सत्यमेव जयते

Ministry of Road Transport & Highways

POCKET BOOK FOR HIGHWAY ENGINEERS

(Third Revision)

Published by
Indian Roads Congress
New Delhi
January 2019

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FOREWORD

I am happy to present this revised edition of Pocket Book for Highway Engineers to the highway profession. It was initially published in December, 1982 and subsequent revisions were made in May, 1985 and February, 2002. Since the year 2002, there have been phenomenal changes in the standards, materials used, specifications of works, technology of construction and maintenance and evaluation of performance in highway engineering. It was, therefore, a long felt need for revision of this Pocket Book to capture the latest methodology.

In this edition of Pocket Book a separate and new chapter on Road Drainage has been included. A chapter on pre-construction activity which includes methods of land acquisition, shifting of utilities and procedure for environmental clearances has also been incorporated. Separate chapters of Pavement Design and Maintenance of Pavement now include Rigid Pavement also. To make aware of the policies of Government of India in highway related matters a new chapter on Central Sector Acts/Policies has also been introduced. The chapter on Road Safety now lay emphasis on various traffic control devices which can reduce the number of accidents on roads.

This Pocket Book has been updated with the latest editions of the Specifications for Road and Bridge Works of Ministry of Road Transport and highways, various related IRC publications and circulars of Ministry of Road Transport and Highways. The Pocket Book contains fourteen chapters and gives information and guidelines on all aspects of highway engineering. This Pocket Book is mainly intended for National Highway works. Major aspects of State Highways have also been covered. I hope it will be useful to all the engineers of the country dealing with highway works.

It is quite natural, this publication cannot be expected to cover all the subjects and details of highway engineering and as such should not be considered as a substitute for the Standards and Specifications as well as Codes of Practice. For guidance relevant IRC Codes and other publications have been added to the text. The Pocket Book should not to be made part of any types of contract document /RFP/tender document.

This Pocket Book was helpful and warmly accepted by the highway profession and I hope this edition will also be equally popular and helpful to the practicing highway engineers as in the past.

Pocket Book has been published by the Indian Roads Congress, as sanctioned under a financial assistance by Ministry of Road Transport & Highways.

Due to rapid changes which are taking place in Highway Engineering, the Pocket Book will need to be updated from time-to-time. To achieve this objective, the regular feedback and suggestion from the profession for further improvement and to bring in latest technology, methodology of construction, materials, etc may be brought to the notice of this Ministry.

New Delhi | (B.N. Singh)

Director General (Road Development) and
Special Secretary to the Government of India

January, 2019

PREFACE TO THIRD REVISION

The roads, particularly, the highways, are considered to be the lifeline of a country. Efficient road connectivity is an essential component not only for socio-economic growth of the region (s)/country but also helps in achieving balanced growth & inclusive growth. The construction of quality roads requires concerted actions on many fronts. The Pocket Book should be based on the latest codes, guidelines, practices, specifications and policies. This document will facilitate highway professionals as ready reckoner.

On the request of Ministry of Road Transport & Highways, the Indian Roads Congress under took the task of revision of Pocket Book for Highway Engineers. For this purpose, IRC constituted a Working Group comprising of Shri S.B. Basu, Chief Engineer (Retd.), MoRTH and Shri S.K. Nirmal, Secretary General, IRC.

The Working Group prepared the draft revision of Pocket Book, taking due guidance from the latest version of IRC Codes/ Manuals/Guidelines/ Specifications, MoRTH Policy Circulars and relevant BIS Standards.

Valuable suggestions received from Shri B.N. Singh, DG (RD) & SS, MoRTH; Shri I.K. Pandey, Addl. Director General, MoRTH; Shri Sanjeev Kumar, Chief Engineer [S&R(P&B) & Road Safety], MoRTH; Shri Varun Aggarwal, Superintending Engineer [S&R (P&B) & Road Safety], MoRTH; Shri Santosh Arya, Executive Engineer [S&R (P&B) & Road Safety], MoRTH were duly considered by the working group while revising the Pocket Book.

Shri Rahul Patil, Deputy Director (Tech.), IRC and Shri Sandeep Negi provided the necessary Technical /Secretarial support.

For revision of the Pocket Book, every effort has been made to bring out the best current practice (s). I am sure this Pocket Book in its present form would prove to be very useful to all practicing highway engineers. The Pocket Book, however, needs to be updated periodically with changes in technology and environment. The MoRTH/IRC would therefore welcome the feedback/suggestions from users for further updation.

(S.K. Nirmal)
Secretary General
Indian Roads Congress

New Delhi
January, 2019

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CHAPTER 1

GENERAL INFORMATION

1.1 Land, Terrain and Classification

India lies entirely in the northern hemisphere. The main land extends between latitudes of $8^0$4'N and $37^0$6'N, longitudes $68^0$7'East and $97^0$25' East and measures about 3,214 km from north to south between extreme latitudes and 2,933 km from east to west between the extreme longitudes. It has a land frontier of 15,200 km. The total length of coast line of the mainland, Lakshadweep Island is 7,516.6 km. The country has total land area of 3.3 million sq.km. India's population as on March, 2011 stood at 1.21 billion. India has 29 States and 7 Union territories. Indian Standard Time is GMT + 5.30 hrs. The mainland comprises of four regions namely, the great mountain zone, plains of the Ganga and the Indus, the desert region and the southern peninsula. The climate of the country can broadly be classified as a tropical monsoon one. But inspite of much of the northern part of India lying beyond the tropical zone, the entire country has a tropical climate marked by relatively high temperatures and dry winters. There are four seasons, namely winter, summer, south west monsoons and post monsoon seasons.

1.2 Road Classification

As per constitution of India, Union Government through the Ministry of Road Transport & Highways (MORTH) is responsible for development and maintenance of National Highways. State governments and Union Territories are responsible for the same, for roads other than National Highways in their respective jurisdiction.

1.2.1 Non-urban Roads:

Non-urban roads in the country are classified into following five categories:

1) **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 The total length of National Highways is 1,32,500 km.

2) **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. The total length of State Highways is 1,56,694 km.

3) **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.

4) **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.

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

   Other District Roads and Village Roads have been combined and known as Rural Roads.

   The total length of Major District Roads and Rural Roads is 53,12,117 km.

1.2.2. Urban Roads:

Urban roads are classified into the following four categories:

1) **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 centers take 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.

2) **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.

3) **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 neighborhoods, 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.

4) **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.

5) **Non-Motorized Transport (NMT) Streets and Greenways:** All motorized traffic will be prohibited, using barrier and enforcement of regulations to prevent their entry and encroachment of NMT space. Such streets will be designed in compliance with universal accessibility guidelines with bicycle parking and access for emergency response vehicles.

1.3 There are following types of roads according to the cross-section of the roads.

1) **Expressways –** These are arterial highways for motorized traffic, with divided carriageways for high speed travel, with full control of access and provided with grade separators at locations of intersection and for high mobility. Generally, only fast moving vehicles are allowed access on expressways.

2) **4 Lane/6 Lane/8 Lane roads –** These roads have divided carriageway and also partially controlled for access. Each carriageway are of either two lane or three or more lane standard.

3) **Two lane roads with or without shoulders -** These road have 7 m wide carriageway and the shoulders on both sides. Part of the shoulders may be paved or unpaved. MORTH has taken a policy decision that all National Highways, except on hill roads will be improved to a minimum standards of two lane carriageway with paved shoulders on both sides irrespective of the traffic intensity on the road.

4) **Intermediate lane roads:** The intermediate carriageway width of 5.5 m is adopted in exceptional circumstances particularly in hill sections. It has been decided to adopt 5.5 m carriageway in hilly stretches of National Highways carrying traffic less then 8000 pcu.

5) **Single lane road –** These are roads with single lane carriageway of 3.75 m width. These are provided for roads having low density of traffic.

1.4 MORTH implements National Highway Projects through the agencies of State Governments, National Highways Authority of India (NHAI), National Highways Infrastructure Development

Corporation Ltd. and Border Roads Organization (BRO). MORTH has also established Project Implementation Unit (PIU) in some states for execution of such project. The National Highways are entrusted to NHAI, BRO, State Government and NHIDCL for their development and maintenance.

NHAI executes high valued projects. NHIDCL has been entrusted with development of National Highways in hilly states and North Eastern Region of the Country. BRO is developing and maintaining National Highways in border area of the country. National Highways within the State except those entrusted to NHAI, NHIDCL and BRO are entrusted to the State Government concerned.

1.5 Modes of Implementation of Highway Projects

Based on the availability of funds, the projects are implemented either from the funds of the Project Authority (Public funded projects) or through the participation of private sectors (Public Private Partnership). For public funded projects, projects may be executed either by conventional "Item Rate Contract" or through the Engineering, Procurement and Construction (EPC) contracts. In item rate contracts, the responsibilities for design lie with the project authority whereas in the EPC contracts the design and development are the responsibilities of the contractors. There are three variants of PPP Projects namely BOT (Toll), BOT (Annuity) and Hybrid Annuity depending on the mode of financing. Present policy of Ministry is that procurement of item rate contracts is to be done only for works upto Rs. 5.00 crore.

1.6 Toll Plaza

As per amendments of the National Highways Act, 1956 the Central Government is empowered to levy fees for service benefits rendered in relation to use of ferry, bridges, tunnels and sections of National Highways. The fees when levied shall be collected in accordance with the rules made under this Act. The rules made are to be notified in official Gazette. The MORTH has also prescribed fees for such services by notifying the fee Rules in official gazette from time to time. As per notifications of September, 2018 MORTH is empowered to collect additional fees for overloaded vehicle.

As per present policy, two lanes in each direction of travel shall be provided with the system of payment through Electronic Toll Collection (ETC) out of which one lane shall be dedicated for ETC exclusively and the second lane shall be stand by ETC lane, stand by ETC lane may be converted to dedicated ETC lane in case of failure / maintenance of first ETC lane.

Legally, there are provisions which enable to collect user's fee (toll) in perpetuity from the vehicles plying on National Highways. Tolls are also source of financing for the projects implemented through PPP mode. Many State governments are also collecting tolls on the roads under the jurisdiction of the State Government. Tolls are collected at Toll Plaza which are constructed at convenient locations outside the influence of local traffic.

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CHAPTER 2

PROJECT PREPARATION

2.1 Preparation of highway projects involves a chain of activities, such as, field surveys and investigations, selection of alignment, carrying out various designs, preparation of drawings and estimates, etc. To be compatible with technical requirement, consistent with economy, it is essential that every project should be prepared after thorough investigations and collecting all relevant information and evaluating all possible alternatives. Detailed procedures of preparation of road projects including survey and investigation are detailed in IRC:SP:19 "Manual for Survey, Investigation and Preparation of Road Projects". The fundamental principle of route selection and alignment improvement is to achieve the least cost on transportation covering initial cost of construction, its maintenance and road user cost.

2.1.1 Broadly following stages are involved in preparation and sanction of project

1. Pre-feasibility study
2. Feasibility study/preliminary project report preparation including cost estimation
3. Detailed engineering and plan of construction

2.1.2 Fig. 2.1 gives a flow chart of the operations involved in highway project preparation.

2.1.3 A check list indicating the major operations involved in survey and investigation of a road project is given at Appendix 2.1.

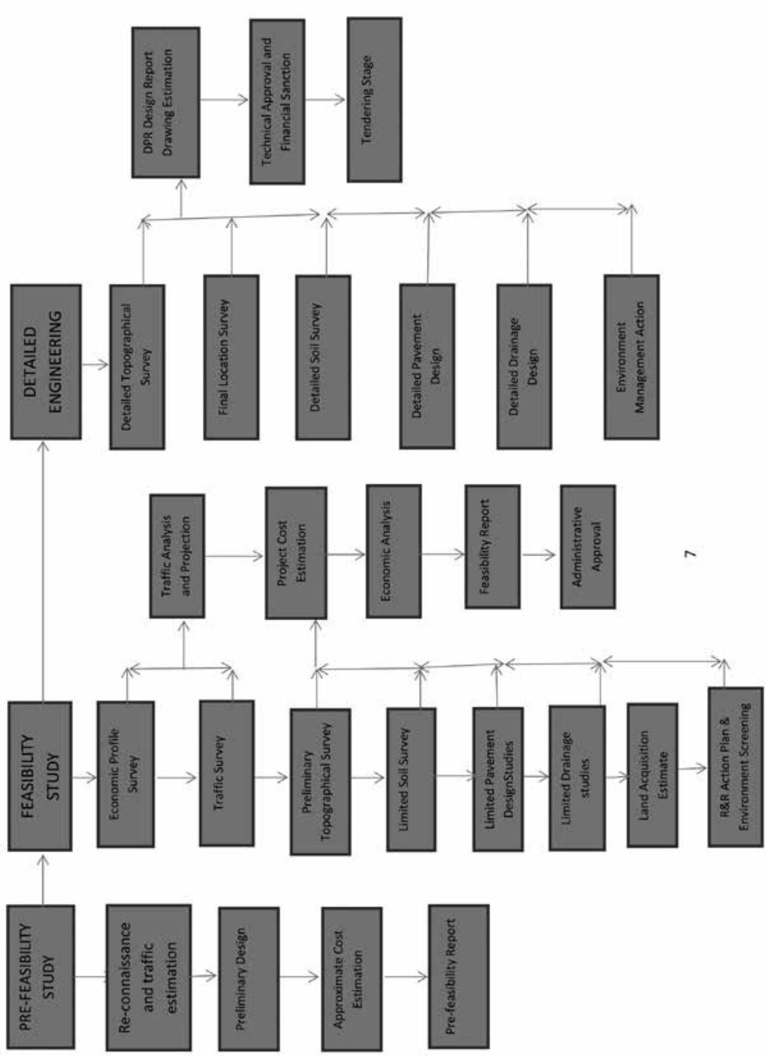

Fig. 2.1 Stages in Project Preparation

The details of various surveys, proforma for presenting the result and typical drawings are given in IRC:SP:19.

2.2 Traffic surveys and analysis

2.2.1 Information about traffic would form basis for fixing the number of traffic lanes, design of pavement, design of intersections and interchanges and economic appraisal of the project.

2.2.2 Following traffic surveys are required to be conducted in connection with the preparation of highway project:

(a) Classified traffic volume counts

(b) Origin – Destination Surveys

(c) Speed and Delay Studies

(d) Traffic Surveys for the design of Intersections and Interchanges

(e) Traffic Surveys for replacing railway level crossings with grade separators

(f) Axle Load Surveys

(g) Accident Records

(h) Pedestrian/animal cross traffic surveys

2.2.3 Classified Traffic Volume Count Surveys

The classified traffic volume count surveys shall be carried out for continuous 7 days (24 x 7) for both the directions. The count stations should be selected such that the result represents the traffic flow in homogeneous section of the highway. Guidance may be taken from IRC:9 “Traffic Census on Non-Urban Roads.” Traffic survey done by Indian Highway Management Company Limited (IHMCL) on National Highways using ATCC (Automatic Traffic Counter and Classifier) may be used. This survey is to be carried out using ATCC system or equivalent technologies for major project on important highways. A seven day count will give Average Daily Traffic (ADT) which can be converted to Annual Average Daily Traffic (AADT) applying seasonal correction and using conversion factors from any traffic count in the region.

2.2.4 Origin – Destination Surveys

When a new road is being planned or extensive improvements are to be carried out to an existing road or a bypass is under consideration, origin-destination survey is to be conducted. The points at which the data is to be collected should be carefully chosen on the road network such that it should be possible to derive the volume of traffic likely to use the facility under consideration. The survey should normally be conducted for three consecutive days on sample basis. For exceptional cases, in heavy density corridors and where the daily variation of traffic is not much, at least one day's survey may be conducted on a normal working day. IRC:102 "Traffic Studies for Planning Bypasses Around Towns" gives guidance in this regard. The commodity movement data should also be collected during the survey.

2.2.5 Speed and Delay Studies

Speed and delay studies on the existing facility provide the basis for estimating causative problems and benefits of the improved facility. The study is conveniently conducted by the 'Moving Observer Method'. By this method a task vehicle is run along with a traffic stream, at approximately the perceptible average speed of the traffic stream. A separate run is needed for each direction. The average of around six runs ensures accuracy of results. By noting down the travel time, including actual running time and stopped delays, the vehicles counted in the opposite direction and those overtaken/overtaking, it is possible to calculate the volume, speed and delay. For further information IRC:102 may be consulted.

2.2.6 Traffic Survey for Design of Intersections and Interchanges

For design of Intersection and Interchanges, turning movement surveys are to be carried out. For this purpose, it would be sufficient to have counts for 2 hours each in the morning and evening peak periods unless there exist extended peak hours. The methodology used in IRC:SP:41 "Guidelines on Design of At-grade Intersection in Rural and Urban Area" needs to be used.

2.2.7 Traffic Surveys for replacing Railway Level Crossing with Grade Separated Structures

It has been decided that all the railway level crossing on National Highways will be replaced by grade separated structures. For many projects particularly on State Highway, the decision regarding replacement of railway level crossings with grade separators is taken on the basis of product of gate closure and fast traffic per day. For this purpose, traffic counts should be taken in a week spread over three consecutive days and 24 hours each day if such information is not already available. The number and duration of gate closures should be ascertained from Railway authorities and also counted at site while conducting 24 hours survey. Information should also be obtained on the angle of crossings of the road way and the railway. If there is a requirement of improvement of geometrics of the approach roads, an index plan including the existing alignment is to be obtained.

2.2.8 Axle Load Survey

Axle load survey is needed to generate data for pavement design. This survey shall be carried out along with the classified volume count survey. Number of days of survey may vary between 24 hours and 3 days. For important NH projects the survey may be carried out for 2 normal days (24 hours). Axle load surveys in both direction shall be carried out on a random sample basis normally for truck only both empty and loaded trucks. However, a few buses may be weighed. Axle load survey shall normally be done using axle load pads or other sophisticated instruments. IRC:SP:19 contains the proforma for collecting data.

2.2.9 Pedestrian/Animal Cross Traffic Survey

For heavily trafficked section, this survey is required to determine the necessity of viaduct for safe pedestrian/animal crossings.

2.2.10 Accident Records

Accident records data base to be obtained for improvement of black spot on the road.

2.2.11 Traffic Projection

Traffic growth should be assessed in the first instance on the basis of observed traffic and other economic indicators. The technique has also been given in IRC:SP:19. IRC:108 "Guidelines for Traffic Prediction on Rural Highways" may also be referred. In addition, diverted traffic and generated traffic are also to be considered. The period of projection depends on the type of the project, importance of the road, availability of finances and other relied factors. For major trunk routes, the desirable and minimum forecast periods are15/20/30 years and 10 years in case of stage construction respectively.

2.3 RECONNAISSANCE SURVEY

2.3.1 The main objective of reconnaissance survey is to examine general character of the area for the purpose of determining the most feasible routes or route for further detailed investigations. This can be accomplished by:

a) Study of digital maps, topographical survey sheets, agricultural, soil, geological and meteorological maps and aerial photographs.

b) Where necessary and feasible, aerial reconnaissance

c) Ground reconnaissance

2.3.2 Study of Survey of India (SOI) maps is useful. The topo sheets are available in the scale of 1:25,000, 1:50,000 and 1:250,000.

2.3.3 In addition to these, special purpose maps like Forest Survey of India maps, vegetation maps, National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) maps, Geological Survey of India maps, wherever available may also be consulted for other details which will be helpful in selection of alignment.

2.3.4 Satellite remote sensing, small format aerial photography, photogrammetry, aerial photography are also useful in difficult terrain. Aerial reconnaissance will help to take final decision about the alignment to be studied in detail.

2.3.5 Based on the information collected during the reconnaissance survey, a report should be prepared. The report should include all relevant information collected during the survey, a plan to the scale of 1:50,000 or larger as available showing the alternative alignments studied alongwith their general profile and rough cost estimates. It should discuss the merits and demerits of the different alternatives to help the selection of one or more alignments for detailed survey and investigation.

2.4 PRELIMINARY SURVEY

2.4.1 The preliminary survey is a large scale instrument survey conducted for the purpose of collecting all the physical information which affects the proposed location of a new highway or improvements to an existing highway. During this phase of the survey, topographic features and other features, which affect highway locations like house, kiosk, monuments and place of worships, cremation or burial grounds, utility and railway lines, stream, river, canal, cross drainage structures are collected. In addition general information like traffic, soil, construction materials, drainages etc. are also collected. All these details are collected for preparation of an accurate base plan showing all these features. Plans and longitudinal section drawing are referred to for detailed study to determine the centre line of the road.

2.4.2 For land based survey, Mobile LiDAR (Light Detection and Ranging) or equivalent technology are to be used for important projects. Aerial mobile LiDAR or equivalent technology are to be used for such projects. This is for meeting the requirement of high accuracy in surveys. In areas, where LiDAR or equivalent technology cannot survey accurately, traditional methods of Total Station/Auto level shall be used to complete the study.

2.4.3 Scales for drawings of Plans and Longitudinal sections are adopted as per follows:

Table 2.1 Scales for Drawings

Horizontal Scale		Vertical Scale
Built up areas and hilly terrain	1:1,000	1:100
Plain and rolling terrain	1:2,500	1:250

The plan should also show contours at 1-3 m interval particularly for roads.

2.5 Environmental Impact Study and Resettlement and Rehabilitation Action Plan

2.5.1 The Environmental Impact Assessment (EIA)

2.5.1.1 The Environmental Impact Assessment (EIA) has become an integral part of highway project preparation work. EIA study is taken up concurrently with the project of feasibility report or the detailed project report. The main purpose of EIA is to identify the environmental impact of the project proposal and its different alternatives, weigh their significance and severance, propose possible mitigating measures and provide necessary information for taking decision regarding the overall acceptability of the project from environmental angle.

2.5.1.2 Environmental impact assessment for the projects funded by Government of India or the state government concerned is to be carried out as per latest guidelines of the Ministry of Environment and

Forest and Climatic Change (MoEFCC). In this regard, IRC:SP:93 "Guidelines on Requirements for Environmental Clearances for Road Projects" may be referred. In respect of highway project, environment clearances are required for green field projects of both National Highways and State Highways, expansion of National Highway greater than 100 km length involving additional right of way or land acquisition greater than 40 m on existing alignment and 60 m on realignments or by passes, State Highway expansion projects in hilly terrain (above 1000 m AMSL) and/or ecologically sensitive areas. Environmental clearances for other projects are not required. It is desirable to consult the website of MOEFCC for their latest guidelines on this subject. For projects funded by external agencies like ADB, World Bank, etc., the environmental impact assessment is to be carried out as per the guidelines of the funding agencies concerned as amended from time to time.

2.5.2 Environment Management Plan (EMP)

2.5.2.1 An Environment Management Plan (EMP) is required to be prepared and implemented in compliance with the statutory environment clearance of a highway project. The clearances are accorded on the basis of submission of EIA by the Project Authority. Promises made by the project authorities while submitting the EIA and the conditions attached by the MOEFCC while according the clearance form the basis for preparation of an EMP, which is implemented during the project execution or operation by the contracting agencies and monitored by the project authorities.

2.5.2.2 The EMP is an extremely important document containing specific measures and proposals aimed at prevailing or mitigating the adverse impact on the environment to ensure its implementation. EMP has to be a part of contract document. The detailed method of preparation of EMP and its implementation are given in IRC:SP:108 "Guidelines on Preparation and Implementation of Environment Management Plan".

2.5.3 Resettlement and Rehabilitation Action Plan (RAP)

2.5.3.1 Whenever project will entail acquisition of land, structures and other assets and cause displacement or loss of assets within the right of way, a socio-economic base line study and preparation of a Resettlement and Rehabilitation Action Plan (RAP) should be undertaken as a part of the project. Since acquisition of land and other assets may be unavoidable and an integral part of the project design and implementation, undertaking a social impact assessment and preparing RAP is also to be included as a part of project design from the start and undertaken in close coordination with environment analysis and environmental action plan. The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 are to be followed for rehabilitation measures. For projects funded by external agencies like ADB, World Bank guidelines of the agencies concerned in this regard are to be followed.

2.6 Feasibility Report

2.6.1 A feasibility report is prepared after the preliminary survey is completed. This report is intended to serve as the basis for according Administrative Approval (AA) for the project by the Project Authority concerned. The Feasibility Report must establish the economic viability and technical soundness of the alternative selected. Thus it must be preceded by engineering surveys and investigation of sufficient accuracy and details as to results in a fairly firm estimation of the cost of the project. It must be based on accurate traffic projections and must contain an economic analysis.

Feasibility Report also includes the economic analysis based on current costs. This may be carried out as per IRC:SP:30 “Manual on Economic Analysis of Highway Projects in India” or using HDM IV after suitable calibration for Indian condition. A sensitive analysis is also to be carried out for different scenarios of benefits and costs.

In case of project being implemented through Public Private Partnership, the financial analysis with different scenario must be presented.

2.6.2 The feasibility report must be accompanied by the drawings like locality map, plan, typical cross section showing pavement details, cross drainage and other structures, intersection drawings, strip plan, preliminary LA plans. A check list for a highway Project Feasibility Report is given at Appendix 2.2.

2.7 Selection of optimum alignment in the design office

2.7.1 Making use of the maps from preliminary survey showing the longitudinal profile, cross sections and contours, a few alternative alignments for the final centre line of the road are drawn and studied and the best one satisfying the engineering, aesthetic and economic requirements is selected. The alignment determined in the design office shall be checked in the field, especially when data base is not adequately updated.

2.8 Final Location Survey

2.8.1 The purpose of the final location survey is to lay out the centerline of the road in the field based on the alignment selected in the design office and to collect necessary data for preparation of the working drawings. Taking of longitudinal section along the selected centre line and cross sections are also part of the final location survey. The accuracy of the survey should be first checked by senior professionals. This will also generate precise land acquisition requirements. The two main operations involved in the survey are the staking out of the final centre line of the road by means of a continuous survey and detailed leveling. The centre line of the road as determined in the design office is translated on the ground by means of continuous transit survey and staking out of the centre line as proceeds. All the Horizontal Intersection Point (HIP) and intermediate Points of Transit (POT) on long tangents should be fixed on hubs on new roads and by means of spikes or nails into the pavement of existing roads. Bench marks are also to be established at 2 km interval for vertical control for location, design and construction, Temporary bench marks at an interval of 250 meters are also to be established

2.8.2 Cross section should be generally taken at an interval of:

Interval (in metre)

50 – 100	-	For plain terrain
50 – 75	-	For rolling terrain
50	-	For built up areas
20	-	For hilly terrain

2.8.3 All the points referencing the centre line and bench marks should be protected and preserved and are to be so fixed at site that there is little possibility of their being disturbed or removed till the construction is completed. The final location survey is considered complete when all the necessary information is available and ready for the designer to be able to plot the final road profile and prepare the project drawings.

2.9 Soil and Material Survey

2.9.1 Soil and other material survey are required to determine the nature and physical characteristics of soil and soil profile for design of embankment and pavement, classification of earth work, subsoil water level and flooding service, sources and suiatibility of aggregates and lead of aggregates and manufactured items.

(i) To determine the nature and physical characteristics of soil and soil profile for design of embankment and pavement including location of possible borrow areas.

(ii) To determine the salt content in soil in areas known to have problems or where the compositions of the design crust requires such testing.

(iii) To determine the proper method(s) of handling soils

(iv) To classify the earthwork involved into various categories such as rock excavation, earthwork in hard soil etc.

(v) To gather general information regarding sub-soil water level and flooding;

(vi) To locate sources for aggregates required for pavement and structures and to ascertain their availability and suitability for use. Source and lead of available manufactured items at economical cost.

(vii) Locate source of good quality water suitable for use in different items of works particularly the current work.

(viii) To design pavement both flexible and rigid pavement.

2.9.2 Investigations for soil and other materials required for construction are carried out in respect of the likely sources and the availability and suitability of materials. Some other investigations, for instance in respect of landslide prone locations may also be conducted at this stage.

2.9.3 The soil and materials location surveys should include study of all available information such as geological maps, data published by the various authorities regarding location of construction materials and the information available with ground water authorities regarding depth of water table. This information should be perused in conjunction with general information gathered during the preliminary survey.

2.9.4 The guidelines and directions contained in various codes and guidelines relevant to the subject of study are to be followed for collection of samples, testings to be done and reporting test results. All the required tests as prescribed in the relevant guidelines and codes are to be conducted as per IS codes as applicable to the tests to be conducted. The test methods as prescribed in the relevant IRC codes and guidelines are to be followed where IS codes are not available.

2.10 ROAD INVENTORY AND CONDITION SURVEY

2.10.1 For highway projects involving improvement to an existing road it is necessary to prepare a road inventory and carry out condition survey to assess the existing condition of the road and structures. The details to be collected and the format for presentation of data are available in IRC:SP:19. Details available with the project authorities in this regard are to be made use of. The inventory data should be stored in computer files using simple utility packages, such as Excel.

2.11 DRAINAGE STUDIES

2.11.1 Adequate information about drainage pattern is necessary to devise an effective drainage system. Drainage studies have the following principal objectives:

(i) Fixing the grade line of the road

(ii) Design of pavement, and

(iii) Design of the surface/sub-surface drainage system

2.11.2 Main components of the drainage investigations are determination of HFL and ponded water level, depth of water table, range of tidal levels and amount of surface runoff. Besides this, for cut sections in rolling and hilly areas, it would be necessary to carry out special investigations for sub-terrane flows and seepage of irrigation water from fields situated above the road.

2.12 STUDY OF CROSS DRAINAGE STRUCTURES

2.12.1 For cross drainage structure i.e. culverts, surveys and investigations are carried out essentially for (i) selection of site and (ii) collection of data for design of the structures. Survey and investigation for culverts are to be carried out as per IRC:SP:13 “Guidelines for the Design of Small Bridges and Culverts.”

2.13 Detailed Project Report

2.13.1 The project data collected during the survey and investigation together with the proposed work out on that basis should be presented in a proper form. This is to be prepared in three parts under the following headings.

(i) The Report

(ii) Estimate

(iii) Drawings

2.13.2 The report part of the DPR may be given under following heads

(i) Executive summary

(ii) Introduction

(iii) Socio-economic profile

(iv) Traffic surveys including traffic forecasts

(v) Engineering surveys and investigations, and proposed road features

(vi) Pavement studies

(vii) Design standards and specifications

(viii) Drainage facilities including cross-drainage structures

(ix) Environmental and social considerations including rehabilitation and resettlement

(x) Materials, labour and equipment

(xi) Rates and cost estimates

(xii) Economic analysis and financial analysis (where required)

(xiii) Construction constraints and programme

(xiv) Miscellaneous

(xv) Conclusion and Recommendations

The design calculations, etc. with regard to the above items should be attached.

2.14 Estimates

2.14.1 The estimation of quantities shall be based on detailed design and drawings of various components of the project. The rates for different items of works shall be on the basis of Schedule of rates of the State where the works being executed. For items not covered in the schedule of rates, the rates shall be based on analysis of rates as per MORTH Standard Data Book and market rates for the inputs. For externally aided projects, rates are to be compared with the similar ongoing works being funded by the agency.

2.14.2 The estimate shall be presented in the following format

1. General abstract of cost
2. Detailed estimate for each major head
   - (i) Abstract of cost
   - (ii) Estimates of quantities
   - (iii) Analysis of Rates
   - (iv) Quarry/material source chat

2.14.3 The estimate shall also provide for the following items

- Toll Plaza
- Arboriculture and Landscaping
- Traffic Safety features, Road furniture and Road Markings
- Weighing Station, Parking areas and Rest Areas wherever required

- Environmental and social safeguard

2.14.4 In addition to the itemwise cost centage charges are also to be added. For National Highways Projects, Contingencies, Quality Control, Worked charged & establishment and Agency charges are to be added. For the projects being funded and executed by the states, the centage charges are added as per latest orders of the State Government concerned.

2.15 Drawings

2.15.1 The drawings usually required for a road project include the following

(i) Locality map-cum-site plan

(ii) Strip plan showing the location of utilities existing and proposed right-of-way, toll plazas, trees and junctions interchanges, etc.

(iii) Land acquisition plans (Scale 1:2000 to 1:8000)

(iv) Plan and longitudinal section (Scale 1:2,500 for horizontal and 1:250 for vertical)

(v) Typical cross-section sheet (Scale 1:50)

(vi) Detailed cross-sections (Scale 1:100)

(vii) Drawings for cross-drainage structure (1:50)

(viii) Road junction drawings and interchanges drawings (Scale 1:500 or 1:600)

(ix) Drawings for retaining walls and other structures.

(x) Drawings for road signs, markings, toll plazas and other facilities.

2.15.2 Drawings should be prepared by using the software of Autocad in a computer using standard software.

2.16 For National Highways and other important highway projects the Detailed Project Report are to be prepared and submitted as per the Terms of Reference (TOR) as circulated in the MoRT&H letter No. H-39011/30/2015-P&P (Pt-I) dated 22nd August, 2016.

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Appendix 2.1

CHECK LIST OF MAJOR OPERATIONS INVOLVED IN THE SURVEY AND INVESTIGATION FOR A ROAD PROJECT

1. Reconnaissance Survey

(i) Map Study

(ii) Aerial reconnaissance

(iii) Ground reconnaissance

2. Preliminary Survey

(i) Collection of general information about traffic, soil, subsoil and surface drainage, etc.

(ii) Establishment of reference bench marks

(iii) Traverse survey

(iv) Fly levels and cross-sections

(v) Map Preparation

3. Determination of Final Centre Line in the Design Office

4. Final Location Survey

(i) Staking of final centre line

(ii) Referencing HIPs, POTs, etc.

(iii) Establishment of permanent bench marks

(iv) Longitudinal and cross-sections

5. Survey of Economic Profile

(i) State's and road influence area's economic profile

(ii) Transport system in the State

6. Traffic Surveys

(i) Study of data from record

(ii) Traffic counts, O-D. Surveys, etc.

(iii) Traffic projections

(iv) Collection of traffic particulars for railway level crossings and road junctions

(v) Axle load surveys

(vi) Analysis of accident records

7. Soil and Materials Surveys

(i) Study of available information

(ii) Soil investigations for low embankments and demarcation of borrow areas

(iii) Special investigations for high embankment

(iv) Detailed investigations for flexible pavement/rigid pavement

(v) Survey and evaluation of naturally occurring aggregates

(vi) Manufactured aggregates/items

(vii) Water for construction purposes

8. Drainage Studies

(i) HFL and ponded water level

(ii) Depth of sub-soil water table

(iii) Special investigations for cut sections and seepage glows

(iv) Surface run-off

9. Cross-drainage Structures

(i) Site selection

(ii) Collection of hydraulic and foundation data

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Appendix 2.2

CHECK LIST FOR A HIGHWAY PROJECT FEASIBILITY REPORT

1. FEASIBILITY REPORT

1.1 Executive Summary

1.2 Economic and social setting

(i) State's economic profile, including GDP, agricultural production, industrial output, mining, etc. and their growth rates.

(ii) State's population and growth rates

(iii) Potential of industrial and other economic growth in the project influence area

1.3 Transport system of the State

(i) Main transport modes and their extent

(ii) Road network in km by classification, carriageway width and surface type

(iii) Vehicle fleet and its growth

(iv) Annual expenditure on roads (original works and maintenance) by road class

(v) Annual road taxes (State and Central)

(vi) Profile of road transport industry

(vii) Road maintenance norms and allotments

(viii) Road accident statistics

(ix) Consumption of petrol and diesel and growth trend

1.4 Organizational structure of P.W.D./Highways Department

1.5 Socio-economic profile of the project area

1.6 Project description

(i) Scope

(ii) Necessity

(iii) Source of funding and budget provision

(iv) Selection of route

(v) Management

(vi) Alignment

(vii) Cross-sectional elements

(viii) Drainage facilities

(ix) Construction technology

1.7 Methodology adopted for the studies

(i) Division into homogenous sections

(ii) Traffic studies like classified counts, Origin-Destination, Axle Load Survey

(iii) Traffic growth rates

(iv) Road inventory, including roughness data

(v) Survey and investigation results

- Soil Surveys
- Material survey
- Pavement deflection data

- Design of cross-drainage works

1.8 Design Report

(i) Project road inventory

(ii) Engineering survey and investigation data

(iii) Design standard and specifications

(iv) Special site conditions effecting design

(v) Pavement design

(vi) Design of cross-drainage and other structures

1.9 Cost estimates

(i) Item rates and rate analysis

(ii) Escalation

1.10 Construction programming

1.11 Economic analysis

(i) Vehicle operating costs

(ii) Time costs

(iii) Accident costs

(iv) Economic costs and benefits

(v) Shadow pricing

(vi) Sensitivity analysis

(vii) Discussion of results

1.12 Construction arrangements

(i) Prequalification procedure

(ii) Bidding procedure

(iii) Supervision arrangements

1.13 Conclusions and recommendation

2. DRAWINGS

(i) Locality map

(ii) Plans showing various alternative alignments considered and the selected alignment.

(iii) L-sections of the selected alignment

(iv) Typical cross-sections showing pavement details

(v) Strip plan

(vi) Drawing showing cross drainage and other structures

(vii) Road junction plans

(viii) Roadways land acquisition plan

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CHAPTER 3

PRECONSTRUCTON ACTIVITIES

3.1 Land Acquisition

3.1.1 National Highways

Land required for development, maintenance and operation of National Highways are acquired as per the National Highways Act, 1956 (NH Act),

3.1.2 Section 3 of NH Act pertains to the acquisition of land. This Act provides for a "competent authority' who is authorized by the Central Government by notification in the official gazette to perform the functions of the competent authority for such area as may be specified in the notification. Steps as described below are to be followed for acquisition of land for works on National Highways.

a) Section 3A – The intention of acquisition of land for National Highway works are to be declared by a notification in the official gazette. The competent authority shall cause the substance of the notification to be published in two local newspapers one of which will be in vernacular language.

b) Section 3B – Any person authorized by the Central Government, after the issue of the notification as per Section 3A, can make any inspection, survey including taking levels, dig or bore into subsoil, set out boundaries and intended lines of works etc.

c) Section 3C – This section empowers any person interested in the land may within twenty one days from the date of publication of the notification as per Section 3A may object for the use of land. This objection has to be in writing with the grounds thereof and to be made to the competent authority. The competent authority gives an opportunity to the objector of being heard either in person or by a legal practitioner and either allows or disallows the objections after hearing all such objections and after making such enquiry as may be necessary.

d) Section 3D- If there is no objection to the land notified under section 3A or where objections have been disallowed, the competent authority shall submit a report to the Central Government and Central Government shall as soon as may declare by notification in the official gazette that the land should be acquired for the purpose of National Highways. On publication of this notification, the land vest absolutely in the Central Government free from all encumbrances. In respect to any land if no declaration under Section 3D is made with a period of one year from the date of publication of notification issued under Section 3A, then this notification shall cease to have any effect.

e) Section 3E – After issue of notification as per Section 3D and depositing the amount for compensation with the competent authority, the competent authority may direct the owner or any other person who may be possession of such land to surrender or deliver the land to the competent authority or any other person as authorized by him within sixty days of the service of notice. The Competent authority shall apply either to the Commissioner of Police or the District Collector as the case may be if any one fails to comply to surrender the land and the Commissioner of Police or District Collector shall enforce such order.

f) Section 3F – Under this section, any person authorized by the Central Government can legally enter and carry out for any work pertaining to National Highway when the land is vested under Section 3D.

g) Section 3G – This section is for determination of the amount payable as compensation for acquisition of any land under this Act. As per policy it has now been decided that the determination of compensation amount and rehabilitation and resettlement of project affected people shall be as per "The Right to Fair Compensation and Transparency in Land Acquisition Rehabilitation and Resettlement Act, 2013". (RFCTLARR Act, 2013)

h) Section 3H – The amount determined under Section 3G shall be deposited by the Central Government with the competent authority before taking possession of the land.

3.1.2.1 MORTH has brought out "A Manual of Guidelines on Land Acquisition for National Highways under the NH Act, 1956" in December, 2018. This Manual is compilation of Ministry's circulars on this subject, guidelines on the process of acquisition of land and other relevant details.

3.1.2.2 MORTH has also taken e-initiative to track land acquisition process. This is a web based portal named as 'BhoomiRashi'. The objective of the portal is to develop a Land Acquisition (LA) system which would provide linkage across authorities, eliminate the need of physical copy, reduce formatting errors/clerical mistakes and easy tracking of the draft notification. The 'BhoomiRashi' portal comprises details of 724 districts, 6494 sub districts (tahsil/taluka) and 6,57,424 villages of the country.

3.1.2.3 MORTH as issued a circular No. NH-15017/21/2018-P&M dated 10th May, 2018 brining out the policy guidelines for land acquisition, tree felling and utility shifting across the alignment. It has been decided that the project implementation agencies shall undertake additional land acquisition on one side of an existing road to the extent feasible for expansion of existing roads to next level of configurations. The acquisition side shall be decided based on the intensity of the existing utilities and trees (following overall cost savings principle) and such side may change form on stretch to another stretch depending upon the most optimal alignment. In addition, other guidelines have also been given to minimize the requirement of additional land acquisition, optimization of utility shifting and felling of trees.

3.1.3. State Highways

The land required for development, maintenance and operation of State Highways are to be acquired following the procedure as per "The Right to Fair Compensation and Transparency in Land Acquisition and Resettlement Act, 2013". The compensation for acquisition of land and rehabilitation, resettlement of the affected persons are also to be done as per this Act, The details of this Act, are available at the website of www.legislative.gov.in

3.2 Environmental Clearances

3.2.1. Environmental and social legal framework

The Constitution of India directs the State to endeavor to protect and improve the national environment and to safeguard the forests and wildlife of the country. Article 51 (g) of the Constitution states that it shall be the duty of every citizen of India to protect and improve the national environment including forests, lakes, rivers and wildlife and to have compassion for living creatures. In order to achieve above objectives the Government of India has created a legal framework for highway projects and are to be followed strictly. The details are available IRC:SP:-93 "Guidelines on Requirements for Environmental Clearances for Road Projects".

3.2.2 Clearance Requirements for Road Projects

3.2.2.1 Clearance Requirements of Project Authorities

- Environmental Clearance (EC) is required for only certain categories of National Highway and State Highway projects, as explained in the subsequent section, under EIA notification, 2006.

- "Consent to Establish" a project is required under the Air Act and Water Act.

- "Consent to Operate" a Plant or Machinery is required under the Air Act and Water Act.

- Clearance from the Coastal Zone Management Authorities (CZMA) of the concerned State is required for projects located in earmarked coastal areas, under the CRZ notification.

- Forest clearance is required for all such projects where a forest area is to be diverted for the project, under the Forest Conservation Act, irrespective of the type of forest or area of forest under diversion.

  If a roadside plantation on the Right of Way (ROW) of the road is notified as a Protected Forest, use of any area under such plantation for road widening is construed as Diversion of Forest Land, and Forest Clearance (FC) is required for the project.

- Wildlife clearance is required for all such projects where the project is located in a Protected Area (PA), which is a collective term for National Parks, Wildlife Sanctuaries, etc.

- Clearance from the Inland Waterways Authority is required in case the project alignment crosses a navigational channel.

- NOC from Central Ground Water Board is required for drawing ground water in notified blocks.

- NOC from Archeological Survey of India is required for any construction/operation within a certain notified distance of a protected monument.

3.2.2.2 Clearance Requirements for Road Projects at pre-construction Stage by Contractors

- Consent to Establish and operate from State Pollution Control Board under the Air Act and Water Act for Hot Mix Plant and Aggregate quarry.

- Hazardous Waste Authorization under the Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2009 from State Pollution Control Board.

- Environmental Clearance from the District Level appraisal committees for borrowing of ordinary earth and extraction of minor minerals.

3.2.2.3 Procedure for obtaining Environmental Clearance

a) The process of obtaining environmental clearance for road projects has been described in EIA notification 2006, as amended from time to time. As per the present policy, environmental clearance is required for all green field projects i.e. expressways and new alignments, widening of national highway more than 100 Km length involving additional land acquisition greater than 40 m on existing alignment and 60 m on realignment or by passes and State Highway widening projects in hilly terrain (Above 1000 m AMSL) and/or ecologically sensitive areas. Environmental clearance is not required in the following cases of existing highways and expressways.

1. Road development projects other than State Highways and National Highways.

2. State Highway widening project located below an altitude of 1000 m AMSL

3. State Highway widening projects not located in an ecologically sensitive area

4. National Highway widening upto 100 km length

5. National Highway widening project of more than 100 km length involving land acquisition upto 40 m (at any place) on existing alignment and 60 m (at any place) on re-alignment or bypasses.

b) The Ministry of Environment, Forest & Climate changes (MOEFCC) has developed a single web portal for submission of proposals for Environment Forest and Wild Life Clearances. The portal is known as "Online Submission & Monitoring of Environment Forest and Wild Life Clearances (OSMEFWC). The portal is accessible at URL- http://efclearance.nic.in.

The project authorities need to register on the portal. After successful registration, the application for seeking Terms of Reference (TOR) for conducting the Environment Impact Assessment (EIA) for the project for seeking Environment Clearance (EC) may be uploaded on line. The stepwise process for uploading the applications is provided on the portal. Alongwith the online submissions, the project authorities are also required to submit hard copies of the application and other documents.

c) The environment clearance procedure can be divided into four stages

- Screening (only for State Highway Projects)
- Scoping – Scoping refers to the process of finalization of the Term of Reference (TOR) for

the EIA study, so that the outcome of EIA and resultant Environment Management Plan (EMP) is precise and relevant to the environmental settings of a particular project.

