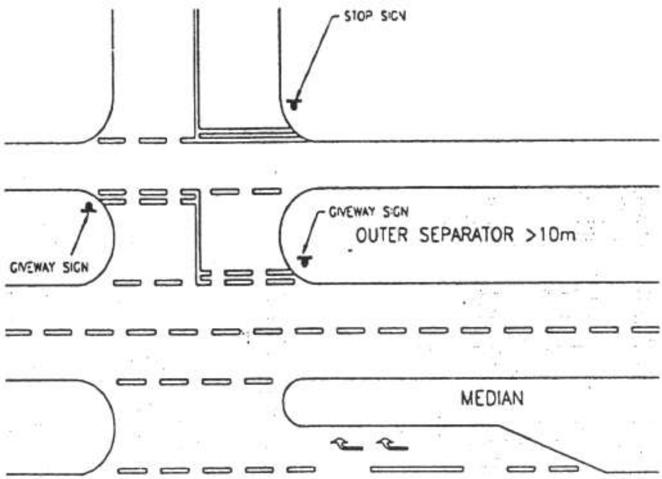


Fig. 4.10. Markings at signal controlled urban intersections



(a) OUTER SEPARATOR UPTO 10m WIDTH



(b) OUTER SEPARATOR WIDER THAN 10m

Fig. 4.11. Stop line with priority to service road

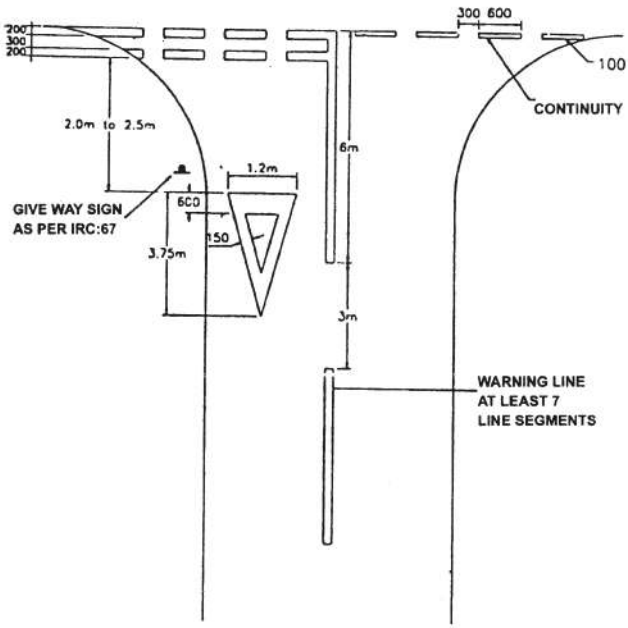


Fig. 4.12. Markings for give way lines

4.7. Road Intersections

4.7.1. **General :** An intersection, where vehicles change their travel routes or cross another traffic stream, presents the driver with added tasks and possible conflicts. The driver will have to carry out different manoeuvers, like, diverging, merging, weaving, crossing, etc., and this calls for adjustment in his speed for lateral shifting of his position with respect to other road users. If not properly designed and notified through signs and markings, an intersection area may be full of surprises to a driver and this in turn increases vulnerability to accidents. Studies have shown that the number of intersections in unit length of road is highly significant as an accident causative factor.

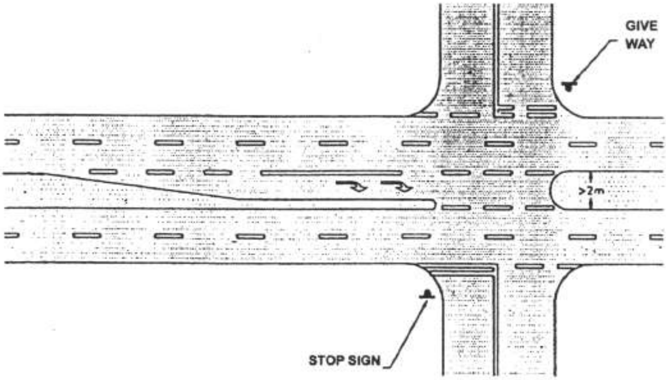


Fig. 4.13. Typical usage of give way and stop lines

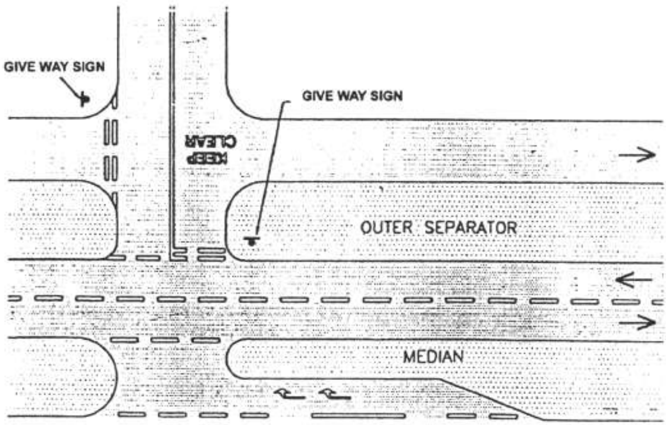


Fig. 4.14. Give way and stop markings

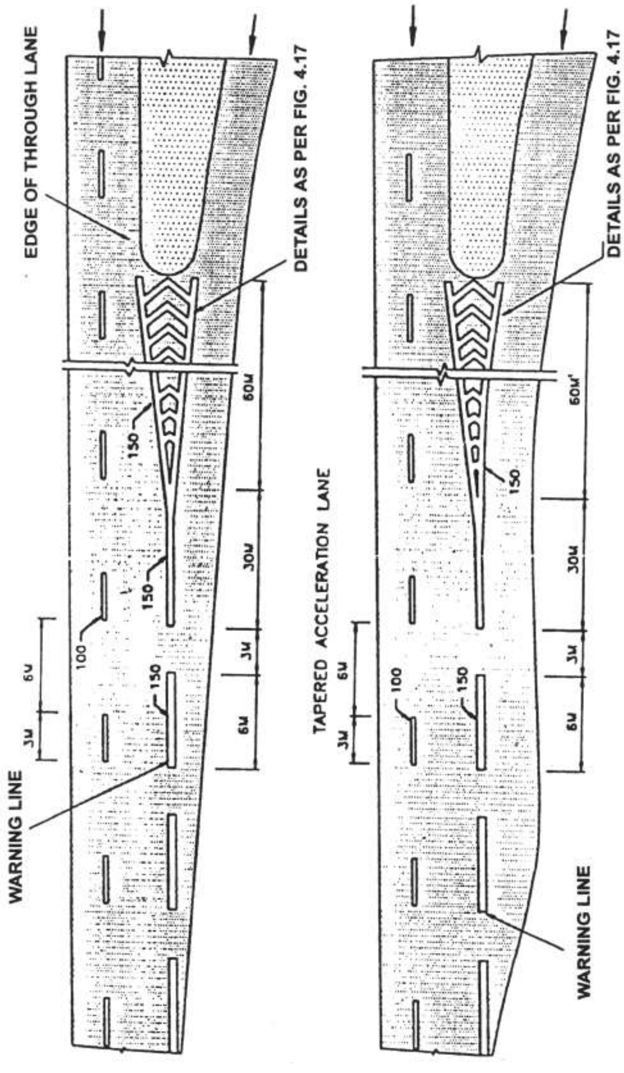


Fig. 4.15. Markings for acceleration lane

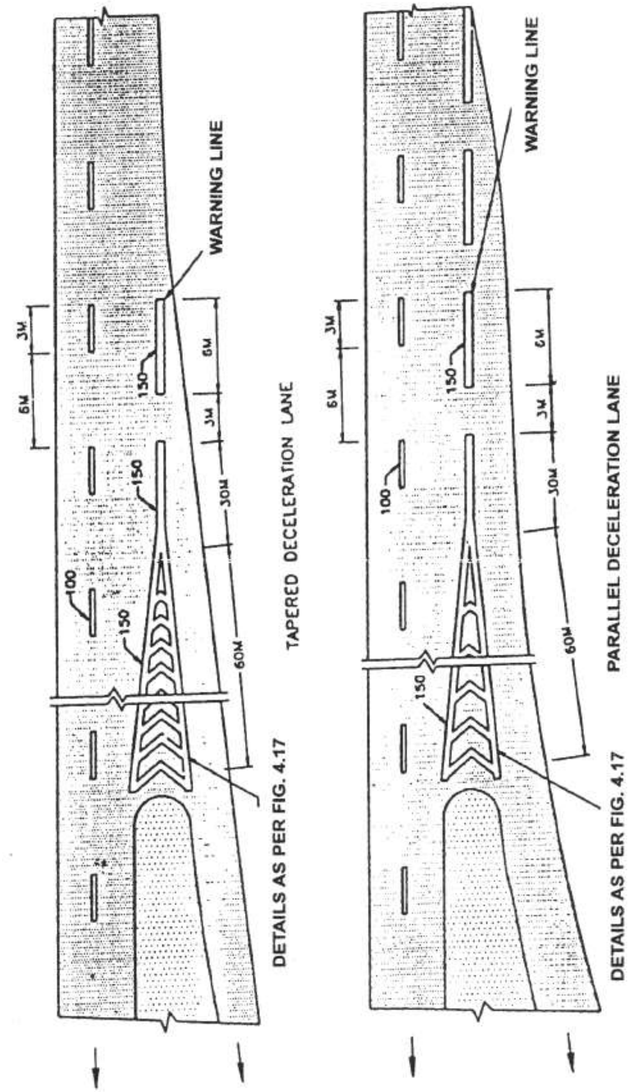


Fig. 4.16. Markings for deceleration lane

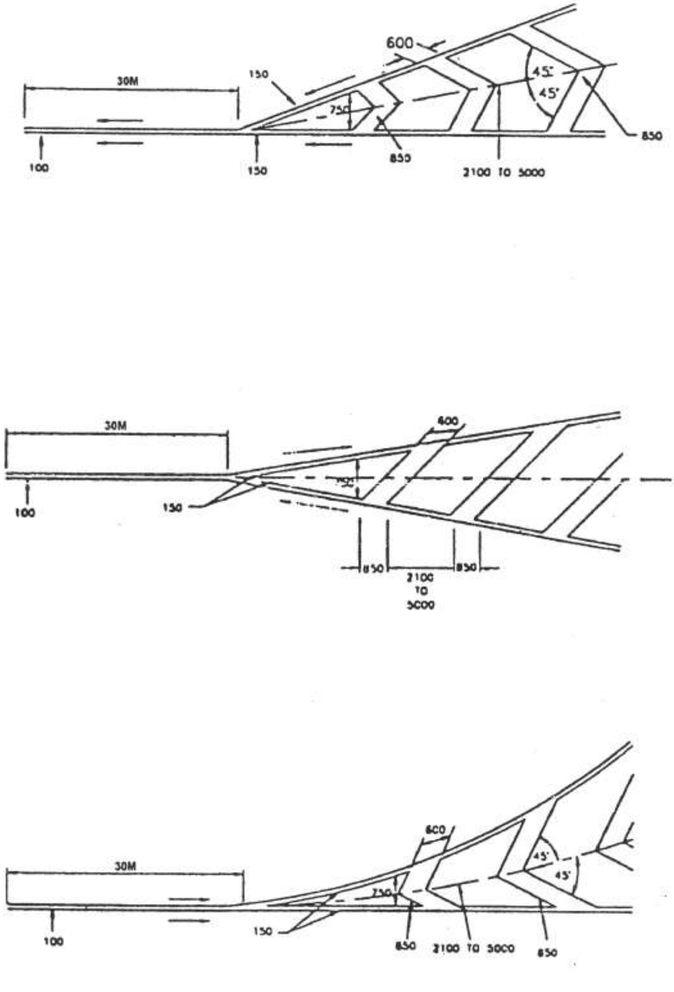


Fig. 4.17. Details of diagonal and chevron markings

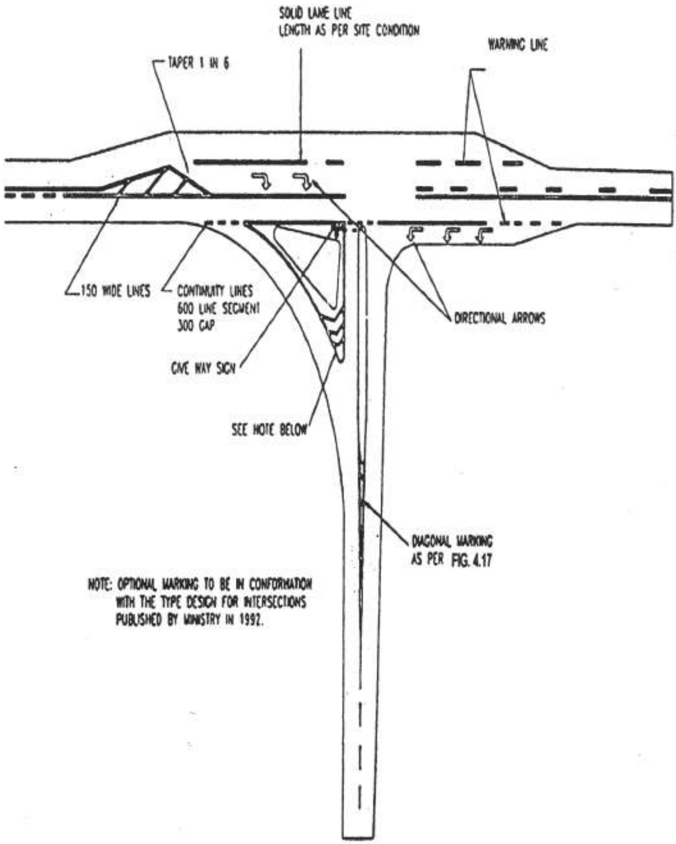


Fig. 4.18. Protected right turn lane

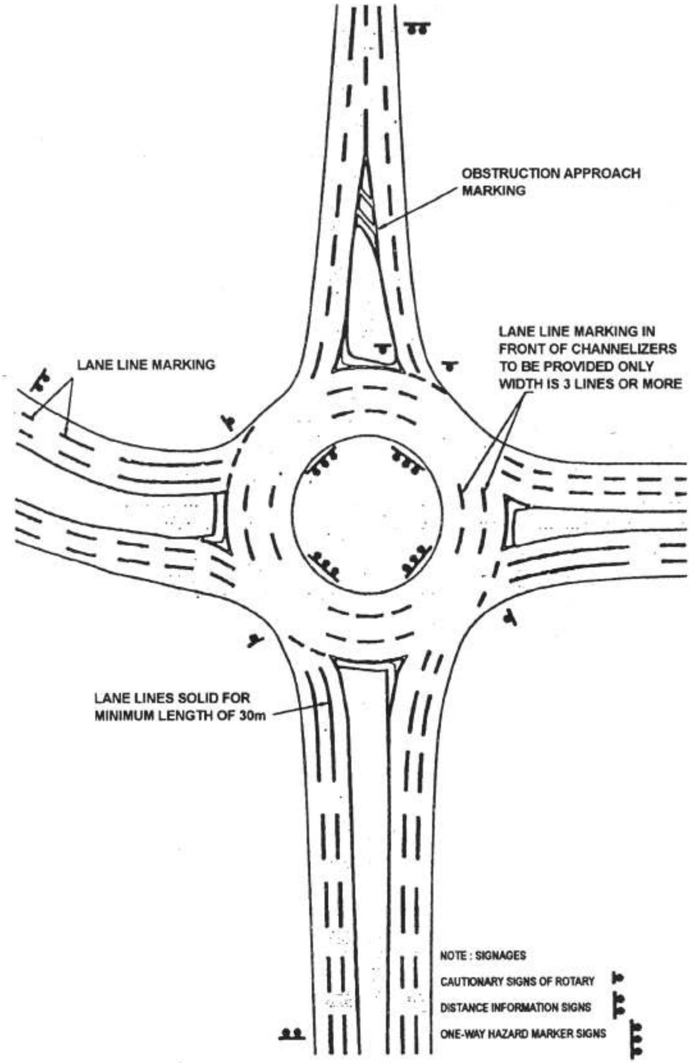


Fig. 4.19. Typical road markings at rotaries

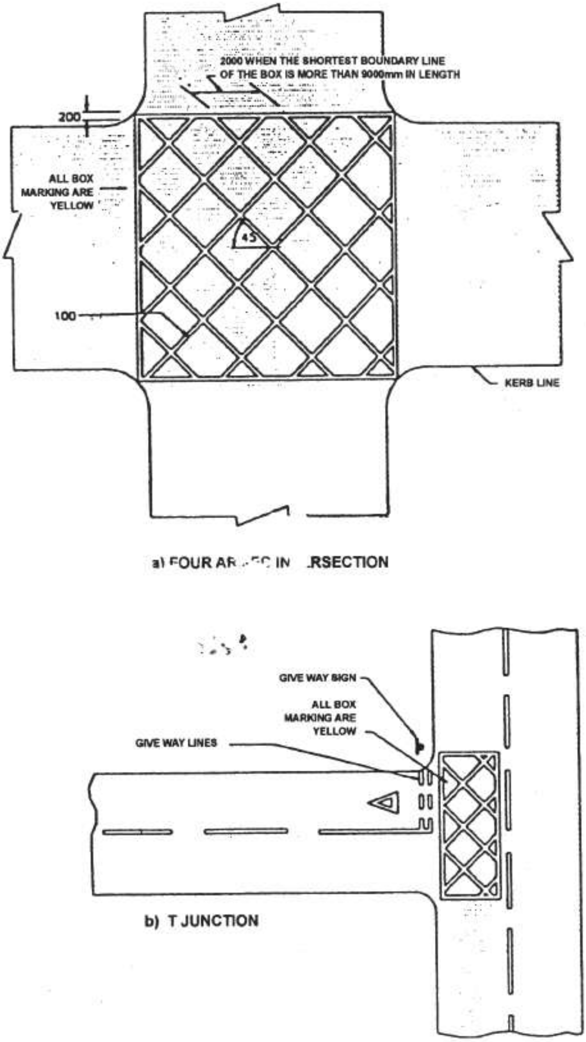
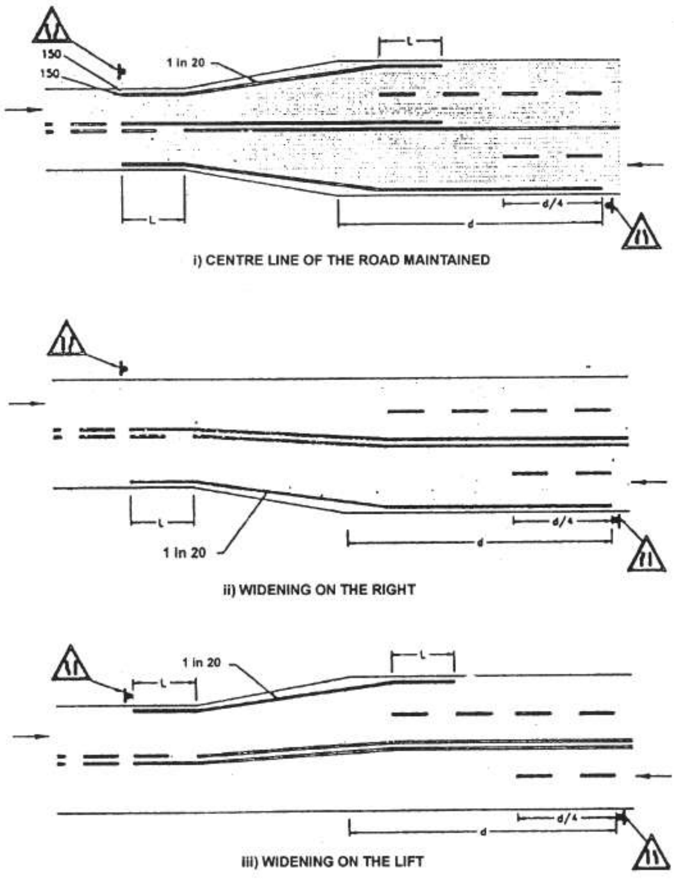


Fig. 4.20. Typical box junction (keep clear) markings



i) CENTRE LINE OF THE ROAD MAINTAINED

ii) WIDENING ON THE RIGHT

iii) WIDENING ON THE LIFT

(a) WIDENING OF TWO LANES TO FOUR LANES
L = 45m for N.H. and S.H. and 22.5m for other Roads.
d = 120m for N.H. and S.H. and 60m for other Roads.

Fig. 4.21. Carriageway transition markings

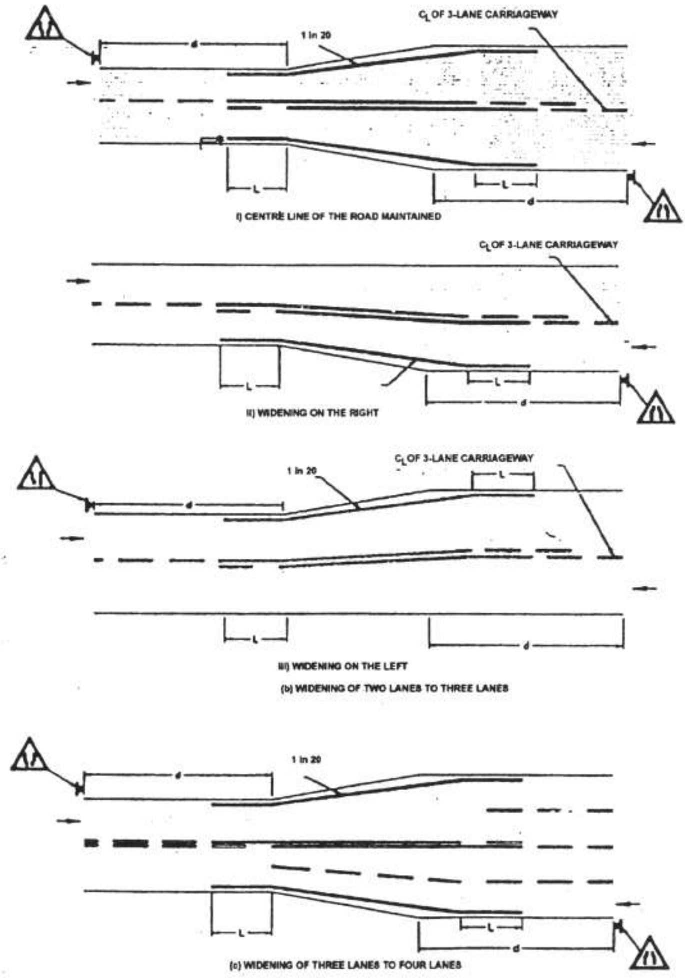


Fig. 4.22. Carriageway transition markings

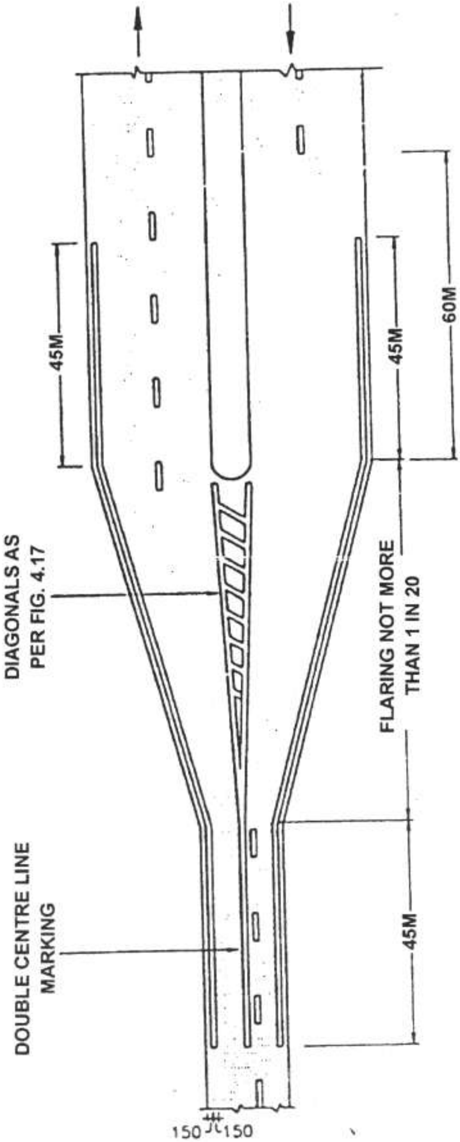


Fig. 4.23. Markings on transition from 2-lane undivided carrigeway (no shift in centre line)

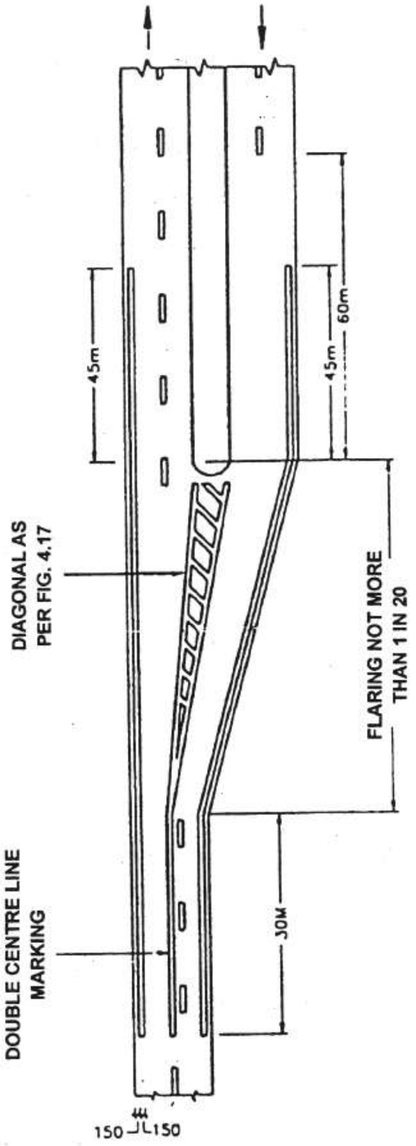
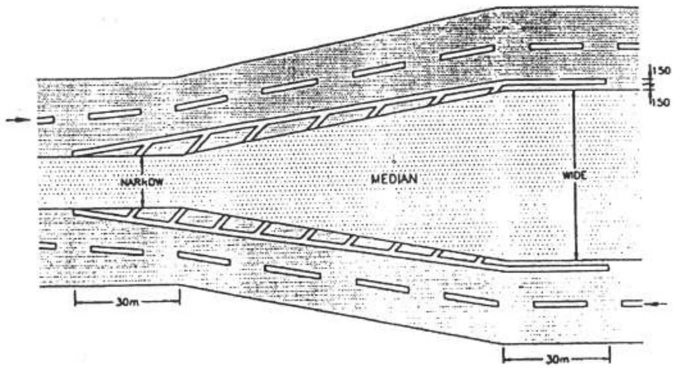
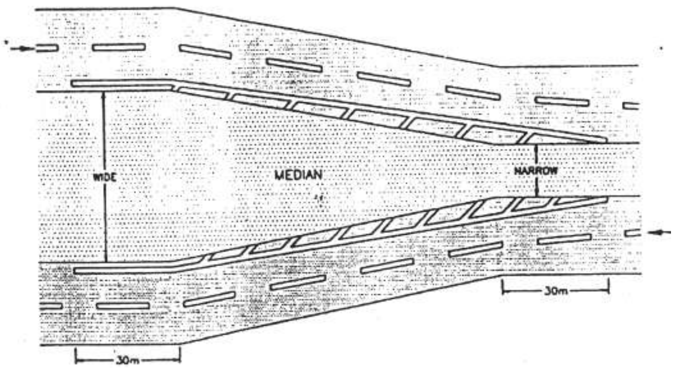


Fig. 4.24. Markings on transition from 2-lane undivided to 4-lane divided carriageway (centre line shifted)

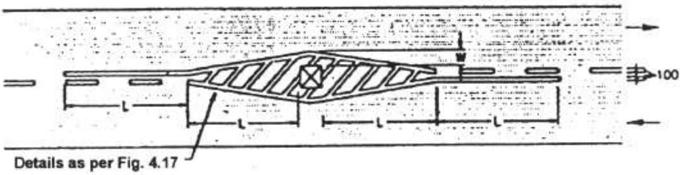


(a) WIDENING OF MEDIAN WIDTH

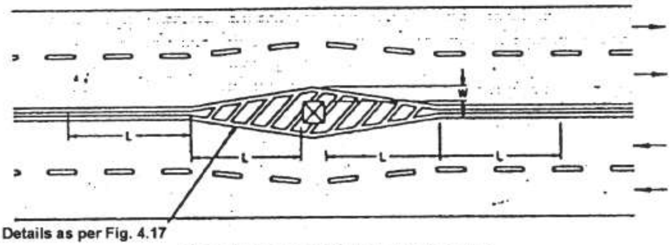


(b) NARROWING OF MEDIAN WIDTH

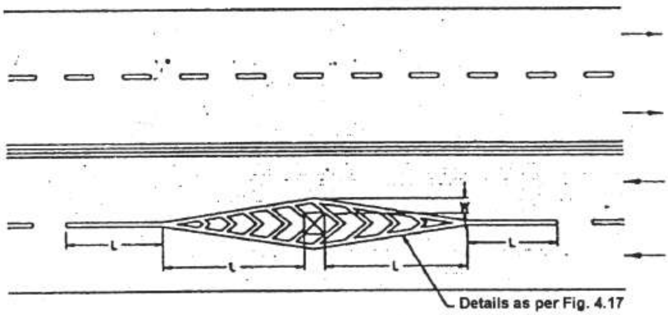
Fig. 4.25. Marking in transition of median width



a) CENTRE OF TWO LANE ROAD



b) CENTRE OF FOUR LANE ROAD



c) TRAFFIC PASSING ON BOTH SIDES OF OBSTRUCTION

Notes : i) Obstruction shown as ⊠

ii) For speeds more than 60 kph, $L = 0.63 \times S \times W$

iii) For speeds 60 kph or less; $L = \dfrac{WS^2}{150}$

Where S = 85m percentile speed in kph

W = offset distance in m

Minimum length of

L = 30m in Urban Area

= 60m in Rural Area

Length 'L' should be extented as required by sign distance considerations.

Fig. 4.26. Typical approach markings for obstructions in the roadway

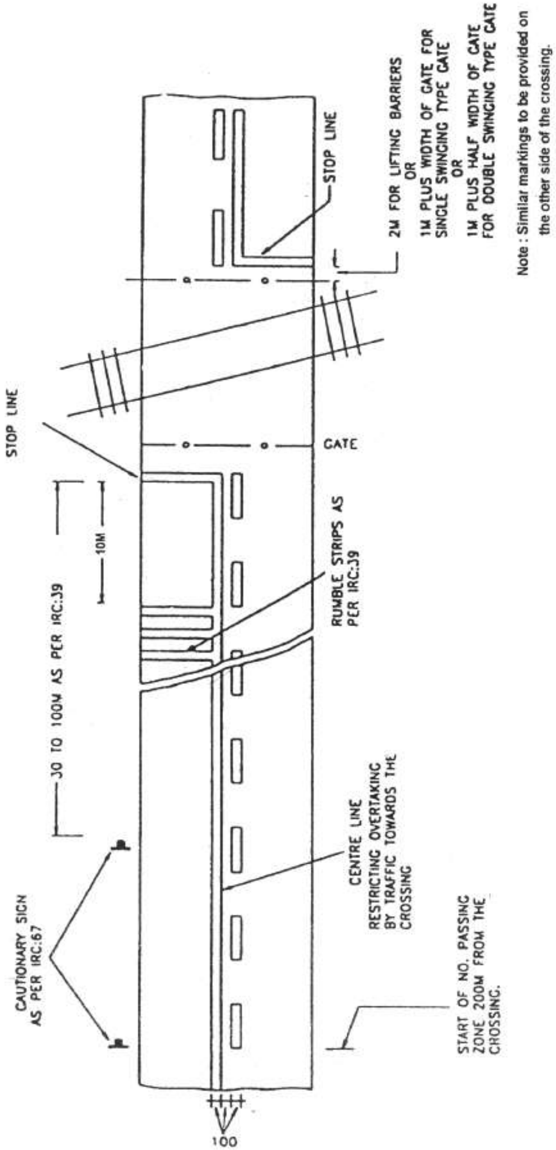


Fig. 4.27. Typical pavement markings at road-rail level crossing

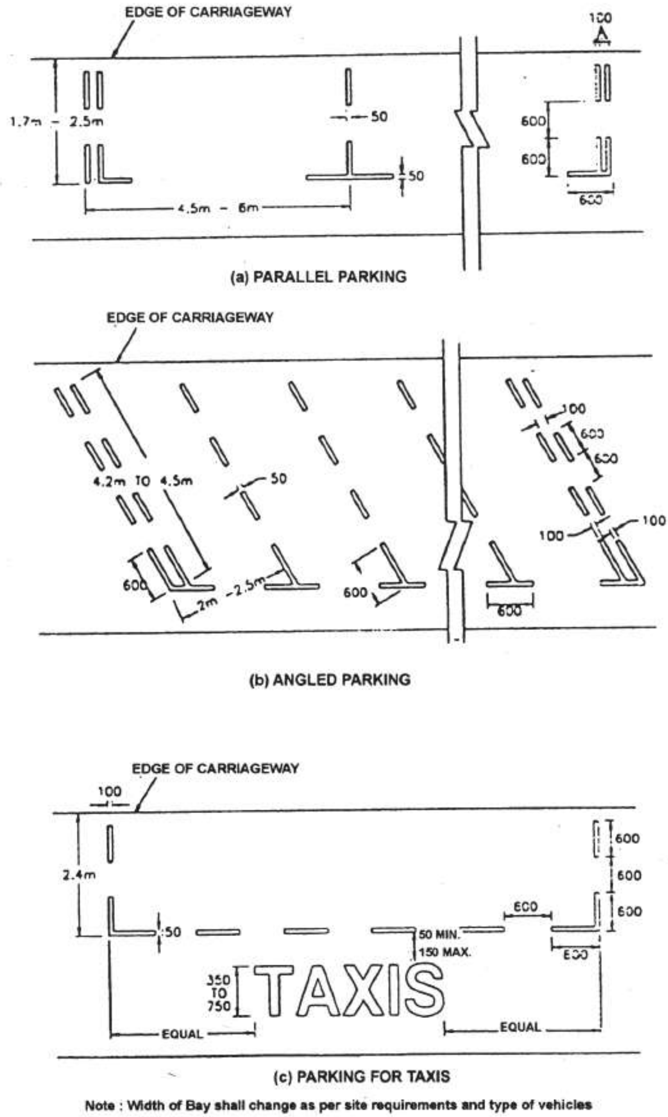


Fig. 4.28. Typical markings for parking spaces

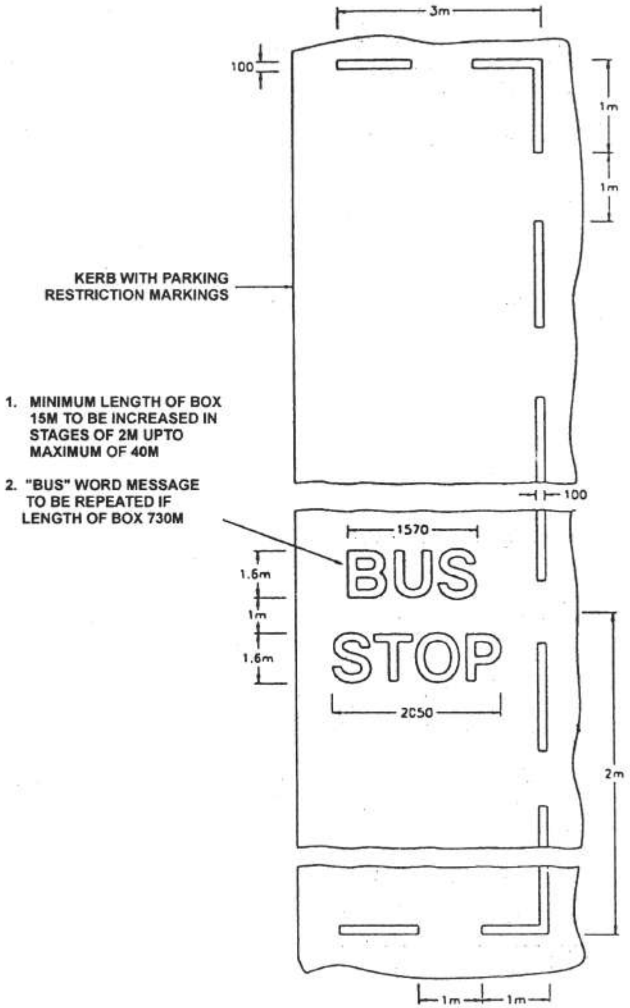


Fig. 4.29. Markings at bus stop

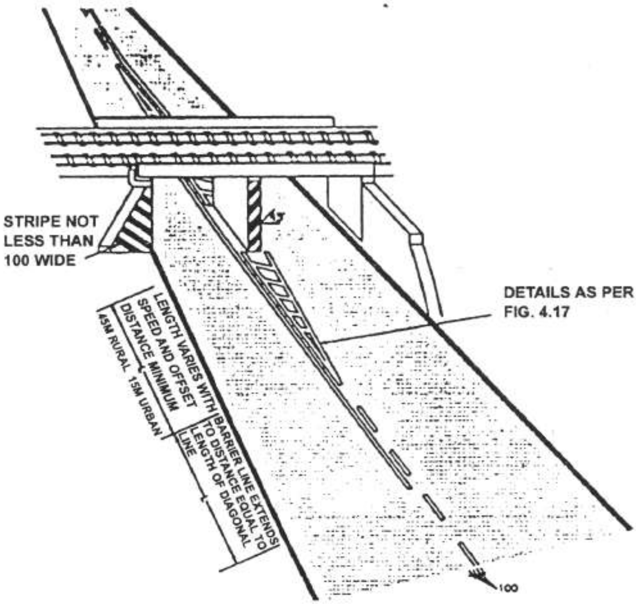


Fig. 4.30. Typical markings on objects in and adjacent to the roadway

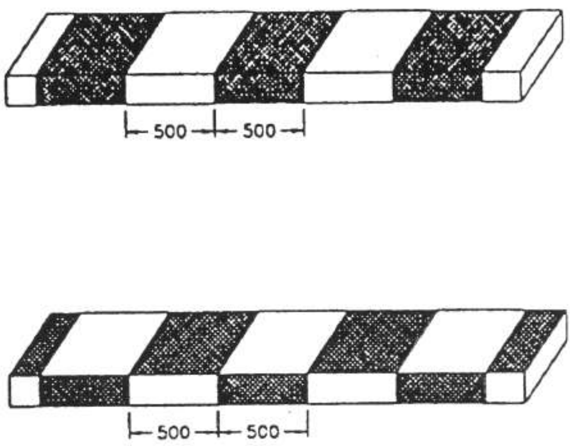


Fig. 4.31. KERB markings

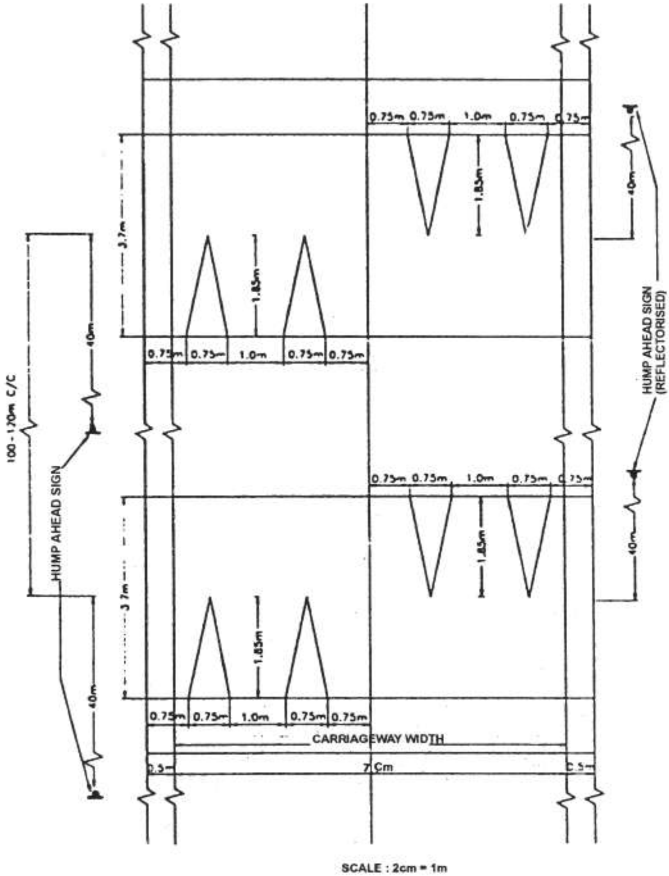


Fig. 4.32. Markings on speed breakers

4.7.2. Intersection types

(1) Intersections are classified under two broad heads, namely, at-grade and grade-separated, depending on the treatment of crossing conflicts. In grade-separated intersection (commonly called an inter-change or flyover) one or more crossing conflicts are obviated by overbridges or underpasses.

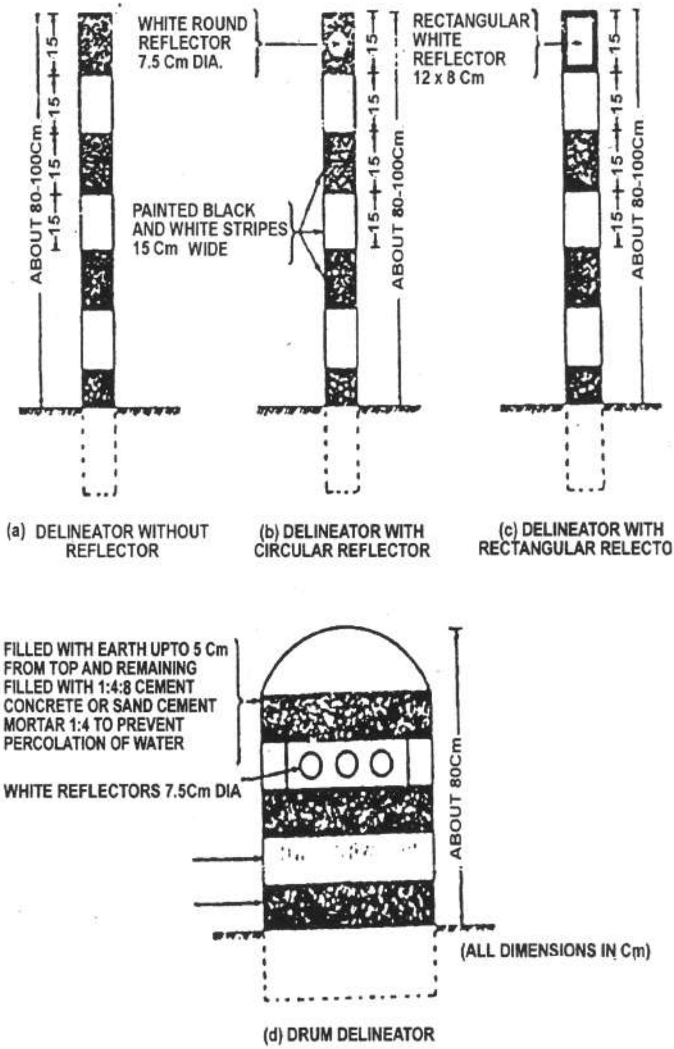


Fig. 4.33. Roadway indicators

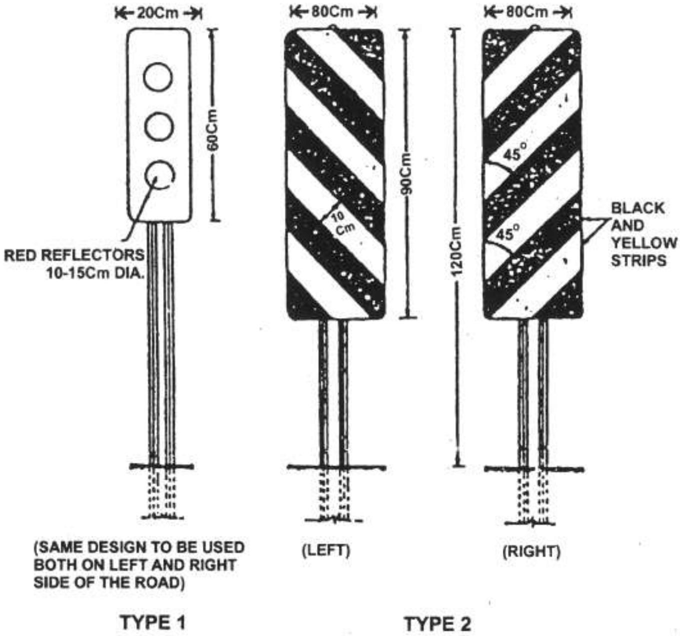


Fig. 4.34. Hazard markers

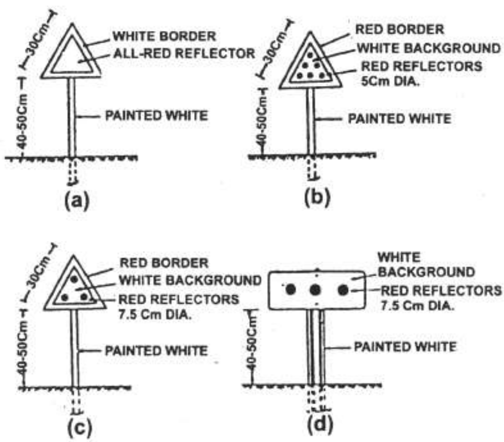
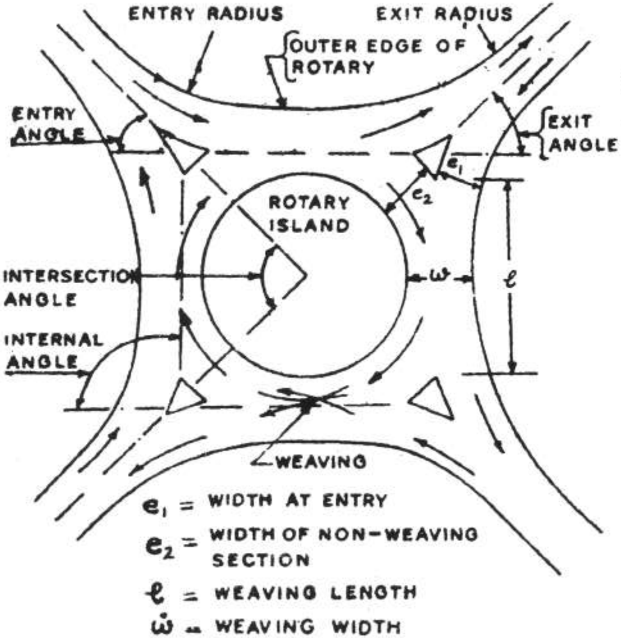


Fig. 4.35. Typical designs of object markers



DESIGN SPEED Km / h	ENTRY RADIUS (m)	WEAVING LENGTH (m)
40	20 − 35	45
30	15 − 25	30

RADIUS OF CENTRAL ISLAND TO BE EQUAL OR SLIGHTLY LARGER THAN ENTRY RADIUS
EXIT RADIUS TO BE 1·5 TO 2 TIMES ENTRY RADIUS.

CHOICE OF ROTARY

VOLUME − 500 TO 3000 Veh/ hr. RIGHT TURNING TRAFFIC EXCEEDS ABOUT 30% OF ALL APPROACHING TRAFFIC

Fig. 4.36. Broad design features of rotary intersection

(2) At-grade intersections may be sub-divided :

i)	by number or shape	-	"T", "Y", Scissor, cross, staggered, staggered and skewed, and multiway.
ii)	by separation of travel paths	-	Channelised
iii)	by type of control	-	Uncontrolled (intersection of two roads, with relatively lower volume of traffic and traffic of same priority where vehicles adjust their speeds rather than stopping), and priority controlled (where there is theoretically no delay occurring on the major road and vehicles on minor road are controlled by "GIVE WAY" or "STOP" sign).
iv)	by conversion of crossing into weaving manoeuvre	-	Rotary or round-about
v)	by separation in time	-	Signal controlled
vi)	by space separation Grade Seperation	-	Flyovers, ROBS, RUBS

4.7.3. **Application**

(1) Rotary is suitable for urban/sub-urban areas where right turning traffic is substantial, and shall not be adopted on high speed rural sections. Lighting is essential. For design of rotary, reference may be made to IRC:65 "Recommended Practice for Traffic Rotaries". See Fig. 4.36. for broad design features.

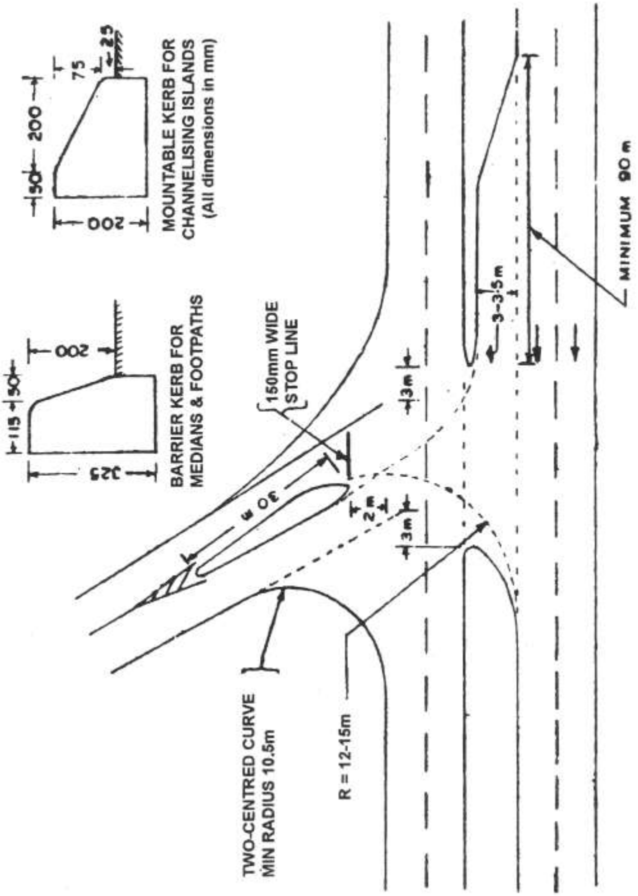


Fig. 4.37. Typical layout of 'T' intersection

(2) Channelised intersections with mountable kerbs for the traffic islands are suitable for rural highways. The islands shall be of sufficient size (min. 6 m^2) to attract attention, and shall be painted in alternate black and white stripes. See Fig. 4.37 for a 'T' intersection layout.

(3) Grade-separations may be warranted where the peak-hour traffic is in excess of 10,000 PCUs. Even at locations with lesser traffic, the natural difference in levels between the intersecting roads, if existing, could be made use of in separating the crossing streams. Interchange will be necessary at all crossings of a highway which is to be developed to completely access controlled standard. Similarly, interchanges will also be required at all major crossings on highways developed to expressway standard.

(4) Signal controlled are essentially for roads in urban/sub-urban areas. A signalised intersection besides other warrants given in IRC:93, is justified if the major street has a traffic volume of 650 to 800 vehicles per hour (both directions) and minor street has 200 to 250 vehicles per hour in one direction only.

4.7.4. Visibility at intersections

4.7.4.1. The safety of traffic can be ensured only if the visibility is full and unimpeded along the intersecting roads. To avoid collisions, sufficient sight distance should be available along the intersecting arms and their included corners. The minimum visibility triangles should be clear of any obstruction upto a height of 1.2 metres above the roadway. Minimum eligibility distance along major roads at priority intersections on rural roads is given in Table 4.15.

4.7.4.2. **Rural road intersections :** At an intersection where the intersecting roads are of more or less equal importance and there is no established priority (known as uncontrolled intersections), visibility should be provided on the principle that drivers approaching the intersection on either highway must be able to perceive a hazard and halt the vehicle, if required before reaching the intersection. Fig. 4.38, explains the requirement of a visibility triangle.

On intersections, involving a major road and a minor road, traffic on minor road is controlled by STOP or GIVE WAY signs/

road markings. Such intersections are known as priority intersections. Fig. 4.39, explains the visibility triangle at priority intersections.

4.7.5. **Radii of curves**

4.7.5.1. The design of intersection curves affects the speed and the ease of vehicle turning. Curve radii, therefore, should ensure control of speed and safety. For design of minimum radii necessary for turning within the minimum space (Table 4.16), AASHTO Standards may be reffered to.

Table 4.15. Minimum visibility distances along major roads at priority intersections on rural roads (Source : IRC:66)

Design speed of major road in kmph	Minimum visibility distance along major road (metres)
100	220
80	180
65	145
50	110

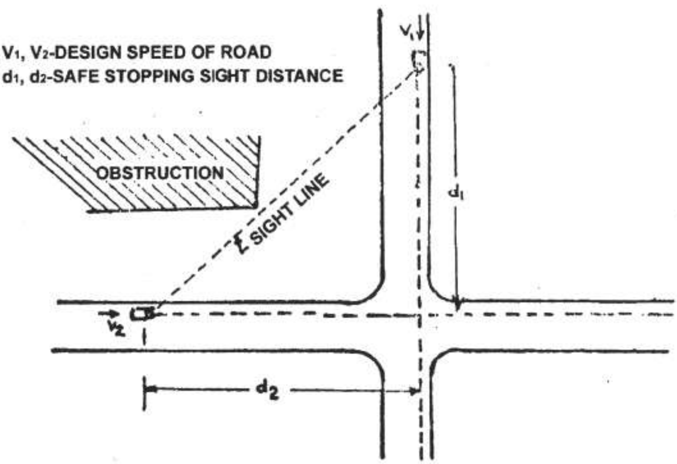


Fig. 4.38. Minimum sight triangle at uncontrolled intersections

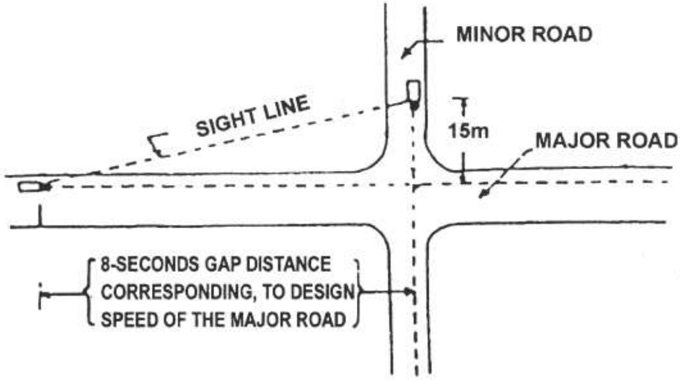


Fig. 4.39. Minimum sight triangle at priority intersections

4.7.5.2. Where the design permits passenger vehicles to turn at speeds 25 km/h or more, the pavement area at the intersections may become excessively large. To avoid this, a corner island is provided to form a separate turning roadway. Refer to AASHTO standards for turning roadways.

