

GOVERNMENT OF JAMMU AND KASHMIR



BRIDGE MANUAL



PUBLIC WORKS (R&B) DEPARTMENT, J&K

CONTENTS

TITLE

PAGE NO.

| | |
|---|-----------|
| 1. GENERAL INTRODUCTION | |
| 1.1 Purpose | 1 |
| 1.2 Applicability | 1 |
| 1.3 Introduction | 1 |
| 2. PROJECT PREPARATION | 4 |
| 2.1 Feasibility Study | 4 |
| 2.2 Preliminary Project Preparation | 5 |
| 2.2.1 Bridge sitting and road alignment | 5 |
| 2.2.2 Reconnaissance survey | 6 |
| 2.2.3 Factors deciding site selection. | 6 |
| 2.2.4 Preliminary survey, subsoil investigations and hydraulic survey: | 7 |
| 2.2.5 Design discharge and linear waterway | 11 |
| 2.2.6. Clearance | 14 |
| 2.2.7 Width of carriageway, footpath and median | 14 |
| 2.2.8 Fixation of span arrangement and selection of the type of structure | 15 |
| 2.2.9 Preliminary design of various components of bridge | 18 |
| 2.2.10 Corrosion protection measures | 23 |
| 2.2.11 Design of river training and protective works | 24 |
| 2.2.12 Preliminary cost estimate | 24 |
| 2.3. Detailed Project Preparation | 25 |
| 2.3.1 Survey | 25 |
| 2.2.2 Hydraulic designs | 26 |
| 2.3.3 Surface and Subsurface Geotechnical Investigations | 26 |
| 2.3.4 Detailed structural design | 46 |
| 2.3.5 Detailed estimate | 47 |
| 2.3.6 Detailed project report | 47 |
| 3. CONSTRUCTION | 50 |

| | |
|--|-----------|
| 3.1 General | 50 |
| 3.2 Formwork and Staging | 50 |
| 3.3 Placing of Reinforcement | 51 |
| 3.4 Foundations | 51 |
| 3.4.1 Open foundation: | 51 |
| 3.4.2 Well foundations | 52 |
| 3.4.3 Pile Foundation | 52 |
| 3.5 Substructure | 52 |
| 3.6 Superstructure | 53 |
| 3.6.1 Concreting | 53 |
| 3.6.2 Pre-stressing | 53 |
| 3.6.3 Grouting | 54 |
| 3.7 Bearings | 54 |
| 3.8 Expansion Joints | 55 |
| 3.9 Materials for Structures | 55 |
| 3.9.1 General | 55 |
| 3.9.2 Bricks and Stones | 55 |
| 3.9.3 Cast Iron | 56 |
| 3.9.4 Cement | 56 |
| 3.9.5 Aggregates (Mineral Aggregates) | 57 |
| 3.9.6 Structural Concrete | 58 |
| 3.9.7 Steel (Other than Structural Steel) | 65 |
| 3.9.8 Structural Steel | 66 |
| 3.9.9 Stainless Steel | 67 |
| 3.9.10 Water | 67 |
| 3.9.11 Timber | 68 |
| 3.9.12 Concrete Admixtures | 68 |
| 3.9.13 Reinforced and Prestressed Concrete Pipes | 69 |
| 3.9.14 Storage of materials | 69 |
| 3.10 Tests and standards of acceptance of material | 69 |
| 3.10.1 Testing and Approval of Material | 69 |
| 3.10.2 Sampling of Materials | 70 |
| 3.10.3 Rejection of Materials not conforming to the Specifications | 70 |
| 3.10.4 Testing and Approval of Plant and Equipment | 70 |

| | |
|---|-----------|
| 3.11 Concrete in Piles | 70 |
| 3.12 Geosynthetics as Special Material | 71 |
| 3.13 Sampling and Testing Frequency of Testing Material | 71 |
| 3.13.1 Sampling | 71 |
| 3.13.2 Testing | 72 |
| 3.13.3 Frequency of Testing | 72 |
| 3.14 Calibration of Instruments of Material Testing & Manufacturing | 75 |
| | |
| 4. QUALITY SYSTEMS FOR ROAD BRIDGES | 76 |
| | |
| 5. PROJECT SCHEDULING AND MONITORING OF WORKS | 77 |
| 5.1 Scheduling | 77 |
| 5.2 Monitoring | 77 |
| 5.3 Record Keeping and Documentation | 78 |
| | |
| 6. BRIDGE INSPECTION AND MAINTENANCE | 79 |
| 6.1 Bridge Inspection | 79 |
| 6.1.1 Introduction | 79 |
| 6.1.2 Purpose of Bridge Inspection | 79 |
| 6.1.3 Planning the Inspection | 79 |
| 6.1.4 Preliminary Study | 80 |
| 6.1.5 Inspection Equipments | 80 |
| 6.1.6 Safety Precautions | 81 |
| 6.2 Maintenance of Bridges | 90 |
| 6.2.1 Introduction | 90 |
| 6.2.2 Symptoms and Remedial Measures | 90 |
| | |
| 7. BRIDGE NUMBERING IN LIGHT OF IRC 7:2017 | 95 |
| 7.1 Introduction | 95 |
| 7.2 Scope | 95 |
| 7.3 Numbering of Structures | 95 |
| 7.4 Salient Information | 96 |

| | |
|---|------------|
| 7.5 Inscription of Structure Number | 96 |
| 7.6 Information Plate | 97 |
| 7.7 Numerals and Details | 97 |
| 7.8. Maintenance | 98 |
| 8. STRUCTURAL HEALTH MONITORING (SHM) OF BRIDGES | 100 |
| 8.1 Introduction | 100 |
| 8.2 Types of Monitoring | 101 |
| 8.2.1 Time Frame | 101 |
| 8.2.2 Scale | 101 |
| 8.3 Monitoring Metrics | 102 |
| 8.3.1 General Metrics | 102 |
| 8.3.2 Concrete Metrics | 102 |
| 8.3.3 Steel Metrics | 103 |
| 8.4 Methods Used in Bridge SHM | 104 |
| 8.4.1 Non-destructive testing methods | 104 |
| 8.4.2. Vibration-based damage identification methods | 105 |
| 8.4.3. Model-based and data-based methods | 105 |
| 8.5 Review of Case Studies of SHM of Bridges | 106 |
| 8.5.1 Russia-Monitoring of Vintage Bridge | 106 |
| 8.5.2 Japan - Monitoring of Suspension Bridge | 106 |
| 8.5.3 India- SHM of Naini Bridge (2001-2004) | 106 |
| APPENDIX – I | 108 |
| Check List for Preparation of GAD | 108 |
| A. General | 108 |
| B. Plan | 109 |
| C. Elevation | 110 |
| D. Section | 111 |
| APPENDIX – II | 112 |
| Check List for Submission of GAD to Railway Department for ROBs | 112 |
| APPENDIX – III | 113 |

Order Copy of Ministry of Shipping, Road Transport and Highways Govt. of India regarding the width of bridges on 2-lane National Highways 113

APPENDIX-IV 118

List of IRC Codes and Special Publications 118

References 126

ACKNOWLEDGEMENT 131

1. GENERAL INTRODUCTION

1.1 Purpose

This Bridge manual has been prepared to provide policies and procedures required for bridge project development for the union territory of Jammu and Kashmir, Public Works Department. This manual provides guidance for the decisions needed in producing a bridge project and includes the policies and standards that are required to prepare a detailed project report for bridge construction. This manual also provides a commentary discussing good bridge practices and references to the additional sources of information.

One of the primary goals of this manual is to provide assistance to the engineers to ensure that “quality” bridges are constructed. “Quality” bridges are safe, durable, economical, aesthetically pleasing and environmentally sound.

This manual provides guidance on bridge designs, construction procedures, criteria and practices. To follow complete analysis and design, to produce a safe, economical and maintainable structure is the responsibility of every engineer involved with the project.

1.2 Applicability

This manual applies to all bridge related transportation projects under contract with the Jammu and Kashmir government departments and for all locally administered centrally aided transportation projects in the union territory of Jammu and Kashmir. Designers/ Engineers of these projects shall comply with the policies, guidelines, details and interpretation of the design, material and construction specifications stipulated in this manual. In addition, its use is recommended for all the other bridge projects in the union territory of Jammu and Kashmir. In case of any discrepancy in the guidelines of this manual with the guidelines of IRC codes, the guideline issued by relevant IRC code shall supersede and govern respectively.

1.3 Introduction

A Bridge is the continuation of a roadway as it separates from the land and supporting this roadway into the air, calls for a structure which is self supporting and withstands traffic / pedestrian loads.

A bridge is a piece of engineering work and like any other engineering construction, involves transforming nature in order to adapt it to man’s requirements.

There are many different designs that all serve unique purposes and apply to different situations. Designs of bridges vary depending upon the function of the bridge, the nature of the terrain where the bridge is constructed and anchored, the material used to make it, and the funds available to

build it. All major bridges are built with the public money. Therefore, bridge design that best serves the public interest has a three-fold goal: to be as efficient, as economical, and as elegant as is safely possible.

A bridge from its conception to completion goes through numerous phases of Planning, Analysis, Design, Administrative Approval, Tendering and Execution.

Post construction activities like routine inspections, maintenance and repairs are also prioritized for enhancing safety and service life of the structure.

This manual aims at providing the necessary guidelines to empower the engineers for achieving the above stated different phases from conception to completion.

A bridge project from conception to construction and final completion of the bridge involves a number of major activities which can be summarized as follows:-

Start - Administrative decision for constructing a bridge.

Feasibility studies:

Preliminary Project preparation – Site selection, Preliminary survey and investigation including hydraulic survey, subsoil investigation, fixation of span arrangements and selection of type of structure. Preliminary design of various components of bridge, preliminary cost estimates.

Detailed project preparation – Detailed survey, hydraulic design, subsurface investigation, detailed structural designs, detailed estimate and detailed project report.

Technical approval and financial sanction –

Decision to take up work from plan funds or to invite private entrepreneurs.

Approval of Tenders and Revised cost if necessary and start of construction work

Construction – Project scheduling and monitoring of quantity / quality and progress of work/PERT/CPM etc.

Inspection and maintenance of bridges

Note: Bridges are usually designed for at least 100 years life and should cater to the projected traffic demands. Utmost care should be exercised in site investigations by following the procedures outlined in the subsequent chapters ensuring only preparation of thoroughly investigated projects which will ultimately facilitate speedy construction and maintenance costs.

General Notes:

- 1. The mandate of latest/updated provisions/specification of BIS/IRC/MoRT&H shall apply, invariably, irrespective of its specific mention in this compilation of concise Bridge Manual.**
- 2. It is highly advised that explanation/clarification, on any section/sub-section, of this manual, may be sought formally from DIQC Department, without making any unnecessary assumptions, unilaterally.**
- 3. On subjects and technical topics of critical engineering importance, involving specific and specialized planning, investigation, design, execution or maintenance procedure/technique,**

an expert approach is highly recommended without underestimating the importance of such specialized consultation, thereof.

- 4. Any typographical errors/omissions may be brought to the notice of DIQC Department, for subsequent corrections and due incorporation, thereof.*

2. PROJECT PREPARATION

Preparation of a detailed project report is a pre-requisite for proper evaluation of the project, its approval by competent authority and finally its execution. Properly prepared project report is very helpful in ensuring timely completion of the project thereby ensuring fullest advantage of the project avoiding time and cost overruns. Project preparation activity can be divided into the following three broad stages:-

- (1) Feasibility Study
- (2) Preliminary Project Report
- (3) Detailed Project Report

For detailed guidelines reference may be made to Special Publication No.54-“Project Preparation Manual for Bridges” published by Indian Roads Congress.

2.1. Feasibility Study

2.1.1. The project preparation for a bridge work starts with the identification of the project. This phase is known as the pre feasibility stage. For this stage, broad features of the project are identified, the possible locations, nature of crossing, traffic dispersal system for different alternatives are identified. The effect of implementation of the project on the traffic scenario in immediate vicinity is also considered. This reconnaissance visit to the area of the intended site is sufficient at this stage.

2.1.2. In the feasibility stage, preliminary surveys, data collection and investigations are carried out. Alternative sites are investigated; design and rough cost estimates for various alternatives are made. The feasibility report covering the recommended alignment including alternatives considered, span arrangement, preliminary cost estimates, economic and financial viability is prepared. Feasibility study should also cover the following aspects:

- (i) The main purpose of the bridge project i.e. the trunk route, economic or interstate importance, access to ports, tourism, agriculture development etc. the place of the project in the road development programme and the priority assigned to.
- (ii) The geographic features of the area such as size, economic (industrial and agricultural), other traffic generated activities in the area, main population centers, their size projections and growth rates, and government's economic programme for the developments.
- (iii) Measurable and non measurable benefits should be listed. The former may consider reduction in operation costs, reduction in travel time for goods and passengers, reduction in maintenance cost in case an old bridge is replaced. The latter may include social and economic development of the adjacent area consequent to the construction of the bridge.

- (iv) A cost benefit analysis should be enclosed and results critically discussed. For calculation of cost benefit analysis, a reference may be made to IRC SP -30: 1993. "Manual on Economic Evaluation of Highway Projects in India (First Revision)".

2.2 Preliminary Project Preparation

Preliminary project preparation involves various stages like recognition of the need, study of maps, reconnaissance survey leading to selection of alternative site, preliminary survey and investigation including subsoil investigation and collection of hydraulic data leading to final site selection and all these activities have to be systematically planned and carried out in their logical sequence.

2.2.1. Bridge sitting and road alignment:

A bridge should ideally be sited across the narrowest width of the river or channel where the course of the channel is straight in considerable length on both up-stream and down-stream sides of the site and the banks are stable having no history of being out-flanked. A bridge should not be sited across meandering stretches of rivers unless it is established that the banks at the bridge site are the nodal points of the river (i.e. the river has a history of touching these points year after year regardless of change in its course elsewhere). Where one of the banks is not well defined and gets over-topped, the option of training the river by construction of a guide bund can also be considered. In case the active channel of the river, especially the alluvial rivers, changes its course within the river basin, the option of training the river by construction of guide bunds on both banks can be considered after ensuring that the adjoining areas in the upstream do not get flooded or the guide bunds themselves are not under attack. The preliminary site selection can be based on information contained in the topographical sheets of the Survey of India, supplemented by actual survey or study of satellite images of the location, which can be obtained from the National Remote Sensing Agency. A model study may be required for bridging rivers having undefined cross section and huge flood plains.

The considerations which decide the inter-se priority between a suitable bridge site and suitable road alignment will be guided by the following principles: -

- (i) The location of a bridge upto a length of 60 meter shall be governed by the suitability of alignment of the road unless there are some special problems at the crossing with regard to design / maintenance of the bridge.
- (ii) For bridges having a length between 60 and 300 meters both suitability of site of the bridge that of the alignment of the approaches shall be considered together.

- (iii) For bridges having total length more than 300 meters, the requirement of good site for the bridge shall have the precedence and the alignment of the approaches will have to conform to the selected bridge site.
- (iv) Where existing two lane highway is proposed to be widened to four lane width, the location of the additional two lane bridge shall be governed by factors mentioned in para 2.2.3.1 (ix) below:

2.2.2 Reconnaissance survey:

In case of an entirely new alignment, the site selection may have to start with the study of available maps before starting the reconnaissance. Usually, topo sheet in the scales 1:2,50,000 and 1: 50, 000 are available from the Survey of India. In case of bridges upto 300 m length, two or three possible road alignment should be marked on the topo sheets considering the topography of the land, land use, soil type, waste bodies, marshes, control points, river profile, straightness of the reach, width of crossing, presence of high banks etc. The two or three possible alignments may have to be considered for reconnaissance. Some landmarks for easy identification during reconnaissance may also have to be marked on topo sheets. The use of google maps shall be allowed as part of the reconnaissance assessment/investigations thereof. However, all critical site specific assessments shall be based upon thorough site specific survey/investigation and its confirmation viz-a-viz GTS survey maps.

2.2.3 Factors deciding site selection.

2.2.3.1 Adequate efforts made in selection of good site for locating a bridge will be amply rewarded in the form of reduced cost of the project and trouble free performance of the bridge. The factors that have to be considered in the selection of a site are indicated below. Though it may not be feasible to satisfy all desirable attributes simultaneously, the selected site should represent the most desirable mix of the attributes consistent with overall economy, including the cost of approaches.

- (i) **Permanency of the channel:** it has to be ascertained from different maps prepared over a long period of time that the river does not have any tendency to meander at the proposed site.
- (ii) **Presence of high and stable banks:** the presence of high non erodible banks generally offers an ideal site, which reduces the cost of approach embankments and their protection work.
- (iii) **Narrowness of the channel and large average depth compared to maximum depth:** this ensures large average depth of flow compared to maximum depth of flow and reduced water way which greatly reduces the overall cost of the bridge structure.
- (iv) **Straight reach of the river u/s and d/s of the proposed site:** straightness of the reach both u/s and d/s ensures uniform distribution of discharge/velocity. Curvature in the stream especially on the u/s leads to obliquity and concentration of the flow on the convex side leading to higher scour, and consequent cost of foundation and protection works. If the bank on the convex side

is erodible it may lead to heavy recurring expenditure in protecting the abutment and the embankment on that side.

- (v) **Freedom from islands or any form of obstruction both u/s and d/s:** any shoal formation disturbs flow characteristics. Gradual silting of one or more channels results in increased concentration of flow in other channels leading to higher scour or bank erosion, channels leading to higher scour or bank erosion, outflanking of the bridge etc. the site should also be away from confluence of tributaries where turbulence and obliquity of flow can be expected which results in higher unpredictable scour and water current forces on substructure.
- (vi) **Possibility of right angled crossings:** Right angled crossings offer minimum possible bridge length and reduce chances of obliquity of flow with respect to the substructure.
- (vii) It is preferable to site the bridge on u/s of the existing cause way, if any.
- (viii) **Possibility of good approach alignment:** curves except gentle ones are preferable to be avoided on approaches and bridges, proper from visibility and safety considerations.
- (ix) Where existing two lane highway is proposed to be widened to four lane width, the additional two-lane bridge shall be sited as close to existing bridge as possible. However, in case of bridges having well foundations, distance sufficient for generation of passive resistance of soil shall be provided.

2.2.3.2 Sitting of grade separators: Sitting of bridges which act as rail/road grade separators will be largely decided by good alignment of the approaches, availability of land and other constraints imposed by rail lines, services etc. at skew crossings, skew angle of more than 45 degrees should generally be avoided.

2.2.3.3 Distance between rail and road bridges: the distance between rail and Road Bridge should be as large as possible but not less than 400 m in any case.

2.2.4 Preliminary survey, subsoil investigations and hydraulic survey:

Once the possible alternative sites are selected on the basis of reconnaissance survey and the criteria for site selection enumerated in para 2.2.3 above, the next step is to conduct the preliminary survey, subsoil investigations and hydraulic survey at each of the alternative sites:

2.2.4.1 Preliminary Survey:

The data to be collected during the preliminary survey are:-

- (i) The names of the state / UT, district, nearest town/village, and river across which the bridge is proposed.
- (ii) The chainage of the highway, location of nearest GTS bench mark with level, latitude and longitude of the site as measured from the survey of India maps.
- (iii) Details of the existing bridges or causeways on the same river in the vicinity which should include:-

- ❖ Description with sketches showing relevant dimensions. - length and depth of submergence, number and sizes of vents, and frequency (including duration) of interruptions to traffic in case of causeways.
 - ❖ Number and length of spans, clear waterway, adequacy or otherwise of waterway with special reference to silted up spans or signs of undue scour or attacks on abutments" and approaches in case of bridges.
- (iv) An index map of the site on a scale of 1: 50,000 indicating the name and chainage of the highway. The name of the river, name of the nearest town/village marking of the alternative sites, location of the nearest GTS benchmark if possible, name of district and state, direction of flow, nature of land-use, general topography of the area and north line.
- (v) Site plans of the bridge for the alternative sites indicating the north line, alignment of the road and the river, the angle of crossing, water spread at LWL, HFL case. Chainage of the proposed bridge at crossing of the river, the direction of flow at maximum discharge, private land boundaries, services, location of deep channels, ponds, places of worship, graveyards, if any, near to the proposed site. Location and reduced level of the temporary bench mark used as datum, location of the L.S. and C.S. of the road and the stream taken within the area of the plan, location of trial pits/borings with their identification number and location of nallah's wells, buildings, rock out crops etc. which may affect the approach alignments.

2.2.4.2. Hydraulic Survey:

Hydraulic data collected for the purpose of the preliminary project report (PPR) has to be good enough for the detailed engineering also. No separate hydraulic data collection is envisaged for detailed engineering except that for model studies, if any, conducted for bridges across major rivers. Wherever practical, the hydraulic data as may be formally facilitated by the Irrigation & Flood Control Department may be utilized. The hydraulic data collected at PPR stage should include:-

- (i) A catchments area map on a scale of 1:50,000 indicating the drainage channels and the land-use pattern including built up areas, barren land, cultivated land, forests, hilly areas etc. and its area in square kilometers. For preparation of the catchment area GTS maps of largest available scale may also be referred for tracing the ridge line.
- (ii) HFL ascertained from watermarks, if any, on the permanent objects on the banks supplemented by local enquiry from nearby inhabitant as to the highest flood levels reached during their living memory'.
- (iii) Information about velocity of flow and presence of floating debris etc. from local enquiry. Velocity of flow is best ascertained during floods by the use of floats by determining the time to traverse two fixed points at measured distance apart.

- (iv) In case a causeway or the existing bridge is of insufficient waterway resulting in afflux, the extent of such afflux is ascertained for arriving at the rough assessment of discharge.
- (v) Names and approximate discharges of all tributaries joining the river within a reasonable distance upstream of the site under consideration.
- (vi) Skew angle of crossing, if any, should be ascertained correctly. Skew angle should be measured in relation to the direction of flow at/near HFL and not in relation to the bank line.

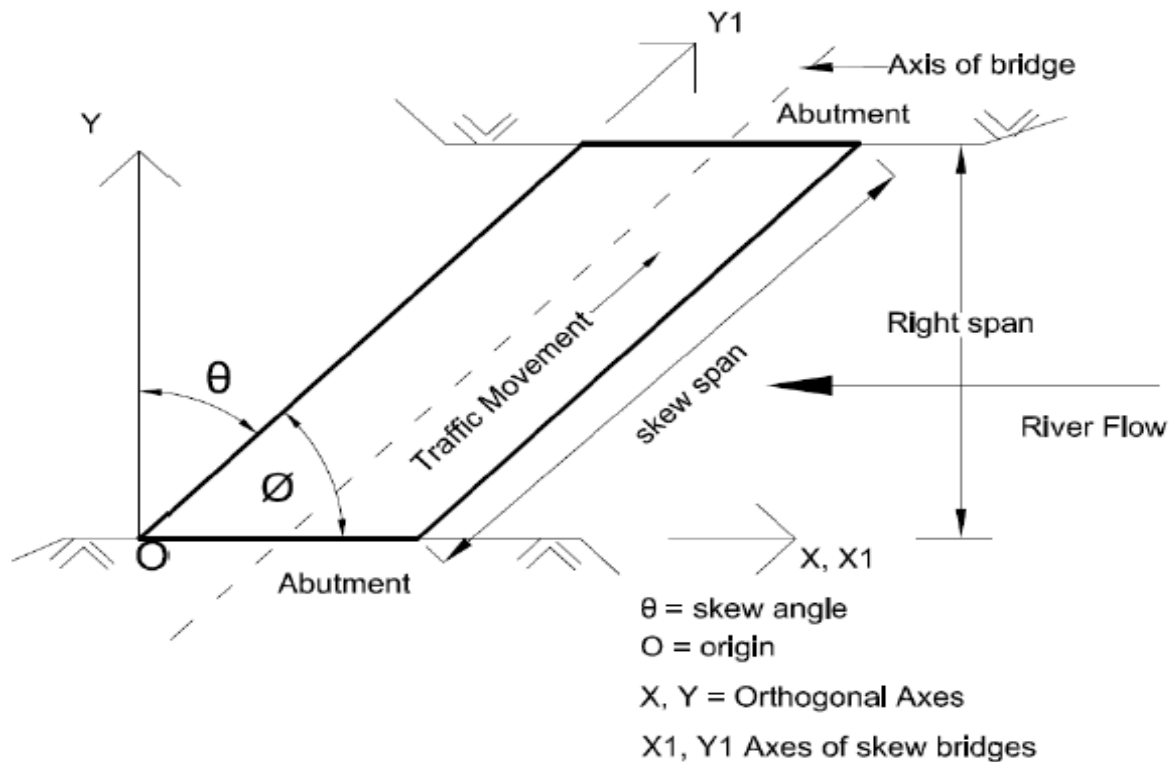


Fig. 2.0 Skew Angle of Bridge

- (vii) The approximate depth of the deep scour hole below HFL mentioning its location, whether general or localized, near any hard obstruction or caused by whirlpool. Information about scour around piers and abutments of any other bridge across the same river in the vicinity from records or by soundings taken near the proposed site during receding floods will be very useful in cross checking the calculated scour and thereby avoiding gross errors.
- (viii) The khadir width in case of wide/meandering alluvial rivers. The width and depth of the channel during dry weather flow, OFL and HFL should be noted, as well as the radii of the larger meanders scaled from the map.
- (ix) Cross section of the river on a vertical scale of about 1/100 and horizontal scale of 1/10000 at the proposed sites indicating:
 - ❖ Name of the river and the site.