- Public Consultation – Public consultation refers to the process by which the concerns of local affected persons and others who have plausible stakes in the environment impacts of the project or activity are ascertained with a view taking into account all the material concerns in the project or activity design as appropriate public consultation is not required for widening projects not involving acquisition of land and projects in border states.

- Appraisal – Appraisal refers to the detailed scrutiny by the Expert Appraisal Committee (EAC) of the application, final EIA report and public hearing proceeding for grant of environmental clearance. On conclusion of the proceedings, the EAC makes categorical recommendation to the regulatory authority concerned either for grant of prior environmental clearance on stipulated terms and conditions, or rejection of the application together with reasons for the same. The appraisal by EAC is completed within six days of the receipt of the final EIA and other documents. The EAC's recommendations are placed within next fifteen days before the competent authority for a final decision.

- The regulatory authority conveys its decision to the applicant within forty five days of the receipt of the recommendation of EAC. The disagreement, if any, alongwith the reasons with the recommendation of EAC is also to be sent to the EAC for reconsideration. The EAC's response on this issues is made within next sixty days. Within next thirty days the views of the authority which is final is conveyed to the applicant.

- Validity of Environment Clearance is for five years for highway projects. It can be extended to maximum period of seven years provided an application is made to the regulatory authority by the applicant.

- It is mandatory for the project management to submit half yearly compliance report in respect of the stipulated prior environmental clearance terms and conditions in hard and soft copies to the regulatory authority concerned, on 1st June and 1st December of each calendar year.

3.3 Coastal Regulation Zone Clearance

a) As per notification dated 06.01.2011 under Section 3 (1), Section 3 (2) (v) and Section 5 (3) (d) of the Environment (Protection) Act, 1986 certain coastal stretches have been declared as Coastal Regulation Zone (CRZ) and activities in the CRZ are thereby regulated.

In general, if a highway project passes within 500 m from the high tide line or crosses back water/creak etc., a prior CRZ clearance is required from Coastal Regulation Zone Management Authorities (CZMA) and MOEFCC. The boundary of 500 m is, however, of sacrosant and the only way to ascertain the limits of CRZ is to refer to the CRZ map of the State.

For regulating development activities, the coastal stretches within 500 m of high tide line on the landward side have been classified into four categories of Category I (CRZ-I), Category II (CRZ-II), Category III (CRZ-III) and Category IV (CRZ-IV). In CRZ-III, with a population density of 2161 per square kilometer as per 2011 census shall have a no development zone (NDZ) of 50 m from the High Tide Line (HTL) and in areas having population density of below 2161 pe square km as per 2011 census NDZ of 200 m is to be maintained.

b) Clearance Procedure

The CRZ notification provides elaborate regulatory requirements for different types of CRZ area. Generally, development activities are not allowed in sensitive CRZ zone. The project authorities are required to consult CZMA of the state for submitting the prescribed application. The alignment map of the highway project is superimposed on the CRZ map of the State to ascertain the location of the project in the CRZ.

If a road project does not otherwise require Environmental Clearance (EC) as per the provisions of EIA notification, 2006, EC is still required in case the project alignment falls in the CRZ area.

3.4 Forest Clearance

a) For any road project where a forest area is required to be taken under road construction, clearance for diversion of forest land for non-forestry purpose is necessary from MOEFCC as per statutory provisions. MOEFCC has ten Regional Offices (ROs). The ROs are authorized to clear linear projects, irrespective of the area or type of forest involved.

b) Procedure for diversion of forest land

The application is submitted online using the web portal of MOEFCC. The stepwise procedure for uploading the application form and other documents is given on the web portal. Hard copies, in prescribed format along with prescribed documents are also required to be submitted by the project proponent, after registration with the office of the Forest Circle concerned to the designated Nodal officer of the State and to the DFO (s) concerned under whose jurisdiction the forest area proposed to be diverted falls.

Forest clearances proposals are procured in two stages. In the first stage, in principle approval is granted (or rejected) for diversion of forest-areas, alongwith certain conditions.

The final (second stage) clearance is issued by MOEFCC after fulfillment of the conditions stipulated in the first stage and receiving any undertaking regarding compliance of the conditions which are due to be fulfilled in due course.

After the receipt of Compliance Report, fulfilling the conditions stipulated in Stage-I (in-principle approval) from the user agencies through the respective State/ UT Governments, Stage-II clearance is accorded by concerned RO of MOEFCC. Following this, the project authorities are handed over the forest land for non-forestry use, by the State Government, provided they have other requisite clearances also. However, for linear projects, tree cutting permission and working permission is granted by the concerned DFO after the Stage-I clearance, after confirmation from the Central

Government that the user agency has deposited the requisite amount for Compensatory Afforestation, NPV, etc.

3.5 Procedure for obtaining Wild Life Clearance

When a road through a protected Area (PA) viz. a National Park, Wild Life, Sanctuary or biosphere reserve etc., prior wild life clearance is necessary from National Board of Wild Life even if the project does not involve diversion of forest land from the PA. In case of forest land diversion is also involved, the proposal of forest clearance for such areas is also processed simultaneously both online and in hard copies. However, forest clearance in such cases is received only after securing wildlife clearance. Even surveys and geotechnical studies in PA require prior clearance from the National Board of Wild Life.

In case of PA the online proposal of forest clearance is submitted first. The proposal for wild life clearance then can be submitted. The stepwise procedure for uploading of web portal is given on the web portal.

The detailed procedure and format of application for all the clearances as mentioned above are described in IRC:SP:93.

3.6 Other Relevant Clearances

3.6.1 Clearance for Eco-Sensitive Zones

a) All the PAs have Eco-Sensitive Zones (ESZ) earmarked all along the periphery of a particular PA. The limits of an ESZ are notified, and vary across the PAs, and along different directions outside a PA. However, unless such boundaries are notified, a 10 km radius from the boundary of a PA is taken as the ESZ. Clearance for such areas is required, only in case the project requires Environment Clearance. In such an eventuality, clearance for the ESZ of a PA is granted by the Standing Committee of the National Board of Wildlife, as per the procedures for Wildlife Clearance.

b) For the areas covered under the Project Tiger, even outside the core area of a PA, and the migratory corridors of Tigers contagious to such areas, clearance is required from the Standing Committee of the National Board of Wildlife on recommendation of the National Tiger Conservation Authority (NTCA) as per the procedure for Wildlife Clearance, under Section 38 (O) (G) of Wildlife Protection Act.

c) For all other ESZs, notified under the Environment Protection Act, clearance is considered as a part of Environment Clearance, only if the requirement of EC is triggered.

3.6.2 Permission from State/Central Ground Water Authority

For the construction of highway, if water requirements are met through ground water, prior permission is required from State/Central Ground Water Board.

3.6.3 Permission of Irrigation Department/Water Resource Department

For the construction of highway, if water requirements are met through River/Canal, etc., prior permission is required from Irrigation Department/Water Resource Department.

3.6.4 NOC from Archaeological Department

As per the provisions of the Ancient Monuments and Archacological Sites and Remains Act, it has been notified that every area, beginning at the limit of the protected area or the protected monument, as the case may be, and extending to a distance of one hundred metres in all directions shall be prohibited area in respect of such protected area. or protected monument. Having regard to the classification of any protected monument or protected areas Central Government may specify an area more than 100 metres to be the prohibited area. No permission for carrying out any public work or project essential to the public or other construction, shall be granted in any prohibited area.

Every area begin in at the limit of prohibited area in respect of every ancient monument or archaeological site and remains of national importance and exending to a distance of 200 metres in all directions shall be regulated area in respect of such monuments and archaeological site and remains. For carrying out any construction or reconstruction or repair or renovation necessary permission is to be obtained from archeological department.

3.6.5 Permission for Quarrying and Borrowing Operations

At the time of construction of highway, permission of Department of Geology and Mines, State Government is required for new quarry and borrowing operations. Environmental Clearance is required for extraction of minor minerals as follows:

a) For mining area upto 5 ha- From District Level Environmental Impact Assessment Authority (DEIAA)

b) For mining area of more than 5 ha and less than 50 ha –From State Environmental Impact Assessment Authority (SEIAA)

c) For mining area of 50 ha or more – From MoEFCC

3.7 Shifting of Public and Industrial utility lines/services along and across National Highways

There may be public and industrial utility lines/services along or across the project highway which interfere with the construction and operation of the project highways. These are to be shifted to new locations. These are also to be shifted if they are hazardous from the safety consideration. The department or organization concern(s) are to be approached for taking necessary action in this regard. If the payments are to be made by the project authority, in cases the highways are declared/constructed later than the laying of the services, the cost estimate for such shifting works are to be obtained from the department or organization concerned. The payments are to be made after obtaining necessary sanctions of the cost estimates from the competent authority.

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CHAPTER 4

GEOMETRIC DESIGN STANDARDS

4.1 Geometric design deals with the visible elements of a highway. Sound geometric design results in safety and economic operation of vehicles.

The standards as detailed below are generally as per IRC:73 "Geometric Design Standards for Rural (Non-Urban) Highways". If specified in the contract/concession agreement, IRC:SP:73 "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulders", IRC:SP:84 "Manual for Specifications and Standards for Four Laning of Highways through Public Private Partnership" and IRC:SP:87 "Manual of Specifications and Standards for Six Laning of Highways through Public Private Partnership" are to be followed for geometric design standards.

4.1.1. Terrain Classification

The geometric design of a highway is influenced significantly by terrain condition. Terrain is classified by the general slope across the alignment. The criteria given in Table 4.1 should be followed.

Table 4.1 Terrain Classification

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

4.1.2 Design Speed

Table 4.2 Design Speed km/h

Road class	Plain	Rolling	Mountainous	Steep
NH & SH				
Ruling	100	80	50	40
Minimum	80	65	40	30

4.1.3 Right of Way (ROW) (Land Width)

Table 4.3 Recommended Right of Way (ROW) Land Width for Different Classes of Road (All in metres)

Sl. No.	Road Classification	Plain and rolling terrain				Mountainous and steep terrain	
		Open areas		Built-up areas		Open areas	Built up areas
		Normal	Range	Normal	Range	Normal	Normal
1.	National and State Highways	45	30-60	30	30-60	24	20

(This is for general guidelines as per IRC:73. However, depending on the requirement in the field the ROW can suitably be adjusted based on the outcome of DPR)

4.1.4 Building lines & Control Lines

Table 4.4 Recommended Standards for Building Lines and Control Lines

S.N.	Road Classification	Plain and rolling terrain			Mountainous and steep terrain	
		Open areas		Built-up areas	Open areas	Built up areas
		Overall width between building lines (metres)	Overall width between Control lines (metres)	Distance between Building Line and road boundary (set-back) (metres)	Distance between Building Line and road boundary (set back) metres)	
1.	National and State Highways	80	150	3-6	3-5	3-5

Note: If the land width is equal to the width between building lines indicated in this column, the building lines should be set back 2.5 m from the road land boundary.

4.1.5 Width of Carriageway

Table 4.5 Width of carriageway

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

** This may be adopted on exceptional cases and particularly in hill roads.

4.1.6 Median

Table 4.6 Width of Median

Type of Section	Minimum Width of Median (m)		
	Plain and Rolling Terrain		Mountainous and Steep Terrain
	Raised*	Depressed	Raised*
Open country width isolated built up area	5.0	7.0	2.5
Built up areas	2.5	Not Applicable	2.5
Approach to grade separated structures	5.0	Not Applicable	2.5

* Including kerb shyness of 0.50 m on either side. In the existing 4-lane reaches also, the minimum kerb shyness of 0.5 m shall be maintained. The additional width of kerb shyness shall be catered by augmenting the carriageways towards the shoulder side.

4.1.7 Shoulder Width

The shoulder width on both sides for undivided carriageway shall be

2.5 m on each side. Out of which 1.5 m may be of paved one. For divided carriageway shoulders on the outer side shall be of 2.5 m out of which 1.5 m shall be paved one.The shoulder widths will be different from these values as per IRC:SP-73, IRC:SP-84 and IRC:SP-87. These IRC Special Publications may be referred for details.

4.1.8 Roadway Width

The roadway width shall be aggregate of width of carriageway, width of shoulder and width median.

Table 4.7

Sl.No.	Road Classification	Roadway width (metres)
1.	National Highways and State Highways (single or two lanes)	12.0*

* This is for 1.5 m wide paved shoulders

4.1.9 Pavement crossfall/camber

The crossfall on straight section, carriageway, paved shoulder shall be 2.5 per cent for bituminous surface and 2.0 percent for concrete surface.

The crossfall of earthen shoulders on straight portion shall be at least 0.5 per cent steeper than the slope of the paved shoulders subject to a minimum of 3.0 percent. On super elevated section, the shoulders should have some crossfall as of the pavement.

4.1.10 Radius of Horizontal curves

Table 4.8 Radius of Horizontal curves
(All dimensions are in metres)

Terrain	NHs & SHs	
	Ruling minimum	Absolute minimum
Plain Terrain	360	230
Rolling Terrain	230	155
Mountainous Terrain areas not affected by snow	80	50
Snow bound areas	90	60
Steep terrain areas not affected by snow	50	30
Snow bound areas	60	33

4.1.11 Extra Width on Curves

Table 4.9 Extra width of pavement on horizontal curves

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

4.1.12 Sight distance

Table 4.10 Sight Distance

Speed km/h	Sight distance (metre)		
	Stopping	Intermediate	Overtaking
30	30	60	
40	45	90	165
50	60	120	235
65	90	180	340
80	120	240	470
100	180	360	640

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

2. Stopping sight distance is the absolute minimum for design. See IRC:73 "Geometric Design Standards for Rural (Non-Urban) Highways" for more details. In case of highway projects being implemented as per specifications as prescribed in IRC:SP:73, IRC:SP:84 and IRC:SP:87 then the distances as prescribed in these Manuals as given below are to be followed.

3. For the roads with divided carriageway, the design should correspond at least to stopping sight distance. It will be desirable to design for intermediate sight distance.

Table 4.11 Sight Distance for Various Speeds

Speed (km/hr)	Minimum Sight Distance (m)	Overtaking Sight Distance (m)
100	360	640
80	240	470
60	180	340
40	90	165

4.1.13 Transition Curve Minimum Transition Lengths for Different Speeds and Curve Radii

Table 4.12 Minimum Transition Lengths for different Speeds and Curve Radii

Plain and Rolling Terrain					Mountainous and Steep Terrain		
Curve radius R (metres)	Design speeds (km/h) 100	80	65	Curve radius (metres)	Design speed (km/h) 50	40	30
	Transition length – metres				Transition length – metres		
100			NA	30			30
150			80	40		NA	25
170			70	50		40	20
200		NA	60	55		40	20
240		90	50	70	NA	30	15
300	NA	75	40	80	55	25	15
360	130	60	35	90	45	25	15
400	115	55	30	100	45	20	15
500	95	45	25	125	35	15	15
600	80	35	20	150	30	15	15
700	70	35	20	170	25	15	NR
800	60	30	NR	200	20	15	
900	55	30		250	15	15	
1000	50	30		300	15	NR	
1200	40	NR		400	15		
1500	35			500	NR		
1800	30						
2000	NR						

NA = Not applicable

NR = Transition not required

4.1.14 Super elevation

4.1.14.1 Superelevation on horizontal curve should be calculated from the following formula

$e = V^2/225R$

e = super elevation in metre per metre

V = speed in km/h and

R = radius in metres

Superelevation obtained from the above expression should be kept limited to the following values

4.1.14.2 Maximum permissible superelevation

Table 4.13 Maximum Permissible Superelevation

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

4.1.15 Gradients

Table 4.14 Gradients

	Gradient (per cent)		
Terrain	**Ruling**	**Limiting**	**Exceptional**
Plain/rolling	3.3	5	6.7
Mountainous, and steep terrain having elevation more than 3000 m above MSL	5	6	7
Steep terrain upto 3000m above MSL	6	7	8

Notes

1. Generally, use ruling gradient for design. In special situations, such as, isolated over bridges 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 gentle 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 a drainage should be 0.5 per cent when drain is lined and 1 per cent if unlined
5. Maximum gradient at hair-pin bend is 2.5 per cent.

4.1.16 Vertical curves

Table 4.15 Length of Vertical Curves

Sl.No.	Summit curve	Valley curve
(a)	For stopping sight distance $L = NS^2/4.4$ (L >S) $L = 2S - 4.4/N$ (L <S)	$L = \dfrac{NS^2}{1.5 + 0.035S}$ (L>S) $L = 2S - \dfrac{1.50 + 0.035S}{N}$ (L<S)
(b)	For intermediate or overtaking sight distance	
	$L = NS^2/9.6$ (L>S) $L = 2S - 9.6/N$ (L<S)	S = Sight distance in metres L = Length of Curve in metres N = Deviation angle

Notes

1. For summit curves, overtaking sight distance should be the general criterion. Where not feasible, 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.

4.1.17 Minimum Length of Vertical Curve

Table 4.16 Minimum Length of Vertical Curve

Design speed (km/h)	Provide curve or 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

4.1.18 Notes on alignment coordination

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

4.1.19 Roadway Width at Cross Drainage Structure and Bridges

4..1.19.1At Culverts

Overall width of culverts (measured from outside to outside of the parapert walls) should be equal to the normal roadway width of approaches on both sides.

4.1.20 Lateral & Vertical Clearance at Underpasses

Wherever the Project Highway is proposed to be taken above/over a cross road, minimum clearances at underpass shall be as follows: These are for general information. The exact width and the spans will depend upon the requirement of Project Authority and Circulars issued by MORTH/State PWDs from time to time.

Lateral Clearance

i) Full roadway width of the cross road shall be carried through the Vehicular Underpass. The lateral clearance shall not be less than 12 m (7 m carriageway + 2 x 2.5 m shoulder width on either side).

ii) For Light Vehicular Underpass the lateral clearance shall not be less than 10.5 m including 1.5 m wide raised footpath on either side.

iii) Guard rail/crash barriers shall be provided for protection of vehicles from colliding with the abutments and piers and the deck of the structures.

Vertical Clearance

Vertical clearance at underpasses shall not be less than the values given below. These are as per IRC:73.

Table 4.17 Vertical Clearance at Underpass

i) Vehicular Underpass	5.0 m (Non urban areas)
ii) Light Vehicular Underpass	3.5 m
iii) Pedestrian and Cattle Underpass	3.0 m (to be increased to 4.5 m, in case certain categories of animals such as elephant/camel are expected to cross the Project Highway frequently.)

As per IRC:SP:73 following minimum clearances are to be maintained.

Table 4.17A Vertical Clearance at Underpass

i) Vehicular Under Pass (VUP)	5.5 m
ii) Light Vehicular Under Pass (LVUP)	4.0 m
iii) Smaller Vehicular Under Pass (SVUP)	4.0 m

Wherever existing slab/box culverts and bridges allow a vertical clearance of more than 2 m, these can be used in dry season for pedestrian and cattle crossing by providing necessary flooring. However, these will not be a substitute for normal requirements of pedestrian and cattle crossings as detailed above.

4.1.21. Lateral and Vertical Clearance at Overpass

Wherever any structure is provided over the Project Highway; the minimum clearances at overpasses shall be as follows:

4.1.21.1 Lateral Clearance

Full roadway width shall be carried through the overpass. Provision shall also be made for future widening of the Project Highway to 4-lane. The abutments and piers shall be provided with suitable protection against collision of vehicles. Crash barriers shall be provided on abutment side and on sides of piers for this purpose. The ends of crash barriers shall be turned away from the line of approaching traffic. The span arrangement for the overpass structure shall be as specified in the tender/contract document.

4.1.21.2 Vertical Clearance

A minimum 5.5 m vertical clearance shall be provided at all points of the carriageway of the Project Highway.

4.2 EXPRESSWAYS

4.2.1 Expressways are defined as an arterial highway for motorized traffic with divided carriageway with full control of access and provided with grade separators at locations of intersections. This facility is for high speed travel and only for fast moving vehicles. No service roads are allowed along the expressways. These details are as per IRC:SP:99 "Manual of Specifications and Standards for Expressways". The salient features of geometric design standards of expressway in rural areas are given below:-

4.2.2 Design Speed

Table 4.18 Design Speed of Expressway

Nature of Terrain	Cross Slope of the Ground	Design Speed (km/hr)
Plain	Less than 10 percent	120
Rolling	Between 10 and 25 per cent	100

Design speed of 80 km/hr may be adopted in an intervening stretch of mountainous terrain with posting of speed limit signs.

4.2.3 Right of Way in Plain/Rolling Terrain

Table 4.19 Right of Way Width of Expressway

Section	Right of Way Width* (ROW)
Rural Section	90 m – 120 m
Rural Sections passing through semi-urban areas	120 m[#]

* The ROW width includes 2 m wide strip on both sides reserved for placement of utilities outside fencing

In case an elevated expressway on viaduct is proposed, the width of ROW may be reduced as per site conditions and availability of land.

4.2.4 Median

Table 4.20 Width of Median

Type of Median	Recommended Median Width (m)	
	Minimum	**Desirable**
Depressed	12.0	15.0
Flush	4.5	4.5
Flush (to accommodate structure/ pier on median)	8.0	8.0

4.2.5 Lane Width of Carriageway

3.75 m (shall have minimum two lanes for each direction of travel)

4.2.6 Shoulders

3 m wide paved and 2 m wide earth shoulder on the outer edge (left side) of the carriageway Crossfall.

4.2.7 Roadway Width

The width of roadway shall depend upon the width of carriageway shoulders and the median.

4.2.8 Crossfall on Different Surfaces

Table 4.21Crossfall on Different Surfaces

Cross –Sectional Element	**Annual Rainfall**	
	1000 mm or more	**Less than 1000 mm**
Carriageway, Paved shoulders, Edge Strip, Flush Median	2.5 per cent	2.0 percent

4.2.9 Super elevation

Super elevation shall be limited to 7 percent if radius of curve is less than the desirable minimum radius. It shall be limited to desirable minimum of 5 percent if radius of curve is more than the desirable minimum. Super elevation shall not be less than the minimum specified cross fall.

4.2.10 Radii of horizontal curve

Table 4.22 Minimum Radii of Horizontal Curves

Design Speed (km/h)	120	100	80
Absolute Minimum Radius (m)	670	440	260
Desirable Minimum Radius (m)	1000	700	400

4.2.11 Transition Curve

Table 4.23 Minimum Length of Transition Curves

Design Speed (km/h)	Minimum Length of Transition Curve (m)
120	100
100	85
80	70

4.2.12 Sight Distance

Table 4.24 Safe Sight Distance

Design Speed (km/hr)	Safe Stopping Sight Distance (m)	Desirable Minimum Sight Distance (m) (Intermediate Sight Distance)
120	250	500
100	180	360
80	120	240

4.2.13 At critical locations or decisions points where changes in cross section occurs such as toll plazas and interchanges, the sight distance shall not be less than the decision sight distance as given below:-

Table 4.25 Decision Sight Distance

Design Speed (km/h)	Decision Sight Distance (m)
120	360
100	315
80	230

4.2.14 Vertical Alignment

Table 4.26 Gradients

Terrain	Ruling Gradient	Limiting Gradient
Plain	2.5 percent	3 percent
Rolling	3 percent	4 percent

4.2.15 Vertical Curve

Table 4.27 Minimum Length of Vertical Curve

Design Speed (km/h)	Minimum Grade Change Requiring Vertical Curve	Minimum Length of Vertical Curve (m)
120	0.5 per cent	100
100	0.5 per cent	85
80	0.6 per cent	70

4.2.16 Lateral and Vertical Clearance at Underpasses

4.2.16.1 Lateral Clearance

Full roadway width of the cross road proposed to be taken below the expressway shall be carried through the underpass. For Vehicular underpass, the lateral clearance shall not be less than 12 m

For light vehicular underpass, the lateral clearance of underpass shall not be less than 10.5 m

For pedestrian and Cattle underpass, the lateral clearance shall not be less than 7 m.

4.2.16.2 Vertical Clearance

Vertical clearance at underpasses shall not be less than the values given in Table below:

Table 4.28 Vertical Clearance at Underpass

i) Vehicular Underpass	5.5 m
ii) Light Vehicular Underpass	3.5 m

iii) Pedestrian, Cattle Underpass	3.0 m (to be increased to 4.5 m, in case certain categories of animals such as elephant/camel are expected to cross the Project Expressway frequently.)

Full road way width for 8 lane carriageway or wider as specified shall be carried through the overpass structure. Wherever any structure is provided over the expressway: the minimum clearance shall be as follows:

A minimum of 5.5 m vertical clearance shall be provided from all points of the carriageway of the expressway

4.2.17 Location of Interchanges

Interchanges are provided for access to the expressway. Location of interchanges is guided by the following situations:

At crossing or nearest points of other Expressways, National Highways, State Highways and important arterial roads

At crossings or nearest points of major roads to important ports, airports, material transport facilities, commercial and industrial areas and places of tourist interest.

4.2.18 Median Openings

Median openings with detachable barrier shall be provided for traffic management for maintenance works and vehicles involved in accidents. It is desirable to provide median openings with detachable barrier at about 5 km spacing.

4.2.19 Fencing and Boundary Stones

Fencing shall be provided all along the Expressway at 2 m inside the ROW boundary. The ROW shall be demarcated by installing boundary stones at the edges.

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CHAPTER 5

DESIGN OF PAVEMENTS

5.1 Flexible Pavement

The new pavements sections should be designed in accordance with IRC:37 "Guidelines for the Design of Flexible Pavement". IRC:37 is based on a Mechanistic- Empirical approach. The flexible pavement has been modelled as a layered structure and stress and strain are computed using linear elastic model IITPAVE, an updated version of FPAVE developed under MORTH Research Scheme R-56 "Analytical Design of Flexible Pavement". The guidelines also cover the design of pavement by including material like (i) different combination of cementitious bases and subbases, (ii) reclaimed asphalt pavement (RAP) base treated with foamed bitumen/bitumen emulsion & (iii) high modulus bituminous mixes with stiffer binders. This code also covers the design of long life pavement.

5.1.1 Design Traffic

The design traffic is estimated in terms of equivalent number of cumulative standard axles of 80 kN to be carried during the design period. Axle load spectrum data are required where cementitious bases are used for evaluating the fatigue damage for heavy traffic.

5.1.2 Initial Traffic

Assessment of the present day average traffic should be based on seven day-24 hour count made in accordance with IRC:9 "Traffic Census on Non-Urban Roads". Only the number of commercial vehicles having gross weight of 30 KN or more and their axle loading is considered for the purpose of design of pavement.

5.1.3 Traffic Growth Rate

The present day traffic has to be projected for the end of design period at growth rate by studying and analysis the data of past trends of traffic growth and also macro-economic parameters and expected demand due to specific developments and land use changes likely to take place during design life. The procedure outlined in IRC:108 "Guidelines for Traffic Forecast on Highways" may be adopted for traffic projection. If the data for the annual growth rate of commercial vehicle is not available or it is less than 5% growth, rate of growth of 5% should be used.

5.1.4 Design Period

It is recommended that design period of 20 years may be adopted for National Highways, State Highways and urban roads. Pavements for very high density corridors (more than 300 msa) and expressways shall preferably be designed as long-life pavements. Otherwise, for such corridors, the pavement shall be designed for a minimum period of 30 years. If Stage construction is adopted for uncertainty of future traffic or possibility of substantial increase of future traffic due to future development, the stage-1 pavement will have at least 40% remaining after Stage-1 period (traffic). Assuming that the life consumed varies linearly with traffic, the design traffic for Stage-1 shall be taken 1.67 times of the Stage-1 period. Stage construction is not allowed for cement treated bases and sub-bases. The thickness of the pavement for the next stage shall be determined after evaluation of the structural condition of pavement by FWD.

5.1.5 Computation of Design Traffic

5.1.5.1 The design traffic in terms of the cumulative number of standard axles to be carried during the design life of the road should be computed using the following equation:

$$N_{des} = \frac{365 \times [(1 + r)^n - 1]}{r} \times A \times D \times F$$

Where,

N_{des} = Cumulative number of standard axles to be catered for in the design in terms of msa.

A = Initial traffic in the year of completion of construction in terms of the number of Commercial Vehicles Per Day (CVPD).

D = Lane distribution factor

F = Vehicle Damage Factor (VDF)

n = Design period in years

r = Annual growth rate of commercial vehicles (expressed in decimal)

The traffic in the year of completion is estimated using the following formula

$$A = P (1 + R)^x$$

Where P = Number of commercial vehicles as per last count

Where x = Number of years between the last count and the year of completion of construction.

5.1.5.2 Lane Distribution Factor (Distribution of commercial and traffic over the carriageway)

Distribution of commercial traffic in each direction and in each lane is required for determining the total equivalent standard axle load applications to be considered in the design.

i) Single-lane roads

Traffic tends to be more channelized on single-lane roads than two-lane roads and to allow for this concentration of wheel load repetitions, the design should be based on total number of commercial vehicles in both directions.

ii) Intermediate Lane Road of Width 5.5 m

Design traffic should be based on 75% of the two way commercial traffic

iii) Two-lane two way roads

The design should be based on 50 per cent of the total number of commercial vehicles in both directions. If vehicle damage factor in one direction is higher, the traffic in the direction of higher VDF is recommended for design.

iv) Four-lane single carriageway roads

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

v) 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. For dual three-lane carriageway and dual four lane carriageway, the distribution factor will be 60 per cent and 45 per cent respectively.

5.1.5.3 Vehicle Damage Factor (VDF)

a) The VDF is a multiplier to convert the number of commercial vehicle of different axle loads and axle configuration into the number of repetitions of standard axle load of magnitude of 80 kN. It is defined as equivalent number of Standard axles per commercial vehicle

b) In case of cemented bases, cumulative fatigue damage principle, applicable to rigid pavement and other structures, is used for determining fatigue life of cement bases for due to axle load repetitions using the data for the spectrum of axle loads.

c) VDF should be arrived at carefully by carrying out specific axle loads surveys for a minimum period of 24 hours on the existing roads in each direction.

Minimum sample size of commerical vehicle to be considered for axle load survey is given in table 5.1

Table 5.1: Minimum Sample size for Axle Load Survey

Commercial traffic volume/ day (cvpd)	Minimum percentage of Commercial Traffic to be surveyed
<3000	20 per cent
3000 to 6000	15 per cent (subject to a minimum of 600 cvpd)
>6000	10 per cent (subject to a minimum of 900 cvpd)

d) For small projects, in the absence of weigh pad, axle loads of typical commercial vehicles plying on the road may be estimated approximately from the type of goods carried. Where information on axle loads is not available and the proportion of heavy vehicles using the road is not large following indicative values of VDF in Table 5.2 can be used.

Table 5.2: Indicative VDF Values

Initial Two-Way Traffic Volume in Terms of Commercial Vehicles Per Day	Terrain	
	Rolling/Plain	Hilly
0 - 150	1.7	0.6
150-1500	3.9	1.7
More than 1500	5.0	2.8

5.1.6 Requirement of CBR of subgrade

5.1.6.1 The subgrade is the top 500 mm of the embankment immediately below the bottom of pavement, and is made up of insitu material, select soil or stabilized soil that forms the foundation of the pavement. It should be well compacted to have a minimum 97 per cent or higher of laboratory dry density or higher achieved with heavy compaction as per IS:2720 (Part 8) for expressways, National Highways, State Highways and other heavily trafficked roads. When the subgrade is formed using a material which is stronger than 500 mm embankment soil or when the subgrade itself is prepared in two separate layers with significantly different strengths the effective contribution of the subgrade and embankment layers has to be considered in design. The determination of effective CBR as well as the detailed guidelines for preparation of samples, testing and acceptance criteria are given in IRC:37 "Guidelines for the Design of Flexible Pavements".

5.1.7 Pavement thickness and composition

5.1.7.1 Once the design traffic and the subgrade CBR are known the pavement composition and the thickness can be decided as per the procedure detailed in IRC:37. The detailed pavement design procedure including principles of pavement design, determination of properties of different layers of pavement and subgrade have been described in the above mentioned guidelines. The cementitious bases have also been described Pavement design catalogues have also been presented in these guidelines for different traffic ranges (upto 50 msa design traffic) , different CBRs and different combination of material composition.

5.1.7.2 IRC:37 also includes a CD, which contains the design software, can be used for design of flexible pavements.

5.2 Design of Rigid Pavement

5.2.1 Rigid pavement for new roads should be designed in accordance with IRC:58 "Guidelines for the Design of Plain Jointed Rigid Pavements for Highways". The design as per IRC:58 is based on the considerations of the flexural stress under the simultaneous action of load and temperature gradient for different categories of axles and also considering sum of cumulative damages caused by axle loads. This guideline also include procedure for design of pavement with widened outer lane, tied concrete shoulders, pavements bonded to stabilized sub-base as well as design of longitudinal, expansion and contraction joints.

These guidelines are applicable to roads having an average number of daily commercial vehicles more than 450 numbers with laden weight exceeding 30 kN. Cement concrete pavement may be designed to have a life span of 30 years or more.

5.2.2 Traffic:

5.2.2.1 Axle load survey is to be conducted for a continuous period of 48 hours. The vehicles to be surveyed may be selected randomly to avoid bias. If the spacing of consecutive axles (wheel base) is more than 2.4 m, each axle shall be considered as single axle. The intervals at which axle groups should be classified for fatigue damage analysis are.

Data on the spacing of axles is also to be collected during traffic survey.

Single Axle	10 KN
Tandem Axle	20 KN
Tridem Axle	30 KN

5.2.2.2 Wheel Base Characteristics

Information on wheel base of commercial vehicles is necessary to identify proportion of axles that should be considered for estimating top down fatigue caused by axle loads during night period. The commonly used spacing of transverse joint is 4.5 m. Thus axles with spacing more than 4.5 m will not contribute to top down fatigue cracking. The percentage of commercial vehicles with spacing between the front and the first rear axle less than the proposed spacing of the transverse joint in concrete slabs should be established from the axle load survey

5.2.2.3 The traffic counts and the corresponding traffic estimates should indicate the day and night traffic trends as the traffic during the day hours is generally responsible for bottom-up cracking whereas the night time traffic may lead to top-down cracking.

5.2.2.4 Assessment of average daily traffic should normally be based on seven day 24 hours count made in accordance with IRC:9. The determination of actual value of annual rate of growth shall be as per methods as prescribed for the design of flexible pavement. The annual growth rate of commercial vehicles shall be taken as a minimum of 5%.

5.2.2.5 The edge flexural stress caused by axle loads for Bottom Up Cracking (Day Time) is maximum when the tyre imprint of the outer wheel touches the longitudinal edge. Typical lateral distribution characteristics of wheel paths of commercial vehicles observed on Indian highways indicate that very few wheels of vehicles are tangential to the longitudinal edge or longitudinal joint on two-lane two-way roads and divided multi-lane highways. Taking into consideration these issues, it is recommended that 25 percent of the total two-way commercial traffic may be considered as design for two lane two way roads for analysis of fatigue damage. In case of four lane and other multilane divided highway, 25% of total traffic in the direction of traffic is to be considered for design.

5.2.2.6 The design traffic for Top-Down Cracking (Night Time) analysis will usually be a fraction of the design traffic considered for bottom-up cracking analysis. Only those commercial vehicles with the spacing between the front axle and the first rear axle less than the spacing of transverse joints is considered for the analysis of top-down cracking. This percentage should be established from axle load / traffic survey. A default value of fifty percent of the design traffic for the bottom-up cracking analysis may be considered for the analysis of top down cracking.

5.2.2.7 The cumulative number of commercial vehicles during the design period may be estimated from the following expression.

$$C = \frac{365 x A((1+r)^n - 1)}{r} -$$

Where, C = Cumulative number of commercial vehicles during the design period, A = Initial number of commercial vehicles per day in the year when the road is opened to traffic

r = Annual rate of growth of commercial traffic volume (expressed as decimal) and

n = Design period in years

The design cumulative number of axle load repetitions for fatigue damage can be obtained from the cumulative number of commercial vehicles as per IRC: 58. Equivalency factor like VDF in rigid pavement is assumed as 2.35 in accordance with IRC:58.

5.2.3 Temperature Consideration

Temperature differential between the top and bottom fibers of concrete pavements causes the concrete slab to curl giving rise to stresses. As far as possible temperature differential values estimated realistically, for the given site using geographical parameters and material characteristic should be used for analysis. In the absence of any local data, the maximum temperature differential values given in IRC:58 may be adopted for the pavement design. The maximum temperature differential during the night is nearly half of the day temperature.

5.2.4 Embankment soil and characteristics of subgrade and subbase

5.2.4.1 CBR of embankment soil placed below the 500 mm select subgrade should be determined for estimating the effective CBR of subgrade and its modulus of subgrade reaction k value for design.

5.2.4.2 The modulus of subgrade reaction 'k' which is defined as the pressure per unit deflection of the foundation as determined plate load tests. The k value is determined from the pressure sustained at a deflection of 1.25 mm. As the plate load test is time-consuming and expensive and therefore the design of k value is often estimated from soaked CBR value. The relationship between the CBR value at different soaked CBR and k value has been given in IRC:58. A minimum CBR of 8% has been recommended for the 500 mm select soil subgrade.

5.2.4.3 If the CBR of the 500 mm thick compacted subgrade is significantly larger than that of embankment below it, the effective CBR is to be determined as per method described in IRC:58.

5.2.4.4 The subgrade needs to be protected by providing separation and drainage layers of Granular Sub Base (GSB). The details of separation and drainage layers have been given in IRC:58.

5.2.4.5 To provide a uniform, stable and permanent support to the concrete slab it is laid over a subbase layer of Dry Lean Concrete (DLC) with minimum thickness of 150 mm having 7 day average compressive strength of 7 Mpa. Cement treated subbase with recycled or marginal aggregated have also been recommended in IRC:58. The interface layer can be made smooth to reduce the interlayer friction by providing a de-bonding interlayer of polythene sheet white or transparent having a minimum thickness of 125 micron.

5.2.4.6 The k values of different types of subbase have also been given in IRC:58

5.2.5 Recommended Design Procedure:

5.2.5.1 As per IRC: 58, steps as given below may be followed for design.

Step 1 : Stipulate design values for the various parameters.

Step 2 : Select a trial design thickness of pavement slab.

Step 3 : Compute the repetitions of axle loads of different magnitudes and different categories during the design life.

Step 4 : Find the proportions of axle load repetitions operating during the day and night periods.

Step 5 : Estimate the axle load repetitions in the six-hour-period during the day time. The maximum temperature differential is assumed to remain constant during the 6 hours for analysis of bottom-up cracking

Step 6 : Estimate the axle load repetitions in the six-hour period during the night time. The maximum negative temperature differential during night is taken as half of day-time maximum temperature differential. Built in negative temperature differential of 5ºC developed during the setting of the concrete is to be added to the temperature differential for the analysis of top-down cracking. Only those vehicles with spacing between the front (steering) axle and the first rear axle less than the transverse joint spacing need to be considered for top-down cracking analysis.

Step 7 : Compute the flexural stresses at the edge due to the single and tandem axle loads for the combined effect of axle loads and positive temperature differential during the day time. Determine the stress ratio (Flexural stress/Modulus of Rupture) and evaluate the Cumulative Fatigue Damage (CFD) for single and tandem axle loads.

Step 8 : Compute the maximum flexural stress in the top surface of the pavement slab with the front axle near the approaching transverse joint and the rear axle close to the following joint in the same panel under negative temperature differential. Determine the stress ratio and evaluate the CFD for different axle loads for the analysis of top-down cracking.

Step 9 : Sum of CFD for the BUC and TDC. If the sum is less than 1.0, the pavement slab is safe against fatigue cracking.

5.2.5.2 The entire design process is programmed on an excel sheet and it is included in a CD enclosed with these guidelines IRC: 58. This will enable the designer to make several trials conveniently. The designer has to provide modulus of the subgrade reaction of the foundation supporting the pavement slab, 28-day strength of concrete, temperature differential; traffic data such as rate of traffic growth, axle load spectrum, proportion of single, tandem and tridem axles, proportion of trucks with wheel base less than transverse joint spacing (say 4.5 m). All relevant traffic and material data are inputs to the excel sheet. It is worth noting that concrete strength increases with age. The excel sheets provide designs by considering 90-day strength of paving concrete (The minimum 28 day flexural strength is taken as 4.5 MPa). Any other strength including that of high performance concrete can be the input. 90 day strength can safely be used because of numbers of conservative assumption in the design.

5.2.6 Design of Joints

5.2.6.1 Cement Concrete Pavements have different types of joints given as:

i) Contraction joints

ii) Construction joints

iii) Expansion joint

iv) Longitudinal joint

5.2.6.2 Contraction joints are transverse joints which relieve the tensile stresses in concrete pavements. The joint spacing of a concrete pavement depends upon the type of coarse aggregates and the average temperature fluctuation in different seasons. The spacing of contraction joints should be limited to 4.5 m to prevent top-down cracking during the night hours. Expansion joints are no longer in use. Construction joints are as far as possible, be placed at contraction joints except in case of emergency.

5.2.6.3 Dowel bars are provided for load transfer of transverse joints. The design of dowel bars recommended as per IRC:58 for the dimension and lengths of dowel bars are given below:

5.2.6.3.1 Recommended dimensions of Dowel Bars for transverse joints of Rigid Pavements are given in Table 5.3

Table 5.3 Dimensions of Dowel Bars for Transverse Joints

Slab thickness, Mm	Dowel Bar Details		
	Diameter, mm	Length, mm	Spacing, mm
200	25	360	300
230	30	400	300
250	32	450	300
280	36	450	300
300	38	500	300
350	38	500	300

Note: The values given are for general guidance. Field performance under heavy loading prevalent in India will be the most appropriate guide. Dowel bars are not satisfactory for slabs of small thickness and shall not be provided for slab of less than 200 mm thickness.

5.2.6.3.2 Longitudinal Joints

Longitudinal joints are required in pavement of width greater than 4.5 m. Tie bars are provided in longitudinal joints. The method of determination of the area of steel required and the length of tie bars are given in IRC:58. The details of tie bars are given below:

Table 5.4 Tie Bar Details

Slab Thickness (mm)	Tie Bar Details				
	Diameter (d) (mm)	Max. Spacing (mm)		Minimum Length (mm)	
		Plain Bars	Deformed Bars	Plain Bars	Deformed Bars
150	8	330	530	440	480
	10	520	830	510	560
200	10	390	620	510	560
	12	560	900	580	640
250	12	450	720	580	640
300	12	370	600	580	640
	16	660	1060	720	800
350	12	320	510	580	640
	16	570	910	720	800

5.3 Design of Continuously Reinforced Concrete Pavement (CRCP)

5.3.1 Continuously Reinforced Concrete Pavement (CRCP) is intended for roads carrying high volume of commercial traffic and where closing road often for maintenance is difficult.

5.3.2 The CRCP may be with elastic joints or without joints. The CRCP with joints are similar to jointed reinforced concrete pavement except that steel reinforcements run through the pavement continuously. Transverse joints are formed in concrete slab by saw cut at 4.5 m spacing for full width and sealed but without discontinuing the steel. The CRCP without joints is a joint less rigid pavement with continuous reinforcement.

5.3.3 The main advantages of CRCP are

- These pavements are rugged and durable for heavy truck corridors or expressways.
- The riding quality remains smoothen as there are no transverse joints but noise problem persists.
- The cost of maintenance is minimal.

5.3.4 CRCP roads are to avoided in the following situations

- In marine climate near sea coast where the reinforcing bars are vulnerable for corrosion.
- In a road having large number of utility lines, it is not desirable to construct CRCP as repair of these utility lines is a difficult task.
- Due to high initial cost, CRCP should be avoided in road catering to light traffic like village road, urban streets and of short length.
- Construction of CRCP using manual method should be avoided. This manual method will be slow and would result in construction of large number of transverse construction joints.

5.3.5 The detailed method of design and construction of CRCP, joints there of and their detailing are available in IRC:118 "Guidelines for Design and Construction of Continuously Reinforced Concrete Pavement".

5.4 Strengthening of Flexible Road Pavements Using Falling Weight Deflectometer (FWD)

5.4.1 Falling Weight Deflectometer (FWD) is an impulse-loading device in which a transient load is applied to the pavement and the deflected shape of the pavement surface is measured. The working principle of a typical FWD is illustrated in Fig. 5.1. D0, D1 etc. shown in Fig 5.1 are surface deflections measured at different radial distances. Impulse load is applied by means of a falling mass, which is allowed to drop vertically on a system of springs placed over a circular loading plate. The deflected shape of the pavement surface is measured using displacement sensors which are placed at different radial distances starting with the center of the load plate. Trailer mounted as well as vehicle mounted FWD models are available commercially. The working principle of all these FWD models is essentially the same. A mass of weights is dropped from a pre-determined height onto a series of springs/buffers placed on top of a loading plate. The corresponding peak load and peak vertical surface deflections at different radial locations are measured and recorded.

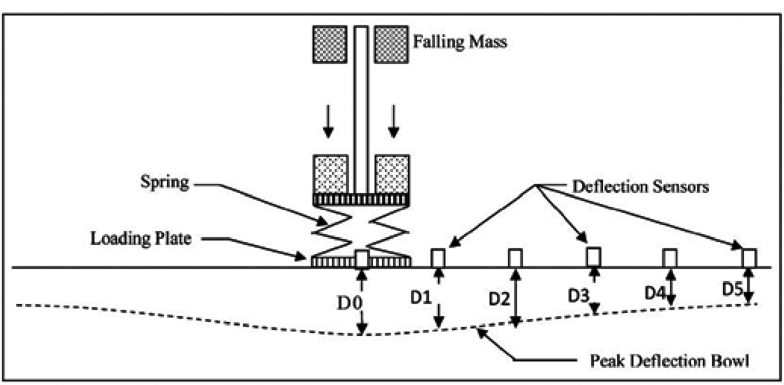

Fig. 5.1Working principal of FWD

5.4.2 The details of FWD calibrations, method of measurement, analysis of data, design of overlay and calculation of the remaining period of service etc. are given in IRC:115 "Guidelines for Structural Evaluation and Strengthening of Flexible Road Pavements using Falling Weight Deflectometer (FWD) Technique". Following steps are to be taken before deflection measurement.