Table 4.16. Design speed and minimum radii

Design speed km/hr	Minimum inner radii (m)
18.5	18
15	23
20	27
30	32
40	37
50	41
75	50
100	57
125	62
150	64
Straight	-

4.7.5.3. **Gap in median at junctions :** To ensure that large vehicles can turn right without difficulty to or from a major road, the gap in the median should normally extend 3 m beyond the continuation of both kerb lines of the minor road to the edge of the major road (Fig. 4.40) and should also be determined by 12-15 m radius control circles tangenial both to the centre line of the minor road and the side of the central verge away from the minor road.

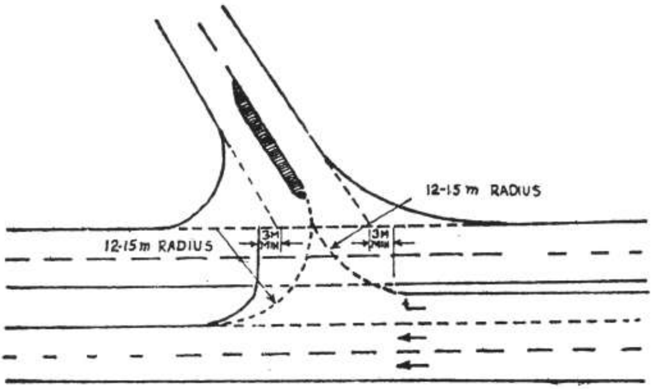


Fig. 4.40. Gap in median at junction

4.7.5.4. **Planning and design**

(1) IRC:SP:41 giving the guidelines for the design of at-grade intersections in rural and urban areas.

(2) Some of the important considerations in the planning and design of at-grade intersections are depicted in Fig. 4.41, Fig. 4.42 illustrates some typical cases of satisfactory and unsatisfactory layouts. Fig. 4.43 shows a graphical relationship developed in U.K. with the help of which, a selection can be made on type of intersection required, based on traffic flows, in urban conditions. The regions with dotted lines between priority, round about and grade separation are the areas of where the selection between the two shall also be governed by other considerations, such as, availability of space and costs, etc.

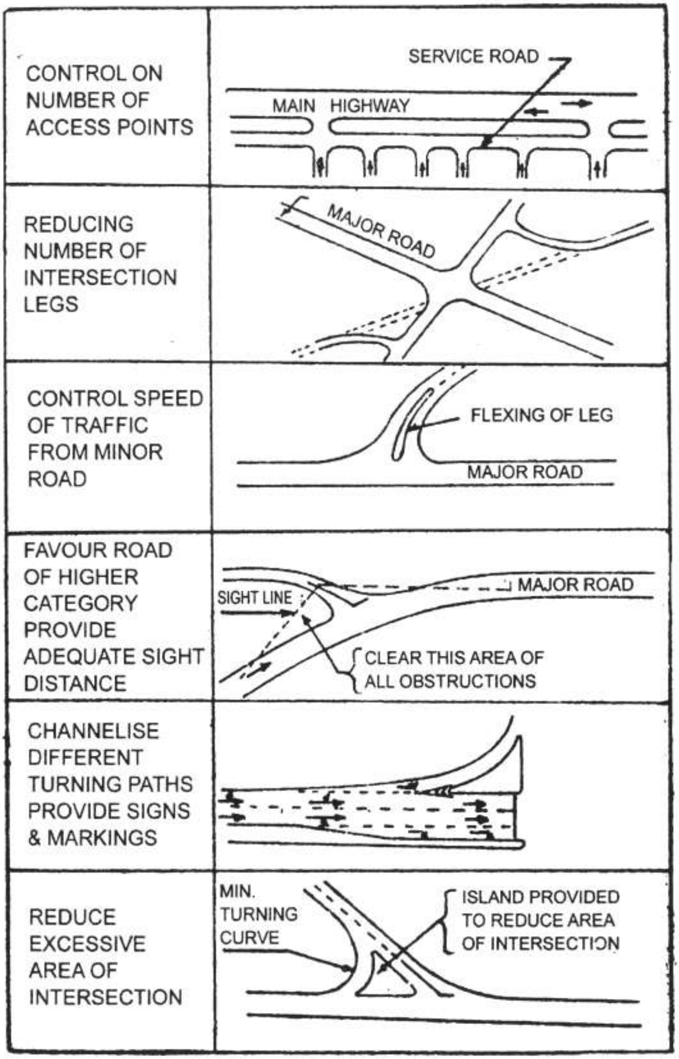


Fig. 4.41. Some of the considerations in the planning and design of at-grade intersections

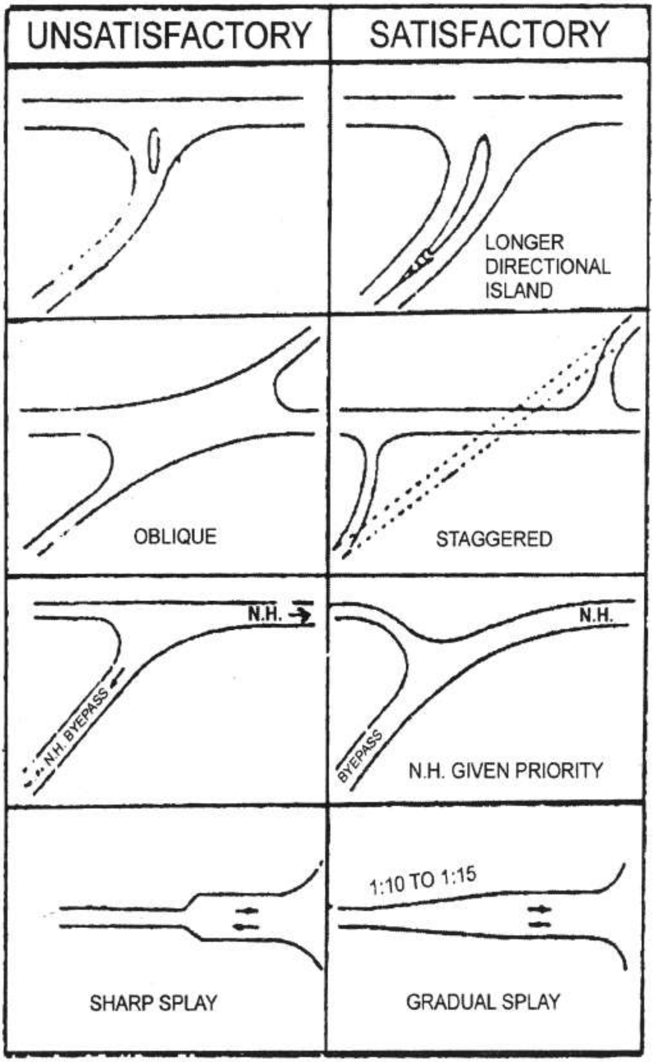


Fig. 4.42. Satisfactory and unsatisfactory design of at-grade intersections

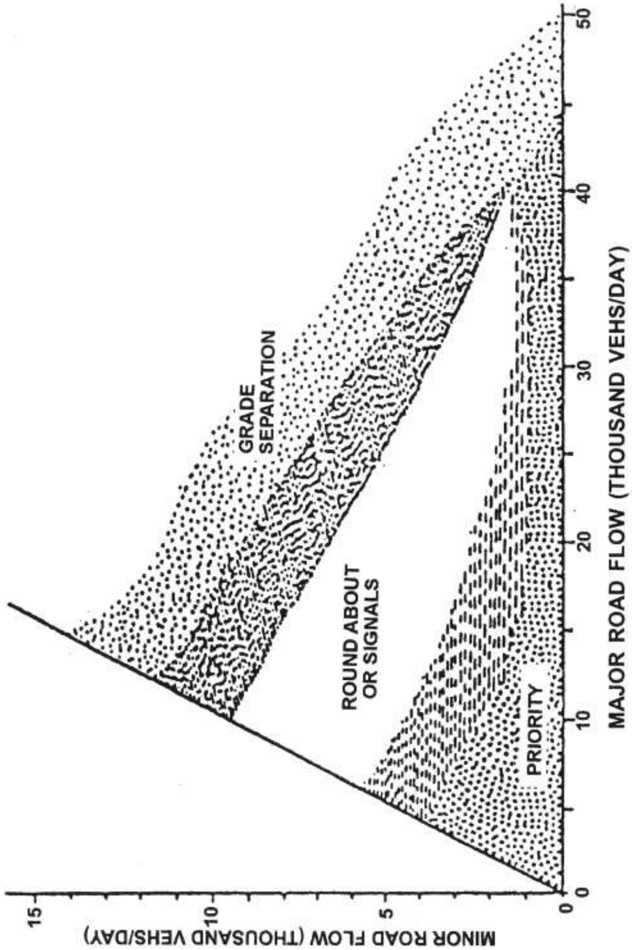


Fig. 4.43. Intersection selection based on traffic flow combination (U.K. Practice)

(3) Road intersections on low-volume roads, e.g. Village Roads and ODRs can be designed without much data, by providing left turning curves of minimum radius 11 m. Suitable designs of the type can be prepared for repetitive application on such roads. The same principle can be applied even to the right angled (or near about right anlged) junction of a low-volume road with a major highway.

(4) On more important roads, e.g., National Highways, State Highways, and those having large turning movements, however, it will be necessary to design the intersections individually based on factual data. Essential data required for the purpose are detailed in Table 4.17.

Table 4.17. Essential data required for design of road intersections

(i)	An index/location plan in the scale of about 1:10,000 to 1:20,000 showing the intersection under consideration and the road/rail/river network in the area to the extent of about 5 km on each side of junction.
(ii)	A base plan of the intersection site in the scale of 1:500 where two or three intersections are located close together, additional base plan to a scale of 1:1,000 should be prepared showing all the intersections affected. It is important to maintain this scale which is being adopted as a measure of uniformity and also to ensure that sufficient length of roads and fairly detailed account of existing features are shown in a drawing sheet of manageable size. The existing roads and salient features, like, road land boundary, location of structures trees, service lane, etc., should be shown for a length of about 200 m for each road merging at the intersections. If the terrain is not plain and/or there is too much of variation of ground level at the site, contours at 0.5 metre interval should also be marked on the base plan and additional longitudinal sections given along the centre line of intersecting roads.
(iii)	The peak hour design traffic data should give its compositional and the directional break-up. A sample

proforma, which is to be used for the purpose of reporting the compositional and directional break up and computing the volume in PCUs for one leg of a four legged intersection, is given in Table 4.18.

For converting vehicles into PCUs, equivalency factors given in Table 4.1 should be used. Separate report sheets will be needed for the other legs of the intersection. The volume of the above traffic in terms of number of vehicles and in PCU should then be reflected in the diagrams shown in the Fig. 4.44 and Fig. 4.45. If the numbers of legs in the intersection are 3 or more than 4, these figures should be suitably modified.

(iv) In the urban/sub-urban areas and intersection near villages with substantial pedestrian movements, the peak hour data on persons crossing the intersecting road arms should be collected for the design of a well planned pedestrian crossing facility at the intersection.

Intersection design data
Peak hour design traffic in no. of vehicles peak hours
Name a location of intersection

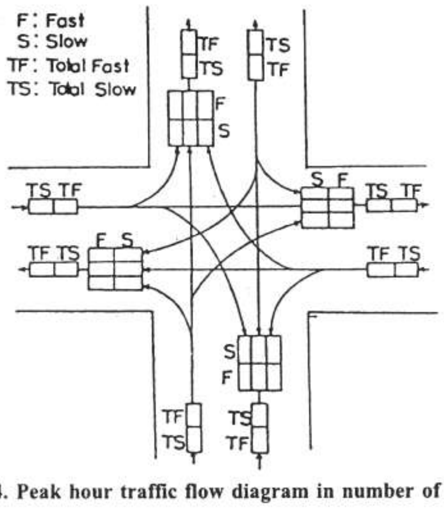


Fig. 4.44. Peak hour traffic flow diagram in number of vehicles

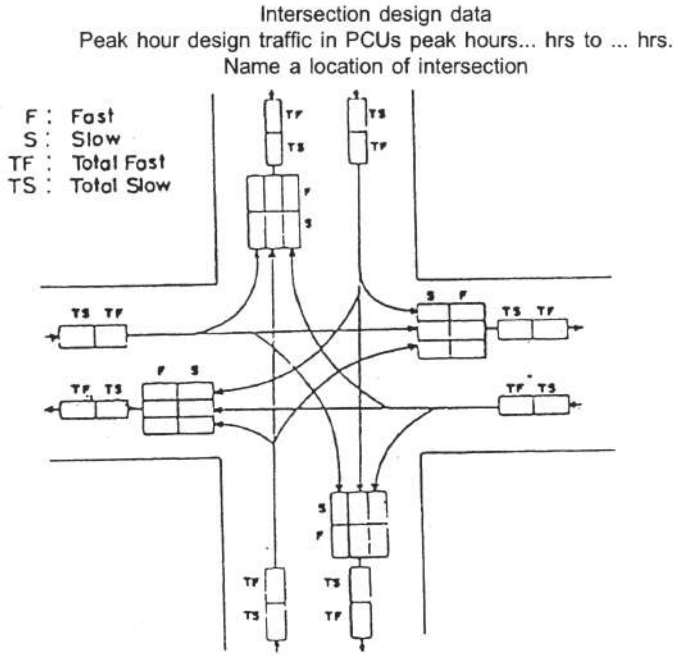
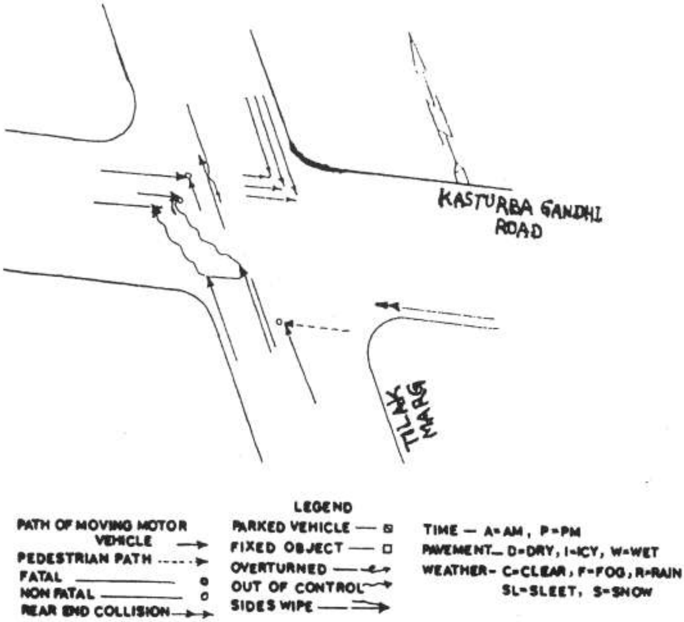


Fig. 4.45. Peak hour traffic flow diagram in PCUs

(v) Other relevant details, such as, the feasibility of providing proper drainage and lighting system at the intersection and also the present and future land use in the vicinity of intersection shall be given.

(vi) Accident data at intersection should be collected as per IRC:53 in Form A-1 and data for one year should be tabulated as shown in Fig. 4.46. This should then be reduced to diagrametrical form. Study of this data on collision diagram would itself indicate the necessary engineering measures required at the intersection.

(5) For all cases, necessary arrangements for drainage of surface water must be made. This is particularly critical in the case of rotary intersections where the pavement crossfall dips towards the central island. Provision of suitable drain at the periphery of the



ACCIDENT SUMMARY	DAYLIGHT				NIGHT				TOTAL			
CLASSIFICATION BY TYPES	FATAL	NON FATAL	PROP. DAMAGE	TOTAL	FATAL	NON FATAL	PROP. DAMAGE	TOTAL	FATAL	NON FATAL	PROP. DAMAGE	TOTAL
APPROACHING AT RIGHTANGLE		1	2	3		1	1	2		2	3	5
APPROACHING SAME DIRECTION			1	1			1	1			2	2
APPROACHING OPP. DIRECTION							1	1			1	1
PEDESTRIAN ACCIDENTS		1		1						1		1
FIXED OBJECT ACCIDENTS												
OTHER ACCIDENTS												
TOTALS		2	3	5		1	3	4		3	6	9

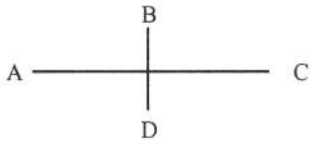
Fig. 4.46. Collision diagram

central island (underground pipe drain with grates or 'V' shaped drain with gully pits at intervals) with outfall pipes will be necessary for such cases.

(6) Necessary signs and pavement markings should be provided for advance information of motorists and for guiding them safely through the intersection area.

(7) The pavement in the intersection area is subject to large horizontal forces (more so in the case of rotary intersections) because of turning movement of vehicles. High stability mixes should be used for paving these areas. On rotary intersections, it will also be advantageous to adopt cement concrete pavement.

Table 4.18. Proforma for presenting peak hour traffic data for design of Intersection



Peak hour ____ hrs. to ____ hrs.

Date : Day:

Name and Location of Intersection ____________________

From		Leg A*						
Entering		Leg B*		Leg C*		Leg D*		
Type	Nos.	PCU equi-valen-ency	PCU	Nos.	PCU equi-val-ency	Nos. equi-val-ency	PCU	Re-marks
	1	2	3 (1×2)	1	2	1	2	
Fast Vehicles								
1. Passenger cars, tempos, auto-rickshaws, tractors, pickup vans		1.00						
2. Motor cycles, scooters		0.50						

3.	Agricultural tractor, light commercial vehicles	1.50
4.	Trucks, buses	3.00
5.	Tractor-trailer, truck trailer units	4.50
	Total Fast	
Slow Vehicles		
6.	Cycles	0.50
7.	Cycle - Rickshaws	1.50
8.	Hand cart	3.00
9.	Horse drawn	4.00
10.	Bullock carts	8.00
Total Slow		
PEDESTRIAN Nos.		

* Specify the name of an important place or land on this LEG, such as, Market LEG, Temple LEG, Mathura LEG, etc.

4.8. Road Traffic Signals

4.8.1. Traffic and engineering data required

4.8.1.1. A comprehensive investigation of traffic conditions and physical characteristics of the location is required to determine the need for signal installation. The following data is required to be collected for proper design and operation of a signal.

i) Number of motorised vehicles entering the intersection in each hour from each approach during 10 consecutive hours of a representative day;

ii) Vehicular volumes of heavy vehicles (e.g. trucks, buses) light vehicles (e.g. passenger cars, taxis, jeeps, tempos), motor cycles, scooters and non-motorised vehicles (e.g. hand carts, bullock carts, rickshaws, cycles, etc.), from each approach for atleast two hours in the morning and two hours in the evening during peak periods;

iii) Pedestrian volume counts on each cross walk during the same periods as vehicular counts in para (ii) above and also during hours of highest pedestrian volumes.

iv) 85th percentile speed of all vehicles on the uncontrolled approaches to the location. If not, at least an average speed of approach must be recorded.

v) A condition diagram showing details of the physical layout including such features as intersectional geometrics, channelisation, grades, sight distance restriction, bus stops and routings, parking conditions, pavement markings, street lighting, drive ways, location of nearby rail-road crossings distance to nearest signals, utility poles and fixtures, and adjacent landuse, etc.

vi) A collision diagram showing accident experienced by type, location direction of movement, severity, time of day, date and day of week for at least one year.

4.8.1.2. The following data are also desirable for a more precise understanding of the operation of the intersection and may be obtained during periods specified in para 4.8.1.1 (ii) above :

i) Delay in seconds per vehicle determined separately for each approach.

ii) The 85th percentile speed of vehicles on the controlled approaches at a point near to the intersection but unaffected by the control.

iii) Pedestrian delay time for at least two 30 minute peak pedestrian delay periods of an average week-day or like periods of a Sunday or Saturday.

4.8.2. Traffic control signals on an intersection should not be installed unless one or more of the following signal warrants are met:

Warrant	1 -	Minimum vehicular volume
Warrant	2 -	Interruption of continuous traffic
Warrant	3 -	Minimum pedestrian volume
Warrant	4 -	Accident experience
Warrant	5 -	Combination of warrants

For details of data requirements, warrants for signal installation, other technical aspects and design features of road traffic signals refer IRC:93 "Guidelines on Design and Installation of Road Traffic Signals"

4.9. Interchanges

4.9.1. An interchange is a grade separated intersection with connecting roadways (ramps) for turning traffic between highway approaches.

An interchange will be necessary at all crossings of a highway which is to be developed to completely access controlled standard. An interchange may also be justified when at grade intersection fails to handle the volume of traffic or when high rate of fatal and major accidents at an intersection do not respond to other traffic control or improvement measures. Interchanges are expensive to construct and a major factor influencing the cost is the type of arrangements made for various traffic movements. Generally, the interchange is considered necessary when the total traffic of all the arms of the intersection is in excess of 10,000 PCUs per hour.

4.9.2. **Types of Interchanges :** Interchages are generally described by the pattern of various turning roadways or ramps, which determine their geometric configuraion. The various types of interchanges and their brief salient features are described below.

a) Trumpet Interchange : This is the simplest interchange form adaptable to 'T' or 'Y' intersections [Fig. 4.47 (a)].

b) Diamond Interchange : This is the simplest of 4-leg interchange designs and is particularly suited for major-minor highway intersection. It is the least costly and will be found ideal for most of the cases both in urban and rural areas [(Fig. 4.47 (b)].

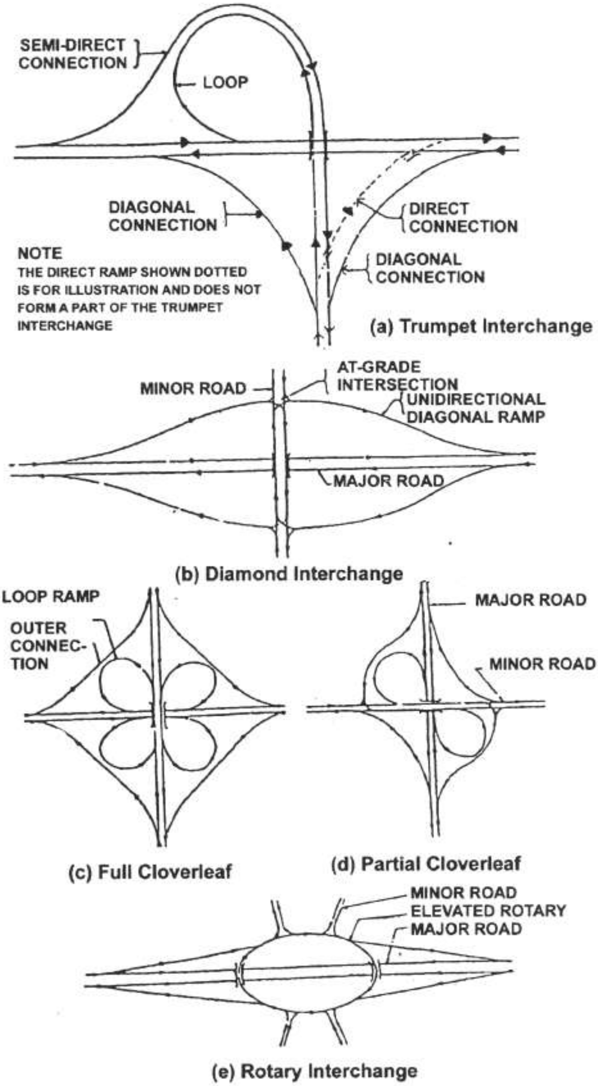


Fig. 4.47. Types of interchanges

c) **Cloverleaf Interchange :** This type of interchange is particularly suitable for the crossing of two major roads of equal importance in rural areas and requires large space [Fig. 4.47 (c)].

d) **Partial Cloverleaf Interchange :** In cases where at grade crossing on one of the roads can be tolerated, partial cloverleaf interchange may serve the purpose [Fig. 4.47 (d)].

e) **Rotary Interchange :** This type of design is particularly suitable where a number of roads intersect at the interchange and where sufficient land is available [Fig. 4.47 (e)].

f) **Directional Interchange :** Directional interchanges have ramps for right turning traffic which follow the natural direction of movement, this type of design requires more than one structure, or a 3-level structure. Though, operationally more efficient than other designs, these generally turn out to a very expensive.

4.9.3. **Signing of Interchanges :** Sufficient number of traffic signs should be provided at suitable locations to :

i) furnish advance notice of the approaches to the interchange;

ii) direct drivers into appropriate lanes for diverging/merging movements;

iii) identify routes and directions;

iv) provide other information of importance to the drivers; and

v) show distances to destinations.

4.9.4. For further details refer IRC:92 "Guidelines for the Design of Interchanges in Urban Areas".

4.10. **Road-Rail Level Crossings**

4.10.1. When railway line and road cross at level, railway level crossing is provided across the road carriageway as a measure of safety. Road-rail level crossings are classified into five types (Special, A, B, C & D Classes) depending upon the importance of the road, volume of road traffic and number of trains passing per day, etc. Of these, first four types of Railway Level Crossings are for controlling road vehicular traffic, whereas, fifth classification is for control of cattle movement and pedestrian traffic. In actual practice, the classification is decided mutually by the Railway and Road Authorities. The angle of crossing between centre line of the road and that of rails should not ordinarily be sharper than 45 degree for vehicular traffic, whereas, for the cattle crossing and footpaths, the angle of crossing should be 90 degrees.

4.10.2. **Safety measures :** Some safety measures on the approaches to Railway Level Crossing necessary for control of accidents are as given below :

i) Speed limit signs and other signs as per IRC:67 shall be installed at suitable locations on either approach;

ii) Rumble strips on both sides of Railway crossing should be provided;

iii) Flashing signals should be provided on both sides of the crossing, if required as per site considerations;

iv) Approaches to Railway level crossing should be made "No Overtaking Zones" and necessary signs installed accordingly on either approach, and

v) Grade separations should be provided to replace the existing level crossings if the product of Average Daily Traffic (fast vehicles only) and the number of gate closures per day exceeds 50,000 in the design year. However, for the new constructions, such as, realignments and bypasses grade separations should be provided if this figure exceeds 25,000 in the design year.

For more details, refer IRC:39 "Standards for Road-Rail Level Crossings".

4.11. Roadside Safety Barriers

4.11.1. The longitudinal roadside barriers are basically meant to shield two types of roadside hazards, i.e., embankment and roadside obstacles and also from preventing the vehicles veering off the sharp curves. The warrants for fill section in terms of its height and slope needing protection with roadside barriers are shown in Fig.

4.48. Types of longitudinal roadside safety barriers which could be used are :

i) "W" beam type steel barrier
ii) Thrie beam type steel barrier
iii) Concrete barrier

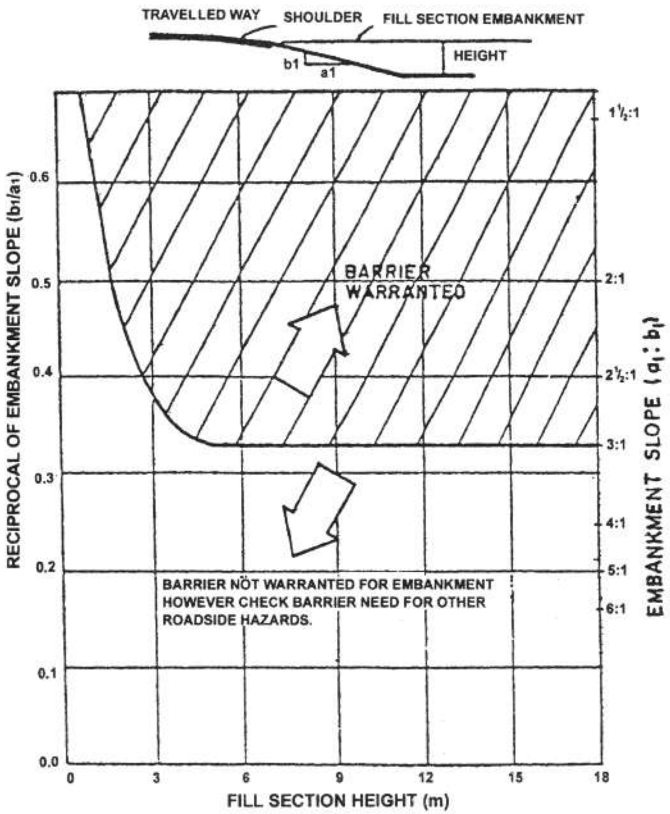


Fig. 4.48. Warrants for roadside barriers on embankments

Typical details of these barriers and the guidelines for their provision are given in Ministry's Circular No. RW/NH-33022/1/94-DO.III dated 24.6.94.

4.12. **Pedestrian Facilities**

4.12.1. Pedestrians are more vulnerable to traffic hazards than any other category of road user. Therefore, it is necessary to provide for facilities for the pedestrian traffic as a measure of safety. The various pedestrian facilities are listed below :

i) Footpaths
ii) Guard rails
iii) Pedestrian crossings
iv) Grade separated crossings, i.e., subways/foot-over bridges

4.12.2. **Footpath (side-walk)**

i) These are generally provided in urban/semi-urban situations where sufficient pedestrian movement is anitcipated. These should be provided on both sides of road and above the level of the carriageway separated by non-mountable kerbs.

ii) The width of footpaths depends upon peak hour pedestrian flows expected to use the facility and could be fixed with the help of guidelines given in Table 4.19 subject to a minimum footpath width of 1.5 metre.

Table 4.19. Capacity of side-walks

Width of side-walk (metre)	Capacity in number of persons per hour	
	All in one direction	In both directions
1.5	1200	800
2.0	2400	1600
2.5	3600	2400
3.0	4800	3200
4.0	6000	4000

4.12.3. **Pedestrian guard-rails :** Pedestrians guard rails are provided to restrict the movement of pedestrian traffic to footpaths and to channelize their crossing the main carriageways at predetermined locations. These are generally provided at hazardous locations on straight reaches near intersections, schools, hospitals, railway stations, bus stops, overpasses sub-ways, central reserves, etc.

4.12.4. **At-grade pedestrian crossings :** Pedestrian must be given their legitimate right to cross the road at suitable locations. The use of controlled or uncontrolled crossing would depend upon the volume of pedestrian traffic. The width of crossings are generally 2-4 metres wide with zebra marking and flashing signals. At signalised intersection it is desirable to provide pedestrian crossings with a separate signal for the pedestrian traffic. Fig. 4.49 shows the zebra marking and other details for pedestrian crossing at an unsignalised intersection/locations other than intersections. Fig. 4.50 shows type design of four arm channelised intersection showing zebra crossing.

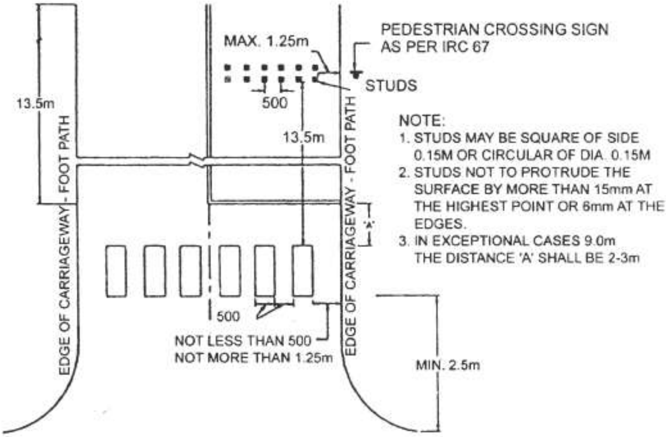
4.12.5. **Grade separated pedestrian crossings :** Where the volumes of pedestrians and the vehicular traffic are very large and grade crossing is found inadequate, grade separated crossing, i.e., foot over bridge or subways may be considered. The subways have been found more popular than the foot over bridges. At signalised intersections, grade separated pedestrian facility may be warranted where insertion of an exclusive pedestrian phase would increase the cycle time for traffic signlas beyond 120 seconds.

4.12.6. For further details refer IRC:103 "Guidelines for Pedestrian Faclities"

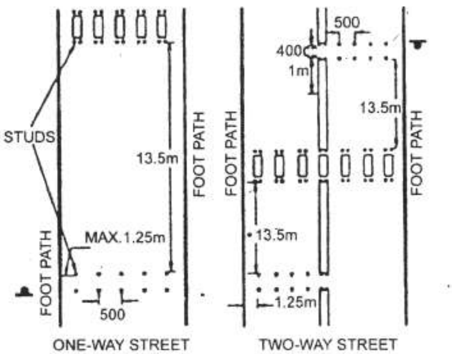
4.13. Maximum Permissible Weights and Dimensions for Road Design Vehicles

4.13.1. The Ministry vide its Notification dated 18.10.96 has specified that in relation to the transport vehicles (other than motor cabs) of various categories detailed in Table 4.20, the maximum gross vehicle weight (GVW) and the maximum safe axle weight (SAW) of each axle of such vehicles shall, having regard to the size, nature and number of tyres and maximum weight permitted to be carried by the tyres as per Rule 95 of the Central Motor Vehicles Rules, 1989, be :

i) vehicle manufacturers rating of the gross vehicle weight and axle weight repectively for each make and model as



(a) PEDESTRIAN CROSSING AT AN UNSIGNALISED INTERSECTION



(b) PEDESTRIAN CROSSING AND APPROACHES THERETO FOR LOCATIONS OTHER THAN INTERSECTIONS

Fig. 4.49. Markings for pedestrian crossing at some typical locations

duly certified by the testing agencies for compliance of rule 126 of the Central Motor Vehicles Rules, 1989, or

ii) the maximum gross vehicle weight and the maximum safe axle weight of each vehicle respectively as specified in Table 4.20 below for the relevant category, or

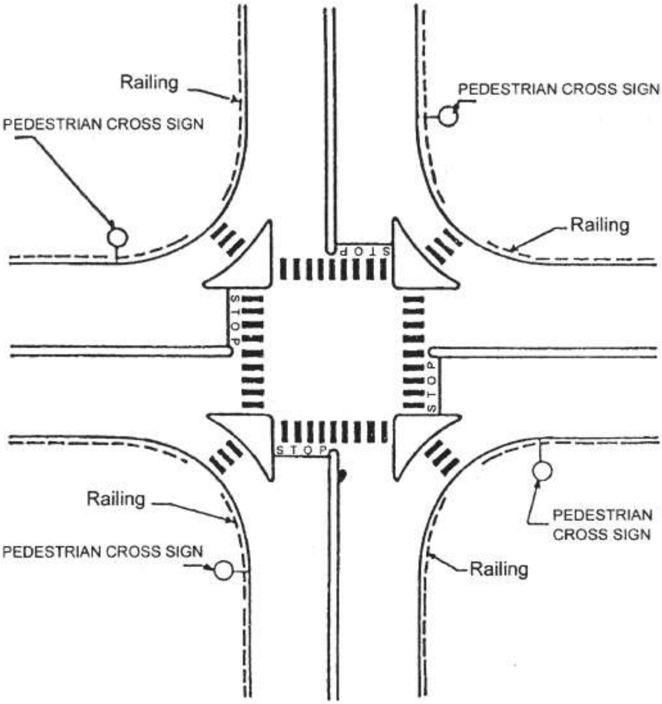


Fig. 4.50. Type design of four arm channelised intersection showing arrangement of zebra crossings

iii) the maximum load permitted to be carried by the tyre(s) as specified in the rule 95 of the Central Motor Vehicles Rules, 1989, for the size and number of tyres fitted on the axle(s) of the relevant make and model, whichever is less.

Provided that the maximum gross vehicle weight in respect of all such transport vehicles, including multi-axle vehicles shall not be more than the sum total of all the maximum safe axle weight put together subject to the restrictions, if any, on the maximum gross vehicle weight given in Table 4.20.

Table 4.20. GVW and SAW for respective transport vehicles

	Transport Vehicles Category	Max. GVW Tonnes	Max. SAW
1	2	3	4
I	**Rigid Vehicles**		
	i) Two Axle	9.00	
	One tyre on front axle		3 tonnes on front axle
	Two tyres on rear axle		6 tonnes on rear axle
	ii) Two Axle	12.0	
	Two tyres on each axle		6 tonnes on front axle 6 tonnes on rear axle
	iii) Two Axle	16.2	
	Two tyres on front axle		6 tonnes on front axle
	Four tyres on rear axle		10.2 tonnes on rear axle
	iv) Three Axle	25.0	
	Two tyres on front axle		6 tonnes on front axle
	Eight tyres on rear tandem axle		19 tonnes on rear tandem axle
II	**Semi-Articulated Vehicles**		
	i) Two Axle Tractor Single Axle Trailer	26.4	
	Tractor :		
	2 tyres on front axle		6 tonnes on front axle
	4 tyres on rear axle		10.2 tonnes on rear axle
	Trailer :		
	4 tyre on single axle		10.2 tonnes on single trailer axle
	ii) Two Axle Tractor Tandem Axle Trailer	35.2	
	Tractor :		
	2 tyres on front axle		6 tonnes on front axle
	4 tyres on rear axle		10.2 tonnes on rear axle
	Trailer :		
	8 tyres on tandem axle		19 tonnes on Tandem axle

1	2	3	4
iii)	Two Axle Tractor Three Axle Trailer	40.2	
	Tractor :		
	2 tyres on front axle		6 tonnes on front axle
	4 tyres on rear axle		10.2 tonnes on rear axle
	Trailer :		
	12 tyre on 3 axle		24 tonnes on 3 axle
iv)	Three Axle Tractor Single Axle Trailer	35.2	
	Tractor :		
	2 tyres on front axle		6 tonnes on front axle
	8 tyres on tandem axle		19 tonnes on rear axle
	Trailer :		
	8 tyre on single axle		10.2 tonnes on single axle
v)	Three Axle Tractor Tandem Axle Trailer	44.0	
	Tractor :		
	2 tyres on front axle		6 tonnes on front axle
	8 tyres on tandem axle		19 tonnes on rear tandem axle
	Trailer :		
	8 tyre on tandem axle		19 tonnes on tandem axle
III.	**Truck-Trailer Combination**		
i)	Two Axle Truck Two Axle Trailer	36.6	
	Truck :		
	2 tyres on front axle		6 tonnes on front axle
	4 tyres on rear axle		10.2 tonnes on front axle
	Trailer :		
	4 tyres on front axle		10.2 tonnes on front axle
	4 tyres on rear axle		10.2 tonnes on rear axle

1	2	3	4
ii)	Two axle truck Three axle trailer	45.4 (restricted to 44.0 tonnes)	
	Truck : 2 tyres on front axle 8 tyres on rear tandom axle		 6 tonnes on front axle 19 tonnes on rear tandem axle
	Trailer : 4 tyres on front axle 4 tyres on rear axle		 10.2 tonnes on front axle 10.2 tonnes on rear axle
iii)	Two axle truck Three axle trailer	45.4 (restricted to 44.0 tonnes)	
	Truck : 2 tyres on front axle 4 tyres on rear axle		 6 tonnes on front axle 10.2 tonnes on rear axle
	Trailer : 4 tyres on front axle 8 tyres on rear tandem axle		 10.2 tonnes on front axle 19.0 tonnes on rear tandem axle
iv)	Three axle truck Three axle trailer	54.2 (restricted to 44.0 tonnes)	
	Truck : 2 tyres on front axle 8 tyres on rear tandem axle		 6 tonnes on front axle 19 tonnes on rear tandem axle
	Trailer : 4 tyres on front axle 8 tyres on rear tandem axle		 10.2 tonnes on front axle 19.0 tonnes on rear tandem axle

4.13.2. Maximum permissible dimensions of road design vehicles are given in Table 4.21 :

Table 4.21. Maximum permissible dimensions of road design vehicles

Dimensions	Type of vehicle	Maximum Permissible Value
Overall Width	Motor vehicle other than transport vehicles	2.5 m
	Transport vehicles	2.7 m
Overall Height	Motor vehicles other than double decked motor vehicle	3.8 m
	Double decked motor vehicle	4.75 m
	Laden trailor carrying ISO Series I Freight Container	4.2 m
Overall Length	Motor vehicle, other than a transport vehicle having not more than two axles	9.5 m
	Transport vehicles with rigid frame having two or more axles	11.25 m
	Articulated vehicle having more than two axles	16.00 m
	Truck trailor or tractor trailer combination	18.00 m

Notes :

1. Overall width of a motor vehicle is measured at right angles to the axis of the motor vehicle between

perpendicular plans enclosing the extreme points. However, a rear-view mirror, or guard rail or a direction indicator (when in operation) shall not be taken into consideration in measuring overall width.

2. Overall height of a motor vehicle is measured from the surface on which the vehicle rests.

3. Overall length means the length of the vehicle measured between parallel plans passing through the extreme projection points of the vehicle exclusive of a starting handle, any hood when down, any fire-escape fixed, any post office letter-box but measuring not more than 30 cm, any loader used for loading/unloading from the roof of the vehicle or any tail or indicator lamp or number plate fixed, any spare wheel or spare wheel bracket or bumper fitted, any towing hook or any other fitment not projecting beyond any fitment mentioned above.

4. For more details, refer "Overall dimensions of motor vehicles" and "Maximum permissible axle weight" under Central Motor Vehicles Rule 1989.

4.13.3. Reference to the Central Government would be necessary when relaxation is required in respect of particular vehicle specially in favour of the operator, when that vehicle has to carry loads higher than the prescribed loads on specific routes. Such request for relaxation should be accompanied by the recommendations of the concerned State Government with detailed drawing/design of the vehicle and a certificate of the State P.W.D. regarding worthiness of the concerned roads/bridges, culverts, etc.

4.14. **Check Barriers on Highway**

4.14.1. The Indian Roads Congress as a body is totally against the erection of any barriers on highways as the barriers act as impediments to the smooth flow of traffic. But in the interest of road users, the designs have been evolved by IRC so that the barriers are as less objectionable as possible. In view of this, erection of barrier may be considered only when it is unavoidable.

4.14.2. Design of check barriers is a highly case specific exercise and each design has to take into account various local considerations including traffic requirements and physical constraints. Yet certain degree of uniformity and consistency is imperative in order to ensure desired level of safety, efficiency and economy of traffic operation.

4.14.3. **Types of check barriers :** Different situations requiring different types of check barriers are given below :

i) **Check barriers on one side :** This type is applicable where checking of vehicles is required for only one direction of traffic, i.e., while entering or exiting the jurisdiction of an authority.

ii) **Check barriers on both sides :** This is the most common type design required at all inter-State border locations and on entry into major towns or cities. This is required where checking of comercial traffic is required in both directions for the purposes of tax collections, etc.

iii) **Check barriers in urban areas :** These are usually erected for security purposes by local police.

4.14.4. The design of various components of check barrier depends largely on the purpose for which, it is to be put up, the length of time it likely to remain in operation, traffic volumes, permissible delays and queue lengths.

4.14.5. The barriers shall be so located as to be visible from a sufficient distance ahead when approached from either direction. The visibility shall at least be equal to the stopping sight distance corresponding to the design speed of the highway on which the barrier is set up.

4.14.6. **Traffic volumes surveys :** Seven days continuous category-wise traffic volume counts, preferably during peak season, may be taken at the location. If this is not possible, at least three days' continuous traffic volume count must be done to work out the average number of commercial and other vehicles to be handled at the barrier. This shall be projected for design period of 15 years (after commissioning of facility).

4.14.7. **Parking and accumulation survey :** There are two situations in respect of this type of survey :

i) Where the check barrier already exists, both parking accumulation and parking duration surveys need to be carried out and queue lengths recorded for each approach direction separately. Time required for servicing the queue must be studied and parking survey should be carried out continuously for a period of three days and data so collected projected for the design period.

ii) In the alternative situation when no check barrier exists, parking demand may be estimated based on continuous survey within influence area of chosen location for 24 hours and observations made under similar conditions elsewhere. However, if the parking is known to occur on some particular day of the week, survey should be carried out on such days.

4.14.8. **Road and space entry survey :** This is essential and must be carried out with utmost care and precision. Accurate physical survey plans must be prepared for 500 metres length on either side of designated check barrier location and for 100 metres width on either side of the centre line of the road. The plans prepared to a scale of 1:500 should indicate all details, like, road land boundary, service lines (both underground and above ground), details of road side developments, properties, cross roads, if any, drainage pattern of the area and location of well grown trees, etc.

4.14.9. **Lay-bye :** The length of the lay-bye(s) should be adequate to cater to peak parking demand estimated on volume projections and average delays expected.

4.14.10. **Barrier gates :** The barrier gate(s) on the main carriageway should preferably be electrically operated and should permit vertical clearance of at least 2.5 metres so that light motor vehicles, government vehicles and military vehicles should be able to move without interruption. However, the barrier gate(s) on lay-bye(s) must have a more effective control on the passage of vehicles and as such vertical clearance across lay-bye below the barriers shall be 1.5 m. The barrier should be painted in alternate black and white bands of 25 cm width for proper visibility.

4.14.11. For more details refer IRC:41 "Type Designs for Check Barriers".

4.15. **Speed Breakers**

4.15.1. Speed breakers are not permitted on National Highways as these defeat the basic objective of providing an obstruction free high speed facility.

4.15.2. Despite clear cut policy, provision of speed breakers is being insisted upon by the public. Considering the circumstances it has been decided that :

i) Speed breakers should not be allowed at new locations on National Highways.

ii) Where the speed breakers already exist, each case should be reviewed carefully and other safety measures, such as, removal of encroachments, provision of speed limit signs, construction of parallel service roads, etc. may be considered.

iii) Where speed control is unavoidable, the speed breakers may be replaced with rumble strips constructed as per Ministry's Circular No. RW/NH-11064/1/91-DO I dated 28.6.96.

iv) The rumble strips consist of intermittant raised bituminous overlays across the roadway. Raised sections can be 15-25 mm high, 200-300 mm wide and spaced about one metre centre to centre. A series of such strips roughly 15-20 in number at one location can caution the motorist sufficiently through combination of vibrations and rumbling noise. Since the coarsed textured overlays are more effective, the raised sections should consist of premixed carpet or bituminous surface dressing. It may be ensured that these strips are provided across the entire width of carriageway and shoulders (supported on a proper base) to check the tendencies of drivers to avoid such strips. A drawing showing design of rumble strips is given in Fig. 4.51 (a & b).

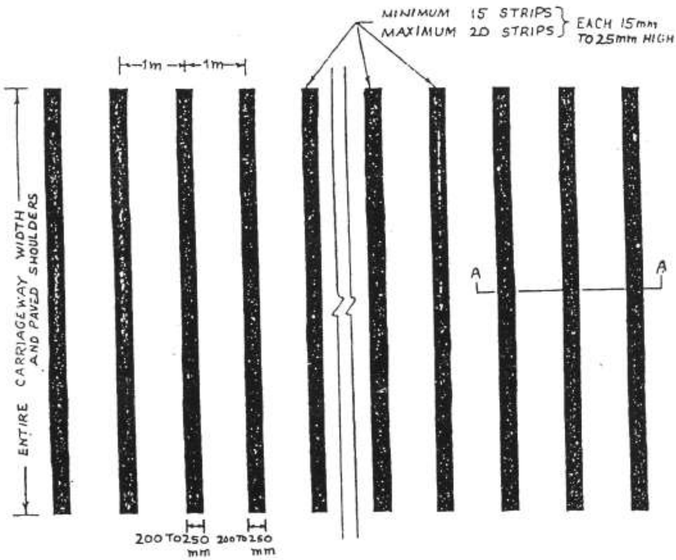


Fig. 4.51 (a). Rumble strips (plan)

4.15.3. On minor roads (other than National Highways), speed breakers may be provided at locations where there is need to control speed of traffic to ensure safety. But careful attention must be paid to the design of the same. The design should be strictly as per IRC:99 and reproduced in Figs. 4.52 and 4.53. All speed breakers must be :

i) Marked with alternate black and white bands as shown in Fig. 4.54. It is desirable that the markings are in luminous paint/strips. Embedded cat-eyes can also be used to enhance night visibility.

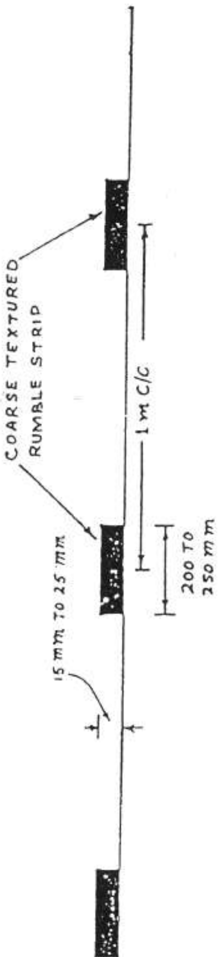


Fig. 4.51 (b). Rumble strips cross-section at "AA" of Fig. 4.51 (a)

ii) Cautionary signs as per IRC:67 must be provided in both directions before rumble strips/speed breakers at a distance more than safe stopping distance. Fig. 4.55 shows the locations of sign boards and markings for speed breakers at T-intersection or railway crossing.

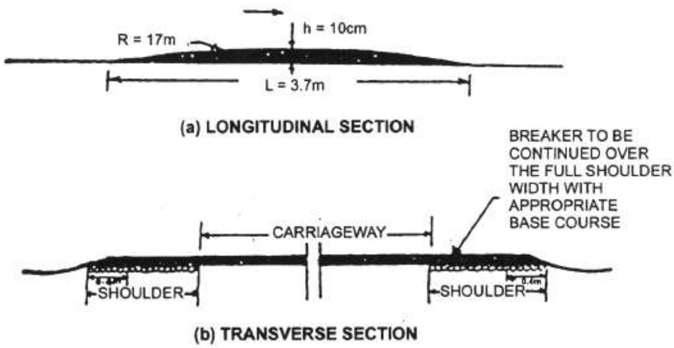


Fig. 4.52. Recommended specification for rounded hump type of speed breaker for general traffic at preferred crossing speed 25 km/h

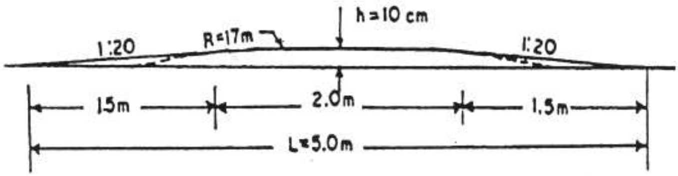


Fig. 4.53. Recommended specification for hump type of speed breaker for heavy truck and bus traffic at preferred crossing speed 25 km/h

4.16. Access Control

4.16.1. Effective access control along a highway facility is a pre-requisite for preventing ribbon development. Interference from the abutting residential and commercial establishments results in congestion and increased accident risk due to numerous conflicting movements. This also results in reduced travel speeds and lower

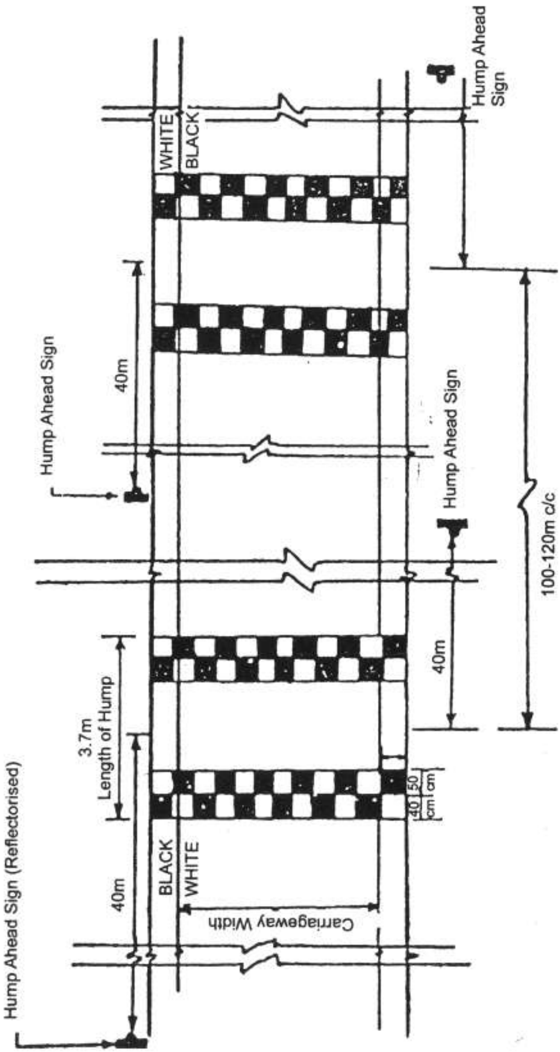


Fig. 4.54. Recommended placement of hump/humps in mid-block section, hump marking in chequered pattern and sign board locations

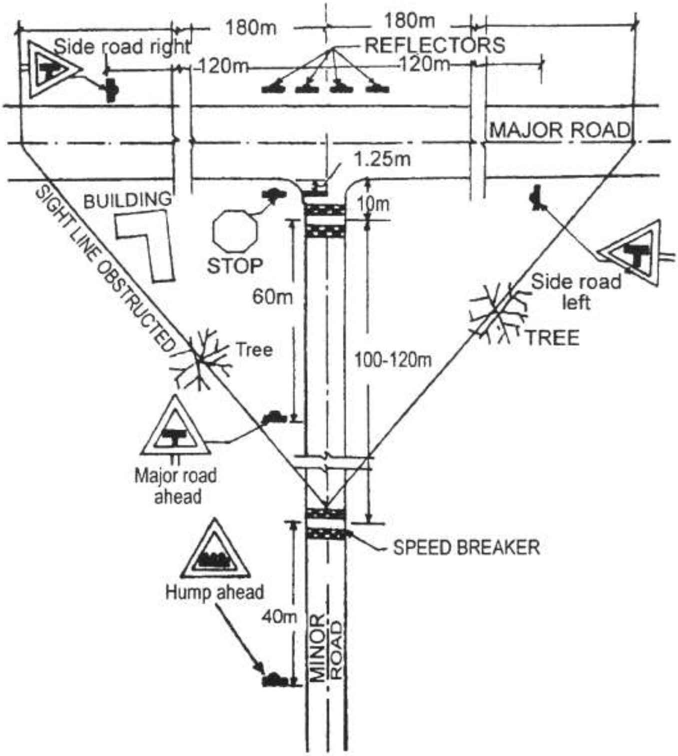


Fig. 4.55. Speed breakers at T-intersection or railway crossing

level-of-service. Access control is one of the proven methods of combating this evil of ribbon development. Details regarding the control access along with spacing of intersections, etc. have been included in IRC:62 "Guidelines for Control of Access on Highways".