- ❖ The (road) chainages and bed levels with reference to the temporary benchmark and ground levels for sufficient distance beyond the edge of the channel
- ❖ Nature of the subsoil in the bed, bank approaches and location of the trial bores.
- ❖ LWL, OFL and HFL
- ❖ Low and high tide levels where applicable.

It should also include one or two additional cross sections at 300 to 500 m u/s and d/s for small and large rivers respectively.

- (x) A longitudinal section of the stream showing the proposed site, HFL, OFL, LWL and bed levels at suitably placed intervals along the approximate centre line of the deep water channel. The horizontal scale shall be same as for survey plan and vertical scale not less than 1:1000.

- (xi) Rainfall data indicating

- ❖ Maximum precipitation in one hour and 24 hours.
- ❖ Rainfall distribution in catchment.
- ❖ Duration, frequency of floods.
- ❖ Rain gauge data of storms for which corresponding stream gauge data is available (data for unit hydrograph)
- ❖ Average annual rainfall characteristics (append relevant meteorological records).

Wherever practical, the rainfall data as may be formally facilitated by the Meteorological Department may be utilized.

- (xii) Stream/channel characteristics

- ❖ Seasonal or perennial
- ❖ Braided, meandering or straight
- ❖ Other classifications like bouldery, flashy, well defined, presence of pools, weeds etc.
- ❖ Highest flood and other major floods and their year of occurrence delineating the areas flooded
- ❖ Afflux if observed

2.2.4.3. Preliminary subsoil investigation

- (i) Preliminary subsoil investigations should include adequate number of trial bores/trial pits for obtaining realistic data for deciding the span arrangement, type of foundation and scour level as specified in IRC:78 for making the preliminary design of the bridge. The exploration shall cover the entire length of the bridge and also extend at either side for a distance of about twice the depth below bed of the last main foundations. It should also include study of available information on the geological formations from geological maps, site reports of existing bridges, aerial photography etc. If significant difference in the foundation strata is anticipated, few bores

at alternative sites may also be required sometimes, so as to help in the final selection of the site.

- (ii) Depth of exploration: The depth of exploration should be at least 1 ½ times the minimum width of the foundation below the proposed foundation level in case of open foundations and deep well foundation. Where such investigation end in any unsuitable or questionable foundation material, the exploration shall be extended to a sufficient depth into firm and stable soil or rock but not less than four times the minimum depth of foundation below the earlier contemplated foundation level. In case of good sound rock, the stipulation of minimum depth may be decreased based on difficulty to conduct core drilling, however minimum depth should not be less than 3 meters.
- (iii) Depth of exploration for pile foundation should be as per Section 1100 of MORT&H Specifications for Road and Bridge Works.

2.2.5. Design discharge and linear waterway

2.2.5.1. Design discharge

The design discharge for which the waterway of the bridge is to be provided shall be based on maximum flood discharge of return period of 100 years. Normally, in the absence of reliable data for "statistical analysis of floods, design discharge may be fixed on the basis of any rational method. Empirical methods are less reliable and may be used with caution. Various methods for calculating discharge are given in IRC-SP 13.

2.2.5.2. Linear Waterway.

For rivers with defined firm banks, the linear waterway is preferably kept equal to HFL spread at the site. However, when the depth of flow near the banks is low in comparison with deep channel portion, constriction of waterway upto 2/3rd of the HFL spread is resorted to form considerations of economy. But careful consideration has to be given on the possibility of excessive scour of the banks or beds on the d/s of the bridge or of excessive afflux on the u/s before deciding on any constriction of waterway.

The likely mean depth and velocity of flow shall be the main guiding factors for deciding the linear waterway to be provided for any bridge. Hence for effective functioning of the waterway, afflux of 10 to 30 cms may be allowed with the due consideration for any possible adverse effects on the upstream.

For rivers with alluvial beds and no defined banks, the effective linear waterway can also be derived from the formula:

$$w = c\sqrt{Q}$$

Where, C is a constant usually taken as 4.8 for regime channels, but varying between 4.5 to 6.3 according to local conditions. The formula should be used judiciously only after ascertaining the soil characteristics in the river bed and regime of the river.

For meandering rivers with several active channels separated by islands or shallow sections, it may become necessary to considerably restrict the waterway by providing training works. The design of the training works and the effective linear waterway are to be preferably based on the model studies.

The effective linear waterway may be compared with that provided under other bridges in the vicinity over the same river after duly considering their performance.

2.2.5.3. Scour depth.

2.2.5.3.1. The probable maximum depth of scour to be taken for the purpose of designing foundations for piers, abutments and river training works shall be estimated after considering all local conditions over a reasonable period of time.

Wherever possible, depth of scour shall be assessed on the basis of actual soundings taken at the proposed site or near it during the receding phase immediately after high flood conditions with necessary allowance for:-

- (i) The design discharge being higher than the one for which observation has been made.
- (ii) The increase in velocity due to constriction of waterway.
- (iii) The increase in scour in the proximity of piers and guide bunds.

2.2.5.3.2. In the absence of actual soundings, the mean depth of scour d_{sm} in meters below HFL may be theoretically calculated from the equation:-

$$d_{sm} = 1.34 \times \sqrt[3]{\frac{D_b^2}{K_{sf}}}$$

Where D_b is the discharge in cumecs per meter width which shall be taken as maximum of the following:-

- (i) Total design discharge divided by the effective linear waterway
- (ii) Discharge per meter calculated after considering concentration of flow, if any, through a portion of the waterway in case of major bridges.
- (iii) Actual observation, if any.

and K_{sf} is the silt factor which is equal to

$$K_{sf} = 1.76\sqrt{d_m}$$

d_m being the weighted mean diameter of the representative sample of the bed material upto the anticipated scour level. In the absence of sieve analysis, IRC:78 prescribes following values of silt factors (Table 2.1).

| Type of Bed Material | d_m Weighted Mean Diameter of Particle in mm | Value of K_{sf} Silt Factor |
|----------------------|--|-------------------------------|
| Fine Silt | 0.081 | 0.500 |
| Fine Silt | 0.120 | 0.600 |
| Fine Silt | 0.158 | 0.700 |
| Medium Silt | 0.233 | 0.850 |
| Standard Silt | 0.323 | 1.000 |
| Medium Sand | 0.505 | 1.250 |
| Coarse Sand | 0.725 | 1.500 |
| Fine Bajri and Sand | 0.988 | 1.750 |
| Heavy Sand | 1.290 | 2.000 |

Table 2.1 Value of K_{sf} Silt Factor

2.2.5.3.3. For the design of foundation of piers and abutments located in the straight reach and having individual foundations without protection works, the maximum depth of scour shall considered as follows:-

(i) In the vicinity of piers = $2.00 d_{sm}$

(ii) In the vicinity of abutments = $1.27 d_{sm}$ (when approaches are retained)

= $2.00 d_{sm}$ (when approaches are washed / with scour all around)

2.2.5.3.4. For the design of floor protection measures and for raft or shallow foundations, the maximum depth of scour shall be considered as follows:-

(i) In straight reach = $1.27 d_{sm}$

(ii) At moderate bend = $1.50 d_{sm}$

(iii) At severe bend = $1.75 d_{sm}$

(iv) At right angled bend = $2.00 d_{sm}$

The above values of scour may be suitably modified where actual observed data is available on similar structures in vicinity of the proposed bridge.

2.2.5.3.5. In case of flashy rivers and boulder strata, the scour is likely to be less what is given by the formula. In such cases, scour depths may be based on actual observations.

2.2.5.3.6. For bridges proposed d/s of a reservoir, the clear water will have higher scouring effect and in such cases also, scour depths shall be based on actual observations.

2.2.5.3.7. For seismic case, scour to be considered in design shall be 0.9 times the maximum design scour depths.

For other details and afflux, refer relevant clauses of IRC-5 and IRC-78.

2.2.6. Clearance

2.2.6.1. Vertical clearance above HFL.

Clearance shall be allowed according to navigational or anti-obstruction requirements in consultation with the concerned authorities for all controlled and natural water courses/channels. For inland waterways, Inland Waterways Authority has framed regulation for classification of inland waterways in India and has recommended minimum clearance for various categories of waterways, which should be referred.

For high level bridges having flat soffit or a soffit with a very flat curve, the minimum vertical clearance to be provided above affluxed HFL shall normally be as follows (Table 2.2):-

| Discharge in Cumecs | Minimum Vertical Clearance in mm |
|-------------------------|----------------------------------|
| Upto 0.3 | 150 |
| Above 0.3 and upto 3 | 450 |
| Above 3 and upto 30 | 600 |
| Above 30 and upto 300 | 900 |
| Above 300 and upto 3000 | 1200 |
| Above 3000 | 1500 |

Table 2.2: Vertical Clearance

2.2.6.1. Clearance for traffic

- (i) The minimum vertical and horizontal clearances (clear height and width respectively available for passage of traffic) to be provided on bridges shall be as specified in IRC-5.
- (ii) For bridges constructed on horizontal curve with super-elevated road surface, the horizontal clearance shall be increased on the side of the inner kerb by a margin equal to 5 meters multiplied by the super elevation; the maximum vertical clearance being measured from the super elevated level of the roadway. The above extra horizontal clearance required is over and above the increase in width required for the design of road on curve.
- (iii) For footways and cycle tracks, the minimum vertical clearance shall be 2.25 meters.
- (iv) For vertical and horizontal clearances at under passes and / rail over bridges the essential provisions IRC: 5 may be referred.

2.2.7. Width of carriageway, footpath and median

2.2.7.1. General (for all roads except national highways):

The provisions given in clause 104.3 of IRC:5-2015 may be applied for all bridges except for National Highways for which para 2.2.7.2 may be referred to.

The carriageway width shall not be less than 4.25 m for a single lane bridge and 7.5 m for a two lane bridge, which shall be increased by 3.5m for every additional lane of traffic for a multiple lane bridge. In addition, the cross section of two lane and multi lane bridges shall satisfy the following:-

Width between the outermost faces of the bridge shall preferably be equal to the full formation width of the approaches. However, in case of bridges having length more than 60m in non-urban areas, reduced width may be permitted by the authorities subject to stipulations as given in clause 104.3.1 of IRC-5-2015.

For bridges on horizontal curve, the roadway width shall be increased suitably to conform to the requirements stipulated in the relevant IRC Road standards.

When a footpath is provided, its width shall not be less than 1.5m. For urban and populated areas having large concentration of pedestrian traffic, the width of the footpath shall be suitably increased.

2.2.7.2. For bridges on National Highways:

All bridges should have width between outer most faces of the railing kerbs equal to the roadway width of the approaches irrespective of their length or location. For details, Ministry's Circular No. RW/NH-33044/2/S8-DO.II dated 09/05/2000 may be referred to.

Footpaths: In urban areas, minimum footpath width of 1.5 m may be provided. In case of divided carriageways, footpath shall be provided only on the left side of the carriageway for each direction of traffic, wherever footpath is not provided, safety kerb of 750 mm width has to be provided as per IRC:5. In case of very high volume of pedestrian traffic, the provision of footpaths of more than 1.5m width or a separate pedestrian bridge may be considered depending on site conditions.

Crash Barriers: Crash barriers shall be provided for all bridges on National Highways to safeguard against errant vehicles. For bridges with footpath, crash barrier "shall be so located as to separate the main carriageway from the footpath for the safety of pedestrians". For further details, IRC-5 "General Features of Design" may be referred to.

Extra width on curves: In case of bridges lying on a curve or a horizontal profile, extra width on bridge shall be" provided as per IRC codal provisions applicable for road section.

2.2.8. Fixation of span arrangement and selection of the type of structure

2.2.8.1. General consideration in selection of type of bridges and span arrangement

Specific site characteristics like width of crossing, nature of stream, depth of flow during different seasons, subsoil characteristics, and the capabilities of contracting agencies who would be interested in building the structure including availability of skilled and unskilled labor are mostly the major considerations in selecting the type of structure and span arrangement in specialized structures like long span bridges. The attempt of the engineers should be towards minimizing the

overall cost of the total structure including approaches within the site specific constraints as obtained. For normal simply supported structures, it has been observed that the total cost of the bridge project tends to be the minimum, when the cost of superstructure approaches to that of foundation and substructure put together which may be applied as a thumb rule for initial trial.

2.2.8.2. Economical range of span lengths for different types of superstructures

Apart from the estimated cost based on schedule of rates, costs as quoted during tendering may be used for constantly updating the cost analysis data. The ranges of span length within which a particular type of superstructure can be economical along with other considerations of foundation etc. are given below:-

| | |
|---|---------------|
| (i) R.C.C. single or multiple boxes | 1.5 to 5 m |
| (ii) Simply supported RCC slabs | 3 to 10 m |
| (iii) Simply supported RCC T beam | 10 to 24 m |
| (iv) Simply supported PSC girder bridges | 25 to 45 m |
| (v) Simply supported RCC voided slabs | 10 to 15 m |
| (vi) Simply supported/ continuous PSC voided slabs | 15 to 30 m |
| (vii) Continuous RCC voided slabs | 10 to 20 m |
| (viii) RCC box sections simply supported/ Balanced cantilever continuous | 25 to 50 m |
| (ix) PSC box sections; simply supported / Balanced cantilever | 35 to 75 m |
| (x) PSC cantilever construction / Continuous | 75 to 150 m |
| (xi) Cable stayed bridges | 100 to 800 m |
| (xii) Suspension bridges | 300 to 1500 m |
| (xiii) Truss bridges simple supported | 30 to 375 m |
| (xiv) Truss bridges with cantilever combination | upto 550m |
| (xv) Simple supported steel plate girder bridge | 10 to 40m |

However, whenever an economical span arrangement and type of structure is decided, it has to be ensured that the required infrastructural facilities, design and construction capabilities, specialized materials etc. are available.

Bailey bridges: These refer to bridge superstructures nominally made up of assemblable units which can be carried in units (Fig. 2.1), assembled and launched in a short period over a gap. They may be provided for the short-term movement of an army or also be used in case of damage to a permanent bridge due to the approaches or even a part of the bridge having been damaged leaving a wide gap, or if the traffic has been suspended and permanent repairs to the bridge are likely to take a long time.

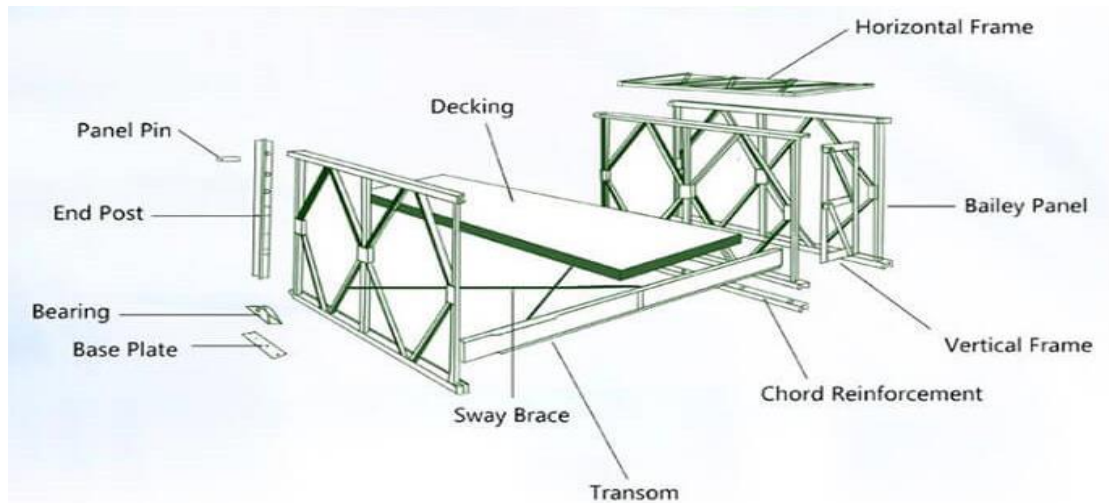


Fig. 2.1 Bailey Bridge

2.2.8.3. Type of foundations

The subsoil characteristics obtained at a particular site and consequently the type of foundations feasible is one of the major considerations in selection of type of structure and span arrangement as already mentioned:

- (i) **Shallow foundations:** Isolated open foundations are feasible where an SBC of about 15 t/m^2 or more is available at shallow depths with non erodible substratum. Here again, open excavation is feasible only upto a depth of 3 to 4 m where the subsoil is porous and water table is high. In cases, where the SBC is still less and where smaller spans are economical from other considerations, raft foundations or box structures with floor' protection and curtain walls are the other options.
- (ii) **Deep foundations:** Where suitable founding strata is available at a depth of 6 m or more with substantial depth of standing water, highly pervious substratum and large scour depth, it may be advisable to go for deep foundation like (a) well, or (b) piles.
 - ❖ **Well foundations:** This is one of the most popular types of deep foundations in our Country, due to various reasons like its simplicity, requirement of very little of equipment's for it's execution, adaptability to different subsoil conditions and difficult site conditions like deep standing water and large depths to good founding strata. Caissons are an adaptation of well foundations to sites with deep standing water.
 - ❖ **Pile foundations:** Pile foundations are another type of deep foundations which are suited for adoption in the following situations, availability of good founding strata below large depth soft soil. Need to have very deep foundations beyond the limit of pneumatic operations usually depth beyond 35 meters or so. In some cases of strata underlying deep standing water and the strata being very hard not permitting easy sinking of wells or based on economic factors

deciding the use of piles as compared to wells. However, pile foundations are not preferred within the flood zone of the river with deep scour.

(iii) Classification of piles

- ❖ Precast driven piles
- ❖ Driven cast-in-situ piles
- ❖ Bored cast-in-situ piles
- ❖ Bored precast piles and
- ❖ Driven steel piles

Further guidance on the design and construction aspects of pile foundations can be obtained from IRC: 78.

2.2.9 Preliminary design of various components of bridge

The Preliminary design should include all calculations needed for finalizing the cross section of the superstructure including the checks for the maximum bending stress and shear stress. It should also include preliminary design of the critical abutment and pier on the basis of preliminary subsoil investigations.

2.2.9.2 Minimum depth of foundations: The following minimum depths may be ensured:

- (i) Shallow foundations in erodible strata:** Such foundations may be taken to a minimum depth of 2.0m if they support an arch superstructure or 1.20 m in other cases provided adequate SBC is available at that depth to support a individual foundation or rafts as the case may be and the foundations are protected against undermining by suitably designed flooring, cut off walls and launching aprons.
- (ii) Deep foundations in erodible strata:** Such foundations shall be taken to such depth where the base pressures calculated based on any rational design method is less than the available S.B.C. and a minimum grip length of 1/3rd of the maximum anticipated scour depth below HFL (i.e. 1/3rd of 2d) is ensured.
- (iii) Shallow foundations in rock:** A minimum embedment of 0.6 m in case of hard rocks having a crushing strength of 100 kg/cm² or more may be provided considering the overall characteristics such as fissures, bedding planes, cavities etc. Higher embedment may be provided for softer varieties considering the above mentioned characteristics and strengthening measures, if any, proposed.
- (iv) Deep foundations in rock:** If hard rocky strata is met with at depths below the maximum scour level, and if deep foundations are resorted to, it shall be ensured that such foundations are evenly seated all along the periphery on sound rocky strata (devoid of fissures, cavities, weathered zones etc). On sloping rock surfaces, the foundations shall be properly seated by

benching and the extent of seating and embedment in each case shall be decided by Engineer-in-charge/bridge designer/relevant IRC Code.

2.2.9.3. Substructure : Substructure include those portions of a bridge which are above the foundation which include piers, abutments, abutments and pier caps, dirt walls, returns, wing wall etc. but excludes bearings and superstructure. It can be built of brick/ stone masonry, plain/ reinforced/ pre-stressed concrete, steel. Selection of a particular type of substructure depends upon the span and type of superstructure, the height of substructure, availability of construction material and construction equipments, period and time of construction and above all on overall economy. The shape of piers and abutments in general, should be such as to cause minimum obstruction to flow of water.

Substructure shall be designed to withstand the loads and forces as specified in IRC: 6, the worst combination of forces and factors of safety shall be as specified in IRC: 78. For allowable stresses and other design requirements relevant IRC Codes depending upon the type of construction material shall be followed.

2.2.9.4. Bearings

(i) Bearings are vital components of a bridge which while allowing of longitudinal and/or transverse rotations and/ or movements of the superstructure with respect to the substructure (thus relieving stresses due to expansion and contraction), effectively transfer loads and forces from superstructure to substructure. Adequate care shall be exercised in selecting the right type of bearings based on the guidelines given below:

- ❖ For solid/voided slab superstructure resting on unyielding supports, no bearings are generally provided if the span length is less than 10m. The top of piers/abutments caps are however rubbed smooth with carborandum stone.
- ❖ For girder and slab spans more than 10m length and resting on unyielding supports, neoprene bearings may be considered. For spans larger than 25m roller and rocker bearings or PTFE bearings could be considered.
- ❖ For very large spans and where multidirectional freedom of movement and rotation are to be allowed provision of POT bearings may be considered.

(ii) The design of metallic bearings and neoprene bearings shall be in conformity with IRC: 83: Parts I & II respectively.

(iii) In case of roller-cum-rocker bearings only full circular rollers are to be provided.

(iv) In order to cater for any possible relative undue movement of bearings over the abutment resulting in girder ends jamming against the dirt wall preferably a larger gap may be provided between the girder end and the dirt wall.

- (v) All bearings assemblies shall be installed in accordance with the instructions contained in the codes and specifications and on the approved drawings. In particular the following important points shall not be lost sight of.
- ❖ All bearings shall be set truly level so as to have full and even seating. Thin mortar pads (not exceeding 12mm) may be used to meet this requirement.
 - ❖ The bottoms of girders resting on the bearing shall be plane and truly horizontal.
 - ❖ In case of rockers and roller bearings, necessary adjustment for temperature at the time of placement, shrinkage, creep and elastic shortening shall be made, such that the line of bearing is as central as possible on the bearing plates at the normal temperature taken in design.
 - ❖ For elastomeric bearing pads, the concrete surface shall be level such that the variation is not more than 1.5mm from a straight edge placed in any direction across the area.
 - ❖ For spans in grade, the bearings shall be placed horizontal by using sole plates or suitably designed R.C.C. pedestals.
 - ❖ Bearings of different sizes must not be placed next to each other to support a span.
 - ❖ Installation of multiple bearings one behind the other on a single line of support is not permitted.
 - ❖ The bearings shall be so protected while concreting the deck in situ that there is no flow of mortar or any other extraneous matter into the bearing assembly and particularly on to the bearing surfaces. The protection shall be such that it can be dismantled after the construction is over without disturbing the bearing assembly.
 - ❖ Special attention should be given to the temporary fixtures to be provided for the bearings during the concreting of superstructure in order to ensure that they do not get displaced during the initial installation itself. The temporary fixtures should be removed as soon as the superstructure has attained its required strength
- (vi) Bearings provided at any end of superstructure shall be along a single line of support and of identical dimensions.
- (vii) Ministry of Road Transport and Highways, Govt. of India carries out pre qualification of the manufacturers of bearings from time to time. The pre qualification is valid for a certain period. It is advisable to procure bearings from such manufacturers only.
- (viii) The regular inspection/maintenance of bearings shall be carried out as per the procedure laid down in relevant IRC Code, the details of same are provided in section 6 of this manual.

2.2.9.5. Superstructure

- (i) It is the superstructure of a bridge that directly supports the traffic and facilitates its smooth uninterrupted passage over natural/ manmade barriers like rivers, creeks, railways, roads etc by

transmitting the loads and forces coming over it to the foundation through the bearings and substructure.

- (ii) The minimum functional requirement of superstructure is specified in IRC: 5 and IRC: 21. In case of box girder superstructure, the minimum clear height inside the box girders shall be 1.5 m to facilitate inspection.
- (iii) Aesthetic aspects will be one of the major considerations while deciding on the type of superstructure of a bridge keeping in view the criteria mentioned therein.
- (iv) Consistent with economy and local availability of the materials, labour and technology for a particular type of superstructure selection may have to be made out of the following material options:
 - ❖ Masonry
 - ❖ Reinforced cement concrete
 - ❖ Pre stressed concrete
 - ❖ Steel or
 - ❖ Composite construction which is a combination, of the any of the above.
- (v) Reinforced cement concrete superstructure: These are the most popular type of superstructures in the present day which may take the form of solid slab, voided slab. T-beam and slab, box girder, rigid frame, arch, balanced cantilever or bow-string girder.
- (vi) Prestressed concrete superstructure: This may also take any of the above forms referred in the previous para.
- (vii) Steel superstructure: With increasing availability of quality steel at international prices in recent years the use of steel for superstructure is becoming an attractive option. The forms, these may take are steel beam, plate girder, box girder, steel truss, arch, cantilever suspension bridges and cable stayed bridges.
- (viii) Composite Superstructure: any combination of above materials considering their distinct advantages for particular elements may be adopted. Most common types of composite construction arc cast in situ or precast girder in prestressed concrete with R.C.C. deck or steel beam/plate girders with RCC deck or cable stayed bridges with RCC or PSC deck.
- (ix) Design: Relevant IRC Codes which have to be complied in the design of superstructure are IRC: 40, IRC: 21, IRC: 18, IRC: 24. IRC: 22 for Masonry, Reinforced Cement Concrete, Prestressed Concrete and Composite Superstructures respectively. Other codes applicable for all types of superstructures are IRC: 5 and IRC: 6. other major guidelines also include IRC: 85. In case IRC codes are silent about some design aspects, provisions, in the IS/International Codes may be followed.