5.4.2.1 Calibration of the FWD

It is essential that FWD's are calibrated for the following for getting accurate and reproducible results.

- Static calibration of the load cells
- Load repeatability of the FWD
- Absolute calibration of deflection transducers

5.4.2.2 Pavement evaluation survey and data collection. The following are the broad categories of survey investigation and data collection exercise; (i) Historical data about the pavement, (ii) condition survey of the pavement for identification of uniform sections having similar conditions; (iii) deflection measurements using FWD and (iv) pavement layer thickness and composition and the subgrade characteristics.

5.4.3 Analysis of Data

Following are the steps for analysis of data obtained from the field observations:-

i) Processing of Load & Deflection Data

ii) Identification of Homogeneous sub sections.

iii) Back calculation of layer moduli

iv) Correction for Temperature

v) Correction for seasonal variation

5.4.4 Estimation of Design Traffic

This traffic in terms of standard axle load of 80 kN repetitions shall be considered for design of overlay. These are to be calculated as per details given in para 5.1 for design of flexible pavement as mentioned above.

5.4.5 The following are the steps to be followed for design of overlays for flexible pavement for Indian Highways by using FWD.

i) Measurement of surface deflections of homogeneous section of the in-service pavement using FWD.

ii) Normalization of the deflections to correspond to a standard target load of 40 kN.

iii) Collection of information about layer type and layer thickness.

iv) Back calculation of pavement layer moduli from the normalized deflections using appropriate back calculation software. Back calculation will be done by considering the pavement to be a three layer system. All bituminous layers will be combined together. Similarly granular base and subbase layers may be combined. For pavements with modified subgrades, the modified layer may be treated as part of subgrade. Cemented subbases may be treated to be part of granular layer.

For pavements with cemented base, unless the pavement is being evaluated for its remaining life within a short period after construction, the cemented layer may be treated as part of granular layer.

v) Adjustment of the bituminous layer modulus (back calculated) to a standard temperature of 35^0C.

vi) Adjustment of the subgrade and granular layer moduli to correspond to post monsoon condition.

vii) Selection of 15th percentile modulus (15% of the values will be less than this value) of each of the three layers considered for analysis.

viii) Analysis of the in-service pavement using liner elastic layer theory with the back calculated (corrected) moduli and layer thickness collected from field as inputs. This includes computation of critical Strains (a) Horizontal Tensile Strain at the bottom fiber of bituminous layer and (b) Vertical Compressive Strain on top of subgrade. The loading configuration and the locations of critical strains for analysis will be similar to those adopted in IRC:37.

ix) Estimation of the remaining life of the pavement using the fatigue in bituminous layer and subgrade rutting performance criteria adopted in IRC:37. The strain values obtained in step viii will be used to estimate the remaining lives from fatigue and rutting consideration. Remaining life of the pavement will be the shortest of the lives obtained from bituminous layer fatigue, subgrade rutting and cemented base fatigue (in case of pavements with cemented base) criteria.

x) For design of bituminous overlay, a trial thickness of overlay of an appropriate material has to be selected and the critical strains have to be evaluated. The modulus value of the bituminous overlay material may be selected as per the guidelines given in IRC:37. Design overlay thickness can be selected by trial in such a way that the computed critical strains are less than the permissible limits given by the performance criteria for the design traffic level considered.

5.5 Design of Strengthening of Flexible pavement using Benkelman Beam Deflection

5.5.1 Details of the method of evaluating the strengthening requirements of flexible pavements are given in IRC:81 "Guidelines for Strengthening of Flexible Road Pavements using Benkelman Beam Deflection Technique." The procedure involves the following main operations. This method may be used for strengthening of pavement for State Highways. This method is not reccomended for NH Projects.

i) It will be preferable if the length of each section of uniform performance is kept at a minimum of 1 km except in the case of localized failure or other situations requiring closure examinations where minimum length of section may be suitably fixed. This is done by visual observations supplemented by rut depth measurments using a 3 m straight edge.

ii) Making 10 equidistant points in each traffic lane of uniform section 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^2.

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^{0}C 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. Correction for seasonal variation is to be done as per the procedure given in IRC:81.

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

Mean deflection (x) = $\dfrac{\sum x}{n}$

Standard deviation (σ) = $\sqrt{\dfrac{(x - \bar{x})^2}{n - 1}}$

Characteristics deflection

a) $D_c = \bar{x} + 2\sigma$ (for major arterial roads, like NH & SH)

b) $D_c = \bar{x} + \sigma$ (for all other roads)

Where x = Individual deflection, mm

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

D_c = Characteristic deflection

σ = Standard deviation

n = Number of deflection measurements

vii) Design traffic may be calculated as given in the design of flexible pavement as mentioned above. The design period may be considered as 10 years.

viii) From the graph in IRC:81 find out the overlay in terms of bituminious macadam construction required for the characteristic deflection and cumulative standard axles as worked out as per above paras (vi) and (vii) respectively.

5.6 Structural Evaluation of Rigid Pavement

5.6.1 Evaluation of structural condition of in-service rigid pavements can be done using Falling Weight Deflectometer (FWD). The strength of the pavement concrete as well as the modulus of subgrade reaction can be estimated so that the capacity of the pavement to withstand future traffic loading i.e. balance life can be determined using cumulative fatigue damage principle as laid down in IRC:58**.**

5.6.2 Structural evaluation exercise should include load transfer at the transverse and longitudinal joints so that the necessary measures may be taken to retrofit dowel and tie bars before extensive damage occurs. The deflection data can be used to detect voids at transverse joints, longitudinal joints, interiors as well as at the corners so that actions can be taken to fill up the voids by grouting to prevent large scale damage to pavements.

5.6.3 IRC:117 "Guidelines for the Structural Evaluation of Rigid Pavements by Falling Weight Deflectometer" gives the details of pavement evaluation process, evaluation of subgrade modulus, elastic modulus of concrete and strength of pavement concrete. Method for filling of voids detected by FWD testing or by any other like GPR etc. by cement grouting and for retrofitting of dowel bars have also been prescribed in these guidelines IRC:117.

5.7 Design of stabilize pavement using Commercial Chemical Stabilizers (CCS)

5.7.1 In recent past different types of CCS have come into market. The companies which are promoting these indicate that there are special chemical compound which have been evolved after long research and should be mixed with cement to enhance the strength and durability characteristics of soil cement mix. These are available in powder form or liquid form. However, since long term performance of roads constructed with such special products is not available, it becomes difficult to accept such products for large scale application.

5.7.2. The details mechanism of acceptance for CCS, material characterization have been given in IRC:SP:89 (Part II) "Guidelines for the Design of Stabilized Pavement". This document may be referred for further details.

5.7.3 The design methodology for CCS Conventional stabilizer like cement, lime & fly ash shall remain the same as provided in IRC:37

5.8 Internal Drainage in Pavement

5.8.1 The performance of a pavement can be seriously affected if adequate drainage measures to prevent accumulation of moisture in the pavement structure are not taken. Drainage measure are especially important when the road is in cutting or built on low permeability soil or situated in heavy rainfall/snowfall area. On new roads, the aim should be to construct the pavement as far above the water table as economically practicable. The difference between the subgrade level and the level of water table/high flood level should generally, not be less than 1.0 m or 0.6 m in case of existing roads which have no history of being overtopped. In waterlogged areas, where the subgrade is within the zone of capillary saturation, consideration should be given to the installation of suitable capillary cut off as per IRC:34-2011 "Recommendations For Road Construction In Areas Affected By Water Logging, Flooding and/Or Salts Infestation" at an appropriate level underneath the pavement. Nevertheless, maintenance of transverse section of the road way in good shape to reasonable crossfall as to facilitate quick run off surface water and provision of appropriate surface and sub surface drains are primary measures to guard against poor drainage conditions. The details regarding drainage provisions are given in IRC:SP:42 "Guidelines for Road Drainage".

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CHAPTER 6

MATERIALS

6.1 General

i) The material should conform to the specification requirement;

ii) The materials are to be delivered at site without breakage, deterioration or pilferage;

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

iv) Any material, not covered in MORTH Specifications, contract specifications or IRC Codes, if required to be used, it shall conform to relevant Indian Standards or accredited by Indian Roads Congress or to the requirement specified by the Engineer. All such material will require approval by the Engineer.

v) If any proprietary items are proposed to be used in the works, they shall be governed by MORTH Specifications for Roads and Bridge Works

vi) If any new material not covered in the specifications of MORTH, IRC or BIS are proposed to be used, then this is to be accredited by IRC and used elsewhere. The performances of this material are to be guaranteed by the user.

6.2 Factory Manufactured Materials

These materials are to be furnished with ISI markings. The test results of these materials are required to be submitted. If required, these materials are to be got tested from independent laboratory approved by the Engineer and test results are to be furnished at the cost of the contractor.

Table 6.1: Requirement of manufactured materials

Sl. No.	Material	Relevant IS Standard	Remarks
1.	Cast Iron 1	IS:210 The grade number shall not be less then 14	
2.	Cement i) Ordinary Portland Cement 33 grade	IS:269	Minimum required design strength is to be achieved without exceeding minimum permissible cement content 450 kg/ cum of concrete.
	ii) Ordinary Portland Cement 43 grade	IS:8112	The Minimum cement content required from durability consideration is not to be reduced.
	iii) Ordinary Portland Cement 53 grade	IS:12269	
	iv) Sulphate resisting Portland cement	IS:12330	Shall be used when sodium sulphate and magnesium sulphate are present in large concentration to be aggressive to concrete
	v) Portland Pozzolana cement (flyash based)	IS:1489 (Part-1)	
	vi) Portland Slag Cement	IS:455	(blended with granulated slag and fly ash)
	vii) Rapid Hardening Portland Cement	IS:8041	
	viii)Low heat Portland Cement	IS:12600	
	ix) Composite Cement	IS:16415	

3.	Reinforcement i) Fe 240 Mildsteel ii) Fe 415 High Strength Deformed Steel Bars iii) Fe 500 or 500 High Strength Deformed Steel Bars iv) Fe 550 or Fe 550 D High Strength Deformed Steel Bars (HSD) v) Fe 600 High Strength Deformed Steel Bars (HSD)	 IS:432 Part 1 IS:1786 IS:1786 IS:1786 IS:1786	
4.	Protection of corrosion of reinforcement	by standard specification - Galvanising - Zinc-Aluminium Coating - Fusion Bonded Epoxy Coating - Cement-Polymer Coating Patented/ General Systems - Epoxy Phenolic-Rebar Coating System - Epoxy Based Coating	IRC:SP:80
5.	Binder/Bitumen i) Viscosity grade of bitumen ii) Modified Bitumen (including PMB NRMB, CRMB) iii) Emulsion iv) Cutback bitumen v) Bitumen for mastic asphalt	 IS:73 IS:15462 and IRC:SP:53 IS:8887 IS:217 Paving/Industrial grade bitumen, MORTH Specifications for Road and Bridge Works	

6.	RCC pipes for humepipe culvert i) NP – 4 types ii) PSC types (NP-4)	 IS:458 IS:784	
7.	Materials for Road Signs i) Reinforcement ii) a) High Strength Bolts b) Precast bolt nuts iii) Plates and Supports iv) Substrate a) Aluminum b) Aluminum Composite Material v) Retro Reflective Sheeting	 IS:1786 IS:1367 IS:1364 IS:226 and IS:2062 IS:736 – Material Designation – 24345 or 1900 IRC:67 IRC:67	
8.	Material for Road Markings including glass beads	IRC:35	
9.	Geosynthetics	As per MORTH Specifications for Road and Bridge Works& IRC:SP:59	

6.3 OTHERS

6.3.1 MATERIALS

a) Lime for soil stabilization – For lime soil stabilization work, lime shall be commercial dry lime slaked at site or preslaked lime delivered to the site in suitable packing. The lime shall have purity of not less than 70% by weight of quicklime (CaO) when tested in accordance with IS:1514. Lime shall be properly stored to avoid prolonged exposure to the atmosphere and consequent carbonation which would reduce its binding properties.

b) Aggregates for Concrete- Coarse aggregates and fine aggregates for concrete shall conform to IS:383 and tests for conformity shall be carried out as per IS:2386

c) Aggregates for flexible pavement course - Physical requirements and grading of aggregates for flexile pavement courses are specified by work and are to be as per MORTH Specifications for Road and Bridge Works. Some of them are covered in Section dealing with pavements.

d) Bricks – Burnt clay bricks shall conform to the requirements of IS:1077 except that the minimum compressive strength shall not be less than 8.4 MPa for individual bricks and mean strength not less than 10.5 MPa for a group of 5 specimens. The size may be according to local practice with a tolerance of ± 5%. The bricks shall have smooth rectangular faces with sharp curves and emit clear ringing sound when struck.

e) Stones – Stones shall be of the type specified. They shall be hard, sound, free from cracks, decay and weathering and shall be freshly quarried from an approved quarry. Stones with round faces shall not be used. The length of stone shall not exceed three times of its height and width of the base shall not be greater than three fourth of the thickness of the wall nor less than 150 mm.

6.3.2 Stacking/storage of materials

All materials 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.

a) Bricks should be stacked in regular tiers as they are unloaded to minimize breakage. Brick to be used in different situations should be stacked separately.

b) 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.

c) Hydrated lime for soil stabilization shall be stored in air-tight containers.

d) Cement should be stored in perfectly dry and water tight sheds. Wooden platforms about 15 or 20 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 be tested for acceptability requirements.

e) Mild steel for reinforcement should be stored in such a way as to avoid distortion and to prevent deterioration by corrosion.

f) Water shall be stored in containers/tanks covered at top and cleaned at regular intervals in order to prevent intrusion of foreign matter or growth of organic matter. Use of water from shallow, muddy or marsh sources shall not be permitted. The intake pipe shall be suitably enclosed to exclude silt, mud, grass and other solid materials and there shall be a minimum depth of 0.60 m of water below the intake at all times.

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CHAPTER 7

ROAD SAFETY INCLUDING TRAFFIC ENGINEERING, MARKINGS, SIGNAGE ETC.

7.1 Road accidents is a negative externality associates with expansion in road network, motorization and urbanization in the country. Road traffic injuries are recognized globally as a major public health problem, for being one of the leading causes of deaths, disabilities and hospitalization, imposing huge socio-economic costs. During the calendar year 2016, the total number of road accidents is reported at 4,80,652 claiming 1,50,785 lives in the country meaning 55 accidents and 17 death every hour. Various measures which promote road safety are presented below:-

7.2 Road Intersection

Road Intersections are points of conflict and hence are prone to accidents. About 37% of total accidents took place on junctions during the calendar year 2016. Therefore, it does not need any further emphasis on the importance of the road intersection. The intersections need proper design and are to be notified through appropriate signs and markings as the driver will have to carry out different manoeuvers, like diverging, merging, weaving, crossing, etc.

7.2.1 Intersection Types and Choice

a) Generally intersections can be classified into following categories depending on the traffic conditions. These are:

1. Uncontrolled Intersections at-grade: These are the intersections between any two roads with relatively lower volume of traffic and traffic of neither road has precedence over the other.

2. Intersection with Priority Control: There is theoretically no delay occurring on the major road and vehicles on the

minor road are controlled by "GIVE WAY" or "STOP" sign.

3. Time separated intersection/Signalized Intersection at – Grade: The detailed warrants for signalized intersection are laid down in IRC:93 "Guidelines on Design and Installation of Road Traffic Signals". A signalized intersection besides other warrants, is justified if the major street has a traffic volume of 650 to 800 vehicles per hour (both direction) and minor street has 200 to 250 vehicles per hour in one direction only.

4. Space Separated Intersection/Grade Separated Intersections: The detailed warrants for interchange or grade separated Intersections are given in IRC:92 "Guidelines for the Design of Interchanges in Urban Areas". According to these, a grade-separated intersections, besides other warrants, is justified when the total traffic of all the arms of the intersection is in excess of 10,000 PCU's per hour.

b) Road Intersections occur in multiplicity of shapes. They can, however, be divided into seven basis forms – T, Y, Scissor, Cross, Staggered, Staggered and skewed, and Multiway. The various shapes of at-grade intersections are shown in Fig. 7.1. The relation of a particular shape is governed by the configurations and geometrics of the intersecting arms.

c) 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 "Guidelines for Planning and Design of Roundabouts" for broad design features.

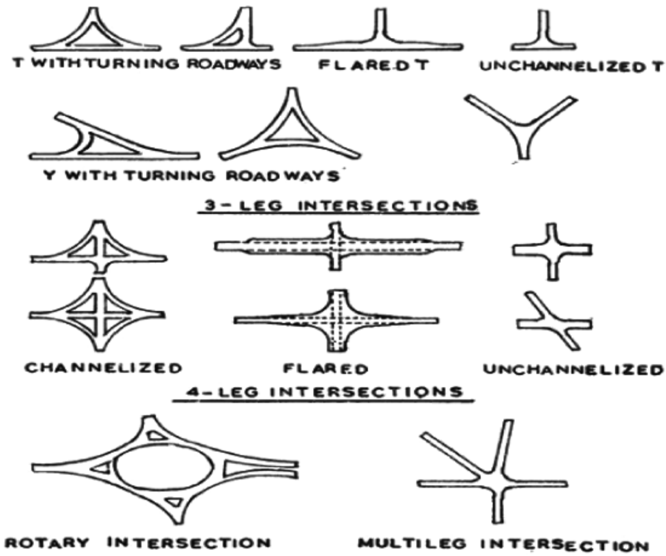


Fig. 7.1 General Type At-Grade Intersection

d) Channelised intersections with mountable kerbs for the traffic islands are suitable for rural highways. The islands shall be of sufficient size (min. $6m^2$) to attract attention, and shall be painted in alternate black and white stripes.

e) Grade-separation 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. Grade separation will be necessary at all crossings of a highway which is to be developed to a completely access controlled standard. Similarly, interchanges will be required at all major crossings on highways developed to access controlled standard.

f) Signal control are essentially for roads in urban/sub-urban areas. A signalized 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 direction) and minor street has 200 to 250 vehicles per hour in one direction only.

For design of at-grade intersections, except for traffic rotaries and signalized intersection, IRC:SP:41 "Guidelines for the Design of At-Grade Intersections in Rural and Urban Areas" may be referred.

7.2.2 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.

ii) A base plan of the intersection in the scale of 1:500 where two or three intersections are located close together. Additional base plan to a scale of 1:1000 should be prepared showing all the intersection affected.

iii) The peak hour design traffic data. The peak hour design traffic data should give its compositional and the directional break up.

iv) In the urban/sub-urban areas and intersection with villages with substantial pedestrian movements, the peak hour data on persons crossing the intersection should be collected for the design of well planned and pedestrian crossing for set movements.

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

vi) Accident data at intersections should be collected as per MORTH forms as detailed in para 7.11

7.2.2.1 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 motorized 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) 85^{th} 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, channelization, 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.

7.2.2.2 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 7.2.2.1 (ii) above:

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

ii) The 85^{th} 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.

7.2.2.3 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

7.2.2.4 Visibility at Intersections

a) 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 obstructions upto a height of 1.5 metre above the road way. Minimum eligibility distance along major roads at priority intersections on rural roads is given in Table 7.1

Table 7.1 Minimum visibility distance along major roads at priority intersections on rural roads

Design Speed of Major Road in kmph	Minimum Visibility Distance along Major Road (metres)
100	220
80	180
65	145
50	110

b) At an intersection where the intersecting roads are more or less of 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 from either highway must be able to perceive a hazard and halt the vehicle if required before reaching the intersection. Fig. 7.1 (a) explainsthe requirement of a visibility triangle.

c) On intersection, involving a major road and a minor road, traffic on minor road is controlled by 'STOP' or 'GIVE WAY' signs/road markings. Such sections are known as priority intersections. Fig. 7.1 (b) explains the visbilty triangle at priority intersections.

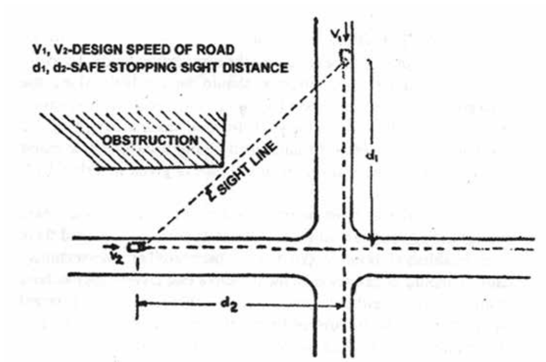


Fig 7.1 (a) Minimum sight triangle at uncontrolled intersections

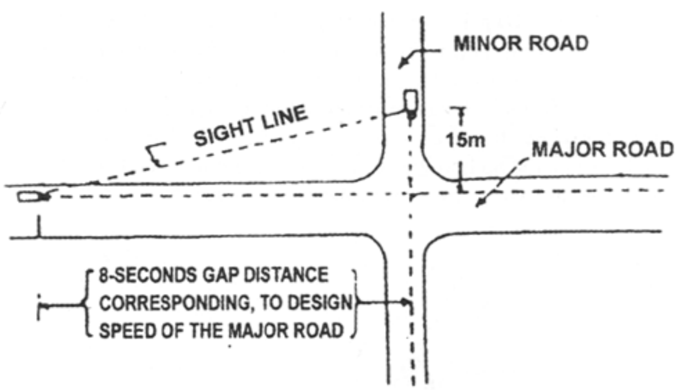


Fig 7.1 (b) Minimum sight triangle at priority intersections

7.2.2.5 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".

7.2.3 Interchange

7.2.3.1 Warrants

The decision to provide interchanges are based on careful consideration of following factors

1. Design consideration – For expressways to ensure continuous flow of traffic on the expressway interchanges are to be provided to avoid at grade intersection with the intersecting roads. However it should be determined based on the priority of the intersecting roads whether to terminate, re-routed or grouped with to provide the interchange.

2. Safety – At grade intersection may require up-gradation based on the number of accidents at the intersection.

3. Congestion – An interchange may be warranted where the Level of Service (LOS) of an at grade intersection is unacceptable and the intersection cannot be modified to provide an acceptable LOS.

4 Site topography – At certain sites, a grade separated intersection may be more feasible than an at grade intersection due to local topography.

5. Traffic Volume – Interchanges are desirable at cross roads with heavy traffic volume. Generally the interchange is considered necessary when the total traffic of all the arms of the intersection is in excess of 10,000 PCU per hour.

6. Road user Benefits – An interchange is warranted if an analysis reveals that road user benefits due to reduction in travel time will exceed the costs over the service life of the interchange.

7.2.3.2 Types of Interchanges

Interchanges can be broadly classified as:

System Interchange : An interchange that maintains free-flow through its elements for all major movements. System interchanges mainly connects from major road to major road. A major road typically refers to an expressway, major highway or major arterial road that does not contain at-grade intersections.

Service Interchange : An interchange that does not maintain free-flow through its elements for all major movements. Service interchanges mainly connects from major road to minor road. A minor road typically refers to a highway, arterial or sub-arterial road that contains at-grade intersection.

7.2.3.3 The common geometric configurations of interchanges are trumpet, diamond, clover leaf, rotary and directional interchanges. Within each type of interchange, there can be several variations such as split diamond, partial clover leafs etc. depending on the ramp arrangements.

7.2.3.4 Typical layouts of all these types are at Fig. 7.2

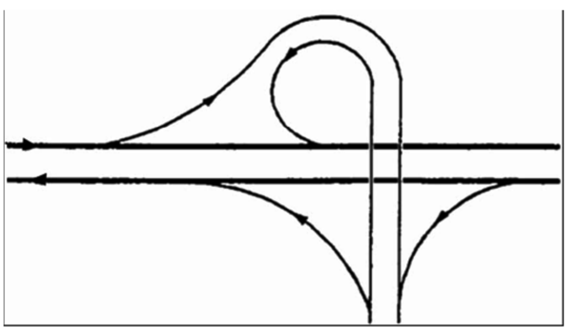


Fig.7.2a. Typecal 3-leg Interchange

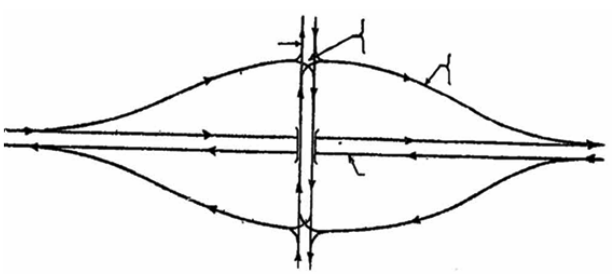


Fig.7.2b. Diamond Interchange

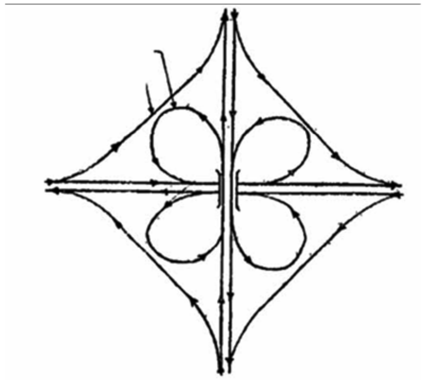


Fig. 7.2c. Full Cloverleaf Interchange

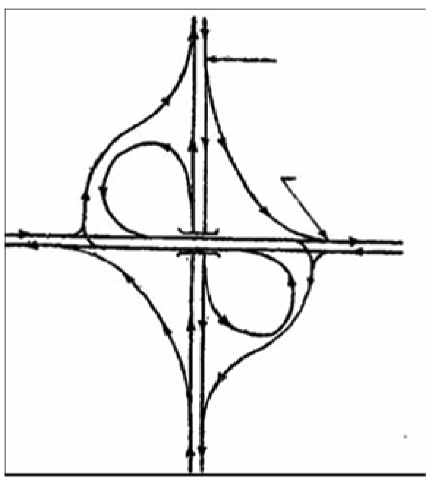


Fig. 7.2 d. Partial Cloverleaf Interchanges

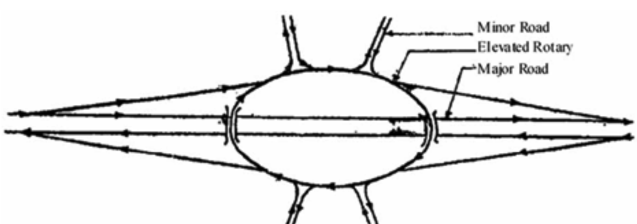


Fig. 7.2 e. Typical Rotary Interchange

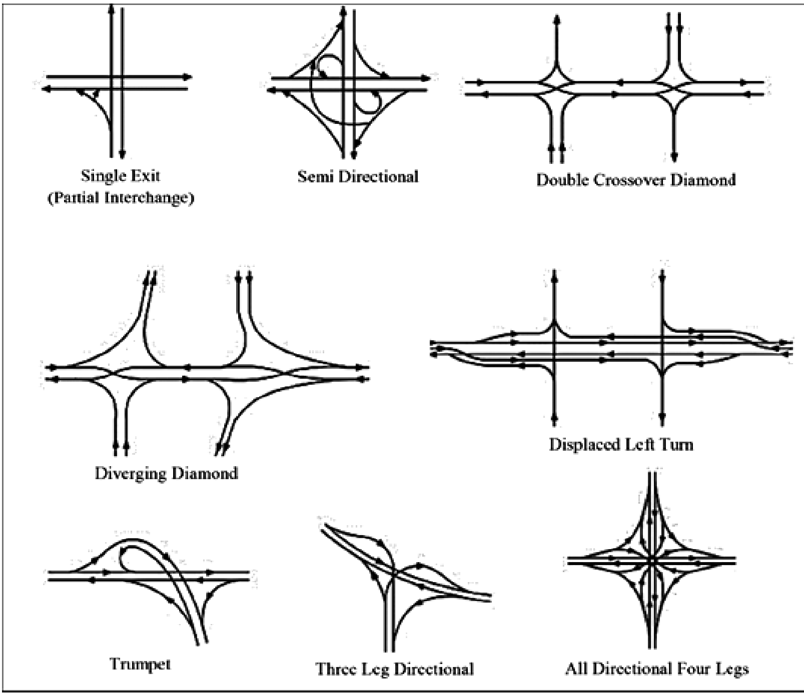


Fig. 7.2.f. Types of Interchanges

7.2.3.5 Details of interchanges, design considerations selection of interchanges, safety considerations etc. are given in IRC:92-2017 "Guidelines for Design of Interchanges in Urban Areas" The present guidelines are applicable mainly for urban roads. But in some cases non-urban roads also have been included and guidelines may be followed.

7.3 Road –Rail level crossing

7.3.1 When railway line and road cross at same 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.

7.3.2 Safety measures

Some safety measure 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 "Code of Practice for Road Signs" 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 Train Vehicle Unit (TVU) i.e. 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, IRC:39 "Standards for Road-Rail Level Crossings" is to be referred.

However, as per policy decision of MORTH all at grade crossing on National Highways with Railways will be replaced by grade separated structures.

7.4 Road Signs

To promote road safety and efficiency by providing for the orderly movement of all road users on all types of roads, road signs are provided. Road signs notify road users of regulations and provide warning and guidance needed for safe, uniform and efficient operation. IRC:67 "Code of Practice for Road Signs" may be referred for details of different road signs, materials to be used etc.

7.4.1 Classification of road signs

a) Mandatory/Regulatory

These inform the road users of law and regulations as per laws. Violation is a legal offence. These are circular in shape except STOP sign which is octagonal and triangular GIVEWAY or YIELD sign. They are with red circular ring which indicates prohibitory regulation and diagonal red bar prohibits the action or movement indicated by the black symbol.

b) Cautionary/Warning

Warn road users of the existence of certain hazardous conditions. These are triangular in shape with red border and black symbol in white background.

c) Informatory/Guide signs

As a general rule, there shall be four sizes of signs namely small, medium, normal and large. Sizes of signs also depend on type of sign. For expressways different bigger size of signs are to be used as the design speed is greater than other types of roads. The size of signs to be used depend on the category of signs and design speed of the road. These signs are rectangular in shape

7.4.2 Siting of signs

Two Lane Roads	-	On the left side of the carriageway
Multilane divided carriageway	-	On left side of each carriageway
Hill Roads	-	On valley side
Lateral clearance of extreme edge of ground mounted signs kerbed roads	-	not less than 300 mm
Unkerbed roads	-	600 mm to 3 m
Vertical clearance		
i) Kerbed roads	-	2.1 m – 2.5 m
ii) Unkerbed roads	-	2 m – 2.5 m

7.4.3 Orientation of Signs

The signs shall normally be placed at right angles to the line of travel of approaching traffic except for signs related to parking which should be fixed at an angle 15^0 to the carriageway.

7.4.4 Size and Colour

The Size of the sign are given in Table 7.2 and 7.3 below

The scheme of colouring of signs shall be as per IRC:67. Signs shall be provided with retro-reflective sheeting and/or overlay film. The reverse side of the sign shall be painted grey.

Except in case of railway level crossing signs, the sign posts shall be painted in 250 m wide bands alternatively black and white. The lowest band next to the ground shall be in black.

Table 7.2 Size and Dimension of Mandatory and Regulatory Signs

Design Speed	Size	Regulatory Signs	Mandatory Signs			
		Diameter (mm)	Diameter (mm)	Border (mm)	Oblique (mm)	Font Size (mm)
Up to 65 kmph	In conjunction with traffic light signal		300	35	35	75
	Small	600	600	50	50	100
66-80 kmph	Medium	750	750	60	60	125
81-100 kmph	Normal	900	900	75	75	125
> 100 kmph	Large	1200	1200	100	100	225

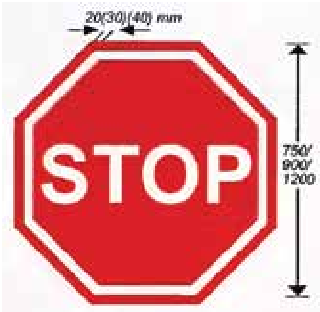
Table 7.3 The Sizes and Dimensions of Cautionary signs and their Sitting Distances

Design Speed	Size	Side (mm)	Border (mm)	Clear Visibility Distances (mm)	Distance of sign from hazard (m)
Upto 50 kmph	Small	600	45	45	45
51-65 kmph	Medium	750	60	60	45-110
66-80 kmph	Normal	900	70	60	110-180
> 80 kmph	Large	1200	90	90	180-245

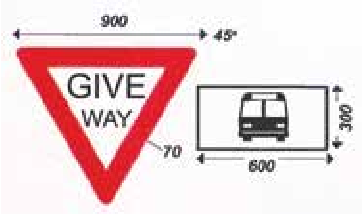
7.4.5 Details regarding road signs are given in IRC:67.

7.4.6 Few typical drawings of different types of signs are given below.

a) Mandatory/Regulatory Signs (Fig 7.3)

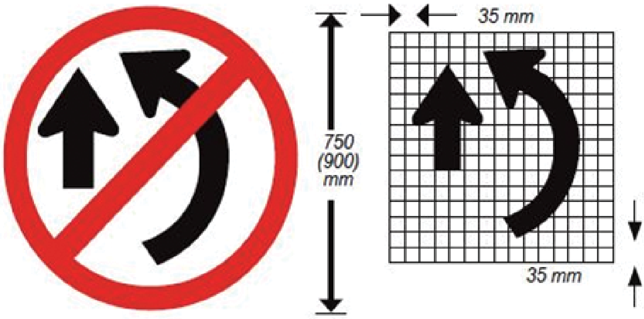


Stop



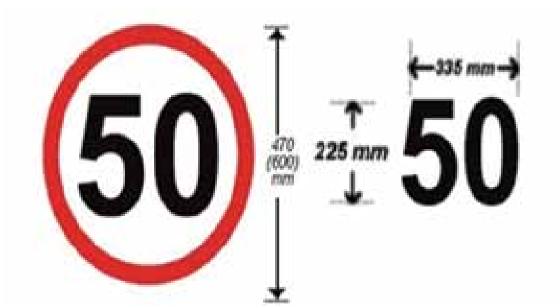
Give Way to Buses exiting the Bus bays

Two Wheeler Prohibited



Overtaking Prohibited

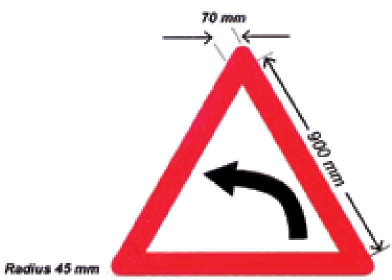
No Parking



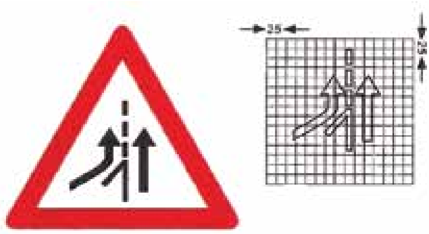
Maximum Speed Limit

Compulsory turn left

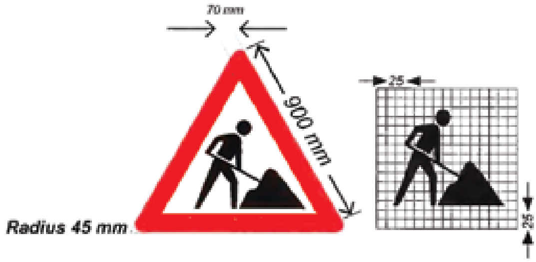
b) Cautionary/Warning Signs (Fig. 7.4)



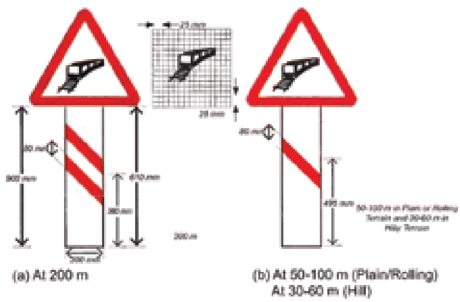
Left hand curve



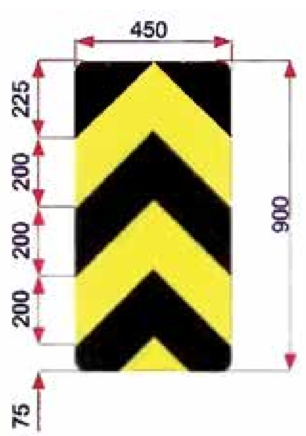
Merging traffic ahead (From left)



Men at Work

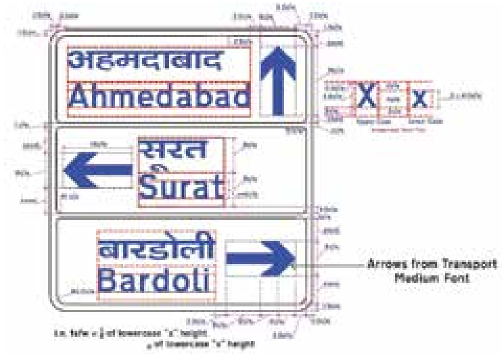


Upgraded Railway Crossing

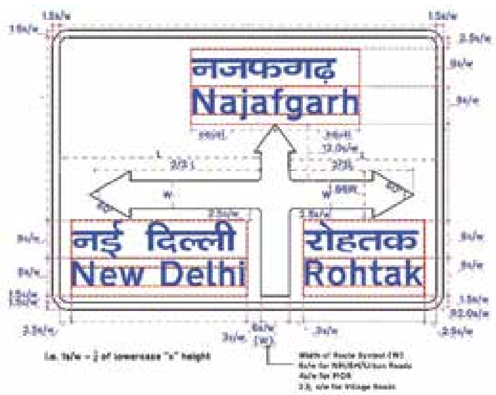


Twoway hazad Marker

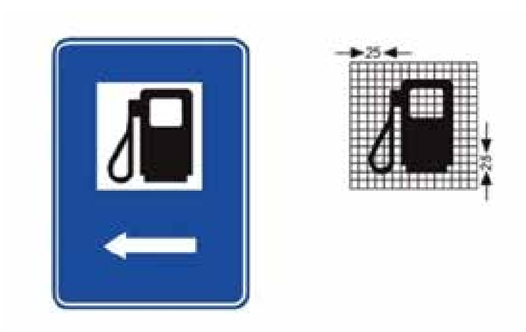
c) Informatory/Guide Signs (Fig. 7.5)



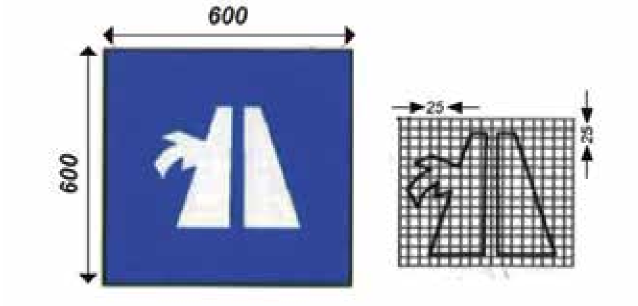
Stack type Advance Direction Sign (Shoulder Mounted)



Map type Advance Direction Sign (Shoulder Mounted)



Filling Station (Fuel Pump)



Ramp for Expressways

Asian Highway Route Marker Sign

The sizes and shapes of other signs are given in IRC : 67

7.5 Road Markings

7.5.1 Road markings perform an important function of guiding and controlling traffic on a highway. The markings serve as a psychological barrier and thus helps to signify delineation of traffic path and its lateral clearance from traffic facilitating movement into safe location and in effect provide for an extension of side walk/cycle track across the road way. Road marking, therefore, indispensable to ensure smooth and orderly flow of traffic and promoting road safety.

7.5.2 Road markings materials

The commonly used materials for road markings are

a) Hot applied thermoplastic compound and

b) Solvent borne and water borne road marking paints

Other specific material for rod making includes cold applied plastic and performed adhesive colour pattern for markings.

The specification of road marking material shall be as per Clause 803 of MORTH Specifications of Road and Bridge Works. Retro reflection is accomplished in pavement marking through the use of glass beads, partially embedded on the surface of the marking as binder material and also spread externally during application time. The quality of glass beads plays in important role in retro reflectivity of pavement marking. The specification of glass beads shall be as per Clause 803 of MORTH Specifications of Road and Bridge Works.

7.5.3 The general colour pattern followed for road markings are given below:-

1. **White -** The colour should be widely used for road markings because of the visibility and good contact. As per MORTH circular no. RW/NH-33044/105/2018-S&R (P&B) dated 07-01-2019 the colour of pavement marking on concrete roads shall also be white instead of yellow.

2. **Yellow** – To convey message in the form of longitudinal marking where it is not permitted to cross the markings. Also used for parking restrictions and to improve other traffic control.

3. **Blue** – Blue colour should be used to indicate new and special markings which are not conventional and also public transportation including three wheelers, scooters, rickshaw and Bus Rapid Transport (BRT) corridor on urban street.

4. **Green** – The green colour should be deployed to distinguish the bicycle and non-motorized transport facilities provided on the road.

5. **Red/Purple** – Where multiple road users are sharing the road space on hazardous location, the red colour marking is primarily used to help people to understand the danger.

7.5.4 Classification of Pavement Markings

Pavement markings are broadly classified into following seven categories based on the placement of markings with regard to vehicular movement and also based on the function of the markings.

i) Longitudinal Marking (LM)

ii) Transverse Marking (TM)

iii) Hazard Marking (HM)

iv) Block Marking (BM)

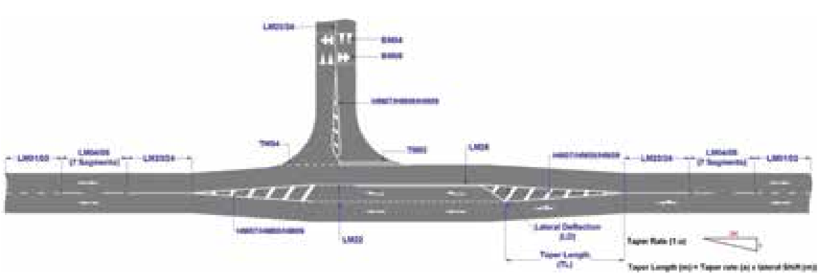
v) Arrow Marking (AM)

vi) Directional Marking (DM)

vii) Facility Marking (FM)

7.5.5 These marking are used in combination for various cases of markings on the road for safe and orderly guidance of traffic. The details of marking in for different applications, road markings materials and general features etc. are given in IRC:35 "Code of Practice for Road Markings"

7.5.6 Few typical cases of markings are given in Fig. 7.6 to 7.9



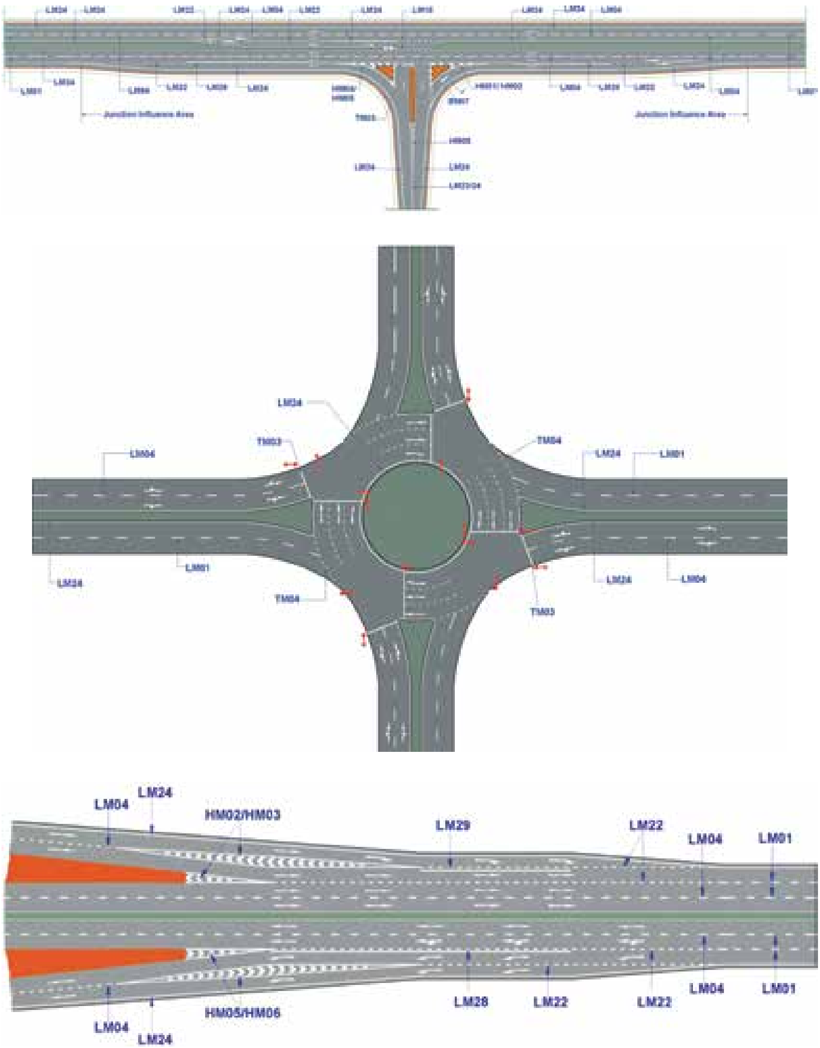


Fig. 7.6 to 7.9 Different types of Pavement Markings

7.5.7 Road Studs

Retro-reflective studs are used to supplement longitudinal/transverse reflectorized markings which would improve visibility in night time in adverse weather conditions. Road studs are also used across the carriageway to serve as speed arrestor coupled with eschewing warnings through creation of rumbling sensation to the user. Road studs shall be made of plastic material with reflectors for all type of roads.