4.16.2. **Access to petrol pumps**

4.16.2.1. National Highway land can be used for approaches to petrol pumps but not for any part of pump system.

4.16.2.2. General requirements governing the location and lay out of petrol/diesel pumps along Highways have been specified in

IRC:12 "Recommended Practice for Location and Layout of Roadside Motor-Fuel Filling and Motor-Fuel Filling-cum-Service Stations". The basic consideration governing these requirements is to minimise, as much as possible, interference to normal flow of traffic on the road by vehicles using the amenity and also to ensure safety. This publication also stipulates that the sanctioning authority should obtain clearance from the appropriate Road Authority for the site and layout before according the sanction.

4.16.2.3. **Stipulated norms regarding location, layout and other features of petrol/diesel outlets :** Location and layout of petrol/diesel pumps should be as per plate annexed to IRC:12 and reproduced with some modifications in Fig. 4.56. IRC:12 specifies the following norms in regard to siting and location of petrol outlets:

a) Locational aspects

i) Clearance distance between two adjacent fuel filling stations should not be less than 300 m.

ii) Clustering of fuel filling stations along the highway should be avoided. If for some reason, two or more fuel filling stations are sited in close proximity, these should be grouped together and a parallel service road provided by way of common access to the Highway.

iii) Fuel filling stations should be well distributed on both sides of road so that vehicles do not have to cut across the traffic to reach a fuel filling station. The fuel filling station on opposite sides of the road should be staggered.

iv) Fuel filling stations near existing check barriers should be at least 1 km away from the barrier.

v) Location of fuel filling stations should not interfere with future improvement to road and nearby junction.

vi) Distance of fuel filling station from a junction should not be less than 300 m in case of expressways and dual carriageway roads, and 100 m in case of other roads.

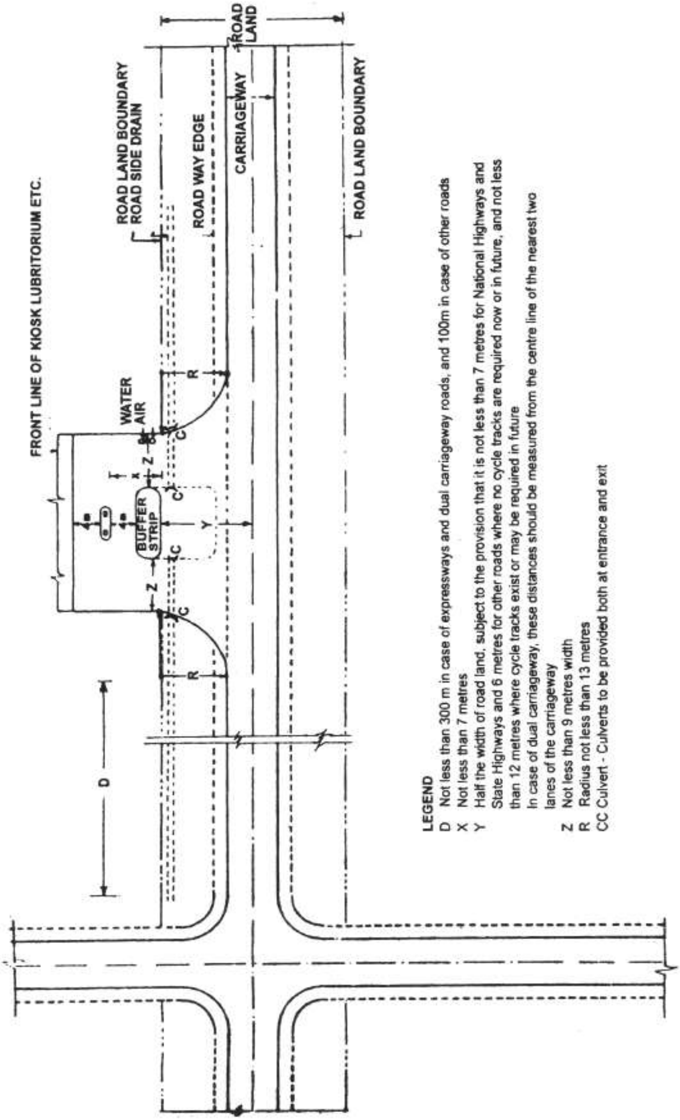


Fig. 4.56. Location and layout of motor-fuel filling and motor-fuel filling-cum-service stations

vii) As far as possible, in plain and rolling terrain, the fuel filling station should be located where the highway is practically level.

b) Frontage

The frontage should be as wide as possible, the minimum being 30 m.

c) Buffer strip

i) A buffer strip of at least 12 m long and 3 m wide should be provided.

ii) The outer edge of buffer strip should be along the outer edge of road land boundary for rural sections and that of footpath or service road, if any, for urban sections.

iii) The distance from the outer edge of buffer strip the centre line of the carriageway should not be less than 7m where no cycle tracks are required and not less than 12 m where cycle tracks exist or may be required in future.

d) Layout of entrance and exit

The entrance and exit should be at least 9 m wide, the ruling radius of the curve being 30 m with the absolute minimum as 13 m.

e) Distance of the fuel pumps from the carriageway

Fuel pump should be outside the road land, subject to the provision that the distance from the outer edge or buffer strip to edge of the strip having fuel pump should not be less than 7 m.

f) Drainage

There should be adequate drainage arrangements in fuel filling stations so that surface water does not flow over the highway, but is collected in suitable drains and led away to natural course. Culverts should be provided at the approaches to facilitate drainage.

4.16.2.4. **Types/extent of violations and infringements in petrol/diesel outlet installation**

A perusal of case studies of some of the petrol/diesel pumps located along National Highways has revealed the following deficiencies and infringements in locations, lay out, etc.:

i) Retail oulet owners having done the development work for the petrol pump and the Oil Companies having energised the pump without the pump owners having obtained the prior approval of the Road Authority and signing of the Licence Deed with Govt. of India;

ii) Close proximity of petrol pumps to each other;

iii) Inadequate distance of pump installation from centre line of National Highway;

iv) Location of petrol pump very near to an intersection;

v) Paving of whole petrol pump area and in continuation of NH land upto the carriageway, which tantamounts to encroachment on the NH land;

vi) Level of pump area being higher to that of NH pavement resulting in flow of rain water on to carriageway;

vii) Lack of proper surface water drainage and cross drainage system; and

  i) Lack of separate entry and exit due to paving of the full frontage and not leaving a buffer strip.

  ii) Non-standard shapes and sizes of buffer strips.

4.16.2.5. **Required sequence of operations/permissions**

i) At the time of making a reference to the District Magistrate/Licensing Authority for a 'No Objection Certificate', the Oil Companies should also simultaneously make a reference to the concerned State PWD/Road Authorities and obtain approval to the location and layout and permission for construction of approach road from the NH to the petrol pump. For facilitating proper interaction and control on installation of petrol/diesel pumps, copies of such references should be endorsed to the remaining concerned Authorities.

ii) As a matter of abundant precaution, the issue of 'No Objection Çertificate' by the District Magistrate/Licensing Authority should be made conditional subject to the Oil Company having obtained necessary approval/permission from the concerned Road Authority and signed the Licence Deed before going ahead with actual installation of the pump, and a copy of the same endorsed to the Road Authority. Stipulations to this effect should be clearly made in the N.O.C. A similar reciprocal procedure should be followed by the Road Authority while according its approval.

iii) The pump should be energised by the Oil Companies only after the Licence Deed for use of NH land for construction of approach road has been signed between the concerned private party and the Government of India, and the 'No Objection Certificate' issued by District Authorities.

4.16.2.6. **Corrective action for existing petrol/diesel pumps:** Licence Deed for use of NH land for approach road to the petrol pump has a validity of three years, and the same is required to be renewed thereafter. While considering the case for renewal of the license deed for the existing petrol pumps, any deficiencies in terms of location, layout, signage, drainage, etc. and any infringements from the stipulated IRC norms should be carefully identified and got rectified from the Oil Company/Outlet Owner by the concerned Road Authority before the licence deed is renewed by the Ministry of Surface Transport. This requirement needs to be meticulously enforced by the concerned Road Authority. All Regional Offices and ELOs of the Ministry are to observe the deficiencies in siting, location and other aspects as brought out above in respect of existing retail outlets and take up the matter with State Chief Engineers for getting the deficiencies rectified at the time of renewal of License Deed.

4.16.3. **Approaches to private property :** The following general principles should be followed :

i) Minimum spacing between intersections - 750 m. Connections from parallel service roads should similarly not be closer than 750 m.

ii) Minimum spacing between driveways to private properties - 300 m from each other or from an intersection. As far as possible, a number of property owners along the highway should be grouped together and parallel service roads constructed to give access at selected points.

iii) Median opening (for divided carriageways) should be limited to intersection with public roads and should not be permitted for individual business need. Where intersections are far apart, median openings, may be provided at about 2 km intervals for U-turns and diversion of traffic to one of the carriageways at times of emergency or major repairs.

The National Highway land, where permitted can be used only for approach road and not for the construction of any other structure. Width of such approach roads at entry to the National Highways should be of two-lane carriageway (7 metre) plus the smooth turning curve to a minimum radius of 11 metres.

Proposals conforming to the above may be approved by the State CEs themselves and the license permitted to construct the approaches, culverts, etc. after he has executed the license deed. For proposals not satisfying the requirements, the parties may be advised for modification. Any proposal which the State CE feels requires certain relaxation, the same should be referred to the Ministry along with the recommendations of the State CE for final decision. Ministry's detailed instructions on licensing of National Highway Land for construction of approach road to private proportions abutting National Highways are available in Ministry's Circulars No.RW/NH-III/P/17/75 dated 30.10.1980 and RW/NH-III/P/72/76-Vol. II dated 19.2.1987.

4.17. Parking Lay-byes

4.17.1. This is a new scheme for providing laybyes along National Highways. The aim is to provide parking facilities at selected locations on National Highways where clear evidence of the need of such facilities is already established, e.g., where cluster of wayside eating places and dhabas, etc. exist.

The scheme involves construction of parallel laybyes with proper entry and exit connections with the National Highway and provided with basic amenities, like, toilets/bathrooms and drinking water besides general landscaping. The general drawings showing the proposed layout have been issued vide Ministry's Circular No. RW/ 34032/5/88-DO II dated 22nd August, 1988 (Circular No. 701.9). These drawings can be modified to suit the site and other requirements. As per this scheme, the cost of land infrastructural services (like, electricity, water supply, drainage, etc.), internal roads, parking areas, approach roads and compound walls will be financed by the Government of India, Provision/extension of other facilities, such as, dhabas/eating places, vehicles repair/spare part shops, etc. will be left to private parties. Such facilities could be situated immediately after the laybyes, but in no case within the National Highway right-of-way.

4.18. Passenger Oriented Wayside Amenities Along National Highways

4.18.1. Provision of passenger oriented wayside amenities along highways is necessary since both the passengers and drivers need certain minimum, wayside facilities to make their travel safe, comfortable and convenient in order to reduce fatigue in a long distance journey. Such wayside facilities to a reasonable extent are operational in some States, like, Haryana and Rajasthan under patronage of State Tourism Departments. For facilitating long distance travel by road and enhancing road safety along National Highways, the Ministry had launched schemes for provision of basic wayside amenities both by Government Sector financing and by private sector financing. Under this scheme, basic facilities, like, parking areas for cars and buses, drinking water, toilet, snack bar/restaurants, rest rooms, dormitory, etc. have been envisaged to be provided at every 50 km on the National Highways.

4.18.2. Suitable sites for setting up of such wayside facilities are at first required to be identified as per broad guidelines for selection of sites given below. Thereafter, action would require to be initiated for acquiring the necessary land. This land thereafter would be offered on lease to the entrepreneurs who agree to provide the stipulated wayside amenities as per the drawings to be approved by the Ministry. The entrepreneurs would be required to enter into an agreement with the Government and sign the lease on agreed terms and conditions. The entrepreneur offering to pay highest amount of lease to the Government per annum subject to a minimum of 10 per cent of the land cost, could be given the land to develop wayside amenities.

Broad Guidelines for Selection of Sites for Passenger Oriented Wayside Amenities

i) Such facilities are to be provided along high traffic density corridors of National Highways where these do not exist at present or are lacking.

ii) Easy availability of the required land for infrastructure development should be kept in view. Approximate area required may be in the neighbourhood of 15,000 to 20,000 m^2.

iii) Site should be away from urban influence and any other similar wayside complexes.

iv) Feasibility of locating the facility close to scenic/historic/ tourist spots should be kept in view.

v) The intended location should have good potential for usage by road travellers/tourists.

vi) Desirably, the site should be 200 to 250 metres away from a road junction.

vii) Preferably, the location should be along a straight reach of the National Highway or on a gentle horizontal curve with adequate sight distance and good visibility. In no case the facility must be located on a sharp curve. Also, it should be possible to widen the carriageway of the National Highway near the selected site to 4-lanes if so warranted from traffic considerations.

viii) The road alignment should preferably have easy gradients in the vicinity of the complex.

ix) Availability of infrastructural facilities, like, drinking water, electricity and drainage, etc. near the site should be duly considered.

x) From environmental considerations, the facility should create minimum disturbance to the surroundings.

xi) Availability of any existing petrol/repair/spare parts facilities near the proposed location should also be kept in view.

xii) The type of facility should be commensurated with the expected passenger category, e.g., at locations frequented by general category travellers, a self-service snack bar/ fast food stall may be better suited, while restaurant type facility might be preferable for passengers of personalised cars/deluxe buses.

xiii) The wayside amenity should be so planned as to allow phased development, subject to the minimum stipulated scale of facilities being provided in the first instance.

4.19. Greening of National Highway Land

4.19.1. As per Ministry's letter No.RW/NH-11052/5/95-DO I dated 26.11.96, public sector corporations/reputed private companies/ voluntary orgnisations are permitted to develop and maintain gardens/ tree plantations/landscaping in vacant National Highway land on either side of the road/central verge/rotaries for beautification and prevention of encroachments. For this purpose, a strip of National Highway land can be allotted to reputed organisations under a Memorandum of Understanding.

4.20. Accident Reporting

4.20.1. Accurate and comprehensive accident records are the foundation of the accident analysis. The effective use of accident records depends upon accuracy of data, maintenance of record and analysis of data. Need for a high standard of accident reporting is the principal pre-requisite for evolving improvements at accident-prone locations of existing roads and other road safety measures. For recording road accidents, Forms A-1 and A-4 given in IRC:53 should be used.

4.21. Manual for Safety in Road Design

A manual for safety in road deisgn has been got prepared by Ministry. The manual highlights appropriate design principles for promoting safety conscious road design. The manual guides the highway engineers and the planners to make road safe. The manual touches safety aspects in all the elements of road design, e.g., land use planning and zoning, access control, wayside amenities, traffic calming horizontal and vertical curves, cross-sections of roads, road signs and markings, delineators, drainage, safety fences and barriers, parking, roadside furniture, plantation, laybyes, road-rail crossings, junction design, safety audits, traffic management, accident investigations, etc. This manual is available on sale from Indian Roads Congress, New Delhi.

4.22. Demarcation of Building Lines and Conrol Lines on the Land Adjacent to the National Highways

4.22.1. Unregulated use and development of land directly abutting the National Highways is affecting the free flow of traffic and making further development works, like, widening difficult, costly and even redundant from operational point of view. A primary reason for this is that the Highway Authorities are unable to demarcate building lines and control lines on the private lands beyond the right-of-way of National Highways since they do not have necessary powers to enforce the above lines. Further, the local people also are generally not aware about these control lines beyond which they should construct their buildings.

4.22.2. Standards for building lines and control lines have been circulated to all States vide this Ministry's Circular No. NH-III/P/72/

76 dated 13th Jan., 1977, wherein, it has been mentioned that the State Governments should strictly enforce the building lines and control lines while approving the scheme of developments and specifying the land use. The State Governments have been requested to enact necessary legislation to enforce this where required. Since, there was no progress in enacting the required control of development activities on the land adjacent to the National Highways outside the right-of-way, since regulation of land outside the National Highways right-of-way vests with the State Governments. Some State Goverments, like, Assam and Rajasthan have already enacted the required legislation for highway other than National Highway. As such these acts need to be modified to cover National Highways also. Copies of Assam Highways Act 1989 and Rajasthan Highways Act 1995 have been circulated to all the State PWDs vide Ministry's Circular No. RW/NH-11014/1/98/PL dated 17th Oct., 1997 for enacting a suitable legislation applicable for National Highways.

4.22.3. Till the required legislation as mentioned above is enacted by the State Governments, it has been suggested by the Ministry vide Circular No. RW/NH-11014/1/98/PL dated 27th Oct., 1998 (Code No. 144.16) that the State Governments may prepare plans showing building lines and control lines along the National Highways and keep these in the office of the Executive Enginner, National Highways Division for persual by architects and other persons planning building activities in the area. Necessary publicity to the effect that such plans are available for perusal by public also needs to be given.

4.23. Plantation and Maintenance of Shrubs and Flowering Plants in the Medians of Highways

4.23.1. It has been observed that adequate attention is not being paid to plantation on medians of Highways. The essential purpose of planting in medians is to cut off headlight glare from traffic in the opposite direction. Flowering plants and shrubs are eminently suited for the purpose. These could be planted in a variety of ways, but a very effective method is in the form of baffles (shrubs planted across the median at an angle at 15 m interval as shown in Fig. 5 of IRC:SP:21 "Manual on Landscaping of Roads"). This method ensure a penetration of view for the drivers. However, if the median width is less than about 3m, baffle plantation will not be effective and a continuous line of shrubs should instead be thought of. Shrubs in the medians should exceed 1-1.5 m in height, otherwise visibility will be affected. Further, in the vicinity of road intersection and median opening, no plantation should be done for a length of 10-15 m to ensure adequate visibility. Also, no plantation should be done where the median is tapered to provide for a turning lane.

4.23.2. All the State Governments and other concerned agencies have been requested vide Ministry's Circular No. RW/NH-11052/3/97-DO-I dated 21st January, 1999 that henceforth, in all National Highway projects being funded through multilateral agencies, like, World Bank, ADB, OECF, etc. or taken up through private sector financing and four/six-laning projects through normal budget, provision must be made for plantation in the medians of Highways.

4.23.3. The plantation on medians could also be arranged through the voluntary bodies/public sector undertakings/reputed private companies through Ministry's policy of Greening of Highways Circulated vide Circular No. RW/NH-11052/5/95-DO-I dated 26th November, 1996.

4.24. **Passing Places on Hill Roads**

4.24.1. Passing places are required on single-lane hill roads to facilitate crossing of vehicles approaching from opposite direction and overtaking of slow moving vehicles. These could also be used to tow aside disabled vehicles so that they do not obstruct traffic. The guidelines for provision of Passing Places are included in the Indian Roads Congress Publications IRC:52 "Recommendations about the Alignment Survey and Geometric Design of Hill Roads" and IRC:SP:48 "Hill Road Manual". According to these guidelines, Passing Places should be provided in general at the rate of 2-3 per km. The normal size of a Passing Place is 3.75 m wide, 30 m long on the inside edge (e.g., carriageway side) and 20 m long on the farther side. The exact location needs to be judiciously determined taking into consideration the available extra width and visibility. All the road construction agencies including the Border Roads Organisation are required to follow these guidelines for provision of Passing Places.

4.24.2. All the Highway agencies are required to take necessary action to provide Passing Places as per IRC guidelines at the missing and required locations on single-lane hill roads as early as possible.

5. PAVEMENT DESIGN

5. PAVEMENT DESIGN

5.1. General

Flexible pavements for new roads should be designed in accordance with IRC:37 "Guidelines for the Design of Flexible Pavements". Earlier the pavement designs were based on empirical methods which had limitations regarding their applicability and extrapolation. Now the analytical method of design has been used to reanalyse the existing designs and develop a new set of designs for design traffic up to 150 msa.

For existing roads, strengthening requirements are evaluated in accordance with Benkelman Beam Deflection technique as described in IRC:81.

5.2. New Roads

5.2.1. **Roads in embankment :** As per the present policy, construction of embankment of new road is done using soil from the designated areas and/or roadway cutting rather from the roadside borrow areas. Good engineering practice requires that the best available material is earmarked for use in the top 500 mm portion of the embankment constituting the subgrade. Based on the detailed investigations for soils expected to be placed in the embankment the road should be divided into sections as dictated by soil changes. For each section, the design should be based on the lowest CBR value of the soil expected to be used in the subgrade. Length of each section to be considered should not generally be less than 500 m.

On completion of the subgrade but before laying the pavement courses, samples of soil in position in subgrade should be tested for CBR to verify whether the design needs any revision.

5.2.2. **Road sections in cutting :** Samples for tests should be taken along the centre line of the road at an elevation corresponding to the design subgrade level. Frequency of testing should be once every half kilometre.

5.3. Strengthening Existing Loads

Extensive studies carried out in other countries have shown that performance of flexible pavements, conditioned by the traffic, is closely related to the elastic deflections of the pavement under the wheel loads. Benkelman Beam Deflection technique which employs this principle is commonly used for working out the overlay requirements for the existing roads in western countries. This method is now adopted for design of overlay on the existing highway pavements in India.

5.4. Design Traffic

5.4.1. **General :** The recommended method considers traffic in terms of the cumulative number of standard axles (8160 kg) to be carried by the pavement during the design life. For the purpose of structural design, only the number of commercial vehicles of gross vehicle weight of 3 tonnes or more and their axle-loading is considered.

It is recommended that National Highways and State Highways should be designed for a period of 15 years. A shorter period of 10-15 years may be adopted for less important roads. Expressways and urban roads may be designed for a longer life of 20 years. The traffic growth rate should be estimated by establishing econometric models (Ref. IRC:108) and by studying the past trends in traffic growth from the historical traffic data. If the same is not available the annual growth rate of traffic may be adopted as 7.5 per cent.

5.4.2. Computation of design traffic

5.4.2.1. The design traffic is considered in terms of the cumulative number of standard axles (in the lane carrying maximum traffic) to be carried during the design life of the road. The following equation may be used to make the required circulation:

$$N = \frac{365 \times A \{(1+r)^n - 1\} \times F \times D}{r}$$

Where,

N = Cumulative number of standard axles to be catered for in the design in terms of msa

A = Initial traffic (commercial vehicles per day) in the year of completion of construction

r = Annual growth rate of commercial traffic

n = Design life in years

F = Vehicles damage factor (number of standard axles per commercial vehicle)

D = Lane distribution factor (as explained in para 5.4.2.2)

5.4.2.2. **Distribution of commercial traffic over the carriageway:**

(i) Single-lane roads (3.75 m width)

The design should be based on the total number of commercial vehicles per day in both directions multiplied by two.

(ii) Two-lane single carriageway roads

The design should be based on 75 per cent of the total number on commercial vehicles in both directions.

(iii) Four-lane single carriageway roads

The design should be based on 40 per cent of the total number of commercial vehicles in both directions.

(iv) Dual carriageway roads

The design of dual two-lane carriageway roads should be based on 75 per cent of the number of commercial vehicles in each direction. The distribution factor shall be reduced by 20 per cent for each additional lane.

5.4.2.3. **Vehicle damage factor** : The vehicle damage factor (standard axles per commercial vehicles) is arrived at from axle-load surveys on typical road sections.

Where sufficient information on axle loads is not available and the project size does not warrant conducting an axle load survey, indicative values of vehicle damage factor as given in Table 5.1 may be used.

Table 5.1. Indicative VDF values

Initial traffic volume in terms of number of commercial vehicles per day	Terrain	
	Rolling/Plain	Hilly
0-150	1.5	0.5
150-1500	3.5	1.5
More than 1500	4.5	2.5

5.4.3. Computation of traffic for use of CBR design curves given in Fig. 5.2. The traffic is considered in units of commercial vehicles per day in both directions expected to ply during the design year.

For two-lane roads the design will be based on the number of commercial vehicles per day in both directions, whereas, single-lane roads should be designed for twice the traffic in both directions.

5.5. Pavement Thickness and Composition

Once the design traffic and the subgrade CBR are known, the total thickness of pavement can be obtained directly using the appropriate design curve. The thickness deduced from the design curves is the physical thickness to be provided and consists of granular sub-base, granular base and bituminous surfacing. The recommended minimum thickness and positions of component layers for new constructions is given in Thickness Combination Block.

5.5.1. **Pavement thickness design charts**

For the design of pavement to carry traffic in the range of 1 to 10 msa, the Pavement Thickness chart given in Fig. 5.1 and for traffic in the range of 10-150 msa, the pavement thickness chart given in Fig. 5.2 are to be used. The design curves relate to pavement thickness to the cumulative number of standard axles to be carried over the design life for CBR values of sub-grade ranging from 2 per cent to 10 per cent. The thickness deduced from Fig. 5.1 or Fig. 5.2 for the given CBR value and design traffic is the total thickness to be provided and consists of granular subbase, granular base and bituminous surfacing. The requirements for the component layers are given in paragraph 5.5.2. Based on these, the recommended designs giving minimum thickness and compositions of pavement layers for new constructions are given in the Pavement Design Catalogue given in IRC:37.

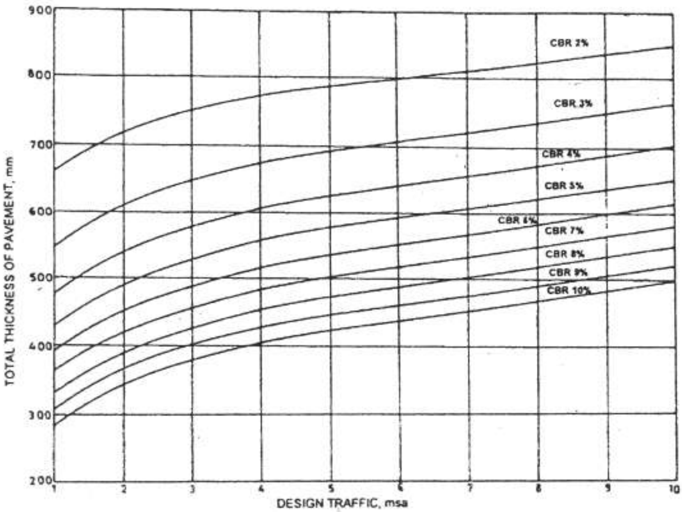


Fig. 5.1. Pavement thickness design chart for traffic 1-10 msa

5.5.2. **Pavement composition :** The requirement of different pavement courses shall conform to the provisions contained in Sections 400 and 500 of Ministry's Specifications. Some important points for guidance are as follows.

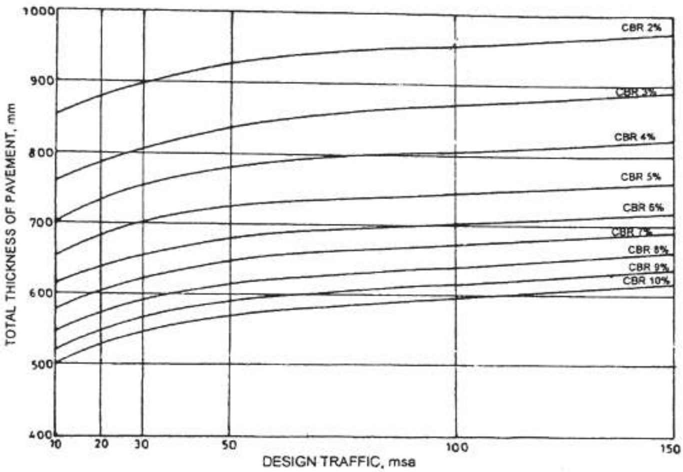


Fig. 5.2. Pavement thickness design chart for traffic 10-150 msa

5.5.2.1. **Sub-base course**

i) The sub-base material should have minimum CBR of 20 per cent for cumulative traffic upto 2 msa and 30 per cent for traffic exceeding 2 msa.

ii) The thickness of the sub-base should not be less than 150 mm for design traffic less than 10 msa and 200 mm for design traffic of 10 msa and above.

iii) Preferably, the sub-grade soil should have a CBR of at least 2 per cent. Where the CBR value of sub-grade is less than 2 per cent, the design should be based on sub-grade CBR value of 2 per cent and a capping layer of 150 mm thickness of material with a minimum CBR of 10 per cent shall be provided in addition to the sub-base.

iv) Where stage construction is adopted for pavements, the thickness of sub-base shall be provided to ultimate pavement section for the full design life.

5.5.2.2. **Base course :** The recommended minimum thickness of granular road base is 225 mm for traffic upto 2 msa and 250 mm for traffic exceeding 2 msa.

5.5.2.3. **Bituminous surfacing :** The surfacing consists of a wearing course or a binder course plus a wearing course depending upon the traffic to be carried. Recommended surfacing materials and its thickness are given in IRC:37.

The type and thickness will depend on the importance of the road, the traffic rainfall, availability of equipment, etc. Generally, asphaltic concrete is indicated where heavy traffic is combined with high rainfall. Semi-dense carpet can serve well against heavy traffic but under medium/low rainfall conditions. Open-graded premix carpet or mix seal surfacing will do in most other cases.

Open-graded thin surfacings (upto 25 mm) are disregarded in computing the total thickness.

5.6. Design of Strengthening Existing Pavement by Deflection Technique

Details of the method of evaluating the strengthening requirements of flexible pavements are given in IRC:81. The revised procedure involves the following main operations:

(i) Pavement condition survey for collecting the basic information about the road structure and based on this, demarcation of the road into sections of more or less equal performance. The length of each section shall not generally be less than 500 metres.

(ii) Marking 10 equidistant points along the outer wheel path (i.e. 60 cms from the pavement edge) for single-lane road, 90 cms for two-lane road and 1.5 metre for four-lane divided carriageway.

(iii) Conducting deflection measurements at the marked points as per CGRA procedure by placing probe of the Benkelman Beam between dual wheels of a loaded truck with rear axle weighing 8170 kg and load equally distributed over two wheels each provided with dual tyres inflated to a pressure of 5.60 kg/cm.

(iv) Ascertain annual rainfall in the area. Also, pavement temperature, moisture content of the subgrade, classification of the subgrade soil at the time of taking deflection measurements may be determined.

(v) Correct the deflection values to standard temperature of 35^0C and account for seasonal variation which is dependent on annual rainfall in the area, classification of subgrade soil and its moisture content at the time of testing. Correction for temperature variation is not applicable in case of roads with thin bituminous surfacings or where the road is subjected to severe cracking or the bituminous layer is substantially stripped.

(vi) For the set of 10 corrected values of deflections find out the mean deflection ($\overline{x}$), standard deviation (σ) and then the characteristic deflection (D.C.) by the following formulae :

Mean deflection ($\overline{x}$) = $\Sigma^n \times i$
$i = 1n$

$$\text{Standard deviation } (\sigma) = \sqrt{\frac{(x-\overline{x})^2}{n-1}}$$

Characteristic deflection (D.C.)

(i) $D_c = \overline{x} + 2$ (for major arterial roads, like, NH & S.H.)

(ii) $D_c = \overline{x} + \sigma$ (for all other roads)

where x = Individual deflection, mm

$\overline{x}$ = Mean deflection, mm

D.C. = Characteristic deflection

σ = Standard deviation

n = Number of deflection measurements

(vii) Calculate cumulative traffic in terms of million standard axles for the design standard axles for the design period as per the following formulae :

$$Ns = \frac{365 \times A\,[(1+r)^x - 1]}{r} \times F$$

where

Ns = Cumulative number of standard axles for design life

A = Initial traffic in the year of completion of construction in terms of commercial vehicles

r = Annual growth rate of commercial vehicles

x = Design life in years

F = Vehicles damage factor

(viii) From the graph in Fig. 5.3. find out the overlay required for the characteristic deflection and cumulative standard axles worked out as per above paras (vi) and (vii) respectively.

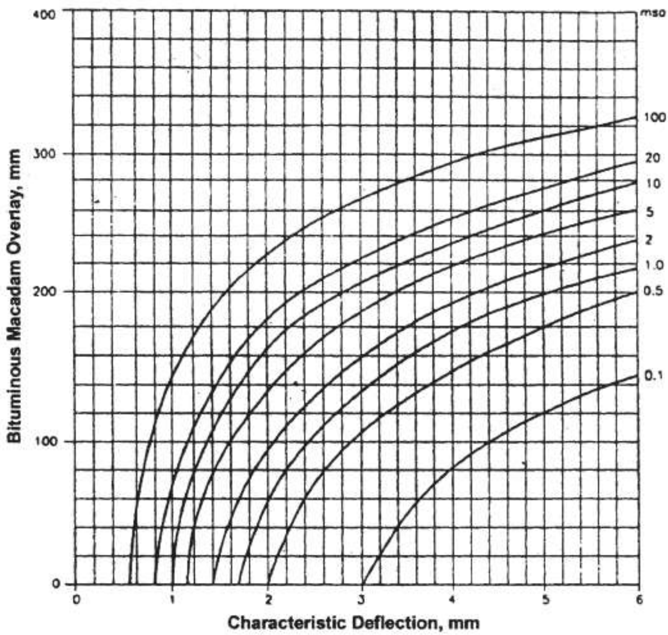


Fig. 5.3. Overlay thickness design curves

6. PROJECT PREPARATION

6. PROJECT PREPARATION

6.1. Technical Appraisal Report

The project preparation starts with the preparation of Technical Appraisal Report (TAR) which essentially consists of:

i) Report

ii) Technical parameters and technical designs

iii) Preliminary cost estimate

iv) Economic feasibility

In the Report main features of the project are brought out and different options investigated are discussed in detail together with Economic Feasibility of the project and justification of the final proposal given.

6.2. Preliminary Project Report

For major projects requiring EFC approval, Preliminary Project Report (PPR) is prepared covering the following -

i) Report

ii) Technical provisions, their basis and technical designs

iii) Economic Evaluation (as per IRC:SP:30)

iv) Environmental Impact Assessment

v) Source of funding, etc.

6.3. Detailed Project Report

6.3.1. After the Preliminary Project Report (PPR) is approved, Detailed Project Report (DPR) is prepared complying with the observations received with approval. This essentially consists of :

i) Report
ii) Detailed Cost Estimate
iii) Detailed Designs
iv) Detailed drawings (Plans, L-Sections, X-Sections, Junctions, Culverts/Bridges, etc.)
v) Draft EFC memo where required by Ministry

6.3.2. The document (see Table 6.1 for broad contents) forms the very basis for the approval of the appropriate authority and for actual construction. It should, therefore, contain all the necessary information, and all proposals must be supported by the field investigation data.

Table 6.1. Broad contents of highway project document

Report		Estimate		Drawings	
1.	Preliminary	1.	General abstract of cost	1.	Locality map-cum-site plan
2.	Road features	2.	Designs	2.	Land acquisition plans
3.	Road design and specifications	3.	Detailed estimates for each major head comprising	3.	Plan and longitudinal section
		a)	abstract of cost		
		b)	estimate of quantities		
		c)	analysis of rates (where warranted)		
		d)	quarry/material source chart		

4.	Drainage facilities including C-D structure	4.	Typical cross-section
5.	Materials, labour and equipment	5.	Detailed cross-section
6.	Rates, year for which SOR is applicable	6.	Drawings for C-D structure
7.	Environmental aspects	7.	Road junction
8.	Traffic flow during construction		
9.	Traffic safety		
10.	Name and signature of technical officer and their designations connected with preperation of the project		
11.	Construction programme		
12.	Miscellaneous		

6.3.3. For the cost estimates, rates from current Schedule of Rates (SOR) are adopted. Items for which rates are not available in SOR, rates may be analysed and adopted. The SOR should be prepared based on Ministry's "Standard Data Book for Analysis of Rates".

6.3.4. It is advisable to include the items mentioned in check list (Table 6.2.). This would help the engineer preparing the project to review his work and to state reasons for leaving some items.

Table 6.2. 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) Histroy, geography, climate, etc.
- iv) Necessity
- v) Details of previous improvement work carried out

1.2. Road Features
- i) Route selection
- ii) Alignment
- iii) Environmental factors
- iv) Cross-sectional elements
- v) Traffic

1.3. Road Design and Specification
- i) Road design
- ii) Pavement design
- iii) Masonry works
- iv) Specifications

1.4. Drainage Faclities including Cross-Drainage Structures
- i) General drainage conditions, HFL, water-table, seepage flows
- ii) Surface drainage, catchwater drains, longitudinal side drains
- iii) Sub-surface drainage-blanket courses, sub-drains
- iv) Cross-drainage structures

1.5. Material, Labour and Equipment
- i) Sources of construction materials, transport arrangements
- ii) Labour availability, amenities
- iii) Equipment

1.6. Rates
- i) Schdule of rates. Mention year and district to which SOR is applicable
- ii) Rate justification

1.7. Construction Programming
- i) Working season
- ii) Schedule of completion of work

1.8. Miscellaneous
- i) Rest houses, temporary quarters and other site amenities
- ii) Diversions and haul roads. Traffic control devices Temporary diversion of traffic during construction
- iii) Wayside amenities
- iv) Roadside plantations, turfing, landscapping
- v) Road safety measures : Comprehensive improvement of accident prone sections. Safety in construction zones

2. Estimate

2.1. General Abstract of Cost
2.2. Detailed Estimates for each Major Head

- 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) Strip plan showing the location of utilities, right-of-way, trees and junctions, etc.
- iii) Land acquisition plans
- iv) Plan and longitudinal section
- v) Typical cross-section sheet
- vi) Detailed cross-sections
- vii) Drawings for cross-drainage structures
- viii) Road junction drawings
- ix) Drawings for retaining walls and other structures.

Note : All the important field investigation data on the basis of which the project proposal have been framed should form a part of the project document (see para 6.3.1.)

6.3.5. Proposals in respect of C-D structures should be based on detailed investigations for selection of the most suitable sites, hydraulic and hydrological information, soil and boring data at the finally selected sites, etc. The following points are particularly relevant :

i) While selecting the site, the economic aspects of the proposal as a whole, i.e., the C-D structure including its approaches should be kept in view.

ii) The project and estimate for both the C-D structure and the approaches should be prepared and processed for sanction concurrently so that the structure and the approaches are completed at the same time.

6.3.6. While fomulating proposals for National Highway works, suitable provisions for road safety features should be made in the estimate.

6.3.7. Centages admissible for National Highway projects are given in Table 6.3.

Table 6.3. Centage charges

	Particulars	Road Projects (per cent)	Bridge Projects (per cent)
1.	Contingencies	3	3
2.	Quality control	1	1
3.	Work charge establishment		
	a) For works upto Rs.25 lakhs	2	2
	b) For works Rs.25-50 lakhs	1.75	1.5
	c) For works above Rs.50 lakhs	1.50	1.0
4.	Agency Charges	9	9

6.4. Economic Analysis

Economic Analysis of a project is carried out to ascertain its viability in terms of returns of the proposed investment on the project. The study can also help to make the most economic alternative among the various options available and to priortise the same. Economic analysis is obligatory in respect of a project costing Rs. 5.00 crore or more.

Economic analysis of projects for construction of two-lane pavements, widening to two-lanes and four-lanes, contruction of bypasses and expressways can be done with the help of computer programme developed by the Ministry and the same can be obtained from Indian Roads Congress.

7. MATERIALS

7. MATERIALS

7.1. General

The important points needing attention of the Engineer are :

i) The materials should conform to the specification requirements.

ii) The materials are delivered to site without breakage, deterioration or pilferage.

iii) The materials are so stacked/stored that they do not deteriorate or get contaminated.

7.2. Factory Manufactured Materials

Generally, these are furnished with ISI markings or test certificates, see Table 7.1. Notwithstanding this, the materials should be subjected to tests for quality before incorporation in the works. At least one set of three tests should be conducted for each batch of material.

Table 7.1. Requirements of manufactured materials

	Material		Relevant ISI Standard for Conformity
1.	Cement	Ordinary Portland Cement 33 Grade	IS: 269
		Rapid Hardening Portland Cement	IS: 8041
		Ordinary Portland Cement 43 Grade	IS: 8112
		Ordinary Portland Cement 53 Grade	IS: 12269

		Sulphate Resistant Portland Cement	IS: 12330
2.	Cast Iron	Grade number > 14	IS: 210
3.	Cast Steel	Grade 280-520 N	IS: 1030
4.	High tensile steel for pre stressing	Plain hard drawn steel wire	IS: 1785 (part I) and
		Cold drawn indented wire	IS: 1785(part II)
		High tensile steel bar	IS: 2090
		Uncoated stress relieved strands	IS: 6006
5.	Mild Steel	Grade S 240	IS: 432 Part I
		Grade S 415	IS: 1786 HYSD
		Other Grade IS: 432 and IS: 1786 are not to be used	
6.	Fusion bonded epoxy coated reinforcement		IS: 13620
7.	Steel		Clause 3, 3A or 4 of IS: 2004
8.	Forged steel pins		Clause 3, 3A or 4 of IS: 1875
9.	Structural Steel	Structural steel (standard quality)	IS: 226
		Structural steel (high tensile)	IS: 961
		Weldable structural steel	IS: 2062
		Weldable structural steel (medium and high strength qualities)	IS: 8500
		Hot rolled rivet bars (upto 40 mm dia) for structural purposes	IS: 1148

		High tensile river bars for structural purposes	IS: 1149
		Steel tubes for structural purposes	IS: 1161
		Hollow steel sections for structural use	IS: 4923
		Structural weather resistant steel	IS:11587
		Specifications for Rolled steel beam, channel and angle sections	IS: 808
		Mild steel tubes	IS: 1239
		Dimension for steel plate, sheet and strip for structural and general engineering purposes	IS: 1730
		Dimension for steel flats for structural and general engineering purposes	IS: 1731
		Dimension for round and square steel bars for structural and general engineering purposes	IS: 1732
		Rolling and cutting tolerances for hot rolled steel products	IS: 1852
10.	Stainless steel		IS: 6603: IS: 6911
11.	Bitumen	Paving bitumen	IS: 73
		Cutback bitumen	IS: 217
		Industrial bitumen for mastic	IS: 702
12.	Emulsion (Cationic type)		IS: 1978
13.	R.C.C. Pipes for culverts	(NP-4 type for NHs)	IS: 458
14.	Geo-synthetics (fabric, grid, net composite)		As per Specifcations of MORT&H

7.3 Other Materials

7.3.1. **Lime for soil stabilisation :** The lime should be commercial dry lime slaked at site or pre-slaked lime delivered to the site in suitable packing. The lime should be designated by its purity, i.e. Ca0 + Mg0 content. As lime deteriorates with time its purity should be checked prior to incorporation in work.

7.3.2. **Aggregates :** These should conform to IS: 383 for cement concrete. Tests for conformity are listed in IS:2586.

7.3.3. **Bricks :** These should conform to IS:1077 except that minimum compressive strength when tested flat shall not be less than 84 kg/cm^2 for individual bricks and 105 kg/cm^2 for average of 5 specimens. Size tolerance ± 5 per cent.

7.3.4. **Timber :** For structural purposes should conform to IS : 883

7.3.5. **Aggregates for pavement courses :** Physical requirements and gradings of aggregates for pavement courses are usually specified by type of work, and are covered in Section 9.

7.4. Stacking/Storage of Materials

7.4.1. All meterials should be stored to prevent their deterioration, or intrusion of foreign matter and to ensure the preservation of their quality and fitness for the work.

7.4.2. **Bricks :** Bricks should be stacked in regular tiers as they are unloaded to minimise breakage. Brick to be used in defferent situations should be stacked separately.

7.4.3. **Bitumen :** Bitumen should be procured in bulk where feasible, or otherwise in drums. Bulk bitumen will need certain special installations. Bitumen drums should be handled and stored in such a way that the bitumen does not leak out.

7.4.4. **Hydrated lime :** Hydrated lime for soil stabilisation shall be stored in air-tight containers.

7.4.5. **Cement :** Cement should be stored in perfectly dry and water tight sheds. Wooden platforms about 15 or 20 cms above the floor should preferably be provided and cement bags stacked 30 cms away from the walls and not more than 8 bags high. However, the bags should be placed close together to reduce circulation of air. The stacks should be covered with tarpaulin. Bulk storage containers, if used, should be cleaned atleast once in 3 to 4 months. Cement more than 3-4 months old should invariably be tested for acceptability requirements.

7.4.6. **Mild steel for reinforcement :** This should be stored in such a way as to avoid distortion and to prevent deterioration by corrosion.

7.4.7. **High tensile steel for prestressing :** This should be stored about 30 cm above the ground in a suitably covered and closed space to protect it from dampness. It shall also be invariably wrapped in gunny cloth, tar paper or any other suitable material.

8. STRUCTURES

8. STRUCTURES

8.1. Pipe Culvert

8.1.1 **Type of pipe :** NP-3 pipes for National Highways conforming to IS:458-1971 should be used till specifications conforming NP-4 pipes mentioned in IS:458-1988 are made available by BIS.

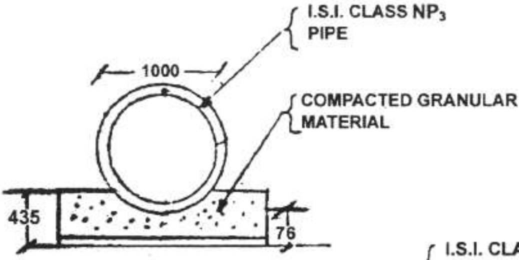
8.1.2. **Bedding :** The bedding must be even and uniform. Projecting rock faces and boulders must be removed before forming the bedding. First class bedding consists of forming and shaping the bed with graded sand or any other granular material passing 4.75 mm sieve. The thickness of bedding layer should be minimum 75 mm [as shown in Fig. 8.1 (a)].

For heights of fill greater than 4 m, continuous concrete cradle bedding as shown Fig. 8.1 (b) may be used. The mix should not be leaner than M 150 concrete, and the pipes should be laid in position, before the concrete has set.

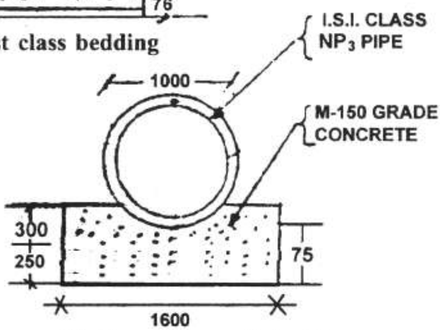
8.1.3. **Laying :** Start laying from the outlet and proceed towards inlet ensuring the specified lines and grade. The minimum longitudinal slope should be 1 in 1,000. Where two or more lines of pipes are to be laid adjacent to each other, they shall be separated by a distance equal to at least half the diametre of the pipe subject to a minimum of 450 mm. Ensure that the pipe has a cushion of at least 0.6 m excluding crust thickness at the top as shown in Fig. 8.1 (c).

8.2. RCC Slab Culvert

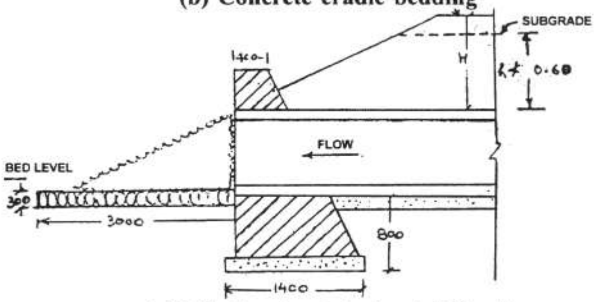
8.2.1. Depending on the scour characteristics of the bed material, open foundations with or without erosion-proof bed flooring is generally adopted. In general, concrete footing should rest over good stratum at a depth of about 1.5 m below the lowest bed level. Where likelihood of deep scour on account of loose strata and high velocity of flow is anticipated, either provision of shallow footing with bed flooring and curtain walls or taking the foundation below the maximum scour depth should be considered depending on feasibility and economy.



(a) First class bedding



(b) Concrete cradle bedding



(c) L-Section through pipe at D/S end

Notes:
1. Minimum height of fill h (excluding crust thickness) over pipe (M) should be 600 mm.
2. First class bedding can be used for H upto 4m. The bedding material shall be well graded sand or granular material passing 75mm sieve.
3. For H from 4 to 8m use concrete cradle bedding. The concrete mix shall not be leaner than M150.
4. Longitudinal slope of pipe should be minimum 1:1000
5. For pipes laid in two or more rows, the minimum horizontal clearance shall be half the dia of pipe subject to minimum of 450 mm
6. All dimension are in mm.

Fig. 8.1. Details of one-metre dia. R.C.C. pipe culverts

8.2.2. Bed flooring where provided should consist of stone pitching set in cement mortar 1:3 or two layers of brick on edge set in cement mortar 1:3. These should be laid over 150 mm thick foundation concrete M 15.

8.2.3. Dimensions of abutment and wing wall for various spans and vent heights are given in Tables 8.1 and 8.2 respectively. Fig. 8.2 shows sections of abutment and wing wall. The top of the bed block should be suitably raised at the middle to suit the road camber.

Table 8.1. Dimensions of abutment for R.C.C. slab culvert

Span	1 m to 4 m			5 m - 6 m		
H	2	3	4	2	3	4
b_1	0.2	0.3	0.4	0.2	0.3	0.4
b_2	0.7	1.1	1.4	0.6	1.0	1.4
b_3	0.3	0.3	0.3	0.4	0.4	0.4
b_4	—	0.2	0.5	—	0.2	0.6
B_1	1.5	2.0	2.4	1.5	2.0	2.5
B_2	2.7	3.6	4.6	2.7	3.6	4.9

Notes : 1. All figures are in metres.
2. For explanation of symbols, see Fig. 8.2.
3. The dimensions are applicable for S.B.C. of 16.5 T/m^2. The design is for IRC Class 70 R or 2-lanes of Class A loading without provision of approach slabs.
4. The sections shall be in C.C. M 15 brick masonry in cement mortar 1:3 or coursed rubble masonry (II sort) in cement mortar 1:3. The foundation concrete shall be in cement concrete M 15.

8.2.4. Fig. 8.3. shows sections through the R.C.C slab. Details of reinforcing steel are given in Fig. 8.4. and Table 8.3. The design has been based on 2-lane IRC Class A or one-lane Class 70 R loading.

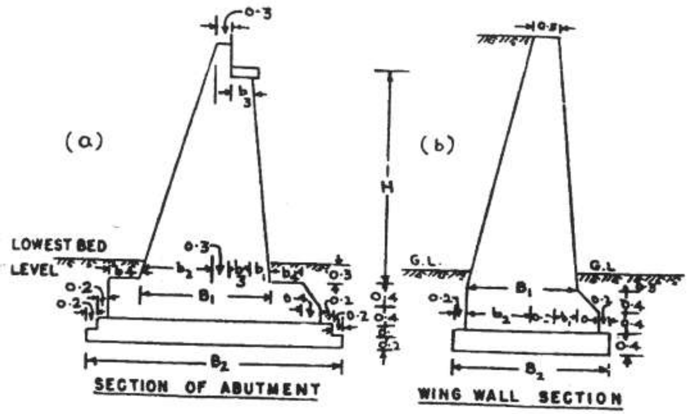
8.2.5. The length of wing walls should be sufficient to eliminate any tendency of the embankment slope (may be taken as 1.5:1) to slip into the stream.

Table 8.2. Dimensions of wing wall (at high end) for RCC slab culvert

Span	Upto 2 m			3 m			4 m			5 m			6 m		
H	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4
b_1	0.23	0.33	0.43	0.24	0.34	0.44	0.24	0.34	0.44	0.25	0.35	0.45	0.25	0.35	0.45
b_2	0.57	0.82	1.07	0.59	0.84	1.09	0.60	0.85	1.10	0.62	0.87	1.13	0.63	0.88	1.13
B_1	1.30	1.65	2.00	1.33	1.68	2.03	1.34	1.69	2.04	1.37	1.72	2.08	1.38	1.73	2.08
B_2	2.10	2.45	2.80	2.13	2.48	2.83	2.14	2.49	2.84	2.17	2.52	2.88	2.18	2.53	2.88

Notes : 1. All figures are in metres

2. For explanation of symbols, design criteria, etc. see '*Notes*' under Table 8.1



NOTE : FOR VALUES OF SYMBOLS SEE TABLE 7·1

Fig. 8.2. Abutment and wing wall sections for culverts

8.2.6. A construction joint between abutment and wing wall should be provided to avoid over-stressing at the junction due to differential settlement.