- (x) Provision for future pre-stressing: In case of pre-stressed concrete superstructure, provision for future pre-stressing to the extent of 20 per cent of total pre-stress force may be made. For this purpose, dummy cables may be laid in the structure which can be used for further pre-stressing if the need arises afterwards.
- (xi) Standard plans for highway bridges: Ministry of Road Transport & Highways gives preference to item rate contracts except in case of special problems, very large projects involving novel design/construction methods, and have brought out various standard plans which include standard plans for (i) RCC Solid Slab Superstructure, with and without footpaths for 3m to 10m spans with 12.00m overall width, (ii) T-Beam and Slab Superstructure of 12m to 24m spans of overall width 12.00 m, (iii) PSC Girder with RCC Deck Composite Superstructure for 30 m span with and without footpath, 35m span with footpaths and 40m span without footpaths and (iv) RCC Solid Slab Superstructures of 15, 22.5, 30 and 35° skew for span 4m to 10m with and without footpaths. These plans are published by MORT&H / IRC.

2.2.9.6. Expansion joints: Expansion joints are provided at the end of deck and cater for movement of deck due to temperature, shrinkage, creep etc. Expansion joints make the deck joint leak proof, protect the edges of slab/girder and also allow smooth passage of loads from one span to other by bridging the gap. Depending upon the gap width to be bridged, there are various types of expansion joints in use at present as detailed below.

- (i) **Buried joints:** Where the gap is 20mm or less, bituminous/asphalted surfacing is laid over a 12mm thick 200mm wide steel plate resting freely over the top surface of deck concrete. To keep the plate in position 8mm dia 100 mm long nails spaced at 300mm c/c along the center line of the plate are welded to the bottom surface of the plate and protrude into the gap.
- (ii) **Filler joint:** This type of joint is suitable for fixed ends of simply supported spans with insignificant movements or simply supported spans not exceeding 10 meters. It can cater for horizontal movement upto 20mm.
- (iii) **Asphaltic plug joint:** It is of asphaltic concrete made from polymer modified bitumen binder and selected single size aggregate. It rests over a 6mm thick and 200mm wide steel plate placed over the gap. The width of the plug varies from 500 to 750mm and its depth varies from 75 to 100mm. It caters for a horizontal movement upto 25mm and vertical movement upto 2mm.
- (iv) **Compression seal joint:** It consists of steel armored nosing at two edges of the joint gap suitably anchored to the deck concrete and a joint sealer performed multi web cellular section of chloroprene elastomer compressed and fixed into the joint gap with special adhesive binder. The seal shall cater for a horizontal movement upto 40mm and vertical movement of 3mm.

- (v) Elastomeric slab seal joint:** It comprises of reinforced elastomeric seal fixed on either side to deck concrete of adjacent spans through bolts. It can cater to a maximum horizontal movement of 40mm.
- (vi) Strip seal expansion joint:** It comprises of an extruded section of chloroprene held in position by edge beams made of either expanded or hot rolled steel section or cold rolled cellular steel sections with suitable profile to mechanically lock the sealing element. The edge beams are anchored to deck by reinforcing bars, headed studs or bolts or anchor plates. The working movement range of the sealing element shall be 70mm.
- (vii) Modular Strip Seal/Box Seal Joint:** A modular expansion joint consists of two or more modules so as to cater to a horizontal movement in excess of 70mm. It allows movement in all the three directions and rotation about all the three axes as per design requirement. During all movement cycles of the joint, opening or closing of all modules are equal.
- (viii) Special Joints:** For bridges having wide deck or span length of more than 120m or/and involving complex movements/rotations in different directions/planes provision of special type of modular expansion joints such as swivel joints may be made.
- (ix) Ministry of Road Transport & Highways, Govt. of India** vide their letters No.RW/NH-34059/1/96 S&R dated 31.3.97 and 17.7.97 have issued interim specifications for expansion joints and subsequent modifications in the list of manufacturers / suppliers which may be followed. Supply of new type of expansion joints may be obtained on the basis of competitive bidding from amongst the manufacturers/suppliers listed at Annexure-II to the above referred letter. Further, a warranty of 10 years of trouble free performance may be insisted upon from the contractors/suppliers for all type of joints except for buried joints and filler joints.

2.2.10. Corrosion protection measures:

Reinforced concrete has generally been considered to be a durable construction material. However, of late distress has been observed in several bridges primarily due to corrosion of embedded reinforcement. The cause of occurrence of corrosion is observed due to hot and aggressive environment, defective workmanship and presence of chloride both in ingredients and/or atmosphere.

It is generally agreed that corrosion does not occur when adequate cover is provided on rebars, aided by well compacted concrete, since both water and oxygen are required in free state to initiate corrosion which will not occur in dry concrete or totally submerged condition. It is, therefore, imperative to use design mix concrete as cited in the Ministry's specification and strict quality control may be observed especially in severe marine conditions. Many approaches are available to inhibit or delay the onset of corrosion in rebars such as (i) usage of inhibitors in concrete, (ii) application of surface sealant (on concrete), (iii) metallurgical improvements in steel, (iv) cathodic protection, and

(v) protective coatings on reinforcement. Ministry has brought out a circular vide No. RW/NH 34041/44/91-S&R dated 21.3.2000 giving detailed guidelines on use of fusion bonded epoxy coated reinforcement and other coatings for bridges on National Highways and other centrally sponsored bridges to be constructed in marine environment susceptible to severe corrosion which may be followed to reduce the chances of corrosion.

2.2.11. Design of river training and protective works

2.2.11.1 River training and protective works is required for ensuring the safety of bridges and their approaches on either side. The selection of the type of river training or protective work will depend upon terrain, overall behavior of the river, location of the bridge vis-à-vis the areas of attack of the river, span arrangement, nearness of the approaches from the influence zone of the river, etc. The types of river training and protective works generally being used are as follows:

- (i) Guide bunds
- (ii) Spurs or groynes
- (iii) River bank protection
- (iv) Approach road protection
- (v) River bed protection

The special features along with the broad design principles for each type are described in IRC:89-1987. "The Guidelines for Design and Construction of River Training and Protective Works for Road Bridges", which may be referred to for details.

2.2.12. Preliminary cost estimate

2.2.12.1 Preliminary cost estimate shall be a reasonably firm cost estimate on the basis of which administrative approval can be accorded. It shall be based on quantities worked out during preliminary design and current schedule of rates from which no major changes either in quantities or in rates shall normally occur except under totally unforeseen circumstances.

2.2.12.2 While preparing detailed project estimate, following additional points should also be kept in view:

- (i) Structural elements like light posts and cable ducts for electrification of new bridges of lengths 300m or more on National Highways may be provided, if required, and the cost thereof included in the estimate for the bridge proper provided that the Municipal Board/ concerned local authority is prepared to meet the initial cost as well as subsequent maintenance charges of electrical installations including cost of wiring, lamps etc. and also to bear the electricity charges. Accordingly, the estimate should be accompanied by a clear certificate from the local authority that is prepared to meet the cost of electric installations and maintenance charges.
- (ii) All proposals for reconstruction of existing weak bridges in National Highways should be accompanied with the rating of the bridges based on detailed provisions contained in IRC

Special Publication No. 9 "Report on rating of bridges" for proper appreciation. Further, the inspection of existing structure should be done for collection of data in accordance with the provisions contained in Chapter R-3 of the aforesaid publication and the required information furnished.

2.3. Detailed Project Preparation

2.3.1 Survey:

Determining the relative positions of points on the surface of the earth (all desirable points of the projected area) is an essential part of project preparation for bridge construction. Final selection of site, type of structure, type of foundation, span arrangement and alignment of approaches would be governed by the relative positions of various point of the site.

After collecting the data, preliminary design is to be undertaken keeping in view the data collected. As the preliminary investigation results are analyzed, there might be need for more details in particular areas. A further topographic survey may be required along the final alignment to verify the changes levels etc. based on detailed provisions contained in IRC: SP:54-2000, a review of the available topographic data should reveal the addition details required. Efforts should be made to collect these through and accurate instrument survey. The data collected should be accurate, detailed and exhaustive enough for use in the detailed designed stage.

Ground surveys conducted at site help in preparations of site map and river cross sections. Keeping in view that these maps are to be used in the identification of alternative locations and alignments, the surveys should be planned to be sufficiently exhaustive.

Establishment of permanent bench marks at site linked to GIS levels which are to be used during detailed survey, construction and maintenance must precede such survey.

Based on IRC: SP:54-2000 clause 5.6.3, for bridge projects across any stream / river, a hydrological survey should be carried out. The basic purpose of collecting hydrological data is to study the rainfall pattern (like intensity, duration, frequency) and run off characteristics of the basin under consideration and thereby determine the likely discharged through the channel, decide the optimum waterway for the bridge and determine the scour depth.

Based on IRC: SP:54-2000 clause 5.6.4 traffic survey should be carried out in accordance with the relevant IRC code (IRC:SP:19-2001).Traffic required to be conducted in connection with the preparation of project are as under :

Classified traffic volume counts.

- (i) Origin–destination surveys.
- (ii) Speed and delay studies.

- (iii) Traffic surveys for the design of road junction.
- (iv) Traffic surveys for replacing railway level crossings with over bridges/subways
- (v) Axle load surveys.
- (vi) Accident records.

2.3.2 Hydraulic Designs

Hydraulic designs done at the preliminary project report stage may be considered adequate unless special circumstances warrant updation of the same.

2.3.3 Surface and Subsurface Geotechnical Investigations

2.3.3.1 General.

The topography of J&K has naturally been gifted with one of the most diverse geological formations ranging from Greater/Intermediate/Lower Himalayas (Mountainous reaches) to Sub-Mountainous (Submontane or Foot-Hill reaches) to Plateau (Upland reaches) to Qasi-Alluvial (Trough reaches) to Alluvium (Alluvial reaches). While the network of our roads, and associated bridges, run across all such geological disposition, it is important to emphasize that very concentrated efforts are required, by executing divisions, to evaluate the surface and subsurface conditions at project sites, by way of coherent geotechnical investigation and application of appropriate geo-technique for facilitating/providing apposite foundation system, thereof.

Surface condition assessment generally includes geomorphology studies, geological mapping, geophysical and photogrammetric methods, while Sub-Surface condition assessment includes shallow or deep soil/rock sounding with sampling and testing so that design, constructability, soundness, safety, longevity of a given bridge project is duly achieved, with rational economics. Such assessment may also, customarily, form a part of other Techno-Economic Feasibility studies, based on which final proposal of bridge may be conceived.

The professional expertise, under subject domain of Surface and Sub-Surface investigation, for bridges, shall include a Geo-Structural/Geotechnical engineer, an Engineering Geologist/Geophysicist and a Hydrologist/ Hydro geologist.

2.3.3.2 Indian Standards Applicable: The mandate of following BIS/IRC Codes shall apply;

IS: 1498, IS:1888, IS: 1892, IS: 2131, IS:2132, IS:2720, IS:4434, IS: 4968, IRC:78, IRC:75, MoRT&H, IS:7292, IS:7317, IS: 7746, IS: 5313, IS: 4464, IS: 4078, IS:10042.

Specification for Road & Bridge Works, MORT&H, under section 2400 covers the requirements of Surface and Sub-Surface Geotechnical Investigations, which have been used as main source of reference literature, in this sub-section of manual.

2.3.3.3 Objective/Scope of Geotechnical Investigations

The principal objectives, that a competent surface/sub-surface investigation shall serve, for comprehensive planning, design and construction of bridge, are summarized below. This

information may get compiled and eventually completed during course of process for preliminary and detailed stages of investigation. However, it is very important to emphasize that construction stage conformation of characteristics of sub-surface geo-materials shall also form a critical part of geotechnical investigations. This is to rationally evaluate the design choices made and check if any requirement arises to make adaptive changes, particularly with regards to sub-structure/foundation support system.

- (i)** To assess and evaluate the nature of soil overburden or rock deposits, which includes Bore-Log for type of geo-material (soil/rock), thickness and spatial variation of various deposits of soil/rock, which are likely to support the foundations of bridge structure.
- (ii)** To determine location and extent of soft/compressible soil layers, presence of any potential localized gas bearing seams or gas pockets or cavities/hollows, which are critical to stability of foundations.
- (iii)** To determine the orientation (dip & strike) of founding rock beds, their fault patterns, location of fault and their activity, fissure/fracture frequency and their permeability.
- (iv)** Assessment of location of HFL/ subsoil water/ground-water and quality of water encountered in foundation zone. This shall include information about any potential artesian condition.
- (v)** In-situ engineering property assessment during Surface and Sub-surface exploration (SRM, ERM, GPR, SPT, DCPT, SCPT, Vane Shear Test, PMT, Drill advancement rate, RQD etc.,)
- (vi)** Assessment of Seismic Activity/Seismic disturbances based on past earthquakes and seismic-zoning of area. This may include liquefaction studies for major bridge projects and assessment of any reported potential liquefaction damages of proximate structures.
- (vii)** Evaluation of all pertinent indexes, physical and engineering properties of soil/rock, based on testing of representative disturbed and un-disturbed samples, retrieved during sub-surface exploration and correlation of same with geophysical data established during surface exploration.
- (viii)** To determine depth wise particle size distribution of representative samples of sub-soil, particularly for river banks/bed of active non-regime rivers, up to significant depth, to assess silt-factor and depth/extent of scour, thereof.
- (ix)** Clarity on stratum profiling and classification of soils/rocks, in particular, with details of density, frictional and pore structure properties, which can be prudent for determining sinking or driving or blasting efforts for foundation.
- (x)** Selection of foundation type and embedment depth, with assessment of load bearing capacity and settlement characteristics.
- (xi)** Assessment of stability aspects of riverbanks, potential identification of slope instabilities or landslides with may have direct repercussions on stability of major bridge components.

- (xii) Assessment of potential subsidence of any part of bridge component due to mining in close proximity.
- (xiii) Assessment of constructional difficulties.

The extent of information, listed above, may get compiled and eventually completed during course of process for preliminary and detailed stages of geotechnical investigations. However, it is very important to emphasize that construction stage conformation of characteristics of sub-surface geo-materials shall also form a critical part of geotechnical investigations. This is to rationally evaluate the design choices made and check if there is any potential requirement to make adaptive changes, particularly concerning sub-structure/foundation support system.

2.3.3.4 Field Investigation Program: Field investigations of sub-surface have usually three phases:

2.3.3.4.1 Reconnaissance: includes a review of available topographic and geological information, aerial photographs and data from previous investigations and site examination.

2.3.3.4.2 Preliminary Explorations: shall include the study of existing geological information, previous site reports, geological maps, aerial photos, etc. and surface geological examination. For large and important structures the information may be supplemented by geophysical methods. In some cases where no previous sub-strata data are available, exploratory geophysical investigation may need to be supplemented by resorting to a few bore-holes. These will help to narrow down the number of sites under consideration and also to locate the most desirable location for detailed sub-surface investigation like bore or drill holes, sounding probes, etc.

2.3.3.4.3 Detailed Explorations: The scope of detailed investigation for bridges may be decided based on data obtained after preliminary investigation so that the bridge site, type of structure with span arrangement and the location and type of foundations, can be tentatively decided. Thereafter, the scope of detailed investigation including the extent of exploration, number of bore-holes, type of soundings, type of tests, number of tests, etc., shall be decided, so that adequate data considered to be necessary for the detailed design and execution, are obtained.

2.3.3.5 Field Work: Soil investigation for foundations shall contain a programme for boring/drilling and retrieval of samples. The field work shall consist of excavation, drilling of bore-holes for the purposes of collection of undisturbed and disturbed samples, standard penetration tests, in-situ vane tests, static and dynamic cone penetration tests, other field tests, as specified by the Engineer and preparation of bore-logs. Collection, preservation and testing of disturbed and undisturbed samples, from bore holes, borrow pits, etc., as specified by the Engineer, shall form a part of the above. All in-situ tests shall be supplemented by laboratory investigations. Relevant Indian Standards such as IS: 1498, IS:1888, IS:1892, IS:2131, IS:2720, IS:4434 and IS:4698 and Appendix I of RIC:78, IRC:75 etc., shall be followed for guidance. The soundings by dynamic method shall be carried out in bore-holes using a standard sampler as specified in IS: 2131.

2.3.3.5.1 Location, Extent and Number of Boreholes:

The Specification for Road & Bridge Works, MoRT&H, section 2402, shall apply under this section. The type and extent of exploration shall be divided into the following groups as per requirement of foundation design and likely method of data collection:

- (i) Foundation requiring shallow depth of exploration
- (ii) Foundation requiring large depth of exploration
- (iii) Fill behind abutments and protection works

The exploration program shall cover the entire length of the bridge and also extend at either side for a distance about twice the depth below bed of the last main foundations. Bores shall be taken at the location of each pier and abutment of the bridge. In case of short-span bridges, it may be adequate if the boreholes are made at alternative pier positions. For long span of over 20m, it will be necessary to take bores at every pier and abutment location. For well and pile foundation, sometimes more than one bore at each pier location is desired, particularly if subsoil is rocky and un-even. For high value projects, it is desirable to have few representative bores in addition on the upstream and downstream of the alignment, to have an idea of the nature of change of strata along the river.

If there is any necessity for designing investigation for approaches particularly on soft soil or with high embankment or there is a possibility of considering alternatives between viaduct or earthen embankment, the extended length and location of the borings beyond the proposed location of abutment should be determined and executed, rationally. However, a minimum of two bores shall be taken in the approaches on either side, along the center line of the bridge alignment, at a distance of 50m and 120m behind the abutment positions. In case of viaducts in the approaches on either side of the bridge, bores shall be taken at the location of each foundation of the viaduct spans.

Wherever the data made available, by the detailed exploration, indicates appreciable variation or where variations in a particular foundation are likely to appreciably affect the construction (specially in case of bridge foundations resting on rock), it will be necessary to resort to additional bores/soundings, in transverse directions also, to establish complete profile of the underlying strata. The additional borings/soundings shall be decided depending upon the extent of variation at a particular foundation location and should cover the entire area of that particular foundation.

2.3.3.5.2 Depth of Bores:

The Specification for Road & Bridge Works, MoRT&H, section 2403, shall apply under this section.

Important Zones of Investigations:

The subsurface investigation for bridges shall be carried out on the following three zones:

- (i) Between bed level and up to anticipated maximum scour depth (below HFL).
- (ii) From the maximum scour depth to founding level.

(iii) From founding level to a significant depth below foundation, which is generally a factored value of width of foundation.

The depth of exploration should be at least 1½ times the width of foundation below the proposed foundation level. Where such investigation end in any unsuitable or questionable foundation material (or with doubtful bearing capacity) the exploration shall be extended to a sufficient depth into firm and stable soils or rock but not less than four times the width of foundation, below the earlier contemplated foundation level. In case of good sound rock with RQD of more than 75, the stipulation of minimum depth may be decreased based on difficulty to conduct core drilling and the minimum depth may be restricted to 3 meters.

2.3.3.5.2.1 Exploration for Embankments and Guide Bunds

For embankments and guide bunds, the depth of exploration should include all strata likely to affect stability of the embankment, guide bund and/or cause undesirable settlement. In general, the requirement of settlement governs the depth of exploration for high embankments in particular. Ordinarily, the depth of bore holes below the ground level may be taken up to 2.5 times the maximum height of embankment/guide bund. However, borings can be terminated at shallower depths when firm strata or bed rock is encountered. Where highly compressible strata are encountered, the boring may have to be taken deeper. In order to ensure that a firm stratum is sufficiently thick, the boring should extend 3 meter into the firm strata.

Detailed exploration for high embankments is to ascertain the average shear strength of each stratum and to ascertain the compressibility characteristics of the clayey strata. It is, therefore, necessary that detailed and well-illustrated description of the characteristics of stratification should be prepared. After the general shape and trend of the boundaries of the various soil deposits have been determined and rough assessment of their strength has been made by sub-surface sounding, with or without sampling in exploratory boring, the location of bore-hole(s) for undisturbed sampling shall be decided. At least one representative undisturbed sample should be collected from each strata. When the homogeneous strata is very thick, one representative sample shall be collected for each 3 m thickness of the strata. For guidance reference may be made to IRC 75.

Whenever a change in the sub-soil strata/rock profile is encountered during construction, further explorations shall be resorted to establish the correct data for further decisions and revisions of foundation designs, thereof.

Logging of bore-holes by radio-active methods shall be done for detailed investigations as specified in the contract or in special provisions.

2.3.3.6 Provisions for investigations for Bridge Foundations resting on Rock

The Specification for Road & Bridge Works, MoRT&H, section 2405, shall apply under this section. Investigation and interpretation of data for rock is a recognized as a specialized work, for which the services of an Engineering Geologist/Structural-Geologist, shall be necessarily availed. To arrive at the characteristic strength of rock mass, reliance shall be placed more on in-situ tests in comparison to laboratory tests.

Identification and classification of rock types for engineering purpose may, in general, be limited to broad, basic geological classes in accordance with accepted practice. Strength assessment shall be based on overall characteristics of rock formation like origin/nature of rocks, spacing and distribution of discontinuities of the rock mass, fracture/joint frequency, bedding planes, faults and presence of weathered seams. Another important factor affecting the behavior of the rock, as founding material, is the weathered zone at top. Assessment of foundations, resting over rock formations shall never be made based on strength of parent rock, alone.

Categorization of rocky subsurface shall also be explicitly made like; Sound Rock ($\geq 85\%$ core recovery), Medium Rock ($\geq 50\%$ core recovery), Intermediate Rock ($\geq 35\%$ core recovery) and Soft Rock ($< 35\%$ core recovery but Standard Penetration Resistance value "N" is > 50). For core recoveries less than 20%, the subsoil strata must be treated as soil, instead of rock.

2.3.3.6.1 Information required from exploration/investigation within rock/rock-mass

Following information shall be deemed mandatory:

- (i) Identification and characterization of Geological System.
- (ii) Depth of rock strata and its variation over the site, particularly over length of bridge.
- (iii) Whether subsurface consists of an isolated boulder or a massive/continuous rock formation, particularly if met with at shallow or erratic depths in adjacent bores,
- (iv) Extent/thickness and character of weathered zone,
- (v) Structure of rock - including bedding planes, faults, fissures, solution cavities etc.,
- (vi) Properties of rock material-strength, geological formation, etc,
- (vii) Erodibility of rock to the extent possible, where relevant, particularly when met at shallow depths,
- (viii) Color, quality and quantity of water coming out during drilling operation.
- (ix) Seismicity of the area, based on macro/micro zonation.

2.3.3.6.2 Extent of Investigation within rock/rock-mass

If preliminary investigations have revealed presence of rock within levels where the foundation is to rest, it is essential to take up detailed investigation to collect necessary information mentioned, above. The exploratory bore-hole shall be drilled into the rock to a depth of about 3 meters to distinguish a boulder from a continuous rock formation.

The extent of exploration shall be adequate enough to cover the whole area of the bridge site for general characteristics and in particular, the foundation location, to obtain definite information regarding depth of rock and its variation over the foundation area. A complete picture of the rock profile both in depth and across the channel width is necessary to assess the constructional difficulties in reaching the foundation levels. The detailed programme of exploration will depend on the type and depth of over-burden, the size and importance of the structure, etc. To decide this, geophysical methods adopted at the preliminary investigation stage will be helpful, this data being supplemented by sounding, bore-holes and drill holes.

The depth of boring in rock depends primarily on local geology, erodibility of the rock, extent of structural loads to be transferred to foundation etc. Normally, it shall pass through the upper weathered or otherwise weak zone, well into the sound rock. Minimum depth of boring in sound rock shall be 3.0meters.

As stated earlier, the drilling through rock is a very specialized work and every care shall be taken to notice and record any small change during drilling. The time required to drill through a certain depth, amount of core recovery, physical condition, length of pieces of core, joints, color of water residue, weathering and evidence of disturbance and other effects shall be carefully noticed and entered in the drilling log. For guidance, IS: 5313 may be referred to. The data shall be presented in accordance with IS: 4464. The cores shall be stored properly in accordance with IS: 4078.

2.3.3.6.2.1 Testing of Rocks

The rock cores obtained shall be subjected to following tests:

- (i) Visual identification for texture, structure, composition, color and grain size.
- (ii) Laboratory tests shall be done for specific gravity, porosity and moisture content.

Use of in-situ tests for measuring strength and deformation characteristics shall be made. In-situ tests shall be made in accordance with IS: 7292; IS:7317; and IS:7746. Use of bore-hole photography will be desirable to evaluate the presence of faults, fissures or cavities, etc.

The quality of rock cores shall be classified according to Rock Quality Designation as presented in **Table: 2.3**, below;

| TABLE-2.3 Classification of Rocks as per RQD | | |
|---|--------------------|---------------------|
| S.No | RQD Percent | Core Quality |
| 1. | 90-100 | Excellent |
| 2. | 75-90 | Good |
| 3. | 50-75 | Fair |
| 4. | 25-50 | Poor |
| 5. | 25 | Very Poor |

2.3.3.6.3 Gravel-Boulder Deposits

Investigation for foundation in Gravel-Boulder Deposits shall conform to specifications of IS: 10042.