7.5.7.1 The studs with different colour of reflector such as white, red, yellow and green are used for highways.

a) White Colour – To indicate traffic lane line and centre of the carriageway

b) Red Colour – To indicate a line which should not be crossed and mainly to delineate the left hand edge of the carriageway.

c) Yellow Colour – To delineate the right hand edge of the carriageway (median side edge) in case of the multilane divided carriageway to indicate a line which should not be crossed.

d) Green Colour – To indicate cross edge lines like lay-byes and to show the boundary of acceleration or deceleration line on the left hand side of the carriageway in case of multi lane divided carriageways.

Typical road marking are shown in Fig. 7.10

7.5.7.2 The details of road studs are given in IRC:35. The clause 804 of Specifications of Road and Bridge Works of MORTH and ASTM D 4280-04 shall be referred for technical specification of road studs.

7.5.7.3 Solar powered road makers are to be used at locations like approach to road crash prone locations and highly hazardous locations like bridge, toll plaza, sharp curves, pedestrian crossings, lane transitions, speed humps, junctions, channelization, construction sites, rail road crossings, median opening, lane changing, accident prone locations.

7.5.7.4 The road markings provided in existing roads should be subjected to safety audit to ensure their uniformity.

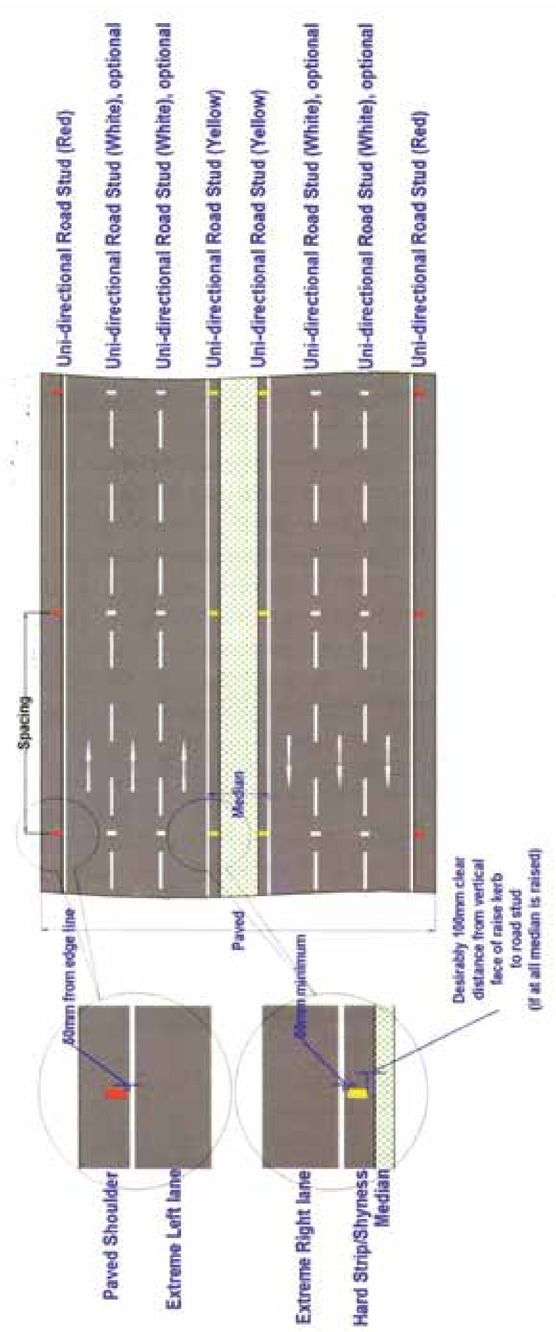


Fig. 7.10. Typical Road Marking

7.6 Traffic Safety Barriers.

7.6.1 Traffic safety barriers also known as crash barriers are provided on high speed highways to prevent accidents when vehicles lose control and run off the road. Especially dangerous road sections with sharp curves, approaches to bridges with restricted roadway, high embankment, hazardous obstacles such as poles, trees and bridge structural elements. Experience has shown that if suitably designed and properly located, it is possible to redirect the vehicle nearly parallel to the direction of the barrier and can minimize the severity of the accident and reduce the damage of property.

7.6.2 Types of Traffic Safety Barriers.

a) There are two general types of traffic safety barriers namely Road Edge Barrier (also known as road side barriers) and Median barriers.

b) Depending upon their mode of performance traffic safety barriers can be classified generally as

   i) Flexible (e.g. Cable wire type barrier)

   ii) Semi-rigid (e.g. Steel beam type barrier)

   iii) Rigid (e.g. Concrete barrier)

7.6.3 Road Side Barrier

A road edge barrier also known as road side barrier, is a longitudinal system used to shield vehicles from hazards on the edge of the road and are generally provided at the following locations.

i) High Embankment with steep slopes

ii) Near road side obstacles

iii) Bridge rail ends

iv) At specific locations for ensuring safety of by standers, pedestrians and cyclists.

v) Dangerous ditches

vi) Steep grades

vii) Accident black spots

viii) Hill roads

ix) Grade separated structures

7.6.4 Median Barriers

Median barriers are those that are provided in the medians of highways for protecting the traffic on both the carriageways. They are intended to prevent head on collision, especially on highways with narrow medians, caused by out of control vehicles jumping across the median. They also shield fixed objects on the median from traffic flow.

7.6.5 The warrants for requirement of traffic safety barriers, details of different types of barriers, specification and maintenance for barriers are given in IRC:119 “Guidelines for Traffic Safety Barriers”.

7.6.6 Figures relating to different types of barriers is given in Fig. 7.11

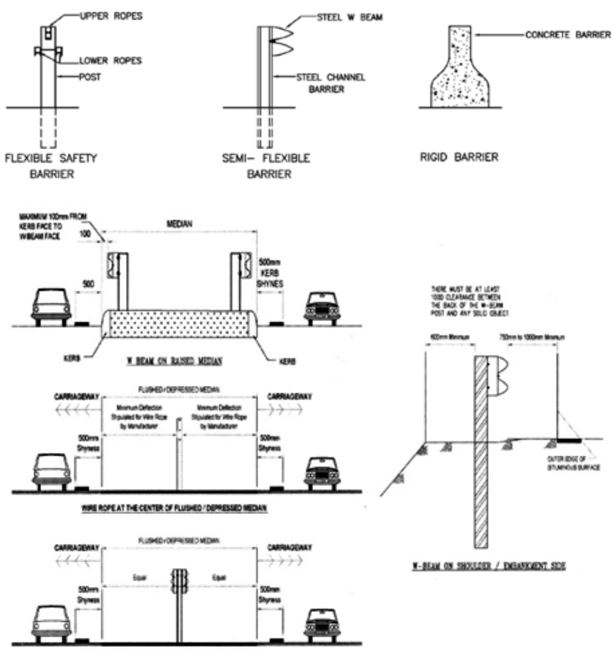


Fig. 7.11 Different types of Barriers

7.6.7 Raised kerbs or drains should not be provided between the carriageway and the barriers. These destabilize the vehicle balance and disturb its equilibrium before it strikes the barriers, thus defeating the essential purpose of safety and redirection of the impacting vehicles. It is a good practice to avoid kerbed and raised median in dual carriageway of highways.

7.6.8 The metal safety barriers shall be compliant with test acceptance criteria of European EN13170-2 Standard or NCHRP 350 for containment levels of N2, H1 and H2 or NCHRP 350 for containment levsl TL 3 and TL 4. The wire rope (cable) barriers shall be compliant with test acceptance criteria of European EN 1317-2 Standard for Containment levels N2, H4 and H2. The concrete, metal and the wire rope (cable) used for the safety barriers shall comply with the requirements given in IRC:119. The manufacturers of the metal safety barriers and wire slope (cable) barriers shall provide all applicable crash test reports that confirm the barriers have passed the crash test conducted by an international accredited crash testing laboratory having all needed all the testing facilities**.**

7.7 Road Delineators

7.7.1 The role of delineators is to provide visual assistance to drivers about alignment of the road ahead, especially at night. Delineators are particularly effective in case of complex locations involving changes in horizontal/vertical geometry and during severe weather conditions such as heavy rain, fog or snow. Reflectors are used on the delineators for better night visibility. Delineators are basically driving aids and should not be regarded as a substitute for warning signs, road markings or barriers for out of control vehicle. 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 from the kerb face. On hill roads, these may be placed either on the parapet or at the edge of the shoulder. The normal spacing between two successive indicators in a straight section shall be about 50-70 m. Roadway indicators have been shown in Fig.7.12. Flexible Median Marker (FMM) should be used for improving median visibility during dark hour. Use of Median Marker provides safety against collision happening with medians during night time or severe weather. Typical application of FMM are shown in Fig. 7.13.

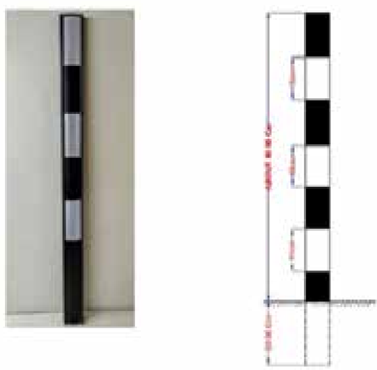
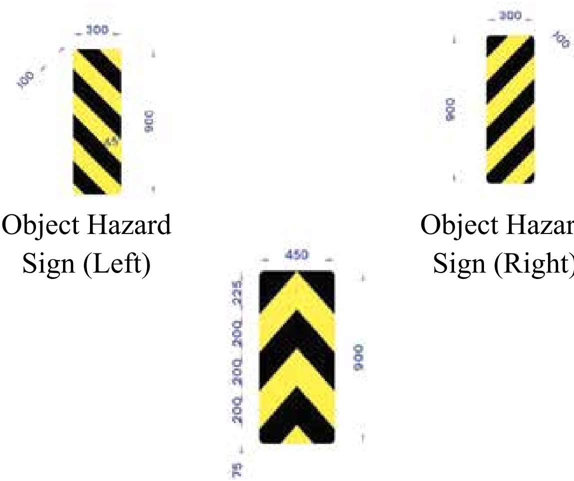


Fig.7.12 Typical view of Delineators

Fig. 7.13. Typical view of FMM

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 narrow than the roadway sideat approaches. Hazard markers are shown in Fig. 7.14.



Object Hazard Sign (Left)

Object Hazard Sign (Right)

Object Hazard Marker Twoway Sign (for Twoway Hazard)

Fig. 7.14. Hazards Markers

iii) Object Markers: These are used to indicate hazards and obstructions within the vehicle flow path, for example channelizing islands close to intersections. Typical design of object markers are shown in Fig. 7.15.

Fig. 7.15. Typical Illustration of Placement of Flexible Object Markers

7.7.2 Details of material of delineators, spacing in different situations, installation and maintenance are given in IRC:79 "Recommended Practice for Road Delineators".

7.8 Variable Message Signs

Variable Message Signs (VMS) messages are used to inform and direct motorists of variable situations in a consistent and orderly manner. The messages are for the purpose of traffic control management and timely traveler information. The information is most often displayed in real time and can be controlled either from a remote centralized location or locally at the site. They are commonly installed on full span overhead sign bridges, post mounted on roadway shoulders, overhead cantilever structures and portable types mounted on trailers/prime movers.

Examples of traveler information provided through VMS include:

i) Travel time between known destinations

ii) Congestion conditions along a high speed corridors

iii) Construction site warning/information notices

iv) Special events notice and motorists instructions

v) Maintenance operations schedule

vi) Severe weather announcement

vii) Incident or accident notification

Generally, VMS system forms part of the Advanced Traffic Management System (ATMS), one of the major components of Intelligent Transport System (ITS).The integrated ATMS Software receives online data from Automatic Traffic Counter & Classifier (ATCC) metrological sensors, traffic control system, CCTV, Video Incident Detection System (VIDS), Emergency Call Boxes (ECB), etc. After processing and analyzing the data information can be automatically shared with road users through VMS, Internet, SMS, FM, radio etc. However, VMS can also be used independently for providing information to the road users effectively. In this case, the inputs to the VMS systems are using manual entry or pre-programmed messages through computers.

IRC:SP:85 "Guidelines for Variable Message Signs" covers purpose of using VMS, warrants for VMS, message content of VMS, VMS for urban areas, portable VMS and design of VMS. The specifications for VMS are at clause 816.11 of MORTH Specifications for Road and Bridge Works.

7.9 Traffic Management in Work Zones

7.9.1 The road construction and maintenance activities are the integral part of road network development. The road works zones are areas of conflict between normal operating traffic, construction works, road building machineries and construction traffic. For construction of new road or new bypass the problem is not that acute except that care has to be taken to avoid and remove conflicts between workers and construction machineries and construction traffic. To ensure safety of all, there is a need to adopt an efficient and effective plan for management of traffic zones. Work Zone Traffic Management Plan (WTMPs) are required to meet the safety needs of regular traffic as well as works traffic, ensuring minimum disruption in access to properties and movement of pedestrians.

7.9.2 The details of WTMPs are available in IRC:SP:55 "Guidelines on Traffic Management in Work Zones". Some illustrations on traffic management practices are attached in Fig. 7.16, Fig. 7.17, Fig. 7.18 and Fig. 7.19.

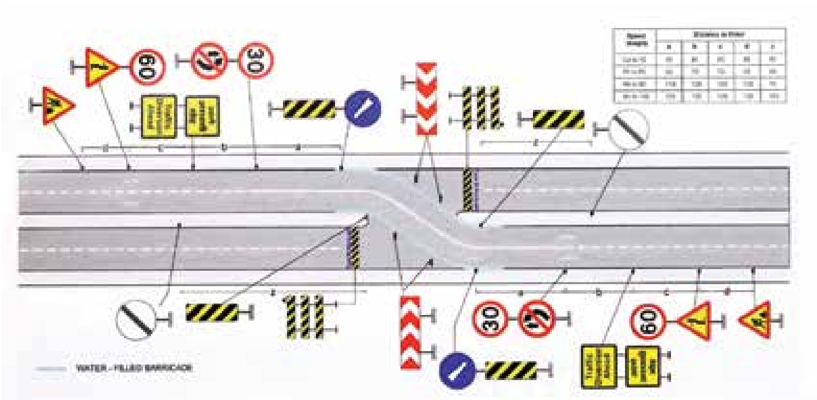


Fig. 7.16 Two Lane to Four Lane (Shifting of Traffic from One Carrigeway to the other)

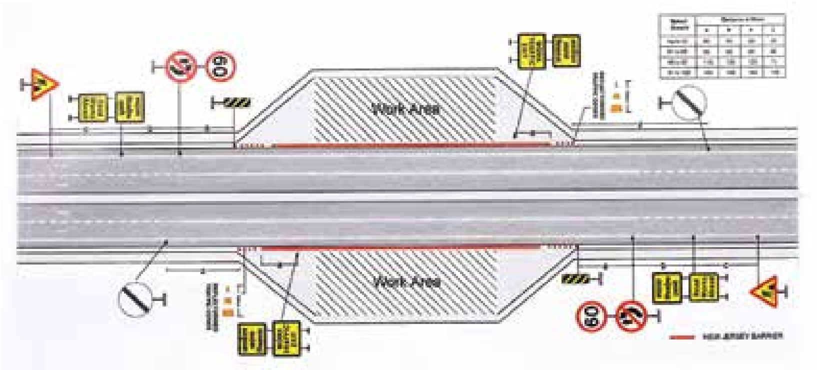


Fig. 7.17 Four Lane to Six Lane (Concentric Widening)

Fig. 7.18 Upgrading of 1 L / Intermediate Lane to TwoLane with Shoulders

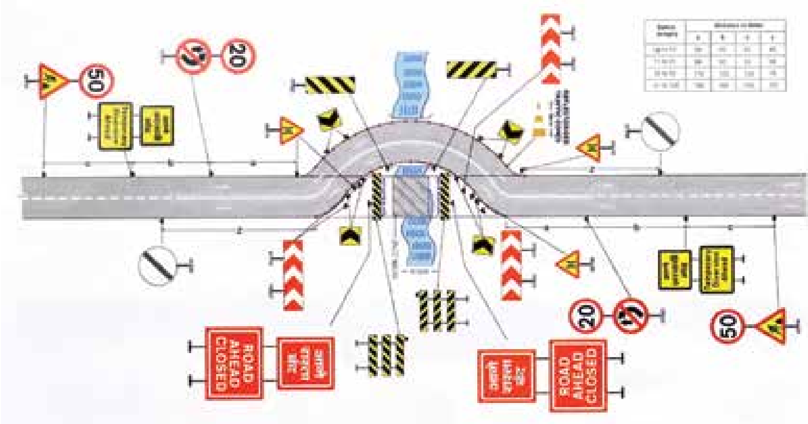


Fig. 7.19 Temporary Diversion for Recconstruction of CD Works

Fig. 7.16 to 7.19. Traffic Management in Work Zones

7.10 Traffic Calming Measures

7.10.1 Vehicle speed is one of the critical factors associated with road accidents because higher speeds reduce the time available to avoid collisions and make impacts in collisions more severe. Research studies from around the world demonstrate conclusively that the frequency and severity of accidents usually reduce with reduction in average speed. The traffic claiming techniques have played an important role in enhancing better safety by ensuring lower driving speeds and smaller speed differences between different road users. Studies have shown that traffic calming can reduce accident level by up to 40 per cent.

7.10.2 The central theme of traffic calming is to reduce the adverse impact of motor vehicles on built-up areas both in urban roads and rural highways. The techniques usually involve reducing vehicle speeds, providing more space for pedestrians and cyclists and improving the local environment.

The classification of traffic calming techniques are as given in Fig 7.20 below.

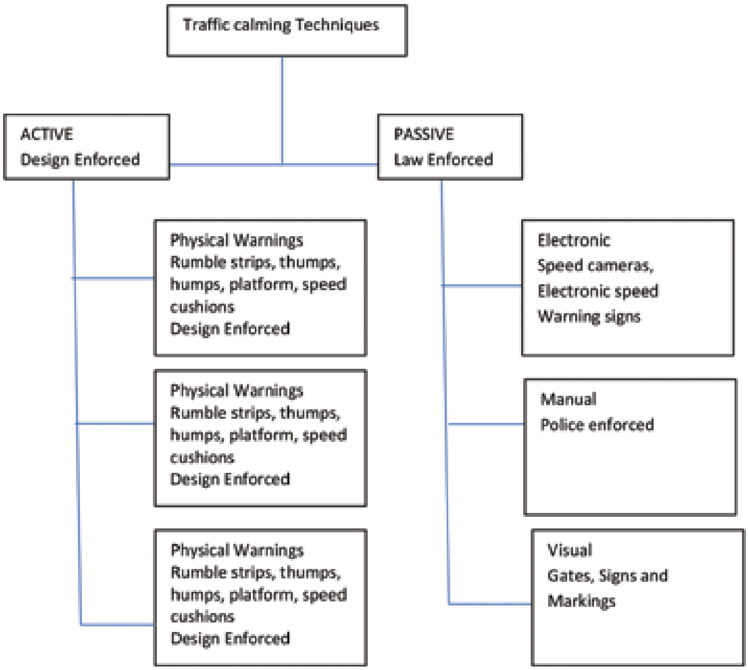


Fig. 7.20 Classification of Traffic Calming Techniques

7.10.3 Physical Warning

7.10.3.1 Traffic Calming (TC) on road infrastructure can be physical measure to curtail the speed forcing driver to slow down to the desired speed

Intent of TC technique/intervention	Method	Successful Examples
Physical signal to driver	Influences driver behavior by means of jerks and vibrations to the vehicle	Road humps, rumble stips, raised crossings, platform junctions raised at pavement level, speed tables and ramps

Psychological signal to driver	Directly affecting his risk perception by visual or audio means	Carriageway width constructions, chicanes, corner blips, planted central reservations, bends in the traffic route etc.

7.10.3.2 The common factor that effect of psychological signal to the driver get reduced over time, as the drivers get used to the measures as part of their routine travel habits.

7.10.3.3 Details of traffic calming techniques in different locations and

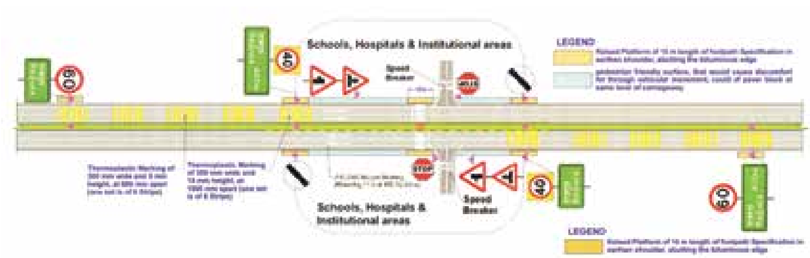


Fig. 7.21 Schematic Diagram for Highway Corridors

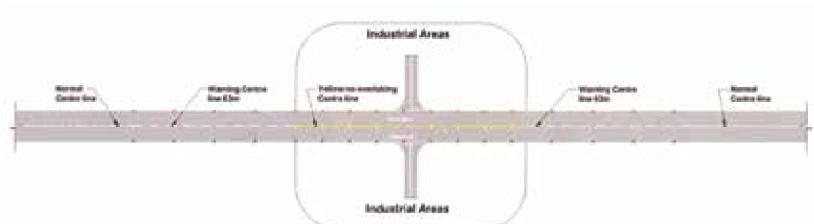


Fig. 7.22 Schematic Diagram for Highway Corridors without Central Medians

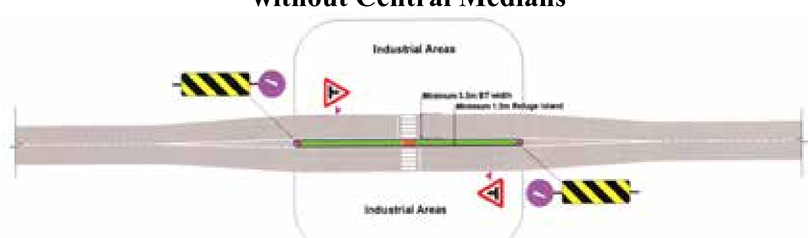


Fig. 7.23 Schematic Diagram Stretches of highways without pedestrian footpaths

Fig. 7.21 to 7.23 Examples of Traffic Calming

other details of traffic calming are given in IRC:99 “Guidelines for Traffic Calming Measures in Urban and Rural Areas”.

7.10.3.4 Typical examples of traffic calming in different locations are illustrated in Fig. 7.21, , Fig. 7.22 & Fig. 7.23.

7.11 Road Accident Recording

7.11.1 Road accident data is the base measure of safety and without it, the scale and nature of road safety problems cannot be established with certainty. The existence of a reliable accident database is thus a crucial element in the management of road safety. The purpose of acquisition of accident data should be to acquire as much relevant knowledge as possible from the data to help to prevent accidents of similar nature from occurring in the future.

7.11.2 The best source of validated accident data will be the police force; either the police man attending the scene of an accident or the office at a police station who receives the report by the involved parties/witness.

7.11.3 The MORTH has prepared a new uniform accident recording format to be adopted by the police in all the State/UTs The copies of the Road Accident Recording Form is attached at Annex 7.1. In addition, there are 17 forms known as Reporting Format to be prepared by the State/UT Departments for reporting to MORTH. The copies of these forms may be downloaded from the site http://pib.nic.in/newsite.

Annex - 7.1

I. ROAD ACCIDENT RECORDING FORM

A. Accident Identification Details

1. FIR No. ☐☐☐☐ 2. Time ☐☐☐☐ 3. Date D D M M Y Y

4. Name of Place ☐ 5. Police Station ☐

6. District ☐ 7. State ☐

8. Type of Area ☐ Urban ☐ Rural

9. Accident Type ☐ Fatal ☐ Grievous Injured (Need Hospitalization) ☐ Minor Injury (No Need of Hospitalization) ☐ Non Injury

10. No. of Fatalities ☐ No. of persons Grievously Injured ☐ No. of persons Minor Injured ☐

11. Property Damage ☐ Public ☐ Private ☐ Others

12. No. of Motorized Vehicles Involved ☐ No. of Non Motorized Vehicles Involved ☐ No. of Pedestrian Involved ☐

13. Type of Weather

☐ Sunny/Clear ☐ Rainy ☐ Foggy/Misty ☐ Hail/Sleet ☐ Others (Specify)

14. Hit & Run ☐ Yes ☐ No

15. Type of Collision

☐ Pedestrian ☐ Hit from Back ☐ Hit from Side ☐ Run Off Road ☐ With Animal

☐ Fixed /Stationary Object ☐ With Parked Vehicle ☐ Vehicle Overturn ☐ Head on Collision ☐ Others (Specify)

B. Road Related Details

16. Road Name ☐ 17. Road Number ☐

18. Landmark ☐ 19. Road Chainage ☐ Km

20. GPS Location

Latitude ☐☐ . ☐☐☐☐☐☐ Longitude ☐☐☐ . ☐☐☐☐☐

21. Lanes ☐ 2 Lanes or less ☐ More than 2 Lanes

22. Surface Condition ☐ Paved ☐ Unpaved

23. Road Type

(a) ☐ Expressway ☐ National Highway ☐ State Highway ☐ Other Roads

(b) ☐ Urban ☐ Non Urban

Contd...

24. Physical Divider ☐ Yes ☐ No

25. Ongoing Road Works/ Construction ☐ Yes ☐ No

26. Speed Limit ☐ < 40 ☐ 40 – 60 ☐ 60 – 80 ☐ >80 ☐ No Speed Sign

27. Visibility (at the time of accident) ☐ Good ☐ Poor ☐ Not Known

28. Accident Spot ☐ Residential Area ☐ Institutional Area ☐ Market/ Commercial Area ☐ Open Area ☐ Others (Specify)

29. Road Features ☐ Straight Road ☐ Curved Road ☐ Bridge ☐ Culvert ☐ Pot Holes ☐ Steep Grade

30. Road Junction (if accident is at Junction) ☐ T Junction ☐ Y Junction ☐ Four Arm Junction ☐ Staggered Junction ☐ Round About Junction

31. Type of Traffic Control (if accident is at Junction)

☐ Traffic Light Signal ☐ Police Control ☐ Stop Sign ☐ Flashing Signal/Blinker ☐ Uncontrolled

32. Pedestrian Involved (if applicable) ☐ No Facility ☐ Footpath ☐ Zebra Crossing ☐ Foot Bridge/ Subway ☐ Not Applicable

Contd...

C. Vehicles Involved in Accident:

Sl. No. (No. '33')	Type of Vehicle (No. '34')	Registration No. (No. '35')	Disposition (No. '36')	Load Condition (No. '37')		Mechanical Failure (No. '38')	Age of Vehicle (No. '39')
				Passenger	Goods		

Coding Instructions:

No. '34'
1. Motorised Two Wheeler
2. Auto Rickshaw
3. Car/Jeep/Van/Taxi
4. Bus
5. Truck/Lorry
6. Heavy Articulated Vehicle/Trolly
7. Tempo/Tractor
8. Bicycle
9. Cycle Rickshaw
10. Hand Drawn Cart
11. Animal Drawn Cart
12. Others (Specify)

No. '36'
1. Needs to be Towed
2. Can be driven away

No. '37'
1. Normally Loaded
2. Overloaded/Hanging
3. Empty
4. Not known

No.'38'
1. Yes
2. No

Contd...

D. Drivers Details

Sl. No. (No. '40')	Sex (No. '41')	Impacting Vehicle (No. '42')	Age (No. '43')	Type of Licence (No. '44')	License No. (No. '45')	Type of Traffic Violation (No. '46')	Type of Injury (No. '47')	Using Requisite Safety Device (No. '48')

No.'41'
1. Male
2. Female

No. '42'
1. Motorised Two Wheeler
2. Auto Rickshaw
3. Car/Jeep/Van/Taxi
4. Bus
5. Truck/Lorry
6. Heavy Articulated Veh./Trolley
7. Tempo/Tractor
8. Bicycle
9. Cycle Rickshaw
10. Hand Drawn Cart
11. Animal Drawn Cart
12. Others (Specify)

No. '44 '
1.Valid Permanent License
2.Learner License
3.Without License

No.'46'
1. Over Speeding
2. Jumping Red Light
3. Driving on Wrong side
4. Drunken Driving
5. Use of Mobile Phone
6. No violation
7. Not Known

No. '47'
1. Fatal
2. Injury needing Hospitalisation
3. Injury not needing/ Hospitalisation
4. Non Injury
5. Not known

No. '48'
1. Seat Belt
2. Helmet
3. Not Known
(In case of Hit & Run)

Contd...

E. Persons Other than Drivers Involved in Accident:

Sl. No. (No. '49')	Persons Involved (No. '50')	Sex (No. '51')	Age (No. '52')	Impacting Vehicle (No. '53')	Type of Injury (No. '54')	Using Requisite Safety Device (No. '55')

No. '50'
1. Passenger
2. Pedestrain
3. Cyclist

No.'51'
1.Male
2.Female

No. '53'
Same as **Sl. 44**

No. '54'
1. Fatal
2. Injury needing Hospitalisation
3. Injury not needing/ Hospitalisation

No. '55'
1. Helmet
2. Seat Belt
3. Not Known (In case of Hit & Run)

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7.12 Road Safety Audit

7.12.1 Road Safety Audit is a formal systematic and detailed examination of a road project by an independent and qualified team of auditors that leads to a report of the potential safety concerns in the project. The outcome of road safety audit is a audit safety report that identifies road safety issues and makes recommendations to remove or reduce the impacts.

7.12.2 There are five stages of a road project at which road safety audit can be conducted namely stage 1: Planning/feasibility stage, stage 2: Detailed design stage, stage 3: Construction stage, stage 4: Pre opening stage, stage 5: Safety audit of existing roads.

7.12.3 Road safety audits may be commissioned only at selected stages according to the cost of the road project or the classification of the road. As a general rule audit (i) any road project on a high speed road and (ii) any road project experiencing high volume of traffic and vulnerable road users.

7.12.4 As a general rule, audit is to be done for any road project on a high speed road an any road project experiencing high volume of traffic and vulnerable road users. For any new project, audit is to be undertaken for all four stages i.e. stage 1 to stage 4. For National Highway and State Highways audit for stage 1 is optional and audit is to be undertaken for stage-2, stage-3 and stage 4. Audit at stage 5 is to be undertaken according to local policy and resources. As per MORTH Circular letter No.RW/NH-29011/11/2015-P&M (SCE) dated 04.07.2018, the Project Implementation Agencies concerned that DPR consultant gives a certificate in the DPR that they have addressed the safety related concerns with inputs from the Road Safety Expert and the IE/AE/SC issues and identical certificate for having taken care of the safety aspects while approving engineering designs. These road safety measures have to be carriedout for all new road projects of National Highways having length of 5 km or more at the stage of Detailed Project Report (DPR)/ Engineering Design. .

7.12.5 The audit team of two persons shall conduct the safety audit. They should have qualification and experience in road safety engineering and have completed and approved road safety audit training programme of at least two week duration and have demonstrated experience with the type of road project and the stage of audit and clearly have no previous involvement in planning or design of the road project.

7.12.6 The IRC:SP:88 "Manual on Road Safety Audit" is a comprehensive guidelines for conducting the Road Safety Audit. This manual contains an overview of road safety audit, the key steps for conducting a road safety audit, managing road safety audit practices for safer roads, safety audit case studies, reporting and road safety audit checklists.

7.13. Equivalency Factors for Vehicle

7.13.1 The traffic on the road is composed of different types of vehicle, it is normal practice to convert the volume into equivalent Passenger Car Unit (PCU) by using equivalency factors given in Table 7.4

Table 7.4 Equivalency factors for various types of vehicles on rural roads

Sl.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	3.0
9.	Horse-drawn vehicle	4.00
10.	Bullock cart*	8.00

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

7.13.2 Capacity and Design Service Volume of Different Categories of Roads

Capacity of Road: The maximum hourly Volume (Vehicles per hour) at which vehicle can reasonably by expected traverse a point or uniform section of a lane on road way during a given time period under the prevailing roadway, traffic and control conditions.

Design Service Volume: Maximum hourly volume at which vehicles can reasonably be expected to traverse a point or uniform section of a lane or road during a given time period under the prevailing roadway, traffic and control conditions while maintaining a designated Level of Service.

Level of Service (LOS): A qualitative measure describing operational conditions within a traffic stream and their perception by drivers/ passengers. There are six LOS recognized commonly designated from 'A' to 'F' with LOS 'A' representing the best operating conditions i.e. free flow and LOS 'F' the worst i.e. forced on break down flow.

Table 7.5 Recommended Design Service Volume for Intermediate Lane roads in Rural Areas

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

Table 7.6 Recommended design service volumes for two-lane roads in Rural Areas

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

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CHAPTER 8

STRUCTURES

8.1 Culverts

Culvert is a cross drainage structures having a total length of 6 m or less between the inner face of the dirt walls or extreme vent way boundaries measured at right angles thereto.

8.1.1 The culverts can be of following types:

a) RCC hume pipes

b) RCC Slab on masonary/concrete abutment and piers

c) Stone slab on masonary/concrete abutment and piers

d) RCC box cell structures

e) RCC/masonary arches on masonary/concrete abutment and piers

Frequency of culverts varies depending on the region and terrain. The location, size and other details of such structure should be decided judiciously to cater for discharge and balancing requirements. Normally selection of site for culverts is guided by road alignment

General Arrangement Drawing (GAD) showing a typical box culvert is given in plate 8.1.

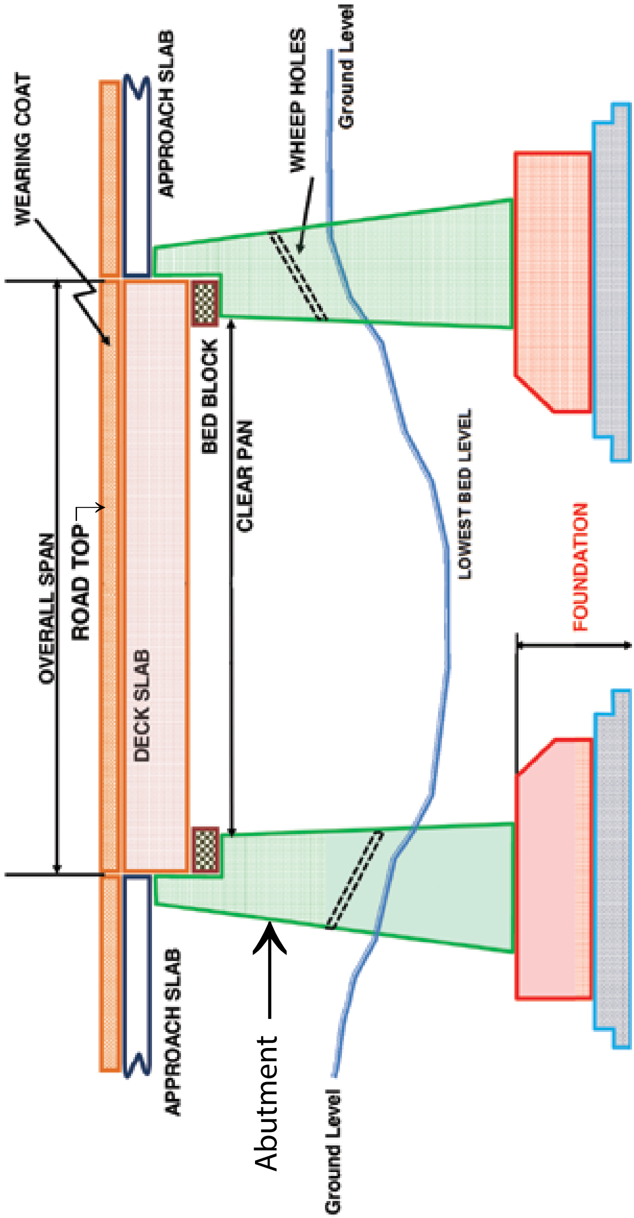

PLATE 8.1 SCHEMATIC DRAWING OF A CULVERT

8.1.2 For design of culverts, following design data are to be collected

a) Catchment Area

A traverse should be made along the water shed when the catchment, as seen from the topo (G.T) sheet is less than 1.25 Sq.km. Larger catchments can be read from the 1 cm = 500 m topo maps of survey of India by marking the watershed in pencil and reading the included area by placing a piece of transparent square paper over it.

b) Cross Sections

For a sizeable stream, at least three cross sections should be taken, namely one at selected site, one upstream and another downstream of the site. Approximate distances, upstream and downstream of the selected site of crossings at which cross sections should be taken will depend on catchment areas and are given in IRC:SP:13 "Guidelines for the Design of Small Bridges and Culverts" The scales of cross section for horizontal and vertical scale 1:1/1000 and 1:1/100 respectively.

c) Highest Flood Level

The highest flood level should be ascertained by intelligent local observations, supplemented by local enquiry and marked on the cross sections.

d) Longitudinal Section

The longitudinal section should extend upstream and downstream of the proposed site for the distances upto the location of taking cross sections as mentioned above.

e) Velocity Observation

Attempts should be made to observe the velocity during an actual flood. If that flood is smaller than the maximum flood, the observed velocity should be suitably increased.

f) Trial Pit Sections

The trial pit may be taken down roughly 2 to 3 m below the lowest bed level. Where the rock or some firm undisturbed soil stratum is not likely to be far below the alluvial stream, a trial pit should be dug down to such rock or firm soil. The trial pit sections should be plotted to show the kind of soil passed through it.

In addition, site inspection of an existing road or railway culverts not very far away from the selected site, if any, will be provide useful information like marks indicating maximum flood level, the afflux, the tendency to scour, the probable maximum discharge, likelihood of collection of brush wood during flood and many other particulars. All these should be carefully recorded.

The details regarding collection of design data have been described in IRC:SP:13.

8.1.3 Following are also to be considered while deciding on the size of the culverts

a) Peak flow and hydraulic requirements

b) Ease of maintenance and desilting operation

c) permissible velocity for fish movement where the channel carries fish

d) movement of debris, gravels and boulders

8.1.3.1 The required size of the culvert is decided on the basis of hydrologic, hydraulic and structural analysis. The details regarding these are available in IRC:SP:13. However, the minimum size of the culvert is fixed on the basis of ease in maintenance.

8.1.3.2 Generally, the alignment of road sections should govern the location, alignment and profile of culverts. Existing culverts deviating from general road profile should be provided with shock free curves. Some cases where the profile could be improved are illustrated in Fig. 8.1.

8.1.4 Design

1. Culverts should be constructed simultaneously with earthwork to have smooth profile on the road and to avoid duplication of compaction of approaches

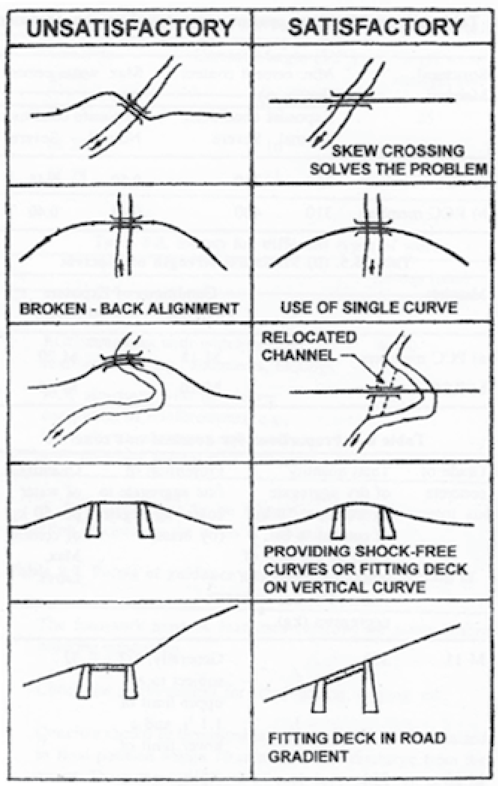

Fig 8.1 Some examples of satisfactory and unsatisfactory location, alignment and profile for culverts

2. From the consideration of maintenance of culverts, it is desirable that span of culvert is kept minimum 2 m and height 1.5 m and diameter of pipe 1.2 m.

3. The cushion between the top of the pipe and road level shall not be less than 600 mm. Pipe culverts shall be of NP 4 type conforming to the requirement of IS:458. First class bedding consisting of compacted granular material can be used for height of fill upto 4 m. The bedding material shall be well graded sand or another granular material passing 5.6 mm sieve. The compacted thickness of granular material shall be a shown in the drawing and in no case it shall be less than 75 mm. For fill height of maximum 8 m concrete cradle bedding having mix not leaner than M 15 shall be used. RCC pipe culverts with single row or upto six rows can be used as they are comparatively cheaper than slab culverts. However, due to short length of pipes as available, culverts for roads having more than 2 lane, box culverts are being used.

4. RCC slab culvert are to be adopted where the founding starta is rocky or of better bearing capacity. In case where adequate cushion is not available for location pipe culvert, RCC slab culvert is to be adopted. RCC slab culverts are also used for cattle crossing.

5. RCC box cell structure is preferred where bearing capacity of soil is low.

6. Balancing culverts are to be located at points on L section of the road where down gradient meet. There balancing culverts balance the discharge from both sides of road.

8.1.5 C.D works in black cotton (BC) soils: To safeguard the structure from the ill effects of the damaging nature of the soil, a sandy media all around the foundation is to be provided. To improve the bearing capacity of BC soils a layer of stone metal/boulder with sand having thickness of about 450 mm to 600 mm can be provided.

8.1.6 The structural details of different types of culvers are given in IRC:SP:13.

8.1.7 The works of culverts are to be carried as per MORTH Specifications for Road and Bridge Works.

8.2 Road Over Bridges (ROB)/ Road Under Bridges (RUB)/ Vehicular Under Pass (VUP)/Passenger Under Passes (PUP).

The location, size etc. have been discussed in previous Chapter 2. The structural design of the major structures like ROB and RUB has been detailed in Pocket Book of Bridge Engineers. The small structures like VUP and PUP are to be designed as culverts and given in this chapter.

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CHAPTER 9

CONSTRUCTION

9.1. Preliminaries

9.1.1. General: Study in depth the contract drawings, contract conditions and special conditions, specifications and other conditions and also the Bill of Quantities or Schedules, 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 reports including material test results.

ii) A set of working drawings mounted on cloth

iii) Specification of works

iv) Bill of Quantities/Schedules

v) Inspection Proforma

vi) Test Results

vii) Method Statements

viii) Daily Diary of Works and Quantity records.

ix) Non-conforming products

x) Quality Audit Records

xi) Records regarding procurement, storge and issue of materials, operation of plant and machinery, traffic divesion, safety and environmental safe guards measure, payment, accounting and approvals

xii) Works Manual

xiii) E copy of all documents

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, if any, 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. Steps are to be taken for safe movement of present traffic in the construction area "Guidelines on Traffic Management in Work Zones" (IRC:SP:55) may be referred for further details

9.1.6 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. General

9.2.1 Precaution for safeguarding the environment

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-of-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 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.

viii) Independent sources of water supply for use in the works are to be provided. All watercourses, waterways ditches, canals, drains, lakes, reservoir are to be protected from pollution.

ix) The construction camps provided shall conform to the state and national building regulations as applicable.

x) Steps in accordance with the applicable laws are to be taken to take care of occupational health and safety for the workforce.

xii) Arrangements are to be made for proper disposal of all forms of waste generated by the constructions operations and in all associated activities.

xii) Transport of hazardous materials, in bulk or in sealed containers shall meet the requirements of the State regulations.

xiii) Remedial measures to be implemented shall be planned before hand in the event of occurrence of emergencies such as spillage of oil or bitumen or chemicals, fire.

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 50m 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 metre 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 of ± 2 mm per km and fitted with micrometer attachment shall be used for all double run leveling work. Setting out of the road alignment and measurement of angles shall be done by using Total Station with traversing target, having a accuracy of one second. Measurement of distances shall be done preferably using precision instruments, like, Distomat.

The work should conform to the clause 109 of MORTH Specifications for Road and Bridge Works.

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, undergrowth grass, etc.) and other deleterious matters should be removed between fill lines.

From embankment/cut areas, remove and store top soil for reapplication later.

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

In wooden 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.

The work shall be carried out as per Clause 201 of MORTH Specifications for Road and Bridge Works.

9.5. Earthwork

9.5.1 Preliminaries: Review the project drawings, special provisions and specifications relating to earthwork prior to the 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.

9.5.2 Excavation for Roadway and Drainage

All materials in excavation are to be classified as one of following: soil, ordinary rock (not requiring blasting), hard rock (requiring blasting), hard rock (blasting prohibited) and marshy soil. This classification is based on the methods, tools and equipment required for excavation.

The area for the roadway and drainage excavation should be cleared and grabbed.

Set out the limits of excavation true to lines, curve, slopes and grades and sections as shown on the drawings. Periodicals checks are to be done on the bench marks and on the construction lines for accuracy.