8.2.7. The bearing should be of reinforced bitumen laminated kraft paper conforming to IS:1938. While concreting the slab, care should be taken to prevent the bearing material from being displaced.

8.2.8. All space between foundation masonry or concrete and the sides of excavation shall be refilled to the original surface in layers not exceeding 150 mm compacted thickness.

8.2.9. The backfill material around the structure should be of granular type having plasticity index and liquid limit not exceeding 20 and 40 respectively. The fill material should be deposited in horizontal layers not exceeding 200 mm compacted thickness and compacted to not less than 95 per cent of density determined as per IS:2720, (Pt.VIII).

8.2.10. Filling upto 300 mm above the top of the pipe shall be carefully done and the soil thoroughly rammed, tamped or vibrated in layers not exceeding 150 mm, particular care being taken to thoroughly consolidate the materials under the haunches of the pipe. Approved pneumatic or light mechanical tamping equipment can be used.

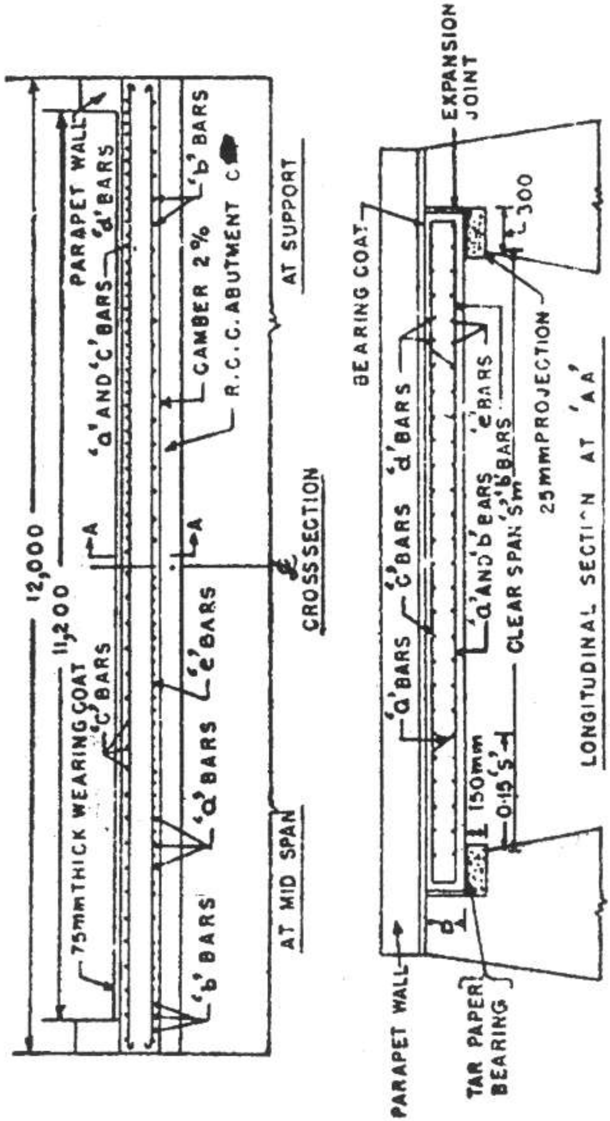


Fig. 8.3. Sections through R.C.C. slab for culverts

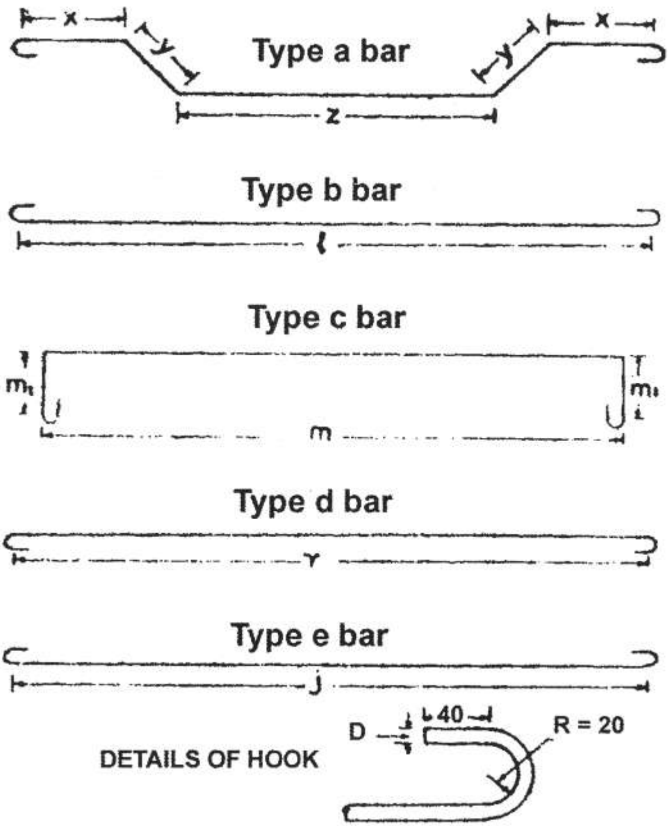


Fig. 8.4. Details of reinforcing steel for culverts

Notes on Laps :

(i) Bar in tension : $\dfrac{\text{Bar dia.} \times \text{tensile stress in bar}}{4 \times \text{permissible average bond stress}}$

or 30 times bar dia., whichever is greater

(ii) Bar in compression $\dfrac{\text{Bar dia.} \times \text{compressive stress in bar}}{5 \times \text{permissible average bond stress}}$

or 24 times bar dia., whichever is greater.

In the case of two bars in close contact along lap length, the lap length shall be increased by 25%

Table 8.3. Details of reinforcing* bars for cement (using M20 cement concrete)

Clear span (m)	Overall length of slab (m)	Overall slab thickness (mm)	Type of bars							Total length cm
			Dia (mm)	Spacing (mm)	No. of bars	X (m)	X (m)	Z (m)	2 (X+Y) +Z+hooks	
1.00	1.60	1.70	10	180	67	0.288	0.170	0.714	1.630	109.21
1.50	2.10	200	12	180	67	0.329	0.212	1.071	2.153	144.251
2.00	2.60	240	10	150	80	0.361	0.269	1.428	2.686	215.04
3.00	3.60	300	10	150	80	0.443	0.353	2.143	3.735	298.80
4.00	4.60	380	12	150	80	0.506	0.467	2.857	4.803	384.24
5.00	5.80	430	16	150	80	0.699	0.537	3.571	6.043	483.440
6.00	6.80	500	12	150	80	0.772	0.630	4.286	7.102	568.160

(contd.)

*Source : Ministry's Circular No. RW/RD/MISC/19/84-OR dated Dec. 1984

Type a, b & c bars - Steel in longitudinal direction

Table 8.3. (Contd.)

Clear span (m)	Type 'b' bars					Type 'c' bars						Total length (m)
	Dia (mm)	Spacing (mm)	No. of bars	r (m)	Total length (m)	Dia (mm)	Spacing (mm)	No. of bars	m (m)	m_1 (m)	$m + 2m_1$	
1.0	10	180	67	1.53	102.51	10	300	40	1.53	0.078	1.726	69.04
1.50	12	180	67	2.03	01	10	300	40	2.03	0.128	2.236	91.44
2.0	12	150	80	2.53	202.4	10	300	40	2.53	0.168	2.866	114.64
3.0	16	150	80	3.53	282.4	10	300	40	3.53	0.217	3.964	158.56
4.0	16	150	80	4.53	362.4	10	300	40	4.53	0.297	5.124	204.96
5.0	16	150	80	5.73	458.4	10	300	40	5.73	0.347	6.424	256.98
6.0	20	150	80	6.656	532.48	10	300	40	6.73	0.405	7.540	301.60

(Contd.)

Table 8.3. (Contd.)

Clear span (m)	Type 'd' bars					Type 'e' bars				Total length (m)
	Dia (mm)	Spacing (mm)	No. of bars	r (m)	Total length (m)	Dia (mm)	Spacing (mm)	No. of bars	Length (m)	
1.00	12	125	13	11.95	155.35	10	300	6	11.95	71.70
1.50	12	100	21	11.95	250.95	10	300	7	11.95	83.65
2.00	12	100	26	11.95	310.70	10	300	9	11.95	107.55
3.00	12	100	36	11.95	430.20	10	300	12	11.95	143.40
4.00	12	150	31	11.95	370.45	10	300	16	11.95	191.20
5.00	12	150	39	11.95	466.06	10	300	20	11.95	239.00
6.00	12	150	46	11.95	549.70	10	300	23	11.95	274.85

Type d & e bars - Steel transverse direction

Notes (for Tables 8.3. + 8.4.)

1. For explanation of symbols, see Fig. 8.4.
2. Design live load - Two lanes of IRC Class A or one lane of Class 70 R.
3. Minimum clear cover should be 25 mm.
4. Dimensions of bars appearing in the schedule and quantities of steel and concrete shown in Table 8.4. are estimated for full two-lane width of 12 metres.

Table 8.4. Quantities of high yield strength deformed bars, reinforcement and cement concrete

Clear span of slab (M)	Cement Concrete M-20	
	Total quantity of reinforcement per span in tonne including 5% for laps and wastages	Total quantity of concrete per span in cubic metres
1.0	0.372	3.26
1.5	0.610	5.04
2.0	0.764	7.49
3.0	1.257	12.96
4.0	1.564	20.98
5.0	2.321	29.93
6.0	2.900	40.00

8.2.11. To provide drainage, a layer of 600 mm thick filter medium should be interposed between the back of the abutment and backfill. The filter material should consist of well-graded gravel, crushed stone or brick bats which will not become powdery under loads. Weep holes should be 150 mm dia and be normally placed at 1 m centre-to-centre both vertically and horizontally. The lowest row of weep holes should be located above the low water level.

8.2.12. Use of high yield strength deformed bars conforming to IS: 1139 or IS: 1786 and M-20 cement concrete is recommended for R.C.C. slabs of culverts.

8.3. Box Culverts

A box culvert can be used as underground subway or as cross-drainage work. The work on development of software for design of Box Culverts for low bearing capacity soils is in progress under Ministry's Research Scheme, R-59.

8.4. Location, Alignment and Profile of Cluverts

Generally, the flanking road sections should govern the location, alignment and profile of culverts. The objective should be that the culverts completely blend with the highway alignment/profile and their presence is not felt by motorists. Existing culverts deviating from general road profile should be provided with shock-free curves at the flanks. Some cases where the profile could be improved are illustrated, in Fig. 8.5.

8.5. Scour Depth

For Scour Depth calculations, IRC: 78 may be referred.

8.6. Cement Concrete

8.6.1. Structural Cement concrete is of two grades, namely "Design Mix Concrete" and "Nominal Mix Concrete".

8.6.2. The minimum cement content and maximum water cement ratio for concrete works for culverts shall be as given in Table 8.5.

8.6.3. Ingredients of nominal mix concrete made from 50 kg. Bag of cement are given in Table 8.6.

8.6.4. Controlled concrete shall be designed for the characteristic strength, characteristic strength is defined as the strength of concrete below whch not more than 5 per cent of the test results are expected to fall. The target mean strength exceed the specified characteristic compressive strength by at least the "Current Margin". The current margin for various grades of concrete are given in Table 8.7.

8.6.5. For each mix, set of six cubes shall be made from each of three consecutive batches. Three cubes from each set of six shall be tested at an earlier age of 28 days and three at an earlier age approved by the Engineer. The average strength of the nine cubes at 28 days shall exceed the specified characteristics strength by the current margin minus 3.5 MP_a.

8.6.6. Maximum nominal size of coarse aggregate for R.C.C. work shall be 20 mm and larger sizes upto 31.5 mm may be permitted in special cases.

8.6.7. The optimum consistency of concrete shall be as indicated in Table 8.8 or as directed by the Engineer.

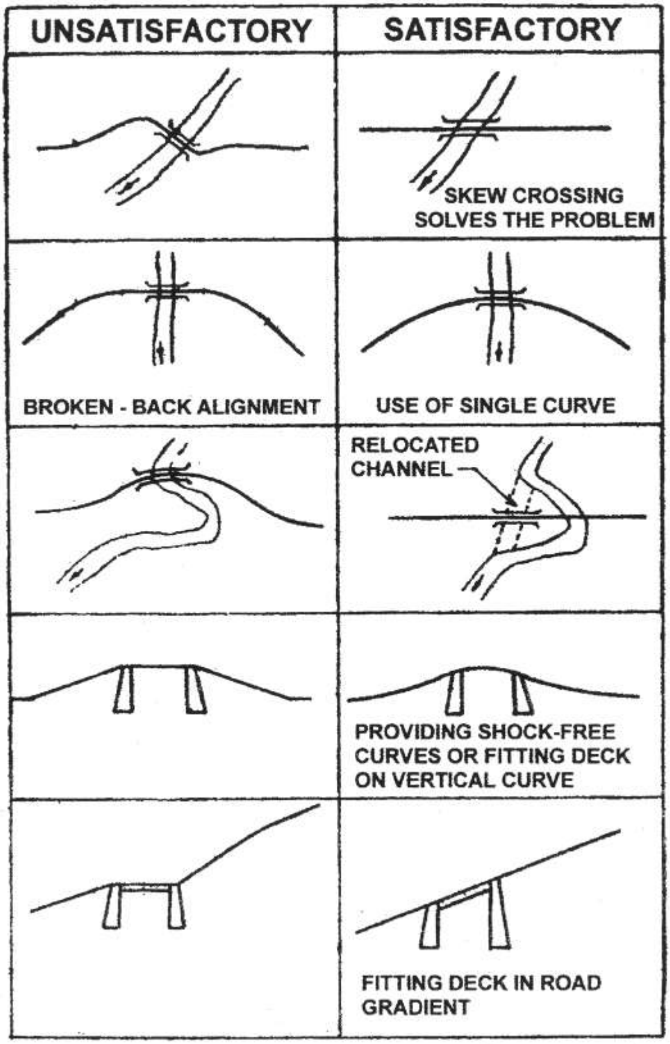


Fig. 8.5. Some examples of satisfactory and unsatisfactory location, alignment and profile for culverts

Table 8.5. (a) Minimum cement content and maximum water cement ratio

Structural Member	Min. cement content (km/cu.m)		Max. water cement ratio	
	Exposure conditions		Exposure conditions	
	Normal	Severe	Normal	Severe
a) PCC members	250	310	0.50	0.45
b) RCC members	310	400	0.45	0.40

Table 8.5. (b) Minimum strength of concrete

Member	Conditions of Exposure	
	Moderate	Severe
a) PCC members	M 15	M 20
b) RCC members	M 20	M 25

Table 8.6. Proportions for nominal mix concrete

Grade of concrete	Total quantity of dry aggregate by mass per 50 kg of cement to be taken as the sum of individual masses of fine and coarse aggregates (kg)	Proportion of fine aggregate to coarse aggregate (by mass)	Quantity of water per 50 kg of cement Max. Litres
M 15	350	Generally, 1:2 subject to an upper limit of 1:1 $^1/_2$ and a lower limit of	32
M 20	250	1:2 $^1/_2$	30

Note: The proportions of fine to coarse aggregate should be adjusted from upper limit to lower limit progressively as the grading of fine aggregates becomes finer and the maximum size of coarse aggregate becomes larger. Graded coarse aggregates shall be used.

Table 8.7. Current margin for various grades of concrete

Concrete grade	Current Margin (MP_a)	Target mean strength (MP_a)
M 15	10	25
M 20	10	30
M 25	11	36

Table 8.8. Slump for different types of works

	Type	Slump (mm)
1)	Plain cement concrete	25
2)	RCC structures with widely spaced reinforcement, e.g., abutments, footings.	40-50
3)	RCC structures with fair degree congestion of reinforcement, e.g., box culverts, abutment caps, walls with thickness greater than 300 mm	75-125

A few precautions to be taken for proper placement and compaction of concrete are given in Table 8.9.

Table 8.9. Points of guidance on placing and compaction of concrete

1. The formwork must be examined carefully for safety before ordering concreting.
2. Check the reinforcement for size, spacing, lapping, etc.
3. Concrete should be deposited in uniform layers and compacted in final position within 30 minutes of its discharge from the mixer. The compacted depth of each layer shall not be more than 0.45 m when internal vibrators are used, and should not exceed 0.3 in all other cases.
4. Do not allow dropping of concrete from a height exceeding 2 m.

5. When concreting is to be received on a surface which has hardened, it shall be roughened, swept clean, wetted and covered with a 13 mm thick mortar layer composed of cement and sand in the same ratio as in the concrete mix.

6. Compact the concrete to produce a dense homogeneous mass with vibrator. Do not apply vibration through the reinforcement.

7. Concrete to be used under water should contain 10 per cent more cement. The slump shall not be less than 100 mm not more than 180 mm. The cofferdams or forms shall be sufficiently tight to ensure still water conditions. Do not allow pumping until 24 hours of concreting.

8. Keep the compacted concrete continuously wet for a period not less than 14 days.

8.7. Cement Mortar

Cement and sand shall be mixed intimately in a mechanical mixer in the specified proportions. Proportioning of cement shall be by weight while sand can be by volumes after making due allowance for bulking. The mortar should be used within 30 minutes of addition of water.

8.8. Brickworks for Structures

Brick shall be soaked in water for minimum period of one hour before use. All brickwork shall be laid in English bond, even and true to line, plumb and level. Bricks shall be laid with frogs up, on a full bed of mortar. All joints shall be properly flushed and packed with mortar so that no hollow space is left. Thickness of joints shall not exceed 10 mm. The masonry shall be kept constantly moist on all faces for a minimum period of 7 days.

9. CONSTRUCTION

9. CONSTRUCTION

9.1. Preliminaries

9.1.1. **General :** Study in depth the contract drawings, contract conditions and special conditions, specifications, special provisions, the technical note issued by the sanctioning authority, the estimate of quantities, etc. to have a clear understanding of the scope and extent of the project.

Check whether the project involves permission or approval of other departments/agencies, e.g., approval for cutting of trees or relocation of utility services, etc.*

* Location of trees, if required to be planted and other landscaping features may also be decided and got approved from the competent authority. Take action to get all these done even prior to award of contract.

Look into the stipulated contract time for completion vis-a-vis the working seasons and calendar months to ensure that the tasks are completed according to the specified programme. For this purpose, modern project management techniques should be used.

Keep at site :

i) Survey and investigation report including material test results.

ii) Bill of quantities.

iii) Site order book; Work diaries

iv) Quality control record book;

v) A set of working drawings mounted on cloth and

vi) Up-to-date construction programme

9.1.2. **Alignment and bench marks :** During the final location survey, stakes, pillars or hubs would have been left on the ground to delineate the final centre line of the road. Have a check on these and replace the missing ones.

Check the bench marks for levels, and tally these with those given on the drawings. Missing or disturbed bench marks should be restored and the actual bench mark levels marked on the plans. Ensure that all the bench marks levels are with reference to the same datum.

9.1.3. **Logistics :** Ascertain from the contractor the haul roads and approach roads through which the materials and other resources are to reach the site.

9.1.4. **Materials, labour and equipment :** List out the materials and their quantities to be provided by the Department. Similarly, do the exercise for equipment. Take action to procure these for supply in time.

Ascertain from the contractor the sources from where he will bring the material for the project, number of labour to be employed and facilities for housing, sanitation, transport, fuel wood and first-aid to be provided for them. Details of site laboratory should also be obtained.

Ensure that necessary repair facilities, spares, stores and POL are available at site.

9.1.5. **Safety measures :** Ascertain from the contractor, the measures he proposes to take for safety of workmen including purchase of insurance policies, and ensure that these satisfy the rules and regulations in force. "Guidelines on safety in Road Construction Zones" (IRC:SP:55) may be referred for further details.

9.1.6. **Arrangements for traffic during construction :** Two methods are possible. (i) by passing traffic along a part of the existing carriageway; and (ii) by passing traffic along a temporary diversion - see Figs. 9.1 and 9.2. The choice will be dictated by duration of the work, traffic intensity, availability of space, etc. In either case, all safety measures, like, signs, markings, delineators, etc. must be provided as shown in these figures before taking up the work in hand.

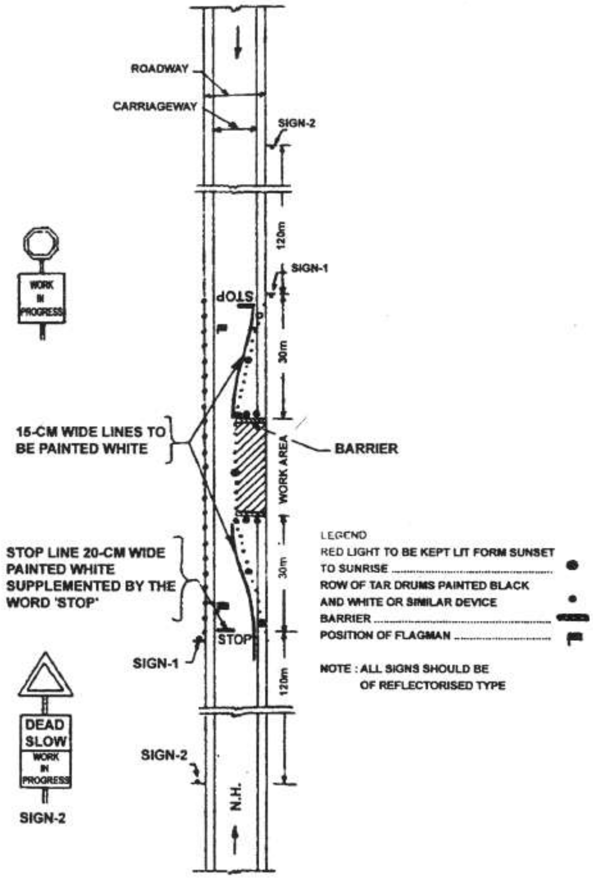


Fig. 9.1. Arrangements for traffic during construction passing traffic over part width of roadway

The first method can be adopted where the duration of work at site is short and the traffic could be passed on half width at a time without undue delay. Treated shoulder should be provided on the side on which work is not in progress. The shoulder should be dressed and brought in line with the pavement and provided with a layer of min^{m} 150 mm thick granular base course covered with bituminous surface dressing in a width of atleaset 1.5 m. The existing

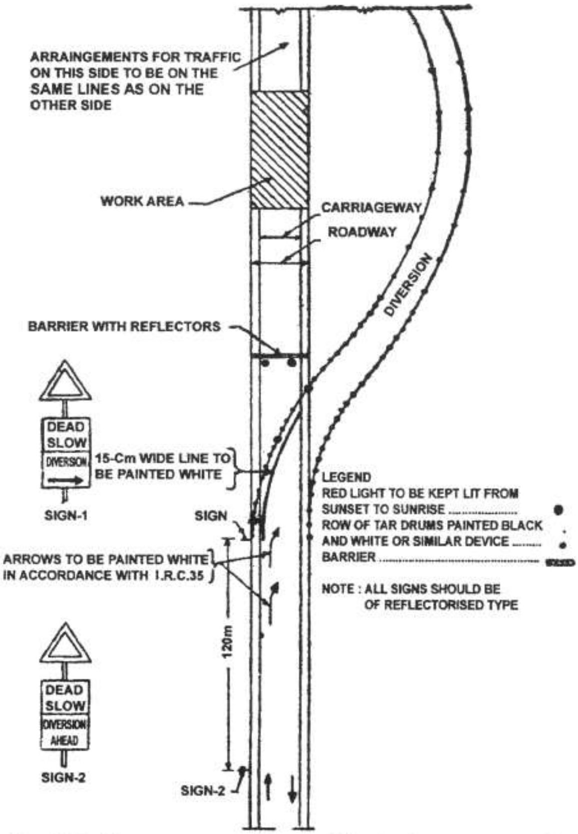


Fig. 9.2. Arrangements for traffic during construction

carriageway and the treated shoulder should be maintained properly during construction and should join smoothly with the main road.

The continuous length for such an arrangement should not normally exceed 500 m. If stretches are longer, passing places atleast 20 m long with additional paved width of 2.5 m shall be provided at every 500 m interval.

Flagmen equipped with flags or hand lights and lanterns, etc. should be positioned at both the ends at all hours.

The second method of temporary diversion may be adopted where the duration of work is expected to be long and traffic is heavy so as to cause undue delay with the first method. The diversion should join smoothly with the main route. The gradient should not exceed 1 in 15.

Temporary diversions should be constructed 7 m wide or width of carriageway whichever is less with atleast 200 mm thick sub-base, 225 mm base course and covered with either premixed carpet and seal coat or mix seal surfacing, 2.5 m earthen shoulders should be provided on both sides of diversion.

The diversion should be well drained to prevent accumulation of water.

9.1.7. **Construction programme :** Review construction programme given in the project report and see whether it is possible to adhere to this in the light of availability of resources and related factors. If not, prepare a revised programme to reflect the actual situation and revised cost, where necessary, and submit to higher authorities with justification, for approval. The programme should be based on Critical Path Method (see IRC:SP-14 for details) for major works and in the form of bar charts for other cases.

9.2. Environment Protection

All precautions should be taken for safeguarding the environment during the course of construction. The following points need special attention:

i) Borrowpits should not be dug in the right-to-way of the road.

ii) During construction, soil erosion should be fully controlled and sedimentation and pollution of natural water courses, ponds, tanks and reservoirs should be avoided.

iii) Bituminous hot mix plant and concrete batching plants should be located away from habitation and industrial establishments. All precautions shall be taken to minimise the levels of noise, vibration, dust and emissions from these plants.

iv) No material shall be used or generated, during construction, which is hazardous to the health of human beings, animals or vegetation.

v) Nuclear gauges shall be used only after ensuring their safe use in accordance with the regulations in force.

vi) All reasonable steps shall be taken to minimise dust nuisance during the construction.

vii) All existing highways and roads used by vehicles supplying material or plant should be kept clean and clear of dust, mud or other extraneous materials.

9.3. Setting Out

All construction should be with reference to the final centre line of the main location survey.

The centre line should be accurately referenced, every 50 m interval in plain and rolling terrains, 20 m intervals in hilly terrains and at all curve points, by marker pegs and chainage boards set in or near the fence line. The schedule of reference dimensions should be prepared and marker pegs shall be maintained till the end of the work.

Working bench marks tied with the reference bench mark, should be established at the rate of four numbers per km and also at or near all drainage structures, other bridge and underpasses. An up-to-date record of all bench marks should be maintained and the working bench marks should be checked frequently.

On construction reaching the formation level stage, the centre line should again be set out and accurately referenced by marker pegs at the outer limits of the formation. Posts of timber or steel should be kept one m from the formation edges showing the finished formation/finished base course/finished road levels. It should be possible to stretch a thread across to verify the finished levels of various courses.

All survey monuments, bench marks, beacons, etc. should be maintained accurately during the construction process. A survey file containing the setting out data for traverse points and levels shall be prepared and maintained during the construction process.

Precision automatic levels, having a standard deviation or + 2 mm per km and fitted with micormeter attachment shall be used for all double run levelling work. Setting out of the road alignment and measurement of angles shall be done by using theodolite with traversing target, having a accuracy of one second. Measurement of distances shall be done preferably using precision instruments, like, distomat.

9.4. Clearing and Grubbing

Demarcate the limits of clearing and grubbing as shown on the drawings.

Mark the roadside trees, shrubs, buildings, utility lines, etc. which are not to be disturbed and ensure that the contractor provides suitable safeguards to protect these from injury or damage.

Before start of work, examine the contractor's work plan including the procedures to be followed for disposal of waste materials and the precautions proposed against soil erosion, air pollution and water pollution.

All trees, stumps, etc. falling within excavation and fill lines should be cut to such depth below ground level that in no case these fall within 500 mm of the subgrade. Also, all vegetation (roots, under-growth grass, etc.) and other deleterious matters should be removed between fill lines.

From embankment/cut areas, remove and store top soil for re-application later.

Have the removed materials of value suitably stacked for reuse or auctioning.

In woodden areas, burning should not be permitted.

Ensure that no hazard to the public is created by the contractor's operations.

Periodically observe the operations to ensure that damage to adjacent property is being prevented and that trees, utilities and structures which are to remain are being preserved.

9.5. Drainage

9.5.1. **General :** The site engineer should have a clear understanding that performance of a road is closely related to drainage, both surface and subsurface. The sources of water involved may be the surface runoff, seepage flow through subterranean channels, ground water movement and moisture transfer within the soil masses, etc. and the effort should be to have the surplus water removed away from the roadway area quickly and effectively.

9.5.2. **Surface drainage :** Ensure that the specified crossfall for both the pavement and shoulders is provided eight from subgrade level and maintained during the earthwork.

Ensure that schedule of work is so arranged that the drains are completed in proper sequence with road works so as to ensure that no excavation of completed roadwork is necessary subsequently.

Ensure that the subgrade is sufficiently above the HFL/ground water table, or the natural ground level, the minimum height being:

For main roads, like, NH/SH	.....	1.0 m
For lower category roads	.....	0.6 m

Provide side drains as per approved drawings. These are normally at the edges of right-of-way where the road is in embankment, and at the edge of roadway if in cutting. The drains may be trapezoidal or 'V' shaped though the former is hydraulically superior. However, if the drain is at roadway edge, prefer 'V' shape as vehicles can partly use the space in case of any exigency. The outfall should be the nearest cross-drainage structure. Bed level of the side drains will be dictated by the available outfall level.

Recommended minimum bed slope of drain is 1/200 if lined and 1/100 otherwise.

Invariably provide catchwater drains on hill roads to intercept the flow down the steep slopes. These drains will need to be stepped out with check dams and energy dissipation devices at each fall in level. The drains should be lined in previous/erodible strata.

9.5.3. **Sub-surface drainage :** This is to keep the subgrade and the pavement structural section free of surplus water resulting from seepage, capillary action, etc.

With box-type of construction (pavement layers not extended to full width of roadway), the situation becomes critical if the subgrade soil is relatively impermeable when water seeping into the pavement through cracks, etc. will find no path to drain out. For such cases, it is preferable to extend the sub-base granular layer (moorum, gravel, etc.) to the full width of formation, or to provide lateral drains at intervals.

Sub-surface drains will generally be required in cut sections of hilly/rolling terrain where seepage flow or spring exist. Investigations at the time of field suveys, particularly if conducted during the dry season may not generally give any indication to necessary information for counter measures. Experience with road construction on similar formations can help. Presence of soft, spongy ground, very damp soil, etc. may also indicate the presence of ground water movement. In any case it is preferable to study the drainage features in the rainy season after the hill-side has been cut down to the formation level and then work out the size, location and invert levels of the drains.

Cut-fill transition will require the provision of a lateral sub-drain to intercept any seepage water flowing through the pavement structure.

Trenches for sub-surface drains should be excavated beginning at outlet proceeding towards the upper end. Similarly, pipes should be laid from the outlet end towards the upper end. Backfill material below the pipe should be laid for full width of trench and compacted before laying the pipes.

Sub-surface drains are intended to intercept and drain off sub-surface water and not surface water. Ensure that the surface water is drained off separately through open side drains without overloading the sub-surface drainage system. Upgrade opening should be tightly closed with concrete plugs or plugs fabricated from the same material as the pipe and securely held in place to prevent entry of soil material.

Criteria for choosing filter material surrounding the pipe are :

i) $\dfrac{\text{D15 of filter}}{\text{D15 of soil}} = 5 \text{ to } 40$

ii) $\dfrac{\text{D15 of filter}}{\text{D85 of soil}} = 5 \text{ or less}$

iii) The grain-size curve of filter should be roughly parallel to that of the base material.

iv) Table 300-3 of Ministry's Specifications lays down grading requirements for filter material.

v) Dia of hole shall not ordinarily be greater than half of D85 size of material surrounding the pipe subject to minimum of 3 mm and maximum of 6 mm.

9.6. Earthwork

9.6.1. **Preliminaries :** Review the project drawings, special provisions and specifications relating to earthwork prior to commencement of work.

Review soil survey report and borrow area charts. Where soil has to be borrowed from outside the road land boundaries, take action to obtain the necessary permits or for temporary acquisition of land.

Obtain detailed plans showing the design of shoring, bracing, sloping or other provisions made for safety of workers. Ensure that these satisfy the safety requirements.

Discuss with the contractor his schedule of earthwork operations, sources of materials, the equipment he proposes to use, etc. Ensure that the plan of operations is in accordance with the requirement of the contract.

9.6.2. **Roadway and drainage excavation :** The area for the roadway and drainage excavation should be cleared and grabbed.

Set out the limits of excavation true to lines and levels. Control pegs for alignment fixation and embankment construction are shown in Fig. 9.3. Have a periodical check on the bench marks and on the construction lines for accuracy.

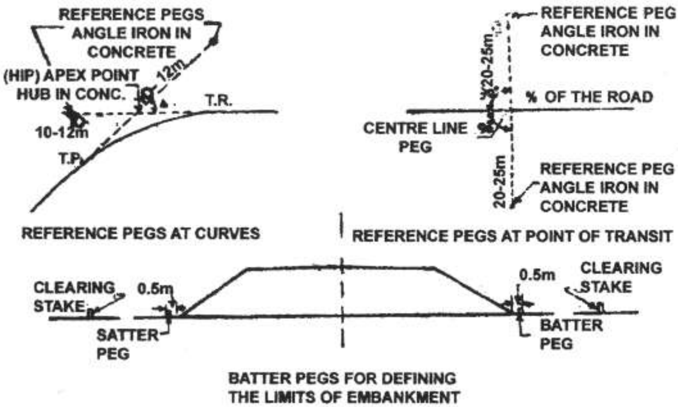


Fig. 9.3. Control pegs for alignment fixation and embankment construction

Keep the objective in view that soil from excavation should be put to best possible use in fill areas unless the material is declared unfit. Where different grades of materials are met with, arrange the operations in such a way that the best material is reserved for use in the top 0.5 m height of the embankment. Avoid double handling of the materials.

Excavated materials usable in pavement construction should be stacked at convenient locations and proper records kept.

Unsuitable material or surplus soil should not be pushed down the valley but used to fill up low areas or dumped at suitable places where it cannot get easily washed away by rain.

Ensure that necessary measures are taken to prevent soil erosion, blockage of streams and water pollution.

Have a close watch on the cut slopes and excavated areas to see whether these require any protection/drainage measures for stability/performance.

Be doubly sure about the classification of the excavated materials. Where additional payment is involved, ensure proper measurements, records and evidence, etc.

Check the finished cut surfaces for levels and slopes regularly.

Have the top soil (removed earlier and conserved) applied on to cut slopes, berms and other disturbed areas. Have these areas sodded or seeded to protect against erosion.

9.6.3. **Blasting :** Points needing specific attention are :

i) Blasting operation should be carried out in presence of a competent and experienced supervisor.

ii) Blasting should be carried out in fixed hours which have been made known to people in the vicinity.

iii) Red flags should be prominently displayed in all directions.

iv) If blasting is within 50 m of any railway track, concerned Railway Authority should be notified of the blasting schedule, well in advance.

v) The magazine for the storage of explosives should be located at approved site and built to the specifications of the explosive department. The magazine should have an effective lightening conductor. All necessary precautions as required by explosive Act should be taken.

vi) The type of explosives and the plan of drilling and firing should be carefully examined for suitability.

vii) The over-burden should be removed and measurements taken before blasting operation is started.

viii) Specified procedures should be strictly followed in case of misfire.

ix) Maintenance of day-to-day account of explosives.

9.6.4. **Pre-splitting technique** : This blasting technique is defined as the establishment of a specified excavation slope in rock by controlled use of explosives and blasting in properly aligned and spaced drill holes. This technique is recommended for harder rock types.

This consists of drilling a series of closely spaced parallel holes (not exceeding 900 mm centre-to-centre) that reasonably conforms to the desired outlines and grade. Production holes should be drilled atleast 2.5 m away from the pre-split plane. The pre-split holes are charged and fired prior to the production holes. This provides for a pre-shared face for the primary blast.

All over-burden soil and weathered rock along the top of the excavation, for a distance of 5 m to 15 m beyond the drilling line, should be removed before drilling the pre-splitting holes.

Normally, this technique should first be applied to short test section to see whether the method has produced acceptable slope without undue shatter.

Any blasting technique which results in damage to the pre-split surface should be discontinued.

9.6.5. **Preparation of cut formation :** Cut formation requires very close inspection for the reason that it is for the first time that the material gets exposed.

Check for suitability of the natural material. Some shales may look hard when dry but get slushy in presence of water. If such unsuitable materials are met with, have these removed to a depth of at least 0.5 m or as otherwise specified and replaced with suitable material.

If density of sub-grade is lower than 97 per cent of the laboratory density determined as per IS:2720 (Part VIII), it shall be loosened to a depth of 500 mm, watered and recompacted in 250 mm thick loose layers to a density not less than 97 per cent of the maximum laboratory dry density.

In rock formation all dish shaped cavities left out by blasting should be cut out at edges to facilitate drainage. Low areas should be filled up with sub-base material and properly compacted.

Any seepage should be intercepted and properly drained.

9.6.6. **Excavation for structures :** The points which require specific attention are :

i) Setting out true to specified lines and levels.

ii) Strength and safety of all temporary shoring, bracing and other earth supporting devices.

iii) Normally, open foundation should be laid dry. De-watering by boiling, pumping, diversion channels and other necessary work should be carried out when seepage flow is met with.

iv) The discharged water should not cause damage to the works, crops or property.

v) Detailed examination of the stratum at the foundation level to see whether the soil fits in with the design assumptions, or the material is unsuitable to be left in place.

9.6.7. **Borrow excavation :** When earth available from the excavation for the roadway formation and drainage excavation falls short of the requirement of embankment construction in the remaining reaches, this should be obtained from approved area(s) outside the land width identified for the purpose.

Check for the location, size and depth of borrowpits, where payment is on the basis of borrow measurements, have cross-sections taken of the area and leave deadmen or cross ridges.

The volume of borrow excavation and of compacted embankment will be different if there is variation in the respective dry densities. For example, if the in-situ DBD of borrow soil is 1.6 gm/cc, and that of embankment 1.8 gm/cc, the quantity of borrow excavation will be larger by 1.8/1.6 times.

On completion of all measurments for payment, have the borrowpits opened out partly at either ends to facilitate easy drainage.

9.6.8. **Embankment construction :** The stability of an embankment depends upon the foundation, the use of suitable materials, proper placing and compacting of the materials and strict adherence to quality control measures. The suitability of embankment material is shown in Table 9.1. Table 9.2. indicates the compaction requirements. Table 9.3. lays down a general guide to the selection of soils. Guide to the selection of compaction plant is listed in Table 9.4.

Materials, from swamps, marshes and bogs, peats, logs, stump, perishable material, OL, OI, OH, material susceptible to spontaneous combustion, material in frozen condition, clay with liquid limit exceeding 80 and plasticity index exceeding 55 and materials with salts likely to result in leaching of the embankment should be considered unsuitable material for construction of embankment.

Have a close inspection of the original ground. Look for seepage and wet patches; lush growth of vegetation indicating high

Table 9.1. Suitability of embankment materials

S. No.	Type of Work	Maximum laboratory dry unit weight when tested as per IS:2720 (Part VIII)
1.	Embankment upto 3 mts. height, not subjected to extensive flooding	Not less than 15.2 kN/cu.m
2.	Embankment exceeding 3 mts. height or embankment of any height subject to long periods of inundations	Not less than 16.0 kN/cu.m
3.	Subgrade and earthen shoulders/verges/backfill	Not less than 17.5 kn/cu.m

Table 9.2. Compaction requirement for embankment and subgrade

S. No.	Type of work	Relative compaction as percentage of maximum laboratory dry density as per IS:2720 (Part VIII)
1.	Subgrade and earthen shoulders	Not less than 97
2.	Embankment	Not less than 95

Note : 1. Ordinarily, the materials satisfying density requirements, given above should be employed for construction of embankment and subgrade. The density requirements are not applicable to light weight materials, e.g., cinder, flyash, etc.

2. The material to be used in subgrade should also satisfy design CBR values it should preferably have a CBR more than 7 per cent. Material with CBR less than 5 per cent shall not be used in sub-grade.

Table 9.3. General guide to the selection of soils

P.R.A. Class	Comparable IS classification probable	possible	Visual description	Proctor density gm/cc	O.M.C. per cent	Anticipated performance
A-1	GW, GP GB, SW, SP, SB, SM	— —	Granular	1.8— 2.3	7-15	Good to excellent
A-2	GM, GC, SM, SC	—	Granular	1.7— 2.2	9-18	Fair to excellent
A-3	SP	—	Sand	1.7— 1.8	9-15	Fair to good
A-4	ML, MH, OL, OH	CL, SM SB, SC	Sandy silts silts	1.5— 2.1	10-20	Poor to good
A-5	MH, OH	—	Silts	1.4— 1.6	20-25	Unsatisfactory
A-6	CL, CT	MH, OH, SC	Silt clay	1.5— 1.9	10-30	Poor to good
A-7	MH, CT, CH, OH	SC	Clay	1.4— 1.8	15-35	Poor to fair

ground water or springs; trees leaning downhill indicating of seepage, the surface soil; twisted trees or bared surface in otherwise timbered area indicating landslide. If such features are observed, consult the designer if the design had taken these into account. If not, seek specific instructions for remedial measures.

In all cases after clearing and grubbing compact the original ground with a minimum of six passes of 8-10 tonne roller. Ensure that any portion of the original ground falling within 0.5 m from subgrade level is compacted at least to 97 per cent or Proctor density determined as per IS:2720 (Part VIII).

Table 9.4. General guide to the selection of compaction plant

Compaction plant	Cohesive soil	Granular and dry cohesive	Uniformly graded
Smoothwheeled roller	Suitable	Suitable	Suitable, if roller is towed and load/cm width < 55 kg
Pneumatic tyred	Suitable	Suitable, if load is > 2 tonnes/wheel	Suitable, if towed, and load < 1.5 tonne/wheel
Vibratory	Suitable, if static load > 7 kg/cm width	Suitable	Suitable; but should be towed if static load > 12 kg/cm width
Sheepsfoot	Suitable	Unsuitable	Unsuitable

Plan for proper sequence of delivering materials to embankment site so that double handling is avoided.

Permit delivery of embankment material to site only if the necessary rollers in working condition are present at site.

Have a special check on the following points during the construction operations :

i) Before starting the construction operation, the site should be cleared and grubbed. The limits of the embankment/sub-grade should be marked by fixing banks at regular intervals. The embankment should be built sufficiently wider than the designed dimension so that surplus material may be trimmed.

ii) If the foundation of embankment is in area with stagnant water, the same should be removed by boiling out or pumping and should be kept dry. The drained water discharge should not cause damage to the works, crops or any other property.

iii) All area to be covered by embankment foundation shall be stripped to specified depths, not exceeding 150 mm, and stored in stock piles of height not existing 2 m for covering embankment slopes.

iv) The soil delivered at site must be obtained from approved sources.

v) Reserve better at the available fill material for the top 500 mm of the embankment and shoulders. If heavy clays have to be used, have these deposited in the bottom layers.

vi) Clods or hard lumps of earth should be broken down. Size of clods should not exceed 7.5 cm when placed in body of embankment and 5 cm when placed in subgrade portion.

vii) The embankment and subgrade material shall be spread in layers of uniform thickness not exceeding 200 mm compacted thickness over the entire width of embankment by mechanical means, finished by motor grader and compacted to the required desity. In case of vibratory rollers or other compaction equipment capable of higher degree of compaction, the loose thickness on each layer of soil for the sub-grade and embankment could be upto 400 mm loose or 250 mm compacted, subjected to the trial demonstration about efficacy of the equipment. Successive layers shall not be placed untill the layer under construction has been thoroughly compacted to the specified requirements. Compacted layer shall be finished parallel to the final cross-section of the embankment.

viii) Moisture content of the soil shall be checked and corrected at the site of placement prior to commencement of compaction. If required, additional water should be sprinkled from a sprinkler capable of applying water with controlable rate of the flow, without any flooding. The water shall be added uniformaly and thoroughly mixed in soil by blades, discs and harrows untill a uniform moisture content is obtained. If the material at site is too wet, it shall be dried by aeration and exposure to the sun till the moisture content is acceptable.

ix) The moisture content at the time of compaction should be in range of -2 per cent to +1 per cent of the OMC. Expansive clay should be compacted at moisture content corresponding to the specified dry density but on the wet side of the optimum moisture content obtained from the laboratory compaction curve.

x) The material to be used in sub-grade for heavily trafficked road should preferably have a CBR of more than 7 per cent. Material with CBR less than 5 per cent shall not be used in sub-grade.

xi) The embankment should be constructed evenly over the full width. Movement of construction plant and other vehicles on embankment should be avoided.

xii) Embankment should not be constructed with steeper side slopes or to widths larger than those required.

xiii) When density measurements reveal any soft areas, further compaction should be carried out. If inspite of that requisite compaction is not achieved, the material in soft areas should be removed and replaced by approved material, compacted to the designed density requirements.

xiv) The number of passes to achieve the desired compaction will depend on the nature of soil and type of compaction plant. For major works, it would be preferably to conduct compaction trials. As a rough guide, about 8-16 passes of the compaction plant appropriate to the type of soil (see Table 9.4) would be required.

xv) Each layer should be rolled to the camber/cross fall of the road and this should be maintained so as to prevent ponding.

xvi) The beds and sloping sides of diverted channels for water courses should be protected against action of water by rubble paving. This should consist of dressed stones of thickness not less than 255 mm and volume not less than .02 cu.m. No rounded boulders should be used.

xvii) Where the embankment width is insufficient to permit the use of conventional rollers, compaction should be carried out with the help of small vibratory rollers, plate compactors, power rammers or other such equipment.

9.6.9. **Embankment under special conditions :** Widening existing embankment or construction against sloping ground

i) End dumping of materials from trucks on widened portions should be avoided as far as possible.

ii) If existing side slopes are steeper than 4:1, cut horizontal benches 0.3 m wide to ensure bond. If the slopes are 4:1 or flatter, the surface may be roughened by ploughing or scarifying.

iii) For wet conditions benches with slightly inward fall and sub-soil drains at the lowest point shall be provided before the fill is placed against slopping ground.

9.6.9.1. **Earthwork over existing road surface :** If within 1 m of the new subgrade level, scarify to a depth of 50 mm or more if specified, if the road surface is BT, and completely removed, if of cement concrete. If the level difference is more than 1 m, allow the existing road surface to stay.

9.6.9.2. **Embankment around structures :**

i) Suspend filling around structures upto a distance of twice the height of the embankment. Permit filling only after the concrete/masonry has been in position for at least 14 days. Bring up the embankment in equal horizontal layers simultaneously on each side to avoid undue thrust and unequal pressure.

ii) The material used for backfill should not be an organic soil or highly plastic clay, plasticity index and liquid limit should not be greater than 20 and 40 respectively.

9.6.9.3. **Embankment construction under water :** Only acceptable granular material or rock should be used for filling under water. The material should consist of graded hard durable particles of size not exceeding 75 mm. This material should be non-plastic having uniformity co-efficient of not less than 10.

9.6.9.4. **Earthwork high embankment :**

i) Earthwork for high embankment should be carried out by stage construction of fills at controlled rates of filling. The embankment should be surcharged for the specified period.

ii) At the stage of formation level, surcharge where used material should be removed. High embankment should remain in place for the required settlement period before excavating footings for structures, like, abutment wing wall, etc.

9.6.10. **Soil erosion and sedimentation control :** Before the start of construction obtain schedules for carrying out temporary and permanent erosion/sedimentation control works which are applicable for the items of clearing and grubbing, road way and drainage excavation, embankment/subgrade construction, bridges, etc.

This work may involve construction of temporary berms, dikes, sediment basins, slope drains and use of temporary mulches, fabrics, mats or other control devices.

All permanent erosion and sedimentation control features should be constructed at the earliest practicable time to minimise the need for temporary erosion and sedimentation control measures. Temporary measures will be used to control only the phenomenon of erosion/sedimentation/pollution that may develop during normal construction operation. If erosion or sedimentation is likely to be a problem, clearing and grubbing operations should be immediately followed by grading operations and permanent erosion/sedimentation control.

Construction work should be started only after the erosion/ sedimentation control operations have been completed.

The surface area of erodible earth material exposed by clearing and grubbing, excavation, etc. should be limited to the minimum practicable.

If required the area of excavation, borrow and embankment operation may be limited so as to commensurate with the progress of erosion/sedimentation control measures.

Temporary erosion/sedimentation/pollution control measures may also be applicable on construction work outside the right-of-way, like, borrowpits, service roads and equipment storage sites.

9.6.11. **Slope protection :** Protection of slopes may consist of either turfing with sods of grass or seeding and mulching operations followed by application of jute netting.

Where the side slopes are steeper than horizontal to vertical, the laying of sods should be started from bottom upwards and the sods should be stacked with pegs or nails spaced 50 to 100 cm apart along the longitudinal axis of the sod strips and through the sods top being kept, flushed with the sods.

The seeds used for seeding and mulching operation should be approved quality and suitable for the soil. Mulching material should consist of stew, hay, wood shaving or saw dust in a dry condition.

The bituminous emulsion used as tie down for mulch should be of the specified grade.

Jute netting should be undyed jute yarn with approximate 25 mm square woven openings. Geo-netting should be made of rectangular mesh having opening of 20x20 mm. The weight of geo-netting should be less than 3.8 kg per 1000 sq.m.

9.6.12. **Construction of rockfill embankment :** In normal circumstances embankment should not be constructed with rockfill material. Rockfill should not be used at least for a depth of 500 mm below the formation level. This should be made up of earthen cushion.

The rockfill should be hard durable and inert material capable of being deposited in layers.

Argillaceous rocks (clay, shales, etc.), unburnt colliery stock and chalk should not be used in rockfill.

The material for rockfill should not exceed 300 mm in size and percentage finer than 125 mm should not exceed 10.

The material shall be spread and levelled in layers. Each lay should be compacted by five passes of vibratory roller (8-10 tonnes). The compacted thickness of each layer should not exceed 500 mm. Before laying the next layer, the surface voids should be filled with broken fragments. The top layer of rockfill should be thoroughly blinded with suitable granular material to seal its surface.

9.7. Sub-bases and Bases (Non-Bituminous)

9.7.1. **Granular sub-base :** The material for granular sub-base should generally conform to the gradings indicated in Tables 9.5. and 9.6. or combination thereof.

9.7.2. **Stabilised soil sub-base :** Mechanical Stabilisation consists of blending the missing fraction (clay with sand and sand with clayey soils) for improving gradation and bringing the plasticity within permissible limits. Gradation, plasticity and density are important controls.

Lime-soil stabilisation is a process of stabilisation of clayey soils by the chemical action of lime on the clay minerals. Generally, soils containing at least 15 per cent of materials finer than 425 μm and having a PI of at least 10 are suitable. However, presence of harmful salts or organic matter may inhibit the stabilisation and it is better to test for lime reactivity of the soil before choosing this technique. A soil whose 7-day unconfined compression strength increases by at least 3 kg/cm^2 with lime treatment can be considered lime reactive.

The lime used for lime soil stabilisation shall be commercial dry lime having a purity of not less than 70 per cent by weight of

Table 9.5. Grading for coarse-graded granular sub-base materials

IS sieve designation	Per cent by weight passing the IS seive		
	Grading I	Grading II	Grading III
75.0 mm	100	—	—
53.0 mm	80-100	100	--
26.5 mm	55-90	70-100	100
9.50 mm	35-65	50-80	65-95
4.75 mm	25-55	40-65	50-80
2.36 mm	20-40	30-50	40-65
0.425 mm	10-25	15-25	20-35
0.075 mm	3-10	3-10	3-10
CBR Value (Minimum)	30	25	20

Table 9.6. Grading for coarse-graded granular sub-base materials

IS sieve designation	Per cent by weight passing the IS seive		
	Grading I	Grading II	Grading III
75.0 mm	100	—	—
53.0 mm	—	100	—
26.5 mm	55-75	50-80	100
9.50 mm	—	—	—
4.75 mm	10-30	15-35	25-45
2.36 mm	—	—	—
0.425 mm	—	—	—
0.075 mm	< 10	< 10	< 10
CBR Value (Minimum)	30	25	20

Note : The material passing 425 micron (0.425 mm) seive for all the three gradings when tested according to IS:2720 (Part V) shall have liquid limit and plasticity index not more than 25 and 6 per cent respectively.

quick lime. It should be properly stored to avoid prolonged exposure to the atmosphere.

The soil for lime soil stabilisation shall be pulverised so that it passes 100 per cent through 26.5 mm IS Sieve and passes 80 per cent by weight through I.S. Sieve 5.6 mm.

Lime-flyash-soil stabilisation is suitable for soils of medium plasticity (PI 5-20) and clayey soils. Lime chemically reacts with the silica and alumina in the flyash to form cementitious compounds which binds the soil particles.

Cement stabilisation is preferable for granular soils free of high concentrations of organic matter ($\ngtr$ 2 per cent) or deleterious salts (sulphate or carbonate content $\ngtr$ 0.2 per cent) are suitable. The plasticity modulus (product of PI and fraction passing 425 μm sieve) should be less than 250 and the uniformity co-efficient should be greater than 5. Cement for cement stabilisation should conform to the requirements to IS:269, 455 or 1489.

The mix design for cement stabilization should be done on the basis of 7-day unconfined compresive strength (UCS) and/or durability test under 12 cycles of wet dry conditions. The laboratory strength values should be at least 1.5 times the minimum field UCS taken for the pavement design.

Lime soil stabilisation or cement stabilisation should not be done when the air temperature in shade is less 100^{0}C. Compaction of lime stabilised soils should be completed within 3 hours of mixing. The corresponding period for cement stabilisation is 2 hours.