2.3.3.6.4 Caution

The interpretation of laboratory results on rock samples depends upon the relationship of the specimens tested to the overall rock characteristics, enumerated in Appendix 1 of IRC: 78. For this purpose, care shall be exercised in the choice of specimen size and its orientation in relation to the joint pattern.

In some cases, the foundation behaviour will be dominated by a possible mode of failure involving movement along some joint surface, fissures or weak layer within a generally strong rock system and also by possible weathering. In-situ shear tests may be conducted wherever feasible, as such tests are likely to give more representative data than the shear tests conducted on core samples.

2.3.3.6.5 Presentation of Data

The data shall be given in diagrammatic form in 3 sheets giving the following details:

Sheet 1: Plan showing the position of bore-holes clearly marked so as to fix the position/location at a future date.

Sheet 2: This shall contain the bore-log chart and test results of the samples separately for each bore-hole/pit etc.

Sheet 3: This shall contain pictorial representation of the bore-log data to get an overall picture of the soil profile at the cross section of the river.

Schematics representation of typical subsoil profile, the actual bore-log and cross-sectional representation of the river, along the bridge, as per IRC: 78-2014, is reproduced at **Fig-2.2a to Fig-2.2c**, below.

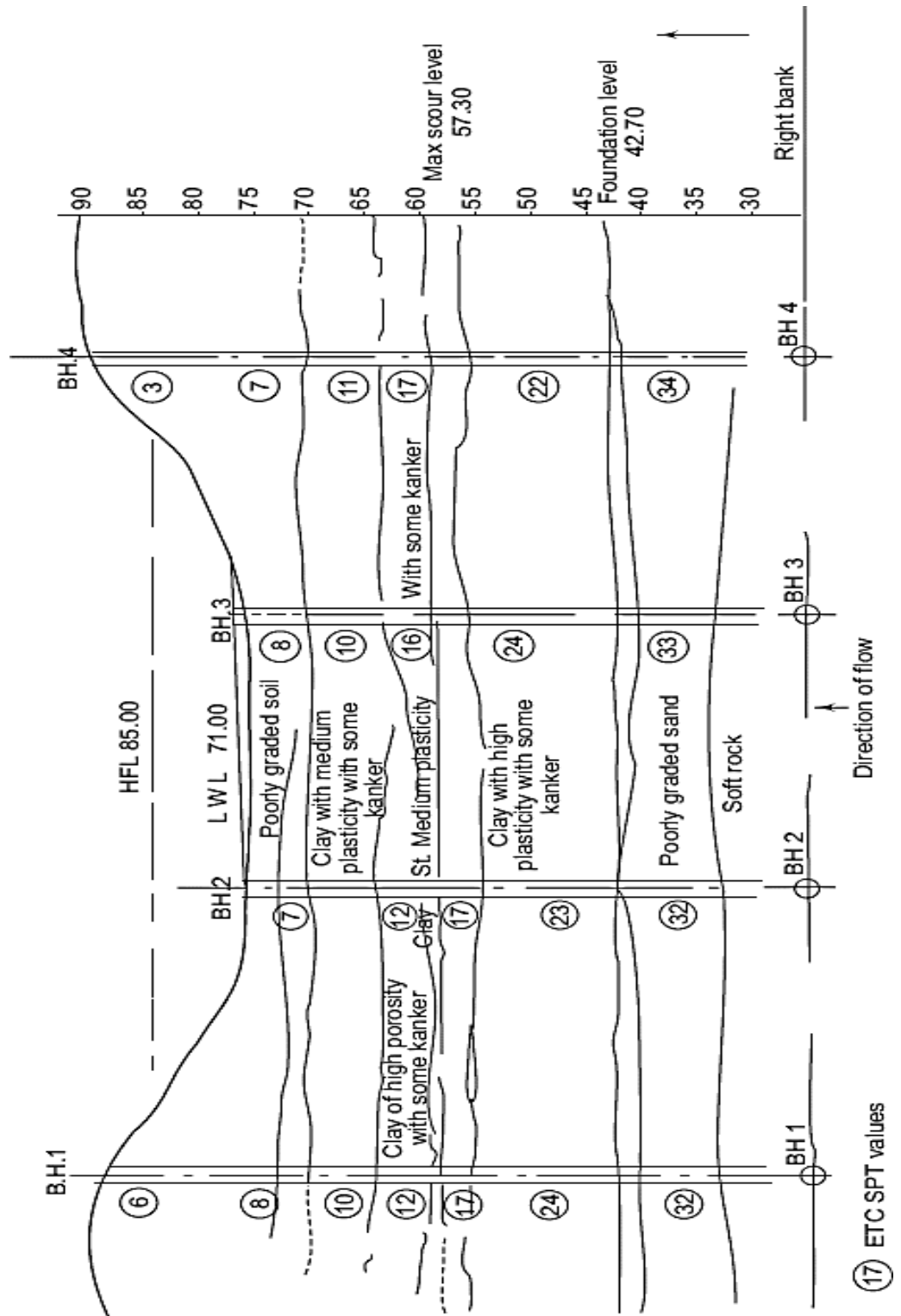


Fig-2.2a: Schematics of typical subsoil profile.

Fig-2.2b: Typical bore-log.

REFER TO IRC 78:2014
PAGE NO.65

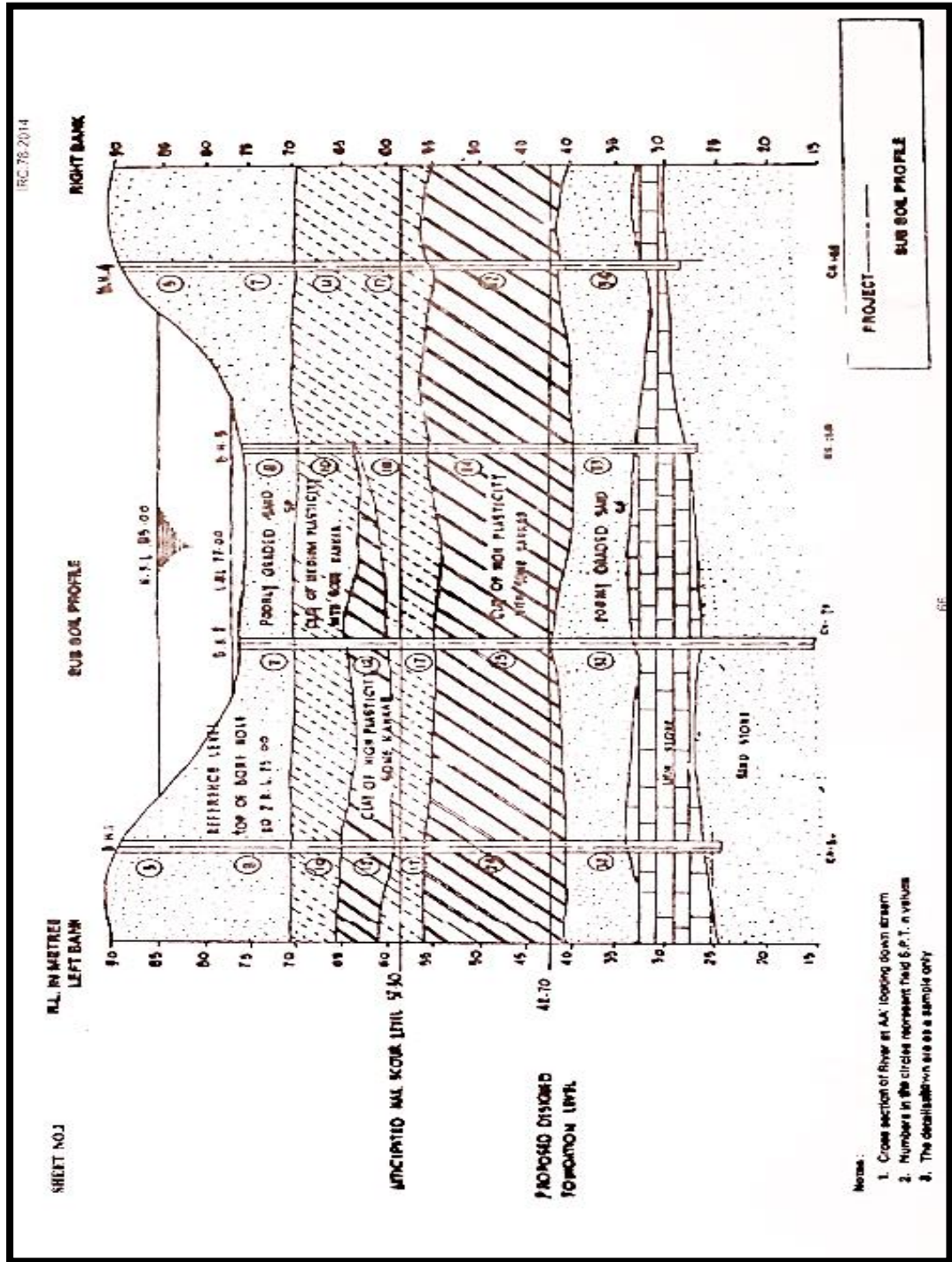


Fig-2.2c: Typical Cross-Section indicating subsoil profile.

2.3.3.7 Boring/Drilling Operation

The Specification for Road & Bridge Works, MoRT&H, section 2406, shall apply under this section. The exploratory boreholes in soils/rocks shall be executed by any of the following methods, depending on the soil/rock type and types of samples required for the investigation:

- (i) Auger Boring
- (ii) Shell and Auger Boring
- (iii) Percussion Boring
- (iv) Wash Boring
- (v) Rotary Boring/Drilling.

Details specifications as per IS: 1892, IS:2132 may be referred.

For preliminary and detailed sub-surface investigation only rotary drills shall be used, in case of rocks. The casing, in such cases, shall also be invariably provided with diameters not less than 150 mm up to the level of hard rock, if any. However, use of percussion or wash boring equipment shall be permitted only to penetrate through bouldery or gravelly strata for progressing the boring but not for the collection of samples. While conducting detailed borings, the resistance to the speed of drilling i.e. rate of penetration, core loss, etc., as already specified in Annexure of IRC: 78, shall be carefully recorded, to evaluate the different types of strata and to distinguish specially sand from sandstone, clay from shale, etc.

2.3.3.7.1 Records of Boring and Trial Pits

The Specification for Road & Bridge Works, MoRT&H, section 2407, shall apply under this section. The field records for the preliminary and detailed exploration shall contain the date when the boring was made, the location of the boring with reference to a permanent system of co-ordinates (Geo-tagging/GPS marking is desirable) and the elevation of the ground surface with respect to a permanent bench mark. They shall include elevation at which the water table and the upper boundary of each of the successive soil strata were encountered, the investigator's classification of the layer on the basis of general information obtained from field examination (refer to Appendix 2.1 of IRC:75) and the value of the resistance obtained by means of Standard Penetration Test. The type of tools used for borings shall be recorded. If the tools were changed, the depth at which the change was made and the reason thereof shall also be noted. Incomplete and abandoned borings shall be described with no less care than successfully completed drill holes. The notes shall contain everything of significance observed on the job such as the elevation at which wash water was lost from the hole.

2.3.3.7.2 Information in Boreholes/Trial pits.

For all borings and trial pits, necessary information as detailed below shall be given. A site plan showing the disposition of the bore holes shall also be attached:

- ❖ Name of Agency.
- ❖ Location with reference map.
- ❖ Pit/Bore-hole number.
- ❖ Reduced level (RL) of ground surface or other reference point.

- ❖ Dates of starting and completion.
- ❖ Name of supervisor.
- ❖ Scales of plans and sections.
- ❖ Description of methods of advancing exploration such as; by hand tools, blasting, boring, etc.
- ❖ General description of strata met with and RLs at which they are met.
- ❖ Position and altitude of contracts, faults, strong joint, slicken sides, etc.
- ❖ Inflow of water, methods of controlling the water, required capacity of pumps for dewatering
- ❖ The level at which the sub-soil water is met with.
- ❖ Dip and strike of bedding and of cleavage
- ❖ Visual description of strata
- ❖ Results of field tests e.g. SPT, in-situ vane shear test etc.
- ❖ Any other information and remarks.
- ❖ The length of the sample in the tube and the length between the top of the tube and the top of the sample, in the tube, shall be measured and recorded, upon removal of sampling tube.

2.3.3.8 Method of Sampling.

The Specification for Road & Bridge Works, MoRT&H, section 2408, shall apply under this section

2.3.3.8.1 Soil Sampling.

The details for method of sampling may be referred from IS:1892 & IS: 2132 and process of sampling shall conform to same. For proper identification of sub-surface material, sample should be recovered containing all the constituents of the materials in their proper proportion. In clayey deposits such samples could be collected by spilt spoon samplers. In the case of sandy deposits, sampling spoons shall be fitted with suitable devices for retaining samples. All data required for soil identification (Appendix 2.1 of IRC:75) should be collected from the samples so extracted when undisturbed samples, which are more desirable for collection of some of the data, are not available. Penetration test should be carried out with the standard split spoon sampler or penetrometers if the soil is coarse grained. When it is known in advance that the soil profile is fairly regular, preliminary and detailed investigation may be combined. Tube samplers can be used in place of split spoon samplers for collecting samples in clayey strata.

Generally there are two types of samples viz. (a) Disturbed sample (b) Undisturbed sample for both soils and rocks, as presented below in Table-2.4.

Table- 2.4 Type and method of sampling for various ground characteristics.

| Nature of Ground | Type of Sample | Method of Sampling |
|------------------|----------------|--|
| Soil | Disturbed | Hand Samples Auger Samples Shell Samples |
| | Undisturbed | Hand Samples Tube Samples |
| Rock | Disturbed | Wash Samples from Percussion of rotary drilling |
| | Undisturbed | Cores |

2.3.3.8.1.1 Disturbed Soil Samples

Disturbed samples of soil shall be obtained in the course of excavation and boring. For procuring samples from below the ground water level, where possible, special type of sampler shall be used. Where Standard Penetration Test is conducted, representative samples shall be obtained from the split spoon. While collecting disturbed samples from borrow areas it shall be ensured that the samples collected represent all types of borrow materials to be used in the construction of embankment and sub-grade. The size of sample generally required shall be as given in Table-2.5.

Table-2.5 Size/Magnitude of sample required for various Soil types.

| S.No. | PURPOSE OF SAMPLES | SOIL TYPE | WEIGHT OF SAMPLE REQUIRED (Kg) |
|-------|---|--------------------------|--------------------------------|
| 1 | Soil identification, natural moisture content tests, mechanical analysis and index properties, chemical tests | Cohesive soils | 1 |
| | | Sands and Gravels | 3 |
| 2 | Compression tests | Cohesive soils and sand | 12.5 |
| 3 | Comprehensive examination of construction material and borrow area soil including soil stabilization. | Cohesive soils and sands | 25 - 50 |
| | | Gravelly soil | 50 – 100 |

While taking out disturbed soil samples, Standard Penetration Test may also be conducted to find out the bearing capacity of the sub-soils at specified levels.

2.3.3.8.1.2 Undisturbed Soil Samples

For undisturbed sampling procedure, the samples shall be obtained in such a manner that their moisture content and structure do not get altered. This may be ensured by use of correctly designed sampler and by careful preservation, packing and transportation.

Standard Penetration Test may have to be conducted in each case to obtain additional data as directed by the Engineer. In soft clay, in-situ vane shear test as per IS: 4434 may have to be conducted. Where all the three operations have to be carried out in one layer, the sequence shall be undisturbed soil sampling followed by in-situ vane shear test, followed by Standard Penetration Test.

For compression test samples, a core of 40 mm diameter and about 150 to 200 mm length may be sufficient, but for other laboratory tests, a core of 100 mm diameter and 300 mm length shall be taken as far as possible, unless otherwise specified by the Engineer. The upper few millimeters of both types of sample shall be rejected as the soil at the bottom of the borehole usually gets disturbed by the boring tools.

2.3.3.8.2 Rock Sampling.

2.3.3.8.2.1 Disturbed samples: The sludge from percussion borings or from rotary borings which have failed to yield a core, shall be collected for a disturbed sample. It may be recovered from circulating water by settlement in a trough.

2.3.3.8.2.2 Undisturbed samples: Block samples taken from the rock formation shall be dressed to a size of about 90 x 75 x 50 mm.

For core samples within rocks, the cores of rock shall be taken by means of rotary drills fitted with a coring bit with core retainer, if warranted.

In case of rock at shallow depths which can be conveniently reached, test pits or trenches are the most dependable and valuable methods since they permit a direct examination of the surface, the weathered zone and presence of any discontinuities. It is also possible to take representative samples for tests. For guidance, IS: 4453 may be referred to.

2.3.3.8.3 Preservation, Handling and Labeling of samples.

The Specification for Road & Bridge Works, MoRT&H, section 2410, shall apply under this section. Care shall be taken in handling and labeling of samples so that they are received in a fit state for examination and testing and can be correctly identified as coming from a specified trial pit or boring. The disturbed material in the upper end of the tube shall be completely removed before applying wax for sealing. The length and type of sample so removed should be recorded.

The soil at the lower end of the tube shall be removed to a distance of about 20 mm. After cleaning, both ends shall be sealed with wax applied in a way that will prevent wax from entering the sample. Wax used for sealing should not be heated to more than a few degrees above its melting temperature. The empty space in the samplers, if any, should be filled with moist soil, saw dust, etc., and the ends covered with tight fitting caps.

Labels giving the following information should be affixed to the tubes.

- ❖ Job designation

- ❖ Sample location
- ❖ Boring number
- ❖ Tube number
- ❖ Sample number
- ❖ Depth
- ❖ Penetration
- ❖ Gross recovery ratio

The tube and boring numbers should be marked in duplicate. The duplicate markings of the boring number and sample number on a sheet which will not be affected by moisture should be enclosed inside the tube.

2.3.3.9 Exploration of Shallow Foundations of Bridges.

The Specification for Road & Bridge Works, MoRT&H, section 2412, shall apply under this section. Test pits or trenches are the most dependable and valuable methods of exploration since they permit direct visual examination and more reliably the type of soil and their stratification. This will also allow in-situ tests like plate bearing tests, shear tests and uni-axial jacking tests, etc. Tests shall be conducted on undisturbed samples, which may be obtained from open pits. The use of Plate Load Test (as per IS: 1888) is considered desirable to ascertain the safe bearing pressure and settlement characteristics. A few exploratory bore holes or soundings shall be made to safeguard against presence of weak strata underlying the foundation. This shall extend to a depth of about 1½ times the proposed width of foundation.

The laboratory results shall correlate with in-situ tests like Plate Load Tests and Penetration Test results.

2.3.3.10 Exploration of Deep Foundations of Bridges.

The Specification for Road & Bridge Works, MoRT&H, section 2412, shall apply under this section. The tests to be conducted at various locations for properties of soil, etc., are different for cohesive and cohesionless soils. These are enumerated below and shall be carried out, wherever practicable, according to soil type.

2.3.3.10.1 Tests for Cohesionless soil

- a) Field tests
 - ❖ Plate Load test as per IS: 1888
 - ❖ Standard Penetration test as per IS: 2121.
 - ❖ Dynamic Cone Penetration test as per IS: 4698 (Part 1 or Part 2)
 - ❖ Static Cone Penetration test as per IS:4968 (Part 3)
- b) Laboratory tests

- ❖ Classification test, index tests, grain size distribution, density/density index etc.
- ❖ Shear Strength by direct shear/triaxial shear test method.
- ❖ Permeability/hydraulic conductivity tests (Where dewatering is expected, IS: 2720 Part 17).

2.3.3.10.2 Tests for Cohesive soil

c) Field tests

- ❖ Plate Load test as per IS: 1888.
- ❖ Standard Penetration test as per IS: 2121.
- ❖ Dynamic Cone Penetration test as per IS: 4698 (Part 1 or Part 2)
- ❖ Static Cone Penetration test as per IS:4968 (Part 3)
- ❖ Vane Shear test as per IS:4434.

d) Laboratory tests

- ❖ Classification test, index tests, grain size distribution, density/density index etc.
- ❖ Shear Strength by direct shear/triaxial shear test method.
- ❖ Unconfined Compression test as per IS:2720 Part-10.
- ❖ Consolidation test as per IS: 2720 Part-5.
- ❖ Permeability/hydraulic conductivity tests (Where dewatering is expected, IS: 2720 Part 17).

2.3.3.10.3 Tests for Subsoil Water

The sub-soil water shall be tested for chemical properties to ascertain the hazard of deterioration to foundations.

2.3.3.11 Testing of material for foundation of guide bund and High Embankments.

The Specification for Road & Bridge Works, MoRT&H, section 2413, shall apply under this section.

The soil properties for the embankment foundation shall be as specified in particular specifications and shall be got verified prior to construction operation. In case the actual soil properties do not match the particular specification, then embankment design shall be revised. Field investigation for the embankment material should be carried out to collect general information as indicated in IRC: 75.

Field investigations for sub-soil strata shall consist of taking minimum two bore holes for each approach to a bridge along center line of the alignment at a distance of 50 m and 120 m behind the abutment positions on both sides. The depth of bore holes below the ground level may ordinarily be 2.5 times the maximum height of the embankment subject to minimum depth of 20 m. Thin walled sampling tubes of 100 mm internal diameter and 450 mm minimum length conforming to IS: 2132 shall be used for collecting undisturbed samples from bore-holes at an interval of 2.5 to 3.5 m. Standard penetration test should be conducted immediately after undisturbed sample is collected.

In addition to the relevant identification tests, mentioned in IRC:75, it shall be necessary to conduct some of the following tests (Table-2.6) on the undisturbed samples collected from the sub-strata for stability analysis of embankment. The choice of test is primarily determined by the type of soil, type of stability analysis, availability of apparatus and cost of investigation.

Table-2.6 Shear Strength Tests for Stability Analysis of Embankments

| S.No. | Stage in Life of Embankment | Strength Parameters | Shear Test | Type of Analysis |
|-------|--|---------------------|--|---------------------------|
| 1. | (a) During construction or immediate post-construction | C_{uu}, ϕ_{uu} | Unconsolidated undrained triaxial shear test on undisturbed samples and on compacted embankment material | Total stress analysis |
| | (b) - do - | S_u | Unconfined compression test in laboratory or vane shear test | - do - |
| | (c) During construction or immediate post-construction | $C'\phi'$ | Consolidated undrained test with pore-pressure measurement on as compacted soil samples of embankment materials and on undisturbed samples | Effective stress analysis |
| 2. | Long term stability | $C'\phi'$ | - do - | - do - |

While compiling a geotechnical report for embankment, results of reconnaissance, filed investigations, location map, sub-soil profile, pertinent geological information, boring logs, subsoil properties, graphs, tables related to laboratory investigations, results of borrow area investigations, as per recommendations of IRC: 75 must be adhered.

2.3.3.12 Subsurface investigation for Piles.

The Specification for Road & Bridge Works, MoRT&H, section 1102, shall apply under this section. The complete sub-surface investigation of strata in which pile foundations are proposed shall be carried out in advance and by in-situ pile tests. At least one bore-hole for every foundation of the bridge shall be executed. Boring should be carried upto sufficient depths so as to ascertain the nature of strata around the pile shaft and below the pile tip. However, depth of boring shall not be less than following:

- a) 1.5 times estimated length of pile in soil but not less than 15 m beyond the probable length of pile.
- b) 15 times diameter of pile in weak/jointed rock but minimum 15 m in such rock.
- c) 4 times diameter of pile in sound, hard rock but minimum 3 m in such rock.

The sub-surface investigation shall define adequately stratification of sub-strata including the nature and type of strata, its variation and extent and specific properties of the same. The investigation shall be adequate for the purpose of selection of appropriate piling system and for estimating design capacities for different diameters and length of piles.

Pressure meter tests may be used in the case of rock, gravel or soil for direct evaluation of strength and compressibility characteristics. Though these tests are of specialized nature they are most appropriate for difficult/uncertain sub-strata especially for important projects.

For piles socketed into rocks, it is necessary to determine the uniaxial compressive strength of the rock and its quality. The investigation shall also include location of ground water table and other parameters including results of chemical tests showing sulphate and chloride content and any other deleterious chemical content in soil and/or ground water, likely to affect durability.

2.3.3.13 Presentation of Surface, Sub-Surface Investigation.

Preliminary or Detailed surface or subsurface investigation shall be compiled and presented in the form of a Competent Geotechnical Investigation Report, with following minimum typical contents, as per Table-2.7.