The work shall be so done that the suitable materials available from excavation are satisfactorily utilized as deemed fit. All reasonable precautions are to be taken for protection and preservation of any or all existing trees, drains, sewers, sub-surface drains, pipes, conduits or any other structures which may be affected by construction operations. All adequate precautions are to be taken to guard against soil erosion, water pollution etc. and appropriate drainage measures are also to be taken. If water is met with in the excavation, it shall be removed by suitable diversions, pumping or bailing out and the excavation is to be kept dry.

9.5.3 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 specified density, it shall be loosened to a depth of 500 mm, recompacted in layers not less than 97 per cent of the maximum laboratory dry desnity as per clause 9.5.6.

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.

Earth work for excavation shall be carried out as per clause 301 of MORTH Specifications for Road and Bridge works.

9.5.4 Blasting Operations

Followings are to be observed:

i) All the statutory laws, regulations, rules, etc. pertaining to the acquisition, transportation, storage, handling and use of explosives shall be strictly followed.

ii) 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 the relevant laws and ordinances. Smoking is to be strictly prohibited in the magazine.

iii) The type of explosives, fuse to be used should be carefully examined for suitability.

iv) The blasting operations shall remain in charge of competent and experienced supervisor and workmen who are thoroughly acquainted with the details of explosives and blasting operations.

v) Blasting should be carried out during pre-determined hours and shall be made known to the people in the vicinity.

vi) Each public utility company having structures in proximity shall be notified sufficiently in advance. In advance of any blasting work within 50 m of any railway track or structures, the railway authority concerned shall be notified on the schedule of blasting operation.

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

viii) Maintenance of day to day account of explosives

The blasting operations are to be carried out as per Clause 302 of MORTH Specifications for Road & Bridge Works.

9.5.5 Excavation for Structures

The points which require specific attention are:

i) Setting out be true to lines, curves, slopes and levels.

ii) Excavation shall be taken to the width of lowest step of the footing including additional width as required for construction operation. The depth to which the excavation is to be carried shall be as shown in the drawing.

iii) Normally, open foundations shall be laid dry. Dewatering by bailing, pumping, diversion channels and other necessary works should be carried out when seepage flow is met with. Where cofferdams are required, these are to be safely designed and made watertight and should be carried to adequate depth and heights.

iv) The discharged water should not cause damage to the works, crops or any other property.

v) Backfilling shall be done with approved material after concrete or masonry is fully set. The backfilling is to be done upto the original surface in layers not exceeding 150 mm compacted thickness to be compacted with the help suitable equipment such as trench compactor, mechanical tamper, rammer plate vibrator etc.

vi) The work shall be carried out as per Clause 304 of MORTH Specifications for Road and Bridge Works.

9.5.6 Embankment Construction

This work also involves construction of subgrades, earthen shoulders and miscellaneous backfills in addition to the construction of embankment for accommodating the roadway.

The materials used for this work shall be soil, moorum, gravel, reclaimed material for pavement, fly ash, pond ash, a mixture of these. Materials from swamps, marshes and bogs, peat, logs stump, perishable material, any soil classified as OL, OI, OH or Pt, material susceptible to spontaneous combustion, materials in frozen condition, clay with liquid limit exceeding 50 and plasticity index exceeding 25 and materials with salts resulting in leaching in the embankment should be considered unsuitable material for embankment. Ordinarily, only the materials satisfying the density requirements as given in the Table 9.1 below shall be used for embankment. This table will not be applicable for light weight fill material e.g cinder, fly ash etc. The material to be used in the subgrade shall satisfy the design CBR value. In case of non availability of such material, stabilization method as per Specifications or by any stabilisation method approved by Accrediation Committee of IRC using accrediated material shall be followed.

Table 9.1 Suitability of embankment materials

S. No.	Type of Work	Maximum laboratory dry unit weight when tested as per IS:2720 (Part 8)
1.	Embankment upto 3 mtrs. height not subjected to extensive flooding	Not less than 15.2 kN/cu.m
2.	Embankment exceeding 3 mtrs. 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

Have a close inspection of the original ground. Look for seepage and wet patches; lush growth of vegetation indicating high 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.

Where necessary, the original ground level shall be levelled to facilitate placement of first layer of embankment, scarified, mixed with water and then compacted by rolling. 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 8).

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 batter pegs on both sides 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 bailing 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) The guidelines and environmental requirements, in respect of excavation and borrow areas as stipulated from time to time by MOEF and local bodies are to be strictly followed by the Contractor.

vi) Reserve better of 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.

vii) Clods or hard lumps of earth should be broken down. Size of clods should not exceed 75 mm when placed in body of embankment and 50 cm when placed in subgrade portion.

viii) Static three wheeled roller, self-propelled single drum vibrator roller, tandem vibratory roller, pneumatic tyre roller pad foot roller etc. of suitable size and capacity shall be used for the different types and grades of materials required to be compacted either individually or in suitable combination. The general guide to the selection of roller for compaction of embankment and sugrade for different types of soils is provided in Table 9.2 (a).

Table 9.2 (a) General guide for selection of roller for compaction of embankment and sugrade

Sl.No.	Type of Soil	Choice of Roller
1.	Granular	i) Static three wheeled roller (8-10 tonne) ii) Vibratory roller (8-10 tonne) iii) Pneumatic Tyre roller (12-15 tonne)
2.	Uniformly graded soil	i) Static three wheeled roller (8-10 tonne) ii) Pneumatic tired roller (12-15 tonne) iii) Vibratory roller (8-10 tonne)
3.	Clay and Silty Soil	Sheeps foot roller

The compaction requirements of subgrade, earthen shoulders and embankment are given below in Table 9.2. (b) It shall be ensured that subgrade material when compacted to the density requirements as per Table 9.2 shall yield design CBR value of the subgrade.

Table 9.2 (b) Compaction requirement of Embankment and Sugrade

S. No.	Type of Work	Relative compaction as percentage of maximum laboratory dry density as per IS:2720 (Part 8)
1.	Subgrade and earthen shoulders	Not less than 97%
2.	Embankment	Not less than 95%
3.	Expansive Clays a) Subgrade and 500 mm portion just below the subgrade b) Remaining portion of embankment	 Not allowed 90-95%

ix) The embankment and subgrade material shall be spread in layers of uniform thickness over the entire width of embankment by a motor grader. The compacted thickness of each layer shall not be more than 250 mm. The compacted thickness of each layer shall not be more than 200 mm when static roller is used. Successive layers shall not be placed until 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.

x) 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 controllable rate of the flow, without any flooding. The water shall be added uniformly and thoroughly mixed in soil by blades, discs and harrowsuntila 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.

xi) 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.

xii) The embankment should be constructed evenly over the full width. Movement of construction plant and other vehicles on embankment should be avoided.

xiii) Embankment should not be constructed with steeper side slopes or to widths larger than those required.

xiv) 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 requirement.

xv) The number of passes to achieve the desired compaction will depend on the nature of soil and type of compaction plant. Compaction trials are to be conducted to demonstrate the efficacy of the equipment to be used.

xvi) Each layer should be rolled to the camber/cross fall of the road and this should be maintained so as to prevent ponding.

9.5.7 Embankment under special conditions:

a) Widening existing embankment or construction against sloping ground

i) 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

ii) Where the width of widened portions is insufficient to permit the use of conventional rollers compaction shall be carried out with light weight vibratory roller, double drum walk behind roller, vibratory plate compactor or vibrating tamper or any other appropriate equipment.

iii) End dumping of materials from trucks on widened portions should be avoided as far as possible.

b) Earthwork over existing road surface: If the existing road surface is grannular type and within 1 m of the new subgrade level, scarify to a depth of 50 mm or more as specified. If the road surface is BT or cement concrete and within 1 m of new subgrade level, bituminous or concrete surface layer shall be completely removed. If the level difference is more than 1 m, allow the existing road surface to stay and shall be roughned. In all cases, it is to be ensured that 500 mm portion below the new subgrade is compacted to the desired density.

c) **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.

d) **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.

e) **Earthwork for high embankment:**

i) In the case of high embankment (more than 6 m high) normally fly ash is to be used or the material from approved borrow area.

ii) When provided, 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. Required instruments are to be installed for monitoring

iii) 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.

Embankement construction shall be carried out as per clause 305 of MORTH Specifications for Road and Bridge Works.

9.5.8 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 is 2 (horizontal) to 1 (vertical) or steeper, the laying of sods should be started from bottom upwards and the sods should be stacked with pegs or nails spaced 500 to 1000 mm 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 straw, 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 geonetting should be less than 3.8 kg per 1000 sq.m. Slope protection works ar to be carried out as per clause 307 of MORTH Specifications for Road and Bridge Works.

9.5.9 Ground improvement for weak embankment foundation using geosynthetic drains and stone columns.

1. The problematic subsoil condition for embankment foundation can be improved by any or combination of the following alternatives. The improvement method can be decided depending on the subsoil condition.

   i) Using geosynthetic drains with surcharge involving to achieve 90% consolidation of subsoil in prescribed time.

   ii) Rammed stone columns

   iii) Stone columns formed by vibroflot techniques.

9.5.9.1 Prefabricated Vertical Drains (PVD)

Prefabricated Vertical Drain (PVD) design and construction shall generally comply with the requirements of IS:15284 (Part 2) and the requirements of Clause 314 of MORTH Specifications for Road and Bridge works.

a) Geosynthetic drains – It shall consist of corrugated or studded or 3-D mesh consisting of an innercore of thick polyester fused at intersection, wrapped in a non-woven geotextile. The width and thickness of band drain shall be as specified and shall be a minimum of 100 mm width and thickness of 5 mm. The drains are to be installed to depths and at spacing as per the design and drawings. Band drains are to be installed using an installation rig/ stitcher mounted on a base machine. The end of the drain shall be attached to a hollow rectangular mandrel or shoe and to be driven by an appropriate mechanism such as lance. The top of the drain above the ground level shall be cut with 150 mm into the drainage blanket.

b) A blanket of well drawing granular material/coarse sand (natural or crushed) conforming to the specified grading of specified thickness compacted to a density of 75 to

80 percent of maximum dry density obtained by heavy compaction. The blanket shall be exposed to atmosphere at its periphery for dissipation of pore pressure.

c) The geotextile fabric for separation and drainage to be laid on the sand blanket shall meet the specified requirements.

The addition of surcharge load by approved material to the specified height is to be done over the geotextile layer with adequate side slopes and for the period as per design requirement to achieve the desired degree of consolidation. The addition of surcharge which will not be a part of embankment/permanent work shall be removed after the desired degree of consolidation is achieved.

Instrumentation and monitoring the behavior of sub soil/embankment shall be form of part of the work. For this purpose following critical parameters shall be monitored with appropriate instrumentation.

a) Monitoring the build up and dissipation of pore pressure

b) Rate and magnitude of vertical settlements of the subsoil.

c) Measurement of shear strength.

9.5.9.2 Rammed stone columns using non displacement method of construction.

a) The design and construction of stone columns shall comply with the requirements of IS 15284 (Part 2) including the requirements given in the MORTH Specifications for Road and Bridge Works.

b) Stone columns shall be formed from well graded crushed stone and gravel compacted to a dense state. The size of the well graded crushed aggregate shall vary from 2 mm to 75 mm as per grading given in the above mentioned MORTH Specifications for Road and Bridge Works.

c) A compacted and well-draining layer of gravel or coarse sand of specified thickness, compacted in layers to a relative density of 75 to 80 percent shall be provided above the existing ground. The blanket shall be exposed to atmosphere at its periphery for porewater pressure dissipation.

d) The rammed stone columns shall be constructed by non-displacement technique namely "Bailer and Casing method as given in IS:15284 (Part 1).

e) The set criteria as given in IS:15284 (Part 1) and the consumption of granular fill for the main quality control measures and shall be observed.

f) Initial and routine field loading tests and recording of data as given in IS:15284 (Part 1) are to be done.

9.5.9.3 Stone columns using vibro replacement (vibroflot) method of construction.

a) The design and construction of stone columns shall comply with IS:15284 (Part 1) with modifications as per MORTH Specifications for Road and Bridge Works.

b) The material for stone aggregate for compacted column shall be crushed stone and gravel shall be clean, hard, angular, chemically inert resistant to breakage and free from organic, trash and other deleterious material. It shall be well graded stones of 75 mm down to 2 mm size and the uniformity co-efficient shall be greater than 3. The aggregate impact value shall not be more than 30 per cent.

c) For drainage blanket, sand/crushed stone, which is hard, inert, resistant to chemical change and free from organic, fresh or other deleterious material are only to be used. This blanket shall be well graded and free draining granular material of thickness 500 mm or more, compacted in layers to a relative desnity of 75 to 80 percent. For pore water pressure dissipation, this blanket shall be exposed to atmosphere at its periphery.

d) The stone columns shall be installed by vibrolflot method as desired in IS:15284 (Part 1) and MORTH Specifications for Road and Bridge Works.

e) Field control and field loading tests of stone columns shall be done as per MORTH Specifications for Road and Bridge Works.

9.6 Sub-bases and Bases (Non-Bituminous)

9.6.1. Granular sub-base: The material for granular subbase should, wherein applicable, conform to the gradings indicated in Table 9.3.

Table 9.3 Grading for Granular Sub-base Materials

IS Sieve Designation	Percent by Weight Passing the IS Sieve					
	Grading I	Grading II	Grading III	Grading IV	Grading V	Grading VI
75.0 mm	100	-	-	-	100	-
53.0 mm	80-100	100	100	100	80-100	100
26.5 mm	55-90	70-100	55-75	50-80	55-90	75-100
9.50 mm	35-65	50-80	-	-	35-65	55-75
4.75 mm	25-55	40-65	10-30	15-35	25-50	30-55
2.36 mm	20-40	30-50	-	-	10-20	10-25
0.85 mm	-	-	-	-	2-10	-
0.425 mm	10-15	10-15	-	-	0-5	0-8
0.075 mm	<5	<5	<5	<5	-	0-3

The physical requirements of the material to be used shall be as per Table 9.4.

Table 9.4 Physical requirements for Materials for Granular Sub-base

Aggregate Impact Value (AIV)	IS:2386 (Part 4) or IS:5640	40% maximum
Liquid Limit	IS:2720 (Part 5)	Maximum 25
Plasticity Index	IS:2720 (Part 5)	Maximum 6
CBR at 98% dry density (at IS:2720-Part 8)	IS:2720 (Part 5)	Minimum 30 unless otherwise specified in the Contract

The construction operations of grannular sub base shall be carried out as per clause 401 of MORTH Specifications for Road and Bridge Works.

9.6.2. 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 and can be used as lower subbase or improved subgrade. The soil used for stabilization shall be local clayey soil having plasticity index greater than 8.

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 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.

The material used for cement or cement fly ash treatment shall be soil including sand and gravel, laterite, kankar, brick aggregate, crushed rock or slag or any combination of these. It shall meet the specified grading and shall have uniformity co-efficient not less than 5. If the material passing 425 micron sieve is plastic, it shall have liquid limit not greater than 45 percent and plasticity index of not greater than 20 percent. The cement shall either be OPC, PPC, or Portland Slag cement. The fly ash shall meet the specified requirement.

The mix design for cement stabilization should be done on the basis of 7-day unconfined compressive 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. The mix design shall be done to achieve a strength of 1.75 MPa on cylindrical specimen.

Lime soil stabilisation or cement stabilisation should not be done when the air temperature in shade is less 10°C. Compaction of lime stabilised soils should be completed within 3 hours of mixing. The corresponding period for cement stabilisation is 2 hours. The soil treated with cement or cement fly ash can be used as subase or base course.

9.6.3. Construction of stabilised soil sub-bases:

Stablised soil sub-bases shall be constructed by mix in place method of construction. Mix in place construction shall be carried out by a rotavator or similar approved equipment.

Manual mixing shall be permitted only where the width of laying is not adequate for mechanical operations.

The moisture content at compaction for cement and lime stabilized bases/Sub bases shall neither be less than OMC nor more than 2 percent above it. The rolling, curing and other construction operations of lime and cement or cement fly ash treated soil are to be carried as per Clause 402 and 403 of MORTH Specifications for Road and Bridge Works respectively.

9.6.4. Water bound macadam: Material for water bound macadam should conform to clause 404 of MORTH Specifications for Road and Bridge Works. The physical requirements, grading requirements and the approximate quantities of aggregate required have been summarised in Table No. 9.5, 9.6, 9.7 & 9.8

Table 9.5 Physical requirements of coarse aggregates for water bound macadam for sub-base/base course

Sl.No.	Test	Test Method	Requirements
1.	*Los Angeles Abrasion Value or **Aggregate Impact Value	IS:2386 (Part 4) IS:2386 (Part 4) or IS:5640**	40 per cent (Max) 30 per cent (Max)
2.	Combined Flakiness and Elongation Indices (Total)***	IS:2386 (Part 1)	35 per cent (Max)

* For subbase the LA value and AIV shall be relaxed to 50 percent and 40 percent maximum respectively.

** 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 9.6 Grading requirements of coarse aggregates

Grading no.	Size range	IS sieve designation	Per cent by weight passing
1.	63 mm to 45 mm	75 mm 63 mm 53 mm 45 mm 22.4 mm	100 90-100 25-75 0-15 0-5
2.	53 mm to 22.4 mm	63 mm 53 mm 45 mm 22.4 mm 11.2 mm	100 95-100 65-90 0-10 0-5

Note: The compacted thickness for a layer shall be 75 mm.

Table 9.7 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 11.2 mm 5.6 mm 180 micron	100 95-100 15-35 0-10
B	11.2 mm	11.2 mm 9.5 mm 5.6 mm 180 micron	100 80-100 50-70 5-25

Table 9.8 Approximate quantities of coarse aggregates and screenings required for 75 mm compacted thickness of Water Bound Macadam (WBM) Sub-base/base course for 10m² area

Classification	Size Range	Loose qty.	Screenings			
			Stone screening		Crushable type such as Moorum Gravel	
			Grading classification and size	For WBM sub-base/ base course (Loose quantity)	Grading classification and size	Loose qty
Grading 1	63 mm to 45 mm	0.91 to 1.07 m^3	Type A 13.2 mm	0.12 to 0.15 m^3	Not uniform	0.22 to 0.24 m^3
Grading 1	63 mm to 45 mm	0.91 to 1.07 m^3	Type B 11.2 mm	0.20 to 0.22 m^3	Not uniform	0.22 to 0.24 m^3
Grading 2	53 mm to 22.4 mm	0.91 to 1.07 m^3	Type B 11.2 mm	0.18 to 0.21 m^3	Not uniform	0.22 to 0.24 m^3

Screenings should generally be of the same material as coarse aggregate.

The quantity of binding material will depend on the type of screening. Generally the quantity required for 75 mm compacted thicknes of WBM will be 0.06 – 0.09 m^3 per 10 m^2. The PI value shall be less than 6.

Where the WBM is to be laid directly over the subgrade, a 25 mm course of screenings (Grading B) or coarse sand - "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 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 construction operation of WBM shall be carried as per clause 404 of MORTH Specifications for Road and Bridge Works.

No traffic should be allowed on the road until the macadam has set. The compacted WBM course should be allowed to completely dry and set before the next pavment course is laid over it. WBM works should not be carried out when atmospheric temperature is less then 10^{o}C in shade.

9.6.5. 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. The thickness of each layer shall not exceed 75 mm compacted thickness. It shall confirm to one of the grading's given inTable 9.6

Coarse aggregate shall be broken cement concrete slabs crushed to a size not exceeding 75 mm and conforming in the specified grading.

The crushed material shall be spread on the prepared subgrade with the help of a motor grader with three wheeled power rollers of 80 to 100 kN capacity or tandem or vibrating rollers of 80 – 100 kN static weight.

The work shall be carried out as per clause 405 of MORTH Specifications for Road and Bridge Works.

9.6.6. Wet mix macadam (WMM): The work shall consist of laying and compacting clean, crushed, graded aggregate and granular material premixed with water, to a dense mass on a prepared subgrade/ sub base/base or existing pavement.

The thickness of a single compacted WMM layer shall not be less than 75 mm. The compacted depth of a single layer of the subbase course may be upto 200 mm when vibrating or other approved types of compacting equipment are used.

The aggregates shall conform to the physical requirements indicated in Table 9.9

Table 9.9 Physical requirements of coarse aggregates for wet mix macadam for sub-base/base course

Sl.No.	Test	Test Method	Requirements
1.	Lost Angeles Abrasion Value or Aggregate Impact Value	IS:2386 (Part 4) IS:2386 (Part 4) or IS:5640	40 per cent (Max) 30 per cent (Max)
2.	Combined Flakiness and Elongation Indices (Total)	IS:2386 (Part 1)	35 per cent (Max)

The specified grading for the aggregates (Table 9.10) should be used for mixing. At the time of compaction quantity of water in the wet mix should not vary from OMC determined as per IS:2720 (Pt. 8), by more than agreed limit.

Table 9.10 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	0-5

Materials finer than 425 micron should have P.I.not exceeding 6.

The construction operations shall be carried out as per clause 406 of MORTH Specifications for Road and Bridge Works.

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 mixer of concrete batching plant.

The mixed material should be uniformly wet and no segregation should be permitted.

The mix should be spread uniformly and evenly in required quantities on the prepared subgrade/sub-base/base by a self-propelled paver finisher. In no case should the mix be dumped in heaps on the area. In exceptional cases, if permitted, motor grader may be used.

After the mix has been laid to the required thickness, the rolling shall be uniformly compacted by a suitable roller. 80-100 kN smooth wheeled roller may be used for a compacted thickness of not exceeding 100 mm. For a compacted single layer upto 200 mm the compaction shall be done with a vibratory roller of minimum static weight of 80-100 kN.

The roller speed should not exceed 5 km/hour.

Rolling should continue till density achieved is at least 98 per cent maximum dry density for the material as per IS:2720 (Part 8).

When irregularity develop during rolling which exceeds 12 mm with a 3 m straight edge, the surface should be loosened and premixed material added or removed as required before rolling again so as to achieve uniform surface.

It is not advisable to lay the wet mix macadam during rains and the tempo of work suffers during rains.

After final compaction of WMM course, the road shall be allowed to dry for 24 hours.

9.6.7. Crusher-run macadam base: Crusher-run macadam base is constructed of materials obtained from crushed rock only, satisfying physical requirements indicated in Table 9.11 and satisfying one of the two aggregate gradings mentioned in Table 9.12 . 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. The works are to be carried out as per clause 407 of MORTH Specifications for Road and Bridge Works.

Table 9.11 Physical requirements of coarse aggregates for crusher-run macadam base

Sl.No.	Test	Test Method	Requirements
1.	Los Angeles Abrasion Value or Aggregate Impact Value	IS:2386 (Part 4) IS:2386 (Part 4) or IS:5640	40 Maximum 30 Maximum
2.	Combined Flakiness and Elongation Indices (Total)	IS:2386 (Part 1)	35 Maximum
3.	*** Water absorption	IS:2386 (Part 3)	2 per cent Maximum
4.	Liquid Limit of material passing 425 micron	IS:2720 (Part –5)	25 Maximum
5.	Plasticity Index of material passing 425 micron	IS:2720 (Part – 5)	6 Maximum

*** If the water absorption is more than 2 per cent, soundness test shall be carried out as per IS:2386 (Part-5)

Table 9.12 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	2-5	2-5

After the base course material has been deposited it shall be thoroughly blade mixed to full depth alternately from edges to centre and back using water to moisten the materials sufficiently to prevent their segregation. Compaction may be 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. 8).

9.7 Bitumen Bound Bases and Surfacings

9.7.1. General Requirements: General requirements on materials, mixing, transporting, laying, compaction, joints and construction of bituminous pavement layers, protection of the environment etc. are laid down in Clause 501 of MORTH Specifications for Road and Bridge Works.

9.7.2.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 primer shall be cationic bitumen emulsion SS1 grade or medium curing cut back bitumen. This work is to be carried out as per clause 502 of MORTH Specifications for Road and Bridge Works. The quantity of bitumen for various types of granular surface shall be as per Table 9.13 below:-

Table 9.13 Quantities of bitumen for prime coat for various types of granular surface

Type of surface	Rate of spray for bitumen emulsion (kg/sq.m)	For cut back	
		Type	Rate of spray (kg/sq.m)
WMM/WBM	0.7 – 1.0	MC 30	0.6 - 0.9
Stabilized soil base/ crusher run macadam	0.9 – 1.2	MC 70	0.9 -1.2

Bituminous primer should not be applied during a dust storm, when the weather is foggy or rainy or windy or when the temperature in the shade is less than 10°C.

The primer distributor should be self-propelled or towed bitumen pressure sprayer capable of spraying the material uniformly at the specified rate and temperature. Hand spraying should be resorted to only in small areas and areas inaccessible to the pressure sprayer.

After application of cut-back, the surface should be allowed to cure for atleast 24 hours.

9.7.3. Tack-Coat: The binder for tack coat should be either catoinic bituminous emulsion (RS 1) or paving bitumen of VG-10 grade conforming to IS:73. Cut back bitumen RC-70 to be used restrictively for site at sub-zero temperature or for emergency application.

The quantity of binder should be as per Table 9.14 .

Table 9.14 Rate of application of Tack Coat

Type of Surface	Rate of spray of binder in kg/sq.m
Bituminous surface	0.20 – 0.30
Granular surface treated with primer	0.25 – 0.30
Cement Concrete pavement	0.30 - 0.35

The binder should be applied uniformly with an approved equipment capable of spraying bitumen at specified rate and temperature to provide a uniform unbroken spread of bitumen.

The succeeding construction should be made only after curing of the tack coat.

The works are to be carried as per clause 503 of MORTH Specifications for Road and Bridge Works.

9.7.4. Dense Bituminous Macadam: The work consists of construction of a single layer of compacted crushed aggregates premixed with bituminous binder for use in base/binder and profile corrective course. The thickness of single layer shall be 50 mm to 100 mm.

Physical requirements of aggregates for Dense Bituminous Macadam are given in Table 9.15.

Table 9.15 Physical requirements for coarse aggregates for dense bituminous macadam

Property	Test	Specification
Cleanliness (dust)	Grain size analysis (IS 2386-Part I)	Max 5% passing 0.075 mm sieve
Particle shape	Flakiness and Elongation Index (Combined) (IS 2386-Part II)	Max 35%
Strength**	Los Angeles Abrasion Value or Aggregate Impact Value (IS 2386-Part IV)	Max 35% Max 27%
Durability	Soundness Sodium Sulphate or Magnesium Sulphate (IS 2386-Part V)	 Max 12% Max 18%
Water Absorption	Water absorption (IS 2386 Part III)	Max 2%
*Stripping	Coating and Stripping of Bitumen Aggregate Mixtures (IS 6241)	Minimum retained coating 95%
Water Sensitivity**	Retained Tensile (AASHTO 0283) Strength	Min 80%

**Notes: If the coating and stripping of bitumen aggregate mix is less then 95% and if the minimum retained tensile strength falls below 80 per cent, antistripping agent as per IS 14982 should be used.

The filler shall be graded within the limits indicated in Table 9.16.

Table 9.16 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

For DBM aggregate gradation and requirement of mix are indicated in Table No 9.17.

Table 9.17 Composition of Dense Graded Bituminous Macadam

Grading	1	2
Nominal aggregate size*	**37.5 mm**	**26.5 mm**
Layer thickness	**75 – 100 mm**	**50 – 75 mm**
IS Sieve1 mm	**Cumulative % by weight of total aggregate passing**	
45	100	
37.5	95 – 100	100
26.5	63-93	90-100
19	-	71-95
13.2	55-75	56-80
4.75	38-54	38-54
2.36	28-42	28-42
0.3	7-21	7-21
0.075	2-8	2-8
Minimum Bitumen content % by mass of total mix	Min 4.0**	Min 4.5**

* The nominal maximum particle size is the largest specified sieve size upon which any of the aggregate is retained

** Corresponds to specific gravity of aggregate being 2.7. In case aggregate have specific gravity more than 2.7, the minimum bitumen content can be reduced proportionately. Further in the region where highest daily mean air temperature is 30°C or lower and lowest daily air temperature is – 10°C or lower, the bitumen content may be increased by 0.5 percent

The bitumen content required shall be determined following the Marshall mix design procedure.

Apart from conformity with grading and quality requirement for individual ingredients, the mixtures shall meet the requirement set out in Table 9.18

Table 9.18 Requirements for Dense Graded Bituminous Macadam

Properties	Viscosity Grade Paving Bitumen	Modified bitumen		Test Method
		Hot Climate	Cold Climate	
Compaction level	75 blows on each face of the specimen			
Minimum stability (kN at 60°C)	9.0	12.0	10.0	AASHTO T245
Marshall flow (mm)	2 – 4	2.5– 4	3.5 – 5	AASHTO T 245
Marshall Quotient (Stability/Flow)	2 – 5	2.5 - 5		MS -2 and ASTM D 2041
% air voids	3-5*			
% Voids filled with Bitumen (VFB)	65-75			
Coating of aggregate particle	95% minimum			IS:6241
Tensile Strength ratio	80% minimum			AASHTO T 283
% Voids in Mineral Aggregate (VMA)	Minimum percent voids in mineral aggregate (VMA) are set out in Table 9.19			

* Note: For all single layer, the recommended target air void content for the mix design is 3.5% and has to be rich in bitumen. For two layer DBM construction the recommended target air void is 3.0%.

The requirements for minimum per cent voids in mineral aggregate (VMA) are set out in Table 9.19.

Table 9.19 Minimum Percent Voids in Mineral Aggregates (VMA)

Nominal Maximum Particle Size1 (mm)	Minimum VMA Percent Related to Design Percentage Air voids		
	3.0	4.0	5.0
26.5	11.0	12.0	13.0
37.5	10.0	11.0	12.0

Job mix formula for DBM shall comply with Clause 505.3.3 of the MORTH Specifications.

The bitumen shall be viscosity grade paving bitumen as per IS:73, modified bitumen conforming to IRC:SP:53 and IS:15462.

Plant trials and laying trials are to be carried out as per clause 505 of MORTH Specifications for Road and Bridge Works.

The construction operation for DBM including laying of and stress absorbing layer should be in accordance with Clause 505.4 of the MORTH Specifications for Road and Bridge Works.

9.7.5. Bituminous concrete (BC): The work consists of construction of bituminous concrete for use in wearing and profile corrective courses. This work consists construction in a single layer on previously prepared bituminous bound surface. A single layer shall be 30 mm/40 mm/50 mm thick.

The coarse aggregate for bituminous concrete mix should satisfy the requirements mentioned in, Table. 9.20. The composition of bituminous concrete pavement layers are indicated in Table 9.21.

Table 9.20 Physical requirements for coarse aggregates for bituminous concrete

Property	Test	Specification	Method of Test
Cleanliness (dust)	Grain size analysis	Max 5% passing 0.075 mm sieve	IS:2386 Part I
Particle shape	Combined Flakiness and Elongation Indices	Max 35%	IS:2386 Part I
Strength	Los Angeles Abrasion Value or Aggregate Impact Value	Max 30% Max 24%	IS:2386 Part IV
Durability	Soundness either Sodium Sulphate or Magnesium Sulphate	Max 12% Max 18%	IS:2386 Part V
Polishing	Polished Stone Value	Min 55	BS:812-114
Water Absorption	Water absorption	Max 2%	IS:2386 Part III
Stripping	Coating and Stripping of Bitumen Aggregate Mix	Minimum retained coating 95%*	IS:6241
Water Sensitivity	Retained Tensile Strength	Min 80%*	AASHTO 283

* If the coating and stripping of bitumen aggrigate mix is less than 95% and if the retained tensile strength falls below 80%, antistripping agent as per IS 14982 should be used.

Table 9.21 Composition of Bituminous Concrete Pavement Layers

Grading	1	2
Nominal aggregate size*	19 mm	13.2 mm
Layer thickness	50 mm	30 – 40 mm
IS Sieve (mm)	Cumulative % by weight of total aggregate passing	
26.5	100	
19	90-100	100
13.2	59-79	90-100
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	Min 5.2**	Min 5.4*

* The nominal maximum particle size is the largest specified sieve size up on which any of the aggregate is retained.

** Corresponds to specific gravity of aggregate being 2.7. In case aggregate have specific gravity more than 2.7, the minimum bitumen content can be reduced proportionately. Further the region where highest daily mean air temperature is 30°C or lower and lowest daily air temperature is – 10°C or lower, the bitumen content may be increased by 0.5 percent.

The mix design and construction operations for bituminous concrete should conform to Clauses 507.3 and 507.4 of the MORTH Specifications for Road and Bridge Works respectively.

9.7.6 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.

Binder: The aggregates shall either be paving bitumen conforming to IS:73 or rapid setting cationic bitumen emulsion (RS-2) conforming to IS:8887 depending on the climatic condition.

Aggregates: The stone chips shall conform to the requirements to the specification for DBM of section 9.7.4 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) of not less than 60. The aggregates shall be single sized, clean, hard, durable, of cubical shape free from dust and soft or friable matter, organic or other deleterious matter. The size of the aggregate shall depend on the type of surface on which it is laid and the traffic intensity. Table 9.22 may be used as guidance and conforming to one of the gradings given in Table 9.23.

Table 9.22 Recommended Nominal Size of Aggregates (mm) for surface dressing

Type of Surface	**Traffic Intensity in Terms of Number of Vehicles Per Day in the Lane Under Consideration**		
	1000-2000	200-1000	20-200
Very hard	10	6	6
Hard	13	10	6
Normal	13	10	6
Soft	19	13	13
Very soft	-	19	13

Table 9.23 Grading requirements for Aggregates used for Surface Dressing

IS Sieve Designation (mm)	Cumulative Percent by Weight of Total Aggregates Passing for the following nominal sizes (mm)			
	19	13	10	6
26.5	100	-	-	-
19	85-100	100	-	-
13	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 19mm mm and retained on 13.2 mm	Passing 13.2 mm and retained on 9.5mm	Passing 9.5mm and retained on 6.3mm	Passing 6.3mm and retained on 3.35 mm

Rates of spread of binder and chips: The rate of spread of binder and chips can be determined as per the procedure given in Manual for Construction and Supervision of Bituminous construction – Appropriate rates of spread are given in Table 9.24.

Pre coated chips: As an alternative to the use of an adhesion agent, the chips may be precoated before they are spread except when the sprayed binder film is a bitumen emulsion. Precoating of chips may be carried out by mixing aggregates with 0.75 to 1.0 percent of bitumen by weight of chips in a suitably mixer. The chips shall be heated to 160^{0}C and mixed with the binder heated to its application temperature. The precoated chips shall be allowed to cure for at least one week or until they become non sticky and can be spread easily.

Table 9.24 Approximate Rate of Application of Binder and Aggregates

Nominal Aggregate Size mm	Binder (Kg/m^2)			Aggregates Cu.m/m^2
	Uncoated Aggregates		Coated Aggregates	
	Bitumen	Emulsion	Bitumen	
19	1.2	1.8	1.0	0.014-0.015
13	1.0	1.5	0.8	0.009-0.011
10	0.9	1.3	0.7	0.007-0.009
6	0.75	1.1	0.6	0.003-0.005

Note: Bitumen for coated aggregates excludes quantity of bitumen required for coating.

Anti-stripping agent: Where the proposed aggregate fails to pass the stripping test and the minimum tensile strength then an approved adhesion agent may be added to the binder in accordance with the manufacturer's instructions.

Construction operations shall confirm to Clause 509.3 of MORTH Specifications for Road and Bridge Works.

9.7.7. Open-graded premix surfacing using viscosity grade paving bitumen

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 MORTH Specifications for Road and Bridge Works, to serve as a wearing course.

Binder: The binder shall be a viscosity grade bitumen of a suitable grade satisfying the requirements of IS:73.

Aggregate: The aggregate shall conform to Clause 504.2.2 of MORTH Specifications for Road and Bridge Works 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 BS:812-(Part 114), shall not be less than 55.

Proportioning of materials: The materials shall be proportioned in accordance with Table 9.25

Table 9.25 Quantities of materials required for 10m² Road Surface for 20 mm thick Open Graded Premix surfacing.

	Materials	Quantity
Aggregates		
a) b)	Nominal Stone size 13.2 mm (passing 22.4 mm sieve and retained on 11.2 mm sieve) Nominal Stone size 11.2 mm (passing 13.2 mm sieve and retained on 5.6 mm sieve) Total	0.18 m^3 0.09 m^3 0.27 m^3
Binder		
a) b)	For 0.18 m^3 of 13.2 mm nominal size of 52 kg bitumen per m3 For 0.09 m^3 of 11.2 mm nominal size of 56 kg bitumen per m^3	9.5 kg 5.1 kg
	Total	14.6 kg

Construction operations shall conform to Clause 510.1.3 of the MORTH Specifications for Road and Bridge works.

9.7.8 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 MORTH Specifications for Road and Bridge Works, 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 IS:8887.

Aggregate : The requirements as given for open graded premix carpet using as per para 9.7.7.

Proportioning of materials: The materials shall be proportioned as quantities given in Table 9.26 .

Table 9.26 Quantities of Aggregate for 10 m² Area for Open Graded Premix Surfacing

Aggregates		
a)	Coarse aggregate nominal 13.2 mm sieve, 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; passing IS 13.2 mm sieve and retained on IS 5.6 mm sieve	0.09 m^3
	Binder	20 to 23 kg

Construction Operations shall conform to Clause 510.2.4 of the MORTH Specifications for Road and Bridge Works.

9.7.9 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 MORTH Specifications for Road and Bridge Works to serve as a wearing course.

Close graded premix surfacing shall either be of Type A or Type B. Type A grading is recommended for use in heavy rainfall areas having rainfall more than 150 cm per year. In other areas, Type B may be used.

Binder: The binder shall be viscosity grade bitumen of a suitable grade as specified and satisfying the requirements of IS 73.

Coarse aggregate: The requirements of clause 9.7.10 for Type A seal coat.

Fine aggregates: The fine aggregates shall consist of crushed rock or natural sands, 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 9.27.

Table 9.27 Aggregate Gradation for Close Graded Premix Surfacing

IS Sieve Designation (mm)	Cumulative Percent 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 for pre mixing 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 508 of the MORTH Specifications for Road and Bridge Works.

9.7.10. 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 of 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: Binder shall be viscosity grade bitumen or bitumen emulsion as per clause 9.7.9 and 9.7.8 respectively.

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 9.15 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 511 of the MORTH Specifications for Road and Bridge Works.

9.7.11. Mastic asphalt

Scope: This work shall consist of constructing a single layer of mastic asphalt wearing course for road pavements and bridge decks. This is not for thin layer on bridge decks below a bituminous concrete layer. Mastic asphalt is composed of suitably graded mineral filler and coarse aggregates, fine aggregates and hard grade bitumen as to form a coherent, void less impermeable mass, solid or semi solid under normal temperature conditions but sufficiently fluid when brought to a suitable temperature to be spread by means of a float in manual construction and by paver in mechanized construction.

Bitumen : The binder for mastic asphalt shall be a industrial grade 85/25 bitumen meeting the requirements as laid in Table 9.28

Table 9.28 Requirements for Physical Properties of Binder for Mastic Asphalt

Property	Test Method	Requirements
Penetration at 25^{0}C in 1/100 cm	IS:1203-1978	20-40
Softening point, ^{0}C	IS: 1205-1978	80-90
Loss on heating % by mass Max.	IS:1212-1978	1
Solubility in trichloroethylene, % by mass Minimum	IS:1216-1978	99
Ductility at 27^{0}C min, cm	IS:1208-1978	3

* In high altitude areas (2000 m) VG-40 conforming to IS 73 grade bitumen shall be used.

Coarse aggregate: The coarse aggregate shall be clean, hard, durable, crushed rock free of disintegrated pieces, organic or other deleterious matter and adherent coatings retained on 2.36 mm sieve. They shall be hydrophobic, of low porosity and satisfy the physical requirements given in Table 9.29 .

Table 9.29 Physical Requirements of Coarse Aggregates for Mastic Asphalt

Property	Test	Requirement Maximum %	Test Method
Particle shape	Combined Flakiness and Elongation Indices	35	IS:2386 Part 1
Strength	Los Angeles Abrasion Value or Aggregate Impact Value	30 24	IS:2386 Part IV IS:2386 Part IV
Durability	Soundness (Sodium or Magnesium) Sodium Sulphate Magnesium Sulphate	5 cycles 12 18	 IS:2386 Part V IS:2386 Part V
Water absorption	Water absorption	2	IS:2386 Part III
Stripping value	Coating and Stripping of Bitumen Aggregate	5	IS:6241

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 9.30. The minimum and maximum thickness of bitumen mastic for wearing course shall be 25 mm and 50 mm respectively except for footpaths of bridges where it shall be 20 mm and 25 mm respectively.

Table 9.30 Grading and Percentage of Coarse Aggregates for Wearing Coarse and Footpath

Sl.No.	Type of Work	Grading of coarse aggregates		Thickness of finished course mm	Percentage of coarse aggregate
		IS Sieve	Percentage passing IS Sieve		
1.	Wearing course for Road Pavement and bridge docks	19 mm 13.2 mm 2.36 mm	100 88-96 0-5	25-40 or 41-50	30-40 or 40-50
2.	Footpaths	6.3 mm 2.36 mm	100 70-85	20-25	15-30

Fine aggregate: The fine aggregate shall be of passing 2.36 mm sieve and retained on 0.075 mm sieve consisting of crushed hard rock, natural sand or a mixture of both.

Filler: The filler shall be limestone powder passing 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 as per Table 9.31

Table 9.31 Grading of Fine Aggregates including Filler

Passing IS Sieve	Retained on IS Sieve	Percentage by weight
2.36 mm	600 micron	0-25
600 micron	212 micron	5-25
212 micron	75 micron	10-20
75 micron	-	30-50

Mix Design : The hardeness number of bitumen mastic shall be determined at 25^0C in accordance with the method specified in

Appendix D of IS:1195-197. It shall confirm to the following requirement

1. Without coarse aggregate at 25^{0}C 30-60

2. With coarse aggregates at 25^{0}C 10-20

Binder Content : The Binder content shall be so fixed so as to achieve the requirement of mix as per hardness number above. The binder content shall be in the range of 14 to 17 per cent by weight of mix.

There are two ways of preparing bitumen mastic. The conventional method is by using a mastic cooker and the other method using fully mechanized unit for large scale work.

In case, the material is not required for immediate use, the bitumen mastic with filler, fine aggregates and bitumen shall be cast into blocks weighting about 25 kg.

The mastic asphalt blocks (without coarse aggregate) shall show on analysis of a composition within the limits as given in Table 9.32.

Table 9.32 Composition of Mastic Asphalt Blocks without coarse aggregate

IS Sieve	Percent by Weight of Mastic Asphalt	
	Minimum	**Maximum**
Passing 2.36 mm but retained on 600 micron	0	22
Passing 600 micron but retained on 212 micron	4	30
Passing 212 micron but retained on 75 micron	8	18
Passing 75 micron	25	45
Bitumen content % by mass	14	17

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.

Manufacture of bitumen mastic and construction operation shall be in accordance with IRC:107 "Specification for Bitumen Mastic Wearing Courses".

9.7.12. Slurry seal

Scope: The work consists of design and laying of mixture of mineral aggregate, slow setting cationic bitumen emulsion, water and additives if needed, proportioned, mixed and uniformly spread over a previously prepared surface.The finally laid slurry seal shall have a homogeneous mat, adhere firmly to the prepared surface and provide friction resistant surface texture throughout its surface life.

Types of Slurry Seal: Different types of slurry seal and their applications are given in Table 9.33

Table 9.33 Types of Slurry Seal

Items	Type I (2-3 mm)	Type II (4-6 mm)	Type III (6-8 mm)**
Application	Filling of hair cracks	Filling of surface cracks 1-3 mm and preventive/ renewal treatment (upto 450 CVPD)***	Filling of surface cracks 3-6 mm and preventive/ renewal treatment (upto 1500 CVPD)***
Quantity* of slurry (kg/m^2)	4.3 to 6.5	8.4 to 9.8	10.1 to 12
Residual binder (% by weight of dry aggregate)	10 to 16	7.5 to 13.5	6.5 to 12

* In terms by weight of dry aggregate

** Indicative only

*** CVPD: Commercial Vehicles per day

The bitumen emulsion shall be a cationic slow setting type SS-2, conforming the requirements of IS:8887

The mineral aggregates shall be crushed stone dust, clean, sharp hard durable and uncoated dry particles and shall be free from soft pieces and organic and other deleterious substances. The properties of aggregates and targeted grading shall conform to the requirements given in Table 9.34 and Table 9.35 respectively

Table 9.34 Properties of aggregate for Slurry Seal

Properties	Test Method	Specification
Sand Equivalent Value	IS:2720 (Part 37)	Min 50 percent
Water absorption*	IS 2386 (Part 3)	Max 2 percent
Soundness with – Sodium sulphate Magnesium sulphate	IS:2386 (Part 5)	Max 12 percent Max 18 percent

* In case water absorption exceeds 2% but is less than 4% same may be permitted subject to conformity of soundness test and wet stripping test

Table 9.35 Aggregate grading for Slurry Seal

Sieve Size (mm)	Percentage by Mass Passing (Minimum Layer Thickness)		
	Type I (2-3 mm)	**Type II (4-6 mm)**	**Type III (6 – 8 mm)**
9.5	-	-	100
6.3	-	100	90-100
4.75	100	90-100	70-90
2.36	90-100	65-90	45-70
1.18	65-90	45-70	28-50
0.600	40-65	30-50	19-34
0.300	25-42	18-30	12-25
0.150	15-30	10-21	7-18
0.075	10-20	5-15	5-15

Mineral filler shall be ordinary Portland cement. The quantity of filler shall be in the range of 0.5 to 2 percent by weight of dry aggregate.