Bitumen stabilisation is suitable for sands and granular soils.

Two-stage stabilisation is preferable to stabilise certain soils in two stages to achieve better strength and other engineering properties. A typical example is to treat clayey soils with lime in the first stage to reduce plasticity and to facilitate pulverisation, and in the second stage to stabilise with cement or bitumen.

9.7.3. **Construction of granular and stabilised soil sub-bases:** The sub-base material should be spread on prepared with the help of a motor grader with blades having hydraulic control for maintaining the required slope and grade during construction.

Manual mixing shall be permitted only where the width of laying is not adequate for mechanical operations.

Mix in place construction shall be carried out by a rotavator or similar equipment.

The moisture content of loose material shall be checked and brought to 1 per cent above or 2 per cent below the CMC. If water is added, the material shall be processed by mechanical or other approved means, like, disc harrows or rotavators, etc., so that the layer is uniformly wet.

The choice of roller should be as per Table 9.4.

9.7.4. **Water bound macadam :** Material for water bound macadam should conform to relevant clause of Ministry's Specification. The physical requirements, grading requirements and the approximate quantities of aggregate required have been summarised in Table Nos. 9.7, 9.8, 9.9 and 9.10.

Table 9.7. Physical requirements of coarse aggregates for water bound macadam for sub-base/base courses

Test		Test Method	Requirements
1.	* Los Angeles Abrasion Value	IS:2386 (Part IV)	40 per cent (Max)
	or		
	* Aggregate Impact Value	IS:2386 (Part IV) or IS:5640**	30 per cent (Max)
2.	Combined Flakiness and Elongation Indices (Total) ***	IS:2386 (Part I)	30 per cent (Max)

* Aggregate may satisfy requirements of either of the two tests

** Aggregates, like, brick metal, kankar, laterite, etc. which get softened in presence of water shall be tested for impact value under wet conditions in accordance with IS:5640.

*** The requirement of flakiness index and elongation index shall be enforced only in the case of crushed broken stone and crushed slag.

Table 9.8. Grading requirements of coarse aggregates

Grading no.	Size range	IS sieve designation	Per cent by weight passing
1.	90 mm to 45 mm	125 mm	100
		90 mm	90-100
		63 mm	25-60
		45 mm	0-15
		22.4 mm	0-5
2.	63 mm to 45 mm	90 mm	100
		63 mm	90-100
		53 mm	25-75
		45 mm	0-15
		22.4 mm	0-5
3.	53 mm to 22.4 mm	63 mm	100
		53 mm	95-100
		45 mm	65-90
		22.4 mm	0-10
		11.2 mm	0-5

Note : The compacted thickness for a layer with Grading 1 shall be 100 mm while for layer with other Gradings, i.e., 2 and 3, it shall be 75 mm.

Table 9.9. Grading for screenings

Grading classification	Size of screenings	IS sieve designation	Per cent by weight passing the IS sieve
A	13.2 mm	13.2 mm	100
		11.2 mm	95-100
		5.6 mm	15-35
		180 micron	0-10
B	11.2 mm	11.2 mm	100
		5.6 mm	90-100
		180 micron	15-35

Table 9.10. Approximate quantities of coarse aggregates and screenings required for 100/75 mm compacted thickness of Water Bound Macadam (WBM) Sub-base/base course for 10m² area

Classification	Size Range	Compacted thickness	Loose qty.	Screenings			
				Stone screening		Crushable type such as Moorum or gravel	
				Grading Classification & size	For WBM sub-base/ base course (Loose quantity)	Grading classification & size	Loose qty.
Grading 1	90 mm to 45 mm	100 mm	1.21 to 1.43 m^3	Type A 13.2 mm	0.27 to 0.30 m^3	Not uniform	0.30 to 0.32 m^3
Grading 2	63 mm to 45 mm	75 mm	0.91 to 1.07 m^3	Type A 13.2 mm	0.12 to 0.15 m^3	-do-	0.22 to 0.24 m^3
-do-	-do-	-do-	-do-	Type B 11.2 mm	0.20 to 0.22 m^3	-do-	-do-
Grading 3	53 mm to 22.4 mm	75 mm	-do-	-do-	0.18 to 0.21 m^3	-do-	-do-

Thickness of a compacted layer should be 100 mm for 90-45 mm, size aggregates and 75 mm for 63-45 mm or 53-22.4 mm size aggregates.

Screenings should generally be of the same material as coarse aggregate. However, if the use of screenings is not feasible, some other non-plastic material, such as, moorum or gravel (other than rounded river borne material) having liquid limit and plasticity index below 20 and 6 respectively may be used provided fraction passing 75 micron sieve does not exceed 10 per cent.

Binding material need not be used if the layer is to serve as base (or is to receive black topping), or where crushable type of screenings, like, moorum is used.

It is a good practice to lay a sub-base of granular/stabilised material before laying WBM. This is particularly important where the subgrade is of clayey type.

Where the WBM is to be laid directly over subgrade, a 25 mm thick layer of stone screenings (Grading B) - "inverted choke" - should be spread on the prepared subgrade before the application of aggregate is taken up. In case of fine sand or silty or clayey subgrade it is advisable to lay 100 mm thick insulating layer of screening or coarse sand on the top of fine grained soil. A preferred alternative to inverted choke is the use of appropriate geosynthetics mesh.

Arrangements for water, rollers in working order and templates/ other tools and equipment for checking the quality of the materials and work must be available at site before the work of laying is started.

The quantities of coarse aggregtes and screenings will vary depending on the actual gradings.

Arrangements for lateral confinement of aggregates must be provided. This can conveniently be done by raising the shoulders in stages equal in thickness to each layer of WBM.

The coarse aggregate should be spread uniformly and evenly on the prepared sub-grade/sub-base by using templates placed across the road about 6 m apart. The thickness of each compacted layer should not be more than 100 mm in grading 1 and 75 mm for gradings 2 and 3. Wherever possible, mechanical devices should be used to spread the aggregates uniformly so as to minimise the need for manual rectification afterwards.

The spreading should be done from stockpiles or directly from vehicles. No segregation of large or fine aggregates should be allowed.

The surface should be checked frequently while spreading and rolling so as to ensure the specified regularity of slopes and camber.

The coarse aggregate should not normally be spread more than three days in advance of the subsequent construction operations.

Three wheeled power rollers at 80 to 100 kN or tandem or vibratory rollers at 80 to 100 kN static weight should be used for rolling. Except on supperelevated portions, where the rolling should proceed from inner edge to outer edge, rolling should begin from the edge gradually progressing towards centre. Successive passes should uniformly overlap the proceeding by at least one half width.

In case screening are to be applied, rolling should be discontinued when the aggregate are partially compacted with sufficient void space to permit application of screening. During rolling slight sprinkling of water may be allowed. Complete rolling is indicated by a loose stone piece getting crushed under the roller without sinking.

After the coarse aggregate has been rolled, screening to completely fill the interstices should be applied gradually over the surface. Screening should not be damp or wet at the time of application. These should not be dumped in piles but applied at a uniform rate, in three or more applications, so as ensure filling of all voids. Dry rolling should be done while the screenings are being spread so that vibrations of the roller cause screenings to settle into the voids of coarse aggregate. Dry rolling should accompanied by brooming. These operations should continue until no more screenings can be forced into the voids of coarse aggregate.

Spreading, rolling and brooming of screens shall be carried out in only such lengths which are likely to be completed within one day's operation.

After screenings have been applied, the surface should be copiously sprinkled with water, swept with hand brooms and rolled. This operation should be continued with additional screenings, applied as necessary, untill the coarse aggregates has been thoroughly keyed, well broomed, firmly set in its full depth and a grout has been formed of screenings.

The base or subgrade should not get damaged due to use of excessive quantities of water. In case lime treated soil sub-base, construction of water bound macadam should be taken up only after sub-base has picked up enough strength.

Apply binding material, wherever required, in a similar fashion as screening. Continue rolling till full compaction is achieved.

After the final compaction of WBM course, the pavement should be allowed to dry overnight. Next morning hungry spots should be filled with screenings or binding material, lightly sprinkled with water, if necessary and rolled.

No traffic should be allowed on the road untill the macadam has set. The compacted WBM Course should be allowed to completely dry and set before the next pavement course is laid over it.

WBM work should not be carried out when the atmospheric temperature is less than 0^0C in the shade.

9.7.5. **Crushed cement concrete sub-base :** This work consists of breaking and crushing the damaged cement concrete slabs and recompacting the same as sub-base in one or more layers. It may also include treating the surface of the top layer with a penetration coat of bitumen.

Coarse aggregate should conform to one of the gradings for WBM work.

Key aggregate, of 11.2 mm size, for the penetration coat, shall consist of crushed stone, crushed gravel, etc. It should be clean, strong, durable, free of disintegrated pieces, organics or other deleterious matter. It should be hydrophobic and of low porosity.

Thickness of each layer should not exceed 100 mm in case of sub-base and 75 mm in case of base course.

The course should be constructed as WBM except that no screening or binding material need be applied.

Before the application of penetration coat, the surface should be cleaned using mechanical broom.

The binder shall be heated and sprayed on the dry surface @ 25 kgs per 10 m^2 by pressure sprayer capable of self heating and spraying bitumen at specified rates and temperatures to provide a uniform, unbroken spread.

Immediately after the application of the binder, key aggregates in a clean and dry state should be spread uniformally on the surface @ 0.13 m^3 per 10 m^2 preferably by means of mechanic gritter.

9.7.6. **Wet mix macadam :** Wet mix macadam construction is an improvement over the conventional water bound macadam providing speedy and more durable construction. It differs from the water bound macadam in that graded aggregates (conforming to requirements indicated in Table 9.11) and granular materials are mixed with predetermined quantity of water in accordance with the specifications to form dense mass which is spread and rolled to approved lines, grades and cross-section to serve as pavement course(s).

Table 9.11. Physical requirements of coarse aggregates for wet mix macadam for sub-base/base courses

	Test	Test method	Requirements
1.	* Los Angeles Abrasion Value	IS:2386 (Part IV)	40 per cent (Max)
	or		
	* Aggregate Impact Value	IS:2386 (Part IV) or IS:5640	30 per cent (Max)
2.	Combined Flakiness and Elongation Indices (Total)	IS:2386 (Part I)	30 per cent (Max)

* Aggregate may satisfy requirements of either of the two test.

The specified grading for the aggregates (Table 9.12) and granular materials should be used for mixing. Quantity of water should not vary from OMC determined as per IS:2720 (Pt. VIII), by more than agreed limit.

Table 9.12. Grading requirements to aggregates for wet mix macadam

IS sieve designation	Per cent by weight passing the IS sieve
53.00 mm	100
45.00 mm	95-100
26.50 mm	—
22.40 mm	60-80
11.20 mm	40-60
4.75 mm	25-40
2.36 mm	15-30
600.00 micron	8-22
75.00 micron	0-8

Materials finer than 425 mm should have P.I. not exceeding 6.

The mix should be prepared in approved mixing plant of suitable capacity having provision for controlled addition of water and forced/positive mixing arrangement, like, pug mill or pan type mixes of concrete batch/plant.

The mixed material should be uniformaly wet and no segregation should be permitted.

The mix should be spread uniformly and evenly in required quantities on the prepared subgrade/sub-base either by a self-propelled paver finisher or a motor grader fitted with blades having hydraulic control suitable for initial adjustment and maintaining the same. In no case should the mix be dumped in heaps on the area.

The thickness of single compacted wet mix macadam layer should not be less than 75 mm nor more than 100 mm. However, the compacted thickness of single layer of the sub-base may be increased upto 200 mm provided vibratory roller of approved type is used for compaction.

The roller speed should not exceed 5 km/hour.

Rolling should continue till density achieved is at least 98 per cent maximum dry density as per IS:2720 (Part VIII).

When surface irregularity of wet mix macadam exceeds permissible tolerance or where the course is otherwise defective (like, subgrade soil getting mixed with the aggregates), the full thickness of the layer should be scarified over the affected area, reshaped with added premixed material as applicable and recompacted. The area treated in this manner should not be less than 5 m long and 2 m wide.

It is not advisable to lay the wet mix macadam during rains and the tempo of work suffers during rains.

After construction of the top WMM layer will need immediate sealing with bituminous surfacing.

Provision of adequate drainage for the foundation area for the construction courses assumes greater importance in this method of construction.

9.7.7. **Crusher-run macadam base :** Crusher-run macadam base is constructed of materials obtained from crushed rock only, satisfying requirements indicated in Table 9.14 and satisfying one of the two aggregate gradings mentioned in Table 9.13. If crushed gravel/shingle is used, minimum 90 per cent pieces retained on 4.75 mm size sieve should have at least two fractured faces.

Table 9.13. Aggregate grading requirements

Sieve size	Per cent passing by weight	
	53 mm max. size	37.5 mm max. size
63 mm	100	
45 mm	87-100	100
22.4 mm	50-85	90-100
5.6 mm	25-45	35-55
710 micron	10-25	10-30
90 micron	2-9	2-9

Table 9.14. Physical requirements of coarse aggregates for crusher-run macadam base

	Test	Test Method	Requirements
1.	*Los Angeles Abrasion Value	IS:2386 (Part IV)	40 Maximum
	or		
	* Aggregate Impact Value	IS:2386 (Part IV) or IS:5640	30 Maximum
2.	**Combined Flakiness and Elongation Indices (Total)	IS:2386 (Part I)	30 Maximum
3.	***Water absorption	IS:2386 (Part III)	2 per cent Maximum
4.	Liquid limit of material passing 425 micron	IS:2720 (Part-V)	Not more than 25
5.	Plasticity Index of material passing 425 micron	IS:2720 (Part-V)	Not more than 6

* Aggregate may satisfy requirements of either of the two tests

** First determine flakiness index, then from remaining non flaky pieces determine elongation index and add up.

*** If the water absorption is more than 2 per cent, soundness test shall be carried out as per IS:2386 (Part-V).

After the aggregates are uniformly deposited by hauling vehicles on the approved sub-grade and distributed over the surface, these are blade mixed to full depth alternately from edges to centre and back using water to moisten the materials sufficiently to prevent their segregation. Alternatively, crushed materials may be mixed using water in mixing plant of Wet Mix Macadam. If compaction is done using 80 to 100 kN weight, smooth wheel roller for single compacted thickness upto 100 mm. If vibratory roller of minimum 80 to 100 kN is used single layer upto 200 mm can be compacted. The speed of roller should not exceed 5 km/hour. Each layer shall be compacted to not less than 98 per cent of maximum density as per IS:2720 (Pt. VIII).

9.7.8. **Mineral aggregates for pavement :** Mineral aggregates should satisfy the requirements laid in Table 9.15. Each size of aggregate should be stacked separately. Similarly, material obtained from different sources should also be stacked separately.

Table 9.15. Size requirements for mineral aggregates

Coarse Aggregate

S.No.	Standard size of aggregates	Designation of sieve through which the aggregates shall wholly pass	Designation of sieve on which the aggregates shall wholly be retained
(i)	75 mm	106 mm	63 mm
(ii)	63 mm	90 mm	53 mm
(iii)	45 mm	53 mm	26.5 mm
(iv)	26.5 mm	45 mm	22.4 mm
(v)	22.4 mm	26.5 mm	13.2 mm
(vi)	13.2 mm	22.4 mm	11.2 mm
(vii)	11.2 mm	13.2 mm	6.7 mm
(viii)	6.7 mm	11.2 mm	2.8 mm

9.8 Bitumen Bound Bases and Surfacings

9.8.1. General requirements on materials, mixing, transporting, laying, compaction, joints and construction of bituminous pavement layers, are laid down in Clause 501 of this Ministry's Specifications.

9.8.2. **Prime coat :** Prime coat consists of application a single coat of low viscosity liquid bituminous material to a porus granular surface preparatory to the superimposition of bituminous treatment or mix. The choice of primer shall depend upon the porosity of the surface to be primed. Details are available in Clause 501.2 of this Ministry's Specifications.

Bituminous primer should not be applied on a wet or dusty surface. At the time of application temperature in the shade should not be less than 10°C.

The primer distributor should be self propelled or towed bitumen pressure sprayer capable of spraying the material uniformally at the specified rate and temperature. Hand spraying should be resorted to only in small areas and areas inaccessible to the pressure sprayer.

The quantity, viscosity and temperature of laying should be as specified in Table 9.16.

Table 9.16. Viscosity requirement and quantity of bituminous primer

Type of surface	Kinematic Viscosity of Primer at 60°C (Centistrokes)	Quantity per 10 sq.m (kg)
Low porosity	30-60	6 to 9
Medium porosity	70-140	9 to 12
High porosity	250-500	12 to 15

After application of cut-back, the surface should be allowed to cure for atleast 24 hours.

9.8.3. **Tack-Coat :** The binder for tack coat should be a bituminous emulsion complying with IS:8887 or cut-back as per IS:217, to be used restrictively for site at sub-zero temperature or for emergency application.

The quantity of binder should be as per Table 9.17.

The binder should be applied uniformly with bitumen pressure sprayer capable of spraying bitumen at specified rate and temperature to provide a uniform unbroken spread of bitumen.

Table 9.17. Rate of application of tack coat

	Type Surface	Quantity of liquid bituminous material in kg per 10 sq.m. area
i)	Normal bituminous surfaces	2.0 to 2.5
ii)	Dry and hungry bituminous surfaces	2.5 to 3.0
iii)	Granular surfaces treated with primer	2.5 to 3.0
iv)	Non bituminous surfaces	
	a) Granular base (not primed)	3.5 to 4.0
	b) Cement concrete pavement	3.0 to 3.5

Note : Where the material to receive an overlay is a freshly laid bituminous layer, that has not been subjected to traffic, or containated by dust, a tack coat is not mandatory where the overlay is completed within two days.

No more than the necessary tack coat for the day's operation should be placed.

The succeeding construction should be made only after curing of the tack coat.

9.8.4. **Bituminous penetration macadam and built-up spray grout :** Bituminous penetration macadam work consists of construction of one or more layers of compacted crushed coarse aggregates with alternate applications of bituminous binder and key aggregates. The built up spray grout consists of, a single course, of a two-layer composite construction with compacted crushed coarse aggregates, application of bituminous binder after each layer and key aggregates on top of the second layer. The aggregates for BPM and BUSG should meet the requirements laid in Table 9.18. Grading requirements and quantities of material required for BPM are indicated in Table Nos. 9.19 and 9.20. Grading requirements for BUSG are indicated in Table 9.21.

The coarse aggregate in a dry and clean form should be spread uniformly and eventually at the specified rates, preferably with the help of tail mounted aggregate spreader.

Table 9.18. Physical requirements of aggregates for bituminous bases

Property	Test	Specification
Cleanliness	Grain size analysis[1]	Max 5% passing 0.075 mm sieve
Particle shape	Flakiness and Elongation Index (Combined)[2]	Max 30 %
Strength*	Los Angeles Abrasion Value[3]	Max 40 %
	Aggregate Impact Value[3]	Max 30 %
Durability	Soundness : [4] Sodium Sulphate Magnesium Sulphate	 Max 12 % Max 18 %
Water Absorption	Water absorption[5]	Max 2 %
Stripping	Coating and Stripping of Bitumen Aggregate Mixtures[6]	Minimum retained coating 95 %
Water Sensitivity[7]	Retained Tensile Strength	Min 80 %

Note : [1]IS:2386 (Part I) [4]IS:2386 (Part V)
[2]IS:2386 (Part I) [5]IS:2386 (Part III)
(the elongation test to be done on non-flaky aggregates in the sample)
[3]IS:2386 Part IV* [6]IS:6241
[7]The water sensitivity test is only to be carried out if the minimum retained coating in the stripping test is less than 95 per cent.

* Aggregates may satisfy requirements of either of these two tests.

The coarse aggregate should be compacted by dry rolling with a 80-100 kN smooth wheeled steel roller. The requirement laid down in Clauses 501.6 and 501.7 of the Ministry's Specifications shall be complied.

Table 9.19. Grading requirements of coarse aggregates and key aggregates for bituminous penetration macadam

IS sieve designation	Per cent by weight passing the sieve			
	For 50 mm compacted thickness		For 75 mm compacted thickness	
	Coarse Aggregate	Key Aggregate	Coarse Aggregate	Key Aggregate
63 mm	—	—	100	—
45 mm	100	—	58-82	—
26.5 mm	37-72	—	—	100
22.4 mm	—	100	5-27	50-75
13.2 mm	2-20	50-75	—	—
11.2 mm	—	—	—	5-25
5.6 mm	—	5-25	—	—
2.8 mm	0-5	0-5	0-5	0-5

Table 9.20. Approximate loose quantities of materials required for 10 sq.m of road surface for bituminous penetration macadam base/binder course

Compacted thickness	Binder		
	Straight run bitumen	Coarse Aggregate	Key Aggregate
50 mm	50 kg	0.60 cum.	0.15 cum.
75 mm	68 kg	0.90 cum.	0.18 cum.

The rolling shall be continued untill the compacted coarse aggregate has firm surface and texture that will allow free and uniform penetration of binder.

Table 9.21. Grading requirements of coarse and key aggregates for built-up spray grout

IS Sieve Designation	Per cent by weight passing the sieve	
	Coarse Aggregate	Key Aggregate
53.0 mm	100	——
26.5 mm	40-75	——
22.4 mm	——	100
13.2 mm	0-20	40-75
5.6 mm	——	0-20
2.8 mm	0-5	0-5

Bituminous binder shall be applied at specified temperature by a pressure distributor at the specified rate, uniformaly over the surface.

Immediately, after the penetration of bitumen, key aggregates in a clean and dry state shall be spread uniformly over the surface preferably by means of a mechanical spreader. If necessary, the surface shall be broomed to obtain uniform application. The entire surface shall then be rolled until the key aggregates are firmly in position.

9.8.5. **Bituminous macadam and dense graded bituminous macadam :** The work consists of construction of a single layer of compacted crushed aggregates premixed with bituminous binder. Bituminous Macadam is more open graded than the Dense Graded Bituminous Macadam.

Physical requirements of aggregate for BM are given in Table 9.18. Physical requirements for Dense Graded Bituminous Macadam are given in Table 9.22.

The filler shall be graded within the limits indicated in Table 9.23.

For bituminous macadam, the bitumen content for premix should be 3 to 3.5 per cent by weight of total mix except otherwise

Table 9.22. Physical requirements for coarse aggregate for dense graded bituminous macadam

Property	Test	Specification
Cleanliness (dust)	Grain size analysis[1]	Max 5% passing 0.075mm sieve
Particle shape	Flakiness and Elongation Index (Combined)[2]	Max 30%
Strength*	Los Angeles Abrasion Value[3]	Max 35%
	Aggregate Impact Value[4]	Max 27%
Durability	Soundness:[5]	
	Sodium Sulphate	Max 12%
	Magnesium Sulphate	Max 18%
Water Absorption	Water absorption[6]	Max 2%
Stripping	Coating and Stripping of Bitumen Aggregate Mixtures[7]	Minimum retained coating 95%
Water Sensitivity**	Retained Tensile Strength[8]	Min 80%

Notes :
1. IS:2386 Part 1
2. IS:2386 Part 1 (the elongation test to be done only on non-flaky aggregates in the sample)
3. IS:2386 Part 4*
4. IS:2386 Part 4*
5. IS:2386 Part 5
6. IS:2386 Part 3
7. IS:6241
8. AASHTO T283**

* Aggregate may satisfy requirements of either of these two tests.

** The water sensitivity test is only required if the minimum retained coating in the stripping test is less than 95%.

Table 9.23. Grading requirements for mineral filler

IS Sieve (mm)	Cumulative per cent passing by weight of total aggregate
0.6	100
0.3	95 - 100
0.075	85 - 100

directed. The composition of Bituminous Macadam should conform to Table 9.24. The manufacturing and rolling temperature are given in Table 9.25. For dense graded bituminous macadam aggregrate gradation and requirement of mix are indicated in Table Nos. 9.26 and 9.27.

Table 9.24. Composition of bituminous macadam

Mix designation Nominal aggregate size Layer thickness IS Sieve (mm)	Grading 1 40 mm 80-100 mm	Grading 2 19 mm 50-75 mm
	Cumulative % by weight of total aggregate passing	
45	100	
37.5	90-100	
26.5	75-100	100
19	-	90-100
13.2	35-61	56-68
4.75	13-22	16-36
2.36	4-19	4-19
0.3	2-10	2-10
0.075	0-8	0-8
Bitumen content, % by weight of total mixture[1]	3.1-3.4	3.3-3.5
Bitumen grade	35 to 90	35 to 90

Note : Appropriate bitumen contents for conditions in cooler areas of India may be up to 0.5% higher subject to the approval of the Engineer.

Table 9.25. Manufacturing and rolling temperatures

Bitumen Penetration	Bitumen Mixing(°C)	Aggregate Mixing(°C)	Mixed Mixing(°C)	Rolling (°C)	Laying (°C)
35	160-170	160-175	170 Max.	100 Min.	130 Min.
65	150-165	150-170	165 Max.	90 Min.	125 Min.
90	140-160	140-165	155 Max.	80 Min.	115 Min.

Table 9.26. Composition of dense graded bituminous macadam pavement layers

Grading	1	2
Nominal aggregate size	40 mm	25 mm
Layer thickness	80-100 mm	50-75 mm
IS Sieve (mm)	Cumulative % by weight of total aggregate passing	
45	100	
37.5	90-100	100
26.5	63-93	90-100
19	-	71-95
13.2	55-75	56-80
9.5	-	-
4.75	38-54	38-54
2.36	28-42	28-42
1.18	-	-
0.6	-	-
0.3	7-21	7-21
0.15	-	-
0.075	2-8	2-8
Bitumen content, % by mass of total mix[2]	Min 4.0	Min 4.5
Bitumen grade (pen)	65 or 90	65 or 90

Notes : 1. The combined aggregate grading shall not vary from the low limit on one sieve to the high limit on the adjacent sieve.

2. Determined by the Marshall method.

The requirements for minimum per cent voids in mineral aggregate (VMA) are set out in Table 9.28.

Job mix formula for Dense Graded Bituminous Macadam shall comply with Clause 507.3 of the Ministry's Specifications.

The construction operation for Dense Graded Bituminous Macadam including laying of and stress absorbing layer should be in accordance with Clause 507.4 of the Ministry's Specifications.

Table 9.27. Requirements for dense graded bituminous macadam

Minimum stability (kN at 60°C)	9.0
Minimum flow (mm)	2
Maximum flow (mm)	4
Compaction level (Number of blows)	75 blows on each of the two faces of the specimen
Per cent air voids	3-6
Per cent voids in mineral aggregate (VMA)	See Table 9.28 below
Per cent voids filled with bitumen (VFB)	65-75

Table 9.28. Minimum per cent voids in mineral aggregate (VMA)

Nominal Maximum Particle Size[1] (mm)	Minimum VMA, per cent Related to Design Air Voids, per cent[2]		
	3.0	4.0	5.0
9.5	14.0	15.0	16.0
12.5	13.0	14.0	15.0
19.0	12.0	13.0	14.0
25.0	11.0	12.0	13.0
37.5	10.0	11.0	12.0

Notes : 1. The nominal maximum particle size is one size larger than the first sieve to retain more than 10 per cent.

2. Interpolate minimum voids in the mineral aggregate (VMA) for design air voids values between those listed.

9.8.6. **Bituminous concrete and semi-dense bituminous concrete :** The work consists of construction, in a single or multiple layers of bituminous concrete prepared as per specified job mix formula, on previously prepared bituminous base. A sinlge layer shall be 25 mm to 100 mm in thickness.

The coarse aggregate for semi-dense bitumen concrete should satisfy the criteria laid in Table 9.29. Aggregate gradation is indicated in Table 9.30. SDBC should satisfy the requirement indicated in Table 9.31.

Table 9.29. Physical requirements for coarse aggregate for semi-dense bituminous concrete pavement layers

Property	Test	Specification
Cleanliness (dust)	Grain size analysis[1]	Max 5% passing 0.075mm sieve
Particle shape	Flakiness and Elongation Index (Combined)[2]	Max 30%
Strength*	Los Angeles Abrasion Value[3]	Max 35%
	Aggregate Impact Value[4]	Max 27%
Polishing	Polished Stone Value[5]	Min 55
Durability	Soundness:[6]	
	Sodium Sulphate	Max 12%
	Magnesium Sulphate	Max 18%
Water Absorption	Water absorption[7]	Max 2%
Stripping	Coating and Stripping of Bitumen Aggregate Mixtures[9]	Minimum retained coating 95%
Water Sensitivity**	Retained Tensile Strength[8]	Min 80%

Notes :
1. IS:2386 Part 1
2. IS:2386 Part 1 (the elongation test to be done only on non-flaky aggregates in the sample)
3. IS:2386 Part 4*
4. IS:2386 Part 4*
5. BS:812 Part 114
5. IS:2386 Part 5
6. IS:2386 Part 3
8. AASHTO T283**
9. IS:6241

* Aggregate may satisfy requirements of either of these two tests.

** The water sensitivity test is only required if the minimum retained coating in the stripping test is less than 95%.

The coarse aggregate for bituminous concrete mix should satisfy the requirements mentioned in Table. 9.32. Composition of Bituminous Concrete Pavement layers and requirements for Bituminous Pavement layers are indicated in Tables 9.33 and 9.34 respectively.

Table 9.30. Composition of semi-dense bituminous concrete pavement layers

Grading	1	2
Nominal aggregate size	13 mm	10 mm
Layer thickness	35-40 mm	25-30 mm
IS Sieve[1] (mm)	Cumulative % by weight of total aggregate passing	
45		
37.5		
26.5		
19	100	
13.2	90-100	100
9.5	70-90	90-100
4.75	35-51	35-51
2.36	24-39	24-49
1.18	15-30	15-30
0.6	-	-
0.3	9-19	9-19
0.15	-	-
0.075	3-8	3-8
Bitumen content, % by mass of total mix[2]	Min 4.5	Min 5.0
Bitumen grade (pen)	65*	65*

Notes :
1. The combined aggregate grading shall not vary from the low limit on one sieve to the high limit on the adjacent sieve.
2. Determined by the Marshall method.

* Only in exceptional circumstances, 80/100 penetration grade may be used, as approved by the Engineer.

The mix design for SDBC should be in accordance with Clause 508.3 of Ministry's Specifications.

The mix design and construction operations for bituminous concrete should conform to Clauses 509.3 and 509.4 of the Ministry's Specifications.

Fine aggregate : The fine aggregate shall be the fraction

Table 9.31. Requirements for semi-dense bituminous pavement layers

Minimum stability (kN at 60°C)	8.2
Minimum flow (mm)	2
Maximum flow (mm)	4
Compaction level (Number of blows)	75 blows on each of the two faces of the specimen
Per cent air voids	3-5
Per cent voids in mineral aggregate (VMA)	See Table 9.28
Per cent voids filled with bitumen (VFB)	65-78

passing the 2.36 mm and retained on the 0.075 mm sieve consisting of crusher run screening, natural sand or a mixture of both. These shall be clean, hard, durable, uncoated, dry and free from soft or flaky pieces and organic or other deleterious substances.

The grading of the fine aggregate inclusive of filler shall be as given in Table 9.23.

9.8.7. Surface Dressing

Scope : This work shall consist of the application of one coat or two coats of surface dressing, each coat consisting of a layer of bituminous binder sprayed on a previously prepared base, followed by a cover of stone chips rolled in to form a wearing course to the requirements of these Specifications. For information on the Design of Surface dressing refer to the Manual for Construction and Supervision of Bituminous works.

Binder : The binder shall have a kinematic viscosity lying in the range 1×10^4 to 7×10^5 centistokes at the expected range of road surface temperatures at the constructioni site during the period of laying. The type of binder to be used will be stated in the Contract documents and shall comply with one of the following :

Paving Bitumen	IS:73
Bitumen Emulsion	IS:8887

Table 9.32. Physical requirements for coarse aggregate for bituminous concrete pavement layers

Property	Test	Specification
Cleanliness (dust)	Grain size analysis[1]	Max 5% passing 0.075mm sieve
Particle shape	Flakiness and Elongation Index (Combined)[2]	Max 30%
Strength*	Los Angeles Abrasion Value[3]	Max 30%
	Aggregate Impact Value[4]	Max 24%
Polishing	Polished Stone Value[5]	Min 55
Durability	Soundness:[6]	
	Sodium Sulphate	Max 12%
	Magnesium Sulphate	Max 18%
Water Absorption	Water absorption[7]	Max 2%
Stripping	Coating and Stripping of Bitumen Aggregate Mixtures[9]	Minimum retained coating 95%
Water Sensitivity**	Retained Tensile Strength[8]	Min 80%

Notes :
1. IS:2386 Part 1
2. IS:2386 Part 1
   (the elongation test to be done only on non-flaky aggregates in the sample)
3. IS:2386 Part 4*
4. IS:2386 Part 4*
5. BS:812 Part 114
5. IS:2386 Part 5
6. IS:2386 Part 3
8. AASHTO T283**
9. IS:6241

* Aggregate may satisfy requirements of either of these two tests.

** The water sensitivity test is only required if the minimum retained coating in the stripping test is less than 95%.

Table 9.33. Composition of bituminous concrete pavement layers

Grading	1	2
Nominal aggregate size	19 mm	13 mm
Layer thickness	50-65 mm	30-45 mm
IS Sieve[1] (mm)	Cumulative % by weight of total aggregate passing	
45		
37.5		
26.5	100	
19	79-100	100
13.2	59-79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen content, % by mass of total mix[2]	5.0-6.0	5.0-7.0
Bitumen grade (pen)	65	65

Notes : 1. The combined aggregate grading shall not vary from the low limit on one sieve to the high limit on the adjacent sieve.

2. Determined by the Marshall method.

Aggregates : The chips shall conform to the requirements of Clause except that their water absorption shall be restricted to a maximum of 1 per cent and they shall have a Polished Stone value, as measured by the method given in BS812 (Part 114), if not less than 60. The chips shall be single sized, clean, hard, durable, of cubical shape free from dust and soft or friable matter, organic or other deleterious matter and conforming to one of the gradings given in Table 9.35.

Table 9.34. Requirements for bituminous pavement layers

Minimum stability (kN at 60°C)	9.0
Minimum flow (mm)	2
Maximum flow (mm)	4
Compaction level (Number of blows)	75 blows on each of the two faces of the specimen
Per cent air voids	3-6
Per cent voids in mineral aggregate (VMA)	See Table 9.28
Per cent voids filled with bitumen (VFB)	65-75
Loss of stability on immersion in water at 60°C (ASTM D 1075)	Min. 75 per cent retained strength

Table 9.35. Grading requirements for chips for surface dressing

IS Sieve Designation mm	Cumulative per cent by weight of total aggregate passing for the following nominal sizes (mm)			
	19	13	10	6
26.5	100	-	-	-
19.0	85-100	100	-	-
13.2	0-40	85-100	100	-
9.5	0-7	0-40	85-100	100
6.3	-	0-7	0-35	85-100
4.75	-	-	0-10	-
3.35	-	-	-	0-35
2.36	0-2	0-2	0-2	0-10
0.60	-	-	-	0-2
0.075	0-1.5	0-1.5	0-1.5	0-1.5
Minimum 65% by weight of aggregate	Passing 19 mm, retained 13.2 mm	Passing 13.2 mm, retained 9.5 mm	Passing 9.5 mm, retained 6.3 mm	Passing 6.3 mm, retained 3.35 mm

Rates of spread of binder and chips : For the purpose of pricing the Bill of Quantities the rates of spread given in Table 9.36 shall be priced.

Table 9.36. Nominal rates of spread for binder and chippings

Nominal Chipping Size mm	Binder (penetration grade bitumen) kg/m^2	Chips Cum/m^2
19	1.2	0.015
13	1.0	0.010
10	0.9	0.008
6	0.75	0.004

Note : (1) These rates of spread are for pricing purposes - see Clause 510.2.3 and Clasue 510.8 of Ministry's Specifications.

(2) For emulsion, these rates of spread are for the residual bitumen and appropriate adjustment must be made to determine the total quantity.

(3) Refer to Manual for Construction and supervision of Bituminous Works for the procedure of determining the rates of spread of binder and chips.

Anti-stripping agent : Where the proposed aggregate fails to pass the stripping test then an approved adhesioni agent (Appendix 5 for details) may be added to the binder in accordance with the manufacturer's instructions. The effectiveness of the proposed anti-stripping agent must be demonstrated by the Contractor, before approval by the Engineer.

Pre-coated chips : As an alternative to the use of an adhesion agent the chips may be pre-coated before they are spread except when the sprayed binder film is a bitumen emulsion. Pre-coating the chips may be carried out in any one of the two methods:

a) Mixing them with 0.75 to 1.0 per cent of paving bitumen by weight of chips in a suitable mixer, the chips being heated to 160^{0}C and the bitumen to its application temperature. The pre-coated chips shall be allowed to cure for at least one week or untill they become non sticky and can be spread easily.

b) Spraying the chips with a light application of creosote, diesel oil or kerosene at ambient temperature. This spraying can be done in a concrete mixer or on a belt conveying the chips from stockpile to gritting lorries.

Construction operations shall confirm to Clause 510.3 of Ministry's Specifications. The application temperature for the grade of binder used shall be as given in Table 9.37.

Table 9.37. Spraying temperatures for binders

Binder grades	Whirling spray jets		Slot jets	
	Min°C	Max°C	Min°C	Max°C
Penetration Grades				
400/500	160	170	140	150
280/320	165	175	150	160
180/200	170	190	155	165
80/100	180	200	165	175

9.8.8. Open-graded premix surfacing

Scope : This work shall consist of the preparation, laying and compaction of an open-graded premix surfacing material of 20 mm thickness composed of small-sized aggregate premixed with a bituminous binder on a previously prepared base, in accordance with the requirements of Ministry's Specifications, to serve as a wearing course.

Binder : The binder shall be a penetration bitumen of a suitable grade as specified in the Contract, or as directed by the Engineer, and satisfying the requirements of IS:73.

Aggregate : The aggregate shall conform to Clause 504.2.2 of Ministry's Specifications except that the water absorption shall be limited to a maximum of 1 per cent. The Polished Stone Value, as measured by the test in BS812-(Part 114), shall not be less than 55.

Proportioning of materials : The materials shall be proportioned in accordance with Table 9.38.

Construction operations shall conform to Clause 511 of the Ministry's Specifications.

Table 9.38. Quantitites of materials required for 10 m^2 of road surface for 20mm thick open-graded premix surfacing using penetration bitumen or cutback

Aggregates		
(a)	Nominal Stone Size 13.2 mm (passing 22.4 mm sieve and retained on 11.2 mm sieve)	0.18 m^3
(b)	Nominal Stone size 11.2 mm (passing 13.2 mm sieve and retained on 5.6 mm sieve)	0.09 m^3
	Total	0.27 m^3
Binder (quantities in terms of straight run bitumen)		
(a)	For 0.18 m^3 of 13.2 mm nominal size stone at 52 kg bitumen per m^3	9.5 kg
(b)	For 0.09 m^3 of 11.2 mm nominal size stone at 56 kg bitumen per m^3	5.1 kg
	Total	14.6 kg

9.8.9 Open graded premix surfacing using cationic bitumen emulsion

Scope : This work shall consist of the preparation, laying and compaction of an open-graded premix surfacing of 20 mm thickness composed of small-sized aggregate premixed with a cationic bitumen emulsion on a previously prepared surface, in accordance with the requirements of these Specifications, to serve as a wearing course.

Binder : The binder for premix wearing course shall be cationic bitumen emulsion of Medium Setting (MS) grade complying with I.S.:8887 and having a bitumen content 65 per cent minimum by weight. For liquid seal coat RS grade of cationic bitumen emulsion shall be used. Where expressly specified in the Contract (MS) grade emulsion shall be used or otherwise directed by the Engineer. Slow Setting (SS) grade cationic bitumen emulsion shall be used for premix seal coat.

Aggregate : The requirements of sub para 3, para 9.8.8 shall apply.

Proportioning of materials : The materials shall be proportioned as quantities given in Tables 9.39 and 9.40.

Construction Operations shall conform to Clause 511 of the Ministry's Specifications.

Table 9.39. Quantities of aggregate for 10 m² area

(A)	**For Premix Carpet**	
(a)	Coarse aggregate nominal 13.2 mm size; passing IS 22.4 mm sieve and retained on IS 11.2 mm sieve	0.18 m^3
(b)	Coarse aggregate nominal 11.2 mm size; pasing IS 13.2 mm sieve and retained on IS 5.6 mm sieve	0.09 m^3
(B)	**For Seal Coat :** Refer to Clause 513.	

Table 9.40. Quantities of emulsion binder

		For $10m^2$ area
(A)	**For Premix Carpet :**	20 to 30 kg
(B)	**For Seal Coat :**	
	(a) for liquid seal coat	12 to 14 kg
	(b) for premix seal coat	10 to 12 kg

9.8.10. **Close graded premix surfacing/mixed seal surfacing:**

Scope : This work shall consist of the preparation, laying and compaction of a close-graded premix surfacing material of 20 mm thickness composed of graded aggregates premixed with a bituminous binder on a previously prepared surface, in accordance with the requirements of these Specifications of the Ministry to serve as a wearing course.

Close graded premix surfacing shall be of Type A or Type B as specified in the Contract documents.

Binder and Coarse aggregate : The requirements of para 9.8.8 shall apply.

Fine aggregates : The fine aggregates shall consist of crushed rock quarry sands, natural gravel/sand or a mixture of both. These shall be clean, hard, durable, un-coated, mineral particles, dry and free from injurious, soft or flaky particles and organic or deleterious substances.

Aggregate gradation : The coarse and fine aggregates shall be so graded or combined as to conform to one or the other gradings shown in Table 9.41 as specified in the contract.

Table 9.41. Aggregate Gradation

IS Sieve Designation (mm)	Cumulative per cent by weight of total aggregate passing	
	Type A	Type B
13.2 mm	—	100
11.2 mm	100	88-100
5.6 mm	52-88	31-52
2.8 mm	14-38	5-25
0.090 mm	0-5	0-5

Proportioning of materials : The total quantity of aggregates used for Type A or Type B close-graded premix surfacing shall be 0.27 cubic metre per 10 square metre area. The quantity of binder used for premixing in terms of straight-run bitumen shall be 22.0 kg and 19.0 kg per 10 square metre area for Type A and Type B surfacing respectively.

Construction Operations shall conform to Clause 511 of the Ministry's Specifications.

9.8.11. Seal coat

Scope : This work shall consist of the application of a seal coat for sealing the voids in a bituminous surface laid to the specified levels, grade and cross fall (camber). Seal coat shall be or either of the two types specified below :

(A) Liquid seal coat comprising of an application of a layer of bituminous binder followed by a cover stone chips.

(B) Premixed seal coat comprising of a thin application of fine aggregate premixed with bituminous binder.

Binder : The requirements of Para 9.8.8 shall apply.

The quantity of bitumen per 10 square metres, shall be 9.8 kg for Type (A), and 6.8 kg for Type (B) seal coat. Where bituminous emulsion is used as a binder the quantities for Type (A) and Type (B) seal coats shall be 15 kg and 10.5 kg respectively.

Stone chips for Type (A) seal coat : The stone chips shall consist of angular fragments of clean, hard, tough and durable rock of uniform quality throughout. They should be free of soft or disintegrated stone, organic or other deleterious matter. Stone chips shall be of 6.7 mm size defined as 100 per cent passing through 11.2 mm sieve and retained on 2.36 mm sieve. The quantity used for spreading shall be 0.09 cubic metre per 10 square metre area. The chips shall satisfy the quality requirements in Table 9.18 except that the upper limit for water absorption value shall be 1 per cent.

Aggregate for Type (B) seal coat : The aggregate shall be sand or grit and shall consist of clean, hard, durable, uncoated dry particles and shall be free from dust, soft or flaky / elongated material, organic matter or other deleterious substances. The aggregate shall pass 2.36 mm sieve and be retained on 180 micron sieve. The quantity used for premixing shall be 0.06 cubic metres per 10 square metres area.

Construction Operations shall conform to Clause 513 of the Ministry's Specifications.

9.8.12. Mastic asphalt

Scope : This work shall consist of constructing a single layer of mastic asphalt wearing course for road pavements and bridge decks. Mastic asphalt is an intimate homogeneous mixture of selected well-graded aggregates, filler and bitumen in such proportions as to yield a plastic and voidless mass, which when applied hot can be trowelled and floated to firm a very dense impermeable surfacing.

Binder : The binder for mastic asphalt shall meet the requirements as laid in Table 9.42.

Table 9.42. Requirements for physical properties of binder

Property	Test Method		Require-ments
Penetration at 25°C		IS:1203	15 ± 5*
Softening point, °C		IS:1205	65 ± 10
Loss on heating for 5th at 163°C, % by mass	Max.	IS:1212	2.0
Solubility in trichloroethylene, % by mass	Min.	IS:1216	95
Ash (mineral matter), % by mass	Max.	IS:1217	1.0

* In cold climatic regions (temperature $\leq$ 10°C), a softer penetration grade of 30/40 may be used.

Coarse aggregate : The coarse aggregate shall consist of crushed stone, crushed gravel/shingle or other stones. They shall be clean, hard, durable, of fairly cubical shape, uncoated and free from soft, organic or other deleterious substances. They shall satisfy the physical requirements given in Table 9.18.

The percentage and grading of the coarse aggregate to be incorporated in the mastic asphalt depending upon the thickness of the finished course shall be as specified in Table 9.43.

Fine aggregate : The fine aggregate shall be the fraction passing the 2.36 mm and retained on the 0.075 mm sieve consisting of crusher run screening, natural sand or a mixture of both. These shall be clean, hard, durable, uncoated, dry and free from soft or flaky pieces and organic or other deleterious substances.

Filler : The filler shall be limestone powder passing the 0.075 m sieve and shall have a calcium carbonate content of not less than 80 per cent by weight when determined in accordance with IS:1514.

The grading of the fine aggregate inclusive of filler shall be given in Table 9.44

Table 9.43. Grade and thickness of mastic asphalt paving, and grading of coarse aggregate

Application	Thickness range (mm)	Nominal size of coarse aggregate (mm)	Coarse aggregate content, % by mass of total mix
Roads and carriageways	25-50	13	40 ± 10
Heavily stressed areas, i.e., junctions and toll plazas	40-50	13	45 ± 10

Nominal size of coarse aggregate IS Sieve (mm)	13 mm Cumulative % passing by weight
19	100
13.2	88-96
2.36	0-5

Table 9.44. Grading of fine aggregate (inclusive of filler)

I.S. Sieve	Percentage by weight of aggregate
Passing 2.36 mm but retained on 0.600 mm	0-25
Passing 0.600 mm but retained on 0.212 mm	10-30
Passing 0.212 mm but retained on 0.075 mm	10-30
Passing 0.075 mm	30-55

Mix design and construction operation shall be in accordance with Clause 515 of the Ministry's Specifications.

The mastic asphalt blocks (without coarse aggregate) shall show on analysis of a composition within the limits as given in Table 9.45. The mixture shall be transported to the laying site in a towed mixer transporter having arrangement for stirring and keeping the mixture hot during transportation.

Table 9.45. Composition of mastic asphalt blocks without coarse aggregate

IS Sieve	Percentage by weight of mastic asphalt	
	Minimum	Maximum
Passing 2.36 mm but retained on 0.600 mm	0	22
Passing 0.600 mm but retained on 0.212 mm	4	30
Passing 0.212 mm but retained 0.075 mm	8	18
Passing 0.075 mm	25	45
Bitumen Content	14	17

Composition within the limits as given in Table 9.45. The mixture shall be transported to the laying site in a towed mixer transporter having arrangement for stirring and keeping the mixture hot during transportation.

9.8.13. **Slurry seal**

Scope : Slurry seals are mixtures of fine aggregate, portland cement filler, bitumen emulsion and additional water. When freshly mixed, they have a thick consistency and can be spread to a thickness of 1.5-5 mm. They may be used to seal cracks, arrest fretting and fill voids and minor depressions, to provide a more even riding surface or a base for further treatment; they may also be used on top of a single coat surface dressing.

Emulsified bitumen : The emulsified bitumen shall be a cationic rapid setting type as approved by the Engineer, conforming to the requirements of IS:8887. Where special mobile mixing machines are available, Class A4* rapid setting or Class K3* road emulsions to BS:434 (Part I) should be used to obtain very early resistance to traffic and rain. Generally, emulsion for slurry seal should be capable of producing a slurry that will develop early resistance to traffic and rain and is sufficiently stable to permit mixing

* The corresponding grades in IS:8887 are only broadly classified as RS, MS and SS and further sub-classification is not available at present.

and laying processes. If approved by the Engineer, a slow setting emulsion may be used. Guidance on selection of an appropriate grade of emulsion is given in the Ministry's Manual for Construction and Supervision of Bituminous Works.

Water : Water shall be of such quality that the bitumen will not separate from the emulsion before the slurry seal is in place. The pH of the water must lie in the range 4 to 7, and if the total dissolved solids in the water amount to more than 500 ppm, the Engineer may reject it, or order the Contractor to conduct a trial emulsion mix to demonstrate that it does not cause early separation.

Aggregate : The aggregate shall be crushed rock, or slag and may be blended, if required, with clean, sharp, naturally occurring sand free from soft pieces and organic and other deleterious substances to produce a grading as given in Table 9.46. The aggregates shall meet the requirements of the film stripping test

Table 9.46. Aggregate grading, binder content and approximate coverage rate

Sieve Size (mm)	Percentage by mass passing		
	Finished thickness of sealing		
	5 mm	3 mm	1.5 mm
9.5	100	—	—
4.75	90-100	100	—
3.35	—	80-100	100
2.36	65-90	75-100	95-100
1.18	45-70	55-90	70-95
0.600	30-50	35-70	55-75
0.300	18-30	20-45	30-50
0.150	10-21	10-25	10-30
0.075	5-15	5-15	5-15
Quantity of residual binder, percentage by mass of aggregate	7.5-13.5	10-16	12-20
Approximately covergae and (kg/m^2)	8-15	4-6	2-4

(IS:6241), and a suitable amount and type of anti-stripping agent added, as may be needed.

Additives : It is usual to use ordinary portland cement, hydrated lime or other additives to control consistency, mix segregation and setting rate. The proportion of the additive should not normally exceed 2 per cent by weight of dry aggregate.

Mixture Design : A range of residual binder contents for each aggregate grading is given in Table 9.46. The optimum mixture design for the aggregate, additive, water and bitumen emulsion mixture should be determined in accordance with ASTM D 3910.

Construction Operations shall conform to Clause 516 of the Ministry's Specifications.

Mixing and transportation of mixture : Mixing (and laying) techniques vary according to the type of emulsion used. For class A4 rapid setting and K3 emulsions, only special mobile mixing machines should be used. These carry supplies of aggregate, emulsion, water and filler (e.g., ordinary portland cement or hydrated lime) and are fitted with metering devices to feed the ingredients in their correct proportions to a mixer fitted to the rear of the machine. From the mixer the slurry is fed into the screed box towed by the machine.

For all other emulsions, mixing may be by hand, concrete mixer or other which effectively coats the aggregate uniformly and produces a slurry seal of suitable consistency for satisfactory laying. For large areas, a bulk transit concrete mixer may be used into which the ingredients (including water) are measured and mixed as the mixer travels to the area to be treated. A screed box fitted with an adjustable rubber screed should be towed by the mixer which feeds it during laying.

The special mobile mixing machine, when used, shall be capable of uniform application to provide a continuous surface without ridges or segregation. Before laying begins, the Contractor shall provide the Engineer with a test certificate showing test results for rate of application carried out under the supervision of a competent authority, demonstrating that the machine has been tested, using the system to be used in the Contract, not more than six weeks before the commencement of the work.

Where the material is to be hand laid, the slurry may be supplied to site pre-mixed in suitable containers and steps shall be taken to ensure that the material in each container is of and even consistency throughout the container immediately prior to use.

9.8.14. **Recycling of bituminous pavement**

1. **Scope :** This covers the recycling of existing bituminous pavement materials to upgrade an existing bituminous pavement which has served its first-intended purpose. Recycling process can be categorised into in-situ recycling (where processing takes place on site), and central plant recycling (where reclaimed material is processed off site). The process can be further sub-divided into hot and cold process. This Specification covers the hot process only. However, reclaimed aggreagate from cold in-situ recycling can be used in the Bituminous Cold Mix process specified in Clause 519 of the Ministry's Specifications subject to the resultant mixes achieving the specified standards.

2. **Proportion of reclaimed materials less than 10 per cent:** If not more than 10 per cent of reclaimed bituminous material is to be used in the production of bituminous macadam or dense graded bituminous base or binder course material, then paras 3 to 10 do not apply. However;

a) all reclaimed bituminous material shall be pre-treated before use such that the material is homogeneously mixed and the maximum particle size of reclaimed material does not exceed 40 mm.

b) the mixed material shall comply with requirements of Clauses 504 or 507 of the Ministry's Specifications as appropriate.

3. **Proportions of reclaimed materials greater then 10 per cent:** Reclaimed bituminous material of an amount greater than 10 per cent, may be used in the production of bituminous macadam and dense graded bituminous base and binder course material, subject to the requirements of paras 4 to 10 below and subject to the satisfactory completion of full trial investigations in respect of all related materials, layer thickness, machine operations and finished works on

a case-by-case basis entirely at the contractors cost and subject to the approval of the Engineer. For estimating purpose, a maximum amount of not greater than 30 per cent reclaimed bituminous material should be assumed.