Table-2.7 Typical Content of a Geotechnical Investigation Report

| S.No | Content Description |
|------|---|
| 1 | <p>General</p> <p>1.1 Introduction.</p> <p>1.2 Project Description & Scope of Investigation Work.</p> <p>1.3 Previous preliminary investigation inputs/reports.</p> |
| 2 | <p>Geologic Condition & General Reconnaissance</p> <p>2.1 Regional/Local Geologic Assessment.</p> <p>2.2 Seismicity/Anticipated Geological Hazard.</p> <p>2.3 Climatic Conditions.</p> <p>2.4 Site Accessibility.</p> <p>2.5 Reported Highest Flood Level & History of Scour from Water Courses.</p> |
| 3 | <p>Field/ Reconnaissance Exploration Protocol.</p> <p>3.1 Site Selection and Extent of Investigation.</p> <p>3.2 Exploration Methodology (Boring/Open Excavation/Drilling).</p> <p>3.3 Sampling Practice (UDS/RD/DS/).</p> <p>3.4 Sub-Soil Water/Seepage Conditions.</p> <p>3.5 Field Bore Logs & General Stratification/ Stratum Profiling.</p> |

| | |
|----------|---|
| 4 | <p>Laboratory Investigations/Testing Protocol.</p> <p>4.1 Soil/Rock Identification/Classification Tests (Index Properties).</p> <p>4.2 Soil/Rock Strength Characterization.</p> <p>4.3 Soil/Rock Compressibility/Compaction Characterization.</p> <p>4.4 Ground /Soil-Water Characterization.</p> <p>4.5 Chemical Analysis.</p> |
| 5 | <p>Foundation Analysis Criterion & Design Parameters.</p> <p>5.1 Analysis Criterion (BIS-Code of Practice).</p> <p>5.2 Geometrical Parameters & Assumptions for Analysis Criterion.</p> <p>5.3 Liquefaction Potential & Probable Ground Damage.</p> <p>5.4 Silt-Factor and Scour Depth (if applicable).</p> |
| 6 | <p>Analysis of Results & Recommendations.</p> <p>6.1 Bearing Capacity Analysis & Results.</p> <p>6.2 Pile Capacity Analysis & Results.</p> <p>6.3 Design inputs for Well-Foundations.</p> <p>6.4 Design inputs for Retaining Fronts.</p> <p>6.5 Design inputs for Excavated Material and its suitability of use.</p> <p>6.6 Design inputs for Approach Embankments.</p> <p>6.7 Recommendations for Bearing Capacity.</p> |
| 7 | <p>Critical Comments/Discussions & All Technical Recommendations.</p> |
| 8 | <p>Appendix</p> <p>Appendix-A (Field Bore Logs with location GPS coordinates).</p> <p>Appendix-B (Laboratory Test Results).</p> <p>Appendix-C (Nomenclature).</p> <p>Appendix-D (References: Codal Specifications, Literature/Internet citations)</p> <p>Appendix-E (Geo-tagged Site Photo Manifestations)</p> |

2.3.3.14 Measurement for Payment and Rate.

The Specification for Road & Bridge Works, MoRT&H, section 2414, shall apply under this section.

In case of bridge and road structures, the work of boring and trial pits shall be considered as incidental to the foundation works and nothing extra shall be paid unless otherwise specified in the contract. In cases where it is specified to be paid separately, like contract for soil investigation, the

work shall be measured in running meters for boring, in cubic meters for trial pits, in number of samples for collection of disturbed and undisturbed samples and in number of tests for each type of test.

The contract unit rate shall include the cost of all labour, materials, tools and plant and equipment required for doing the boring or making pits as per these specifications, taking out and packing the samples, sending and getting them tested in approved laboratories and making available the test report as specified or directed by the Engineer inclusive of all incidental costs to complete the work as per the specifications.

2.3.4. Detailed Structural Design

2.3.4.1. Preferably detailed design should be done top downwards, i.e. Superstructure to be finalized first, bearings next and so on, though it is started from foundation onwards in design and build contracts.

2.3.4.2. Superstructure

- (i) Detailed design and detailing of each of the elements of the superstructure have to be done during this phase.
- (ii) In case computer programmers' are used for the analysis and/or detailing, it has to be ensured that the programmer has been adequately validated.

Also listing of input data and input values needs to be thoroughly checked and indicated for verification by approving authority.

2.3.4.3. Bearings: Detailed design of bearings shall conform to IRC: 83 Parts I & II for metallic and neoprene bearings and in case of special type of bearings like POT/PTFE bearings, specialized literature and codes and Ministry's Specifications for Roads & Bridge Works Section 2000 clause 2006 may be referred and complied with.

2.3.4.4. Substructures: Unlike the typical design in preliminary stage, while preparing detailed design all individual piers, abutments, return walls etc. which have any difference with regard to the forces acting, height of substructure etc. have to be separately analyzed and designed individually if economy/safety demands so.

2.3.4.5. Foundation: In the case of foundations also each individual foundation has to be designed separately during the detailed design stage taking into account difference in founding levels and the subsoil data as obtained at each of the individual foundation locations during detailed subsurface investigations.

2.3.4.6. Secondary elements: Detailed design of secondary elements like railings/crash barriers, expansion joints, kerbs, footpaths, approach slab etc. have also to be included in the D.P.R.

2.3.5 Detailed estimate

2.3.5.1. Detailed Estimate shall be based on detailed items of work constituting the construction of proposed bridge with an unerring precision which shall not deviate the final bill unless under unforeseen circumstances. The items of the estimate may be arranged systematically in the following order.

- (i) Preparatory works
- (ii) Foundation
- (iii) Substructure
- (iv) Superstructure
- (v) Protection Works/ River training works
- (vi) Miscellaneous items
- (vii) Sub-estimate for approaches
- (viii) Centage charges like quality control contingencies work charged establishment and agency charges.
- (ix) Clearance of accumulated debris during and after foundation works which may constrict / obstruct the water way.

2.3.5.2. The bill of quantities have to be based on detailed quantity estimates which again have to be based on detailed design and dimensions so arrived at for all the elements of the bridge on SSR latest.

2.3.5.3. The rates adopted shall be the current schedule of rates applicable for the region and wherever same items are not covered by the schedule, the rate for the same shall be based on detailed analysis of rates in vogue.

2.3.5.4. The abstract of cost estimate containing the complete nomenclature of each item of works, final quantities as worked out in the detailed estimate, rates as in Para 2.3.5.3 cost of each item and remarks, if any, shall invariably form part of the detailed estimate.

2.3.6 Detailed project report:

Detailed Project Report should contain the following live volumes namely:

- 1) Final Report
- 2) Detailed Designs
- 3) Detailed Estimate
- 4) Detailed Bill of Quantities and Specifications
- 5) Detailed Drawings.

2.3.6.1. Final report: The final Report should contain:

- (i) Introductory report indicating the location of the bridge, the need for the same, the population and economic activities likely to be served by the bridge, alternative sites considered and the aspects in favor of the site finally selected.
- (ii) Design data for the bridge including survey data, hydraulic data and subsoil data.
- (iii) Detailed information on the general arrangement selected for the bridge and the factors favoring the choice.
- (iv) Report on the environmental impact assessment as per the format laid in JKPWD Manual 2020 appendix 100.2.
- (v) A schedule of construction including a CPM chart in case of major projects; and at least a Bar chart indicating important mile stones in other cases.
- (vi) After analyzing various economical options in preliminary designs, the final most economical design should be adopted in detailed project report.

2.3.6.2. Detailed designs: Detailed design sheets of all components of the bridge have to be included in this volume.

2.3.6.3. Detailed estimate: This volume should contain all the items covered under Para 2.3.5.

2.3.6.4 Detailed bill of quantities and specifications: The detailed bill of quantities should contain the reasonably firm quantities of each item of work forming part of the project worked out on the basis of detailed drawings. The detailed specifications of each of the items of the project.

2.3.6.5 Detailed drawings: This volume should contain the following:-

- (i) Index plan
- (ii) Site plan
- (iii) At least three cross sections of the river.
- (iv) A longitudinal section connecting the cross section points.
- (v) A contour survey plan
- (vi) Bore log data
- (vii) A general arrangement drawing of the bridge superimposed on the cross section of the river at the proposed site also indicating the bore details
- (viii) Detailed drawings of all the components of the bridge
- (ix) Complete details of existing bridges, if any
- (x) Plan and L section of approaches
- (xi) Cross section of approaches
- (xii) Detailed drawings of CD. Works

(xiii) Miscellaneous drawings

2.3.6.6 Bridge Utilities: -Bridges don't just help people and vehicles move from place to place, although that is their most visible function. Bridges in fact serve as a supporting structure for lots of utilities. Everything from water supply pipe lines, electric cables to fiber optic cables runs through the space running throughout the bridge.

Without bridges, pipeline would need to be buried or suspended in the air. Bridges protect these utilities from threats like weather, animals and other accidents. Bridge – attached utilities are far easier to access and maintain than utilities installed underground.

Here are few reasons why bridge attached utilities should be installed by experts in conjunction with the construction of a new bridge, not after the job.

- (i) Holistic design always creates a higher performing product. When utility pipelines are considered during construction, the entire structure can be designed and built with pipelines, joints and maintenance access points in mind.
- (ii) Integrated design reduces the risk of unforeseen consequences of a new utility installation such as weakening of bridge component or stress on the structural support.
- (iii) When designed specifically for a place and time rather than implemented ad-hoc, utility components can be matched specifically to the bridge including its materials and aesthetics.

2.3.6.6.1 Provision for Utilities as specified in IRC: 5-2015

A Bridge structure shall cater for fixtures for electric posts, lamps posts and suitable ducts for carrying electric cables etc. as required to cater for utility services.

Utility services like cables, and pipelines for water, gas, petroleum products resting directly on bridge structures should be avoided. These may be placed on a structures supported on piers and abutments.

While planning, there is need for proper accessibility of the services utilities for inspection and maintenance without hindrance to traffic moments.

3. CONSTRUCTION

3.1 General

3.1.1 The construction of a bridge involves building of its various components such as foundation, substructure, superstructure and other ancillary works which include construction of approaches, finishing works and protective works for the bridge.

3.1.2 The execution of a bridge may be taken up departmental or through a contracting agency. Before start of construction work, care must be taken to ensure that the following documents are available:

- (i) Sanction letter and technical note, if any.
- (ii) Bill of quantities.
- (iii) Copy of contract document along with any special conditions thereof.
- (iv) Copy of approved set of plans and detailed working drawings.
- (v) Survey, investigation and sub-soil test reports.
- (vi) Standards, specifications, guidelines, codes of practices etc., according to which the work must be executed as per contract.

All the above documents shall be as per the format already laid down in JKPWD Manual 2020.

3.1.3 Finalize the site and decide location of site office, storage sheds, batching plant, casting yard, labour camp etc. to be checked w.r.t HFL, flood plains etc.

3.1.4 Identify sources of construction materials like sand, coarse aggregate and boulders etc. and supply of cement and steel including the time required in transportation of these materials to the site of work.

3.1.5 Draw a detailed work program (CPM) on the basis of availability of plant, equipment, material, manpower etc. Refer IRC Special Publication No. 14 - A manual for application of the critical path method.

3.1.6 Identify major milestones to serve as important dates for reviewing the progress of work.

3.1.7 After having cleared the site, transfer the alignment of the bridge and ground with the help of reference pillars fixed at site during the location survey. Fix up permanent bench marks, reference pillars. Use Auto levels, accurate theodolite, total station and other precision electronic instrument.

3.1.8 The construction of various components of bridge works, protective works shall conform to ministry's Specification for Road and Bridge Works and relevant IRC Bridge Codes/Standards.

3.2 Formwork and Staging

Formwork shall include all the temporary and permanent forms required for forming the concrete of the shape, dimensions and surface finish as shown on the drawing or as directed by the

Engineer, together with all props, staging, centering, scaffolding and temporary construction required for their support.

Materials and components used for formwork shall be examined for damage or excessive deterioration before use/re-use and shall be used only if found suitable after necessary repairs. The formwork shall be constructed with timber or metal. In case of timber formwork, the material shall also be examined for signs of attacks by decay, rot or insect attack or development of splits apart from any other physical damage. The metals used for forms shall be of such thickness that the forms remain true to shape. All bolts should be counter sunk. The structural steel tubes used as support for forms shall have a minimum thickness of 4mm.

All the materials, the designs, erection and removal of formwork shall conform to IRC 87-2018 "Guidelines for Formwork, False-work and Temporary Structures for Road Bridges".

3.3 Placing of Reinforcement

Reinforcing steel shall conform to the dimensions and shapes given in the approved Bar Bending Schedules. Reinforcement bars shall be placed accurately in position as shown on the drawings. The bars, crossing one another shall be tied together at every intersection with binding wire (annealed) conforming to IS-280: 2006: Mild Steel Wire for General Engineering Purposes" to make the skeleton of the reinforcement rigid such that the reinforcement does not get displaced during placing of concrete, or any other operation. The diameter of binding wire shall not be less than 1 mm. Layers of reinforcement shall be separated by spacer bars at approximately one meter intervals. The minimum diameter of spacer bars shall be 12 mm or equal to maximum size of main reinforcement or maximum size of coarse aggregate, whichever is greater. No person shall be allowed to walk directly over the reinforcement placed in position.

Necessary stays, concrete/polymer cover blocks, metal chairs, metal hangers, supporting wires etc or other subsidiary reinforcement shall be provided to fix the reinforcement firmly in its correct position. Use of pebbles, broken stones, metal pipes, bricks, mortar or wooden blocks etc as devices for positioning reinforcement shall not be permitted. Placing and fixing of reinforcement shall be inspected and approved by the Engineer before concrete is deposited.

3.4 Foundations

3.4.1 Open foundation:

Excavation for laying the foundation shall be carried out in accordance with Section 300 of Ministry's Specifications. Any depth excavated below the specified level shall be made good with M 15 concrete in case of foundation resting on soil and foundation grade concrete for foundations in

rock. Open foundation shall be constructed in dry conditions. When the bearing surface is earth, a layer of M 15 concrete shall be provided below foundation concrete. The thickness of this layer shall be 100mm minimum unless otherwise specified. Where water is met with an excavation, adequate measures such as bailing out, pumping, constructing diversion channels etc shall be taken to keep the foundation trenches dry and to protect the green concrete against damage. All spaces excavated and not occupied by the foundation, shall be refilled with earth upto surface of surrounding ground. In case of excavation in rock, the annular space around foundation shall be filled with M 15 concrete upto the top of rock.

3.4.2 Well foundations:

3.4.2.1. The construction procedure shall conform to the provisions contained in Section 1200 of Ministry's Specifications.

Well sinking: Sinking of well can be accomplished by the following methods:-

- (i) Open grabbing with / without kentledge
- (ii) Jackdown methods
- (iii) Pneumatic sinking of wells
- (iv) Blasting

3.4.2.2 Blasting: Blasting may be employed with prior approval of competent authority to help sinking of well for breaking obstacles such as boulders or for leveling the rock layers for square setting of wells. Blasting may be resorted to only when methods are found ineffective.

3.4.3 Pile Foundation:

The piles may be either pre-cast concrete piles or cast in situ driven or bored piles. The detailed procedure for construction of pile foundation shall conform to the specification given in section 1100 of m RT&H's specifications and Clause 711 of IRC: 78.

3.5 Substructure

3.5.1 Materials shall conform to section 1000 of Ministry's Specifications.

3.5.2 Piers and abutments: Masonry form work concrete and reinforcement for piers and abutment shall conform to Section 2200 of Ministry's Specification.

3.5.3 Pier cap and abutment cap: The surface of cap shall be finished smooth and shall have a slope for draining of water. For short span slab bridges with continuous support on pier caps the surface shall be cast horizontal. The top surface of the pedestal on which bearing are to be placed shall also be cast horizontally.

The surface on which elastomeric bearings are to placed shall be wood float finished to a level plane which shall not vary more than 1.5 mm from straight edge placed in any direction across

the area. The surface on which other bearings (steel bearings, pot bearings) are to be placed shall be cast about 25 mm below the bottom level of bearings.

3.5.4 Dirt/ballast wall, return wall and wing wall: In case of cantilever walls, no construction joint shall be permitted. Wherever, feasible, the concreting in cantilever walls shall be carried out in continuation of the ballast wall.

No horizontal construction joint shall be provided. If shown on drawings or directed by the engineers, vertical construction joints may be provided. Vertical expansion gap of 20 mm shall be provided in return wall/wing wall at every 10 m intervals. Weep holes shall be provided as prescribed for abutments.

The finish of the surface on the earth side shall be rough while the front face shall be smooth finished.

Architectural coping for wing wall/return wall in brick masonry shall conform to Section 1300 of Ministry's specifications.

3.5.5 Tolerances in concrete elements shall conform to Section 2208 of Ministry's specifications.

3.6 Superstructure

3.6.1 Concreting:

Concreting shall be done as per Section 2300 of Ministry's specifications.

3.6.2 Prestressing:

Before commencement of the prestressing, it shall be ensured that all the tendons are free to move between the jacking points.

The tendons shall be stressed at a gradual and steady rate and the extension recorded at each increment of jack pressure.

The extension of the tendons at the agreed pre-specified total force shall be within 5 per cent of the agreed calculated extension. Any appreciable variation between the calculated extension and actual extension should be notified and settled in consultation with the Engineer-in-charge before proceeding with further tensioning.

Stressing shall be done from both ends unless one end prestressing is specified in the drawings.

Prestressing record of all the cables shall be maintained in the format given in Appendix 1800/II of Ministry's Specifications for roads & bridge works (third revision).

Efficiency of prestressing jack should be found before hand and catered for in the extension of cables.

3.6.3 Grouting:

Grouting of cable ducts shall be carried out as per Appendix 1800/III of Ministry's Specifications.

Grouting shall be carried out as early as possible as but not later than 2 weeks of stressing in tendon.

Before grouting, ducts shall be flushed with water for cleaning as well as for wetting the surfaces of the ducts walls. Water used for flushing should be of same quality as used for grouting. It may, however, contain about 1 per cent of slaked lime or quick lime. All water should be drained through the lowest vent pipe or by blowing compressed air through the duct.

Water/cement ratio of grout mix should be as low as possible, consistent with workability. This ratio should not normally exceed 0.45. Mixing time depends upon the type of the mixer, but will normally be between 2 and 3 minutes. However, mixing should be for such duration as to obtain uniform and thoroughly blended grout, without excessive temperature increase or loss of expansive properties of the admixtures. The grout should be continuously agitated until it is injected.

It is essential that the grout is maintained in a homogeneous state and of uniform consistency so that there is no separation of cement. Use of grout mixers to obtain a colloidal grout is essential.

The pump should be a positive displacement type and should be capable of ejecting the grout in a continuous operation and not by way of pulses. The grout pump must be fitted with a pressure gauge to enable pressure of injection to be controlled. The minimum pressure at which the grout should be pumped shall be 0.3 MPa and the grout pump must have a relief arrangement for bypass of the grout in case of build-up of pressure beyond 1 MPa. The capacity of the grout pump should be such as to achieve forward speed of grout of around 5 to 10m per minute. The slow rates are preferable as they reduce the possibility of occurrence of voids.

Pumping of grout should continue till the mix coming out at the other end is of the same consistency.

Grouting record should be maintained in the format given at Appendix 1800/IV of Ministry's Specifications (Third revision) – 1995.

3.7 Bearings:

Bearings shall conform to the provisions contained under Section 200 of Ministry's specifications for Road & Bridge Works published in April 1995 and IRC: 83 – Part I & Part II.

3.8 Expansion Joints:

The fabrication and fixing of expansion joints shall be as per approved drawings and in accordance with Section 2600 of Ministry's Specifications and with manufacturers' recommendations and Ministry's interim specifications issued vide letter no. RW/NH/34059/1/96 dated 31/03/97 with amendment issued from time to time.

3.9 Materials for Structures

3.9.1 General

Material to be used in the work shall strictly conform to the specifications mentioned on the drawings and other specifications as may be mentioned in other design document, including BOQ. Material, not covered in this section, which may be required to be used in the work, shall conform to relevant Indian Standards, if there are any, or to the requirements specified by the Engineer.

The Contractor shall notify the Engineer of his proposed sources of materials prior to delivery and same shall be duly approved by the engineer. If it is found after trial that sources of supply previously approved do not produce uniform and satisfactory products, or if the product from any other source proves unacceptable at any time, the Contractor shall furnish acceptable material from other sources at his own expense.

Samples of material from the approved source shall be tested for all relevant parameters for conformity to applicable specifications. For manufactured items like cement, steel reinforcement, structural steel, admixtures and pre-stressing strands etc., the contractor shall intimate the Engineer the details of the source, testing facilities available with the manufacturer and arrangements for transport and storage of material at site. At the demand of an engineer, the contractor shall be able to furnish samples and test results of recently received batch of material. The engineer, at his discretion, in case of observing and inconsistency, may require the contractor to test the material in an independent laboratory, duly approved by the engineer, as part of third party evaluation. The cost of such additional tests shall be borne by the contractor.

If any proprietary items are proposed to be used in the works, they shall be governed by the provisions of Specification for Road & Bridge Works, MoRT&H (Clause 115.4).

3.9.2 Bricks & Stones.

Burnt clay bricks shall conform to the requirements of IS:1077, except that the minimum compressive strength when tested flat shall not be less than 8.4 Mpa for individual bricks and 10.5 Mpa for average of 5 specimens. They shall be free from cracks and flaws and nodules of free lime. The brick shall have smooth rectangular faces with sharp corners and emit a clear ringing sound when struck. The size may be according to local practice with a tolerance of ± 5 per cent.

Stones shall be of the type specified. It shall be hard, sound, free from cracks, decay and weathering and shall be freshly quarried from an approved quarry. Stone with round surface shall not be used. The stones, when immersed in water for 24 hours, shall not absorb water by more than 5 per cent of their dry weight when tested in accordance with IS: 1124. The length of stones shall not exceed 3 times its height nor shall they be less than twice its height plus one joint. No stone shall be less in width than the height and width on the base shall not be greater than three-fourth of the thickness of the wall nor less than 150 mm.

3.9.3 Cast Iron.

Cast iron shall conform to IS: 210. The grade number of the material shall not be less than 14.

3.9.4 Cement.

Cement to be used in the works shall be any of the following types with the prior approval of the Engineer:

- (i) Ordinary Portland Cement, 33 Grade, conforming to IS: 269.
- (ii) Ordinary Portland Cement, 43 Grade, conforming to IS: 8112.
- (iii) Ordinary Portland Cement, 53 Grade, conforming to IS: 12269.
- (iv) Sulphate Resistant Portland Cement, conforming to IS: 12330.
- (v) Portland Pozzolana Cement, conforming to IS: 12330.
- (vi) Rapid Hardening Portland Cement, conforming to IS: 8041.
- (vii) Portland Slag Cement, conforming to IS: 455.
- (viii) Low Heat Portland Cement, conforming to IS: 12600.

Manufacturers test certificate shall be submitted to the engineer by the contractor for every consignment of cement. The certificate shall cover all the tests for chemical requirements, physical requirements and chloride content as per relevant codes/specifications.

Independent tests of samples drawn from the consignment, shall be carried out at the site laboratory or in an independent laboratory, as may be approved by an engineer. The tests like Setting time, Compressive Strength must be mandatory. Any cement still in storage, in bags, for more than 3 months, from the date of last test, may be got re-tested.

Cement conforming to IS: 269 (33-Grade) shall be used only after ensuring that the minimum required design strength can be achieved without exceeding the maximum permissible cement content of 450 kg/cum of concrete, without use of mineral admixtures.

Cement conforming to IS: 8112 and IS: 12269 (43 & 53 Grade) may be used provided the minimum cement content mentioned elsewhere from durability considerations is not reduced.

Details on use of other types of cement and limitations may be referred from Specification for Road & Bridge Works, MoRT&H, Section: 1006.

3.9.5 Aggregates (Mineral Aggregates).

3.9.5.1 Coarse Aggregates.

For plain and reinforced cement concrete (PCC and RCC) or pre-stressed concrete (PSC) works, coarse aggregate shall consist of clean, hard, strong, dense, non-porous and durable pieces of crushed stone, crushed gravel, natural gravel or a suitable combination thereof or other approved inert material. They shall not consist pieces of disintegrated stones, soft, flaky, elongated particles, salt, alkali, vegetable matter or other deleterious materials in such quantities as to reduce the strength and durability of the concrete, or to attack the steel reinforcement. Coarse aggregate having positive alkali-silica reaction shall not be used. All coarse aggregates shall conform to IS: 383 and tests for conformity shall be carried out as per IS: 2386, Parts I to VIII.

The contractor shall submit for the approval of the Engineer, the entire information, indicated in Appendix A of IS: 383.

Maximum nominal size of coarse aggregate for various structural components in PCC, RCC or PSC, shall conform to Section 1700 of Specification for Road & Bridge Works, MoRT&H. The maximum value for flakiness index for coarse aggregate shall not exceed 35 per cent. The coarse aggregate shall satisfy the following requirements of grading (Table-3.1).

| IS Sieve size | Per cent by Weight Passing the Sieve | | |
|---------------|--------------------------------------|--------|---------|
| | 40 mm | 20 mm | 12.5 mm |
| 63 mm | - | - | - |
| 40 mm | 95-100 | 100 | - |
| 20 mm | 30-70 | 95-100 | 100 |
| 12.5 mm | - | - | 90-100 |
| 10 mm | 10-35 | 25-55 | 40-85 |
| 4.75 mm | 0-5 | 0-10 | 0-10 |

Table-3.1 Grading Requirements of Coarse Aggregates

3.9.5.2 Fine Aggregates.

For plain and reinforced cement concrete (PCC and RCC) or prestressed concrete (PSC) works, fine aggregate shall consist of clean, hard, strong, dense and durable pieces (<4.75mm) of crushed stone, crushed gravel, which must be free of veins and adherent coating or other deleterious substances. Suitable combination of natural sand, crushed stone sand, crushed gravel sand may also be adopted. They shall not contain dust, lumps, soft or flaky, materials, mica or other deleterious

materials in such quantities as to reduce the strength and durability of the concrete, or to attack the embedded steel.