The water shall be potable, free from harmful salt and containments. The pH of water shall be in the range of 6 to 7.

Chemical additives may be used to accelerate or retard the break-set time of the slurry or to improve the resulting surface finish.

Mix design of slurry seal shall be done as per clause 512.4 of MORTH Specifications for Road and Bridge Works.

The indicative limits of various ingredients for job mix of slurry seal are given in Table 9.36

Table 9.36 Indicative Quantity of Ingredients for Slurry Seal

Ingredients	Limits (Percent by Weight of Dry Aggregates)
Cationic Bitumen Emulsion	10 to 16 for Type I 7.5 to 13.5 for Type II 6.5 to 12 for Type III
Water	6 to 12
Filler	1.0 to 2.0
Additive	0.5 to 2.0

The construction operations of slurry seal shall be as per clause no. 512.5 of MORTH Specifications for Road and Bridge Works.

9.7.13. Recycling of bituminous pavement

1. **Scope:** This work covers the recycling of existing bituminous pavement materials to upgrade an existing bituminous pavement which has served its initially intended purpose. Recycling process can be categorized 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. The details as below are for hot process.

2. Reclaimed bituminous material may be used in the production of dense graded bituminous base and binder course material, subject to the requirements of paras 3 to 9 below and subject to the satisfactory completion of full trial investigations in respect of all related materials.

For estimating purpose, a maximum not greater than 60 per cent of reclaimed bituminous material shall be assumed.

3. **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 two lane carriageway shall be taken.

4. **Bitumen extraction:** The procedure described in ASTM D-2172 shall be used to quantitatively separate aggregates and bitumen from any representative sample of reclaimed bituminous pavement.

5. **Aggregate evaluation:** Mechanical sieve analysis (IS:2386, Part 1, 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, either in existing pavements, from stockpiled of known origin or from another suitable source shall be identified, 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.

6. **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 to be added in the final mix is essentially a trial and 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 9.37.

Table 9.37 Minimum Recovered Binder Penetration of Recycled Mixture

Specified Grade of Binder Viscosity Grade	Minimum Recovered Penetration Value of Binder after Mixing
40 (45 pen)	27
30 (65 pen)	39
10 (90 pen)	54

7. **Rejuvenators:** The use of rejuvenators, and a test to measure their effectiveness, shall be as per para 519.6.3 of MORTH Specifications for Road and Bridge Works.

8. **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 specified grading of Dense Bituminous Macadam. Reclaimed aggregate, if any, or any aggregate normally used for the desired bituminous mixture, or both, may be used for this purpose.

9. **Combined aggregate grading:** The blend of reclaimed and new aggregate shall meet the grading criteria specified in the relevant

parts of Clause 505 of MORTH Specifications for Road and Bridge Works as appropriate. The blend of aggregates shall be checked for resistance to stripping as specified in for the specification of DBM.

10. Mixture design: The combine aggregate grading and binder content shall comply with the relevant tables in Clauses 505 of MORTH Specifications for Road and Bridge Works. For dense bituminous macadam the mixture design shall also comply with the requirements for the DBM.

11. 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 519 of the MORTH Specifications for Road and Bridge Works may be referred.

12. Mixture design and construction operations should conform to Clause 519 of the MORTH Specifications for Road and Bridge Works.

9.7.14. 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 SS-1 complying with the requirements of IS 8887 and spraying shall not take place when temperature is below 10^0C, nor in windy or dusty conditions, nor when it is raining or the surface to be sprayed is wet.

Construction operation shall conform to Clause 513 of the MORTH Specifications for Road and Bridge Works.

9.7.15. Bituminous cold mix (including gravel emulsion): Bituminous Cold Mix consists of a mixture of unheated mineral aggregate and emulsified or cutback bitumen laid in single layer of

25 – 75 mm. Two types of mix are considered, namely, Designed Cold Mix and Recipe Cold Mix. For details Clause 518 of MORTH Specifications for Road and Bridge Works may be referred.

9.7.16. Sand asphalt base course : This work shall consist of a base course composed of a mixture of sand, mineral filler where required and bituminous binder, placed and compacted upon a prepared and accepted subgrade in accordance with the 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 Viscosity Grade VG 30 or VG 20, as specified in the Contract, confirming to 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 and with other physical properties conforming to the requirements of this Table 9.38.

Table 9.38 Sand Grading and Physical Requirements for Asphalt Base Course

Sieve Size (mm)	Cumulative Percentage by Weight of Total Aggregate Pressing
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 4)	40 max.

Filler: When required, filler shall consist of finely divided mineral matter, such as rock dust, hydrated lime or cement as approved by the Engineer. The filler shall conform to Clause 505.2.4. of the MORTH Specifications for Road and Bridge Works.

Mix design and construction operation shall conform to Clause 506 of the MORTH Specifications for Road and Bridge Works.

9.7.17. Crack prevention courses: This will consists of providing one or two coats of an elastomeric rubber membrane known as Stress Absorbing Membrane (SAM) over cracked surface, followed by a covering of aggregate chips and a Stress Absorbing Membrane Interlayer (SAMI), which is a material similar to SAM or which consists of bitumen impregnated geotextile as per specification where a two coat of SAM or SAMI is required the second coat shall be applied within 90 days of the first coat. For details like materials and the quantities required to be used, construction operation Clause 517 of the MORTH Specifications for Road and Bride Works may be referred.

9.7.18 Micro-Surfacing

The work comprises of design, testing and construction of micro-surfacing composed of modified bitumen emulsion, mineral aggregate, water and necessary additives, (if needed) proportioned, mixed and uniformly spread over a properly prepared surface for surface treatment of pavements.

Micro-surfacing is applied on an existing pavement surface which is structurally sound but the surface shows signs of premature ageing, aggregate loss, cracking, high degree of polishing etc. It may be used as surface sealing treatment to improve skid resistance, surface durability to seal fine and medium cracks and preventive maintenance and periodic renewal treatment on low and medium traffic roads. Types of micro-surfacing and rates of application are given in Table 9.39.

Table 9.39 Types of Micro-Surfacing and Rate of Application

Items	Type II (4 to 6 mm)**	Type III (6 to 8 mm)**
Application	Preventive and Renewal Treatment for Roads Carrying < 1500 CVPD	Preventive and Renewal Treatment for Roads Carrying 1500 to 4500 CVPD
Quantity of mix* (kg/m^2)	8.4 to 10.8	11.1 to 16.3
Residual binder (percentage by weight of dry aggregate)	6.5 to 10.5	5.5 to 10.5

* By weight of dry aggregate
** Indicative only

The bitumen emulsion shall be modified bitumen emulsion conforming to the required specified in Clause 514.3 of MORTH Specification for Road and Bridge Works.

Aggregates, filler, water and additives shall meet the requirements as for the work of slurry seal as per clause number 514 of MORTH specifications for Road and Bridge Works.

Design and proportioning of micro surfacing mix shall be as per clause 514.4 of MORTH Specifications for Road and Bridge Works. Indicative limits for various ingradients for job mix of micro surfacing shall be as given in table 9.40 below

Table 9.40 Indicative ingredients in mix

Ingredients	Limits (Percent Weight of Aggregate)
Residual bitumen	6.5 to 10.5 for type II and 5.5 to 10.5 for Type III
Mineral filler	0.5 to 3.0
Additive	As needed
Water	As needed

Design, proportioning, micro-surfacing mix and construction operation shall be as per Clause 514.4 and 514.5 MORTH Specifications for Road and Bridge Works respectively.

9.7.19 Stone Matrix Asphalt (SMA)

The work shall consist of construction in a single or multiple layers of fibre stabilized SMA for use as wearing course/binder course on a previously prepared bituminous bound surface. The 13 mm SMA shall be used for wearing course with nominal layer of thickness of 40 to 50 mm binder course The 19 mm SMA shall be used for binder course with nominal layer thickness of 45-75 mm.

The bitumen shall be viscosity grade paving bitumen conforming to IS:73 or modified bitumen complying with IS:15462 and IRC:SP:53 of appropriate type and grade capable of yielding the specified design mix requirements.

The coarse aggregate shall consist of crushed rock retained on 2.36 mm sieve. It shall be clean, hard, durable of cubical shape and free from dust and soft organic and other deleterious substances. The aggregate shall satisfy the physical requirements as given in Table 9.41.

Table 9.41 Physical Requirements for Coarse Aggregates for Stone Matrix Asphalt

Property	Text	Method	Specification
Cleanliness	Grain Size Analysis	IS:2386 (P-1)	<2% passing 0.075 mm sieve
Particle Shape	Combined Flakiness and Elongation Index	IS:2386 (P-1)	<30%
Strength	Los Angeles Abrasion Value	IS:2386 (P-4)	<25%
	Aggregate Impact Value	IS:2386 (P-4)	< 18%
Polishing*	Polished Stone Value	IS:2386 (P-114)	>55%

Durability	Soundness (either Sodium or Magnesium) – 5 cycles		
	Sodium Sulphate	IS:2386 (P-5)	<12 %
	Magnesium Sulphate	IS:2386 (P-5)	
Water Absorption	Water Absorption	IS:2386 (P-3)	<2%

* Polishing requirement does not apply when the coarse aggregate is used for intermediate (binder) course.

Fine aggregates (passing 2.36 mm sieve and retained on 0.075 mm sieve) shall consists of 100 percent crushed, manufactured sand resulting from crushing operations. The fine aggregate shall be clean, hard, durable, of fairly cubical shape non plastic and free from soft pieces, organic or other deleterious substance. The sand equivalent test value for the fine aggregate shall be not less than 50. The fine aggregate shall be non plastic.

Mineral filler shall consist of finely divided mineral matter such as stone dust and/or hydrated lime. Flyash shall not be permitted as filler. The grading of filler shall be within the limits as indicated in Table 9.42. The Filler shall be inert material free from organic impurities and shall have PI not greater than 4. PI requirement will not apply if filler is hydrated lime.

Table 9.42 Grading Requirement of Mineral Filler

IS Sieve (mm)	Cumulative % Passing by Weight of Total Aggregate
0.6	100
0.3	95-100
0.075	85-100

Only pelletized cellulose fiber shall be used in SMA. The dosage rate for cellulose fibres is 0.3 percent minimum by weight (on loose fiber basis) of the total mix. The dosage rate shall be confirmed so that the bitumen drawn down does not exceed 0.3% when the designed mix is tested in accordance with ASTM D6390.

The mix design for SMA, production and construction shall be as per clause 515 of MORTH Specifications for Road and Bridge Works.

9.7.20 Readymade Bituminous Pothole Patching Mix

The material shall consist of plant mixed, ready made pothole patching bituminous mixture composed of mineral aggregate coated with bituminous material. The material shall be capable of being stocked for at least six months without stripping and shall be workable at all times. Unless specified otherwise, this mix shall be supplied in 50 kg plastic lined, sturdy bags. The material is intended for patching potholes upto 75 mm deep. For deeper potholes patching mix shall be placed and compacted in 75 mm thick layers.

Bitumen – Medium curing cutback bitumen MC-800 conforming to IS:217 shall be used. MC cutback bitumen shall be treated with a proper type and amount of an antistripping agent conforming to IS:14982. The resulting mix shall pass the wet coating tests, static – immersion test and water resistant test.

Coarse aggregate – The coarse aggregate shall consist of crushed rock, crushed gravel or other hard material retained on 2.36 mm sieve. It shall be clean, hard durable and cubical shape free from dust and soft organic and other deleterious substances. The aggregate shall satisfy the physical requirements as specified in IRC:116 “Specifications for Ready Made Bituminous Pothole Patching Mix using Cut Back Bitumen”.

Fine Aggregate – Fine aggregate shall consist of crushed mineral material passing 2.36 mm sieve and retained on 75 micron sieve. It shall be clean, hard, durable and free from dust and soft organic and other deleterious substances. No natural sand shall be permitted.

For further details on composition of mixture, preparation and storage of mixture, preparation of potholes, placing and compacting of readymade mix IRC:116 may be referred.

9.7.21 Warm Mix Asphalt

The basic principle of this technology is that by adding certain additives at the final stages of the mix production, the coating of the aggregates by the binder is greatly enhanced and can be achieved at a considerable less temperature (typically 30^0C less) compared to a sufficiently high temperature to make it fluid enough to surround the aggregates and coat their surfaces. In hot mix processes, it is viscosity of bitumen alone, which is less at higher temperature that plays the main role in coating of aggregates. In warm mix technology this can be achieved in three different ways by increasing the volume of bitumen, by making the bitumen less viscous, by reducing the surface tension at aggregate bitumen interface etc.

A range of warm mix technologies have potential for use in bituminous construction like Dense Bituminous Macadam (DBM), Bituminous Concrete (BC) and Recycled Asphalt Pavement.

The Warm-Mix Technology uses a variety of patented products, as additives, which come in different forms such as solid, liquid and powder and use different processes for administering the additives and mixing.

Further details are available in IRC:SP:101 "Interim Guidelines for Warm Mix Asphalt"

9.8. Concrete Sub-Bases: Dry lean concrete (DLC) sub-base : Ordinary portland cement (OPC) (43 grade and 53 grade IS269), or portland slag cement (PSC) (IS:455) or portland pozzolana cement (PPC) [IS:1489 (Part-I)], composite cement (IS:16415) may be used. If the sub-grade contains soluble sulphate in excess of 0.5 per cent, the cement used shall be sulphate resistant portland cement conforming to IS:1230 or Portland Slag cement upto 50%.

Coarse and fine aggregates shall be natural aggregate conforming to IS:383. If required, coarse aggregate should be washed and drained. Fine aggregate should be free from soft particles, clay, sea shale, loam, cemented particles, mica, organic and other foreign matter. The water absorption of aggregate shall not exceed 3 percent.

Maximum size of coarse aggregate shall be 26.5 mm. The blended aggregate should conform to the grading indicated in Table 9.43.

Table 9.43 Grading of Aggregates for Dry Lean Concrete

Sieve Designation	Percentage Passing (by Weight)
26.50 mm	100
19.00 mm	75-95
9.50 mm	50-70
4.75 mm	30-55
2.36 mm	17-42
600 micron	8-22
300 micron	7-17
150 micron	2-12
75 micron	0-10

Water used for mixing and curing of concrete shall be clean and free from injurious amounts of oil, salt, acid, alkali, sugar, vegetable matter or other substances harmful to concrete. It should meet the requirements stipulated in IS:456. Potable water is generally considered satisfactory for mixing and curing.

Fly ash, 15-30 percent or ground Granulated Blast Furnace Slag (GBFS) 25-50 percent by weight of cementitious material may be used in concrete as part replacement of OPC and in such case, the OPC content shall not be less than 100 kg/m^3 of concrete. The fly ash shall conform to IS:3812 (Part-I) and granulated blast furnace slag shall confrom to IS:12089.

The average compressive strength of each concrete group of 5 concrete cubes shall not be less than 7 MPa at 7 days. In addition, the compressive strength of any individual concrete cube shall not be less than 5.5 MPa at 7 days.

The concrete mix shall be proportioned with a maximum aggregate cement ratio of 14:1 where OPC is used and 12:1 where PPC or PSC is used. The minimum cementitious materials contract shall not be less than 140 kg/cum of concrete.

The optimum water content should be determined by trial mixes to ensure full compaction under rolling. While laying subbase in main carriageway, the DLC may have 1 percent higher moisture content to compensate evaporation loss during transport.

The subgrade shall conform to the grades and cross sections as per drawings and shall be uniformly compacted to the modified proctor density of not less than 97 percent. The lean concrete subbase shall not be laid on a subgrade softened by rain after is final preparation. A day before laying the lean concrete the subgrade surface shall be given a fine spray of water and rolled with one or two passes of smooth wheeled roller after a lapse of 2-3 hours.

The batching and mixing shall be carried out preferably in a forced action central batching and mixing plant having necessary automatic controls to ensure accurate proportioning and mixing. Calibration of the batching and mixing plat shall be carried out at regular intervals normally every month.

The plant mixed lean concrete shall be transported by, covering with tarpauline, tipping trucks to ensure a continuous supply of material to feed the laying equipment to work at a uniform speed and in an uninterrupted manner.

Lean concrete shall be laid by a hydrostatic paver. The equipment shall be capable of laying the full material in one layer in an even manner without segregation. The laying of the two lane road subbase shall be done in full width.

The compaction shall be carried out immediately after the material is laid and levelled. The rolling shall be continued on the full width till there is no further visible movement under the roller and the surface is closed. 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

25^0C and 30^0C and 120 minutes, if less than 25^0C. This period may be reviewed in the light of result of the trial length. Work shall not proceed when the temperature of concrete exceed 30°C Double drum smooth wheeled vibratory rollers of minimum 80 to 100 KN static weight are suitable for rolling dry lean concrete. The minimum dry density shall be 97 percent of that achieved during trial length construction. The density achieved at 0.5 mm from the edge should not be less than 95 percent of that achieved during trial construction. Day's work shall be stopped by vertical joints. The edge of the compacted material shall be cut back to a vertical face when work starts next day.

As soon as the lean concrete surface is completed curing shall be done by covering the surface by hessian cloth in two layers which shall be kept continuously moist for 7 days by sprinkling water. If water curing is not possible curing should commence by spraying with liquid curing compound and covering with wet hessian for three days.

The trial length shall be constructed (in two days), at least 14 days in advance of the proposed day of commencement of work. The length of trial construction shall be a minimum of 60 m length and for full width of the pavement. The trial length shall contain the construction of at least one transverse construction joint involving hardened concrete and subase to be laid subsequently.

IRC:SP:49 "Guidelines for the use of Dry Lean Concrete as Sub-Base for Rigid Pavement" provides full details of this work.

9.9 Jointed Plains Concrete Pavement

Material

Cement

Any of the following types of cement capable of achieving the design strength may be used

1. Ordinary Portland Cement IS:269 (43 grade and 53 grade) including 5% performance improver (mineral admixture etc. as per IS:269)

2. Portland – Pozzolona Cement IS:1489 (Part-1)

3. Portland Slag Cement IS:455

4. Composite Cement (blended with granulated slag and fly ash) IS:16415

If the soil around concrete pavement has soluble solts, like sulphates in excess of 0.5 percent, the cement used shall be sulphate resistant Portland cement, IS:12330

Admixture

Chemical Admixture

Admixture conforming to IS:9103 may be used to improve workability of concrete or extension of setting time, on satisfactory evidence that they will not have any adverse effect on the properties of concrete and on embeded steel. The maximum quantity of chemical admixture shall be 2 percent by weight of cementitious material. Compatibility and optimum dose of the particular admixture (from a specific manufacturer) with specific cement type (from a particular manufacturing plant) to be used shall be established by Marsh Cone Test as per ASTM C 939.

Mineral Admixture

Following types mineral can improve the workability, long term strength and durability of concrete

a. Fly Ash (as per IS:3812 (Part 1)

   Fly ash upto 25 percent by weight of cementitious material may be mixed at site with OPC of 43/53 grade.

b. Ground Granulated Blast Furnace Slag (GBFS)

   Factory manufacturered GBFS (as per IS:10875) upto 50 percent by weight of cementitious material may be mixed at site with OPC of 43/53 grade.

c. Silica Fume

Silica fume upto 10 percent by weight of OPC if specified in design may be used.

d. Metakaolin

Metakaolin conforming to IS:16354 may be used upto 20 percent of the cementitious material.

Aggregates

Aggregates for pavement concrete shall be complying with IS 383. The aggregates shall be free from chert, flint, chalcedony or silica in a form that can react with alkalis in the cement. The total chloride content shall not exceed 0.06% by weight and total sulpate content shall not exceed 0.25% by weight. In case, the aggregates are not free from dirt same may be washed and drained for at least 72 hours before batching. Aggregate having water absorption more than 2% shall not be used. The combined flakiness and elongation index shall not be more than 35%. Aggregate Impact Value shal not be more than 30%. Fine aggregate shall consist of natural sand or crushed stone sand or a combination of the two and shall confirm to IS:383.

The maximum size of coarse aggregates shall not exceed 31.5 mm and the combined grading is given in Table 9.44

Table 9.44 Aggregate Gradation for Pavement Quality Concrete (PQC)

Sieve Designation	Percentage Passing		
	31.5 mm Nominal Size	**26.5 Nominal Size**	**19 mm Nominal size**
37.5 mm	100	100	100
31.50 mm	90-100	100	100
26.50 mm	85-95	90-100	100

19.0 mm	68-88	75-95	90-100
9.50 mm	45-65	50-70	48-78
4.75 mm	30-55	30-55	30-58
600 micron	8-30	8-30	8-35
150 micron	0-10	0-10	0-12
75 micron (Wet Sieving)	0-5* 0.2**	0-5* 0-2**	0-5* 0-2**

* Crushed Sand, ** Natural sand

Water should conform to the requirement as mentioned for Dry Lean Concrete

A separation membrane shall be used between the PQC and DLC sub base unless PQC is designed as bonded to DLC sub base. Separation membrane shall be impermeable polythene sheet 150 micron thick as per IS:2508. Alternatively, non woven geotextile, 4 mm thick may also be used as separation layer between PQC and DLC.

The dowel bars shall conform to IS:432 of Grade 1. Tie bars shall be Thermo-Mechanically Treated (TMT) bars conforming to IS:1786 and grade of Fe 500. If steel mesh is used, it shall conform to IS:1586. The steel shall be coated with appropriate anti-corrosive coating as per IS:13620. Whenever steel bars are used as temperature, reinforcement bars, those shall be deformed TMT bars as per IS:1786 and shall preferably welded.

The joint sealing compound shall be hot poured, elastomeric type or cold polysulphide/polyurethane/silicon type having flexibility, durability and resistance to age hardening. Synthetic joint filler board for expansion joints are also proposed for use only at some abutting structures, like bridges and culverts, and shall be of 20-25 mm thickness with a tolerance of $\pm$ 1.5 mm.

Pre-formed joint sealing material shall be a vulcanised elastomeric compound using polychloprene (Neoprene) as the base polymer. The joint seal shall conform to requirements of ASTM D 2628.

Fibre may be used subject to the provision in the design to reduce shrinkage cracking and improve post-cracking residual strength. The fibres may be steel fibre as per IRC:SP46 or polymeric synthetic fiber.

Types of Joints

There are four types of joints These are

i) Expansion Joint: Expansion joint provides the space into which pavement can expand thus relieving compressive stresses due to expansion and inhibiting any tendency towards buckling of concrete slabs.

ii) Contraction Joint: Contraction joint relieves tensile stresses in the concrete and prevents formation of irregular cracks due to restraint in free contraction of concrete. Contraction joints also relieve stresses due to warping.

iii) Longitudinal joint: Longitudinal joint relieves stresses due to warping. These are commonly used for dividing the pavement into lanes when width of the slab becomes more than 4.5 m.

iv) Construction joint: Construction joints are provided whenever day's construction operations starts and stops/ ends. These are full depth joints construction should be so planned that day's construction activity may end at the location of regular contraction joint. It may also be provided where paving stops for more than half an hour due to stoppage of work.

Depending on the locations, the joints can also be classified as Transverse joints and Longitudinal joints. Transverse joints can be expansion, contraction or construction joints and shall be placed across the direction of traffic direction. These shall make a right angle with the centre line of the pavement. This joint shall be continuous from edge to edge of the pavement through all lanes constructed at the same time or different times. The maximum spacing of transverse joint shall be 4.5 m. Dowel bars as per dimensions, locations and spacing are required at expansion joints to transfer wheel loads to the adjacent slab. For slabs of thickness less than 200 mm dowel bars need not be provided.

The details of different types of joints and their constructions have been given in IRC:15 “Code of Practice for Construction of Jointed Plain Concrete Pavements”.

The proportioning of concrete and mix design shall be done as per IRC:44 “Guidelines for Cement Concrete Mix Design for Pavements”.

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. More bins amy be required to handle mineral admixtures like fly ash, GBFS and also different types of sands like fine, coarse and crushed etc. 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 personnel engaged in plant operation, inspection and testing.

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 mixer 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 intervals not exceeding one month.

Mixers should be of pan type, reversible type with single or twin shaft 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 mixing of each batch will continue for 60 seconds after all the materials are discharged into the mixer or as recommended by the manufacturers of the plant.

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 from the mould, screed and float-finsih, 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 design and specifications. The paver should be equipped with electronic sensors to pave the slab to the required thickness, camber, grade and alignment in the case of slip form pavers. Vibrators should operate at a frequency of 8000 to 10000 HZ at a paving speed of 0.8 to 1.0 m/minutes. No concreting should be done when the concrete temperature is above 30^0c.

Freshly mixed concrete from the central batching and mixing plant shall be transported to the paver site by means of truck/tippers of sufficient capacity in adequate numbers. Tarapauline 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 uninterrupted manner with a uniform speed throughout the day's work. The trial length of the concrete pavement shall be constructed at least one month in advance of the proposed start of concrete paving work. The trial length shall be constructed away from the carriageway but with at least a sub-base layer stipulated below it. Prior to the construction of the trial length, a detailed method statement shall be submitted giving description of proposed materials, plants and equipments to be used in the constructions. The trial length of slab shall be at least 60 m for mechanized construction and 30 m for semi-mechanized construction. Trial lengths shall be constructed in two equal parts over a period comprising at least part of two separate working days. Transverse joints and longitudinal joints with the required dowel bars and tie bars shall be constructed and assessed in the trial length.

The details of materials, tools, plants and equipment, construction methodology and quality control are given in IRC:15.

9.10 Continuously Reinforced Concrete Pavement (CRCP)

Continuously Reinforced Concrete Pavement (CRCP) is intended for roads carrying very high volume of commercial traffic and where closing road often for maintenance is difficult. Unlike the jointed plain cement concrete pavement no transverse joints are provided in CRCP but longitudinal joints are necessary if the carriageway width is more than a lane width. Longitudinal steel is provided in CRCP primarily to control transverse cracks which appear due to shrinkage taking place in fresh concrete and also hold them together. This pavement is similar to jointed reinforced concrete pavement except that steel runs through the pavement continuously.

For design of pavement thickness, IRC:58 can be adopted. An extra thickness of 10-15 mm may be provided to for compensating the wear and tear and also depth of texture. Thickness in the range of 250 mm to 300 mm is generally found to be satisfactory depending upon present traffic volume. Longitudinal steel percentage of 0.65 to 0.8 percent of pavement cross section is found to result in acceptable crack spacing and width as per CRSI FHWA, USA. The steel bars used are normally of 16 mm to 20 mm diameter and are grade Fe 415. In India TMT bars of Fe-500 conforming to IS:1786 can readily be used.

The construction of CRCP can be done as detailed out in IRC:15. The paving can be done using either slip form of fixed form paver. For further details IRC:118 "Guidelines for Design and Construction of Continuously Reinforced Concrete Pavement (CRCP)" may be referred.

9.11 Fibre Reinforced Concrete Pavement (FRCP)

Initially fibres were used in concrete as secondary reinforcement or for crack control in less critical elements. Now Fibre Reinforced Concrete as the main (structural) reinforcement in slab on grade, industrial floors, pavements and as the structural base. These can also be used in sub bases for pavements or cement treated sub bases which are susceptible to shrinkage cracking. In general fibre concrete can be used in all applications where plain concrete can be used. FRC gives improved impact resistance and flexural fatigue endurance. Structural FRC can be usefully deployed in the following areas

i) Concrete Pavements (PQC/Overlays, thin and Ultra-thin whitetopping) for roads, runways, bridge.

ii) Overlays for rehabilitation or strengthening of roads, runway, bridge decks.

iii) Thin or ultrathin overlays where overhead clearance is critical.

iv) Rotaries, intersections and locations where odd shapes of pavements are required.

v) Toll Plaza with only polymeric fibres or in combination with steel fibres.

FRC pavement can be opened to traffic earlier if the flexural strength of concrete of about half the specified value can be achieved at an age of 1 to 3 days only, by choosing an appropriate mix proportion and fibre content.

Fibres may be of steel fibres or polymeric fibres. Steel fibres should have an ultimate strength of at least 800 MPa. Steel Fibres can be straight or deformed. Polymeric fibres with low elastic modulus which are monofilament or fibrillated form varying in length from about 12 mm to 40 mm. These fibers are normally used to control plastic shrinkage cracking. Macro polymeric fibers in 30 to 60 mm length of higher elastic modulus can increase the toughness and strength capacity of the FRC pavement. Micro fibres are in 12 mm to 40 mm length and have diameter less than 0.2 mm.

Maximum size of aggregate shall depend upon the thickness of pavement and the average spacing of well dispersed fibres in concrete. For most application maximum size of aggregates could be 20 mm.

Table 9.45 shows range of proportions for FRC for pavement application. This table is guidance for initial trial mix. The final mix proportion after successful trials may differ from the guidance in the Table 9.45.

Typical 9.45 Range of Constituent in FRC Mixes

	Maximum Size of Aggregate		
Mix parameters	10 mm	20 mm	31.5 mm
Fibre content in % volume			
Micro fibres	0.5 to 1.0	0.2 to 0.6	0.1 to 0.3
Macro fibres	1.0 to 3.0	0.3 to 1.0	0.3 to 0.6
Cementitious content kg/m^3	400-520	380-500	350-430
Water/cementitious ratio #	0.30 to 0.40	0.30 to 0.45	0.30 to 0.50
% fine to total aggregate	50 – 68	45 – 60	40 – 50
Entrained air content*	4-8	4-6	3-5

Based on effective coefficient for cementitious (mineral admixture), say 0.4 for flyash

* For Freeze thaw resistance

For further details on FRC pavement, including mix proportioning design of mixes, dosing of fibres, mixing, construction, material specification IRC:SP:46 "Guidelines for Design and Construction of Fibre Reinforced Concrete Pavements" may be referred.

9.12 White topping

White topping is defined as a Portland Cement Conrete (PCC) overlay constructed on the top of an existing bituminous pavement. White topping is thus PCC resurfacing (Overlay) as rehabilitation or structural strengthening on bituminous pavement. The PCC overlay may or may not be bonded to the layer below. A PCC overlay is commonly applied where rutting of bituminous pavements is a recurring problem. Concrete overlays offer the potential for extended service life, increased structural and functional capacity, reduced maintenance requirements and lower life-cycle costs when compared with bituminous overlay alternative.

White topping is classified into three types. These are i) Conventional White Topping, ii) Thin White topping and iii) Ultra-thin White Topping.

This is based on the degree of bonding between the under laying bituminous layer with PCC overlay and the thickness of the overlay.

Conventional White topping – It consists of a PCC overlay of thickness 200 mm or more which is designed and constructed without consideration of any bond between the concrete overlay and underlying bituminous layer. Conventional white topping is designed and constructed like new rigid pavement without assuring any composite action. The existing bituminous surface is treated as sub base like Dry Lean Concrete (DLC).

Thin White Topping (TWT) – PCC overlay of thickness greater than 100 mm and less than 200 mm is classified as TWT. The bond between the overlaid PCC and underlying bituminous layer is often a consideration but it is not mandatory and maybe ignored in the design. High strength concrete with fibres is commonly used. Joints are at shorter spacing of 0.6 m to 1.25 m.

Ultra-Thin White Topping (UTWT) – PCC overlay of thickness equal to or less than 100 mm is classified as UTWT. In this case bonding between underlying bituminous layer and PCC layer is mandatory. Milling the existing bituminous surface to an average depth of 25 mm is normally used to provide the bonding at the interface of the existing bituminous surface and PCC overlay. High strength concrete with fires is normally provided with closely spaced joints at an interval of 0.6 to 1.25 m.

The details of materials to be used, mix proportioning and strength of concrete and construction methodology for different types of white topping are given in IRC:SP:76 "Guidelines for Conventional and Thin White Topping"

9.13 Geo-synthetics

Geosynthetic is a general classification for all synthetic materials used in geotechnical engineering application. It includes geotextiles, geogrids, geostrips, geomembranes, geonets, geocomposites, geocells, geosynthetic mats, paving fabric and glass grid etc. Geofabrics made from natural fibres such as jute and coir are classified as natural geotextiles and may also be used in different geotechnical engineering applications.

Geotextile – Geotextile fabric shall be a woven, non-woven or knitted fabric consisting of long chain polymetric filaments or yarns such as polypropylene, polyethylene or polyester or any combination thereof. There are several application areas for geotextiles requiring specific functions namely separation, filtration, drainage, reinforcement or a combination thereof.

Geogrids – A deformed or non-deformed net like polymeric material used with foundation, soil, rock, earth or any other geotechnical engineering related material. Geogrids have relatively high strength, high modulus and low creep sensitive polymers with appertures varying from 10 to100 mm in size or more. Geogrids can be of uniaxial grid, biaxial grid or three dimensional grids and the openings holes in geogrids are either elongated ellipse, near squares with rounded corners, squares or rectangles. Geogrids are used as reinforcement in pavements and reinforced soil slope. Geostrip is another form of geogrid which is used in reinforced soil structure.

Geomembranes – An essentially impermeable membrane (linear or barrier) used with foundation, soil, rock, earth or in any other geotechnical application used to control fluid migration.

Geomembranes are made from PVC or polyethylene sheets which are duly protected from ultraviolet exposure by carbon black or any antioxidant and thermal stabilizers. These are used as capillary cut off in roads in water logged areas.

Geonets – Geonets are used in combination with other types of geosynthetics. These are usually formed by continuous polymeric ribs at acute angle to one another.

Geocomposite – A manufactured material, which could be a combination of any two or more synthetic materials, like geotextile, geogrids, geo-nets and geomembrane etc. Prefabricate Vertical Drains (PVD)/Band Drains and Fin Drains come under category of geocomposites.

Geocells– It is a three dimensional structure with inter-connected cells. The geocells are made of polyester/polypropylene/high density polyethylene stabilized with carbon black and may be used in erosion control of slopes.

Geosynthetic mats: These are two dimensional or three dimensional mats with specified thickness, made of multi-filaments with apertures to allow vegetation growth for erosion control application. These are used for erosion protection of slopes.

Geospacer: Geospacer is a three dimensional synthetic extruded from polymeric material such as HDPE. It provides separation and a void between layers to provide in plane drainage. The material is UV Stabilized with carbon black. Geonets are often laminated with geotextiles on one or both sides and are referred as drainage material and increasingly used to replace traditional gravel drainage layers.

Paving Grid/Glass-Fibre Grid/Asphalt-Interlayer Composites (AIC)/Composite Paving Grid :

Asphalt Reinforement : These are products for strengthening of asphaltic layer for pavement. Paving fabric is made from the fibres with non-weaving process (needle punch and heat bonded) and applied by providing tack coat with asphaltic layer. The Paving Grid/Glass Fibre grid shall be manufactured from a glass fibre roving or polymeric grid pattern, resistant to chemical attack, mildew and rot. A grid combined with a paving fabric called a composite. AIC is made from non-woven geotextile with fibre glass rovings, will provide dual functions.

Use of Geosynthetics:

In a given application, a geosynthetic can perform one or several functions to improve the mechanical and/or hydraulic behavior of the structure in which it is incorporated. The basic functions performed by a geosynthetic are as follows:

1. Separtion/Filtration
2. Reinforcement
3. Drainage
4. Moisture Barrier
5. Erosion Control

The primary functions of geosynthetics are indicated in the Table 9.46

Table 9.46 Primary Functions of Geosynthetics

Type of Geosynthetic	Primary Functions of Geosynthetics					
	Separation	Reinforcement	Filtration	Drainage	Impermeable Barrier	Erosion Control
Geotextiles	✓	✓	✓	✓		✓
Geogrid		✓				✓
Geo Membrane	✓				✓	
Geonets				✓		✓
Geospacer	✓			✓	✓	
Geocell		✓				✓

Geomat				✓		✓
Paving Fabric					✓	
Paving Grid		✓				
Geo Composite	✓	✓	✓	✓	✓	✓

Note: The given matrix of primary functions is indicative only; each product can have multiple functions as per site conditions.

For further details on use of geosynthetics IRC:SP:59 "Guidelines for Use of Geosynthetics in Road Pavements and Associated Works" and MORTH Specifications for Road and Bridge Works, may be referred.

The details regarding properties, test methods for different geosynthetic materials are given in IRC:SP:59. Property requirements and selection criteria of geosynthetics based on function are also incorporated in IRC:SP:59.

In respect of construction guidelines for use of geosynthetics in Road Works IRC:SP:59 may be referred.

The MORTH in their Circular Letter No.RW/NH-33044/64/2018-S&R (P&B) dated 16.7.2018 have decided that all the implementing agencies and State government have to use geosynthetics in a bigger way as per the existing IRC Codes/Guidelines and MORTH Specifications and Guidelines.

Natural Geotextiles

These geotextiles are made of natural fibres like jute or coir. The blankets/mats/mesh made of these fibres are sometimes further reinforced with polymeric nettings to enhance its tensile strength and for holding the fibres intact. These fabrics have excellent drapability and aid in quick growth of vegetation and are used for erosion control.

Use of Natural Geotextiles – Natural geotextile which is made of natural fibres like jute or coir may be used for control of erosion. Natural geotextile shall be used to control surface erosion of top cover soil on cut or fill slopes to facilitate vegetation to grow. The natural fibre geotextiles made of jute meet the minimum requirement as stated in IS 14715 – Woven Jute Geotextiles Specification. However for coir fibre geotextiles, it shall meet the requirements as specified in MORTH Specifications for Road and Bridge Works. After laying the mat, a minimum cover of soil shall be spread followed by spreading the seeds and fertilizers. A slow release supplementary fertilizer may be applied to speed up the growth of the vegetation. In the absence of rain, blankets shall be regularly watered for viable growth till vegetation sustains on its own. The details of installation procedure are given in clause 707 of MORTH Specifications for Road and Bridge Works.

9.14 Reinforced Soil

9.14.1 The reinforced soil retaining structures can be used as i) reinforced soil retaining wall, ii) reinforced soil abutment, iii) reinforced soil slope.

The reinforcing element shall be metallic in the form of strips (aluminum alloy strip, copper strip, carbon steel strip, galvanized steel strip, stainless steel strip, ladder) or mats of metal (steel grids, woven and welded steel wire meshes) or synthetic (PET, HDPE, PVA, PP) reinforcement in the form of grid or strip or strap or combination of metallic or synthetic or any other proprietary material as approved and shown in the drawings.

The specification of metallic reinforcement and synthetic reinforcement and project specific tests/data are given in clause 3100 of MORTH specification for Road and Bridge Works and are to be complied accordingly.

Earth fill: The fill material in the reinforced soil zone shall have drained or effective angle of friction not less than 30^0 by conducting drained direct shear test (IS:2720, Part 13). In case, the fill material has 25 percent or more particles of 4.75 mm or larger, drained shear test using large shear box may be conducted (IS 2720: Part 39: Section 1). The gradation of fill soil shall be as per following limits.

Sieve Size	Percentage Passing
75 mm	100%
425 micron	0-60%
75 micron	Less than 15
PI	≤ 6

Materials with more than 15 percent passing 75 micron sieve but less than 10 percent of particles smaller than 15 microns are acceptable provided PI is less than 6 and angle of friction is not less than 30^0.

Fly ash may be used as fill material in reinforced soil walls provided its angle of internal friction is not less than 30^0 and PI is less than 6. Gradation requirements need not be completely satisfied. Fly ash shall satisfy requirements concerning pH and environmental conditions of the fill.

The fill material used in the reinforced soil shall be free from organic or other deleterious material and shall not react adversely (chemically, electrically or biologically) with the reinforcement material and/or facia material.

Where galvanized steel reinforcement used, the fill material shall be free draining granular material and shall meet the following requirements as per Table 9.47

Table 9.47 Recommended Limits of Electrochemical Properties for Reinforced fills with Steel Reinforcement

Property	Criteria	Test Method
Resistivity	>3000 ohm-cm	AASHTO T-288
pH	>5 and < 10	AASHTO T-289
Chlorides	< 100 PPM	ASTM D 4327
Sulphates	< 200 PPM	ASTM D 4327

Where geosynthetic reinforcement is used as reinforcing element manufactured from polyester yarn, pH value of the fill material shall be between 3 and 9 and for reinforcing elements manufactured from PVA, PP and HDPE, the pH value shall be greater than 3.

The facing system shall be one of the following

a) Precast reinforced concrete panels

b) Precast concrete blocks and precast concrete hollow box

c) Gabion facing

d) Wrap around facing using geosynthetics

e) Metallic facing, prefabricated in different shapes including welded wire grid and woven steel wire mesh

f) Other proprietary and proven systems

Facing shall be sufficiently flexible to withstand any deformation of the fill and foundations.

The details of these different facia material are given in Clause 3105 of MORTH Specifications for Road and Bridge Works

Connection between the facia panels and the reinforcing element shall be by using either nut or bolt insert with bodkin-joint, hollow-embedded devices polymeric/steel strips/rods/pipes, fibre glass dowels or any other material shown in the drawings. The connection between the panel and the reinforcement shall provide for 100 percent of the long-term design strength of the reinforcing element in continuity.

In case of modular block faica and other type of facia such as gabion facia, where the reinforcement is held by friction between the facia block and the reinforcement, the connection strength shall be determined as per ASTM D 6638 “Standard Method of Test for Determining Connection Strength between Geosynthetic Reinforcement and Segmental Concrete Units”

The construction details of reinforced soil structures are given in Clause No. 3106 of MORTH Specifications for Road and Bridge Works.

9.14.2 Reinforced Soil Slope

Construction of reinforced soil structures that have a slope face angle flatter than 70^0 are dealt here.

Any type of material used as reinforcing element for the construction of soil slope shall meet the requirement of reinforcing material for reinforced soil structure as detailed in Section 9.14.1 above.

The fill material used as the reinforcing fill in the reinforced soil slope shall meet all the fill requirements of reinforced soil structure as given in Section 9.14.1 above. However, the friction angle of the fill material in this case shall not be less than 28^0.

Facia of reinforced soil slope shall be one of the following types

a) Wrap around using geosynthetics
b) Gabion facing
c) Metallic facing, prefabricated in different shapes including welded wire grid and woven steel wire mesh
d) Precast reinforced concrete panels
e) Precast concrete blocks and precast hollow box.

The specification for all these materials are given in Clause 3105 of MORTH Specifications for Road and Bridge Works.

Laying and compaction of the reinforced soil slope and the compaction of the fill shall conform the requirement as given in Clause 3107 of MORTH Specifications for Road and Bridge Works.

9.15 Soil Nailing

9.15.1 Generally used soil nail installation techniques in practice are drilled and grouted soil nails and driven soil nails. Grouted nail applications are recommended for all types of soil nail applications and in particular, for walls with vertical height more than 7 m. Driven nails shall only be used when wall height is less than 7.0 m.

9.15.2 Following are the in situ conditions considered favourable for the prospective use of soil nailing technique.

a) Soil shall be able to stand unsupported to a depth of about 1 m – 2 m high vertical or nearly vertical cut for 12-24 hrs.

b) Groundwater table shall be sufficiently below level of the lowermost soil nail at all cross-sections.

c) Favourable soils: Stiff to hard fine – granular soils, dense to very dense granular soils with some apparent cohesion, weathered rock with no weakness planes and glacial soils.

9.15.3 Drilled and grouted soil nails or simply grouted nails are approximately 75 mm to 200 mm diameter nail holes drilled in the soil mass to be retained, which shall be followed by placing steel reinforcement bars (tendon) and grouting of the drill hole. Driven soil nails are relatively small in diameter (20 mm to 25 mm) and are mechanically driven to the ground and usually spaced approximately 0.5 m to 1.0 m apart.

9.15.4 Following general materials are required for the construction of typical soil nailing structure.

1. Reinforcement bar (Nail or Tendon)
2. Nail head
3. Grout
4. Centraliser

The details of these materials and their specifications are given in Clause 3200 of MORTH Specifications for Road and Bridge Works.

9.15.5 Facing Types

Soil nail walls are generally provided with two types of facings a) temporary facing and b) permanent facing

Temporary facing shall be constructed by providing reinforcement in the form of welded wire mesh conforming to IS:1566 throughout the wall face, and by additional bearing plates and waler bars (rebars of smaller lengths placed in the vicinity of nail head) at the nail heads, which is subsequently short created in accordance with IS:9102. Overall temporary facing thickness shall vary from 75 mm to 200 mm.

Permanent facing may be constructed as cast in place reinforced cement concrete conforming to IS:456, Precast concrete or any suitable material to achieve desired strength and aesthetics. Reinforcement in the permanent facing may be adopted in the form of welded wire mesh or reinforcement bars in either direction. Minimum thickness of permanent facing shall not be less than 200 mm. Permanent facing shall be connected to the temporary facing by means of headed studs usually four number per plate welded on the bearing plates installed during construction temporary facing.

9.15.6 Typical sequence of construction of a soil nail wall shall be in accordance with following steps:

Step 1: Excavation of initial cut of 1.0 m to 2.0 m depending upon the capacity of in-situ soil to stand unsupported for about 12-24 hrs;

Step 2: Drilling hole for nail;

Step 3: Installation of nails followed by grouting and placing of drainage strip;

Step 4: Placing of construction facing and installation of bearing plates;

Step 5: Repetition of process till final level is reached, and

Step 6:Placing of final facing

9.15.7 Other geotechnical aspects, design considerations, drainage measures, corrosion protection, different tests are detailed in Clause 3200 of MORTH Specifications for Road and Bridge Works.

9.16. Special Measures to Hilly Areas

9.16.1. 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.

9.16.2. 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 level 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 interceptor 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. Cut slopes should be stable for the strata cut, and where necessary, provide suitable breast walls, pitching, etc.

vii) 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 MORTH Specifications for Road and Bridge Works.

viii) 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.

ix) 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.

x) Clause 306 of MORTH Specifications for Road and Bridge works may be referred for further details.