4. **Materials for recycled pavement :** The recycled materials shall be a blend of reclaimed and new materials proportioned to achieve a paving mixture with the specified engineering properties. The reclaimed materials shall be tested and evaluated to find the optimum blend meeting the mixture requirements. Such testing and evaluation shall be carried out on representative samples, either cores sampled from the carriageway or samples taken from stockpiles in accordance with current practice. The sampling frequency should be sufficient to determine how consistent the reclaimed material is and to provide representative samples for composition analysis and measurement of properties of recovered binder. As an absolute minimum, one sample to represent 500 m of lane carriageway shall be taken.

5. **Bitumen extraction :** The procedure described in ASTM D-2172 shall be used to quantitatively separate aggregate and bitumen from any representative sample of reclaimed bituminous pavement.

6. **Aggregate evaluation :** Mechanical sieve analysis (IS:2386, (Part I), wet sieving method) shall be performed on the aggregate portion of the reclaimed bituminous pavement sample to determine the grading. It is essential that the reclaimed materials to be recycled are consistent, as variable materials will cause problems with the control of quality and impede the efficiency of the recycling operation. Suitable sources of consistent material of sufficient quantity for the scheme being considered need to be identified either in existing pavement, from stockpiled plannings of known origin or from another suitable source, before a decision can be made on the optimum percentage of reclaimed material.

After selecting the proportion of reclaimed material to be recycled, the grading of the mixture may need adjustment, to meet specification requirements, by the addition of selected aggregate sizes.

7. **Evaluation of bitumen :** When the amount of reclaimed bituminous materials to be used in the mixture exceeds 10 per cent,

the penetration value of the recovered binder from the reclaimed bituminous material, before mixing, shall exceed 15 pen, after recovery of binder in accordance with requirements of BS 2000 : (Part 397), when tested in accordance with IS:1203. Provided the above requirement is met, hardening of the old binder, during the original mixing process or through ageing, can be compensated for by adding a softer bitumen, to obtain the appropriate final grade of binder.

The determination of the type and amount of binder required from the mixture shall mix is essentially a trial error procedure.

After mixing with recycled materials, the binder recovered from the mixture shall have a recovered penetration value not less than the value specified in Table 9.47.

Table 9.47. Minimum recovered binder penetration of recycled mixture

Specified Grade of Binder (Penetration)	Minimum Recovered Penetration of Binder after Mixing
45	27
65	39
90	54

8. **Rejuvenators :** The use of rejuvenators, and a test to measure their effectiveness, is described in para below.

9. **Untreated aggregate :** If necessary, fresh untreated aggregate shall be added to the reclaimed bituminous pavement to produce a mix with the desired grading. The aggregate shall be checked for quality requirements in accordance with Table 9.18 or Table 9.22 as appropriate. Reclaimed aggregate, if any, or any aggregate normally used for the desired bituminous mixture, or both, may be used for this purpose.

10. **Combined aggregate grading :** The blend of reclaimed and new aggregate shall meet the grading criteria specified in the relevant parts of Clause 504 or 507 of the Minitry's Specifications as appropriate and as approved by the Engineer. The blend of

aggregates shall be checked for resistance to stripping as specified in Table 9.18 or Table 9.22 as appropriate.

11. **Mixture design :** The combine aggregate grading and binder content shall comply with the relevant tables in Clauses 504 or 507 of this Ministry's Specifications. For dense graded bituminous mixtures the mixture design shall also comply with the requirements of Table 9.27.

Mixture design and construction operations should conform to Clause 517 of the Ministry's Specifications.

12. **Reclaiming old pavement materials :** The removal of pavement materials to the required depth shall be accomplished either at ambient temperature (cold process) or at an elevated temperature (hot process), as approved by the Engineer. For details, Clause 517 of the Ministry's Specifications may be reffered.

13. Mixture design and construction operations should conform to Clause 517 of the Ministry's Specifications.

9.8.15. **Fog spray :** Fog Spray is a very light application of low viscosity bitumen emulsion for purpose of sealing cracks less than 3 mm wide or incipient fretting or disintegration in an existing bituminous surfacing, and to help reduce loosening of chips by traffic on newly finished surface dressing.

The bitumen emulsion shall be as specified in the Contract or as instructed by the Engineer. The emulsion shall be

SS-1 h* (SS-1 can be used if the former is not available) complying with the requirements of ASTM D-977, or;

CSS-1 h* (CSS-1 can be used if the former is not available) complying with the requirements of ASTM D-2397.

Before use these emulsions shall be diluted, 1 part emulsion to 1 part water. Alternatively, Class A1-40* or K1-40* emulsions complying with the requirements of BS 434(Part 1)1984 may be

* The grades in IS:8887 are only broadly classified as RS, MS and SS further sub-classification is not available at present.

used. These emulsions have a lower viscosity than the above ASTM grades, they are rapid setting and they do not require to be diluted. Because of their low viscosity they should be used as soon as possible after delivery. If this is not possible, the drums should be very thoroughly rolled before use.

Construction operation shall conform to Clause 518 of the Ministry's Specifications.

9.8.16. **Bituminous cold mix (including gravel emulsion):** Bituminous Cold Mix consists of a mixture of unheated mineral aggregate and emulsified or cutback bitumen. This Specification deals only with plant mix (as opposed to mixed-in-place). Two types of mix are considered, namely, Designed Cold Mix and Recipe Cold Mix. The Design Mix procedure shall be used unless the Recipe Mix procedure is specifically approved by the Engineer. For details Clause 519 of Ministry's Specifications may be referred.

9.8.17. **Sand asphalt base course :** This work shall consist of a base course composed of a sand. mineral filler where required and bituminous binder, placed and compacted upon a prepared and accepted subgrade in accordance with these Specifications and the lines, levels, grades dimensions and cross-section shown on the drawings or as directed by the Engineer.

Note : Sand asphalt base course is used in special situations like quality aggregates not being available within economical leads and/or water needed for conventional base course not being readily available, as in desert areas.

Bitumen : The bitumen shall be paving bitumen of Penetration Grade S65 (60/70) or S90 (80/100), as specified in the Contract, both as per Indian Standard Specifications for "Paving Bitumen" IS:73.

Sand : The sand shall be clean, naturally occurring or blended material free from any deleterious substances, dry and well graded within the limits given in Table 9.48 and with other physical properties conforming to the requirements of this Table.

Filler : When required, filler shall consist of finally divided mineral matter, such as, rock dust, hydrated lime or cement as

Table 9.48. Sand Grading and Physical Requirements

Sieve Size (mm)	Cumulative percentage by weight of total aggregate passing
9.5	100
4.75	85-100
2.36	80-100
1.18	70-98
0.60	55-95
0.30	30-75
0.15	10-40
0.075	4-10
Plasticity Index (%)	6 max.
Sand equivalent (IS:2720, Part 37)	30 min.
Los Angeles Abrasion Value (IS:2386, Part IV)	40 max.

Note : Maximum thickness for sand asphalt is 80 mm.

approved by the Engineer. The filler shall conform to Clause 507.2.4. of the Minstry's Specifications.

Mix design and construction operation shall conform to Clause 520 of the Ministry's Specifications.

9.8.18. **Modified binder :** Modified binders comprise a base binder, to which is added either natural rubber, crumb or a polymer, such as, Styrene-Butadiene-Styrene (SBS), Ethylene-Vinyl-Acetate (EVA) or Low Density Polyethylene (LDPE). The purpose is to achieve a high performance binder with improved properties, particularly at extremes of temperature.

Base Binder : The base binder into which the modifier is incorporated shall conform to IS:73. The choice of grade shall be such that it is compatible with the modifier and, when mixed shall have the properties described in Caluse 521.3 of the Ministry's Specifications.

Modifier : The modifier shall be a natural rubber, crumb rubber or any other polymer which is compatible with the base binder and which allows the properties given in Clause 521.3 of the Ministry's Specifications to be achieved. For further details, IRC:SP:53 may be referred to. The modifier, in the required quantity shall be blended at the refinery or at the site plant capable of producing modified binder.

Modifier Properties : The quantity of modifier to be added shall be determined by tests on the base binder and the modified binder and the properties desired. A reference may be made to the Manual for Construction and Supervision of Bituminous Works for indicative dosage of different types of modifiers. The properties of the modified binder and mixing operations shall be as per requirements of Clause 521 of the Ministry's Specifications.

9.8.19. **Crack prevention courses :** This covers the provision of Stress Absorbing Membrane (SAM) and Stress Absorbing Membrane Interlayer (SAMI) as measures to inhibit the propagation of cracks. A SAM is an elastomeric bitumen rubber membrane, which is laid over a cracked road surface, together with a covering of aggregate chips, in order to extend the life of the pavement before major treatment is carried out. SAM can be laid as a single coat or a double coat. A SAMI is layer which is applied to a cracked pavement surface but which is followed (within 12 months) by the application of an overlay course. A SAMI may be a material similar to that used for a SAM. It may alternatively consist of a bitumen impregnated geotextile. For details Clause 522 of the Ministry's Specifications may be referred.

9.8.20. **Quality control tests :** Quality Control Tests for bituminous pavements have been revised. For details Clause 903.4 of the Ministry's Specifications may be referred.

9.9. Profile Corrective Course

9.9.1. Profile Corrective Course (levelling course) may be defined as pavement base material course laid for correcting the existing pavement profile which has lost its shape or has to be given a new shape to meet the requirement of modified cross-section and/ or improvement of longitudinal profile. P.C.C. differs from strengthening course in that it does not contribute to the structural improvement of the pavement as it provides material in varying thickness to correct cross-profile and improve longitudinal grades, where necessary.

9.9.2. The type of material for the profile corrective course depends upon the site situation and has to be decided depending upon whether it will be laid as part of the overlay or that it will be laid separately intervening between underlaying and overlaying layers. When the maximum thickness of profile corrective course does not exceed 40 mm, it is advisable to provide PCC as integral part of overlay course. In other cases separate layers with specifications same as that of the underlying layer or intermediate between underlying layer and overlay may be provided. In specific cases of short sags or depressions in the pavement, it may be necessary to provide corrective course in the form of flat wedges of 100 mm thickness maximum. Whenever isolated high spots projecting over the pavement surface exist the same should be cut by milling machine or some other suitable method, to minimise the requirement of PCC.

9.9.3. In placing multiple lifts, the lift of the shortest length should be provided first. The successive lifts extending over and fully covering underneath layer and proceeding till the finished level matches with levels of the pavement on either side. This method obviates development of a series of joints as shown in Fig. 9.4. Camber correction and correction of super-elevation are shown in Fig. 9.5.

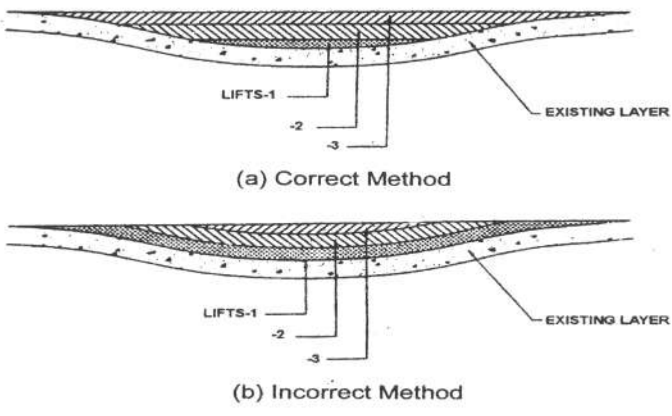


Fig. 9.4. Depression Filling

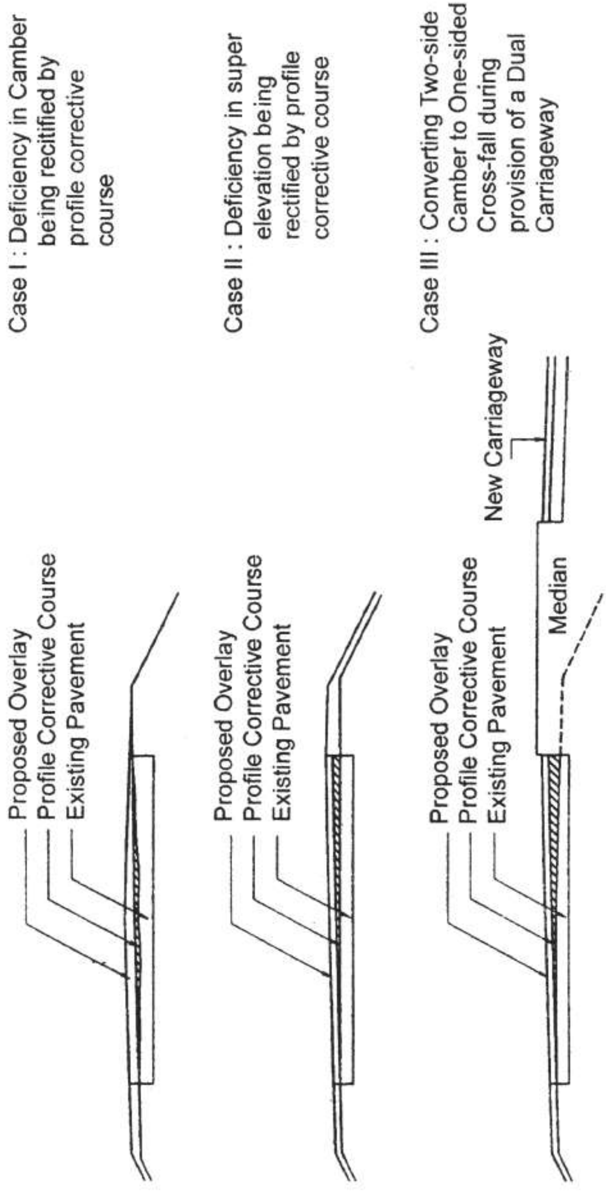


Fig. 9.5. Camber and super-elevation correction

9.10. Concrete Sub-Bases/Bases

9.10.1. **Dry lean concrete sub-base :** Ordinary portland, or portland slag or portland puzzolana cement conforming to IS:269, IS:455 and IS:1489 respectively may be used. If the sub-grade contains soluble sulphate in excess of 0.5 per cent, cement used shall be sulphate resistant and shall conform to IS:6909.

Coarse and fine aggregates shall conform to IS:383. If required coarse aggregate should be washed and drained. Fine aggregate should be free from soft particles, clay, lignite, shale, loam, cemented particles, mica, organic and other foreign matter.

Maximum size of aggregate shall be 26.5. The blended aggregate should conform to the grading indicated in Table 9.49.

Table 9.49. Aggregate gradation for dry lean concrete

Sieve Designation	Percentage passing the sieve by weight
26.50 mm	100
19.00 mm	80-100
9.50 mm	55-75
4.75 mm	35-60
600.00 micron	10-35
75.00 micron	0-8

Water used for mixing and curing of concrete shall be free from injurious amounts of oil, salt, acid, vegetable matter or other substances harmful to the finished concrete. It should meet the requirements stipulated in IS:456.

The mix should have a maximum aggregate cement ratio of 15:1. Optimum moisture content should be determined by trial and construction should be carried out with water content between the optimum and optimum + 2 per cent.

Minimum cement content shall not be less than 150 kg/cu.m. of concrete. A trial length, outside main work, having a minimum length of 60 m and full width of pavement and containing atleast one transverse construction joint should be constructed to determine the optimum moisture content, density and strength of lean concrete.

The concrete work should not be carried out if concrete temperature is greater than 30°C. If required chilled water or ice flakes should be used. The work should also not be carried out in adverse conditions, like, high temperature, low relative humidity, excessive wind velocity imminence of rain or concrete temperature below 5°C.

The sub-grade should be finished to proper lines grades and cross-sections. It should not be softened by rain after preparation. For areas with plastic soils, like, BC soil, the soil should be pre-treated with about 2 per cent of lime. The sub-grade should be given a fine spray of water and rolled one day before laying the lean concrete.

Batching and mixing should preferably be carried out in a force action central batching and mixing plant. The average compressive strength of the lean concrete should not be less than 10 MPa at seven days. In addition, the minimum compressive strength of any individual cube should not be less than 7.5 MPa at seven days.

The concrete should be transported by tipping trucks ensuring that no segregation takes place. Some practical measures for reducing segregation are listed below :

i) The maximum size of the aggregates should be restricted to 25 mm.

ii) While stockpiling aggregates the height of layer should be restricted to 1-2 metres and each layer should be spread horizontally. This is shown in Fig. 9.6.

iii) Dumpers should be moved back and forth as shown in Fig. 9.7. to stagger heaps.

iv) Use of down-pipe from conveyor belt to dumper in reducing segregation may be considered, where applicable. This is shown in Fig. 9.8.

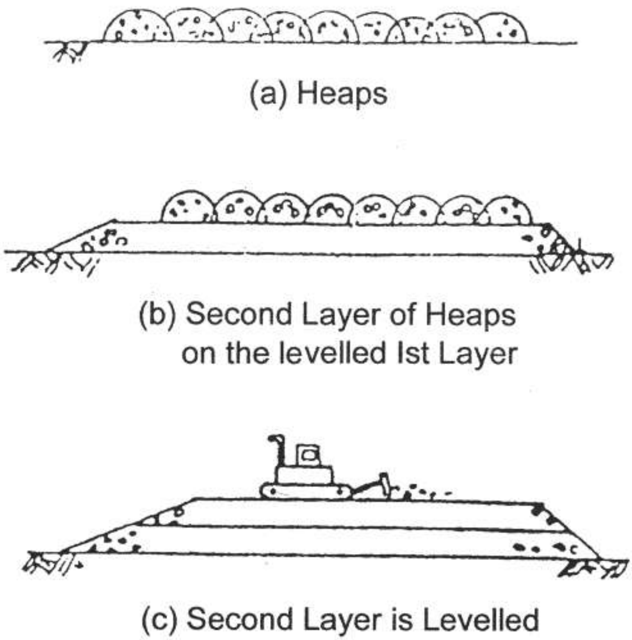


Fig. 9.6. Correct Method of Stock Piling Aggregates

v) If a paver is employed, it should be operated at moderate speed. At higher speeds, coarser fraction tend to move towards edges.

Concrete should be spread over the full width preferably with a paver with electronic sensors. The minimum dry density shall be 97 per cent of that achieved during the trial length construction as described below. The density achieved at 0.5 m from the edge should not be less than 95 per cent of that achieved during trial construction.

The time between mixing of the first batch of concrete and final finishing time should not exceed 90 minutes when the concrete temperature is between 25°C and 30°C and 120 minutes when the

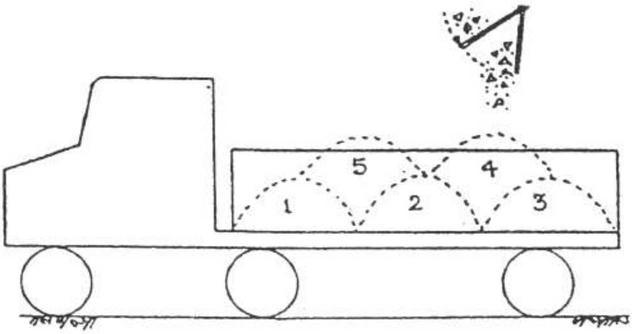
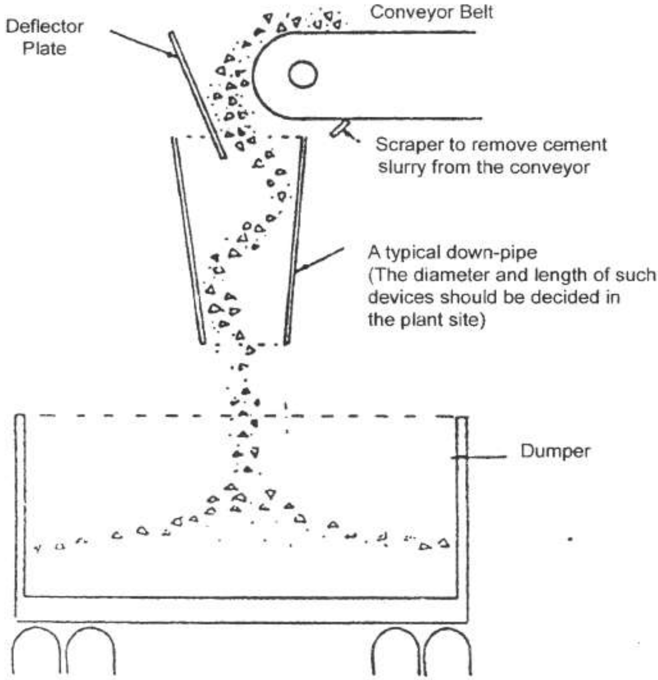


Fig. 9.7. Correct method of discharging concrete from mixing plant onto the dumper for reducing segregation



Use of down-pipe in reducing segregation

Fig. 9.8. Correct methods of discharging concrete

concrete temperature is less than 25°C. This period may be reviewed in the light of results of the trial run.

Mixing and placing of concrete shall progress only at such rate as to permit proper finishing, protecting and curing of the pavement.

80 to 100 kN static weight are suitable for rolling dry lean concrete. In addition, to the number of passes required for compaction, there should be a preliminary pass without vibration for bedding and a final pass without vibration to remove roller marks. Special care should be exercised during compaction near joints, kerbs, channels, side forms, around gullies and manholes. If necessary plate vibrators may be used at these locations.

Immediately after the compaction, curing should commence either by spraying with liquid curing compound and covering with wet hessian for three days, after the compound looses tackiness, or directly covering the surface with wet hessian kept moist for seven days.

As far as possible transverse joints should be at right angles to the pavement edge. Also, the transverse joints should be provided in line with the joints in the slab of the adjoining lane.

Sufficient forms should be available to atleast 200 metres length at all times. This should be set to the required alignment in advance of paving operation for 200 metres length or anticipated length of pavement to be laid in next 24 hours, whichever is more.

A separation membrane should be provided between concrete slab and sub-base to obviate stresses developing at the interface as a result of temperature changes in the concrete slab. This should be 125 microns thick impermeable plastic sheet laid flat without creases and nailed to the lower layer with concrete nails. The overlap in plastic sheet, where necessary, should be at least 300 mm.

9.10.2. **Concrete base :** Concrete base should be laid over a sub-base discussed in para 9.10.1. If the sub-base is found damaged at some places or has cracks wider than 10 mm it should be repaired with fine cement concrete or bituminous concrete before laying separation layer. Prior to laying of concrete it should be ensured that separation membrane is in position and is clean of dirt or other extraneous material and free from any damage.

Ordinary portland cement of grades 33, 43 or 53 conforming respectively to IS:269, IS:8112 and IS:12269 should be used. If the soil has soluble salts, like, sulphate in excess of 0.5 per cent, the cement used shall be sulphate resistant and shall conform to IS:12330.

Guidance regarding matching the strength of cement with the designed strength of concrete may be obtained from IS:SP:23, "Handbok for Concrete Mixes". Cement content should be between 350 and 425 kg/cum of concrete.

Admixtures conforming to IS:6925 and IS:9103 may be used to improve workability of concrete or extension of setting time. If air entrained admixture is used, the total quantity of air-in-air entrained concrete as a percentage of the volume of the mix should be 5 ± 1.5 per cent. The aggregate should comply with provisions of IS:383 and in addition, should have a Los Angeles Abrasion test value less than 35 per cent, chlorideoin less than 0.06 per cent by weight, Sulphuric anhydride less than 0.25 per cent by weight, water absorption less than 2 per cent and a loss of less than 12 per cent in soundness test with sodium sulphate (18 per cent for megnesium sulphate).

Fine aggregate and water should conform to the requirements already mentioned in para 9.10.1.

Mild steel dowels and tie bars should conform to the relevant requirements of IS:432, IS:1139 and IS:1786. The dowel bars should conform to grade S 240 and tie bars to grade S 415 of IS.

The concrete should be prepared after proper mix design using methods mentioned in IS:10262 "Recommended Guidelines for Mix Design". Workability of the concrete should be established by slump test. A slump of 30+15 mm is considered reasonable.

Placing of concrete may be taken up in weather conditions already described in para 9.10.1. The concrete base may be constructed by fixed form paver, or a slip form paver. Only where such placing are not possible, construction should be taken up by hand guided methods.

After the placing of the slab and before the application of the curing membrane, the surface shall be brush textured in accordance with the prescribed specifications.

In cases where side forms are used as soon as side forms are removed, edges of the slab shall be corrected wherever irregularities have occurred by using fine aggregate composition of one part of cement and three parts of chips.

9.10.3. **Joints :** Provisions of joints are necessitated due to:

i) expansion, contraction and warping of concrete slabs resulting from temperature and moisture changes;

ii) facilitate a break in the construction at the end of day's work or for any unexpected interruption to work progress; and

iii) construction of pavements in lanes of convenient width.

Types of Joints

Transverse joints are of the following types :

a) Expansion Joints

These provide for space in concrete to allow for expansion of slab. The practice with regard to spacing of expansion joints vary from 20 metres to a few hundred metres. Recent practice is to omit expansion joints and provide the same at junctions of roads with structure, like, bridges, etc.

b) Contraction Joints

These joints are provided in concrete pavements to prevent stresses induced as a result of ambient temperature falling below the laying temperature. These are normally 3 to 5 mm width and provided upto 1/3rd to 1/4th the slab thickness. Spacing of contraction joints is generally 5 metres. For reinforced concrete pavements the maximum spacing varies from 7.5 m to 17.0 m depending upon thickness of slabs.

c) Construction Joints

These joints are provided at the end of a day's work or when the work is stopped unexpectedly due to interruption for more than 30 minutes. These are either contraction joints or expansion joints.

d) Longitudinal Joints

These are required when the width of concrete pavement is more than 4 metres wide. These are intended to provide for warping and even uneven settlement of subgrade. Generally, the joints are butt type but dummy type joints are also used. These are saw cut joints for atleast 1/3rd of the depth of slab.

All foreign material in the joints should be removed first. The manual cleaning of the joints is done with a raker followed by coir brushing. The fine particles are removed with the help of air compressor. After the joints have been cleaned, primer is used. The primer has very low viscosity and penetrates in the pores of the concrete. This is followed by joint filler and finally sealing compound is used. The primer used earlier helps to improve bond between sealing compound and concrete.

The joints should be sealed flush with the adjacent pavement surface on either side in summer and should be filled to a depth of 3-4 mm below the surface in winter so that they may become flush on expanding during hot weather.

Dowel bars are required for the transverse joints to

i) transfer part load across the adjacent slab

ii) stresses becoming critical

iii) assist in the event of loss of subgrade support at the location of joint

Dowel bars are generally mild steel round bars embedded and bonded into concrete on one side of the joint and the other half length deliberately prevented from bonding with concrete on that side. A recess is provided at the sliding end for free movement of slab when used in the expansion joints.

The dowel bar should be supported on cradles/dowel chairs in pre-fabricated joint assemblies positioned prior to the construction of the slabs or mechanically inserted with vibration into the plastic concrete by method which ensures correct placement of the bars besides full re-compaction of the concrete around the dowel bars.

Dowel bars should be positioned at mid depth of the slab, and centered equally about intended lines of the joint. They should be aligned parallel to the finished surface of the slab and to the centre line of the carriageway and to each other.

Dowel bars should be covered by a thin plastic sheath for atleast two-thirds of the length from one end for dowel bars in contraction joints or half the length plus 50 mm for expansion joints. The sheath shall be tough, durable and of and average thickness not greater than 1.25 mm. The sheathed bar shall comply with the specified pullout tests.

For expansion joints, a closely fitting cap 100 mm long consisting of waterproofed cardboard or an approved synthetic material, like, PVC or GI pipe should be placed over the sheathed end of each dowel bar. An expansion space at least equal in length to the thickness of the joint filler board should be formed between the end of the cap and the end of the dowel bar by using compressible sponge to block the entry of cement slurry between dowel and cap. It may be taped.

Tie bars are provided to prevent adjacent slabs from separating, particularly on curves or at fills. The tie bars are not meant to add structural capacity of the slabs and are designed to withstand only tensile stresses.

Tie bars in longitudinal joints should be deformed steel bars of strength 415 MPa complying with IS:1786.

Tie bars projecting across the longitudinal joint shall be protected from corrosion for 75 mm on each side of the joint by a protective coating of bituminous paint.

Tie bars in longitudinal joints shall be made up into rigid assemblies with adequate supports and fixings to remain firmly in position during the construction of the slab. Alternatively, tie bars at longitudinal joints may be mechanically or manually inserted into the plastic concrete from above by vibration using a method which ensures correct placement of the bars and recompaction of the concrete around the tie bars.

Tie bars shall be positioned to remain within the middle third of the slab depth, approximately parallel to the surface and prependicular to the line of the joint, with a minimum cover of 30 mm below the joint groove.

9.10.4. **Equipment of proportioning and laying :** The batching and mixing plant should include minimum four bins, weighing hoppers with automatic weighing devices using load cells and scales for the fine aggregate and for each size of coarse aggregate. If cement is used in bulk, a separate scale for cement should be included.

The weighing hopper should be properly sealed and vented to preclude dust during operation. Approved safety devices shall be provided and maintained for the protection of all personal engaged in plant operation, inspection and testing.

Bins with minimum number of four adequate separate compartments should be provided in the batching plant.

Batching plant should be equipped to proportion aggregates and bulk cement by means of automatic weighing devices using load cells.

Each stationary mixer should be equipped with an approved timing device, capable of making audible warning signal, which will automatically lock the discharge lever when the drum has been charged and release it at the end of the mixing period.

The mixers should be cleaned at suitable intervals. The pickup and throw-over blades in the drums should be repaired or replaced when they are worn down 20 mm or more.

Batching Plant should be calibrated in the beginning and thereafter at suitable interval not exceeding one month.

Mixers should be of pan type, reversible type or any other mixer capable of combining the aggregates, cement and water into a thoroughly mixed and uniform mass within specific mixing period and discharging the mixture without segregation.

The accuracy of weighing devices should be $\pm$ 2 per cent in case of aggregates and $\pm$1 per cent for water and cement.

The capacity of batching and mixing plant should be atleast 25 per cent higher than the proposed capacity of laying/paving equipment.

The design features of batching plant should be such that shifting operations should not take very long time.

The concrete should be placed with an approved fixed form or slip form paver with independent units designed to (i) spread (ii) consolidate, screed and float-finish and (iii) texture and cure the freshly placed concrete in one complete pass of the machine in such a manner that a minimum of hand finishing will be necessary and so as to provide a dense and homogeneous pavement in conformity with the specifications. The paver should be equipped with electronic controls to control/sensor line and grade from either or both sides of the machine. Vibrators should operate at a frequency of 8300 to 9600 impulses per minute under load at a maximum spacing of 60 cm.

Saw machine shall be either electric or petrol/diesel driven type. A water tank with flexible hoses and pump shall be made available in this activity on priority basis. The concreting work should not commence if the saws are not in woking condition.

Freshly mixed concrete from the central batching and mixing plant shall be transported to the paver site by means of truck/tippers. Covers shall be used for protection of concrete against the weather. The trucks/tippers should be capable of maintaining the mixed concrete in a homogeneous state and discharging the same without segregation and loss of cement slurry. The feeding to the paver is to be regulated in such a way that the paving is done in an uniterrupted manner with a uniform speed throughout the day's work.

9.11. **Geosynthetics**

9.11.1. **Materials** : Geotextile should be made of polyethylene or polypropylene or polyester or similar fibres, either woven or non-woven in variety, through machne made process of heat bonding or needle punching or weaving techniques. These fabrics are required to pass water through but retain the soil particles, as for sub surface drains which required specific cross-plane permeability or permitivity.

Geogrid should be made from integrally jointed, mono or bi-directionally oriented or stretched meshes made from polythylene or polypropylene or polyester or similar polymer, with high scant modulus, in square, rectangular, hexagonal or oval mesh form. Their junction strength shall be high with high creep resistance, and dimensional stability. Their open structure shall permit effective interlocking with soil, aggregates, rock, etc., they shall be used as a tensile member or reinforcement. Characteristics strength of such geogrids varies from 40 kN/m to 200 kN/m peak strength at a maximum elongation of 15 per cent in the direction of the length of the roll.

Geonet should be made from a single extruded unoriented process from polyethylene or polypropylene or similar polymer. It should have square or rectangular net shape aperture when used for protective works, like, gabions and mattresses. While in polygonal aperture it should be used as a separator. It should not be used as soil reinforcement due to its high creep characteristics, neither as a slop reinforecement or soil retaining wall or asphaltic reinforcement. Geonets used in protective works for highway structures should be at least 650 gm/sq.m. in unit weight. It should be black in colour.

Geomembrane should be made from PVC or polyethylene of at least 0.8 mm thickness, duly protected from ultra-voilet exposure with 2.5 per cent carbon black, in black colour, supplied in roll form with 3 m or above width. The joints of these sheets shall be heat bonded or seamed for effective permeation cut off, at site using standard equipment as part of the laying process. While fixing on to a slope, they shall not be punctured or stappled to impair their use.

Geocomposites should be made using heat bonded, seamed stitched or wrap techniques. Their principal use shall be to regulate drainage in cross-plane or in-plane directions.

Some of the application areas for geotextiles and related materials and their functions are given in Table 9.50.

Table 9.50. Applications and functions of geosynthetics

S.No.	Application Area	Geosynthetic involved	Functions performance
1.	Embankments on soft soil	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 R = reinforcement
GG = geogrid F = filtration
GC = geocomposite D = drainage
GN = geonet B = barrier
S = separation

9.11.2. **Geosynthetics for highway pavements :** Paving fabric beneath a pavement overlay or between pavement layers to provide a water resistant membrane and crack retarding layer should be a non-woven heat set material consisting of at least 85 per cent by weight polyethene, polyesters or polyamides. The paving fabric shall be resistant to chemical attack, rot and mildew and shall have no tears or defects which will adversely alter its physical properties. The fabric should be specifically designed for pavement applications and be heat bonded only on one side to reduce bleed-through of tack coat during installation. The fabric should meet the physical requirements of Table 9.51. Heavy duty paving fabrics should be used in areas experiencing unusually high impact forces or heavy loads, such as, airport runways and taxiways

Table 9.51. Physical Requirements - paving Fabric

Property	Units	Standard Requirements	Test Method
Tensile Strength	Kg	36.3	ASTM D 4632
Elongation	%	50	ASTM D 4632
Asphalt Retention	Kg/10 sq.m.	10	Texas DOT 3099
Melting Point	^{0}C	150	ASTM D 276
Surface Texture	—	Heat bonded on one side only	Visual Inspection

Notes :

1. Certification of conformance from paving fabric manufacturer may be required.
2. All numerical values represent minimum average roll values (average of test results from any sampled roll in a lot shall meet or exceed the minimum values) in weaker principal direction. Lot shall be sampled according to ASTM D 4354 "Practice for Sampling of Geosynthectics for Testing".
3. Conformance of paving fabrics to specification property requirements shall be determined as per ASTM D 4759 "Practice for Determining the Specification Conformance of Geosynthetics".

Tack coat used to impregnate the fabric and bond the fabric to the pavement shall be a paving grade bitumen of 80-100 penetration. A cationic or anionic emulsion may be used as approved by the Engineer. Cutbacks or emulsions which contain solvents should not be used.

Paving fabric should be kept dry and wrapped such that it is protected from the elements during shipping and storage. At no time shall the paving fabric be exposed to ultraviolet light for a period exceeding fourteen days.

Minimum air and pavement temperature should be at least 10°C and rising for placement of bitumen and shall be at least 15°C and rising for placement of bitumen emulsion.

The pavement surface shall be thoroughly cleaned of all dirt, water and oil. Cracks 3 mm wide or greater should be cleaned and filled with suitable bituminous material. Crack filling material shall be allowed to cure prior to paving fabric placement. Potholes and other pavement distress should be repaired.

Paving fabric should be placed on tack coat using mechanical or manual laydown equipment capable of providing a smooth installation with a minimum amount of wrinkling or folding. The paving fabric should be placed prior to the tack coat cooling and loosing tackiness. Paving fabric should not be installed in areas where the overlay asphalt tapers to a thickness of less than 40 mm. Excess paving fabric which extends beyond the edge of existing pavement or areas of tack coat application shall be trimmed and removed. Wrinkles or folds in excess of 25 mm should be silt and laid flat. All transverse joints and silt folds or wrinkles should be single-lapped in the direction of the paving operation.

Turning of the paver and other vehicles should be done gradually and kept to minimum to avoid movement and damage to the paving fabric. Abrupt starts and stops shall also be avoided. Damaged fabric shall be removed and replaced with the same type of fabric.

9.12.3. **Geosynthetics for protection works :** Mattresses constructed with geogrids or geonets should be used for thickness of 300 mm or above. The mesh opening should have aperture between 35 mm and 100 mm. The mesh should have following characteristics:

i)	Aperture :	Rectangular, square or oval shaped (and not in diamond, round or polygonal shape)

ii)	Colour :	Black
iii)	Mechanical Properties :	Peak strength not less than 10 kN/m at maximum elongation of 15 per cent. Not more than 5 per cent elongation at half peak load.
iv)	Stands/Fabric Form :	Integral joints with junction strength of 100 per cent of plain strands as measured by TRI-GG3 standards. Material shall have ISO 9002 certification.
v)	Life :	At least 8 years in case of continuous exposure and 5 years for burried applications (defined as capable of retaining at least 75 per cent) of its original strength after the life span stated.

Gabion and mattress boxes should be assembled in-situ, on a level surface.

The bottom sides, and end panels should be erected after removal of all kinks, kept in an upright position to form rectangular boxes by joining the sides with connectors of 40 mm × 6 mm size, or by ring staples. The top corners shall be tie tensioned from sides or keep it erect for filling. For gabions of 600 mm or more height, suitable cross internal ties shall be placed in layers of 300 mm connecting opposite sides in lateral braces tied with polymer braids of ultra-violet stabilised variety so as to ensure protection against bulging of the gabions during filling with stones.

The filling of the gabion/mattress should be done by hand in layers so as to minimise voids and achieve specified density. The stones in contact with the surface of the geogrids/geonets should be placed in such a way that their sharp edges are kept turned inside so that they do not damage the material of the geogrids/geonets. The opposite panels of the boxes should be firmly secured with lateral ties to withstand the design forces. The bottom of the gabion mesh shall be secured in a key type excavation for preventing slide. The space between the gabion and earthen sides shall be filled with sand and the filling compacted. In most of the cases design should be supplemented with a layer of geotextile under the gabion/mattress to prevent migration of fines.

Mattresses of minimum height 300 mm should be used for boulder apron in crates. The typical size of a single continuous unit should be 1 m × 5 m with baffles at 1 m centres. The size of boulders shall be at least 100 m or double the size of the aperture whichever is larger. The specific gravity of stones not less than 2.65. Gabions if placed in the apron should be of size 1 m × 5 m in plan with height at least 600 mm, with baffles in 1 m centres.

Groynes or spurs of gravity retaining variety should be constructed using geogrid/geonet gabions palced in a stable configuration one over the other to form a well.

9.11.4. **Reinforced earthwork with geotextiles :** The reinforcing element shall be of geosynthetic (fabric, grid or strip), aluminium alloy strip, copper strip, or galvanised carbon steel strip mats of metal.

Aluminium alloy strip should comply with BS:1470 quality 5454 in the H 24 condition.

Copper strip should comply with BS:2870 quality C 101 or C 102 in the 1/2 H condition and should have 0.2 per cent proof stress of not less than 180N/mm^2.

Carbon steel strip which should be galvanized and comply with BS:1449 (Part 1), either quality KHR 34/20 P or quality 50/35 P, each having a silicon content of not less than 0.25 per cent and not more than 0.40 per cent. The fabricated element shall be galvanized in accordance with BS:729, and the average zinc coating weight for any individual test area shall not be less than 1000 gm/sq.m.

Stainless steel strip shall comply with BS:1449 (Part 2) quality 316 S 31 or 316 S 33 except that the material shall be cold rolled to provide a 0.2 per cent proof stress of not less than 400 N/sq.mm and the tensile strength shall not be less than 540 N/sq.m.

All metallic components buried in soil shall be of electrolytically compatible materials.

Geogrid should carry a certification of BIS or ISO 9002 for all works. While the reinforcing element for wall or slope portion shall be with mono-oriented geogrid, the reinforcement for the foundation of a reinforced earth wall or slope with bi-directionally oriented geogrid. The geogrid should be inert to all naturally occurring chemicals, minerals and salts found in soil.

The fill material for reinforced earth structures should have an angle of interface friction between the compacted fill and the reinforcing element of not less than 25°C, measured in accordance with IS:13326 (Part 1). The soil should be predominantly coarse grained; not more than 10 per cent of the particles shall pass 75 micron sieve. The soil should have properties such that the salts in the soil should not react chemically or electrically with the reinforcing elements in an adverse manner.

The facing should be sufficiently flexible to withstand any deformation of the fill. It should comprise of one of the following :

i) Reinforced concrete (cast in-situ or precast) slabs

ii) Plain cement concrete form fill hollow block (Precast)

iii) Masonry construction, rubble facia

iv) Other proprietary and patented proven system

Connection between the facia and the reinforcing element should be by using polyethylene strips/rods, fibre glass dowel.

The reinforcing elements should be placed at right angles to the face of the wall, with greater cross sectional dimensions in the horizontal plane.

The compacted layer shall not be more than 200 mm, to achieve compaction of 95 per cent of maximum laboratory density where measured as per IS:2720 (Part 8). Temporary formwork should be used to support the construction.

9.11.5. **Geotextile in sub-surface drains :** The geotextile fabric should be woven or non-woven fabric consisting of long-chain polymeric filaments or yarns, such as, polypropylene, polyester or any combination thereof, formed into a stable network such that the filaments or yarns retain their relative position to each other.

The goesynthetic material of which the drain is made should be treated with carbon black so that they are protected from the deleterious effects of short term exposure to ultraviolet light, and be resistant to degradation by acid, alkalis, common chemicals, bacteria, fungi and moulds occurring in soils and highway construction materials.

The geotextile should

a) sustain a load of not less than 10 kN/m at break and have a minimum failure strain of 10 per cent when determined in accordance with BS:6906 (Part 1) or shall have a grab tensile strength more than 0.4 kN/m and grab elongation corresponding to this limit in accordance with ASTM D 4632.

b) the apparent opening size, shall satisfy the following :

   i) Soil with 50 per cent or less particles by weight passing IS sieve 75 microns, apparent opening size less than 0.6 mm.

   ii) Soil more than 50 per cent particles by weight passing IS sieve 75 microns, apparent opening size less than 0.927 mm.

c) allow water to flow through it at right angles to its principal plane, in either direction at a rate of not less than 10 litres/m^2/sec. under a constant head of water of 100 mm, determined in accordance with BS:6906 (Part

3) or ASTM D 4491 or as stated in the design drawing. The flow rate determined in the test shall be corrected to that applicable to temperature of 15°C using published data on variation in viscosity of water with temperature.

d) have a minimum puncture resistance of 200 N when determined in accordance with BS:6906 (Part 4) or ASTM D 4833.

e) have a minimum tear resistance of 150 N when determined in accordance with ASTM D 4533.

The installation of drains shall be as per the design drawings. Where fin drains are assembled on site, the assembly area shall be clean and dry and free of any wind-borne pollutants. No geotextile or core material should be exposed to daylight (or any source of ultraviolet radiation) for a period exceeding a cumulative total of 50 hours. Where fin drains are laid in trench, the bottom of the trench shall be free of irregularities and should be brought to the required level. Rock and other hard protrusions should be removed and any excess cut in the trench bottom filled and compacted back to the required grade with suitable excavated or imported material. Fine drains should be capable of being jointed longitudinally or laterally into pipe systems or chambers for inflow and outflow purposes. Joints parallel to the direction of flow and any exposed edged shall be protected from a ingress of soil by a geotextile wrapping with a minimum overlap of 150 mm.

9.12. **Special Measures to Hilly Areas**

9.12.1. **The problem :** Some of the important special problems arising in the construction of roads in hilly areas are :

i) Road construction will invariably involve cutting which will disturb the natural inclination of the soil to create conditions for triggering landslides.

ii) Bared and steep cut slopes are conducive to serious erosion.

iii) Surface run-off earlier draining along the natural hill slopes will be directly discharging into the roadway unless intercepted. Another problem is safe disposal of concentrated flows from cross drainage structures on the valley side.

iv) The cut formation will be exposed for the first time, and may bringforth several features, such as, seepage, flow, presence of poor unsuitable soils and shales, etc.

v) The cut portions will be in the heaving cycle while the adjoining fillings will be in the consolidation cycle. Unless special care is taken, this can cause serious unequal settlements.

9.12.2. **Remedial measures** : For combating these problems squarely, several measures are warranted right from the stage of planning. Some of the important measures in this regard are :

i) Roads should be located through geologically stable strata.

ii) Avoid large-scale cutting and filling, and follow the lie of the land as far as possible. When in cutting, adopt half-cut and half-fill type of cross-section which involves least disturbance to the natural ground.

iii) Align the roads away from streams and torrents and potential landslide/erosion prone areas.

iv) Provide catchwater and intercepter drains. After cutting has been made, look for seepage flows and take measures to intercept these.

v) Locate and align culverts in such a way that severe erosion at outlets and siltation at inlets are avoided. Take necessary precautions/safeguards to ensure safe disposal of water discharged into the valley side.

vi) Do not push surplus excavated materials down the valley, but have these dumped in low areas where these cannot get easily washed away.

vii) Cut slopes should be stable for the strata cut, and where necessary, provide suitable breast walls, pitching, etc.

viii) Where erosion is likely to be a problem, clearing and grubbing operations should be so scheduled and performed that grading operations and permanent erosion control features can follow immediately thereafter. Otherwise, provide temporary erosion control measures between successive construction stages - see Clause 306.3 of Ministry's Specifications.

ix) Provide all bared surfaces with vegetative cover. Also, provide for strip forests for a minimum distance of 30 m on either side of the road.

x) Consult officers of Forest/Geological Deptts., right from the stages of survey and investigations. For any seriously problematic areas, consult specialist organisations for appropriate solutions.

9.13. Quality Control for Road Works

It is the prime reponsibility of the Engineer-in-charge to ensure that the work performed and all the materials incorporated in the work conform to the specification requirements. Objective tests for checking the quality of materials are available, but he should not wait till materials are delivered at site. Some of the actions he could take are :

i) Obtain the test certificates of manufactured materials from the sources from where these are to be procured.

ii) For manufactured items for which I.S.I. marking facilities are not available, he should inspect the place of manufacture to ensure that the materials used and the processes adopted can turn out products satisfying the specification requirements.

iii) In the case of mineral aggregate, he should inspect the quarry, or even station his representative there to ensure that only approved rock is crushed to the required sizes.

iv) For works involving processing (e.g., stabilisation) or compaction involving equipment, he may, if so provided for in the contract, ask the contractor to do the work on a trial stretch to ensure that the equipment and procedures used can turn out quality work.

Constructions organisations should preferably have quality control units independent of the construction staff. These units are intended to bring out any deficiency in the material or work to the notice of the Engineer-in-charge, as a second check. Presence of these units will not, however, absolve the Engineer-in-charge of his prime responsibility.

Details of the quality control tests, their frequency, the method of rectifying the defects, etc., are contained in IRC:SP:11 "Handbook of Quality Control for Construction of Roads and Runways".

It is essential that the results of all quality control tests and observations should be systematically recorded and carefully preserved.

The frequency of control tests on embankment construction, non-bituminous bases and bituminous bases are included in Table Nos. 9.52., 9.53. and 9.54.

Table 9.52. Quality control tests and their frequency for embankment construction

	Particulars	Frequency
1.	**Borrow Material**	
a)	Sand content [IS:2720 (Pt. IV)]	Two test per 3,000 m^3 of soil
b)	Plasticity test [IS:2720 (Pt. V)]	Each type to be tested, 2 tests per 3,000 m^3
c)	Density test [IS:2720 (Pt. VII)]	Each type to be tested, 2 tests per 3,000 m^3
d)	Deleterious content [IS:2720 (Pt. XXVII)]	As required
e)	Moisture content test [IS:2720 (Pt. II)]	One test per 250 m^3
f)	CBR (for material to be placed in subgrade) [IS:2720 (Pt. XVI)]	As required
2.	**Compaction Control** (density test)**	
a)	Body of embankment	At least one test per 1,000 m^2 for each layer
b)	Subgrade and shoulders	At least one test per 500 m^2 for each layer

** Control should be based on the mean value of a set of 5-10 density measurements in case of embankment body and 10 measurements for subgrade and shoulders. Acceptance shall be subject to the conditions that the mean dry density equals or exceeds the specified density and the standard deviation is below 0.08 gm/cc.

Table 9.53. Control tests and their minimum frequency for sub-bases and bases (excluding bitumen bound bases)

S. No.	Type of Construction	Test	Frequency (minimum)
1.	Granular	i) Gradation	One test per 200 m^3
		ii) Atterberg limits	One test per 200 m^3
		iii) Moisture content prior to compaction	One test per 250 m^3
		iv) Density of compacted layer	One test per 500 m^3
		v) Deleterious constituents	As required
		vi) C.B.R.	As required
2.	Lime/Cement Stabilised Soil Sub-base	i) Quality of lime/ cement	One test for each consignment subject to a minimum of one test per 5 tonnes
		ii) Lime/Cement content	Regularly, through procedural checks
		iii) Degree of pulverisation	Periodically as considered necessary
		iv) CBR or Unconfined Compressive Strength test on a set of 3 specimens	As required
		v) Moisture content prior to compaction	One test per 250 m^2
		vi) Density of compacted layer	One test per 500 m^2
		vii) Deleterious constituents	As required
3.	Water Bound Macadam	i) Aggregate Impact Value	One test per 200 m^3 of aggregate
		ii) Grading	One test per 100 m^3
		iii) Flakiness and Elongation Index	One test per 200 m^3 of aggregate

		iv) Atterberg limits of binding material	One test per 25 m^3 of binding material
		v) Atterberg limits of portion of aggregate passing 425 micron sieve	One test per 100 cubic metre of aggregate
4.	Wet Mix Macadam	i) Aggregate Impact Value	One test per 200 m^3 of aggregate
		ii) Grading	One test per 100 m^3 of aggregate
		iii) Flakiness and Elongation Index	One test per 200 m^3 of aggregate
		iv) Atterberg limits of portion of aggregate passing 425 micron sieve	One test per 100 m^3 of aggregate
		v) Density of compacted layer	One test per 500 m^3

Table 9.54. Control tests and their minimum frequency for bituminous works

Sl. No.	Type of Construction	Test	Frequency (minimum)
1.	Prime Coat/ Tack Coat	i) Quality of binder	Two samples per lot to be subjected to all or some tests as directed by the Engineer
		ii) Binder temperature for application	At regular close intervals
		iii) Rate of spread of Binder	Two tests per day
2.	Seal Coat/ Surface Dressing	i) Quality of binder	Two samples per lot Dressing to be subjected to all or some tests as directed by the Engineer

		ii) Aggregate Impact Value	One tests per 50 m^3 of aggregate
		iii) Flakiness and Elongation Index	— do —
		iv) Stripping value of aggregate	Initially one set of 3 representative specimens for each source of supply. Subsequently when warranted by changes in the quality of aggregates
		v) Water absorption of aggregates	— do —
		vi) Grading of aggregate	One test per 25 m^3 of aggregate
		vii) Stone polishing value	As required
		viii) Temperature of binder at application	At regular close intervals
		ix) Rate of spread of materials	One test per 500 m^3 of work
3.	Open-graded Premix Carpet/ Mix-Seal Surfacing	i) Quality of binder	Two samples per lot to be subjected to all or some tests as directed by the Engineer
		ii) Aggregate Impact Value	One test per 50 m^3 of aggregate
		iii) Flakiness and Elongation Index of aggregates	— do —
		iv) Stripping value	Same as mentioned under S.No. 2
		v) Water absorption of aggregates	Same as mentioned under S.No. 2
		vi) Grading of aggregates	One test per 25 m^3 of aggregates
		vii) Stone polishing value	As required

		viii) Temperature of binder at application	At regular close intervals
		ix) Binder content	Two tests per day
		x) Rate of spread of mixed materials	Regular control through checks on materials and layer thickness
4.	Bituminous Macadam	i) Quality of binder	Two samples per lot to be subjected to all or some tests as directed by the Engineer

10. DATA FOR REVISED ESTIMATE

10. DATA FOR REVISED ESTIMATE

10.1. Measures to Avoid Revision

10.1.1. Quite often, it becomes necessary to revise an estimate for several reasons which could be put under the following broad groups :

i) Tender rates being higher than the sanctioned rates;

ii) Change in scope and technical/unforeseen reasons.

10.1.2. The excess due to higher tender rates cannot generally be avoided though the extent can be brought down considerably by adopting current Schedule of Rates in the estimate and reducing lag time between the dates of estimate preparation and tendering award of work. Ministry's Circular No. RW/NH-11060/1/87-DO I dated 28.8.92 specifies that sanction of projects which are not started within one year from the date of sanction automatically lapses unless specifically agreed to by the Ministry due to extentuating circumstances. Therefore, quick action needs to be taken for completion of all necessary formalities before award of work to the contractor.

10.1.3. The other reasons attributed as technical or unforeseen may be changed in calssification and source of soils as also source of other materials, like, stone aggregate, sand, etc., incorrect survey data requiring higher quantities, provision of improvements of geometrics or in structures not anticipated earlier, need for raising the formation level, etc. All these could have been seen, sorted out and provided for, had the surveys and investigations been detailed and accurate. Careful attention is, therefore, needed at that stage for avoiding revisions on these accounts.

10.1.4. Acquisition of land for improvement of geometrics of the road or for approaches to Railway Overbridge/high level bridge, etc. need to be sanctioned separately and well in advance to ensure completion of L.A. proceedings and take over of the land before the project is sanctioned. Inclusion of L.A. provision in the project estimate often results in time and cost over run and hence not desirable. The rates for the land obtained from the Revenue

Authorities should be provided in L.A. estimate and provisions based on L.A. Act 1984.