Motorized/Mechanized sand washing machines should be used to remove impurities from sand. Fine aggregate having positive alkali-silica reaction shall not be used. All fine aggregates shall conform to IS:383, with test conformity to IS: 2386, (Parts 1 to VIII). The Contractor shall submit to the Engineer the entire information indicated in Appendix A of IS: 383. The fitness modulus of fine aggregate shall neither be less than 2.0 nor greater than 3.5.

Sand/fine aggregate for structural concrete shall conform to the following grading requirements (Table-3.2):

| IS Sieve size | Per cent by Weight Passing the Sieve | | |
|---------------|--------------------------------------|---------|----------|
| | Zone I | Zone II | None III |
| 10 mm | 100 | 100 | 100 |
| 4.75 mm | 90-100 | 90-100 | 90-100 |
| 2.36 mm | 60-95 | 75-100 | 85-100 |
| 1.18 mm | 30-70 | 55-90 | 75-100 |
| 600 micron | 15-34 | 35-59 | 60-79 |
| 300 micron | 5-20 | 8-30 | 12-40 |
| 150 micron | 0-10 | 0-10 | 0-10 |

Table-3.2 Grading Requirements of Fine Aggregates

Note: When the grading falls outside the limits of any particular grading zone (other than 600micron IS-sieve) by total amount not exceeding 5%, it shall be regarded as falling within that zone. However, for crushed stone sand, the permissible limit on 150-micron IS sieve is increased to 20% (Ref: IS: 383, Clause:4.3)

3.9.6 Structural Concrete

Materials of structural concrete shall conform to ingredient material requirements under Specification for Road & Bridge Works, MoRT&H, Section: 1000. The detailed specification on Structural Concrete shall be referred from Section 1700 of Specification for Road & Bridge Works, MoRT&H.

The specifications under Section 1700 of Specification for Road & Bridge Works, MoRT&H shall cover following;

3.9.6.1 Grades of Concrete, for Nominal, Standard and High Performance Concrete.

The grades of concrete shall be designated by the characteristic strength as given in Table-3.3 below, where the characteristic strength is defined as the strength of concrete below which not more than 5 percent of the test results are expected to fall.

| S.No | Types of Concrete/Grade Designation | | | Characteristic Strength in MPa |
|------|-------------------------------------|--------------------------------|--|--------------------------------|
| | Nominal Mix | Standard Designed Mix Concrete | High Performance Designed Mix Concrete | |
| 1. | M15 | M15 | | 15 |
| 2. | M20 | M20 | | 20 |
| 3. | | M25 | | 25 |
| 4. | | M30 | M30 | 30 |
| 5. | | - | M35 | 35 |
| 6. | | M40 | M40 | 40 |
| 7. | | M45 | M45 | 45 |
| 8. | | M50 | M50 | 50 |
| 9. | | | M55 | 55 |
| 10. | | | M60 | 60 |
| 11. | | | M65 | 65 |
| 12. | | | M70 | 70 |
| 13. | | | M75 | 75 |
| 14. | | | M80 | 80 |
| 15. | | | M85 | 85 |
| 16. | | | M90 | 90 |

Note:

a) Definition of Nominal, Standard & High Performance Concrete may be referred from MoRT&H, Section 17030.1.

b) Requirements of High Performance Concrete shall be referred to Section 1715 of Specification for Road & Bridge Works, MoRT&H.

The minimum grades of concrete and corresponding minimum cement content and maximum water/cement ratios for different exposure conditions shall be as per Table-3.4, below

| Exposure Condition | Maximum W/C Ratio | Minimum Cement Content, kg/cm ³ | Minimum Grade of Concrete |
|--------------------|-------------------|--|---------------------------|
| Moderate | 0.45 | 340 | M25 |
| Severe | 0.45 | 360 | M30 |
| Very Severe | 0.40 | 380 | M40 |

Note:

1) Above table is applicable for 20mm mineral aggregates.

2) Cement content shown above shall be increased by 40kg/m³ for use of 12.50mm nominal maximum size of aggregate (NMSA) and decreased by 30kg/m³ for use of 40mm NMSA.

3) The maximum cement content excluding any mineral admixtures (Portland Cement Content alone) shall not exceed 450 kg/m³.

4) Use of Design Mix Concrete shall invariably be preferred. Nominal mix shall however be permitted only for minor bridges and culverts or other incidental construction where requirement is up to M20 only.

For concrete subject to Sulphate attack, the requirements may be referred from Table-1700-3 of Specification for Road & Bridge Works, MoRT&H.

3.9.6.2 Proportioning of Concrete.

Proportioning of concrete shall be as per requirements of section 1704 of Specification for Road & Bridge Works, MoRT&H-2013. Contractor shall design the mix in case of “Design Mix Concrete” or propose nominal mix in case of “Nominal Mix Concrete”, and submit same to the Engineer for approval of the proportions of materials, including admixtures to be used. Water-reducing admixtures (including plasticisers or super-plasticisers) may be used at the Contractor’s option, subject to the approval of the Engineer. However, if design mix specifically has been recommended with any admixtures, same shall be binding on contractor. Other types of admixtures shall be prohibited, unless specifically permitted by the Engineer. Design Mix shall be encouraged from an Authorized/NABL accredited laboratory.

The optimum consistency of various types of structures shall be as per Table-3.5, below.

| Table-3.5 Requirements of Consistency | | |
|--|--|--|
| S.No | Type | Slump (mm) at the time of Placing |
| 1 | (a) Structures with exposed inclined surface requiring low slump concrete to allow proper compaction. | 25 |
| | (b) Plain cement concrete. | 25 |
| 2 | RCC structures with widely spaced reinforcements; e.g. solid columns, piers, abutments, footings, well steining | 40 – 50 |
| 3 | RCC structures with fair degree of congestion of reinforcement; e.g. pier and abutment caps, box culverts well curb, well cap, walls with thickness greater than 300 mm. | 50 – 75 |
| 4 | RCC and PSC structures with highly congested reinforcements e.g. deck slab girders, box girders, walls with thickness less than 300 mm | 75 – 125 |
| 5 | Underwater concreting through tremie e.g. bottom plug, cast-in-situ piling | 150 – 200 |
| Note: Refer Section 1704.1 of Specification for Road & Bridge Works, MoRT&H, for additional requirements of optimum consistency | | |

3.9.6.2.1 Requirements of Design Mixes

For specific requirements under design mixes, section 1704.2 of Specification for Road & Bridge Works, MoRT&H, shall be adhered.

The target mean strength of specimen shall exceed the specified characteristic compressive strength by at least the “current margin”.

- 1) The current margin for a concrete mix shall be determined by the Contractor and shall be taken as 1.64 times the standard deviation of sample test results taken from at least 40 separate batches of concrete of nominally similar proportions produced at site by the same plant under similar supervision over a period exceeding 5 days, but not exceeding 6 months.
- 2) Where there is insufficient data to satisfy the above, the current margin for the initial design mix shall be taken as given in Table-3.6 below, till sufficient data is available to determine the current margin.

| Table-3.6 Current Margin for Initial Design Mix | | |
|--|-----------------------------|-----------------------------------|
| Concrete Grade | Current Margin (MPa) | Target Mean Strength (MPa) |
| M 15 | 10 | 25 |
| M 20 | 10 | 30 |
| M 25 | 11 | 36 |
| M 30 | 12 | 42 |
| M 35 | 12 | 47 |
| M 40 | 12 | 52 |
| M 45 | 13 | 58 |
| M 50 | 13 | 63 |
| M 55 | 14 | 69 |
| M 60 | 14 | 74 |
| M 65 | 15 | 80 |
| M 70 | 15 | 85 |
| M 75 | 15 | 90 |
| M 80 | 15 | 95 |
| M 85 | 16 | 101 |
| M 90 | 16 | 106 |

The requirements of Trial Mixes and Control of Strength of Design Mixes shall be adhered as per section 1704.2.2 & section 1704.2.3 of Specification for Road & Bridge Works, MoRT&H.

3.9.6.2.2 Requirements of Nominal Mixes

Requirements for nominal mix concrete unless otherwise specified, shall be as detailed in Table-3.7, below.

| Concrete Grade | Total Quantity of dry aggregate by mass per 50 kg of cement to be taken as the sum of individual masses of fine and coarse aggregates (kg) | Proportion of fine to Coarse aggregate (by mass) | Maximum Quantity of Water for 50kg of Cement | |
|----------------|--|--|--|-----|
| | | | PCC | RCC |
| M 15 | 350 | Generally 1:2, subject to upper limit 1:1:5 and lower limit of 1:2:5 | 25 | - |
| M20 | 250 | | 25 | 22 |

3.9.6.2.3 Additional Requirements.

Concrete shall meet with any other requirements as specified on the drawing or as directed by the Engineer. Additional requirements shall also consist of the following overall limits of deleterious substances in concrete:

- a) The total chloride content of all constituents of concrete as a percentage of mass of cement in mix shall be limited to values given below:

| | | |
|---|---|-------------|
| Prestressed Concrete | : | 0.1 percent |
| Reinforced concrete exposed to chlorides in service (e.g. structures located near sea coast) | : | 0.2 percent |
- b) Other reinforced concrete construction : 0.3 percent
- c) The total water soluble sulphate content of the concrete mix expressed as (SO₃), shall not exceed : 4 percent by mass in the mix.

Proper checks shall be exercised on Suitability of proposed Mix Proportions, Mix Proportioning process and Water/Cement Ratio as per guidelines of section 1704.5 & 1704.6 of Specification for Road & Bridge Works, MoRT&H.

Grading of aggregates for pumped concrete shall be adhered as per section 1704.7 of Specification for Road & Bridge Works, MoRT&H.

3.9.6.3 Admixtures

Use of admixtures such as Superplasticizers, or air entraining, water reducing, accelerating and retarding agents for concrete, may be used with the approval of the Engineer. As the selection of an appropriate concrete admixture is an integral part of the mix design, the manufacturers shall recommend the use of any one of his products only after obtaining complete knowledge of all the actual constituents of concrete as well as methodologies of manufacture, transportation and compaction of concrete proposed to be used in the project work. Admixtures/additives shall be used conforming to IS: 910, subjected to approval of the Engineer.

The general requirements of admixtures shall be as per section 1007 of Specification for Road & Bridge Works, MoRT&H. However, use of mineral admixtures shall be used as per clause 1714.1 and 1715.2 of Specification for Road & Bridge Works, MoRT&H.

Some of the requirements of Admixtures have been discussed in following Section 3.10, of this chapter,

3.9.6.4 Size of Coarse Aggregates

The size (maximum nominal) of coarse aggregates for concrete to be used in various components shall be given as Table-3.8, below.

| Table-3.8 Requirements of Maximum Nominal Size of Coarse Aggregates | |
|--|---|
| Components | Maximum Nominal size of coarse Aggregate(mm) |
| 1) RCC well curb | 20 |
| 2) RCC/PCC Well Steining | 40 |
| 3) Well cap or Pile cap, Solid type piers and abutments | 40 |
| 4) RCC work in girders, slabs, wearing coat, kerb, approach slab hollow piers and abutments, pier / abutment caps, piles | 20 |
| 5) PSC work | 20 |
| 6) Any other item. | As specified by Engineer |

Maximum nominal size of aggregates shall also be restricted to the smaller of the following values:

- ❖ 10 mm less than the minimum lateral clear distance between individual reinforcements.
- ❖ 10 mm less than the minimum clear cover to the reinforcements.
- ❖ One quarter of minimum thickness of member.

The proportions of the various individual size of aggregates shall be so adjusted that the grading produces densest mix and the grading curve corresponds to the maximum nominal size adopted for the concrete mix.

3.9.6.5 Equipment for Batching, Mixing, Transportation, Placing and Compaction

The various requirements of various Equipment, including that used for Batching, Mixing, Transportation, Placing and Compaction shall be as per Section 1707 and 1708 of Specification for Road & Bridge Works, MoRT&H.

3.9.6.6 Concreting Under Water & Extreme Weather

The various requirements of concreting under water and other extreme weather conditions shall be as per Section 1710 & Section 1711 of Specification for Road & Bridge Works, MoRT&H.

3.9.6.7 Protection and Curing

Concreting operations shall not commence until adequate arrangements for concrete curing have been made by the contractor. Curing and protection of concrete shall start immediately after compaction of the concrete to protect it from:

- ❖ Premature drying out particularly by solar radiation and wind
- ❖ High internal thermal gradients
- ❖ Leaching out by rain and flowing water.
- ❖ Rapid cooling during the first few days after placing.
- ❖ Low temperature or frost
- ❖ Vibration and impact which may disrupt the concrete and interfere with its bond to the reinforcement.

Where members are of considerable size and length, with high cement content, accelerated curing methods may be applied, as approved by the Engineer. The additional requirements under Curing using Water Curing, Steam Curing and use of Curing Compound may be referred under section 1712 of Specification for Road & Bridge Works, MoRT&H.

3.9.6.8 Finishing

Immediately after the removal of forms, exposed bars or bolts, if any, shall be cut inside the concrete member to a depth of at least 50 mm below the surface of the concrete and the resulting holes filled with cement mortar.

All fins caused by form joints, all cavities produced by the removal of form ties and all other holes and depressions, honey comb spots, broken edges or corners, and other defects, shall be thoroughly cleaned, saturated with water, and carefully pointed and rendered true with mortar of cement and fine aggregate mixed in the proportions used in the grade of concrete that is being finished and of as dry a consistency as is possible to use.

Considerable pressure shall be applied in filling and pointing to ensure thorough filling in all voids. Surfaces which have been pointed shall be kept moist for a period of twenty thousand four hours. Special pre-packaged proprietary mortars shall be used where appropriate or where specified in the drawing.

All construction and expansion joints in the completed work shall be left carefully tooled and free from any mortar and concrete. Expansion joint filler shall be left exposed for its full length with clean and true edges.

Immediately on removal of forms, the concrete work shall be examined by the engineer before any defects are made good.

- ❖ The work that has sagged or contains honeycombing to an extent detrimental to structural safety or architectural appearance shall be rejected.

- ❖ Surface defect of a minor nature may be accepted. On acceptance of such work by the Engineer, the same shall be rectified as directed by the Engineer.

3.9.7 Steel (Other than Structural Steel)

3.9.7.1 Cast Steel

The use of cast shall be limited to bearings and other similar parts. Steel for casting shall conform to Grade 280-520 N of IS: 1030. In case where subsequent welding is unavoidable in the relevant cast steel components, the letter N at the end of the grade designation of the steel casting shall be replaced by letter W. Generally, 0.3% to .0.5% copper may be added to increase the corrosion resistance properties.

3.9.7.2 Steel for Prestressing

The prestressing steel shall conform to either of the following:

- (i) Plain hard drawn steel wire conforming to IS: 1785 (Part I) and IS: 1785 (Part II).
- (ii) Cold drawn indented wire conforming to IS: 6003.
- (iii) High tensile steel bar conforming to IS: 2090.
- (iv) Uncoated stress relieved strands conforming to IS: 6006.
- (v) Uncoated stress relieved low relaxation seven ply strand, conforming to IS: 14268.

3.9.7.3 Reinforcement/Un-tensioned Steel

For plain and reinforced cement concrete (PCC and RCC) or prestressed concrete (PSC) works, the reinforcement/un-tensioned steel, as the case may be shall consist of the following grades of reinforcing bars.

| Grade Designation | Bar Type conforming to governing IS Specification | Characteristic Strength f_y MPa | Elastic Modulus GPa |
|-------------------|---|-----------------------------------|---------------------|
| Fe 240 | IS: 432 Part I Mild Steel Bar | 240 | 200 |
| Fe 415 | IS: 1786 High Yield Strength Deformed Bars (HSD) | 415 | 200 |
| Fe 500 or Fe 500D | IS: 1786 High Yield Strength Deformed Bars (HSD) | 500 | 200 |
| Fe 550 or Fe 550D | IS: 1786 High Yield Strength Deformed Bars (HSD) | 550 | 200 |
| Fe 600 | IS: 1786 High Yield Strength Deformed Bars (HSD) | 600 | 200 |

Table-3.9 Grading Requirements of Reinforcement Steel

Note: If any grade of steel, above, is not commercially available, steel of next higher grade may be used. Other grades of bars conforming to IS: 432 and IS: 1786 shall not be permitted.

All steel shall be procured from original producers, no re-rolled steel shall be incorporated in the work. Only new steel shall be delivered to the site. Every bar shall be inspected before assembling on the work and defective, brittle or burnt bar shall be discarded. Cracked ends of bars shall be discarded.

Purchase of steel, as far as possible must be made from Original Manufacturer and as per Specifications conforming IS:1786. Engineer may allow the procurement of steel from other suppliers, provided same is conforming IS:1786. Further, in such case, apart from having the manufacturer's test certificate, the steel shall be got tested by third party test facility, which must be NABL accredited laboratory, ensuring conformity to IS: 1786. However, regular third party evaluation of lots of steel may be carried out, at the discretion of engineer.

3.9.7.4. Fusion Bonded Epoxy Coated Reinforcement/Un-tensioned Steel

Fusion-bonded epoxy coated reinforcing bars shall meet the requirements of IS: 13620. Additional requirements for the use of such reinforcement bars may be referred to Specification for Road & Bridge Works, MoRT&H, Section:1009.3.2. Coating of Hot dipped galvanized reinforcing steel shall be provided, wherever required, and as per IS: 12594-1988.

3.9.7.5 Grey Iron Castings

Grey Iron castings to be used for bearings shall have the following minimum properties and shall conform to testing as per IS: 210:

| | |
|---------------------------------------|------------|
| (i) Minimum ultimate tensile strength | 370 MPa |
| (ii) Modulus of Elasticity | 147000 MPa |
| (iii) Brinell Hardness | 230 MPa |
| (iv) Shear Strength | 370 MPa |
| (v) Compressive Strength | 1370 MPa |

3.9.7.6 Steel Forgings

Forged steel pins shall comply with clause 3, 3A or 4 of IS: 1875 and steel forgings shall comply with clause 3, 3A or 4 of IS: 2004. Raw materials of the forging will be taken as per IS: 1875 with minimum reduction ratio of 1.8:1. Alternatively, if forging is made from ingot, a minimum reduction ratio between the ingot and forging will be 4:1. Forging shall be normalized.

3.9.8 Structural Steel

Unless otherwise permitted herein, all structural steel shall before fabrication comply with the requirements of the following Indian Standards:

IS: 226 : Structural Steel (Standard Quality).

IS: 961 : Structural Steel (High Tensile).

IS: 2062 : Weldable Structural Steel.

IS: 8500 : Weldable Structural Steel (medium & high strength qualities).

- IS: 1148 : Hot rolled rivet bars (upto 40 mm dia) for structural purposes.
- IS: 1149 : High tensile rivet bars for structural purposes.
- IS: 1161 : Steel tubes for structural purposes.
- IS: 4923 : Hollow Steel sections for structural use.
- IS: 11587: Structural weather resistant steel.
- IS: 808 : Specifications for Rolled Steel Beam, Channel and Angle Sections.
- IS: 1239 : Mild Steel Tubes.
- IS: 1730 : Dimension for Steel Plate, sheet and strip for structural and general engineering purposes.
- IS: 1731 : Dimension for Steel flats for structural and general engineering purposes
- IS: 1732 : Dimension for round and square steel bars for structural and general engineering purposes
- IS: 1852 : Rolling and cutting tolerances for hot rolled steel products

The use of structural steel not covered by the above standards may be permitted with the specific approval of the authority. Detailed description on use of Structural Steel may be referred under Specification for Road & Bridge Works, MoRT&H, Section-1900. This covers following in particular;

- (i) Assorted materials including casting & forging, fastners, welding consumables, welds and paints.
- (ii) Detailed fabrication requirements.
- (iii) Erection & testing.
- (iv) Test and standards of acceptance.

3.9.9 Stainless Steel

Stainless steel shall be austenitic chromium-nickel steel, possessing rust, acid and heat resistant properties conforming to IS: 6603 and IS: 6911. Mechanical properties/grade for such stainless steel shall be as specified by the accepting authority, but in no case be inferior to mild steel. Generally, stainless steel is available as per AISI grades. AISI 304 which is equivalent to grade 04Cr18Ni110 of IS: 6911 satisfies the requirements of mechanical properties of structural steel. Other grades of stainless steel for specific purposes may be provided as per specific requirements. For application in adverse/corrosive environment, stainless steel shall conform to AISI 316L or O2G17NiMo2 of IS: 6911.

3.9.10 Water

Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete

or steel. Potable water is generally considered satisfactory for mixing concrete. Mixing and curing with sea water shall not be permitted. pH value of water shall not be less than 6.

In case of any doubt about the quality of water, test samples may be casted, with same water, to ascertain critical test parameters like compressive strength and initial/final setting time of cement. Sample of water referred for testing shall represent the water proposed to be used for concreting.

Average 28 days compressive strength of at least three 150mm concrete cubes, prepared with proposed water, shall not be less than 90% of average strength of other three samples of concrete, prepared with distilled water. Guidelines and conformity of IS: 516, shall apply.

Maximum permissible values for concentrations within water, shall be referred from Specification for Road & Bridge Works, MoRT&H, Section: 1010.

3.9.11 Timber

The timber used for structural purposes shall conform to IS: 883.

3.9.12 Concrete Admixtures

Admixtures are materials added to the concrete before or during mixing with a view to modify one or more of the properties of concrete in the plastic or hardened state. Concrete admixtures are proprietary items of manufacture and shall be obtained only from established manufacturers with proven track record, quality assurance and full-fledged laboratory facilities for the manufacture and testing of concrete.

3.9.12.1 Mineral Admixtures

Mineral admixtures, as part of replacement of Portland Cement, with approval of engineer, shall include Fly-Ash (conforming IS:3812-3), Granulated slag (conforming IS:12089), and Silica fumes (conforming IS:15388).

3.9.12.2 Chemical admixtures

Chemical admixtures shall be used when contractor/supplier can provide following information concerning each admixture, after obtaining the same from the manufacturer:

- (i) Compatibility of admixture with cement.
- (ii) Normal dosage and detrimental effects, if any, of under dosage and over dosage.
- (iii) The chemical names of the main ingredients in the admixtures.
- (iv) The chloride content, if any, expressed as a percentage by the weight of the admixture.
- (v) Values of dry material content, ash content and relative density of the admixture which can be used for Uniformity Tests.
- (vi) Whether or not the admixture leads to the entertainment of air when used as per the manufacturer's recommended dosage, and if so to what extent.

- (vii) Where two or more admixtures are proposed to be used in any one mix, confirmation as to their compatibility.
- (viii) Whether there is any increased risk of corrosion of the reinforcement or other embedments, as a result of using the admixture.
- (ix) Adverse effects on Durability of concrete

3.9.12.3 Physical and Chemical Requirements

Admixtures shall conform to the requirements of IS: 9103. In addition, other conditions as mentioned in Specification for Road & Bridge Works, MoRT&H, Section: 1012, for physical and chemical requirements, shall be satisfied:

3.9.13 Reinforced and Prestressed Concrete Pipes

Reinforced concrete pipes for highway structures shall be of NP4 type conforming to the requirements of IS:458. Prestressed concrete pipes (NP4), conforming to IS: 784, can also be used.

3.9.14 Storage of Material

All material may be stored at proper places so as to prevent their deterioration or intrusion by foreign matter and to ensure their satisfactory quality and fitness for the work. The storage space must also permit easy inspection, removal and re-storage of the materials. All such materials even though stored in approved godowns/places, must be subjected to acceptance test prior to their immediate use.

The guidelines for storage of Bricks, Aggregates, Cement, Reinforcement/Un-tensioned Steel, Prestressing Material, Water etc, may be referred from Specification for Road & Bridge Works, MoRT&H, Section: 1014.

3.10 Tests & Standards of Acceptance

All materials, even though stored in an approved manner shall be subjected to an acceptance test, prior to their immediate use, as per applicable standard. Independent testing of cement for every consignment shall be subjected to an acceptance test prior to their immediate use.

Independent testing of cement for every consignment shall be done by the Contractor at site in the laboratory approved by the Engineer before use. Any cement with lower quality than those shown in manufacturer's certificate shall be debarred from use. In case of imported cement, the same series of tests shall be carried out before acceptance.

3.10.1 Testing and Approval of Material

The Contractor shall furnish test certificates from the manufacturer/supplier of materials along with each batch of materials, finished products used in the construction as per requirements of conditions of contract and the relevant specifications. The contractor shall set up a field laboratory

with necessary equipment for testing of all materials. The testing of all the materials shall be carried out by the Engineer or his representative for which the Contractor shall make all the necessary arrangements and bear the entire cost.

Tests which cannot be carried out in the field laboratory have to be got done at the Contractor's cost at any recognized laboratory/testing establishments approved by the Engineer.

3.10.2 Sampling of Materials

Samples provided to the Engineer or his representative for their inspection/retention are to be in labeled boxes suitable for storage. Samples required for approval and testing must be supplied well in advance by at least 48 hours or minimum period required for carrying out relevant tests to allow for testing and approval. Delay to works arising from the late submission of samples will not be acceptable as a reason for delay in the completion of the works. If materials are brought from abroad, the cost of sampling/testing whether in India or abroad shall be borne by the Contractor.