9.17. Quality Control for Road Works

It is the prime responsibility 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.

The different quality control tests and their minimum frequency on different layers of subbase, bases (non bituminous) and bituminous layers are given in Clause 903 of MORTH Specifications for Road and Bridge Works.

IRC:SP:112 Manual for Quality Control in Road and Bridge Works gives further details on quality control of road works

It is essential that the results of all quality control tests and observations should be systematically recorded and carefully preserved, preferebly in digital format, for quick and convenient retreival.

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CHAPTER 10

ROAD DRAINAGE

10.1. Adequate drainge is a primary requirement for maintaining the structural soundness and functional efficiency of a road. Rapid dispersal of water from pavement and subgrade is a basic consideration in the road design. Roads are constructed with two types of drainage system: surface drainage and subsurface drainage.

10.2 Surface Drainage: Two types of surface drainages are provided a) Transverse Drainage and b) Longitudinal Drainage

10.2.1 Transverse Drainage: It is used to provide the continuity of natural water lines intercepted by the road. It is designed to avoid the flooding of the platform and surrounding areas e.g. aqueducts, culverts and cross drainage structures.

10.2.2 Longitudinal Drainage: It is used to gather and channelize the precipitated water on the road surface and from the side slopes and nearby land thus avoiding its access to the road surface e.g. unlined and lined longitudinal drains and kerb channel drains.

10.3 Sub-surface Drainage: Two types of subsurface drains are constructed to dispense trapped water inside the subgrade and pavement layers. These are longitudinal interception drains and longitudinal water table lowering drains.

10.4 Following survey, investigations and designs are required for designing a drainage system.

a) Preparation of alignment plan, longitudinal and cross sections and contour map.
b) Hydrological survey such as rainfall analysis and runoff estimation
c) High flood stastical information for the region.
d) Hydraulic design
e) Geotechnical Investigation

Recourse to remote sensing methods such as aerial photography and satellite remote sensing may have to be made wherever required.

10.5 Surface Drainage of Pavement

10.5.1 When a road is constructed on a natural terrain, the waterways are intercepted and necessary measures have to be taken to divert such water from the road. Besides, water received on road surface from rainfall and snowfall has to be disposed of as quickly as possible from safety considerations. Side ditches, lined drains, catch-drains and cross drainage structures are provided as part of the overall surface drainage system.

10.5.2 With a view to facilitate quick removal of rain water, longitudinal profile of the road normally is not designed flat. When the road is provided with kerbs, a minimum longitudinal gradient of 0.3 percent is considered essential. To get clear the runoff water rapidly from the pavement surface, cross fall or camber to the pavement is provided. Diagrams showing cross fall in different pavement configuration are shown in Fig. 10.1, 10.2 & 10.3.

Fig. 10.1. Typical One-way Camber in Super Elevated Sections

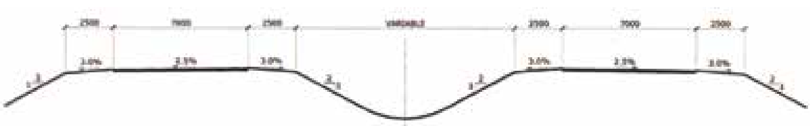


Fig. 10.2. Cross Section of a four lane rural highway with depressed median without lined saucer drain

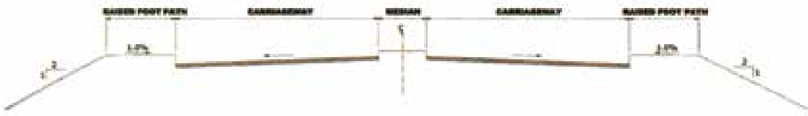


Fig. 10.3. Typical Cross Section of divided carrageway with kerbs (Urban situation)

10.5.3 Drainage of shoulders

Black topped shoulders are durable and help in quick disposal of surface water. In case of earthen shoulders camber/cross fall provided is more than by 0.5 percent of the pavement surface. Silt and clayey soil is more suceptable to erosion whereas good moorum/gravely soil is relatively less prone to erosion. Earthen and granular shoulders have to be periodically maintained by levelling and compacting. This operation involves adding of fresh material to compensate for loss of soil due to erosion, vehicle movement etc. and compacting the same after adding required water to achieve MDD. To reduce the erosion at the longitudinal edge where shoulder joins side slopes, rounding the sharp corner and compacting by a hand held plate compactor is helpful.

10.5.4 Drainage of side slopes

Side slopes can be protected by providing turfing with sods/seedings and mulching/jute netting/coir netting etc. The details can be seen in Clause 307/308 of MORTH Specifications for Road and Bridge Works, IRC:56 "Recommended Practice for Treatement of Embankment and Road Slide Slopes for Erosion Control and IRC:SP:42 "Guidelines on Road Drainage".

10.5.5 Drainage of high embankments

In high embankments special arrangements like flumes/chutes are provided at regular interval so the water collected from the shoulder is channelized to these flumes/chutes. An energy dissipater would be required at the toe to control the high velocity with plain chutes. But stepped chutes is preferable as it is a self-energy dissipating structure. The spacing of chutes depends on the intensity of precipitation, gradient and type of side slope surfacing etc. Generally a 20 m C/C spacing can be considered as reasonable.

The plain chutes are either semi circular RCC pipes or insitu/precast RCC sections. A concrete bed anchored intermittently is provided under the chutes. Stone pitching of 1.0 m width (normally) with a filter bed is provided on both sides of the chutes. The rest of the slope is normally covered with grass turfing or stone pitching as per site conditions. A schematic view of slope protection arangement with plain chutes/flume is shown in Fig. 10.4. Details have been described in IRC:SP:42.

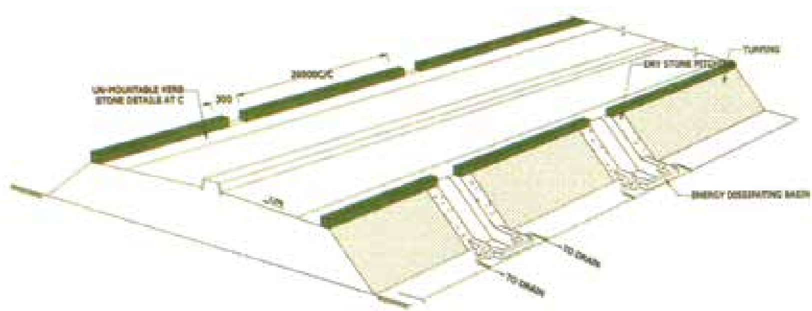


Fig. 10.4. A Schematic View of Slope Protection Arrangement with Plain Chute/Flume

10.5.6 Drainage of Medians

Medians may be raised or depressed. Earth filling must be flush with kerb and with two sided camber. If turf is provided on the top there is not much chance of too much water infiltrating to lower layers. In raised median sections with one sided cross fall, water can be diverted from one carriageway to other by having an opening/channel in the median. These are provided at 10 m to 20 m intervals depending upon the intensity of rainfall, road width etc. An open drain or a buried pipe provided for collecting surface water which can be disposed of at a nearby cross drainage structures. In case of depressed median, central drain is to be lined effecting to prevent seepage of water to lower pavement layers. Photographs 10.1, 10.2 & 10.3 are given as few of the examples of drainage of medians.

Photographs 10.1, 10.2 and 10.3 - Few examples of drainage of medians

10.5.7 Further details on surface drainage as detailed above and surface drainage arrangements for reinforced soil, intersections, including rotaries are given in IRC:SP:42. Maintenance of side drains, medians and culverts have also been detailed in IRC:SP:42.

10.6 Subsurface Drainage

10.6.1 The moisture which reached lower layer of pavement form different sources is termed as subsurface moisture. Disposal of this moisture away from the pavement body is termed as subsurface drainage. Consequences of lack of effective subsurface drainage system results in premature failure of pavement with formation of cracks, settlement, rutting in case of bituminous pavement whereas formation of crack, fragmentation and settlement of slab in case of cement concrete slabs.

10.6.2 Sources from which water/moisture reaches lower layers of pavement

i) from poor quality of bituminous mixes which are permeable,

ii) from the cracks, potholes and joints,

iii) from the failed joint seals of cement concrete pavement,

iv) through the longitudinal joint between pavement and shoulders,

v) from earth filled medians and shoulders,

vi) seepage of water from the adjoining high ground in the cut section of hilly terrain or form impounded water level higher than the road level in the abutting agricultural fields,

vii) from capillary rise of moisture when water table is high

10.6.3 Drainage of infiltrated moisture form pavement and shoulder surface can be done by providing suitable sub-base layer. Sub base shall have two sub layers namely drainage layer and filter layer. The upper layer of sub base functions as a drainage layer to drain away the water that may enter though surface cracks. The lower layer of sub base should function as the filter/separation layer to prevent intrusion of sub grade soil into the pavement. The aggregate gradation recommended for drainage are layer III & IV of MORTH Specifications for Roads and Bridge Works (Section 401). Gradations

I, II, V, and VI specified in the same specification are recommended for filter/separation layer. Filter and drainage layers should be designed as per IRC:SP:42 and IRC:SP:50 “Guidelines on Urban Drainage”. It is necessary to extend both drainage and filter layers up to the slope of embankment (day lighted) to have efficient drainage. Commercially available geo-synthetic drainage composite can also be provided in lieu of aggregate layer meeting the requirement which will function as both filter and drainage layers whereever it proves to be cost effective and technically meeting the requirements. A diagram showing the proposal for disposal of sub surface moisture with a lined drain is shown in Fig. 10.5

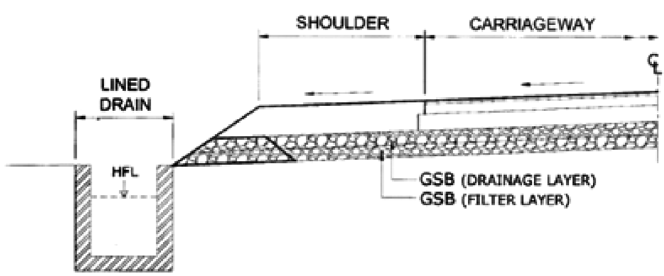
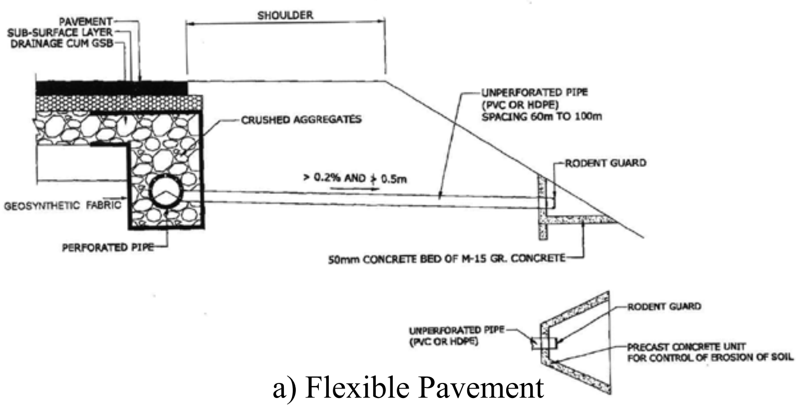
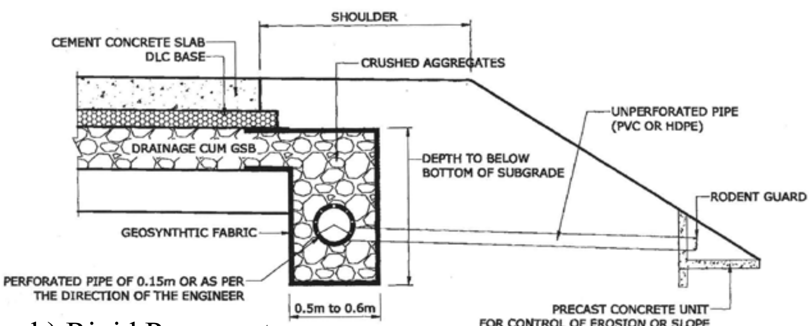


Fig. 10.5 Proposal for Disposal of Sub-surface Moisture in case of lined side drain

French drains can be provided where sub surface drain is terminated under the shoulder. Durable crushed aggregates are used as backfill material around partially perforated PVC or HDPE pipe. One of the filter material suggested in Table 309.3 of MORTH Specifications for Road and Bridge works can be adopted to be used as backfill material. Normally a partially perforated PVC or HDPE pipe is buried near the bottom to collect and dispose of the moisture collected. The geosynthetic filer fabric shall satisfy filter criteria taking into consideration the properties of soil around it. Clause 702 of MoRTH Specifications for Roads and Bridge Works on geosynthetic filter gives the details. The details of these drains are shown in Fig. 10.6



a) Flexible Pavement



b) Rigid Pavement

Fig. 10.6 Drainage Layer Terminated at Pavement Edge

Fin drain as shown in Fig. 10.7 can also be provided at the junction of pavement and shoulder for collection of water and disposing it off.

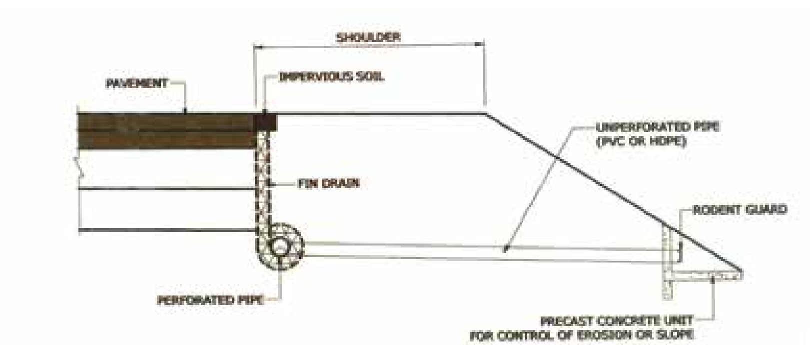


Fig. 10.7 Details of a Fin Drain

10.6.4 Management of Seepage moisture from hills is the seepage form the adjoining hill and problem of surface water can be managed by providing drains for both surface and subsurface draines. Diagrams at Fig. 10.8 and Fig 10.9 show the drainage arrangement in hill sections.

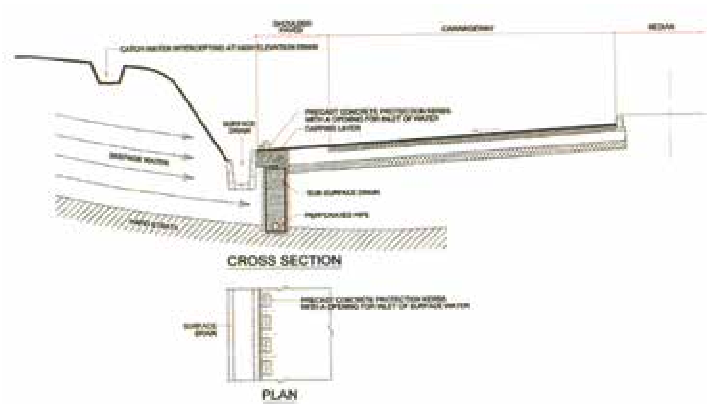


Fig. 10.8 Surface and Subsurface Drainage in Hill Section

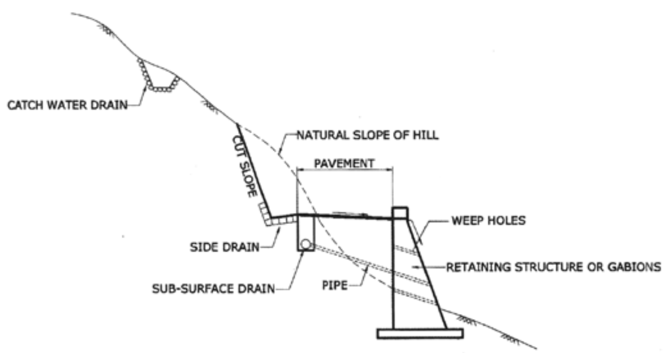


Fig. 10.9 Drainage in Cut and Fill Sections in a Hilly Terrain

Where there is a steep longitudinal gradient in cut sections, there is a chance of water seeping from higher ground along the middle of carriage way. Transverse and diagonal subsurface drains are provided to intercept this seeping water. Typical layouts of these types of drainage arrangements are shown in Fig.10.10 and Fig.10.11.

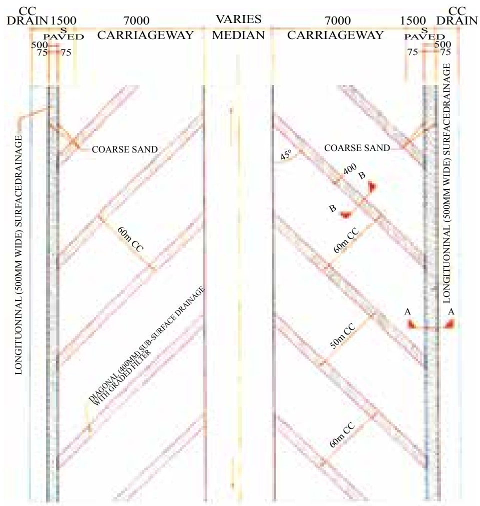


Fig. 10.10 Layout Plan of Longitudinal and Diagonal Subsurface Drains

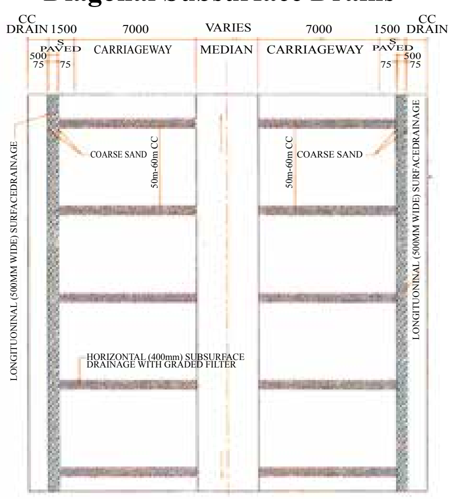


Fig. 10.11 Layout Plan of Longitudinal and Horizontal Subsurface Drains

RCC box drains as shown in Fig. 10.12 can be provided to act as both surface drains and subsurface drains. The drain will have grated opening for collecting surface run off from the pavement and at the same time it can intercept seepage water from cut section in hilly terrain though well designed weep holes.

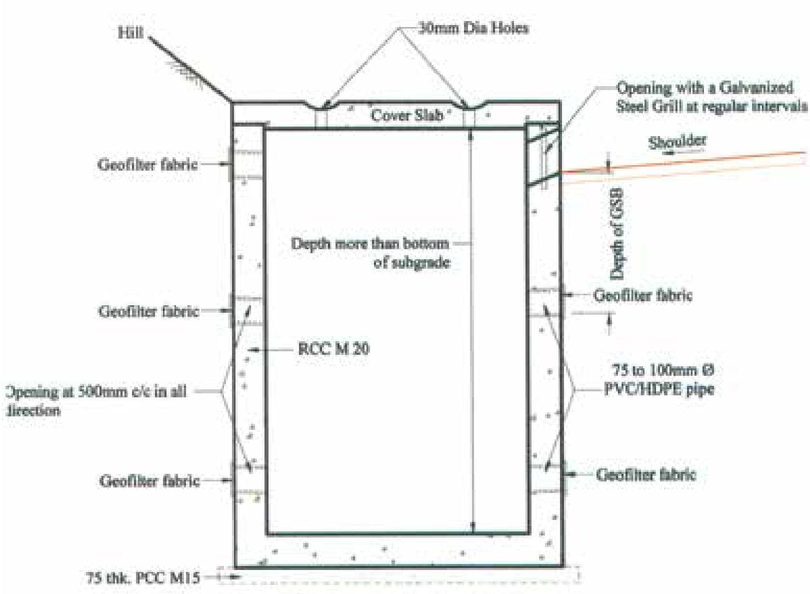


Fig. 10.12 R.C.C. Box Drains

10.6.5 Treatment of capillary rise of water

Locations where water table or high flood level is too high: it is likely to affect subgrade and embankment and weaken them. It is, therefore, recommended that the bottom of subgrade should have a free board of not less than 0.6.-1.0 m above design HFL. If increasing of road level is difficult or due to financial implications, a capillary cut off should be provided. Capillary cutoff consists of sand blanket, HDPE sheet, drainage composite etc. A cushion of 10-15 cm thick layer of sand on granular material is required to be provided over the capillary cut off layer. The details of capillary cutoff and a blanket of granular material of sand are systematically shown in Fig. 10.13.

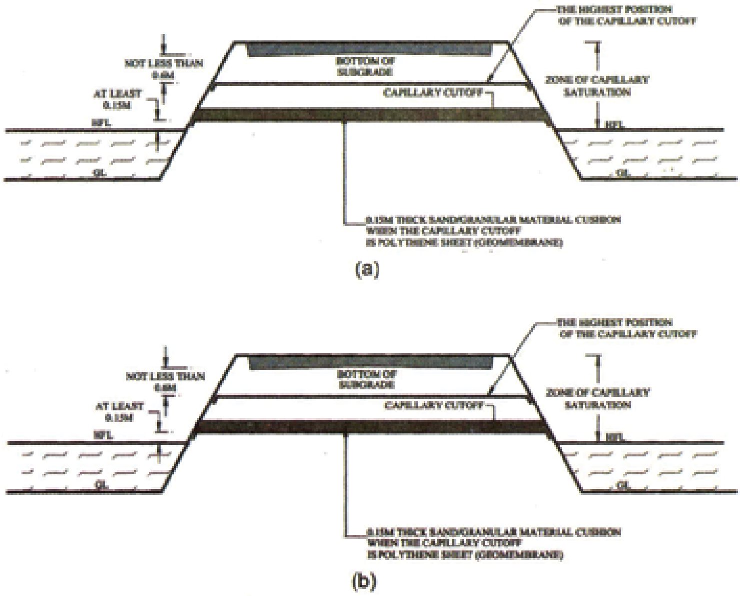


Fig. 10.13 Details of Capillary Cut-off Layers

The details of other sub surface drainage arrangement and their designs etc. are given in IRC:SP:42.

10.7 For hydrological and hydraulic design of road drainage, IRC:SP:42 may be referred.

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CHAPTER 11

PROJECT FACILITIES

11.1. Access Permission to Fuel Stations, Private Properties and Rest Area Complexes

a) Fuel Stations

The petrol/diesel retail outlets shall generally be a part of the rest area complex along the highways. Rest areas should have various amenities for users e.g. places for parking, toilets, restaurants, rest room, kiosks for selling sundry items, bathing facilities, crèche etc. Petrol/diesel retail outlets and service stations with or without rest area amenities have, hereinafter referred to as fuel stations. These aspects should be incorporated while planning for improvement and upgradation of highways and/or planning of new fuel stations along the highways. The rest area complex can be planned subject to their commercial viability. It shall be ensured that the location of the proposed fuel station does not interfere with future improvements of the highways and nearby intersection/junction.

The fuel stations are to be located where the grounds are practically level, there are no sharp curves not less than those specified for minimum design speed or steep grades (more than 5%) and where sight distances would be adequate for safe traffic operations. The proposed locations should not interfere with the placement and proper functioning of highway signs, signals, lighting or other devices that affect traffic operation. It is also to be ensured, while considering a proposal for new fuel stations that the fuel stations on the corridor are well distributed on both sides of the highways so that vehicles do not have to cut across the traffic to reach them. Separate fuel stations need to be planned for the vehicles travelling in the lanes in opposite direction.

If two or more fuel stations are to be sited in close proximity for some reasons, these would be grouped together to have a common access through a service road of 7.0 m width and connected to the highway through acceleration, deceleration lanes.

The fuel stations are also not to be located within the distance 1000 m from any barrier including that of toll plaza and railway level crossing. Fuel stations should be located at a minimum distance of 200 m and 500 m from the start of an approach road of a Road Over Bridge (ROB) and the start of a grade separator or a ramp respectively.

The access to the fuel stations along the National Highways shall be through deceleration and acceleration lanes. The deceleration lane and acceleration lane may be dispensed with for fuel stations along urban roads and roads in hilly terrain.

For the safety and convinience of traffic, the minimum distance of the proposed fuel station from an intersection, the minimum distance between to adjacent fuel stations, the minimum sizes of the plots access layout, drainage arrangement, enforcement of right of way, biilding line and signage system for fuel stations located on National Highways shall be as specified by MORTH

b) Access to Private Properties

The private properties may be residential properties and other properties. The Residential Properties (RPs) shall mean individual plots with not more than four dwelling units.

The other properties (OPs) whether private or government shall include (excluding Fuel Retail Outlets for which separate guidelines exist) all other properties such as Industrial units, Hotels, Motels, Hospitals, School, Educational/Research Institutes, Housing Complexes, Recreational Clubs, Religious Structures, etc.

There shall be no direct access to the National Highway from OPs. The access shall be through service road including required declaration and acceleration lane in case of both urban and rural reaches. The service road shall be constructed and maintained by the organization/ owners of OPs concerned. The land required is also to be provided by them at their own cost. The owner of OPs has also to pay the fees specified by the Government. For RPs, as far as possible there shall be no direct access to the National Highway in urban/built up reaches. The access shall be through service road only. The Highway Authority may construct such service roads, subject to availability of funds. The direct access to RPs in rural areas can be granted.

The above mentioned details and further details on the locations, layout and access to fuel stations access permission to private properties, Rest Area Complex etc. on National Highways are given in the Ministry's circular letter No.RW/NH-33023/19/99- DO III dated 24.7.2013 and 25.08.2014 and IRC:12 Unified Guidelines for Access Permission to Fuel Stations, Private Properties, Rest area Complexes and such other facilities along National Highways".

The procedures for obtaining permission from the Highway Authorities are also available in these documents.

11.2 Pedestrian Facilities

Every traveller is a pedestrian at some stage of his or her travel and hence pedestrian facilities are very significant in urban transportation. In view of the paradigm shift from 'moving the vehicles' to 'moving the persons while planning for transportation facilities for highways passing through the cities, provision of integrated and barrier free pedestrian facilities is essential to ensure inclusive mobility. IRC:103 "Guideline for Pedestrian Facilitis" provides the details of such facilities.

In this regard, MORTH has issued guidelines for pedestrian facilities on National Highways for persons with disabilities or using mobility aids vide circular letter no. RW/NH-33044/28/2015/S&R (R) dated 17.6.2015. This circular highlights the provisions to be made for person with disabilities or using mobility aids.

Pedestrian Crossings

Pedestrian Crossing can be broadly classified as i) At grade Pedestrain Crossing and ii) Grade Seperated Crossing.

At grade pedestrian crossing: At grade pedestrian crossing where the pedestrian cross the carriageway at the same level as that of vehicular movement. At grade crossing can be classified with respect to locational aspects as per below.

i) Pedestrians crossing at intersections

ii) Pedestrian crossing away from intersection (e.g. mid-block crossings)

At grade pedestrian crossing at intersection could be controlled or uncontrolled

Controlled crossings are achieved normally through provision of zebra crossings whether at an un-signalized or signalized intersection. Pedestrian crossings must inevitably integrated with the overall design of the intersection.

Uncontrolled crossing are those where the pedestrian cross walk is marked by studs or paint line but not controlled by any system of signals. Provision of uncontrolled pedestrian crossing must, as far as possible, be avoided.

Provision of a grade separated pedestrian facility may be warranted at locations where one or more of the following conditions exist:

Warrants

1) Volumes of pedestrian and vehicular traffic are so large that insertion of an exclusive pedestrian phase will increase the cycle time for traffic signals beyond 120 seconds;

2) Vehicular traffic demands uninterrupted flow as associated with major arterial roads, expressways;

3) Controlled at-grade pedestrian crossing decisively fails to mitigate the problems of pedestrian-vehicle collision. Viability of a grade separated pedestrian

facility must be checked against delay costs for both pedestrian and vehicle drivers/users including increase in vehicle operating cost inflicted by increased delays. Effective law enforcement is necessary to control incidental crossing of Stop Line by vehicles.

Requirement of Pedestrian Subway

The pedestrian subway shall have a width and vertical clearance of 4.8 m and 2.75 m respectively. There should be a good level of lighting, at least 50 lux to have a clear view from one end to the other end. CCTV cameras along with notices are to be placed to enhance security and should have coverage for the entire length. Stalls shall be encouraged and set up as it gives sense of safety to pedestrian. Subways may be hump subways or full subways. In hump subways both the car lane users and pedestrians need to have a change in level. In case of full subways the pedestrian paths are lowered to a depth where a clear height of 2.75 mm minimum can be achieved using 1:20 slope ranks with appropriate landing. The car users need not to change the level.

The details of different types of subways are given in IRC:103

Foot Over Bridge (FOB). This is of least priority since the walking length increase considerably.

Pedestrian guard rails

Pedestrian guard-rails are an important design element to prevent indiscriminate crossing and spilling over of pedestrian on to the carriageway. Their judicious use can help to ensure that pedestrian cross the streets at predetermined and safe location. It is also obligatory that sufficient width of footpath is made available where guard rails are provided. The design of guard rails should be neat, simple in appearance, as far as possible, vandal proof The details of design, applications and installation guidelines are given in IRC:103

11.3 Passenger oriented wayside amenities (Rest Ares)

To make the travel safe, comfortable and convenient and in order to reduce fatigue in a long distance journey, passenger oriented way side amenities along National Highways are to be provided. As per the Ministry's guidelines provisions are to be made for passenger oriented wayside amenities at every 50 Km of National Highways. In these wayside amenities following facilities are to be provided.

1) Parking lots
2) Snack bar/Restaurant
3) Toilets
4) Rest Rooms for short stay
5) First Aid
6) Telephone booth
7) Petrol pump/minor repair shop (optional)
8) Kiosks for sale of miscellaneous/sundry items
9) ATMs
10) Vending machines
11) Land Scaping

Approximate area required may be in the neighbourhood of 15,000 to 20,000 m^2. Site should be away from urban influence and any other similar wayside complexes. The location should be along a straight reach or on a gentle horizontal curve with adequate site distance and good visibility and should have easy gradient in the vicinity of complex.

There shall be adequate signage system on the highway about the location of the wayside amenity. The area should be illuminated during the night with minimum illumination of 40 lux.

11.4 Truck lay-by

Shall be provided along the National Highways at locations having significant parking demand. The lay-bys should be located in the straight road as far as possible, so as to be fully visible to the approaching traffic. Truck lay-bys shall in general, be located near check barriers, interstate borders, places of conventional stops of the truck operators etc. and to be indentified on the basis of field suvery. For effective segregation lay-by from the main carriageway a sufficiently wide dividing verge of at least 5 m wide shall be provided. A system of longitudinal and cross drainage is to be provided for proper drainage. Provisions of safe drinking water, toilets, bathrooms and telephone are to be made.

The environment of the whole lay-by area should be improved by good aesthetic treatment, tasteful landscaping withplants, green verges etc.

The lay-bys should have a minimum length of 100 m in straight portion with 7.0 m width. The entry and exit to the lay-bys shall be by deceleration and acceleration lane respectively of adequate length. Adequate signage systems are to be installed for proper guidance. The truck lay bys and 50 m length of the highway on both sides of the lay-by shall be illuminated at night a minimum illumination of 40 lux.

11.5 Bus Bays and Bus Shelters

The buses shall be allowed to stop for dropping and picking up passengers only at the bus bays. The number and broad location of the proposed bus bays will be indicated in the drawings. The bus bays shall conform to the standards and specifications as given in the Contract documents. In cases where bus stands are provided by the State Government Transport Authority concerned, only access road within the ROW is to be provided.

Location

The locations, of the bus bays shall be fixed on the following principles.

i) The bus stops shall be sited away from bridges and after important structures and embankment sections more than 3m high.

ii) As far as possible, bus bays shall not be located on horizontal curves or at the summit of vertical curves.

iii) The location shall have good visibilities, not less than the safe stopping sight distance.

iv) The bus bays shall not be located too close to the road intersections. The location of the bus bays may be fixed after due consultation with the local communities to be expected to use such facilities.

v) At major four-way intersections involving transfer of a substantial number of passengers from one pick up stop to the other , it might be desirable to construct a single, composite but stop of suitable design to cater to all the bus routes collectively.

vi) In hilly areas, the bus bays shall be located, preferably, where the road is straight on both sides, gradients are flat and the visibility is reasonably good (usually not less than 50m).

It will be preferable to choose locations, fulfilling the above mentioned requirements and where it is possible to widen the road way economically for accommodations bus bays.

Layout and Design

i) The layouts of the bus bays shall be as indicated in the drawings.

ii) The channelising island between the paved shoulder and bus bays shall not be raised but it shall be paved with CC blocks.

It can also be provided with 'Ghost Island' in case of space constraints.

iii) Bus bays shall be provided on both sides of project highway, for each direction of travel, independently. Bus bays on opposite sides shall be staggered to a certain extent to avoid congestions on the highway. At intersections, the bus bays for up and down direction shall be located on further sides of the intersection.

iv) Covered steps with rise not exceeding 150 mm and minimum 5 m wide alongwith ramp with railing on both sides are to be provided. The bus bays and passenger shelter shall be designed to provide for safe and convenient use by persons with disabilities as well.

v) The bus bays shall be provided with an appropriate shelter for passengers.

Pavement in the bus bays shall have adequate crust with respect to the wheel loads along with the loads due to frequent braking and acceleration expected.

Adequate drainage arrangements are to be provided at the bus bays.

Proper road markings at the bus bays are to be provided for convenience of the bus driver and passengers.

The total area at ROW near the bus bays shall be landscaped and planted with shady trees for giving pleasing appearance of the area.

The entire bus bay area shall be provided with lighting of minimum illumination of 40 lux.

11.6 Highway Patrol Units

Highway Patrol Unit(s), which shall continuously patrol the highway not exceeding 50 km are to be established in the toll plaza locations and shall remain in contact with the control room on a real time basis. The patrol shall render assistance to users in distress and disabled vehicles through own intervention or by calling assistance from control rooms, crane operators, or ambulance as required. The patrol shall promptly clear the road of any obstruction. When the obstruction takes time to be cleared, the section shall be cordoned off by placing traffic cones, which shall be illuminated during night. The specifications of patrol vehicle including equipments and manpower are given in IRC:SP:73 "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulder".

11.7 Emergency Medical Services

These services shall include setting up of medical aid posts. Two patient capacity rescue ambulance alongwith medical on board equipments, medicines and manpower are to be provided. These details are given in IRC:SP:73.

11.8 Crane Services

A crane of adequate capacity (minimum 20MT) at each toll plaza location (s) with all necessary equipment is to be provided. It shall be capable of reaching the site incident within 30 minutes of call and clear the disabled / accident vehicles. It shall also be fitted with a GPS based vehicle tracking system to monitor its movement on 24 hours x 7 days of a week basis.

11.9 Communication System

A suitable communication system with all necessary equipment for meeting operation and maintenance obligation is to be provided.

11.10 Intelligent Transportation System (ITS)

An Intelligent Transportation System (ITS) is an advanced application which, without embodying intelligence as such, aims to provide innovative service relating to different modes of transport and traffic management and enable users to be better informed and make safer, more coordinated and smarter use of transport network.

Although ITS may refer to all modes of transport, European Union defined ITS as systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users and in traffic management and mobility management with other modes of transport. ITS may improve the efficiency in a number of situations i.e. road transport, traffic management, mobility, etc. The purpose of ITS is to improve transportation safety and efficiency and also advance capability of road system. IRC:SP:110 "Application of Intelligent Transport System for Urban Roads" provides details of ITS.

It is extremely important to manage and regulate traffic safely and efficiently. Therefore, the most important part is to collect all kinds of traffic data from all sources including primary and for using a real time data in order to work out an optimal solution for traffic problems. Advance traffic management appears to be one of the best options in this regard. The Advance Traffic Management System (ATMS) is an ITS Tool for traffic management system and are to be provided on high speed corridors.

The ATMS shall have the following Sub-systems

i) Emergency Call Boxes (ECBs)

ii) Mobile Communication System

iii) Variable Message Signs System (VMS)

iv) Metrological Data System

v) Automatic Traffic Counter cum Classifier System (ATCC)

vi) Video Surveillance System

vii) Video Incident Detection System (VIDS)

ATMS shall be able to provide certain facilities to highway users, provide the information/data to traffic managers for efficient and effective handling of traffic and also provide certain control to traffic manager for controlling of traffic. ATMS shall provide online recording and reviewing of the voice and visual information for record and analysis.

Further details on ATMS and Specification of the sub-systems are provided in MORTH Specifications for Road and Bridge Works and IRC:SP-110.

11.11 Operation and Maintenance (O&M) Centre

There shall be Operation and Maintenance Centre (s) either at toll plaza (s) or at any other location. The O&M Centre would have following minimum facilities:

i) Main control centre and administrative block

ii) Equipment for operation and maintenance of storage space for them

iii) Storage Space for equipment and material for traffic signs and markings

iv) Workshop

v) General garage and repair shop

vi) Testing laboratory

vii) Parking space for minimum 4 numbers of large vehicles and other expected vehicles during peak hours including those for working staff and visitors

The O&M Centre shall have illumination as provided in IS:1944 (Parts I and II) and shall have system for security with safe entry and exit.

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CHAPTER 12

MAINTENANCE OF PAVEMENT (FLEXIBLE AND RIGID)

12.1. Flexible Pavement (Bituminous Pavement)

Timely and regular maintenance of roads have been known to provide economic rate of return of as high as 15 to 20% depending upon the category of road and traffic volume. It also helps in deferring the demand for rehabilitation which is costlier investment than preventive maintenance. Therefore, timely and appropriate maintenance of bituminous surface using sustainable/suitable materials and methods is significant for preservation of road asset and to serve the intended purpose.

12.1.1. The maintenance operations are classified into following three categories.

a) Routine Maintenance – This is done by filling of potholes, repairing of cracks at a regular interval round the year.

b) Preventive Maintenance – It is performed to improve or extend the functional life of pavement surface while in good condition.

c) Periodic Maintenance – This is done by applying a renewal coat with appropriate specification and is required to be carried out periodically at the specified frequency or based upon condition and performance of road surface depending upon category of traffic and climatic conditions. Maintenance is also required for pavement markings on the bituminous surfaces, as and when required, to guide the road users and to improve safety.

12.1.2 System Approach

12.1.2.1 Pavement Management System (PMS) consists of a comprehensive coordinated set of activities with the planning, design, construction, maintenance, evaluation and research of pavement. A major objective of PMS is to assist the highway engineer in making consistent and cost effective decision related to the construction, maintenance and rehabilitation of pavements.

12.1.2.2 Pavement Maintenance Management System (PMMS) is a technical or operational methodology for managing or directing and controlling maintenance, in a scientific manner, for optimum benefits.

12.1.3 The first step towards planning maintenance operations is the evaluation of the existing pavement surface in terms of physical condition. For this purpose pavement condition surveys may be undertaken by the visual assessment of the pavement surface and recorded in standard format. In case, more precise condition data is required, the surface distress is recorded by actual measurements. The details of standard formats are given in IRC:82- "Code of Practice for Maintenance of Bituminous Road Surfaces". The rating of pavement may be assigned as per criteria given in the Table 12.1 below.

Table 12.1 Pavement Distress Based Rating for Highways

Defects (type)	Range of Distress		
Cracking (%)	> 10	5 to 10	< 5
Ravelling (%)	> 10	1 to 10	< 1
Potholes (%)	> 1	0.1 to 1	< 0.1
Shoving (%)	> 1	0.1 to 1	< 0.1
Patching (%)	> 10	1 to 10	< 1
Settlement and Depression (%)	> 5	1 to 5	< 1
Rut depth (mm) using 3 m straight edge	10	5 to 10	< 5
Rating	> 1	1.1 - 2	2.1 - 3
Condition	Poor	Fair	Good

12.1.3.1 Apart from visual surveys, functional and structural evaluation of pavement based on riding quality (i.e. road roughness), skid resistance and deflection should also form the basis for taking maintenance decision in case of highways.

12.1.3.2 For preventive and periodic renewal requirement or short term/long term maintenance strategies, it is desirable that at least two condition surveys are conducted every year on each stretch first before and the second after monsoon. On National Highway Network survey vehicles for capturing the inventory data and road condition are to be used for facilitating collection of data storage and easy reterival. On other roads, the condition surveys are to be carried out from a vehicle travelling at a speed of 5 km/hr supplemented by inspection of the critical locations by walking by a team or by an automated survey vehicle with experienced highway engineer at a responsible level.

12.1.4 The type of defects in bituminous surfacing are grouped under four categories

i) Surface Defects: These include fatty surface, smooth surface, streaking, and hungry surface.

ii) Cracks: These include all types of cracks, viz, hair-line cracks, alligator cracks, longitudinal cracks, edge cracks, shrinkage cracks, and reflection cracks.

iii) Deformation: These include rutting, corrugations, shoving including those caused by layer slippage, shallow depressions, settlements and upheavals etc.

iv) Disintegration: These include stripping, loss of aggregates, raveling, potholes, and edge breaking.

12.1.4.1 The location and severity of distress are important to select appropriate maintenance treatments, materials and technique.

12.1.4.2 Further, details on each of these distress types, their symptoms, location, causes, severity levels and treatment are given in IRC:82. Photographs of distresses of few types are attached at Annex 12.1

12.1.4.3 Preventive maintenance is a planned maintenance activity, which decreases rate of surface deterioration and extend life of bituminous pavement. All types of preventive maintenance have limitations for pavements with the structural failure.

12.1.4.4 The typical preventive maintenance treatments are given below:-

- Crack sealing/crack filling

- Fog seal
- Slurry seal
- Microsurfacing
- Chip seal
- Thin surfacing
  - ✓ Surface dressings
  - ✓ Thin hot mix/cold mix bituminous overlay
- Ultrathin Friction courses

Materials and methods for rectification of distress on bituminous surface are given in IRC:82.

12.1.5 Periodic Renewal (PR)

12.1.5.1 The objective of PR is to preserve the required serviceability level of pavement surface and offset the wear and tear caused by traffic and weathering. The PR is needed to prevent further deterioration of the pavement and to ensure that qualities are kept up for the future requirement of traffic during to design life of the pavement.

12.1.5.2 The renewal programme for each section of a road should be decided well in advance. The plan for a renewal programme should be prepared on the basis of periodic inspection of the road surface for assessing its condition and needs for providing renewal treatment. Inspection should be carried out manually or through automated machine. In addition, special inspections are necessary before and after the rains. It is not practicable or desirable to follow implicitly of any specified frequency irrespective of the condition of the road surface proposed to be renewed.

12.1.5.3 The stretches of the road showing signs of distress such as hungry surface/hairline cracking, raveling etc. should be invariably included in the programme. The stretches of the road which would be due for periodic renewal should be closely inspected for its inclusion or not in the programme. The specification of PR work will depend on the type of existing bituminous surface and its condition at the time of renewal. Bituminous concrete has been recommended for National Highways

12.1.5.4 MORTH has now emphasized for use of recycling technology for PR works for reducing the dependence on limited natural resources i.e. crude oil and aggregate and also for addressing the environmental issues to lower demand of fuel, bitumen and aggregate. It has been decided that hot in place recycling is to be preferred over conventional surface renewal (laying new bituminous concrete) on National Highways works. MORTH with the circular dated 11.1.2018 has intimated to all concerned to begin with and to equip more and more contractors capable of taking recycling work, at least 25% of the stretches of National Highways to be sanctioned for PR works with hot in place recycling technology. However, the stretches falling in hilly terrain, in North East areas or in other difficult terrain may be excluded for taking up hot inplace recycling. Efforts should be made to select continuous long stretches for hot in place recycling with a minimum length of 10 km continuous stretch. The works should be carried out as per MORTH Specifications for Road and Bridge Works and IRC:120 "Recommended Practice for Recycling of Bituminous Pavements".

12.2 Rigid Pavement (Cement Concrete Pavement)

12.2.1 All pavements deteriorate with time. The rate of deterioration of cement concrete pavement is comparatively much slower than the flexible pavement. The concrete pavements are therefore expected to have a larger service life. In case of concrete pavements, some distress at a few isolated locations, however, do take place immediately after or during an early stage after completion. If these isolated distresses are rectified well in time, then longer life of concrete pavement is assured without much need of detailed periodic maintenance rehabilitation.

The main types of maintenance required in respect of cement concrete pavements are as follows:

a) Routine Maintenance: Routine maintenance may be defined as those treatment that are applied to a pavement in order to keep the pavement functioning properly.

b) Programmed Maintenance: It covers works undertaken to arrest deterioration and restore the asset to its original condition.

c) Rehabilitation and Strengthening: It refers to programmed works that are undertaken to structurally restore the condition of a road sections to impart further design life to carry expected traffic loads.

d) Emergency Repair: It covers responding to complaints or emergencies.

12.2.2.1 A site condition survey once a year, preferably in the beginning of monsoon season should be undertaken to assess the existing pavement condition and to identify pavement distress.

12.2.2.2 Distresses in concrete pavement are either structural or functional. Structural distresses primarily affect the pavement's ability to carry traffic load. Functional distresses mainly affect the riding quality and safety of traffic.

12.2.2.3 Structural distresses are manifested by cracks in the pavement. Any uncontrolled/random crack like longitudinal, transverse, diagonal, intersecting cracks that extended through the depth of the slab for more than the half of the depth of the PQC slab is considered as a structural crack. Structural cracks unless repaired effectively reduce the load carrying capacity of the pavement and adversely impact the designed service life of the pavement. Use of proper construction techniques and traffic load controls can reduce/avoid structural cracks.