10.2. Information for Revised Estimate

10.2.1. **General :** Where an estimate has to be revised, the revised estimate document must contain all the necessary information and back-up data for clear understanding and appreciation of the reasons for revision, the extent of excess against each reason, justification, etc. So that the document prepared is complete in all respects, it is advisable to cross-check the information with a check-list (see Ministry's Circular No. NH-III/P/50/76 dated the 1st July, 1976 as regards National Highway revised estimate).

10.2.2. **Broad contents of revised estimate :** The revised estimate document should be divided into a number of parts dealing with different aspects. Important among these pertaining to NH projects are summarised below :

a) Estimate Report
- need for revision
- detailed reasons for change in scope, specification, rates, etc.
- discussion on alternate courses of action cosidered.
- drawing reference to Ministry's letters approving changes in scope, specification, higher tender rates, etc.
- if prior approval of Ministry had not been taken, reason as to why this was not done.
- if provision is made for restoration of damages, explain why this should not be the responsibility of the contractor.
- the present stage of work, the date of start and the target date of completion.
- if the work has been completed, explain why the revised estimate was not submitted in time.
- briefly narrate audit objections of significance pending clearance.

b) Certificates
- certificate for cent per cent arithmetical check by a responsible officer.
- the land acquisition rates have been ascertained from competent authority.
- that the estimate does not provide for the cost of land belonging to the State Govt. and that this will be made available free of cost.
- that the estimate is based on actuals in case of completed items/works.

c) Compliance with Technical and Inspection Notes
- reports of compliance with Technical and Inspection notes issued by the Ministry

d) Comparative Statement
- comparative statement should be in the format indicated in Table 10.1.
- detailed reasons for excess/saving
- provisions for all needed items.
- do not provide any major lumpsum provisions. If required to be provided, these should be supported by detailed sub-estimates with justification for exceeding original provision.
- indicate as to which rates are based on actuals, on tender, on current SR, and on analysis.
- give credit for salvage value of dismantled materials, empty bitumen drums, trees cut from NH land, stones/aggregate obtained from cuttings, etc.
- apportionment of cost where applicable between concerned authorities, e.g., between Road and Rail Authorities for approaches to over/under bridges in replacement of level crossings, between Road and Irrigation Authorities where a road requires diversion or raising because of coming up of an irrigation project, between Centre and the State, where necessary.
- correct provision for precentage charges. Centage charges in case of completed works should be as per actuals limited to permissible limits (see para 6.3.).

Table 10.1. Comparative statement for revised estimates

Name of work: NH No. : Job No. State :

Items of work	Original estimate			Revised estimate			Saving/excess due to variation in qty.			
	Qty	Rate	Amt	Qty	Rate	Amt	Qty	Rate	Saving	Excess
1	2	3	4	5	6	7	8	9	10	11
I. As per original estimate										
II. New and/or deviated items										
III. Excess due to difference in cost of procurement and supply materials like cement, steel, etc.										
IV. Centage charges										
Total										

(Table Contd.)

Savings/excess due to variations in rates				Total Savings/ Excess		Remarks and justification for deviations from the sanctioned estimate
Qty	Rate	Sav-ings	Excess	Saving Cols. (10+14)	Excess Col. (11+15)	
12	13	14	15	16	17	18

Notes : 1. The work done/to be done by different executing agencies should be shown separately.
2. Rate in col. 9 should be the same as that in col. 3.
3. Rate in col. 13 should be col. 6 - col. 3.
4. Qty. in col. 8 should be col. 5 - col. 2.
5. Qty. in col. 12 should be same as col. 5.

f) Details of Measurements
- — details of measurements for all items figuring in abstract of cost.

g) Contract Document
- — enclose a copy of the contract document where there are excesses due to any contract clause, e.g., escalation clause.

h) Analysis of Rates
- — analysis of rates not covered by tenders or by schedule of rates.
- — quarry/borrow area chart in support of leads provided. Reasons for changes in quarry/material source.
- — full details regarding extra amount spent for steel/ cement, etc., including sources, rates of procurement and justification for paying higher rates.
- — rate analysis of items executed departmentally.

i) Designs
- — details of changes in design, along with reference to approval of Ministry.
- — enclose copies of modified designs along with justification.
- — remarks on realisation of design assumptions at site.

j) Drawings
- — enclose all necessary drawings to draw reference to any standard drawing if used.
- — the drawings should clearly show both the original and revised proposals in case there may be any difference.

k) Audit Paras
- — brief report on pending audit paras.

l) Pending Claims
- — brief report on claims pending settlement

11. ROAD MACHINERY

11. ROAD MACHINERY

Mechanisation of road construction is not only necessary for speedy completion but also for overall economy and for achieving the desired quality of the finished job. Starting from grubbing or site clearance, the road construction machinery can be deployed at all stages of construction till completion of the project. The requirement of appropriate machinery for excavation of different operations of road construction is given in Tables 11.1 to 11.6. The expected output of machines is given in Table 11.7.

Table 11.1. Compaction of embankment and sub-grade

S.No.	Type of Soil	Choice of Roller	Remarks
1.	Granular and dry cohesive soil	i) 8-10 Ton three smooth wheeled roller	
		ii) 80-100 kN Vibratory Compactor	
		iii) Pneumatic Tyred Roller	Load per wheel 20 kN
2.	Uniformly graded soil	i) 8-10 Ton three smooth wheeled roller	
		ii) Pneumatic tyred roller	Load per wheel 15 kN
		iii) 8-10 Ton vibratory roller	
3.	Cohesive Soil	Sheep foot roller	
4.	Cohesion less soil	Vibratory roller	

Table 11.2 Selection of plant for earth moving Operations

Sl.No.	Operation	Choice of Plant	Remarks
1	2	3	4
1.	Clearing and grubbing clearing light scrub grass, etc.	a) Dozer	
		b) Motor Grader	Can easily be used if scrub is very light.

1	2	3	4
2.	Clearing debris and rubble	a) Dozer	
		b) Front End Loader smaller size	
		c) Tractor with heavy duty	For clearance of large objects.
3.	Excavation, earth movement and embankment		
A)	Light and medium soils requiring preliminary loosening	a) Dozer	Best unit for hauls of under 90 m. Also, for hill cuts and cuts down vertical faces for roads.
		b) Scraper Tractor towed Motorised	Tractor towed scraper for hauls for 60 m to 300 m motorised scraper for hauls of 300 m.
			Best unit for building shallow road embankments across generally flat terrains.
		d) Excavator and dumper	
		e) Front End Loader and tipping trucks	
B)	Heavy soils	a) Dozer, Crawler/ Dozer wheeled.	
		b) Towed Scraper with pusher Motorised scraper with pusher, proceeded by rooter.	
		c) Motor Grader proceeded by tractor towed rooter.	Preliminary rooting is essential from motor graders.

1	2	3	4
	Spreading: Distributing fill in layers of uniform thickness	a) Scraper, tractor towed or motorised	Best machine for hauling and spreading thin layers of material.
		b) Motor Grader	Used for spreading and withdrawing materials of workable nature.
		c) Tipping Trucks	Can spread their loads to a limited extant.
		d) Crawler Dozer	Best machine for initial spreading of workable material.
	Cambering	a) Motor Grader	Best machine for providing final camber
		b) Crawler Dozer	Can provide camber during initial excavation for road formation.
		c) Scraper, tractor towed or motorised	Can provide camber during initial excavation for road formation.
	Scarifying and shaping earth roads	a) Grader with scarifier	Best machine for loosening and shaping top layer of earthen.
	Maintenance of earth haul roads	a) Motor Grader Wheel Crawler	Best machine for this work
		b) Wheel/Crawler Dozer	Should be used only if grader not available
	Watering	Truck or Trailer mounted water tanker with a sprinkler and water pump	

Table 11.3. Selection of plant for compaction

S.No.	Operation	Choice of Plant	Remarks
1.	Soil stabiliastion	(i) 8-10 ton three smooth wheeled roller	
		(ii) Vibrating roller	
3.	Granular base, sub-base	i) 8-10 Ton three smooth wheeled roller	
		ii) Vibratory Roller	
3.	Macadam and other course aggregate base courses	i) 8-10 Ton three smooth wheeled roller	
		ii) Steel wheeled vibratory roller	
4.	Mix-in-place asphalt base course	i) 8-10 Ton three smooth wheeled roller	
		ii) Vibratory compactor Tandom 8-10 Ton	
		iii) Pneumatic tyre roller	
5.	Plant-mix base levelling or surface courses	i) 8-10 Ton three smooth wheeled roller	For break-down rolling
		ii) Steel wheeled tandom roller	For break-down rolling
		iii) Pneumatic tyred roller (self propelled)	For intermediate rolling
		iv) Tandom roller	For intermediate rolling
		v) Rubber tyred roller	For final rolling

Table 11.4. Selection of plant for bituminous pavement

S.No.	Operation	Choice of Plant	Remarks
1.	Surface dressing	i) Bitumen Pressure Distributor, if bulk bitumen supply is available	For uniform application of binder
		ii) Chip Spreader	For even spreading of chips to correct thickness.
2.	Bituminous grouting (Penetration machine)	i) Bitumen boilers with sprayers.	
	a) Semi grout b) Full grout	ii) Bitumen pressure distributor if bitumen is supplied, in bulk	
3.	Seal coat	Mini hot mix plant 6-10 Ton/hr. capacity	For laying manually
4.	Premix carpet	i) 20-30 and 40-60 Tons/hr. hot mix plant	If there is sufficient work load.
		ii) Paver finisher iii) Tipping truck iv) 8/10 Ton three smooth wheeled roller v) Rubber tyred roller	Paver finisher for mechanical spreading and tipping truck for haulage would be a good combination.
5.	Hot mix BM/AC	i) Mechanical broom	
		ii) Bitumen boilers with sprayers	For tack coat

S.No.	Operation	Choice of Plant	Remarks
		iii) Bitumen pressure Distributors	
		iv) Hot Mix Plant 40-60 Ton or more/hr.	Batch or continue type
		v) Electronic paver finisher with sensor	To match the capaccity of Hot Mix Plant
		vi) Tipping trucks	6 to 8 nos. depending on the distance from the plant
		vii) Front end loaders	For cold feed loading
		viii) Generators, if required	For electrical hot mix plants
		ix) 8-10 Ton three smooth wheeled roller	
		x) Vibratory Tandom roller	
		xi) Rubber Tyred Roller	

Table 11.5. Selection of plant for sub-base/base course

	Operation	Choice of Plant	Remarks
1.	Soil Stabilisation	i) Soil Stabiliser	
		ii) Rotavator	
		iii) Vibratory road roller	
		iv) 8-10 Ton three wheeled smooth road roller	
		v) Water sprinkler	

	Operation	Choice of Plant	Remarks
2.	Water Bound Macadam (WBM)	i) Aggregate spreader	
		ii) Water sprinkler	
		iii) 8-10 Ton three wheeled smooth road roller	
		iv) Tipping trucks	
3.	Wet Mix Macadam (WMM)	i) Multi-stage stone crushing plant	
		ii) Concrete mixer	Suitable for small quantity of works
		iii) Wet mix plant	Plant should have twin shaft pugmill
		iv) Paver finisher	It has better control of thickness and profile.
		v) Tipping trucks	
		vi) 8-10 Ton three wheeled smooth road roller	
		vii) Vibratory road roller	
4.	Granular Sub-base (GSB)	i) Motor grader	
		ii) Tipping trucks	
		iii) 10 Ton smooth three wheeled road roller	
		iv) Vibratory road roller	
		v) Water sprinkler	

Table 11.6. Selection of plant/machineries for concrete pavement

S.No.	Operation	Choice of Plant	Remarks
1.	Dry Lean Concrete (DLC)	i) Multi stage stone crushing plant ii) Concrete batching/ mixing pant iii) Fixed form paver iv) Transit mixer v) Compactor	
2.	Paving Quality Concrete (PQC)	i) Multi stage stone Crushing plant ii) Concrete batching/ Mixing plant iii) Fixed form/Slip-form paver finisher iv) Concrete cutter (Saw cutting machine) v) Texturing machine vi) Curing machine vii) Concrete placer viii) Transit mixer ix) Dowel bar inserter	

Table 11.7. Tentative output of road machinery

1.	Scraper (Motorised) towed	160 cum/day
2.	Dozer	200 cum/day
3.	Motor Grader	600 cum/day
4.	Excavator 1m^3 capacity	400 cum/day
5.	Three smooth wheeled road roller output	
	a) Earthwork	450 cum/day
	b) Moorum/Gravel	450 cum/day
	c) Pavement	
	i) WBM Stone base course	45 cum/day
	ii) WBM/WMM wearing course	40 cum/day
	iii) DBM	40 cum/day

	d) Surfacing Dressing	
	i) First Coat	2500 sqm/day
	ii) Second Coat	3500 sqm/day
	e) Premix Carpet	
	i) 25 mm thick	2000 sqm/day
	ii) 20 mm thick	2000 sqm/day
6.	Earthwork compaction by sheep foot road roller	600 cum/day
7.	Vibratory road roller earth-work (depends upon the thickness) of layer and type	600 cum/day
8.	Other machinery	
	a) Mini Hot Mix Plant 6-10 TPH	8 Ton/hr.
	b) Hot Mix Plant 40-60 TPH	50 Ton/hr.
	c) Paver Finishers 75-160 TPH	75 Ton/hr.
	d) Bitumen Boiler	2000 Litre/hr.
	e) Water Tankers	10,000 Litres
	f) Bitumen Pressure Distributors	10,000 Litres
	g) Stone Crusher	
	h) Wet Mix Macadam Plant 60 T/Hr.	50 Ton/hr.
	i) Stone Crusher less than 100 Ton/hr.	Depend upon the requirement
	j) Multi stage stone crusher more than	100 Ton/hr.
	k) Concrete Batching Mix/Plant upto 50 cum/hr	40 cum/hr
	l) Concrete Batching Mix Plant more than 50 cum/hr	Depend upon the requirement

9. Haulage by trucks/tippers

When lead = 2 kilometres, trips per day = 8 nos.

When lead = 8 kilometres, trips per day = 6 nos.

When lead = 16 kilometres, trips per day = 5 nos.

When lead = 30 kilometres, trips per day = 4 nos.

Note : No. of working days per year = 200

12. GUIDELINES FOR INSPECTION OF IN-SERVICE ROADS

12. GUIDELINES FOR INSPECTION OF IN-SERVICE ROADS

12.1. General

Roads are continuously subject to wear and tear by the traffic plying on them. Besides this, damages are also caused by forces of nature and climatic conditions. Periodical inspection of the roads by qualified engineers are warranted on several counts. Some of these are :

i) to take prompt corrective measures;

ii) to have a clear understanding as to why certain reaches perform better worse, for facilitating prior action and for perfecting the technology; and

iii) to serve as a record of year to year performance for planning purposes, etc.

12.2. Road Register

A pre-requisite to meaningful inspection is the inverntory of all related features of the road and continuous record of improvement works. This can be conveniently compiled for each section of the road, usually 5-10 km long, in the form of Road Register. Such Register will not only form the basic records for the road but will also be helpful to the inspecting officers.

The Road Register should essentially consist of three parts, the first giving statistical information, the second giving the basic inventory of information as existing or originally constructed, and the third giving the strengthening/renewal work carried out from year to year. Important details to be included in the Register are indicated in Table 12.1.

12.3. Inspection

The road should be inspected frequently and twice a year, once before the start of rainy season and also soon after the rainy

Table 12.1. Important information to be included in road register

I. Statistical data	II. Basic inventory	III. Annual strengthening/renewals
Location Date of construction Rainfall : Annual average and rainfall season	Plan and L-Section giving the following information in numercial figures, symbols, or signs :	Strengthening : Work done yearwise showing the thickness and type of layer
Traffic : Traffic census data base 1 on 7-day count, showing vehicles by type, year by year Financial statement : Expenditure on different items of work separately for capital works and maintenance year by year	i) width of land roadway and carriageway ii) horizontal curves with their radii iii) railway/road crossings iv) Cross-drainage structures, ventway type and condition v) floodable reaches, H.F.L. vi) average height of fill cut vii)soil type, design CBR, pavement composition viii)sight distance, gradients ix) location of roadside amenities	Renewal : thickness and type of renewal yearwise and km-wise

season by responsible engineers as per points detailed in Table 12.2. During the rains, arrangements should be made to have a close watch on flood levels, possibility of overtopping of road sections, general flow pattern of run-off water, proper functioning of drains and culverts, etc., so that prompt measures could be taken for regulating traffic flow and also forwarding off major damages.

Table 12.2. Points to be looked for during inspection and action to be taken prior to during/after rains

Prior to rain	During rains	After rains
Cleaning/clearing all drains, catch pits, etc. Repairing damages to all protective works, like, pitching, etc.	Have close watch on flood levels, any tendency for overtopping, and blockage of drains/culverts, etc.	Access the damage, give top priority for repairing breaches and removing blockage
Filling scour holes at abutment/ pier of C-D works	Repair potholes and keep road traffic worthy	Watch for water oozing out of shoulders/slopes. If so, cut out to release and remove the locked up water
Storing and protecting road construction materials safe from floods Repaving/sealing/ pavement cracks potholes, etc. Dressing berms so that these easily shed off water	In case of any breach, cordon off the affected stretch by barriers, arrange for traffic diversion, notify the public of the diversion, and take immediate action in making up the breach.	Repair potholes/ cracks, etc. Study stretches showing recurring damages to ascertain causes and to evolve remedial measures

13. COMMON TESTS ON MATERIALS AND WORKS

13. COMMON TESTS ON MATERIALS AND WORKS

A large number of tests are required to be conducted on materials incorporated and work performed in a highway project. Outlines of some of the commonly used tests are given in the following paragraphs. It should, however, be understood that these outlines are intended to draw the attention of the site engineers and not to serve as the procedure for such tests. For detailed procedure of the individual tests, reference may be made to the relevant standards of B.I.S. or other authorities as applicable.

(1) Determination of Moisture Content of Soils (IS:2720 Pt. II)

Where facilities are available, the method consists of drying a sample of the soil in the oven at 105°C-110°C for a period (normally, not more than 24 hours) till the dry weight of the soil becomes constant.

In the field, the alcohal method, though less accurate, can be used as a quick test. It consists of taking the soil specimen in a evaporating dish, pouring over it methylated spirit at the rate of about one millilitre for each gram of soil, mixing the two materials and igniting the spirit. After burning away of the spirit, the dish is cooled and weighed.

(2) Liquid Limit and Plastic Limit (IS:2720, Pt. V)

The liquid limit test is conducted on the standard instrument with soil specimens at various moisture contents. The liquid limit is taken as that moisture content where the standard groove will close under an impact of 25 blows.

The plastic limit is the water content at which the soil will begin to crumble when rolled into a thread of 3 mm in diameter. The plasticity index is taken as the difference between liquid limit and plastic limit.

(3) Moisture-Density Relationship (IS:2720, Parts VII & VIII)

Two degrees of compaction, light compaction (IS:2720, Part VII) and heavy compaction (IS:2720, Part VIII) are usually specified. The former compaction also goes by the term Proctor compaction and latter by the term modified Proctor.

In light compaction, the wet soil is compacted in three equal layers by the rammer of weight 2.6 kg and free fall 31 cm with 25 evenly distributed blows on each layer. In heavy compaction, rammer weights 4.89 kg and the free fall is 45 cm. Compaction is done in 5 equal layers, each being given 25 blows.

The procedure is to compact the soil with different moisture contents and drawing a moisture density curve to find out the maximum dry density and the corresponding moisture content (CMC).

(4) Laboratory CBR (IS:2720, Part XVI)

The apparatus consists of a mould 15 cm diametre with a base plate and collar, a loading frame with cylindrical plunger of 5 cm collar and diametre gauges for measuring the expansion on soaking and the penetration values. Briefly, the test consists of causing the plunger to penetrate the compacted specimen with specified surcharge in the mould at 1.25 mm/minute under 4 days soaked or unsoaked condition. A load penetration graph is plotted correction is applied and the load corresponding to 2.5 and 5 mm penetration values are found. This load is expressed as a percentage of the standard load at the respective deformation level to obtain the CBR value. The standard loads for 2.5 mm and 5 mm penetrations are 1,370 kg and 2,055 kg respectively. The CBR usually selected is at 2.5 mm penetration. For this test, only the material passing 20 mm sieve is used.

(5) Flakiness and Elongation Indices (IS:2386, Part I)

The flakiness of an aggregate is defined as percentage by weight of particles in it whose least dimension (thickness) is less than three-fifths of their mean dimension. The elongation index of an aggregate is defined as the percentage by weight of particles whose greatest dimension (length) is greater than one and four-fifths times their mean dimension. The flakiness index is first determined and the elongation index is then carried out on the remaining non-flaky stone particles.

The representative sample of aggregates to be tested is washed, dried and weighed in accordance with the prescribed method. Each particle is gauged in turn for thickness on a metal gauge of specified pattern. The cumulative total of particles passing through slots width-wise for each fraction is determined and flakiness index calculated as sum total expressed as percentage of total weight. The remaining non-flaky stone aggregates are then checked length-wise and elongated particles separated. The elongation index is the sum total weight of particles retained on slots length-wise in each fraction divided by the total weight of non-flaky stone aggregates.

(6) Field CBR (IS:2720, Pt. XXXI)

The method consists of preparing the surface on which the test is to be carried out, applying the load gradually and noting down the penetration values. To reproduce the actual surface conditions, it may be necessary to soak the surface to be tested to the desired degree.

Truck, tractor, truss or any other suitable equipment is used for providing reaction for loading. A mechanical screw loading jack with swivel head is used for applying the load to the penetration piston. For loading, the procedure is more or less same as for Laboratory CBR determination.

(7) In-situ Density by Sand Replacement Method (IS:2720, Pt. XXVIII)

The principle of the method is to find the volume of a hole cut in the layer to be tested by filling it up with sand of known density. Moisture content of the soil sample is determined to work out the dry density.

A hole roughly 10 cm dia and 15 cm deep is made and the excavated soil is carefully collected and weighed. Sand pouring cylinder is placed on the hole and the sand allowed to run to fill up the hole.

(8) Aggregate Impact Value (IS:2386, Part IV)

The apparatus consists of a metal base and a cylindrical steel cup of internal dia. 10.2 cm and depth 5 cm in which the aggregate specimen is placed. Metal hammer 13.5 - 14 kg weight having a free fall from a height of 38 cm is arranged to drop through vertical guides. Aggregate sample passing 12.5 mm sieve and retained on 10 mm sieve is filled in the steel cup in three layers by tamping each layer with 25 blows. After subjecting the test specimen to 15 blows, the crushed aggregate is sieved through 2.36 mm sieve. The aggregate impact value is expressed as the percentage of fines formed in terms of the total weight of the sample.

(9) Bitumen Penetration Test (IS:1203)

Test determines the hardness or softness of bitumen by measuring the depth in tenths of millimetre to which a standard loaded needle will penetrate vertically in 5 seconds. The sample is maintained at 25°C. The penetrometer consists of a needle assembly with a total weight of 100 grams and a device of releasing and locking it in any position.

(10) Marshall Stability Test (ASTM:D 1559)

This test is generally applicable for dense-graded hotmix asphalt mixes. The apparatus consists of a cylindrical mould of 10.16 cm dia. and 6.35 cm height with a base plate and collar. The specimen is compacted by a hammer of 4.54 kg weight and having a free fall of 45.7 cm. Seventy five blows of the hammer are given on each face of the specimen for compaction.

The specimen is tested by applying a load on its peripherry perpendicular to its axis in a loading machine of 5 tonne capacity at the rate of 5 cm per minute. The flow value is measured as deformation in units of 0.25 mm. The test is carried out when the specimen is at a temperature of 60°C. The stability value is the maximum load taken by specimen, and the flow value is the deformation at this load.

(11) Stripping Value (IS:6241)

200 grams of aggregate passing 20 mm sieve and retained on 12.5 mm sieve is mixed with 5 per cent binder by weight heated to 160°C. The aggregates are also heated to 150°C prior to mixing. After complete coating, the mixture is transferred to 500 ml beaker and allowed to cool at room temperature. Distilled water is added to immerse the coated aggregates. The beaker is covered and kept at 40°C. After expiry of 24 hours, it is cooled to room temperature and the extant of stripping is estimated visually while the specimen is still under water.

(12) Tray Test for Control of Rate of Spread of Binder (IRC:SP:11)

Light metal trays of about 20 cm × 20 cm and 3 cm deep, previously weighed and numbered are placed at intervals along the road in the path of the binder distributor. After passing of the distributor, the trays are removed to find out the rate of spread of binder. Tests with such trays at a number of locations can also indicate the uniformity of distribution.

(13) Tray Test Rate of Spread of Grit in Surface Dressing (IRC:SP:11)

The principle is similar to that of finding the rate of spread of binder mentioned at (12) above.

(14) Binder Content of Paving Mixtures by Centrifuge (IRC:SP:11)

A representative sample of about 500 grams is exactly weighed and placed in the bowl of the extraction apparatus and covered with commercial grade benzene. The mixture is allowed to stand for about one hour before starting the centrifuge. The machine is revolved at speeds upto a maximum of 3,600 rpm. The speed is maintained till the solvent ceases to flow from the drain. The machine is allowed to stop and another 200 ml of the benzene is added and the procedure is repeated. The filter ring from the bowl is removed, dried in air and then in oven to constant weight at 115°C and weighed.

(15) Checking Surface Regularity Using a Straight-Edge (IRC:SP:11)

The test is made with 3-metre straight-edge made of steel or seasoned hard wood. If made of wood, the test face should be shod with a metallic plate. The wedge should preferably be metallic but may be of seasoned hard wood. It should be graduated to read undulations upto 25 mm with a least count of 3 mm.

For recording undulations in the longitudinal profile, the straight-edge is placed parallel to the centre line of the road and the wedge inserted where the gap is maximum and the reading taken. The straight-edge is then slided forward by about half the length and the wedge reading repeated.

(16) Water Sensitivity of Bituminous Mixes (ASTM D1075-88)

At least six test specimen of 4 inches in diametre by 4 inches in height (or 101.6 mm × 101.6 mm) are made as per the standard procedure. Each set of six test specimens are sorted into two groups of three specimens each so that the average bulk specific gravity of the specimen in Group 1 is essentially the same as per Group 2.

Group 1 - The test specimens are brought to the test temperature of 77 ± 1.8°F (or 25 ± 1°C) by storing them in air bath maintained at the test temperature for not less than 4 hours and the compressive strengths are determined as per standard procedure.

Group 2 - The test specimen are immersed into water for four days at 120 ± 1.8°F (or 49 ± 1°C). After four days these are transferred to the second water bath maintained at 77 ± 1.8°F (or 25 ± 1°C) and stored there for 2 hours. Thereafter, the compressive strengths of the specimen are determined as per the standard procedure.

The numerical index of resistance of bituminous mixtures to the deterimental effect of water is then calculated as percentage of original strength that is retained after immersion period as below :

$$\text{Index of retained strength } \% = \frac{S_2}{S_1} \times 100$$

Where
S_1 = Compressive strength of immersed specimen (Group 2)
S_2 = Compressive strength of dry specimen (Group 1)

(17) Sand Equivalent Test (IS:2720, Part XXXVII)

Sand equivalent may be defined as a measure of silt or clay contamination in fine aggregate as determined by test. The test provides a rapid field method for determining qualitative changes in the aggregates during production or placement.

A measured quantity of clean fine aggregate passing 4.75 mm IS sieve is poured in a graduated acrylic plastic cylinder of 32 mm inside diametre and 430 mm height. A siphon assembly fitted in 4 litres bottle of working sodium chloride solution is placed 915 ± 25 mm above the work surface. A quantity of 100 ± 2 mm of working calcium chloride solution is siphoned into the graduated cylinder followed by tapping of the cylinder on palm of the hand for expulsion of air bubbles. The specimen is then irrigated with irrigator tube for flushing fines upwards untill the final level in the cylinder stands at 380 mm. Stabbing and twisting with irrigator tube is continuously done to ensure that the clay-like-material is forced into suspension above the sand. After the prescribed sedimentation period of 20 minutes the height of flocculated clay is read and height of sand in the cylinder is determined. Sand equivalent is calculated as follow:

$$SE = \frac{Sr}{Cr} \times 100$$

Where
SE = Sand Equivalent
Sr = Sand reading
Cr = Clay reading

Note : Certain precautions are necessary for the test which may be followed to arrive at reliable results.

(18) Soundness Test (IS:2386, Part-V)

Clean, dry aggregates are sieved through a set of sieve and separated into different sizes. Each fraction is weighed and immersed in the saturated solution of sodium sulphate or magnesium sulphate for 16 to 18 hours, and thereafter dried in an oven at 105-110^{0}C to a constant weight, thus making one cycle of immersion and drying. The test is repeated on each fraction for specified number of cycles. After completing the last cycle, the sample is dried and each fraction of the aggregate is examined visually to see if there is any evidence of excessive splitting, crumbling or disintegration of the grains. Each fraction is sieved through specified sieve size and percentage of sample passing through the sieve is recorded as a loss. The weighted average loss is then calculated as prescribed.

(19) Los Angeles Abrasion Test (IS:2386, Part-IV)

This test is for measuring abrasion resistance of aggregates. Apparatus consists of a circular drum of internal diametre of 700 mm and length 500 mm mounted on horizontal axis. An abrasive charge consisting of cast iron spherical balls of 48 mm dia (weight 390-445 gm) which is placed in the drum along with the aggregates (weight 5-10 kg). The drum is rotated with a speed of 30-33 R.P.M. for 500-1000 revolutions, depending upon the gradation of the material. After specified revolutions, the material passing through 1.7 mm sieve (fines) is separated. The weight of fines expressed as percentage of the total weight of the sample is the Los Angeles Abrasion value.

(20) Swell Test

Two specimen are prepared using the estimated optimum bitumen content. The specimen are compacted at 110^{0}C using a kneading Compactor, with a circular ram the pressure of which increases without impact and maintained for about 0.4 seconds and then released.

The compacted specimen is allowed to stand at room temperature for at least one hour to permit rebound after compaction before it is subjected to Swell Test. For the test the mould together with a specimen is placed in 190 mm diametre × 64 mm deep aluminium pan with perforated bronze disc on the specimen. Then a triped fitted with dial gauge assembly is attached to the bronze disc to give reading of 2.54 mm on the dial gauge. This is followed by addition of 500 ml of water on the top of the specimen and the distance from the top of mould to the surface of water is measured. After twenty-four hours the dual gauge is again read nearest to 0.025 mm and the change in the reading is recorded as well. Also, the distance from top of the mould to surface of water is measured with the graduated scale and the change recorded as permeability or amount of water in millilitres that percolates into the test specimen.

(21) Water Absorption Test (IS:2386, Part III)

A sample of stone aggregate of weight not less than 2000 gm is placed in wire basket and immersed in distilled water at a temperature between 22°C and 32°C with a cover of at least 5 cm above the top of the basket. Immediately, after immersion the entrapped air is removed and the sample is kept immersed in water for 24 + ½ hours. The basket containing the sample is weighed in water (Weight A_1). Thereafter, the basket is emptied and weighed in water (Weight A_2). The aggregate are then surface dried and weighed in air (Weight B). Now the aggregates are oven dried and cooled, and weighed (Weight C) in air.

Specific gravity = C/(B-A)

Apparent specific gravity = C/(C-A)

$$\text{Water Absorption} = \frac{100\ (B-C)}{C}$$

Where,

A = Weight in gm of saturated aggregate in water (A_1-A_2)

B = Weight in gm of saturated aggregate in air

C = Weight in gm of oven-dried aggregate in air

(22) Determination of Polished Stone Value (BS:812, Part 114-1989)

The polished stone value (PSV) gives a measure of resistance of road stone to the polishing action of vehicles under conditions similar to those occurring on the surface of a road.

The test for determination of polished stone value is done in two parts. In the first part, samples of stone are subjected to accelerated polishing. In the second part, the state of polish reached is measured by means of a friction test.

Accelerator Polishig Machine consists of wheel referred to as 'Road Wheel' having a flat periphery and of such a size and shape as to permit 14 specimens to be clamped on the periphery so as to form a continuous cylindrical surface of stone particle of 45 mm width and 406 mm outer diameter. Each specimen consist of single layer of closely spaced stones set-in sand cement mortar covering an area of 90.5 × 44.5 mm.

The road wheel is rotated at a speed of 320+5 revolutions per minute. Two solid rubber tyred wheels of 200 mm diameter and with a width of 38 mm are brought to bear on the road wheel with a total force of 725 + 10 N. Corn emery is fed at rate of 27 + 7 g/min continuously with water on the road wheel for a period of 3h ± 1 minute. The tests are interrupted at 1 hour ± 5 minutes and 2h ± 5 minutes to clean any excess corn emery which has collected in the base.

After removing, the specimens are washed under water at 18^{0}C to 22^{0}C for 30 minutes. The polishing stone value is thereafter tested by machine consisting of Rubber sliding shoe mounted at the end of pendulum. The slider when released brushes past the specimen and comes to halt. The scale on the machine directly measures, PSV.

14. MAINTENANCE

14. MAINTENANCE

14.1. General

Maintenance of a road network involves a variety of operations from planning, programming and scheduling to actual implementation in the field and monitoring. Whatever be the approach of system adopted, the essential objective should be to keep the road surface and appurtenances in good condition, and to extend the life of the road asset to the maximum extent possible. Broadly, the activities include identification of defects and the possible causes thereof, determination of appropriate remedial measures, implementation of these in the field and monitoring of the results. This will involve several sub-systems of identification, evaluation, planning, scheduling, management of man, materials and equipments, reporting and performance evaluation.

14.2. Basic Maintenance Objectives

The basic objectives of maintenance function are to maintain and operate the highway system in a manner such that :

a) Comfort, convenience and safety are afforded to the public;

b) The investment in roads, bridges and appurtenances is preserved;

c) The aesthetics and compatibility of highway system with the environment is preserved; and

d) The necessary expenditure of resources is accomplished with continuing emphasis on economy.

14.3. Classification of Maintenance Activities

The maintenance activities can be broadly classified under the following three sub-heads :

14.3.1. **Ordinary repairs/routine maintenance :** The ordinary repairs include the following nature of work :

i) Upkeep of road pavements and side shoulders;

ii) Upkeep of roadside drain system;

iii) Upkeep of culverts and bridges, and earth retaining structures and parapets;

iv) Keeping the sign boards, km stones and other traffic aids and furniture in good shape and condition;

v) Maintenance of roadside arboriculture; and

vi) Upkeep and maintenance of rest houses, inspection bungalows and gang huts.

14.3.2. **Periodic maintenance :** It covers periodic renewals to the carriageway whether it is gravelled road, metalled road or blacktopped road to ensure the adequate level of serviceability is maintained.

14.3.3. **Special repairs and flood damage repairs :** This include the details of urgent repairs not covered under ordinary repairs/periodic maintenance.

14.4. Planning of Maintenance Activities

14.4.1. **Inventory of road :** The first step to planning of maintenance operation is the evaluation of the existing road in terms of its physical condition, structural capacity and surface profile (roughnes), etc. For this purpose, basic broad inventory containing all details of the existing highway should be available. The following data are required to have a complete inventory :

i) District map on the scale of 1:50,000;

ii) Strip maps of particular section of the road; and

iii) Surface history of the road.

14.4.2. **Condition survey :** When all the inventory data of the road are available, condition survey can be carried out :

a) By visual inspection; and

b) By mechanical evaluation

The minimum frequency of inspection for condition surveys is suggested in Table 14.1.

Table 14.1. Suggested minimum frequency of inspection for condition survey

Type of road	E.E.		A.E./A.E.E.		Section I/C	
	Routine	Special	Routine	Special	Routine	Special
NH & SH	Twice in a year (April & October)	Before and after mon-soons	Once in two mon-ths Jan., March, May, July, Sept., Nov. & Dec.	Before and after mon-soons Twice during rains	Once a month	Every week

The inspection should be carried out not only to check the condition of works but also for planning future strategies. While carrying out inspection, the check list of items given in para 14.4.2.1. should be kept in mind.

14.4.2.1. Check list of items required to be inspected during inspection for maintenance of roads : Assistant Engineers and Junior/ Sub-Engineer while going on inspection on roads in their jurisdiction should examine the points mentioned below :

a) Safety aspects :

i) Safety precautions for blockade and breaches taken ;

ii) Deep cuts on roads ;

iii) Damaged culvert/bridge ;

iv) Branches of trees at less height ;

v) Power line crossings provided with guard cradles as per IRC:32 ;

vi) Vertical clearances for power lines should be as per IRC:32 ;

vii) Horizontal clearances for poles carrying power and telecommunication lines as per IRC:32 ;

viii) Berms not lower than 25 mm for carriageway; and

ix) For new plantation only, the horizontal clearances to be kept as minimum 5 m wherever possible.

b) Carriageway and crust conditions :

i) Location magnitude of potholes and patches;

ii) Condition of edges;

iii) Magnitude and location of undulations; and

iv) Location of crust failure, along with their causes.

c) Berms (shoulders) :

i) Width of berms is adequate or not as per PWD specifications;

ii) Cross slope kept as 3 to 5 per cent;

iii) Side slopes;

iv) Berms properly dressed; and

v) If turning exists, whether it is properly cut or not.

d) Road drainage :

i) Cross-sectional area of drains adequate or not;

ii) To check if the drains are blocked or damaged; and

iii) Whether proper disposal is provided to the drains.

e) Road fixture :

i) Km stone, 5th km stone, 200 m stones and boundary stones exist in proper condition;

ii) Traffic signs correctly located and maintained;

iii) Location and condition of berms on curves and high embankments;

iv) Painting and numbering of culverts required; and

v) History of the road mentioned on km stones.

f) Road protection works :

i) Retaining walls and pitchings on slopes properly maintained or not;

ii) Condition of drains, spouts and weep holes in retaining walls and in pitching on slopes; and

iii) Condition of parapet walls on culverts, etc.

g) Roadside trees :

i) Check in numbering of trees done or nots

ii) Disposal of dead trees; and

iii) Register of trees maintained

h) Road Geometrics

i) Horizontal curves laid out properly or not;

ii) Extra width on curves conforms to IRC:38;

iii) Sight distances conform to IRC standards;

iv) Vertical curves properly laid out or not; and

v) Rulling gradients conform to IRC standards.

14.4.3. Field procedure for inspection and planning maintenance works

14.4.3.1. **General :** Each road should be divided in sections of 5 km and each km should be further sub-divided into 200 metre stretches for inspection purposes. All roads must invariably be inspected immediately before and after rains in addition to routine inspections.

The extent of defects should be marked in bar lines extending over lengths which they occur and the severity of the defect may be marked in colours as detailed below in accordance with the maintenance criteria as given in para 14.5.

1.	Severe	Requiring urgent action-in red
2.	Less severes	Requiring special attention-in dotted red
3.	Defect	Requiring recurrent action-in blue
4.	Ordinary	In dotted blue

Recording must be both accurate and legible. Reaches in 30 metre length should be measured correct to the nearest metre and width to the nearest 0.1 metre.

The numerical figures indicating numbers, length, area, etc. of the defects should be indicated over the bar lines in the ink. The recording is to be done in the inspection card.

The list of the instruments and equipments required for inpection work is as follows :

1.	Tape measuring 30 mts., steel	1 No.
2.	Tape measuring 15 mts., steel	1 No.
3.	Steel tape, 3 mts.	1 No.
4.	Spirit level with straight edge and camber templates with graduated wedge	1 No.
5.	One metre square light-weight portable, frame	1 No.
6.	Printed inspection forms	1 No.
7.	Clip board and ball point pen	
8.	Colour pencils, sketch pencil	
9.	Warning signs	2 No.
10.	Maps of the area	
11.	Maintenance Manual	

14.4.3.2. **Methods of assessment**

Visual assessments : Most of the assessments should be done with careful observations. However, instruments are to be used for purposes of accuracy.

Side drains and turn outs : Side drains should be maintained at least one metre below the formation level. The depth and cross-section should be checked and measured at least 200 m intervals.

Corrugations : They can be measured with a straight edge and measuring wedge at 200 m intervals along the roads. The mean of the reading at each 200 m is to be recorded. The readings are to be at closer intervals, say 50 m, whereby visual inpection, it is noted that the surface is highly corrugated.

Rutting : The depth of rut is to be measured by keeping the straight edge placing transversely across the wheel tracks and using graduated measuring wedge. The mean value for the wheel tracks to be worked out.

Potholes : The area covering majority of potholes should be measured along with number in every 200 metreage. The percentage area is to be worked out.

Camber and cross-fall : It should be checked with a camber templates on both sides of the centre line.

Loss of materials : The thickness of the W.B.M. layer should be checked at 15 m intervals to assess the loss of material. The measurements should be done at least at three places across the road.

Cracking : The light weight portable frame of 1 m x 1 m size should be planned and type and extent of cracking should be assessed visually at 200 m intervals or the places of defects whichever is less.

14.5. Maintenance Activities

Once the inspection of the road for condition survey has been carried out the activities to be carried out for proper maintenance of road are required to be fixed.

14.5.1. **Maintenance criteria :** Guidance regarding assignment of priorities is given in Table 14.2. which also indicates the priorities for various operation.

Table 14.2. Maintenance criteria

	Feature	Criteria	Action	Priority
A.	**Features concerned with safety of traffic**			
A-1	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 listed in Cl. 12.7	Urgent
A-2	Minor cuts, ruts or blockades	Cuts or blockades which do not completely obstruct the traffic but endanger safety of traffic	Get blockades removed and get the cuts repaired	Urgent

A-3	Branches of trees at height less than 4.5 m over the roadway	Any kind	Get them cut in order of lower ones first	Special attent-ion
B.	**Carriageway and crust conditions**			
B-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 preferably with slurry seal or fog seal or as per Ministry's Specifications	Rout-ine
			b) Binder @ 1.5 kg/m^2 of bitu-men emulsion or 1 kg/m^2 of cut-back or local sealing	
		b) Cracking in large areas exceeding 25 per cent of the total area	c) Surface Dripping as per Ministry's specifications	Special atten-tion
B-2	Stripping	a) In local areas not exceeding 25 per cent of the total area	Apply local sealing	Rout-tine
		b) In long areas ex-ceeding 25 per cent of the total area	Apply sur-face dress-ing use antistripping compounds	Special atten-tion

B-3	Bleeding	a) In local areas not exceeding 25 per cent of the total area	Spread and roll over 6 mm size aggregate, heated to 60ºC	Rout-tine
		b) In local areas exceeding 25 per cent of total area	Apply sur-face dress-ing	Special atten-tion
B-4	Rutting	a) Less than 50 mm accompanied by cracking	Apply tack coat @ 0.5 kg/m^2 and fill bituminou. mix using a rake and leaving an excess thickness of about one-third the depth of rut. Compact till surface is levelled and local sealing of cracks.	Routine
		b) More than 50 mm accompanied by cracking	With surface dressing of over cracks overlay required	Work of ori-ginal nature
B-5	Potholes	Potholes, as soon as they occur	Local restor-ation by pat-ching prefer-able	Special atten-tion
B-6	Reflection cracks	a) Widely spaced cracks	Slurry for fog seal	Recu-rrent

		b) Closely spaced	Apply surface dressing use of geotextiles	Special attention
B-7	Edge subsidence and rutting	Any extent	Patch road edge and repair shoulder	Recurrent
B-8	Defective camber	Any extent	Check and correct by reconstructoning to proper camber profile	Special attention
B-9	Undulations	Any extent	Investigate the cause and rectify	Special attention
B-10	Loss of material from unpaved road	Any extent	Do regravelling	Special attention
C.	**Shoulders-side-drains**			
C-1	Deformation or scour of shoulders	Any extent	Fill and compact and bring its surface to desired camber	Routine
C-2	Silting of side-drains	Any extent	Clean out the drains	Routine
C-3	Damage or scouring of drain	Any extent	Reconstruct to adequate shape and size	Special attention

D.	**C.D. Works**			
D-1	Causeways			
	a) Potholes in paved surface	Any extent	Repair by filling	Special attention
	b) Erosion at inlet/outlet	Any extent	Repair	Special attention
	c) Guide posts/ flood guage missing	Any	Repairs/ Replace	Special attention
D-2	Culverts			
	a) Silting	Any	Desilting	Special attention
	b) Erosion at inlet/outlet	Any extent	Repairs	Special attention
	c) Settlement cracks	Any	Repairs	Special attention
E.	**Other Works**			
E-1	Road furniture and warning dirty or corroded or damaged missing	Any extent	Clean and repair/replace	Routine
E-2	Missing road sings	Any	Fix new one	Special attention

14.5.2. **Criteria for renewal :** Renewal cycle of bituminous surfacing depends on traffic density, rainfall and lane width. Guidelines for renewal cycle are given in Table 14.3.

Table 14.3. Renewal cycle

Class of road	Lane width	Traffic (commercial)	Type of renewal and periodicity of the renewal treatment for		
			Low rainfall upto 150 cm per year	Medium rainfall 150-300 cm per year	High rainfall above 300 cm per year
National Highways	Single	i) Less than 450	SD — 4	SD — 4	SD — 4
		ii) 450-1500	SD — 4	SD — 3	SD — 3
		iii) More than 1500	PC — 6	PC — 5	PC — 4
				or	
			MS — 8	MS — 7	MS — 6
	Double	i) Less than 450	SD — 5	SD — 4	SD — 4
		ii) 450-1500	SD — 4	SD — 3	SD — 3
		iii) More than 1500	PC — 6	PC — 5	PC — 4
				or	

	$\frac{MS}{8}$	$\frac{MS}{7}$	$\frac{MS}{6}$

Note : 1) SD - Single coat of surface dressing with 0.10 m^2 of chips and 11 kg of bitumen for 10 sq.m.

PC - 20 mm premix chipping carpet as per Ministry's Spacifications

MS -Mix seal surfacing as per Ministry's Specifications.

2) The denominator refers to the periodicity of renewal in years.

3) For areas subject to snowfall and hilly areas with steep side slopes and heavy rainfall, the periodicity of renewal may be at closer intervals.

4) The periodicity of the renewal indicated in the Table above should only be taken as a general guideline for the purpose of budgetting and determinig the extent of renewal programme. It does not indicate either the expected life of the particular type of treatment or the imperative need for renewals after the period indicated.

14.5.3. **Maintenance of bituminous pavements** : The details of various types of defects and their treatment are given in Table 14.4.

Table 14.4. Symptoms, causes and treatment of defects in bituminous surfacing

Type of distress		Symptoms	Probable causes	Possible types of treatment
A.	**Surface defects**			
1.	Fatty surface	Collection of binder on the surface	Excessive binder in premix, sp-	Sand blinding ; open-graded pre-mix; liquid seal

			ray or tack coat, loss of cover to aggregates; excessively heavy axle loads	coat; burning of excess binder; removal of affected area
2.	Smooth surface	Slippery	Polishing of aggregates under traffic 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.	Hairline cracks	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.
2.	Alligator cracks	Interconnected cracks forming a series of small blocks	Weak pavement, unstable conditions of subgrade or lower layers, excessive over loads or brittleness of binder	Where the pavement is structurally sound, the cracks should be filled with a low viscosity

3.	Logitud- inal cracks	Crack on a straight line along the road	Poor drainage shoulder settlement, weak joint between adjoining spreads of pavement layers or differential frost heave	binder or a slurry seal or fog seal depending upon the width of cracks. Unsound cracked pavements will need
4.	Edge crack	Crack near and parallel to pave- ment edge	Lack of support from shoulder, poor drainage, frost heave, or inadeqaute pavement width	strengthening or rehabilitiation treatment
5.	Shrink- age cracks	Cracks in transverse direction or inter- connected cracks forming a series of large blocks	Shrinkage of bituminous layer with age	
6.	Reflect- ion cr- acks	Sympethetic cracks over joints and cr- acks in the pavem- ent underneath	Due to joints and cracks in the pavement layer underneath	
C.	**Deformation**			
1.	Slippage	Formation of crescent-shaped cracks pointing in the direction of the thrust of wheels	Usual thrust of wheel 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	Logitudinal depressional in the wheel tracks	Heavy channalised 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 mix, oscillations set up by vehicles, springs, or faulty laying of surface course	Scarification and relaying of surfacings, of cutting of high spots and filling of low spots
4.	Shoving	Localised bulging of pavement surface along the crescent-shaped cracks	Unstable mix, lack of bond between layers, or stop type movements and those involving negotiation of curves and gradients	Removing the material to firm base and relaying a stable mix
5.	Shallow depressions	Localised shallow depressions	Presence of inadequately compacted pockets	Filling with premix materials
6.	Settlement and upheaval	Large deformation of pavement	Poor compaction of fills, poor drainage, inadequate	Where fill is weaks the defective fill should be

			pavement or frost heave	excavation and re-done. 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 binder and aggregate, 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
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 deal, fog seal, or slurry seal depending on the extent of damage
3.	Ravelling	Failure of binder to hold the aggregate shown up by	Poor compaction, poor bond between	Application of cutback covered with coarse sand,

		pock marks or eroded areas on the surface	binder and or aggregate insufficient binder, brittleness of binder, etc.	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 breaker of pavement edges	Water infiltration poor lateral support from shoulders, inadequate strength of pavement edges, etc.	Cutting the affected area to regular sections and re-building with simultaneous attention paid to the proper construction of shoulders

14.6. Execution Schedule and Methods

14.6.1. **Annual calendar of road maintenance activities :** Reccommended practice for road maintenance activity is given in Table 14.5.

14.6.2. **Maintenance methods :** Table 14.6. gives an indication of the range of maintenance methods potentially appropriate for use in India.

14.6.3. **Output of workman :** To get the desired output from labour, clear-cut directions should be given and tasks to be performed, identified and fixed. Recommended norms for road gangs are given in para 14.6.4. Also, proper tools and plants having multi-purpose use, increase efficiencies of the labour. A list of such tools to be kept with each gangman is given in the Table 14.7.

Table 14.5. Annual calendar of road maintenance activities

Sl. No.	Items	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Remarks
1.	Repairs of road berms including jungle clearance	x	x	x	–	–	–	x	x	x	–	–	–	
2.	Repairs to side drains	–	–	–	–	x	x	x	x	x	–	–	–	
3.	Collection of patch repairs material for WBM roads	–	–	–	–	x	x	–	x	x	–	–	–	
4.	Collection of patch repairs matrial for WBM roads	x	x	x	–	–	–	–	x	x	x	–	–	
5.	Patch repairs work for WBM roads	–	–	–	–	x	x	–	x	–	–	–	–	

6. Patch repair work for B/T roads	–	–	–	–	x	x	–	x	x	x	–	–
7. Repairs to sign and caution boards	–	–	–	–	–	–	–	–	x	x	x	–
8. Painting of km all round the year stone and road markings	–	–	–	–	–	–	–	–	x	x	x	–
9. Maintenance of T&P												
10. Removal of encroachment						- do -						

[x]This shows the recommended period for activity in North India

Table 14.6. Spectrum of maintenance methods appropriate for use in India

Activity/ task	Labour Based Methods	Inter- mediate	Equipment Based Methods
1. Excavation of soils and rock	Soft soil Firm soil Hard soil Soft soil Medium rock	Phowrah* " Pick axe*** Crowbar "	Dozer for short leads slips Dozer tipper**
	Hard rock for leads of	Hand drilling and blasting****	Compressed air/drill blasting

2.	Loading handling unloading	0-50 m 50-100 m 100-200 m	Phowrah animal carts	Phowrah wheel barrow	Phowrah animal carts	Power winch wheel barrow	Dozer wheel loader
3.	Heating and mixing bitumen	Heat chipping**** and bitumen over open wood fire, mixed by rake		Heat bitumen in tar** boiler, heat chippings and mix with bitumen in small or medium sized mechanical mixer		Integrated hot mix plant*	
4.	Hauling and laying bitumen mix	Haul by head load or by a bamboo stretcher, lay by rake		Haul by wheel barrow, lay by hand propelled screed board		Tipper and paver	
5.	Laying surface dressing	Bitumen through**** containers with holes, chips from baskets		Bitumen through hand lancess** chips from basket		Chip spreader and* bitumen distributor	
6.	Compaction of base material	Durmats****		Hand held mechanical*** rammers		Vibrating compactors* Rollers**	

* Excellent ** Good *** Average **** Poor

14.6.4. **Recommended norms for tasks for road gangs :**

1. Earthwork such as, in berms, desilting of drains, etc.
   - a) Ordinary soil — 2.5 cum/person/day
   - b) Hard soil — 1.75 cum/person/day
2. Dressing of berms — 75 sqm/person/day
3. Jungle clearance — 100 sqm/person/day

Table 14.7. Tools for gangman
(One gang for 20 m beat having 5 gang men and one mate)

Road Work	Essential (with gangs)	Option with Section In-charge
1. Spades	3 Nos.	
2. Pan (parat)	3 Nos.	
3. Pick axes	2 No.	
4. Axe	1 No.	
5. Hand-cart with solid rubber tyres	1 No.	
a) Wooden-5 kg to 10 kg weight	1 No.	
b) Iron-10 to 15 kg weight	1 No.	
6. Tar sprinklers (Jharas)		1 No.
7. Tar buckets		1 No.
8. Tar kettle or tar boiler (mm)		1 No.
9. Brushes :		
a) Wire brushes	5 Nos.	
b) Coir brushes	5 Nos.	
c) Hair brushes	5 Nos.	
10. Hammer	1 No.	
11. Rope	12 mm	1 No.
	6 mm	1 No.
12. Cross slope template for berms with original level (camber 3 per cent)	1 No.	
13. Tar thermometre		4 Nos.
14. Spring balance		1 No.
15. Tape 15 m	1 No.	
16. Measuring wooden boxes (15 cm × 25 cm × 40 cm)		2 Nos.
17. G.F. bucket	1 No.	
18. Straight edge		1 No.
19. Caution board		2 Nos.
20. Goggles for dust protection (for desert areas)		10 Nos.