3.10.3 Rejection of Materials not conforming to the Specifications

Any stack or batch of materials(s) of which samples(s) does not conform to the prescribed tests and quality shall be rejected by the Engineer, or his representative, and such materials shall be removed from site by the Contractor, at his own cost. Such rejected materials shall not be made acceptable by any modifications/rectification.

3.10.4 Testing and Approval of Plant and Equipment

All plants and equipment used for preparing, testing and production of materials for incorporation into the permanent works shall be in accordance with manufacturer's specifications and shall be got approved by the Engineer before use.

3.11 Concrete in Piles

The basic materials and the specifications for steel reinforcement, structural concrete, prestressed concrete and structural steel to be used in pile foundations shall be as given in the relevant sections above or as per Specification for Road & Bridge Works, MoRT&H, Section: 1000, 1700,1800 & 1900.

3.11.1 Concrete in Piles

Requirements of concrete to be used in cast-in-situ and precast piles shall be as per following Table-3.10 below;

| | Cast in-situ Concrete by Tremie | Precast Concrete |
|-------------------------|---------------------------------|----------------------|
| Grade Designation | M35 | M35 |
| Minimum Cement Content | 400kg/m ³ | 400kg/m ³ |
| Minimum w/c ratio | 0.40 | 0.40 |
| Slump (mm) at placement | 150-200 | 50-75 |

Table-3.10 Requirement of Concrete in Piles

Note: minimum cement content and minimum w/c ratio are to be based on total cementitious material, including mineral admixtures.

Concrete mix should have homogeneous mixture with required workability for the system of piling adopted. Suitable and approved admixtures (mineral/chemical) may be used in concrete mix where necessary, as cement reducing agents or water reducing agents/plasticizers/super plasticizers.

Where piles are exposed to action of harmful chemicals or severe conditions of exposure due to presence of sulphate, chloride etc, it may be preferable to opt for higher grades of concrete restricting water cement ratio to 0.45. For improving resistance against the penetration of chlorides and sulphates from surrounding soils or water, mineral admixtures such as fly ash, silica fumes, GGBFS conforming to BIS/International Standards and as per IRC:112, may be used.

3.12 Geosynthetics as Special Material

Geosynthetic is a general classification for all synthetic materials used in geotechnical/geo-structural engineering application. It includes geo-textiles, geo-grids, geo-nets, geo-membranes, geo-cells, geo-mats, natural geotextiles, paving fabric/glass grids and geo-composites.

Such material generally have quite a wide range of applicability for bridge construction like slope protection, reinforcement, drainage, separation, erosion control, capillary cut-off, water barrier etc. Specification for Road & Bridge Works, MoRT&H, Section: 700, covers the various applications of Geosynthetic materials in road and bridge works including supplying and laying as per special provisions.

3.13 Sampling and Testing Frequency of Testing Material

3.13.1 Sampling

The testing of material shall be conducted based on samples collected from field or quarries or batching plants as per relevant standards codes / prescribed procedures. The minimum weight of sample shall be adequate to conduct test for which it has been sampled. For sampling, random numbering statistical method shall be used. The random sampling procedure to be followed as given in IRC/IS/ASTM/AASHTO codes etc.

3.13.2 Testing

The Contractor and the Executing Departments/Agency's Quality Control Engineer shall ensure that any test is carried out as per relevant code mentioned therein and the record of testing is maintained in laboratory. Tests which could not be conducted in field / lab shall be conducted in an independent laboratory.

The tests shall be conducted on unbiased samples, taken from field as per relevant Specification for Road & Bridge Works, MORT&H or the relevant Indian Road Congress (IRC). Where the said specifications are silent in regard to the specifications in question, in that case, the specifications under the Bureau of Indian Standards (BIS)/ AASHTO/ ASTM and BS code shall apply in that order. All tests shall be conducted in Engineering Testing Laboratory established by Contractor under the supervision of qualified Quality Control Engineer, from the Executing Department/Agency.

All test results shall be properly maintained in laboratory. Any substandard material in the work shall be identified immediately and Contractor shall be informed in writing for removing as per concession agreement.

3.13.3 Frequency of Testing

The type and frequencies of various quality control tests conducted on unbiased samples collected from field/quarry/source, shall be deemed mandatory. The Contractor's QC Engineer/Material Engineer and Executing Department/Agencies Field Engineer/QC Engineer shall ensure that frequencies of test are maintained as per relevant specifications. Confirmatory test if desired shall be carried out in Independent Laboratory. Any sub-standard material incorporated in work should be identified immediately and the Executing Department/Agencies shall inform the Contractor, in writing, for the removal, of same, from the site. The frequencies of various tests to be conducted shall be as per relevant code and MORT&H specification.

The brief account of various Tests & their Frequency, which is required to be maintained as per relevant provisions of codes/specifications, is presented as per Table-3.11 below or same may be referred as per well documented Contract Agreement:

Table- 3.11 Brief Requirement of various Tests & Frequency

| Sr. No. | Description of Work / Tests | Ref. Codes | Frequency | Acceptance Standards |
|---|--|------------------|--------------------------|--|
| NOTE: Most latest mandate of BIS/IRC/MORT&H code/specifications shall apply, wherever applicable | | | | |
| 1. Coarse Aggregate for Structures (MORTH Specification clause 1007 & I.S 383- 1970) | | | | |
| i. | Grading | IS:2386 (Part 1) | Before starting of work | As per Table 1000-1 of MORTH Specifications & As per Table -1 of IS 383. |
| ii. | Estimation of deleterious materials and organic impurities | IS:2386 (Part 2) | Once for source approval | Table -1 of IS 383. |

| Sr. No. | Description of Work / Tests | Ref. Codes | Frequency | Acceptance Standards |
|---|--|----------------------------|---|--|
| NOTE: Most latest mandate of BIS/IRC/MoRT&H code/specifications shall apply, wherever applicable | | | | |
| a. | Coal and Lignite | - | One test per source | Max. 1% |
| b. | Clay Lumps | - | One test per source | Max. 1% |
| c. | Material finer than 75 micron. | - | One test per source & one test per day | Max. 3% |
| d. | Total of all Deleterious Matters | - | One test per source | Max. 5% As per table- 2 of IS: 383 |
| iii. | Specific gravity, density, voids, water absorption and bulking | IS:2386 (Part 3) | One test per source | Water absorption max-2% |
| iv. | Mechanical properties (Aggregate Impact Value-AIV or Loss Angeles Abrasion Value-LAAV) | IS:2386 (Part 4) | One each source of supply and when called for by the Engineer In charge | AIV - 45% max for concrete LAAV - 50% max for concrete |
| v. | Soundness in Sodium Sulphate and Magnesium Sulphate | IS:2386 (Part 5) | One test per source | Max. 12% and Max. 18% respectively. |
| vi. | Alkali aggregate reactivity | IS:2386 (Part 7) & IS: 383 | One test per source | Innocuous aggregate |
| vii. | Petrography examination | IS: 2386 (Part 8) & IS:383 | One test per source | Information required for approval of source |
| viii. | Flakiness Index | IS: 2386 (Part 1) | Before starting of work | Not greater than 35% |
| Maximum Nominal Size of Coarse Aggregates Shall be referred from MoRT&H Table 1700-7 | | | | |
| 2. Sand/ Fine Aggregate for Structures (MORTH Specifications Clause 1008 & IS: 383-1970) | | | | |
| i. | Fineness modulus of fine aggregate | IS: 383 | One test for 15 m ³ | Min. 2.0 and Max. 3.5 |
| ii. | Soundness in Sodium Sulphate and Magnesium Sulphate | IS: 2386 (Part 5) | One test per source | Max. 10% and Max. 15% respectively. |
| iii. | Deleterious Constituents | IS: 2386 (Part 2) | One test for 15 m ³ | |
| a. | Coal and Lignite | - | One test for 15 m ³ | Max. 1% |
| b. | Clay Lumps | - | One test for 15 m ³ | Max. 1% |
| c. | Shale | - | One test for 15 m ³ | Max. 1% |
| d. | Total of all Deleterious Matters | - | One test for 15 m ³ | Max. 5% |
| v. | Material Passing 75 micron | IS: 2386 (Part 1) | Before starting of work | Max. 3% for natural sand and 15% for crushed aggregate (As per IS 383- 1970) |
| vi. | Specific Gravity | IS: 2386 (Part 3) | One test per source | Min 2.5 |
| vii. | Water Absorption | IS: 2386 (Part 3) | One test per source | Max. 2% |
| viii. | Surface Moisture Content (Free moisture) | IS: 2386 (Part 3) | When required | Max. 5% |

| Sr. No. | Description of Work / Tests | Ref. Codes | Frequency | Acceptance Standards |
|---|---|-------------------------|--|---|
| NOTE: Most latest mandate of BIS/IRC/MoRT&H code/specifications shall apply, wherever applicable | | | | |
| ix. | Alkali – Aggregate Reactivity | IS: 2386 (Part 7) | One test per source | Innocuous aggregate |
| x. | Grading Requirement | IS: 2386 (Part 1) | Before starting of work | As per Table 1000-2 of MORTH Specifications |
| xi | Bulking | IS: 2386 | One test per source | |
| 3. Admixture | | | | |
| i | Chemical Tests | As per IS: 9103 | Once per source | As per IS: 9103 |
| 4. Construction Water | | | | |
| i | Alkalinity and Acidity | MORT&H clause 1010 | Once per source | MORT&H clause 1010 |
| ii | Solids | As per IS: 3025 | One test per source | As per IS 3025 |
| 5. Steel | | | | |
| i | Physical & Chemical test | As per IS:1786 | As per IS 1786 | As per IS 1786 |
| 6. Size Stones | | | | |
| i | Water absorption | As per relevant IS:1124 | One each source of supply and when called by the Engineer In charge | Not more than 5% of its dry weight |
| ii | Dimension check | - | As directed by Engineer | - |
| lii | Type of rock | As per IS: 2386 | As directed by Engineer | - |
| 7. Cement | | | | |
| i | Fineness | As per IS: 4031 | One each source of supply and when called by the Engineer In charge | Limit as per IS 269: 2015 |
| ii | Initial/ Final setting time | As per IS: 4031 | One each source of supply and when called by the Engineer In charge | Limit as per IS 269: 2015 |
| iii | Compressive strength (3days,7days,28days) | As per IS: 4031 | One each source of supply and when called by the Engineer In charge | Limit as per IS 269: 2015 |
| 8. Mortar | | | | |
| i | Compressive strength | As per IS: 2250 | One sample for every 2 m ³ of mortar subject to a minimum of three samples for a day work | As per IS 2250 |
| 9. Lime | | | | |
| i | Chemical properties | as per IS: 6932, 1514 | Three final test sample for a lot size up to 100 tones as per table 3 in IS 712- 1984 | as per IS 6932, 1514 |
| ii | Physical properties | As per IS: 6932 | Three final test sample for a lot size up to 100 tones as per table 3 in IS 712- 1984 | as per IS 6932 |

10. Structural Concrete (MORT&H Specifications Section 1700)

Requirements of Structural Concrete shall be as described in Section 3.9.6, above, with following requirements for quality assurance of concrete.

| Sr. No. | Description of Work / Tests | Ref. Codes | Frequency | | Acceptance Standards |
|---|--|------------|---|--|---|
| Note: a) Random sampling and lot by lot acceptance inspection shall be made for the 28 days Cube Strength. b) Concrete shall be tested in lots with no individual lot more than 30 cu.m in volume. c) Different grades of mixes of concrete shall be divided into separate lots. d) Concrete of a given lot shall be used in the same identifiable component of the Bridge. e) A sample of concrete shall be the average of | | | | | |
| i | Sampling of 150mm size cube specimen of each mix. | | 3 cubes for 7 days & 6 cubes for 28 days | Compressive strength test | IS:1199 |
| ii | Cube strength (At least 3 cubes on 7 days & 6 cubes on 28 days) Note: A sample shall be understood as average of strength of 3-cubes. | IS:516 | Each trial mix | | a) 7days strength: for preliminary assessment only. b) 28 days cubes strength shall achieved Target mean strength Individual variation in test of cubes should not be more than $\pm 15\%$ of Average. |
| iii | Sampling of concrete for each grade at site and compressive strength (At least one sample shall be taken from each shift of work) | IS: 1199 | Qty of concrete (m3) | No. of Samples | MORTH Specifications Clause 1717.7 The mean strength determined from any group of four consecutive non-overlapping samples should exceed the specified characteristic compressive strength by 3Mpa. a) Strength of any sample is not less than the specified characteristic compressive strength minus 3 MPa. b) When Concrete does not satisfy the above conditions, representative cores shall be extracted from hardened concrete for compression test in accordance with IS:1199 & IS:516. |
| | | | 1 – 5 6 – 15 16 – 30 31 – 50 51 and above | 1 2 3 4 4 plus one additional sample for each additional 50 m3 or part thereof | |

3.14 Calibration of Instruments of Material Testing & Manufacturing:

All measuring instruments and testing equipment (field and laboratory) shall be uniquely numbered, properly stored, suitably handled in a manner appropriate to its sensitivity & calibration. Each equipment shall be maintained in a known state of calibration. If any instrument is repaired, steps shall be taken.

4. QUALITY SYSTEMS FOR ROAD BRIDGES

4.1 To ensure building of safe, serviceable, durable and economically viable bridges, it is necessary to have a strategy for management of human skills by way of quality system defining quality policy, quality assurance and quality audit. Guidelines on quality systems for road bridges have been evolved by IRC vide SP: 47 - 1998 “to facilitate preparation of appropriate quality systems for new bridge projects and application of these guidelines will inculcate in all those involved in this building activity that provide the product or services expected of them consistently. These guidelines cover quality system for activities of bridge structure using concrete elements and include project preparation, design and drawing, construction and supervision, contract management, quality of materials and equipments used in construction and workmanship. The guideline also stipulate organizational requirement for adoption of quality system by suppliers, purchasers, owners, approving authorities and consultants. These guidelines have been made applicable for all the bridge structures on National Highways and centrally financed schemes by the Ministry vide Circular No. RW/NH 34066/5/S&R dated 20th Dec. 1999.

5. PROJECT SCHEDULING AND MONITORING OF WORKS

5.1 Scheduling

In construction project it is very important to identify the risk factors affecting the project at the early stage in order to control and monitor the progress at every stage of the construction work to avoid the time and cost overruns of the project. This can be achieved by proper project management process.

For all important bridge projects, it is essential to have a CPM/ PERT chart for the entire project. Reference may be made to Special Publication No. SP-14 of IRC Construction agency should submit the chart preferably along with the tender, and in any case before commencement of work. For minor bridges, bar charts fixing the targets for the major activities along with the construction schedule may be submitted.

The various activities involved in the completion of the project right from the award of work to its completion shall be identified both in terms of time and money as also the resources like manpower, T&P and materials etc., required for the completion of the activity, the entire purpose being to streamline the construction procedures and take advance action in respect of those activities which affect the subsequent activities and in particular, the activities in critical path, so as to avoid any delay arising in the completion of the project. The inter-dependency of different activities should be correctly shown and the activity durations considered shall be realistic. The CPM chart should be updated regularly as the work progresses.

Availability of resources, viz, manpower, material, plant and machinery and funds shall be clearly identified to enable their mobilization / procurement well in time.

5.2 Monitoring

It is important to monitor the progress of work during execution so that time frame already set for completion of the work is not exceeded. So to complete the project on time the site Supervisor shall maintain progress of the work on daily, weekly and monthly basis and same shall be forwarded to higher authorities.

5.2.1 To monitor the progress of the work at various stages, necessary data must be maintained at site showing the position of each activity, targets to be achieved, bottlenecks, if any, expenditure and position of funds, etc.

5.2.2 Monthly/quarterly progress reports may be prepared in the Performa prescribed by the department and submitted regularly to the concerned officers for their information and for keeping a

close watch on the progress of the work and the problems encountered in the field with a view to sort them out.

5.2.2 It is necessary to ensure simultaneous completion of a bridge work and its approaches. Accordingly, progress made on the approaches may also be indicated.

5.3 Record Keeping and Documentation.

It is important to record an activity or conversation in writing and not leave these events to memory. It is extremely difficult to recall events that have occurred five or six years in the past. If an activity or event is not recorded in writing and there is a conflict in those positions, then the arbitrator or judge is left in a difficult position of determining which witness is more credible.

Good record keeping is based on a fair and unbiased recording of actual facts and not speculation or denigration of personalities. Written factual records of any event will always be preferred over oral recollections or reconstruction of the event.

If a claim or dispute appears to arise this should be recorded with the other parties. Relevant photographs of change in work and circumstances forming the basis of a claim often lead to a quick resolution of the dispute.

Record of design and drawings as approved for construction and completion of drawings as per actual construction should be maintained meticulously at the division / circle office or at Chief Engineer's office. To save storage space micro filming system may be introduced.

6. BRIDGE INSPECTION AND MAINTENANCE

6.1 Bridge Inspection

6.1.1 Introduction

Bridges are key elements of the Road or Railway network because of their strategic location and the dangerous consequences when they fail or when their capacity is impaired. The fundamental justification for a bridge inspection programme lies in the assurance of safety. Timely and economic planning and programming of remedial and preventive maintenance and repair work, or even bridge replacement with the minimum interruption to traffic are dependent upon detailed bridge inspection. It is particularly necessary in case of old bridges not designed to modern loading standards and also whose materials of construction have deteriorated as a result of weathering.

Inspection is aimed at identifying and quantifying deterioration, which may be caused by applied loads and factors such as dead load, live load, wind load and physical/chemical influences exerted by the environment. Apart from inspection of bridge damage caused by unpredictable natural phenomena or collision by vehicles or vessels, inspection is also needed to identify or follow up the effect of any built-in imperfections. Inspection can also help to increase life of older bridges. For example, there are certain types of deterioration which appear early in the life of a bridge and which, if not recorded and repaired promptly, can lead to considerable reduction in the length of service life of the bridge.

6.1.2 Purpose of Bridge Inspection

Specific purposes of bridge inspection can be identified as detailed below:

- ❖ To know whether the bridge is structurally safe, and to decide the course of action to make it safe.
- ❖ To identify actual and potential sources of trouble at the earliest possible stage.
- ❖ To record systematically and periodically the state of the structure.
- ❖ To impose speed restriction on the bridge if the condition/ situation warrants the same till the repair/ rehabilitation of the bridge is carried out.
- ❖ To determine and report whether major rehabilitation of the bridge is necessary to cope with the natural environment and the traffic passing over the bridge.
- ❖ To provide a feedback of information to designers and construction engineers on those features which give maintenance problems.

6.1.3 Planning the Inspection

Careful planning is essential for a well-organized, complete and efficient inspection. The bridges over water are inspected at times of low water, generally after the monsoon. Bridges requiring high climbing should be inspected during seasons when winds or extreme temperatures

are not prevalent. Bridges suspected of having trouble on account of thermal movement should be inspected during temperature extremes. The bridges are inspected starting from foundations and ending with superstructures. Planning for inspection must include the following essential steps:

- ❖ Decide the number of bridges to be inspected on a particular day.
- ❖ Go through the previous inspection reports of those bridges before starting the inspection.
- ❖ Try to have plans and other details of important bridges.
- ❖ Plan any special inspection equipments, staging etc. required in advance.
- ❖ Don't rush through the inspection just for completion sake. Remember that you are inspecting the bridge only once in a year.

6.1.4 Preliminary Study

While going for bridge inspection one should be familiar with the historical data of the bridges i.e.

- ❖ Completion plans, where available
- ❖ Pile and well foundation details
- ❖ Earlier inspection reports
- ❖ Reports regarding the repairs/strengthening carried out in the past.
- ❖ For major girder bridges, stress sheets are useful.

6.1.5 Inspection Equipments

The following equipments are required for thorough inspection of the various elements of bridges:

- ❖ Pocket tape (3 or 5 m long)
- ❖ Chipping hammer
- ❖ Plumb bob
- ❖ Straight edge (at least 2 m long)
- ❖ 30 metre steel tape
- ❖ A set of feeler gauges (0.1 to 5 mm)
- ❖ Log line with 20 kg lead ball (to be kept at bridge site)
- ❖ Thermometer
- ❖ Elcometer
- ❖ Wire brush
- ❖ Mirror (10x15 cm)
- ❖ Magnifying glass (100 mm dia.)
- ❖ Crackmeter
- ❖ Chalk, Waterproof pencil, pen or paint for marking on concrete or steel

- ❖ Centre punch
- ❖ Calipers (inside and outside)
- ❖ Torch light (5 cell)
- ❖ Screw drivers
- ❖ Paint and paint brush for repainting areas damaged during inspection
- ❖ Gauge-cum-level
- ❖ Piano wire or leveling instrument for camber measurement
- ❖ 15 cm steel scale
- ❖ Inspection hammer (350-450 gm)
- ❖ Rivet testing hammer (110 gm)
- ❖ Schmidt hammer
- ❖ Concrete cover meter
- ❖ Binoculars (Optional where required)
- ❖ Camera (Optional where required)

Depending on the bridge site and the need envisaged during inspection, some additional equipments that may become necessary are listed below:

- ❖ Ladders
- ❖ Scaffolding
- ❖ Boats or barges
- ❖ Echo sounders to assess the depth of water/ scour depth
- ❖ Levelling equipment (to assess camber)
- ❖ Hand held laser distance/range meter.
- ❖ Dye penetration test equipment (to detect cracks specially in welds)

6.1.6 Safety Precautions

While inspecting bridges, one should adopt certain safety measures which are listed below:

- ❖ Wear suitable dress so that loose ends do not get caught; too-tight-a-dress may hamper your free movements.
- ❖ If you normally wear glasses for improving your eye sight, wear them when climbing up or down the sub- structures or superstructures.
- ❖ Keep clothing and shoes free of grease.
- ❖ Scaffolding or platforms should be free from grease or other slippery substances.
- ❖ Scaffolding and working platforms should be of adequate strength and must be secured against slipping or over turning.
- ❖ Line block or power block shall be taken as and when necessary.

- ❖ No short cuts, at any cost, should be adopted.

A Proforma for inspection report for road bridges (extracted from IRC SP 35 Guidelines for inspection and maintenance 1990) is given below.

INSPECTION PROFORMA (for Routine Inspection)

1. **General**
 - 1.1. **Name of bridge/No. of bridge/Name of river**
 - 1.2. **Name of Highway/Location of Bridge**
 - 1.3. **Type of Bridge High level/submersible**
2. **Last Routine Inspection on** _____ **by** _____
3. **Traffic Intensity (latest census)** _____ **PCU/T per day**
4. **Condition of**
 - (a) **Approaches**
 - (b) **Protective works (Pitching, apron, toes, floor, guidebunds)**
5. **State**
 - (a) **H.F.L.** _____ **Yes/No**
 - (b) **Inadequacy of waterway** _____ **Yes/No**
 - (c) **Erosion of banks as evident** _____ **Yes/No**
6. **Foundation and substructure (State whether any abnormal scour, settlement/tilting/cracks/cavitation/damages/growth of vegetation)**
7. **Bearings (State condition/movements/deformation/cleanliness/condition of grease)**
8. **Superstructure**
 - (a) **Concrete (RCC and PSC) (State whether leaching/stains/cracks/spalling/scaling/excessive deflection condition of articulation and inside box)**
 - (b) **Steel (State condition of protective system/corrosion/deformations/rivet and weld condition/buckling and kinking/waviness/fracture/cleanlines)**
 - (c) **Masonry Arches (State condition of joints/cracks/vegetation growth/bulging of spandrel walls and parapets/deformation).**
9. **Miscellaneous**
 - (a) **Wearing course (Surface condition and drainage)**
 - (b) **Drainage (Spouts/Ventholes/clogging/cleanliness)**

- (c) Parapets and Handrails, etc.,
(condition and profile)
 - (d) Footpath (condition and drainage)
 - (e) Expansion joints
(Cleanliness/Wearing out and alignment/
gap width/hump/drainage/deformation/
corrosion/cracks)
 - (f) Utilities (State condition)
10. Have actions been taken on the observations and Yes/No
recommendations from the last Routine/Principal
inspection ?
11. Recommended corrective measures
(Attach separate sheet if space is insufficient)

Name, designation
and dated signature of
reviewing officer
(Next higher Authority
of the Inspecting Officer)

Name, designation
and dated signature
of Inspecting Officer

INSPECTION PROFORMA

Check List for Inspection Report

1. **GENERAL**
 - 1.1. Name of bridge/No. of the bridge/Name of the River.
 - 1.2. Name of the Highway, Bridge Location
 2. **Type of Bridge — High level/Submersible**
 - 3 (A) Date of last such Inspection by
 - (B) Date of last routine Inspection by
 - (C) Traffic Intensity PCU/T per day
(The latest census)

4. **APPROACHES**
 - 4.1. Condition of pavement surface (check unevenness settlement, cracking, pot holes, etc.)
 - 4.2. Side slopes/(Check pitched or unpitched, condition of pitching/turfing, any signs of slope failure etc.)
 - 4.3. Erosion of embankment by rain cuts or any other damage to embankment.
 - 4.4. Approach slab (check settlement, cracks movement etc.)
 - 4.5. Retaining walls: (Checks, subsidence, tilting, condition of weepholes guardstone and railing)
 - 4.6. Accumulation of silt and debris on submersible, approaches in cutting and embankment.
 - 4.7. Approach geometrics (check whether it satisfies the standards in force).