12.2.2.4 Functional distress do not necessarily reduce the load carrying capacity of pavements but affect the riding quality and safety. Roughness, loss of surface texture or any other surface related defects, problems like faulting, scaling, raveling and pop-outs etc. fall under this category.

12.2.2.5 Common defects and distresses in concrete pavements, cracking

i) Cracks

   a) Plastic shrinkage cracks.

b) Crow foot or Y shaped cracks.

c) Edge cracks.

d) Corner cracks breaks.

e) Transverse cracks.

f) Longitudinal cracks.

g) Diagonal cracks.

h) Durability "D" cracking.

i) Punchouts.

ii) Surface Defects

a) Pop-outs/Small holes.

b) Animal/Wheel impressions.

c) Scaling.

d) Ravelling.

e) Deep abrasion/scooping of surface (following accident).

f) Polished aggregates/glazing/smooth surface.

iii) Joints Defects:-

a) Spalling.

b) Sealant failure and/or loss.

c) Faulting at joints.

d) Separation at joints.

iv) Other Miscellaneous Defects:-

a) Blowups.

b) Pumping.

c) Patch Deterioration.

d) Drop off.

The causes of common distresses have been given in IRC:SP:83 "Guidelines for Maintenance, Repair and Rehabilitation of Cement Concrete Pavements"

12.2.3 Assessing Maintenance Needs

12.2.3.1 The maintenance needs should be assessed every year as part of the planning of road maintenance programme. The overall assessment of the maintenance needs be done on the basis of condition surveys which can take various forms such as:

Visual condition surveys by manual method or by automated survey equipment.

Roughness survey by profillograph and bump integrator

Deflection tests by Falling Weight Deflectometer (FWD)

Friction/Skid resistance by sand patch, British pendulum and Mu-metre

Drainage Condition Survey

Non Destructive Testing (NDT) techniques like ultrasonic pulse velocity, Impact

12.2.3.2 The details of conducting these surveys and proformas for collection of data for all these assessment are given in IRC:SP:83.

12.2.3.3 The degree of severity of distresses as assessed for the surface condition recorded from the visual survey can be defined by rating of distress. A 5-level distress rating system has been recommended. This is given in Table 12.2 below

Table 12.2 Five Level Distress Rating System

Distress Rating	Slab Condition	Severity (Defects) Rating
0	Excellent	Not Discernible
1	Very Good	Minor
2	Good/Average	Moderate
3	Fair	Major
4	Poor	Extreme
5	Very Poor	Unsafe/Unserviceable

12.2.3.4 Type of repair can be appropriately decided from the distress rating. The details of such repair strategy have been given in IRC:SP:83

12.2.4 Photographs of some of the common types of defects along with suggested typical repair techniques as per distress survey are given in Annexure 12.2.

12.3 Inspection of In-Service Roads

Periodical inspections of the roads by qualified engineers are warranted. The minimum frequency of inspection for condition by different level of engineers from Section Engineer to Executive Engineer concerned shall be as per details given in the Manual for Maintenance of Roads of MORTH published by IRC.

A pre-requisite to meaningful inspection is the up-to-date inventory of all related features of the road and continuous record of all the original and maintenance works as executed in that road. This can be conveniently complied for each section of the road usually 5-10 Km long in the form of Road Register. The Road Register should contain at least three basic details. The first giving statistical details like location, date of construction of the road, rainfall details, year-wise traffic census data base, vehicles by type on 7-day count basis and financial statement showing year-wise expenditure on capital works and maintenance works on different items of works.

The second data is upto date latest basic inventory of the road like details of features in the plan and L-section of the road in numerical figures, symbols or signs.

These details shall include the i) width of ROW, roadway and carriageway, ii) horizontal curves with their radii, iii) railway/road crossing, iv) cross drainage structures, v) floodable reaches, HFL, vi) average height fill, cut vii) soil type, design CBR, pavement composition, viii) gradients, sight distances, ix) location of road side furnitures, inspection bungalows, rest areas, fuel stations etc.

The third details shall be year wise and kilometer wise information of the works done for both original and maintenance works. The details of Road Register are to be updated on regular basis and are to be maintained in digital format for easy storage and quick retrieval at any time. Back up hard copy of all data are also be maintained.

The road should be inspected frequently and twice a year once before the start of the rainy season and also soon after the rains by responsible engineers. Prior to the rain all the measures to drain the storm water, carrying out repair works on damages to all protective works, abutment and pier of CD Works, repair of pavement surface and storing and protecting road construction materials are to be done based on the inspection. During the rains, arrangements should be made to have a close watch on flood levels, possibility of overtopping of road sections, general flow of pattern of run-off water, proper functioning of drains and culverts so that prompt measures could be taken for regulating traffic flow and also forwarding off major damages.

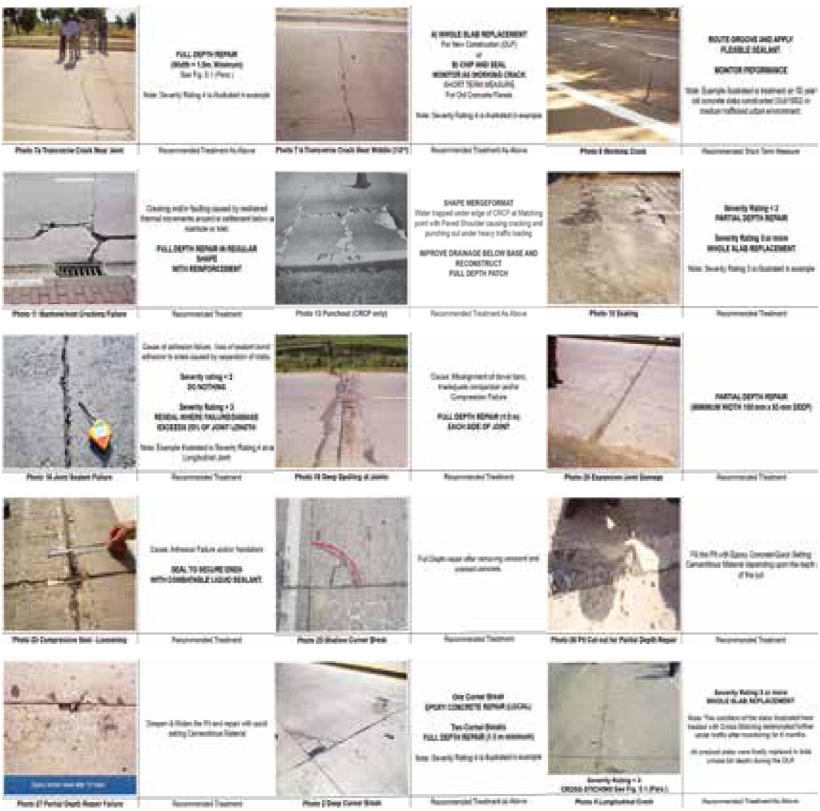
After the rains, inspections are to be carried out to assess the damages caused by rain/flood and to give top priority for repairing breaches and removing blockages. Oozing out of water from shoulders/slopes, if any, are also to be observed. If so necessary measures to cut out to release and remove the locked up water are to be taken up. Repair of potholes/cracks are to be taken up to make the road trafficable. Stretches showing recurring damages are to be studied to ascertain causes of such damages and taking up remedial measures.

12.4 Road Maintenance Standards

The Contractor, engaged for maintenance, shall maintain the road assets in proper condition that comply with the Road Maintenance Standards and ensure road user safety and comfort. The maintenance activities shall be so planned that the defects are repaired well before they reach maximum defective condition as per the permissible tolerances. The Road Maintenance Standards for different components shall be as per IRC:SP:95 “Model Contract Document for Maintenance of Highways”.

Annexe 12.1. Photographs of Distress on Flexible Pavements

Annex-12.1. Photographs of distresses on flexible pavements



Annexe 12.2. Common types of Defects on cement concrete pavement alongwith suggested typical repair techniques

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CHAPTER 13

QUALITY ASSURANCE SYSTEM

13.1 Definitions

Quality: The totality of features and characteristics of a product or service that bear upon its ability to satisfy stated or implied needs.

Quality Policy: The overall quality intentions and direction of an organization as regards quality as formally expressed by top management.

Quality Management: The aspect of the overall management function that determines and implements the quality policy.

Quality Systems: The Organization structure, responsibilities, procedures, processes and resources for quality management.

Total Quality Management: A management approach of an organization centred on quality, based on the participation of all its members and aiming at long term success through customer satisfaction and benefits to all members of the organization and society.

Quality Assurance: All the planned and systematic activities implemented within the quality system and demonstrated as needed to provide adequate confidence that an entity will fulfill requirements for quality.

Quality Control: The operational techniques and activities that are used to fulfil the requirements for quality

13.2 Class of Quality Assurance

Depending upon the rigors of control and cross verification, four classes of Quality Assurance (QA) are prescribed below:

Table 13.1 Class of Quality Assurance

Class of Quality Assurance	Class Nomenclature
Nominal QA	Q-1
Normal QA	Q-2
High QA	Q-3
Extra High QA	Q-4

Quality Assurance (QA) class needs to be decided prior to start of the project preparation. However, during the course of project implementation, QA class of some of the items/attributes may be upgraded to next class based on specific requirements. Provision for such upgradation needs to built into the contract. For National Highways & State Highways, Coastal roads, roads in high altitude and high rainfall (average over 2000 m) areas Q-3 class of QA is applicable. For Expressways, tunnels and elevated highways Q-4 class is applicable. IRC Manual IRC:SP:112 "Manual for Quality Control in Road and Bridge Works" has been developed for Q-3 class QA.

13.3 Quality Assurance Plan (QAP)

13.3.1 A document chronicling the actions to be taken and steps to be followed by each party to the project for successful implementation of the project duly fulfilling the quality requirements.

13.3.2 The road project cycle involves three broad stages i.e. Project preparation, Project Development and Construction. Therefore, for a single project different quality assurance plan needs to be prepared by different parties in different stages. These are summarized below:-

Table 13.2 Requirements of QAP by Different Parties

Project stage	Requirements of QAP by different parties to project
Project Preparation	DPR Consultant will prepare QAP for Project Preparation
	Client will have a general protocol for association with DPR consultant and scrutiny/verification of data, design and drawings
	Independent Engineer/Authority's Engineer will have a protocol to review drawings in BOT/EPC Contract

Development	Employer/Authority will have a general protocol for bid document preparation, bid evaluation and award
Construction	Contractor/Concessionaire will prepare QAP
	Supervision manual prepared by Engineer/Consultant will contain Quality Assurance mechanism to be followed by the Engineer/Consultant
	Employer/Authority will have a general protocol for Quality Control

13.3.3. Model structures of QAPs for Consultants, Contractors, Supervision Consultants as mentioned above and protocol for Employer/Authority are given in IRC:SP:112. The process to ensure quality requirements for factory manufactured materials, products and specialized items have been given in IRC:SP-112.

13.4 Many materials used in road construction are factory manufactured materials such as steel, cement, bitumen etc. and also finished items and products such as bridge bearings, expansion joints, crash barriers etc. Only some of the required tests to be equipped for carrying out the factory manufactured materials along with natural materials like soil, sand stone etc. The finished items are usually tested in manufacturer's own laboratory or in a specialized third party laboratory.

IRC:SP:112 provides tentative lists and testing requirements of most of the factory manufactured materials, products and specialized items along with availability of site testing facility for them.

13.5 Personnel

Both the Contractor/Concessionaire and Engineer/Consultant are required to engage adequate number of personnel with required knowledge, experience and expertise to control quality. The knowledge and experience of lab technician who actually carry out the tests is also critical. The size and complexity of a project determines the range of personnel, their knowledge, experience and expertise. IRC:SP:112 suggests the tests of quality personnel required with contractor/ concessionaire and Engineer/Consultant for projects of different sizes and complexities. The organizational structure of the quality control personnel along with qualification and experience requirements are also specified.

13.6 Field Laboratory set up

13.6.1 The number and location of the field laboratories are to be decided on the basis of size, packaging, field organization structure and the project site. There can be a central/main laboratory for each package. Further plant laboratories can be established if they are located in different locations than the main camp site. Test equipments at each plant laboratory will be specific to the plant established at that location. General infrastructure requirements of the laboratory, layout and suggestive list of equipment and consumable for main/ plant laboratory, routine and special upkeep of equipment have also been given in IRC:SP:112. A typical layout plan of the central/main laboratory along with the list of equipment for central/main laboratory are attached at Annexure 13.1 & 13.2 respectively.

13.6.2 All the tests shall be conducted as per relevant Indian Standard Codes of Practice as mentioned in Section 900, other sections of MORTH Specifications for Road and Bridge Works and the relevent IRC Codes. In the absence of Indian Standards for any test, reference may be made for any other appropriate international code of practice such as ASTM, BS, etc. Suggested codes of practice for various tests to be conducted on naturally occurring materials in original/crushed forms and various types of mixes are also given in IRC:SP:112.

13.6.3 All the formats to be used for recording the results of various tests shall be included in the QAP. A copy of each such test format shall be made available in the field laboratories. Test results shall be promptly entered in suitable registers and/or forms (paper/electronic) soon after conducting the tests. Electronic copies of the records shall be maintained in a way which facilitates quick and easy retrieval. The proformas for recording and reporting the tests and results are available in IRC:SP:112.

13.7.1 Reliability of factory manufactured materials and finished items for which specified test cannot be conducted in site laboratory has a lot of concern which needs to be duly addressed through a combination of testing in manufacturers/third party laboratories and rigorous protocol to ensure adoption of correct practices by the manufacturers.

13.7.2 Only some of the tests of few factory manufactured material and factory manufactured finished items can be got tested at the field laboratory . The quality policy of the supplier shall be furnished by the Contractor/Concessionaire to the Engineer/consultant who will ascertain that the quality policy of such supplier shall commensurate with the specified details as per IRC:SP:112. In large/complex projects, the Engineer/Consultant may further exercise independent check about the adherence of quality policy of the supplier. For all such material and products the supplier/manufacture is required to submit detailed document describing the "Quality Management Plan (QMP) as detailed in IRC:SP:112. The quality of such material is also be confirmed either by witnessing tests in manufacturer's laboratory or conducting third party testing.

13.8 Calibration

Calibration is a comparison between a known measurement (the standard) and the measurement using the instrument to be calibrated.

Primary objective of calibration is to check and ensure that the measurements made by Inspection, Measuring and Testing (IMT) equipment has the same accuracy as specified by the equipment manufacturers. In practice, calibration also includes repair of device. Calibration of equipment is a must for certainty/reliability of the test results. Calibration of plant and equipment such as Hot Mix Plants, Concrete Batching Plants are also very important. Calibration requirement ranges from sieves to nuclear density metre. As a general rule, the IMT equipment measuring devices shall be calibrated at the frequency specified by the manufacturers of the specific equipment. Details of calibration requirement and material have also been given in

IRC:SP:112. The requirement for equipment calibration, measurement and traceability are given in ISO/IEC 17025.

13.9 Statistical Analysis – Variability of materials, workmanship and construction process is a reality in road construction. Adding to the variability of materials and processes there is also considerable variation in testing process resulting in measurement errors. Acceptance procedure requires statistical analysis of test results. These have been detailed in IRC:SP:112. Acceptance criteria for different materials/ finished products/items of work are given in relevant sections of MORTH Specifications for Road and Bridge Works.

13.10 New Material

13.10.1 Several new materials are being developed from time to time which are not incorporated in MORTH Specifications for Road and Bridge Works. The new materials which are accredited by Indian Roads Congress (IRC) are only to be used. Following guidelines shall be followed when decisions have been taken to use these materials in the works.

a) All new materials proposed to be used in the work should be fit for the intended purpose and to be tested in the reputed laboratory as per direction of the Authority.

b) The material should have a technology and production base that is capable of producing the required quantity with consistent and reproducible quality.

c) Full responsibility of the manufacturer shall be guaranteed toward performance of the material.

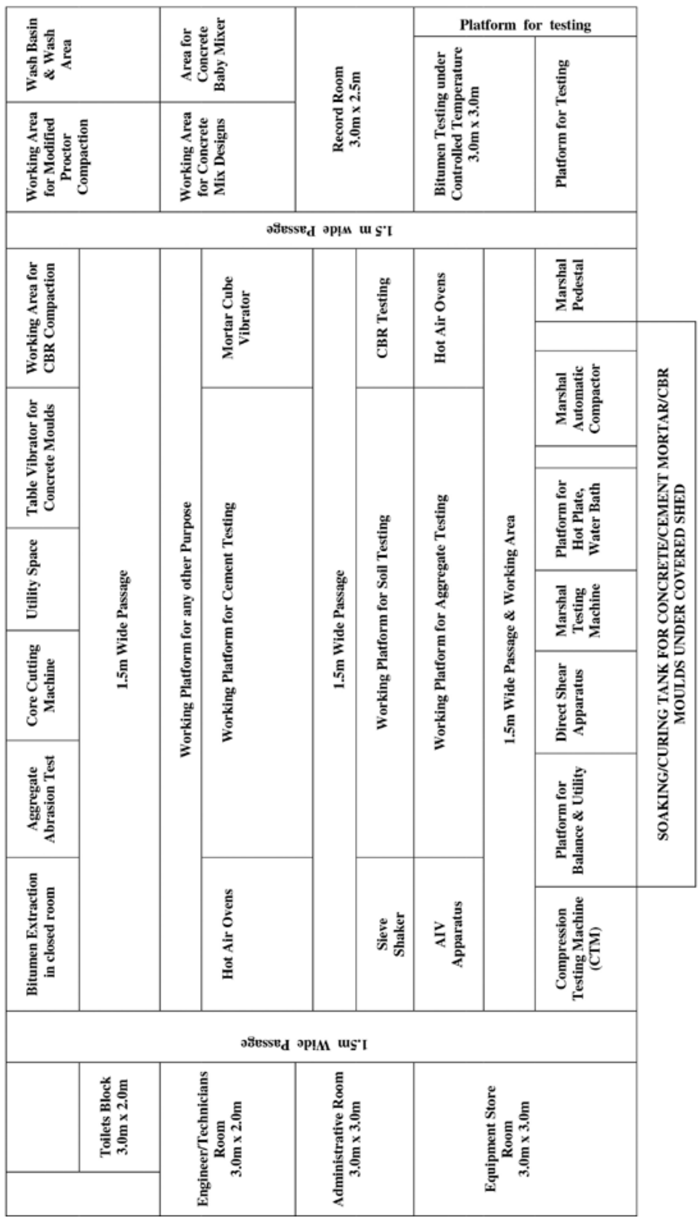
d) The manufacturer's quality policy shall be submitted.

e) The specification limits of the material shall be informed for different quality characteristics.

f) Undertaking of the manufacturer about no adverse environmental impact shall be furnished with test reports.

Annexure 13.1

A typical layout plan of the central/main laboratory



Layout Plan for Central/Main Laboratory (20.0 m x 10.0 m)

Annexure 13.2

LIST OF EQUIPMENTS FOR CENTRAL/MAIN LABORATORY

1. Soil Testing Equipment

   a) Weigh Balances

      i) 5-20 kg capacity Electronic type – Accuracy 1 gm

      ii) 500 gm capacity Electronic type – Accuracy 0.01 gm

      iii) Electronic 5 kg capacity Accuracy 0.5 gm

      iv) Chemical Balance 100 gm capacity accuracy 0.001 gm

   b) Oven-electrically operated, thermostatically controlled (including thermometer), stainless steel interior from 0^oC to 220^oC

   c) IS Sieves: 200 mm internal dia (brass frame and steel/ or brass wire cloth mesh) consisting of sieve sets of required sieve sizes complete with lid.

   d) Sieve shaker capable of shaking 200 mm dia sieves – electrically operated with time switch.

   e) Stop watches 1/5 sec. Accuracy

   f) Glass ware compressing beakers, pipettes, dishes, measuring cylinders (100 to 1000 cc)

   g) Enamel trays

      i) 600 mm x 450 mm x 5 mm

      ii) 450 mm x 300 mm x 40 mm

      iii) 300 mm x 250 mm x 40 mm

   h) Liquid Limit device with ASTM grooving tools as per IS:2720 (Part 5).

i) Sampling pipettes fitted with pressure and suction inlets, 10 ml. capacity.

j) Compaction apparatus (Proctor) as per IS:2720 (Part 7) complete with collar base plate and hammer and all other accessories.

k) Modified AASHTO compaction apparatus as per IS:2720 (Part 8) or heavy compaction.

l) Sand pouring cylinder with conical funnel and tap and complete as per IS:2720 (Part 28) including modern equipment.

m) Natural sand passes through 1 mm and retained on 600 mm as per IS:2720 (Part 28).

n) Sampling tins with lids 100 mm dia x 75 mm ht. ½ kg capacity and miscellaneous items like moisture tins with lid 50 gm etc.

o) Lab CBR testing equipment for conducting CBR testing, load frame with 5 Tonne capacity, electrically operated with speed control as per IS:2720 (Part 16) and consisting of following

   i) CBR moulds 150 mm dia – 175 mm ht

   ii) Tripod stands for holding dial gauge

   iii) CBR plunger with settlement dial gauge

   iv) Surcharge weight 147 dia 2.5 kg wt. spacers disc 148 mm dia 47.7 mm ht. with handle.

   v) Perforated plate (Brass)

   vi) Soaking tank for accommodating CBR moulds

   vii) Proving rings capacity of 10kN, 25kN and 30kN.

viii) Dial gauges 25 mm travel – 0.01 mm/division.

p) Dynamic cone penetration test equipment

q) Nuclear moisture density meter or equivalent

r) Speedy moisture meter complete with chemicals

s) Rifle Box

t) Differential Free Swell Index as per IS:2720 (Part 40)

u) Hydrometer & Hydrometer jar

2. Aggregate Testing Equipment

a) Sieves: as per IS:460

i) IS Sieves of required sizes (450 mm internal dia) sets as per BIS complete with lid and pan.

ii) IS Sieves 200 mm internal dia (brass frame and steel/or brass wire cloth mesh) consisting of sieve sets of required sieve sizes completes with lid.

b) Sieve shaker capable of shaking 200 mm, 300 mm and 450 mm dia sieves-electrically operated with time switch

c) Enamel trays

i) 600 mm x 450 mm x 50 mm

ii) 450 mm x 300 mm x 40 mm

iii) 300 mm x 250 mm x 40 mm

iv) Circular plates of 250 mm dia

d) Flakiness and Elongation index test apparatus

e) Aggregate impact test apparatus as per IS:2386 (Part 4)

f) Los-Angeles abrasion test apparatus as per IS:2386 (Part 4)

g) Apparatus for determination of specific gravity of fine and coarse aggregate as per IS:2386 (Part 3)

h) 3 liter, 15 liter and 30 liter cylinder as per IS:2386 (Part 3) for checking bulk density of aggregate with tamping rod

 i) Electronic balance of 500gm, 2.0 kg, 5 kg and 10.0 kg sensitive to 0.1 gm.

3. Cement and Cement Concrete Testing Equipment

a) High frequency mortar cube vibrator for cement testing

 i) Cement motor moulds (70.6 mm W x 70.6 mm L x 70.6 mm H)

b) Vicat needle apparatus for setting time with plungers as per IS:269

c) Soundness testing apparatus for cement (Le Chattlier)

d) Weigh Balances

 i) 5-20 kg capacity electronic type – accuracy 1 gm

 ii) 500 gm capacity electronic type – accuracy 0.01 gm

 iii) Electronic 5 kg capacity accuracy 0.5 gm

 iv) 50 kg capacity electronic type –accuracy 2 gm

e) Concrete mixer power driven, 1 cft capacity

f) Moulds

- i) 150 mm x 300 mm ht. cylinder with capping component along with the capping set.
- ii) Cube 150 mm and 100 mm (each size)

g) Apparatus for slump test

h) Variable frequency and amplitude vibrating table size 1 m x 1 m as per the relevant British standard

- i) Compression and Flexural strength testing machine of 2000 KN capacity with additional dial for flexural testing

j) Core cutting machine with 10 cm dia. diamond cutting edge.

k) Lechatelier flask.

4. Bitumen Testing Equipment

a) Constant temperature bath for accommodating bitumen test specimen, electrically operated and thermostatically controlled (to accommodate minimum six specimens)

b) Penetrometer automatic type, including adjustable weight arrangement and needless as per IS:1203

c) Bitumen laboratory mixer including required accessories (20 ltrs.)

d) Ductility meter

e) Furol Viscometer

f) Softening Point Test Apparatus (Ring and Ball app)

g) Digital thermometer

h) Rifle box

i) Thin film oven test apparatus for modified binder either with PMB or CMRB.

j) Mastic Asphalt hardness testing equipment

k) Sand equivalent test apparatus

l) Thermometers

m) Gas stove and Cylinder

n) Soxhlet extraction or centrifuge type apparatus complete with extraction thimbles with solvent and filter paper.

o) Glass ware compressing beakers, pipettes, dishes, measuring cylinders (100 to 1000 cc and metallic thermometes range upto 300°C)

p) Hot plates 200 mm dia (1500 watt)

q) Oven-electrically operated, thermostatically controlled (including thermometer), stainless steel interior from 0°C to 220°C.

r) Cannon Manning Viscometer for determination of Absolute viscosity and Cannon Fenseke Viscometer for determination of Kinematic viscosity.

s) Marshall stability test apparatus as per ASTM-D6927 with 25 KN and 50 KN proving ring and automatic compactor and mould for marshall and modified Marshall test.

t) Core cutting machine suitable for up to 150 mm dia core.

5. Sub-Soil Testing Equipment.

a) Direct shear test apparatus having 12 variable speed and 2 KN proving ring with all the accessories given in IS:2720 Part 13.

b) Weigh Balances

   i) Electronic 5 kg capacity accuracy 0.5 gm

   ii) 500 gm capacity electronic type accuracy 0.01 gm

c) Oven-electrically operated, thermostatically controlled (including thermometer), stainless steel interior from 0°C to 220°C.

d) Sieves: as per IS:460 IS sieve 200 mm internal dia (brass frame and steel/or brass wire cloth mesh) consisting of sieve sets of required sieve sizes complete with lid and pan.

e) Liquid limit device with ASTM grooving tools as per IS:2720 (Part 5)

f) Sampling pipettes fitted with pressure and suction inlets, 10 ml. capacity.

g) Sampling tins with lids (100 mm dia x 75 mm ht.) of 500 gm capacity and miscellaneous items like moisture tins with lid 50 gm etc.

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CHAPTER 14

CENTRAL SECTOR ACTS/POLICIES

14.1. The National Highway Act, 1956

This is an Act to provide for the declaration of certain highways to be National Highways and for matters connected therewith. This Act also now provides methods for acquisition of land to National Highways works. This act came into force on 15th April, 1957. Thereafter additions or omissions in the Act have been made several times for streamlining development works on National Highways.

14.1.1 Important provisions in the Act

Section 2 empowers the Central Government to declare any highway as a National Highway and Central Government can also omit any National Highway.

Section 3 provides for acquisition of land required for building, maintenance, management or operation of a National Highway or part thereof.

Section 3A to Section **3J** which deal with acquisition of land have been detailed earlier.

Section 4 As per this section all National Highways shall vest in the Union.

Section 5 defines that it is the responsibility of the Central Government to develop and maintains all National Highways. By this provision the Central Government by notification in the official gazette may direct that any function related to the development and maintenance of any National Highways shall also be exercised by the Government of the State within which the once National Highway is situated. Central Government can also direct for similar activity to any officer or authority subordinate to the Central Government or to the State Government.

Section 6 The Central Government may give directions to any state Government for carrying out of any provisions of this Act or of any notification or order made there under.

Secton 7 Empowers the Central Government for levying fees for services or benefits rendered in relation to the use of ferry's, permanent bridges costing more than Rs.25 lakhs, temporary bridges, tunnels on National Highways and the use of sections of National Highways.

Section 8A provides that the Central Government may enter into an agreement with any person in relation to the development and maintenance of the whole or part of National Highway. This section also empowers that the person with whom the agreement has been made can collect and retain fees at the rate fixed by the Central Government. The person concerned shall have powers to regulate and control traffic on that section of the National Highway. This provision made in 1997 facilitated private participation for development and maintenance of National Highways.

Section 9 is for making rules for carrying out the purposes of the Act Under this provision, following rules have been made.

1. The National Highway Rules, 1957
2. The National Highways (Temporary Bridges) Rules, 1964.
3. The National Highways (collection of fees by any person for the use of section of National Highways/permanent bridge/ temporary bridge on National Highways) Rules, 1997.
4. The National Highways (Rate of fee) Rules, 1997.
5. The National Highways (Fees for the use of National Highway section and permanent bridge – public funded project) Rules, 1997.
6. The National Highways (Manner of depositing the amount by the Central Government with the competent authority for acquisition of land) Rules, 1998.

14.2 The Control of National Highways (Land & Traffic) Act, 2002.

This Act is for providing for control of land within the National Highways right of way and traffic moving on the National Highways and also for removal of unauthorized occupation thereon. This Act came into force on 27.1.2005. There are eight chapters in this Act.

14.2.1 The Chapter 1 – Preliminary – short title, extent and commencement of this Act are included in this Chapter.

The Chapter II – Highway Administrations and Tribunals etc.Section 3 and 4 deals with the establishment of Highway Administrations and their powers and functions.

A body or authority consisting one or more officers of the Central Government or the State Government to exercise powers and discharge functions under this Act are to be established. The jurisdiction, powers and functions of Highway Administration have been defined. These will be notified by an official gazette. There may be one or more Highway Administration for a state or union territory or for a highway.

Sections 5 to 19 are for Tribunal to be set up for entertaining and deciding the appeals filed affected by the order of the Highway Administration. However, the National Highway Tribunal (NHT) have been subsumed into the Airport Tribunal through section 167 of the Finance Act, 2017 and has come into force with effect from 26.05.2017. There will be no separate Tribunal for National Highways. The Act has been amended accordingly and section 6 to section 13 have been ommited. These sections deal with the jurisdiction, powers and authority of Tribunal as well as the procedure and powers of the Tribunal.

As per Section 20, the Highway Administration may appoint gazetted officers of the Central Government or State Government or officer the National Highways Authority of India or any other Authority constituted under any other enactment to exercise powers and discharge functions of the Highway Administration.

Chapter III for is prevention of unauthorized occupation of highway land and their removal.

Sections 23 to Section 27 are included in this Chapter

As per these Sections, all lands forming parts of the National Highway including the land which has been acquired for the National Highway shall be deemed to be the property of the Central Government. The Highway Administration shall maintain land records in the prescribed manner. No person shall occupy any highway land or discharge any material on the land without written permission. Such permission may be granted subject to the conditions and on payment of rent and other charges. Such permission shall be valid for one year from the date of issue unless it is renewed. The Section 26 deals with the process of removal of unauthorized occupation.

Chapter IV is for control of access to the National Highways.

Section 28 to 30 forms part of this Chapter. As per Section 28 'No person shall have right to access to a National Highway except permitted by the Highway Administration either generally or specifically. The general permission shall be given by issuing notification in the official gazette. Specific permission shall be obtained by making an application with prescribed fees.

Chapter V deals with Regulation of Different Types of Traffic on National Highways. Section 31 to Section 37 of the Act are under this chapter. The Highway Administration shall have the power to regulate and control plying of vehicles on National Highways. Highway Administration can prohibit use of heavy vehicles on certain highways if Highway Administration is satisfied that any section of highway including bridge, culvert/or causeways have not been designed to carry vehicles exceeding the prescribed laden weight. Highway Administration can order for temporary or permanent closure of any highway or part thereof in the interest of safety of the highway. The Highway Administration has also the power to prohibit or restrict the use of any highway by a class or classes of traffic. The act also provides that no vehicle or animal to stand or proceed or a highway unless the same is under prescribed safety control.

Chapter VI is for regulation of construction on highway land for public utilities and drain. Under section 38 of the Act no person can construct, install, shift, repair, alter or carry on poles, pillars, advertisement towers, transformers, cable wise, pipe drain, sewer, canal, railway line, tramway, telephone boxes, repeater stations, street path or passage of any kind on highway land or across, under over any highway without prior written permission of the Highway Administration.

Section 39 is under the Chapter VII Offence and penalty. There is provision under this Section that if any person who has been evicted from any unauthorized occupation on a highway land again occupies any highway land without permission, he shall be punishable with imprisonment upto one year or with monetary fine or both.

Chapter VIII Miscellaneous deals with miscellaneous matters provisions for making rules for carrying purposes of this Act has also been made under section 50. Under this Act six number of rules were notified for enforcement of this Act.

MORTH by notification dated 26th October, 2016 has established 21 Highway Administrations for the entire network of the country. The Director General (Road Development) and Special Secretary, MORTH will be the Highway Administration for the sections of National Highways entrusted to National Highways Authority of India (NHAI) and National Highways and Infrastructure Development Corporation Limited (NHIDCL). Regional Officer MORTH posted at different State Capitals have been declared as Highway Administration for the sections of National Highways except those entrusted to NHAI and NHIDCL under their jurisdiction.

14.3 The Central Road and Infrastructure Fund Act, 2000

An act to give statutory status to the Central Road and Infrastructure Fund for development of National Highways, railway projects, improvement of safety in railways, state and rural roads and other infrastructure and for these purposes to levy and collect by way of cess, a duty of excise and a duty of custom on petrol and high speed diesel and deemed to have come into force on the 1st day of November, 2000. This Act was previously known as Central Road Fund Act, 2000. This Act has been amended by the Finance Bill 2018 and has been renamed as Central Road and Infrastructure Fund Act. 2000 to extend the scope of coverage to other infrastructure sectors. The Section 3 of the Act provides that Central Government by notification in the office gazette levy and collect cess, a duty of excise and custom on petrol and high speed diesel oil. The present rate of cess on petrol and diesel is R.8.00 per liter.

Section 7 of the Act deals with the utilization of fund. It specifies fund can be utilized for the

- i) Development and maintenance of National Highways
- ii) Development of the rural roads.
- iii) Development and maintenance of other State Roads including roads of interstate and economic importance.

iv) Construction of roads either under or over the railways by means of bridges and erection of safety works at unmanned rail road crossings, new lines, conversion of existing standard lines into gauge lines and electrification of rail lines.

v) Undertaking other infrastructure projects.

The other infrastructure projects include ports, shipyards, inland waterways, Airport, Urban Public Transport besides roads and railways, infrastructure for energy, water and sanitation, communication and social and commercial infrastructure. The social and commercial infrastructure includes educational institutions, sports and infrastructure, hospitals tourism infrastructure, etc. The Act also provides that the Central Government may amend this list of infrastructure depending upon the requirement for development of infrastructure projects. The share of fund to be apportioned as per Section 7A of the Act to each of the infrastructure project shall be finalized, by a committee headed by the Finance Minister, depending on the priorities of the project.

Section 9 of the Act provides powers of the Central Government to administer the fund and shall take such decisions regarding investment on projects of roads and other infrastructure as it considers necessary and take such measures as may be necessary to raise funds for development and maintenance of roads and other infrastructures.

Section 10 of the Act defines the functions of the Central Government which are

Administration and management of the share of fund allocated to the development and maintenance of the roads and other infrastructure.

Coordination and complete and timely utilization of all sums allocated out of funds.

Formulation of criteria for selection of specific projects of state roads of interstate and economic importance for approval and financing.

Release and monitoring of funds for specific projects of state roads.

Formulation of criteria for allocation of funds for development and maintenance of National Highways and other infrastructure projects.

Allocation of share of funds to each State and Union Territory.

Section 11 of the Act provides that the committee headed by Finance Minister as described earlier will decide the share of the fund to be spent on development and maintenance of roads, the funds allocated to the States and Union Territories shall be retained until it is required for expenditure. It also gives power to the Central Government as per opinion of the Central Government any State of Union Territory has failed to take steps for regulation and control of motor vehicles as per the Motor Vehicle Act and Rules in their jurisdictions to stop the allocation of further fund. The balance to the credit of the fund in respect of any allocation shall not lapse at the end of the financial year.

14.4 Motor Vehicles Act, 1988

The Motor Vehicles Act, 1988 is an Act of the Parliament of India which regulates all aspects of road transport vehicles. The Act came into from 01.07.1989. The Act provides in detail the legislative provisions regarding licensing of drivers/conductors, registration of motor vehicles, control of transport vehicles, special provisions relating to state transport undertakings, control of traffic, insurance, liability, offences and penalties, claims, tribunals, etc.

The control of traffic provides for interalia, limits of speed, weight and dimensions of vehicles, power to erect traffic signs, driving regulations, signals and signaling devices, wearing of protective head gears etc.

The Act also provides powers of Central Government and State Government to make rules for the purpose of carrying into effect the provisions of the Act. The Central Motor Vehicle Rules, 1989 as made by the Government and amended from time to time provide classification of various categories of motor vehicles, rules regarding licensing of drivers of motor vehicle, registration of motor vehicles (trade certificate, registration, certificate of fitness), permits, construction of motor vehicles, safety provisions in motor vehicles (dimensions, permissible axle load, brake lights, etc), occupant safety, safety of pedestrians, safety of vulnerable road users, emissions, noise, liability, offences and penalties, etc. It also contains transport schemes (rent a cab, tourist bus etc.).

14.5 Safe Axle Weight

Notifications of MORTH dated 16.7.2018 and 6.8.2018 have revised the safe axle weights of various categories of vehicles. These are given below in Table 14.1

Table 14.1 : Maximum Safe Axle Weight

Maximum Safe Axle Weight		
Sr. No.	**Axle Type**	**Maximum Safe Axle Weight**
1.	Single Axle	
1.1	Single Axle with single Tyre	3.0 tonnes
1.2	Single Axle with two Tyres	7.0 tonnes
1.3	Single Axle with four Tyres	11.5 tonnes
2.	Tandem axles (Two axles) (Where the distance between two axle is less than 1.8 m)	
2.1	Tandem axle for rigid vehicles, trailers and semi-trailers	21 tonnes*
2.2	Tandem axle for Puller tractors for hydraulic and pneumatic tyres	28.5 tonnes
3.	Tri-axles (Three axles) (where the distance between outer axle is less than 3 m)	
3.1	Tri-axle for rigid vehicles, trailers and semi-trailers	27 tonnes*
4.	Axle Row (Two axles with four tyres each) in Modular Hydraulic Trailers (9 tonnes load shall be permissible for single axle)	18 tonnes
Note: If the vehicle is fitted with pneumatic suspension, 1 tonne extra load is permitted for each axle.		

2. The gross vehicle weight (GVW) shall not exceed the total permissible safe axle weight as above and in no case shall exceed

   (i) 49 tonnes in case of rigid vehicles and

   (ii) 55 tonnes in case of semi articulated trailers and truck-trailers, except modular hydraulic trailers.

3. Modular hydraulic trailers can carry goods of indivisible nature of any load subject to the regulatory approvals as may be required.

Due to revision of the safe axle weights, the Gross Vehicle Weight on vehicle with different axle combination have also been revised.

The State enforcement authorities are to rigorously enforce the regulations and take strict action against overloading by goods vehicles on road and are to be ensured that such vehicles are stopped and made to unload the excess load before being allowed to proceed further, in addition to levy penalties under section 194 of the Motor Vehicle Act, 1988.

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REFERENCES

List of IRC Publications referred in this Pocket Book

S.NO.	CHAPTER	REFERENCES
1.	Chapter 2	• IRC:9-1972"Traffic Census on Non-Urban roads" • IRC:102-1988 "Traffic Studies for Planning Bypasses Around Towns" • IRC:108-2015 Guidelines for Traffic Prediction on Rural Highways" • IRC:SP:13-2004 "Guidelines For The Design Of Small Bridges and Culverts" • IRC:SP:19-2001 "Manual for Survey, Investigation and Preparation of Road Projects". • IRC:SP:30-2009 " IRC Manual of Economic Analysis of Highway Project" • IRC:SP:41-1994 "Guidelines on Design of At-grade Intersection in Rural an Urban Areas" • IRC:SP:93-2017 "Guidelines on Requirements for Environmental Clearances for Road Projects" • IRC:SP:108-2015 "Guidelines on Preparation and Implementation of Environment Management Plan".
2.	Chapter 3	• IRC:SP:93-2017 "Guidelines on Requirements for Environmental Clearances for Road Projects"
3.	Chapter 4	• IRC:73-1980"Geometric Design Standards for Rural (Non-Urban) Highways" • IRC:SP:73-2018 "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulders" (Second Revision) • IRC:SP:84-2019 "Manual for Specifications and Standards for Four Laning of Highways through Public Private Partnership" (Second Revision) • IRC:SP:87-2019 "Manual of Specifications and Standards for Six Laning of Highways through Public Private Partnership" (Second Revision) • IRC:SP:99-2013 "Manual of Specifications and Standards for Expressways"

4.	Chapter 5	• IRC:9-1972 "Traffic Census on Non-Urban Roads" • IRC:34-2011 "Recommendations For Road Construction In Areas Affected By Water Logging, Flooding and/Or Salts Infestation" • IRC:37-2018 "Guidelines for the Design of Flexible Pavement" • IRC:58-2015 "Guidelines for the Design of Plain Jointed Rigid Pavements for Highways" • IRC:81-1997 "Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique. • IRC:108-2015 "Guidelines for Traffic Forecast on Highways" • IRC:115-2014 "Guidelines for Structural Evaluation and Strengthening of Flexible Road Pavements using Falling Weight Deflectometer (FWD)" • IRC:117-2015 "Guidelines for the Structural Evaluation of Rigid Pavements by Falling Weight Deflectometre" • IRC:118-2015 "Guidelines for Design and Construction of Continuously Reinforced Concrete Pavement" • IRC:SP:42-2014 "Guidelines on Road Drainage" • IRC:SP:89-2018 (Part II) "Guidelines for the Design of Stabilized Pavement".
5.	Chapter 6	• IRC:35-2015 "Code of Practice for Road Markings" • IRC:67-2012 "Code of Practice For Road Signs" • IRC:SP:53-2010 "Guidelines on Use of Modified Bitumen in Road Construction" • IRC:SP:59-2019 "Guidelines for Use of Geosynthetics in Road Pavements and Associated Works". • IRC:SP:80-2008 "Guidelines for Corrosion Prevention, Monitoring and Remedial Measures for Concrete Bridge Structures".

6.	Chapter 7	• IRC:35-2015 "Code of Practice for Road Markings" • IRC:39-1986 "Standards for Road-Rail Level Crossings" • IRC:65-2017 "Guidelines for Planning and Design of Roundabouts" • IRC:67-2012 "Code of Practice For Road Signs" • IRC:79-2018 "Recommended Practice for Road Delineators" • IRC:92-2017 "Guidelines for Design of Interchanges in Urban Areas" • IRC:93-1985 "Guidelines on Design and Installation of Road Traffic Signal" • IRC:99-2018 "Guidelines for Traffic Calming Measures in Urban and Rural Areas" • IRC:119-2015"Guidelines for Traffic Safety Barriers" • IRC:SP:41-1994 "Guidelines for the Design of At-grade Intersections in Rural and Urban Areas" • IRC:SP:55-2014 "Guidelines on Traffic Management in Work Zones" • IRC:SP:85-2010 "Guidelines for Variable Message Signs" • IRC:SP:88-2018 "Manual on Road Safety Audit"
7.	Chapter 8	• IRC:SP:13-2004 "Guidelines for the Design of Small Bridges and Culverts".

8.	Chapter 9	• IRC:15-2017 "Code of Practice for Construction of Jointed Plain Concrete: • IRC:44-2017 "Guidelines for Cement Concrete Mix Design for Pavements" • IRC:107-2013 "Specifications for Bitumen Mastic Wearing Course". • IRC:116-2014 "Specifications for Ready Made Bituminous Pothole Patching Mix Using Cut Back Bitumen". • IRC:118-2015 "Guidelines for Design and Construction of Continuously Reinforced Concrete Pavement (CRCP) • IRC:SP:46-2013 "Guidelines for Design and Construction of Fibre Reinforced Concrete Pavements" • IRC:SP:49-2014 "Guidelines for the Use of Dry Lean Concrete as Subbase for Rigid Pavement". • IRC:SP:53-2010 "Guidelines on Use of Modified Bitumen in Road Construction • IRC:SP:59-2019 "Guidelines for Use of Geosynthetics in Road Pavements and Associated Works". • IRC:SP:101-2019 "Guidelines for Warm Mix Asphalt" • IRC:SP:112-2017"Manual for Quality Control in Road and Bridge Works"
9.	Chapter 10	• IRC:56-2011 "Recommended Practice For Treatment Of Embankment Slopes For Erosion Control" • IRC:SP:42-2014 "Guidelines. Of. Road Drainage" • IRC:SP:59-2019 "Use of Geotextiles in Road Pavements and Associated Works"

10.	Chapter 11	• IRC:12-2016 "Unified Guidelines for Access Permission to Fuel Stations, Private Properties, Rest Area Complexes and such other Facilities along National Highways". • IRC:103-2012 "Guidelines for. Pedestrian Facilities" • IRC:SP:73-2018 "Manual of Specifications and Standards for Two Laning of Highways with Paved Shoulders" • IRC:SP:110-2017 "Application of Intelligent Transport System for Urban Roads"
11.	Chapter 12	• IRC:82-2015 "Code of Practice for Maintenance of Bituminous Road Surfaces" • IRC:120-2015 "Recommended Practice For Recycling Of Bituminous Pavements" • IRC:SP:83-2018 "Guidelines for Maintenance, Repair and Rehabilitation of Cement Concrete Pavements" • IRC:SP:95-2011 "Model Contract Document for Maintenance of Highways".
12.	Chapter 13	• IRC:SP:112-2017 "Manual for Quality Control in Road and Bridge Works"

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