4.	Patches by	
	a) Surfacing painting	0.2 cum/person/day
	b) Premix carpet	0.75 cum/person/day
5.	W.B.M. patches	0.30 cum/person/day
6.	Blinding of WBM surface	150 sqm/person/day
7.	Edge covering	60 metre/person/day
8.	Other items as per norms worked out from BSR of that area.	

Note : The quantity mentioned is that of grit and ballast used for patch repairs.

14.7. Arrangements when Traffic is Suspended on Section of Highway because of Breach/Damage

14.7.1. Arrangements when traffic is suspended on a section of a National Highway because of flood breach or damage caused due to certain other reasons are as follows :

i) 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 intersection, 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 120 metres away. In addition, a prominent road close 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 traffic. 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 availed of to notify the public about road closure, and alternative routing for the through traffic.

ii) 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 120 m further away. These should be supplemented by a "road closed" sign affixed to the barrier in a prominent position word messages on the sign may be in more than one language as dictated by needs of the road users.

iii) The barricades should be protected by red warning lamps at night which should stay lit from sun-set to sun-rise. In addition, alternative black and white diagonal strips should be marked on these for effective advance warning, preferably reflectorised paint should be used for this purpose.

iv) 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 officer 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 tar drums which should be removed only for permitting the construction vehicles to pass each time and put back in position immediately thereafter.

v) Signs, lights, barriers and other traffic control devices should be kept maintained in a satisfactory condition till such time that the traffic is restored and allowed to follow its normal path.

14.7.2. Action to be taken in case the road is breached or blocked at various levels are indicated below.

14.7.2.1. **Action to be taken by the mate :** The following actions will be taken by the mate :

a) Immediate report of the road breach/blockade will be made to Sub/Junior Engineer and Assistant Engineer. The following points will be included in the reports :
   i) Name of the road
   ii) Location of the breach/blockade
   iii) Length and nature of the breach/blockade
   iv) Date and time of occurrence
   v) Assessment of the assistance in the form of men and material required.

b) "Road closed" boards and "Diversion" boards shall be fixed on both sides at 120 m distance in advance of the hazard in case of N.H. & S.H. (In case of MDRs and ODRs this distance will be 90 m and 60 m respectively).

c) Arrangements for red lights to be done in case of darkness.

d) Beldars will be deployed to guide the traffic to prevent any accident.

e) Construction of diversion, if possible.

14.7.2.2. **Action to be taken by engineering subordinate :** The engineering subordinate in-charge of the road will take the following actions at once :

a) He will at once visit the site of the hazard and shall ensure that :
   i) Road has been closed by means of barricading with empty drums or kachha wall or by any other means available at the site.
   ii) That caution and diversion boards have been fixed on both the sides.
   iii) Arrangements made to guide the traffic by posting gangmen having red flags.
   iv) Arrangements made for red light and chowkidars, etc.

v) Steps to stop further damages to the road are taken as per site requirements.

vi) Possiblities of construction of diversion to be explored. If possible, the diversion should be constructed with available resources.

b) He will immediately report to the Assistant Engineer, Executive Engineer and Superintending Engineer telegraphically regarding the road breach, duration of blockade of the traffic followed by a detailed report containing :

i) Name of the road
ii) Location of the breach/blockade
iii) Length and average depth of the breach
iv) Duration of suspension of the traffic
v) Date and time of occurrence
vi) Requirement of men and material for restoration of traffic and road and the approximate cost

c) All-out arrangements and efforts shall be made for restoration of traffic.

d) He will intimate the details of any looser and injuries to the public, if any including the extent of compensation if payable.

14.7.2.3. **Action to be taken by the Assistant Engineer :** The Assistant Engineer will take the following actions in case of an emergency of road breach, etc.:

a) He will at once inspect the site of the hazard.

b) He will inspect all safety measures taken by the engineering subordinate.

c) He will ensure that the restoration of traffic is done at the earliest.

d) He will send a detailed report regarding the breach/ blockade enumerating all the points given under para 14.7.2.2.

e) In addition to these he will also include the following points :
   i) The causes of the breach/blockade
   ii) Forecast estimate for restoration traffic and road
   iii) Remedial measures to avoid any future occurrence with forecast estimates
   iv) Any other information which he wants to include.

Maintenance

14.7.2.4. **Action to be taken by the Executive Engineer :** The Executive Engineer will take the following actions in case of an emergency of a road breach of similar blockade:

a) He will at once visit the site of breach. In case of more than one occurrences, he will inspect them in order of priority and importance.
b) He will ensure speedy restoration of traffic.
c) He will send a detailed report about the road damage indicating:
   i) Nature and cause of damage with locations
   ii) Proposals for remedial measures with financial implication.
   iii) Nature and course of consequential damages to public properties, etc.
   iv) Action taken for restoration of traffic and restoration of damages with financial implications.

d) He will be fully responsible for all the actions taken for the protection and safety of traffic and road.

Cement Concrete Pavements

Cement Concrete Pavements, if constructed properly, require very limited maintenance during their service period. Necessity for repairs to concrete pavements arise construction or as a result of subsequent damage or deterioration. If concrete pavements are constructed with necessary quality controls they will require only maintenance at joints where oxidised joint fillers and sealants have to be periodically replaced by new materials.

Resealing of Joints and Cracks

Joint sealing compounds deteriorate with the age and are likely to be plucked out of the joint. Foreign matter may also be forced into the joints. To allow movement at the joint and also to prevent ingress of moisture it is necessary that the joint should be cleaned periodically to a depth of atleast 25 mm and refilled with fresh sealent. The procedure given below may be followed:

1) Removal of existing sealant by ploughing with a rectangular shaped tooth.

2) Reconstructing the defective joint where spalling is serious.

3) Resurfacing the joint or crack side walls with diamond saw blades to provide adequate width.

4) Cleaning the newly sawed walls with water followed by drying and sand blasting, etc.

5) Placing high quality sealant.

Filling Voids and Restoring Slab Support

The technique is required to fill small voids that develope beneath the slab due to pumping. This is achieved by drilling slab of grout injection holes and applying pumping pressure. The following sequence of operations is followed :

1. Select only those joints and cracks that exhibit loss of support (void)

Locations of loss of support are identified with visual surveys, deflection measurements using Falling Weight Deflectometre, Bankelman Beam and Road Rate ground penetrating radar, etc.

2. Select proper under sealing material

The material must be capable of penetrating very thick voids and must have sufficient strength and durability to resist loading, moisture and temperature effects, e.g., asphalt cements, pozzolanic cement grouts and lime stone dust cement grouts, etc.

3. Careful and Controlled Resealing

a) Slab lift must be closely controlled to avoid overgrouting which may result in premature slab break.

b) Down force exerted during the drilling of grout injection holes must be controlled to avoid causing deterioration or spalling.

c) Pumping pressure must be limited to avoid damage to the pavement from excessive slab lift.

d) All joints must be properly sealed and sub-drains placed to get rid of moisture.

Spall Repairs

Timely intervention for repairs of any structure is always beneficial. This is also true to cement concrete pavement which, if repaired early, are not only economical in respect of remedial measures but also affect speedy operation, i.e., time available for closing the road to traffic is reduced.

Partial depth repairs are undertaken to extend life of concrete. If properly done with durable materials these repairs can perform satisfactorily for some years. When slab deterioration is located primarily in the upper third of the slab and where load transfer devices are still functional they can be more cost effective than full depth repairs.

Partial depth repairs consist of removal of small and shallow areas of deteriorated concrete, dressing manually with a chisel and hammer to form regular geometrical shape with sides parallel and perpendicular to the joints in the concrete pavement and thereafter filling the recess with suitable material of comparable strength and finishing the same smoothly with the existing pavement slab. The repair material should be bonded with the existing sound concrete and become intergral part of the concrete slab. When overlay is required to be laid on cement concrete pavement, it is essential to complete such repairs first or otherwise reflection cracking may result causing premature failure of the overlay.

Repair Materials

Different materials used for repairs of cement concrete pavements are briefly discussed below:

Portland Cement Mixes

Repairs with ordinary cement are possible but long curing period is inhibiting factor as in most projects the road is required to be opened to traffic within a few hours.

Bituminous Mixes

Sometimes bituminous mixes are used for repair of distress in concrete pavements. This provides quicker process of repairs. But this can only serve as a temporary measure as such repairs cannot be satisfactory.

Resin Mixes

Based on extensive studies carried out by CRRI, IRC brought out IRC:77 "Tentative Guidelines for Repair of Concrete Pavements Using Synthetic Resins".

Many resin systems of varying properties are available in each of the two broad resin groups, viz., epoxy and polyester. Therefore, for a particular application the resin system should be selected with due consideration of the factors affecting the choice. The factors are location, climate ambient temperature, type of repair, bond and its durability.

Synthetic resin are multiple component systems, comprising main resin compound and its curing agents, which are required to be kept tightly closed separately and retain their properties for certain period. This period which represents the useful storage life of the resin known as "Shelf Life". The resin is used after mixing the components together. The period upto which a resin formulation is usable after inter mixing of components is called "Pot-life". The pot-life of synthetic resin is 30-45 minutes and is adversely affected by increase in ambient temperature .

For repairs during hot weather, the resin components should be kept in shade and adequate fire protection measures should be taken during mixing and placing operations.

Sulphur Sand Mixes

Sulphur sand mix can also be used for quick repair of concrete slabs. For this purpose, sulphur is used in molten form. The surface to be repaired requires to be heated to 100-200^{0}C as "pot-life" of molten sulphur is only 15 minutes. Also, adequate safety precautions need to be taken as sulphur dioxide fumes formed due to the reaction of sulphur with oxygen of the atmosphere, are harmful.

15. CEMENT CONCRETE PAVEMENTS

15. CEMENT CONCRETE PAVEMENTS

15.1. **General**

15.1.1. This work shall be carried out as per specifications and in conformity with the lines, grades and cross-sections shown on the drawings. The design parameters, viz., thickness of pavement slab, grade of concrete, joint details, etc. shall be as stipulated in the drawings. The work shall include furnishing of all plant and equipment, materials and labour and performing all operations in connection with work, as approved by the Engineer.

15.2. **Materials**

15.2.1. The contractor has to obtain approval of the Engineer for source of materials atleast 45 days before commencement of work.

15.2.2. Any of the following types of cement capable of achieving the design strength may be used with prior approval of the Engineer:

- i) Ordinary Portland Cement, 33 Grade IS:269
- ii) Ordinary Portland Cement, 43 Grade IS:8112
- iii) Ordinary Portland Cement, 53 Grade IS:12269

Guidance may be taken from IS:SP:23, "Handbook for Concrete". Cement to be used may preferably be obtained in bulk form. If cement in paper bags are proposed to be used, no paper pieces should enter the concrete mix. Bulk cement should be stored in accordance with Clause 1014 of the Specifications of the Ministry.

15.2.3. Admixtures conforming to IS:6925 and IS:9103 shall be used to improve workability of the concrete or extension of setting time. If air entering admixture is used, the total quantity of air in air-entrained concrete as a percentage of volume of the mix shall be 5+1.5 per cent for 25 mm nominal size aggregate.

15.2.4. Aggregates for pavement concrete shall be natural material complying with IS:383 but with a Los Angeles Abrasion Test result not more than 35 per cent. The limits of deleterious materials shall not exceed the requirements set out in IS:383.

15.2.5. Coarse aggregate shall consist of clean, hard, strong, dense, non-porous and durable pieces of crushed stone or crushed gravel and shall be devoid of pieces of disintegrated stone, soft, flaky elongated very angular or splintery pieces. The maximum size of the coarse aggregate shall not exceed 25 mm for pavement concrete. Continuously, graded or gap graded aggregates may be used, depending on the grading of the fine aggregate. No aggregate which has water absorption more than 2 per cent shall be used in the concrete mix. The aggregates shall be tested for soundness in accordance with IS:2386 (Part 5).

15.2.6. The fine aggregate shall consist of clean natural sand or crushed stone sand or a combination of the two and shall conform to IS:383. Fine aggregate shall be free from soft particles, clay, shale, loam, cemented particles, mica and organic and other foreign matter. The fine aggregate shall not contain deleterious substances more than the following :

Clay	4.0 per cent
Coal and Lignite	1.0 per cent
Material passing IS sieve No. 75 micron	4.0 per cent

15.2.7. Dumping and stacking of aggregates shall be done in an approved manner.

15.2.8. Water used for mixing and curing of concrete shall be clean and free from injurious amount of oil, salt, acid, vegetable matter or other substances harmful to the finished concrete. It shall meet the requirements stipulated in IS:456.

15.2.9. Mild steel bars for dowels and tie bars shall conform to the requirements of IS:432, IS:1139 and IS:1786 as relevant. The dowel bars shall conform to Grade S 240 and tie bars to Grade S 415 of I.S.

15.3. Construction

15.3.1. Cement concrete shall be proportioned as per the mix design approved by the Engineer, cement content shall vary between 350 and 425 kg per cum. Batching and mixing should be done at a Central batching and mixing plant with automatic controls.

15.3.2. The workability of the concrete at the point of placing shall be adequate for the concrete to be fully compacted and finished without undue flow. The control of workability in the field shall be exercised by the slump test as per IS:1199. A slump value in the range of 30+15 mm is reasonable for paving works but this may be modified depending upon the site conditions.

15.3.3. If the sub-base on which concrete is to be laid is found damaged at some places or it has cracks wider than 10 mm, it shall be repaired with fine cement concrete or bituminous concrete before laying separation layer. Prior to laying of concrete it shall be ensured that the separation membrane made of impermeable plastic sheeting of 125 microns thick laid flat without creases is placed in position and the same is clean of dirt or other extraneous materials and free from any damage. Wherever overlap of plastic sheets is necessary, the same shall be atleast 300 mm.

15.3.4. The locations and type of joints shall be as shown in the drawing.

15.3.5. The location of the joints should be transfered accurately at the site and mechanical saw cutting of joints done as per stipulated dimensions. It should be ensured that the full required depth of cut is made from edge to edge of the pavement. Transverse and longitudinal joints in the pavement and sub-base shall be staggered so that they are not coincident vertically and are atleast 1m and 0.3 m apart respectively. Sawing of joints shall be carried out with diamond studded blades soon after the concrete has hardened to take the load of the sawing machine and personnel without damaging the texture of the pavement.

15.3.6. The contraction joints shall be cut as soon as the concrete has undergone initial hardening and is hard enough to take the load of joint sawing machine without causing damage to the slab.

15.3.7. The expansion joints shall consist of a joint filler board and dowel bars duly approved by the Engineer and as detailed in the drawings. The filler board shall be positioned vertically with the prefabricated joints assembled along the line of the joint with the prescribed tolerances and at such depth below the surface as will not impede the passage of the finishing straight edges or oscillating beams of the paving machines. The adjacent slabs shall be completely separated from each other by providing joint filler board. Space around the dowel bars, between the sub-base and the filler board shall be packed with a suitable compressible material to block the flow of cement slurry.

15.3.8. Transverse construction joints shall be placed whenever concreting is completed after a day's work or is suspended for more than 30 minutes. These joints shall be provided at the regular location of contraction joints using dowel bars. The joint shall be made butt type. At all the construction joints, steel bulk heads shall be used to retain the concrete while the surface is finished. The surface of the concrete laid subsequently shall conform to the grade and cross-sections of the previously laid pavement.

15.3.9. The longitudinal joints shall be saw cut as per details of the joints shown in the drawing. The groove may be cut after the final set of the concrete. Joints should be sawn to atleast 1/3 the depth of the slab + 5 mm as indicated in the drawing.

15.3.10. The dowel bar shall be supported on cradles/dowel chairs in pre-fabricated joint assemblies positioned prior to the construction of the slabs or mechanically inserted with vibration into the plastic concrete by a method which ensures correct placement of the bars besides full re-compaction of the concrete around the dowel bars. Dowel bars should be positioned at mid depth of the slab within a toerance of $\pm$ 20 mm, and centred equally about intended lines of the joint within a tolerance of $\pm$ 25 mm. They should be aligned parallel to the finished surface of the slab and to the centre line of the carriageway and to each other within specfied tolerance.

15.3.11. Dowel bars should be covered by a thin plastic sheath for at least two-thirds of the length from one end for dowel bars in contraction joints or half the length plus 50 mm for expansion joints. The sheath shall be tough, durable and of an average thickness not greater than 1.25 mm. The sheathed bar shall comply with the prescribed pull-out tests.

15.3.12. Tie bars in longitudinal joints should be deformed steeel bars of strength 415 MPa complying with IS:1786 and in accordance with the specified requirements.

15.3.13. All concrete work should be carried out within the prescribed weather and seasonal limitations.

15.3.14. Freshly mixed concrete from the central batching and mixing plant should be transported to the paver site by means of trucks/tippers capable of maintaining the mixed concrete in a homogenous state and discharging the same without segregation and loss of cement slurry to ensure a constant supply of concrete.

15.3.15. The total time from the addition of the water to the mix, untill the completion of the surface finishing and texturing shall not exceed 120 minutes when concrete temperature is less than 25°C and 90 minutes when the concrete temperature is between 25°C to 30°C.

15.3.16. Addition of water to the surface of the concrete to facilitate the finishing operations will not be permitted.

15.3.17. While the concrete is still plastic, its surface shall be brush textured and the surface and edges of the slab cured by the application of a sprayed liquid curing membrane. After the surface texturing, but before the curing compound is applied, the concrete slab shall be marked with the chainage at every 100 m interval.

15.3.18. As soon as the side forms are removed, edges of the slabs shall be corrected wherever irregularities have occurred by using fine concrete composed of one part of cement to 3 parts of fine chips and fine aggregate.

15.4. **Curing**

15.4.1. Immediately after the surface texturing, the surface and sides of the slab shall be cured by the application of approved resin-based aluminised reflective curing compound which hardens into an impervious film or membrane with the help of a mechanical sprayer. The compound shall become stable and impervious to evaporation of water from the surface of the concrete within 60 minutes of application. In addition to spraying of curing compound, the fresh concrete surface should be covered by moist hessian and the same then be kept damp for a minimum period of 14 days.

15.5. **Trial Length**

The trial length shall be constructed atleast one month in advance of the proposed start of concrete paving work and approved by the Engineer.

15.6. **Joints**

15.6.1. All transverse joints in surface slabs should be sealed using approved sealants 14 days after construction.

15.6.2. Before sealing the temporary seal provided for blocking the ingress of dirt, soil, etc., shall be removed. A highly compressible heat resistant paper-backed debonding strip as per drawing shall be inserted in the groove to serve the purpose of breaking the bond between sealant and the bottom of the groove and to plug the joint groove so that the sealant may not leak through the cracks.

15.6.3. When sealants are applied, and appropriate primer shall also be used if recommended by the manufacturer and it shall be applied in accordance with their recommendation.

15.6.4. If hot applied sealant is used, it shall be heated and applied from a thermostatically controlled, indirectly heated preferably with oil jacketed melter and pourer having recirculating pump and extruder. For large road projects, sealant shall be applied with extruder having flexible hose and nozzle. The sealant shall not be heated to a temperature higher than the safe heating temperature and not for a period longer than the safe heating period, as specified by the manufacturer. The dispenser shall be cleaned out at the end of each day in accordance with the manufacturer's recommendations and reheated material shall not be used.

15.7. **Maintenance**

Cement concrete pavement, if constructed properly, will require only maintenance at joints where oxidised joint filler and sealants have to be periodically replaced by new materials. The details are given in para 14.7.2.4.

16. ENVIRONMENT

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16.1. In order to mitigate adverse impact on the environment, it is imperative to consider the environmental impact of highway projects at all stages including the planning stage. This situation warrants identification of activities of highway construction/ improvement programmes, which can adversely affect the environment and take necessary steps to minimize detrimental effects. Specifications and contracts for highway projects should include manadatory provisions for preservation of environment.

16.2. **Selection of Alignment**

Select alignment so that the highway :

i) does not pass through forest land, particularly reserved forest;

ii) does not pass through wild life sanctuary and is preferably located 5 kilometres away from it;

iii) is away from the important human habitat or centre of pollution;

iv) is away from the public buildings, religious buildings and buildings of historical and cultural importance;

v) avoids or minimizes acquisition of agriculture land and does not disturb high landscape quality; and

vi) in hilly areas, expert geologist advise should be obtained about rock formation.

16.3. **Planning for Borrow Areas/Quarry Location**

i) Minimize borrow areas requirements by careful designing and cut/fill balance.

ii) Plan for replantation at borrow sites after use.

iii) Ensure that quarry/borrow area does not result in instability or excessive erosion. The plan should incorporate appropriate drainage system with settling ponds.

iv) Avoid significant habitat area when siting quarries/ borrow areas, minimize area of land acqusition by careful planning of extraction. Use dust suppression devices on crusher plant. Provide workers with dust masks and water stock piles to minimize dust. Restrict noisy operations to daylight hours.

v) In no case, the earth should be borrowed from land adjacent to road.

16.4. Construction

i) Contract document should include mandatory provisions to carry out excavation after adequate sprinkling of water for each lift on area to be excavated.

ii) Notify well in advance of the blasting, if necessary, for excavation to the public and all concerned and take all necessary precautions.

iii) Siting of asphalt plant should be atleast 500 metres away and downwind of human habitat.

iv) Introduce traffic control at junctions.

v) Use multipurpose approach in selection sites for borrow areas. The depression in the ground after borrowing earth can be converted into a lake for recreational purposes. The natural ground can be levelled by removal of high mounds, etc.

16.5. Disposal of Soil

Disposal of soil should be as per approved plans in identified areas, which should include drainage.

16.6. **Landscaping**

16.6.1. Landscaping of roads embraces a number of measures at different stages of development. First is the design of horizontal alignment, vertical profile, structures, like, bridges and retaining walls, and road furniture, such as, signs, signals, lighting system, etc., so that these components are not out of scale with the surroundings. Second is the apt contouring of all gound affected by the works, especially the cutting and embankments with a view to unify the landscape and avoiding any visual jolt. Third is the planting of trees, grass and shrubs which properly integrate with the environment. Fourth is the creation of necesary service facilities for rest, recreation, etc. of the road travellers.

16.6.2. Landscaping which is concerned primarily with visual effects is difficult to define in a precise manner. As such it is not possible to lay down rigid standards for landscaping. The treatment to be adopted will vary from place to place depending on the topography, climate and other environmental features. For best results, highway design and landscaping should be regarded as complementary and tackled as single planning task. To assure necessary co-ordination, especially on major projects, it may be worthwhile obtaining services of a landscape architect to integrate the related aspects. Even on small jobs there should be arrangement to consult landscape architects and horticulturists. Apart from this, consideration should be given to preparation of perspective drawing and models so that landscape features can be studied in advance and further improvements made where possible.

16.6.3. The following points should be kept into consideration for landscaping :

i) Every effort should be made to conserve existing features, such as, wooden areas, streams, ponds, rock outcrop, old historical buildings and gardens, etc.

ii) Acquisition of adequate right-of-way for providing green buffer strips between shoulders and land boundary to improve the landscape. In urban areas, it may be desirable to provide screen planting to avoid nuisance of noise, ugly sites, dust and fumes, etc.

iii) Alignment of the road can be made pleasing by providing horizontal curves of larger radii with suitable transitions and proper co-ordination of horizontal and vertical curves. This together with appropriate contouring and plantation along the road enhances the aesthetics.

iv) Speed of travel is a recognised factor in landscape design. On fast speed highways, the overall composition of landscape is of significance, whereas, on slow speed roads, minor wayside details are noticed by the travellers.

v) Climate factors, like, rainfall, humidity and temperature influence road landscape design because only specific varieties of vegetation thrive in a particular climate. Therefore, plantation should be restricted to local species.

vi) In case of divided highway, the two carriageways need not always be sited adjacent to each other or at the same level. If the natural ground has steep slope across the road it may be advisable to have the second carriageway at different level or slightly away. However, the space between the two carriageways should be properly utilized for plantation.

16.7. Arboriculture

16.7.1. Arboriculture is an important component of landscaping. This may be functional as protection of slope against erosion, screening unsightly views, reducing headlight glare, providing shade in summer or only for aesthetic purposes. In either case, the objective should be to help to restore the on-going lanscape.

16.8. Environmental Appraisal

16.8.1. A questionnaire for environmental appraisal should be prepared as per the following format. This should be submitted alongwith the project proposal at the time of obtaining technical and financial approval.

QUESTIONNAIRE FOR ENVIRONMENTAL APPRAISAL OF RAIL/ROAD/HIGHWAY PROJECTS

1. General

1.1. Name of the project :
   a) Objective of the proposal
   b) Brief description of the project proposal
   c) Project justification/need
   d) Present status of the project
   e) Operational Plan (time schedule of major activities of project steps)

1.2. Location of the project :
   a) Place
   b) District
   c) State/Union Territory

1.3. Approximate area/population to be served

1.4. Overall project cost

1.5. Number of tracks-broad gauge/metre gauge

1.6. Type of traction-electric/diesel/steam, etc.

1.7. Size and magnitude of the project
   a) Length of Rail/Road/Highway
   b) Width of the Rail/Road/Highway
   c) Total land required

1.8. Alternative alignments/sites examined

2. Environmental Setting/Project Location

2.1. Environmental characteristics of the areas traversed along the alignment for a strip of 10 km each on both sides for a Rail/Road/Highway project to be delineated and mapped on a base map 1:50,000

i) National Park
ii) Recreation areas
iii) Non-hunting areas
iv) Wildlife sanctuary
v) Natural reserves
vi) Mangrove forests
vii) Biosphere forests
viii) Primary (virgin) rain forest
ix) Declared watershed areas to be used for Community potable water supply
x) Swamp lands/wetlands
xi) Agricultural lands
xii) Land occupied by ethnic minorities
xiii) Industrial
xiv) Residential
xv) Commercial
xvi) Irrigated areas
xvii) Non-irrigated croplands
xviii) Tree-crop lands
xix) Grazing land
xx) Historical and cultural sites and monments
xxi) Religious sites, temples, churches, etc.
xxii) Government and Public Institutions
xxiii) Others (Specify)

Description of these identified critical areas should focus on the following :

- Ecosystems (i), (iii - x) as above
- Total size of the ecosystem
- Major ecological functions (e.g., habitat, breeding area, soil stabilisation, hydrologic regulation)
- Major social functions (recreation, etc.)
- Number of people depending on functions of the ecosystem (visitors, serving potable water, etc.)
- Impact of rail/road/highway construction/operation on the functions of critical ecosystem (pollution, destruction, etc.)
- Land-use (ii), (xiii-xv), (xx-xxii) as above

- Significance of critical land use/environmental items
- Impacts of rail/road/highway construction operation on critical land use or items (pollution, visual disturbance, etc.)

xiv) as above

- Brief description to ethnic community
- Impacts of rail/road/highway projects on ethnic minority
- Reaction within the community on the project

2.2. Details of forest land involved :

i) Legal status of forests (namely, reserved, unclassed, etc.)
ii) Details of flora existing in the area including the density of vegetation
iii) Topography of the areas indicating gradient aspect, altitude, etc.
iv) Its vulnerability to erosion, whether it forms a part of a seriously eroded area or not.
v) Whether it forms a part of national park, wildlife sanctuary, nature reserve, biosphere reserve, etc. If so, details of the area involved.
vi) Rare/endangered species of flora and fauna found in the area.
vii) Whether it is a habitat for migrating fauna or a breeding ground for them.
viii) Any other feature of the area relevant to the proposal.

2.3. If the project for which forest land is required involves dispacement of people or requires raw material from any forest area, the details of proposal's for rehabilitation and procurement of raw material be furnished.

2.4. Proposed steps to be taken to compenstate for the loss of forest area, the vegetation and wildlife.

2.5. Stripping and site clearing

- size of the area to be stripped
- location (to be shown on map)

- soil type
- volume and quantity of earth removed
- location of dump sites (to be shown on map).

2.6. Details of bridges/tunnels/cuttings, etc :-

- size of areas to be cut (length, height)
- location (to be shown on map)
- soil type
- volume and quantity of earth removed
- location of eventual dump sites (to be shown on map)

2.7. Details of embankments/landfills, etc.

- size of areas to be filled
- location (to be shown on map)
- soil type
- volume and quantity required for filling

2.8. Data for last 2-3 decades regarding soil erosion, floods, silting, earthquake, settling, landslides and cyclones, etc.

2.9. Measures being adopted against such calamities.

2.10. Likely modifications of hydrology in the area leading to canalisation, alteration of water flow, alteration of surface and underground drainage, etc.

2.11. Likely hazards to safety of workers and nearby residents due to quarrying including use of explosives.

2.12 a) Has an air quality impact assessment been carried out as per guidelines and report enclosed?

b) Has a noise impact assessment been carried out as per guidelines and report enclosed?

2.13. Hazards to aquatic ecology/flooding due to runoff contamination.

2.14. Likely health hazards to passengers and nearby residents due to escape of sanitary wastes, spill of hazardous materials, etc.

2.15. Pollution of ground water from fills.

2.16. Fuel supply arrangements to the labour force during construction period.

3. Proposed Safeguard

3.1. Measures proposed for protection and renewal of forests, agricultural land, grazing land, top soil, natural resources and water resources, etc.

3.2. Measures adopted during construction for balancing cut and fill, rehabilitation of dump sites, reclaiming borrow pits, securing, embankment soil and slope stabilisation, preventing soil erosion and siltation, containing blasting and bulldozing.

3.3. Measures to control corridor type of developement along the alignment.

3.4. Likely impacts of the proposal on socio-economic development of the region.

3.5. What type of mitigative measures have been incorporated for abatement of noise, e.g., noise screens or plantation, etc.?

3.6. Details of green belts and corridor plantation along the alignment incorporated in the project proposal and funds allocated for the same. Give area of green belts proposed to be created on both sides of the alignment in addition to number of trees proposed to be planted.

3.7. Measures proposed for off-setting adverse impact on fragile eco-systems.

3.8. Measures to ensure that uncontrolled development will not occur.

3.9. Measures undertaken to ensure :

a) Prevention of pollution of irrigation waters;

b) Prevention of pollution of sources for potable water supply systems.

3.10. Measures proposed to off-set adverse social impacts.

17. MISCELLANEOUS

17. MISCELLANEOUS

17.1. Script for Kilometre Stones

The script should be as given in Table 17.1.

Table 17.1. Script for Kilometre Stones

Km. No.	Script for place name	Place to be shown
0	Roman	Terminal/starting station and next important town
1	Hindi (Devnagri script)	Next important town
2	Local language	— do —
3	Hindi (Devnagri script)	Terminal/starting station
4	Local language	— do —
5	Roman	Terminal/starting station and next important town
6.	Hindi (Devnagri script)	Next important town

17.2. Plantation of Trees along NHs

17.2.1. There is no limitation on the number of rows of tress to be planted but the first or the nearest row should be at a minimum distance of 10-12 m from the centreline of the extreme traffic lane. Atleast, one row of the trees should be of fruit-bearing variety.

17.2.2. Areas which are likely to be used for widening of the road within the next 10 years should not be planted with permanent trees. Other requirements of geometrics, sight distance, borrowing earth, etc., should also be kept in view.

17.2.3. The need for cutting of trees for National Highway works is normally felt while considering proposals for fixing new alignment or for improvement of the existing alignment or for improvement by way of widening the carriageway, etc. Among other factors influencing the final decision, the need for considering change(s) in the alignment proposal to avoid cutting of trees, should be examined in detail.

17.2.4. If after considering various possibilities, cutting of trees cannot be avoided, the proposal involving cutting minimum number of trees may be finalised. Simultaneously, the proposal for cutting tree supported with necessary details may be submitted to the concerned State Forest Department for their concurrence. As per the present policy, permission for cutting of trees is given on furnishing an undertaking that ten times the number of trees to be cut, will be planted.

17.2.5. Receipts and revenue from avenue trees should be credited to the appropriate Central Government head.

17.3. Preventing and Removal of Encroachments on NH Land

17.3.1. It is essential that urgent action is taken to remove all the existing encroachments expeditiously so as to eliminate nuisance and ensure safe and free flow of traffic. Any or all of the following methods may be used to remove encroachments on highways :

i) Action be taken under Section 133 of the Criminal Procedure Code. In order to bring the case under Section 133, the prosecution has to prove that the land in question is either a public way or a public place.

ii) Encroachment upon a public road is an obstruction to the public path and it is a nuisance in itself under Section 269 of the Indian Penal Code. No argument by a user can justify an encroachment upon a public way. The question of sufficient width of the road being left in support of the encroachment for public use is no ground for allowing encroachment or obstruction to continue.

iii) Criminal proceedings may be initiated against the wrong-door under the various provisions of Indian Penal Code, Criminal Procedure Code and such of the Police Acts are applicable to Central subjects, like, National Highways which are a Union subject under the Constitution.

iv) Section 291 of the Indian Penal Code punishes a person continuing a nuisance after he is enjoined by a public servant not to repeat or continue it. Sections 142 and 143 of the Code of Criminal Procedure empower a Magistrate to forbid an act causing a public nuisance. The Civil Procedure Code also empowers a court to issue temporary injunction. To be able to expedite removal of encroachments, each PWD Division must prepare accurate land maps with documentary evidence for the ownership rights and keep them handy for checking and for producing in evidence.

v) Action under the relevant clauses of the Highway Act/ Land Control Act of the respective State Govts.

17.3.2. A few other aspects which should also be kept in view with regard to prevention of encroachments are :

i) Continuous plantation in rows on the road land boundaries alongwith plantation on the roadside will leave no space for encroachment.

ii) In urban areas, any space acquired for highway purpose should be brought into that use without any loss of time. If there is likelihood of any time lag, the area should be fenced out to prevent encroachment.

iii) The road land boundaries should be got delineated on the field, and the title of the land should be readily available in case of any court proceedings.

iv) Provision of road-user amenities, like, roadside rest areas, truck parks, roadside lay-byes, service stations, etc. along the highways in a planned manner will reduce the temptation for encroachment (see also para 17.4.).

17.4. Accommodation of Underground Utility Services, like, Electric cables and Pipelines for Water Gas Petroleum Products along and across National Highway.

17.4.1. Detailed guidelines in the matter are contained in Ministry's Circular No. N.H. III/P/66/76 dated the 19th November, 1976 and the subsequent reiterating circular of even number dated the 11th May, 1982.

17.4.2. Normally, utility services should not be located longitudinally within the N.H. right-of-way. However, State Chief Engineers have been authorised to permit the laying of the utility services in difficult cases where no other altenative is possible provided the following conditions are satisfied :

i) The utility lines should be as close to the extreme edge of land boundaries as possible but in no case less than 15 m from the centre line of the nearest carriageway.

ii) The lines shall not be permitted when the road formation is situated in double cutting. Nor shall these be laid over existing bridges/culverts without the prior approval of GOI.

iii) The lines shall be sufficiently below the ground level (min. 0.6 m) so as not to obstruct road drainage.

iv) Any proposal to lay high tension electric cables along bridges should be covered by a certificate that it will not have any deleterious effect on any of the bridge components and traffic safety.

17.4.3. The utility lines can be permitted to cross the National Highway either encased in pipes or through conduits specially built for the purpose at the expense of the agency owning the line. Existing drainage structures shall not be allowed to carry the lines across unless specially permitted by the GOI.

17.4.4. The casing pipe carrying the utility line shall be of steel, cast iron or R.C.C. and shall have adequate strength and be large enough to permit ready withdrawal of the utility line. Ends of the casing pipe shall be sealed from the outside. The top of the casing pipe shall atleast be 1.2 m below the road surface subject to being atleast 0.3 m below the drain invert.

17.4.5. The casing pipe may be installed under the road embankment either by boring or digging a trench, though the former method should be preferred. Where the trench method is adopted, the sides should be cut as nearly vertical as possible and should be 30-60 cm wider than the pipe diameter. The bedding shall be to depth not less than 30 cm and should be of granular materials free of lumps and clods. The backfill should be in two stages, filling the sides to the level of the top of the pipe in the first stage and filling over the pipe upto the subgrade level in the second. The fill shall be in layers of 15 cm thickness and compacted adequately with suitable rammers. The road crust should be to the same strength as the existing crust on either side of the trench. The work should be carried out in one lane at a time while the other lane is kept open to traffic, or suitable diversion provided where required. All safety measures, like signs, barricades, flagmen and redlights (during night hours) should be provided.

17.5. Laying and Protection of Co-axial and Trunk Telephone Cables belonging to the P&T Department on National Highways

17.5.1. Detailed guidelines on the subject are contained in Ministry's Circular No. NH-III/P/66/76 dated the 10th November, 1976 read with the amendment of even number dated the 20th August, 1982.

17.5.2. These telephone cables should ordinarily run along the road land boundary or at a minimum distance of 15 m from the centreline of the nearest carriageway. In special cases, however, the cables could be allowed underneath the shoulders at a distance of 0.6 m from the outer edge of the road embankment provided the same are located atleast 4.5 m away from the centreline of the nearest carriageway and 1.2 m below the road surface.

17.5.3. On culverts and bridges, the cables should be carried in a pipe of suitable size, or through a duct if existing. On arch type structure where cushion is 0.5 m or more, the pipe carrying the cable may be burried on the top of the arch adjoining the parapet wall by digging close to the wheel guards. Where the cusion is less 0.5 m, the pipe may be burried under the wheel guard masonry and the wheel guard re-built.

17.5.4. Where the above methods are not possible, the carrier pipe should be clamped to the outside parapet wall of the culvert/ bridge. If even this is not possible, the pipe may be fixed on top of the road curb close to the inside face of the parapet wall by means of suitable clamps.

17.5.5. Repeater station, if any, shall not be less than 15 m from the centreline of the nearest carriageway and so located as not to obstruct visibility of the motorists.

17.5.6. Where the above conditions are fulfilled, the State governments may authorise the State Chief Engineers to grant permission for laying the cables under intimation to the Ministry.

17.5.7. It shall be ensured that no damage is caused to the telephone cables while carrying out improvement/maintenance works on the highway. For this purpose, it will be necessary to verify in advance if any cable of the P&T Department exists at the location where the work is to be taken up. Where any cable is present, the Executive Engineer of the P.W.D. should get in touch with his counterpart in the P&T Department and draw up an agreed programme for executing the work so that the latter could make suitable arrangements for guarding the cables. This procedure should also be adopted in cases where permission is given by the P.W.D. to other agencies for laying other utility services.

18. USEFUL TABLES

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Table 18.1. S.I. Units

Dimension	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Force	newton	N
Stress/pressure	pascal	Pa
Angle	radian	rad
Temperature	kelvin	K
Energy	joules	J

Prefix	Symbol	Multiplying Factor
gega	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
milli	m	10^{-3}
micro	u	10^{-6}
nano	n	10^{-9}

Standard gravitational acceleration = 9.80665 m/s^2
1 kgf/m^2 = 9.80665 N/m^2 = 9.80665 Pa
1 kgf/cm^2 = 98066 Pa = 98.066 kPa

Table 18.2. Symbols for units

Quantity	Name of Unit	Symbol
length	metre	m
	millimetre	mm
	kilometre	km
	micron	µm
area	square metre	m^2
	square millimetre	mm^2
volume	cubic metre	m^3
mass	kilogram	kg
	gram	gm
	tonne	t
density	kilogram/cubic metre	kg/m^3
time	second	s
	minute	min
	hour	h
temperature	degree Celsius	^0C
velocity	metre per second	m/s
	kilometre per hour	km/h
force	newton	N
	kilonewton	kN
moment	newton metre	N.m.
	kilonewton metre	kN.m.
pressure/stress	pascal	Pa
	megapascal	MPa

Table 18.3. Relative designation of test sieves

IS designation (IS:460-1962)	Equivalent designation conforming to	
	BS:410-1962	ASTM F11-61
100 mm	4 in.	4 in.
80 mm	3 in.	3 in.
63 mm	2 1/2 in.	2 1/2 in.
50 mm	2 in.	2 in.
40 mm	1 $^1/_2$ in.	1 $^1/_2$ in.
25 mm	1 in.	1 in.
20 mm	3/4 in.	3/4 in.
12.5 mm	1/2 in.	1/2 in.
10 mm	3/8 in.	3/8 in.
6.3 mm	1/4 in.	1/4 in.
4.75 mm	3/16 in.	No. 4
2.36 mm	No. 7	No. 8
1.18 mm	No. 14	No. 16
600 micron	No. 25	No. 30
500 micron	No. 30	No. 35
425 micron	No. 36	No. 40
300 micron	No. 52	No. 50
150 micron	No. 100	No. 100
75 micron	No. 200	No. 200

Table 18.4. Conversion factors

Multiply		By	To obtain
1.	Length		
	Inches	2.54	Centimetres
	Feet	0.3048	Metres
	Miles	1.6093	Kilometres
2.	Area :		
	Sq. inches	6.4516	Sq.cm.
	Acres	0.4047	Hectares
3.	Volume :		
	Cu. inches	16.3871	Cu.cm.
	Cu. feet	0.0283	Cu.metres
	Gallons (Imp. Gallon)	4.546	Litres
4.	Mass :		
	Pounds	0.4536	Kilograms
	Tons	1.0161	M. Tonnes
5.	Density :		
	Pounds/cft	16.0184	Kg/cu.m.
6.	Stress/pressure :		
	Pounds/sq. inch	0.0703	Kg/cm^2
	Pouns/sq. foot	4.8838	Kg/m^2
	Tons/sq. foot	10.9366	Tonnes/m^2
7.	Bending moment :		
	Ft. pounds	0.1383	Kg.m
8.	Flow :		
	Cusec	0.0283	m^2/sec.

REFERENCES

REFERENCES

(A) List of IRC Publications Referred to in this Pocket Book

Number Designation	Title
IRC:10-1961	Recommended Practice for Borrowpits for Road Embankments Constructed by Manual Operation
IRC:12-1983	Recommended Practice for Location and Layout of Roadside Motor-Fuel Filling and Motor-Fuel Filling-cum-Service Stations (Second Revision)
IRC:32-1969	Standard for Vertical and Horizontal Clearances of Overhead Electric Power and Telecommunication Lines as Related to Roads
IRC:35-1997	Code of Practice for Road Markings (with Paints) (First Revision)
IRC:37-2001	Guidelines for the Design of Flexible Pavements (Second Revision)
IRC:38-1988	Guidelines for Design of Horizontal Curves for Highways and Design Tables (First Revision)
IRC:39-1986	Standards for Road-Rail Level Crossings (First Revision)
IRC:41-1997	Type Designs for Check Barriers (First Revision)
IRC:52-2001	Recommendations About the Alignment Survey and Geometric Design of Hill Roads (Second Revision)
IRC:53-1982	Road Accident Forms A-1 and 4 (First Revision)
IRC:62-1976	Guidelines for Control of Access on Highways
IRC:64-1990	Guidelines for Capacity of Roads in Rural Areas (First Revision)
IRC:65-1976	Recommended Practice for Traffic Rotaries
IRC:66-1976	Recommended Practice for Sight Distance on Rural Highways
IRC:67-2001	Code of Practice for Road Signs (First Revision)
IRC:73-1980	Geometric Design Standards for Rural (Non-Urban) Highways

IRC:77-1979	Tentative Guidelines for Repair of Concrete Pavements Using Synthetic Resins
IRC:78-2000	Standard Specifications and Code of Practice for Road Bridges, Section VII - Foundations & Substructure (Second Revision)
IRC:81-1997	Tentative Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique (First Revision)
IRC:92-1985	Guidelines for the Design of Interchanges in Urban Areas
IRC:99-1988	Tentative Guidelines on the Provision of Speed Breakers for Control of Vehicular Speeds on Minor Roads
IRC:102-1988	Traffic Studies for Planning Bypasses Around Towns
IRC:103-1988	Guidelines for Pedestrian Facilities
IRC:106-1990	Guidelines for Capacity of Urban Roads in Plain Areas
IRC:108-1996	Guidelines for Traffic Prediction on Rural Highways
IRC:SP:11-1988	Handbook of Quality Control for Construction of Roads and Runways (Second Revision)
IRC:SP:14-1973	A Manual for the Applications of the Critical Path Method to Highway Projects in India
IRC:SP:19-2001	Manual for Survey, Investigation and Preparation of Road Projects (Second Revision)
IRC:SP:21-1979	Manual on Landscaping of Roads
IRC:SP:41-1994	Guidelines on Design of At-Grade Intersections in Rural & Urban Areas
IRC:SP:48-1998	Hill Road Manual
IRC:SP:53-2002	Guidelines on Use of Polymer and Rubber Modified Bitumen in Road Construction (First Revision)

(B) List of Indian and Foreign Standards Referred to in this Pocket Book

(a) Indian Standards

IS:73-1992	Paving Bitumen Specification (Second Revision)
IS:210-1993	Grey Iron Castings (Fourth Revision)
IS:217-1988	Cutback Bitumen-Specification (Second Revision)
IS:226-1975	Superseded by IS: 2062
IS:269-1989	33 Grade Ordinary Portland Cement (Fourth Revision)
IS:383-1970	Coarse and Fine Aggregates from Natural Sources for Concrete (Second Revision)
IS:432-1982	Mild Steel and Medium Tensile Steel Bars and Hard-drawn Steel Wire for Concrete Reinforcement
(Part-I)	Mild Steel and Medium Tensile Steel Bars (Third Revision)
IS:455-1989	Portland Stag Cement (Fourth Revision)
IS:456-2000	Code of Practice for Plain and Reinforced Concrete (Fourth Revision)
IS:458-1988	Precast Concrete Pipes (with and without Reinforcement) (Third Revision)
IS:460-1985	Test Sieves
IS:702-1988	Industrial Bitumen (Second Revision)
IS:808-1989	Dimensions for Hot Rolled Steel Beam, Column Channel and Angle Sections (Third Revision)
IS:961-1975	Superseded by IS: 8500
IS:1030-1998	Carbon Steel Castings for General Engineering Purposes (Fifth Revision)
IS:1077-1992	Common Burnt Clay Building Bricks (Fifth Revision)
IS:1139-1966	Superseded by IS:1786
IS:1148-1982	Hot Rolled Rivet Bars (upto 40 mm dia) for Structural Purposes (Third Revision)

IS:1149-1982	High Tensile Rivet Bars for Structural Purposes (Third Revision)
IS:1161-1979	Steel Tubes for Structural Purposes (Third Revision)
IS:1199-1959	Method of Sampling and Analysis of Concrete
IS:1203-1978	Determination of Penetration (First Revision)
IS:1205-1978	Determination of Softening Point (First Revision)
IS:1212-1978	Determination of Loss of Heating (First Revision)
IS:1216-1978	Determination of Solubility in Carbon Disulphide or Carbon Tetrachlorate or Trichoroethylene (First Revision)
IS:1217-1978	Determination of Mineral Matter (Ash) (First Revision)
IS:1239-1990 (Part 1)	Mild Steel Tubes (Fifth Revision)
IS:1239-1990 (Part 2)	Mild Steel Tubular and other Wrought Steel Pipe Fittings (Third Revision)
IS:1489-1991 (Part 1)	Portland-Pozzolana Cement Fly Ash based (Third Revision)
IS:1498-1970	Classification and Identification of Soils for General Engineering Purposes (First Revision)
IS:1514-1990	Methods of Sampling and Test for Quick Lime and Hydrated Lime (First Revision)
IS:1730-1989	Dimensions for Steel Plates, Sheets Strips and Flats for General Engg. Purposes (Second Revision)
IS:1731-1971	Dimensions for Steel Flats for Structural and General Engg. Purposes
IS:1732-1989	Dimensions for Round and Square Steel Bars for Structural and General Engineering Purposes (Second Revision)
IS:1785-1983	Plain Hard-drawn Steel Wire for Prestressed Concrete
(Part II)	As Drawn Wire (First Revision)

IS:1786-1985	High Strength Deformed Steel Bars and Wires for Concrete Reinforcement (Third Revision)
IS:1852-1985	Rolling and Cutting Tolerances for Hot Rolled Steel Products (Fourth Revision)
IS:1875-1992	Carbon Steel Billets, Blooms, Slabs and Bars for Forgings (Fifth Revision)
IS:1938-1990	Cotton Cambs for Use in Jute Looms (Second Revision)
IS:1978-1982	Line Pipe (Second Revision)
IS:2004-1991	Carbon Steel Forging for General Engineering Purposes (Third Revision)
IS:2062-1999	Steel to General Structural Purpose (Fifth Revision)
IS:2090-1983	High Tensile Steel Bars Used in Prestressed Concrete (First Revision)
IS:2132-1986	Code of Practice for Thin Walled Tube Sampling of Soils (Second Revision)
IS:2386-1963	Methods of Test for Aggregates for Concrete
(Part 1)	Particle Size and Shape
(Part 3)	Specific Gravity, Density, Voids, Absorption and Bulking
(Part 4)	Mechanical Properties
(Part 5)	Soundness
IS:2586-1986	Bench Vices (Second Revision)
IS:2720	Methods of Test for Soils
(Part 2)-1973	Determination of Water Content (Second Revision)
(Part 4)-1985	Grain Size Analysis (Second Revision)
(Part 5)-1985	Determination of Liquid and Plastic Limits (Second Revision)
(Part 7)-1980	Determination of Moisture Content/Dry Density Relation Using Light Compaction (Second Revision)

(Part 8)-1983	Determination of Water Content-Dry Density Relation Using Heavy Compaction (Second Revision)
(Part 11)-1993	Determination of the Shear Strength Parameters of a Specimen Tested in Unconsolidated Undrained Triaxial Compression without the Measurement of Pore Water Pressure (First Revision)
(Part 12)-1981	Determination of Shear Strength Parameters of Soil from Consolidated Undrained Triaxial Compression Test with Measurement of Pore Water Pressure (First Revision)
(Part 13)-1986	Direct Shear Test (Second Revision)
(Part 15)-1986	Determination of Consolidation Properties (First Revision)
(Part 16)-1987	Laboratory Determination of CBR (Second Revision)
(Part 27)-1977	Determination of Total Soluble Sulphates (First Revision)
(Part 31)-1990	Field Determination of California Bearing Ratio (First Revision)
(Part 37)-1976	Determination of Sand Equivalent Values of Soils and Fine Aggregates
(Part 38)-1976	Compaction Control Test (Hilp Method)
IS:4923-1985	Hollow Steel Sections for Structural Use (First Revision)
IS:5640-1970	Method for Determining the Aggregate Impact Value of Soft Coarse Aggregate
IS:6006-1983	Uncoated Stress Relieved Strands for Prestressed Concrete (First Revision)
IS:6241-1971	Methods of Test for Determination of Stripping Value of Road Aggregates
IS:6603-1972	Stainless Steel Bars and Flats
IS:6909-1990	Supersulphated Cement

IS:6911-1992	Stainless Steel Plate, Sheet and Strip (First Revision)
IS:6925-1973	Methods of Test for Determination of Water Soluble Chlorides in Concrete Admixtures
IS:8041-1990	Rapid Hardening Portland Cement (Second Revision)
IS:8112-1989	43 Grade Ordinary Portland Cement (First Revision)
IS:8500-1991	Structural Steel – Microalloyed (Medium and High Strength Qualities) (First Revision)
IS:8887-1995	Bitumen Emulsion for Roads (Cationic Type)-Specification (First Revision)
IS:9103-1999	Admixtures for Concrete (First Revision)
IS:10262-1982	Guidelines for Concrete Mix Design
IS:12269-1987	Specification for 53 Grade Ordinary Portland Cement
IS:12330-1988	Specification for Sulphate Resisting Portland Cement
IS:13326 (Part I)-1992	Evaluation of Interface Friction between Geosynthetics and Soil-Method of Test, Part I: Modified Direct Shear Technique
IS:13620-1993	Fusion Bonded Epoxy Coated Reinforcing Bars
IS:SP:23-1982	Handbook on Concrete Mixes (Based on Indian Standards)

(b) Foreign Standards

ASTM: D977-91	Standard Specification for Emulsified Asphalt
ASTM: D-1075	Effect of Water on Cohesion of Compacted Bituminous Mixtures
ASTM: D-1559	Test for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus
ASTM:D-2172-95	Standard Test Methods for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
ASTM:D2397-94	Standard Specification of Cationic Emulsified Asphalt

ASTM: D3910-90 (Reapproved 1995)	Standard Practice for Design, Testing and Construction of Slurry Seal
ASTM: D-4533	Test Method for Trapezoid Tearing Strength of Geotextiles
AASHTO:	Resistance of Compacted Bituminous Mixture to
T283-89	Moisture Induced Damage
BS: 410-1969	Test Sieves
BS: 434 Part 1	Bitumen Road Emulsions (Anionic and Cationic)
BS: 729-1971	Hot Dip Galvanized Coating on Iron and Steel Articles
BS: 812-1975	Testing Aggregates
Part 114-1989	Method for Determination of the Polished-Stone Value
BS: 1449-1956	Steel Plate, Sheet and Strip
Part 1-1972	Carbon Steel Plate, Sheet and Strip
Part 2-1967	Stainless and Heat Resisting Plate, Sheet and Strip
BS: 1470-1972	Wrought Aluminum and Aluminum Alloys for General Engineering Purposes – Plate, Sheet and Strip
BS: 2000	Methods of Test for Petroleum and its Products
Part 397-1995	Recovery of Bitumen Binders-Dichloromethane Extraction Rotary Film Evaporator Method
BS: 2870	Rolled Copper and Copper Alloys : Sheet, Strip and Foil
BS: 6906	Methods of Test for Geotextiles
Part 1	Determination of the Tensile Properties Using a Wide Width Strip
Part 3	Determination of Water Flow Normal to the Plane of the Geotextile under a Constant Head
Part 4	Determination of the Puncture Resistance (CFR Puncture Test)