5. **PROTECTIVE WORKS**
 - 5.1. Type (mention whether guidebund or protection around abutments or spurs).
 - 5.2. Check damage to the layout, cross section profile (check whether the layout and the general cross sections are in order).
 - 5.3. Check condition of slope pitching, apron and toe walls indicating the nature of damage if any (check for proper slope, thickness of pitching in the slopes, width and thickness of apron, erosion of toe walls, etc.)
 - 5.4. Check condition of floor protection works, indicate nature of damage if any, (Condition of impervious floor, flexible apron, curtain walls, etc.)
 - 5.5. Check any abnormal scour noticed.
 - 5.6. Reserve store material (check against specified quality).

6. **WATERWAY**
 - 6.1. Check presence of obstruction, island formation, vegetation, undergrowth etc.
 - 6.2. Check any abnormal change in flow pattern

- 6.3. Check maximum flood level observed during the year and mark the same on the pier/abutment both on the U/S and D/S (Local enquiry if necessary)
- 6.4. Check signs of abnormal afflux from U/S & D/S watermarks on piers if any
- 6.5. Check adequacy of waterway
- 6.6. Check of erosion of bank
- 7. **FOUNDATION**
 - 7.1. Check settlement, abnormal scour, tilting, if any
 - 7.2. Check cracking, disintegration, decay, erosion, cavitation etc.
 - 7.3. Check damage due to impact of floating bodies, boulders, etc.
 - 7.4. For sub-ways report seepage, vehicle impact, if any, damage to the foundations, etc.
- 8. **SUBSTRUCTURE** : (piers, abutments, return walls and wing walls).
 - 8.1. Check efficacy of drainage of the backfill behind abutments (check functioning of weep holes, evidence of moisture on abutment faces, etc.)
 - 8.2. Check tilting, cracking, disintegration decay and other damages, etc.
 - 8.3. Check conditions of side retaining walls like cracking, disintegration and seepage, if any (For subways)
 - 8.4. Check large excavations done in the road below in the vicinity of flyover or road over bridge of viaduct
 - 8.5. Check damages to protective measures to pier and abutments (for viaducts, flyover and R.O. Bs.)
 - 8.6. Check damages to protective coating or paint
- 9. **BEARINGS**
 - 9.1. Metallic bearings (State types/Sliding plate/Rocker Roller/PTFE/Pot bearings)
 - 9.1.1. Check general condition (check rusting, cleanliness, seizing of plates), silting, accumulation of dirt in case of submersible bridges
 - 9.1.2. Functioning (check excessive movement, tilting, jumping off guides)
 - 9.1.3. Greasing (check date of last greasing/oil bath and whether to be redone or not)
 - 9.1.4. Effectiveness of anchor bolts (check whether they are in position and tightened)
 - 9.2. Elastomeric bearings (State numbers)
 - 9.2.1. Check condition: of pads (oxidation, creep, flattening, bulging, splitting, displacements, if any)
 - 9.2.2. Check general cleanliness
 - 9.3. Concrete bearings
 - 9.3.1. Check any signs of distress (cracking, spalling, disintegrating staining, dishing etc.)
 - 9.3.2. Check any excessive shifting
 - 9.3.3. Check loss of shape
 - 9.3.4. Check general cleanliness

- 9.4. Check cracks if any in supporting member (abutment cap, pier cap, pedestal)
- 9.5. Condition of d/s stoppers (for submersible bridges)
- 10. **SUPERSTRUCTURE**
- 10.1. **Reinforced concrete and prestressed concrete members**
- 10.1.1. Check spalling, disintegration or honey combing, (special attention; to be given at points of bearings)
- 10.1.2. Check cracking (pattern, location, explain preferably by photograph and plotting on sketch. A map of the cracking should be produced. The size and distribution of cracks and their penetration should be noted)
- 10.1.3. Check exposed reinforcement, if any
- 10.1.4. Check wear of deck surface
- 10.1.5. Check scaling (This is gradual and continuous loss of surface mortar and aggregate over irregular areas)
- 10.1.6. Check surface stains and rust stains along with the locations
- 10.1.7. Check Leaching (Effects are most usually evident on the soffits of decks)
- 10.1.8. Check corrosion of reinforcements, sheathing and tendons if visible
- 10.1.9. Check leakage (Leakages of water can take place through concrete decks, construction joints or thin component sections of the deck viz., kerbs, etc.)
- 10.1.10. Check damages if any due to moving vehicles
- 10.1.11. Check condition of drainage system (spouts, collection pits, grating, etc.)
- 10.1.12. Check condition of articulation (cracks, exposed reinforcement if any)
- 10.1.13. Check excessive vibrations, if any
- 10.1.14. Check excessive deflections (sag) or loss of camber if any at same point each time
- 10.1.15. Check cracks, if any, around anchorage zone for prestressed concrete members
- 10.1.16. Check excessive deflection (sag) at central hinge, tip, of cantilever for cantilever bridge
- 10.1.17. In box girders, the interior faces of flangers and webs need to be examined for signs of cracking and report excessive accumulation of water or debris. Interior diaphragms will also require examination, particularly for any signs of cracking at their junction to the webs
- 10.1.18. Check accumulation of silt and debris on surface of deck (for submersible bridges)
- 10.1.19. Check peeling off of protective coat or paint
- 10.2. **Check Steel Members**
- 10.2.1. Check condition of protective system
- 10.2.2. Check corrosion, if any
- 10.2.3. Check excessive vibrations, if any
- 10.2.4. Check alignment of members
- 10.2.5. Check condition of connection (adequacy, looseness of rivets, bolts or wornout welds, specially on connection of stringers to cross girders, cross

- girders to main girders, gussets or splices, condition of hinges, splices, etc.)
- 10.2.6. Check excessive loss of camber and excessive deflections and deformations, if any
- 10.2.7. Check buckling, kinking, warping and waviness
- 10.2.8. Check on the cleanliness of members and joints (check choking of drainage holes provided in the bottom booms).
- 10.2.9. Check apparent fracture if any
- 10.2.10. Check excessive wear (such as in pins in joints of truss) and their locations requiring close monitoring
- 10.2.11. Check conditions inside the closed members
- 10.3. Check masonry arches
- 10.3.1. Check condition of joints mortar, pointing, masonry, etc.
- 10.3.2. Check Profile, report flattening by observing rise of the arch at centre and quarter points
- 10.3.3. Check cracks, if any, (indicate location, pattern, extent, depth; explain by sketches)
- 10.3.4. Check drainage of spandrel fillings (check bulging of spandrel walls, if any)
- 10.3.5. Check growth of vegetation
- 10.4. Check all Cast Iron/Wrought Iron Components
- 10.4.1. These materials occur in older bridges and the defects which they exhibit are in general very similar to those described above for steel. It should be recognised that the homogeneity and purity of the material will not be upto the present day standards of steel, as such the inspection process has to take into account the variability of materials. (Blow holes and cracking are probably the main defects that occur during the casting of the metal and its cooling.)
11. **EXPANSION JOINTS**
- 11.1. Functioning (cracks in wearing course, existence of normal gap, excessive noise, etc.)
- 11.2. Check condition of sealing material (for neoprene sealing material, check for splitting, oxidation, creep, flattening, bulging and for bitumen filler, check for hardening, cracking, etc.)
- 11.3. Check secureness of the joints
- 11.4. Top sliding plate (check corrosion, damage to welds, etc.)
- 11.5. Locking of joints (Check locking of joints especially for finger type expansion joints).
- 11.6. Check for debris in joints
- 11.7. Report rattling, if any
- 11.8. Check drainage for expansion joint
- 11.9. Check alignment and clearance
12. **WEARING COAT (CONCRETE/BITUMEN)**
- 12.1. Check surface condition (cracks, spalling, disintegration, pot holes, etc.)
- 12.2. Check evidence of wear (Tell-Tale rings, check for thickness as against actual thickness, check data of last inspection)

- 12.3. Compare additional thickness with design thickness, with reference to kerb height
13. **DRAINAGE SPOUTS AND VENT HOLES**
- 13.1. Check clogging, deterioration and damage, if any
- 13.2. Check the projection of the spout on the underside (see whether structural members are being affected)
- 13.3. Check adequacy thereof
- 13.4. For subways report about adequacy of drainage and pumping arrangements, etc.
- 13.5. For submersible bridges, report on functioning.
14. **HANDRAILS, PARAPETS**
- 14.1. Check general condition (check expansion gaps, missing parts if any etc.)
- 14.2. Check damage due to collision
- 14.3. Check alignment (report any abruptness in profile)
15. **FOOTPATHS**
- 15.1. Check general condition (damage due to mounting of vehicles)
- 15.2. Check missing footpaths slabs
- 15.3. Cleanliness of ducts along footpaths
16. **UTILITIES**
- 16.1. Check leakage of water and sewage pipes
- 16.2. Check any damage by telephone and electric cables
- 16.3. Check condition of lighting facilities
- 16.4. Check damages due to any other utilities
17. **BRIDGE NUMBER**
- 17.1. Check condition of painting
18. **ENVIRONMENT**
- Check for signs of aggressiveness
19. **AESTHETICS**
- 19.1. Check any visual intrusion, hoardings, vegetation on structural members, etc.
- 19.2. Check whether all actions for maintenance and repairs recommended during last inspection have been done or not (give details)
20. **MAINTENANCE AND IMPROVEMENT RECOMMENDATION**

| S.No. | Item needing attention | Action recommended | Time by which to be completed | Remarks |
|-------|------------------------|--------------------|-------------------------------|---------|
|-------|------------------------|--------------------|-------------------------------|---------|

21. Certificate to be accorded by the inspecting official
Certified that I have personally inspected this bridge.

Signature of the Inspecting
Officer

Date :
Duration of
Inspection

From AM/PM
to AM/PM
Method of inspection

POSSIBLE ASSESSMENT METHODS (ONLY INDICATIVE)

| Assessment of | Possible method (s) |
|------------------------------|---|
| Concrete | |
| Strength | "Schmidt-hammer" |
| Quality | Ultra-sonic; |
| Lamination | Sounding |
| cover | Profometer |
| Steel | |
| Cracks | Ultra-sonic; |
| Cable/wire failure | radiographic; |
| corrosion | electrical halfcell potential; |
| | electrical resistivity meter; |
| Global behaviour | |
| movements | Surveying instruments; dial gauges (straining gauges) |
| extensometric measurement | Strain gauges and extensometers; |
| pressures, Forces | Pressure transducers or load cells |
| Miscellaneous | |
| thickness of coatings | Paint film gauge |
| waterproofing | (digital elecometer) |
| membranes | electrical resistance; |
| vibrations | Acelerometer |
| widening of cracks | Glass tell-tales |

6.2 Maintenance of Bridges

6.2.1 Introduction

Bridges represent a considerable capital asset not only because of the heavy investment required in constructing or replacing them but also because some of them form part of the historic and cultural heritage of a country. None of the bridges is endowed with an eternal life. Lack of maintenance generally results in reduced life and deterioration in the bridge structure. The adage “Prevention is better than cure” and “A stitch in time saves nine” are eminently true for bridges, where defects can rapidly lead to serious consequences if action is not taken in time. Demands made on bridges as also problems in attending to them have increased over the years. Therefore, it is essential to prolong the life of structures and rehabilitate them wherever necessary and possible.

The maintenance of bridge involves the up-keeping of the bridge components in good and serviceable condition so as to ensure a longer life of the bridge as envisaged at the time of its design and construction. Even if the bridges are well designed and properly constructed, periodic maintenance, if needed, is very essential to keep them in good serviceable condition. Therefore the bridges should be inspected and properly maintained.

6.2.2 Symptoms and Remedial Measures

Some of the common symptoms and remedial measures thereof are listed below:

| Nature of the Problem | Remedial Measures |
|------------------------------|--|
| a) Foundation | |
| i) Settlement: | |
| Moderate | - Packing under superstructure |
| Severe | - Stabilize by piles around foundation |
| | - Do micro pilling or root piling or rebuild |
| ii) Scour: | |
| Moderate | - Protect by flooring |
| | - Dump boulders around piers in scoured portion. |
| Severe | - Protect by piles around the foundation. |
| b) Substructure | |
| i) Weathering of masonry : | |
| Joints - Superficial | - Pointing |
| Deep | - Grouting with cement or epoxy |
| | - Plaster the masonry |
| Leaching of lime mortar | - Cement grouting |
| Leaching of masonry | - Guniting |

- ii) Vertical cracks
 - Grouting with cement or epoxy
 - Jacketing
- iii) Horizontal cracks
 - Increase the section by jacketing
- iv) Leaning/bulging
 - Backfill drain
 - Weep holes
 - Soil Anchoring/rock anchoring
 - Jacketing
 - Rebuilding
- v) Hollow left in masonry due to defective workmanship
 - Cement grouting
- vi) Reduction of gap at end of girder.
 - Check the bearing
 - Pull back the girder after checking the verticality of piers.

c) Training and Protection Works

- i) Damaged pitching
 - Repair with stone and point them.
- ii) Toe wall damaged
 - Rebuild them
- iii) Damaged apron or washed away
 - Repair or rebuild them
- iv) Reduction in section of guide bund/spur etc.
 - Repair before monsoon

d) Bed Blocks

- i) Crushing of bed blocks under bed plates
 - Repair them with epoxy mortar after removing all loose material
- ii) Shaken/loose bed blocks
 - Pointing around the bed blocks
 - Epoxy grouting
 - Provide through bed blocks
- iii) Cracked bed block
 - Recast bed blocks either cast-in-situ or precast
- iv) Cracks in masonry below bed block
 - Repair the crushed masonry with epoxy mortar

e) Bearings

- i) Corroded but not seized
 - Clean and Grease it
- ii) Corroded and seized
 - Replace it
- iii) Shearing of strips, anchor bolts
 - Check the movement of girder.
 - Strengthen the approaches.
 - Repair the sheared parts.
- iv) Impact at bearing
 - Check the levels of bed blocks.

- v) Flattening of rollers
or cracked rollers
 - vi) Tearing/cracking/
bulging of elastomeric Bearings
- Provide a layer of epoxy mortar in the gaps.
 - Replace the rollers
 - Replace the bearing with good quality bearing.

f) Superstructure

1. Arches

- i) Weathering
 - ii) Visible distortion
 - iii) Cracks in arch
 - iv) Cracks/bulges in
parapet/spandrel
wall
- Pointing
 - Grouting with cement or epoxy
 - Guniting
 - Jacketing intrados or extrados in profile
 - Grouting with cement or epoxy.
 - Jacketing intrados or extrados
 - Draining the back fill
 - Providing Ties
 - Rebuilding

2. Steel Girders (Riveted and welded)

Plate Girder / Open Web Girder

- i) Early steel
 - ii) Weathered paint
surface
 - iii) Flaking & peeling of steel
 - iv) Distortion of
bracings
 - v) Distortion of
stiffeners
 - vi) Loose rivets at
floor system joint
 - vii) Cracks in steel works
- Replace the girder
 - Check with reduced stresses
 - Painting
 - Provide cover plates
 - Change the bracings. Also check for its adequacy.
 - May be due to over load.
 - Redesign and provide a heavier section
 - Replace the rivets.

a. Whenever a crack is detected in the steel work, its cause should be established and further propagation, if any, monitored. If the crack is propagating in a direction perpendicular to the stress in member, holes 20 or 22 mm dia

may be drilled at crack ends to arrest the crack propagation. The edge of holes should be placed at visible ends of the crack. After holes are drilled it should be checked that crack tips have been removed and turned bolts of 20 or 22 mm dia as the case may be should be provided in the holes and fully tightened. Any reduction in strength of girder due to the crack and drill of holes should be given due consideration.

b. The method of repair of crack should be decided based on the location and severity of the crack.

As a long term solution the cracked member may be strengthened by cover plate (s), adequately riveted. If this is not feasible, the defective member may have to be taken out and repaired/replaced.

c. Permanent measures may consist of the cracked member being retrofitted with riveted or bolted splice or where feasible the entire member may be replaced.

d. Field welding should not be undertaken for repair of cracks.

- viii) Rust mark over metalized surface Possibility of crack/ loose rivet at joint - same as above (vii)
- ix) Progressive loss of camber - May be due to overload or bad riveting. Check for stresses and strengthen it.
- Regirder the bridge
 - Lift the panel joints and re-rivet the girder joints.

3. Pipes

- i) Distortion of section/cracks - Change the pipe by rebuilding
- ii) Sag - Strengthen sagged portion.

4. RC/PSC Slabs

- i) Map pattern surface cracks (not progressive) - Keep under observation
- ii) Structural cracks - Grouting with epoxy
- iii) Spalling of concrete - Guniting

5. RC/PSC Girders

- i) Cracks in anchorage zone - Epoxy grouting
- Replace the girder.

- ii) Spalling/crushing
- iii) Shear cracks, Flexural cracks

- Guniting
- Epoxy grouting.

6. Composite girders

- i) Separation of the concrete or
Crack in Concrete

a. If separation of the concrete deck slab Slab from the steel girder is noticed, the location and length should be marked distinctly with paint for easy identification. Repair and retrofit scheme should be prepared after fully investigating the cause of the problem.

Epoxy grouting may be done to bind the deck slab and the girder where the defect is noticed and the girder should be kept under close observation.

If the epoxy grouting is not found effective, vertical prestressing or strapping may be necessary for which holes should be drilled in the deck slab near the girder in the affected location and vertical prestressing/ strapping provided.

b. The drainage system of the deck slab should be thoroughly cleaned and repaired as necessary before the onset of monsoon.

c. Wearing coat where provided, should be maintained.

- ii) Defects in steel portion

- Similar action as mentioned under heading of steel girders.

7. BRIDGE NUMBERING IN LIGHT OF IRC 7:2017

7.1 Introduction

A uniform system of numbering of all the structures is essential for proper asset management. All culverts, minor bridges, major bridges, underpasses, flyovers, grade separators and tunnels on road shall be assigned separate numbers. This is a means for their easy identification of location and type of structure for the personnel for inspection and maintenance.

7.2 Scope

7.2.1 This document covers structures on all roads in the country.

7.2.2 Structures shall include

- (i) All culverts, including slab, box, hume pipes etc.
- (ii) All bridges
- (iii) All underpasses
- (iv) All overpasses, pedestrian bridges etc.
- (v) ROB's, flyovers and grade separator etc.
- (vi) Tunnels
- (vii) Any other structure

7.3 Numbering of Structures

7.3.1 All structures on a road shall be numbered in serial order, in each kilometer separately.

7.3.2 The number shall be in the form of a fraction, the numerator denoting the number of kilometer in which the structure is situated and the denominator the km wise serial number of the structure. For instance, the 5th structure in the 4th km (i.e. between km stones 3 and 4) shall be designated as 4/5, and the 8th structure in 25th km as 25/8.

7.3.3 For multi-lane carriageways, there should be either one combined structure or separate bridge structures. In case of one combined structure, the structure number shall be designated as in Sub-Clause 7.3.2 above. In case of separate bridge structures, the structure number shall be indicated as mentioned hereinafter. As the section progresses, the left hand side structure will have a suffix 'L' and the right hand side structure will have a suffix 'R' Similarly, the structures on service roads will have additional suffix For example (Table 7.1):

| S. No. | Location of Structures | Structure No. |
|--------|--|---------------|
| | 2 nd structure between km 280 and 281 | |
| 1 | Left side structure on service road | 281/2 L S |

| | | |
|---|--|-----------|
| 2 | Right side structure on service road | 281/2 R S |
| 3 | Left side structure on main carriageway | 281/2L |
| 4 | Right side structure on main carriageway | 281/2R |

Table 7.1 Numbering of Bridge

7.3.4 If any new culvert bridge or structures are built subsequently, say between the 3rd and 4th structure in km 375, the same shall be designated as 375/3/1, 375/3/2, etc.

7.4 Salient Information

For inspection and maintenance, it is useful to have mention of following salient information about structures:

- ❖ Year of construction
- ❖ Name of Channel / River / Crossing
- ❖ Length
- ❖ Span arrangement
- ❖ HFL
- ❖ Roadway
- ❖ Type of structure e.g. RCC/PSC, T-Beam and slab, Box girder, RCC/Stone Slab, Box culvert, tunnel feature, Arch, HP, Steel, Cable stayed, Extra-dosed.

These shall be provided on separate plate on the right hand side of the carriageway or the road.

7.5 Inscription of Structure Number

7.5.1 The structure number shall be inscribed near the top left hand side parapet wall railing posts for end of crash barrier as seen by traffic in the end elevation when approaching the structure from each direction. These are illustrated in Figs.1, 2 and 3.

7.5.2 In situations where instead of parapet walls, the structure is provided with railings, but having no end supporting pillars on which the number etc. could be inscribed, the number of the structure shall be indicated by means of a separate numbering plate of the size 300 mm x 300 mm. There shall be two such numbering plates, one for each direction. The plates shall be welded or fixed securely on the left hand side facing the carriageway as close to entrance to the structure as possible.

7.5.3 In case of structures, such as pipe culverts, where there are usually no parapet walls or railings at the roadway level, two stone or R.C.C. marker posts, having a cross section of 150 mm x 150 mm and exposed height of at least 300 mm, shall be set up on the left side, one in each direction. Care shall be taken to locate the marker posts fully outside the prescribed roadway width. The culvert

number shall be either engraved or painted. Alternatively, the number might also be inscribed at a suitable location on the head wall of the structure above the highest flood level.

NOTE: Deck Level shall indicate the level of bridge deck at the starting point of bridge as the section progresses, as under:

- ❖ *For 2-lane bridge - Deck Level at the road kerb (right side)*
- ❖ *For multi-lane carriageway - Deck Level at median*

7.6 Information Plate

7.6.1 The information of the structure shall be inscribed on two information plates one in each direction and fixed in the end elevation on a plate size near the top right hand side parapet wall / railing parts or end post of crash barrier etc. in the end elevation when approaching the structure. Information plate shall be of size 300 mm x 500 mm (for minor bridge and culverts) and 500 mm X 1000 mm (for major bridges and other structures) Illustration is given in Fig. 4. The plate shall be fixed near the top right hand side.

7.6.2 In situation where instead of parapet walls, the structure is provided with railings, but having no end supporting pillars on which information could be inscribed, the same shall be indicated on a separate information plate of size 300 x 500 mm. There shall be two such information plates, one in each direction. The plates shall be welded or fixed securely on the right hand side facing the carriageway as close to the entrance to the structure as possible.

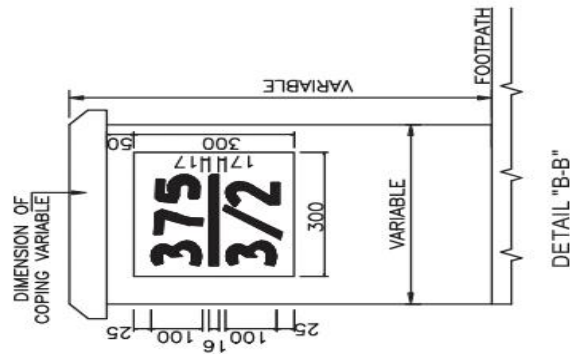
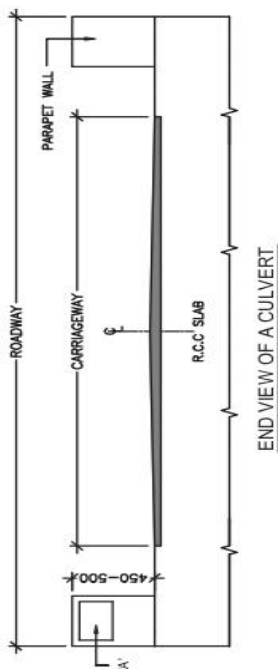
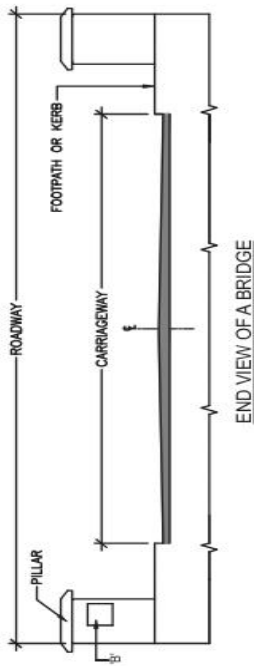
7.6.3 In case of structures, such as pipe culverts where there are usually no parapet walls or railings, at the roadway level, two stone or R.C.C. posts having a cross section of 150 x 150 mm and exposed height of at least 500 mm, shall be set up on right side, one in each direction, on which an information plate of size 300 x 500 mm shall be fixed or welded securely. Care shall be taken to locate the posts and the plates fully outside the prescribed roadway width.

7.7 Numerals and Details

The numerals used shall be 100 mm high and of international form conforming to IRC: 30-1968 Standard Letters and Numerals of Different Height for use on Highway Signs. These shall be painted on smooth panels as prescribed. In case of right hand panel the height shall be suitably adjusted so that it does not obstruct the visibility. The colour of the background shall be canary yellow, ISI Shade 309.

7.8. Maintenance

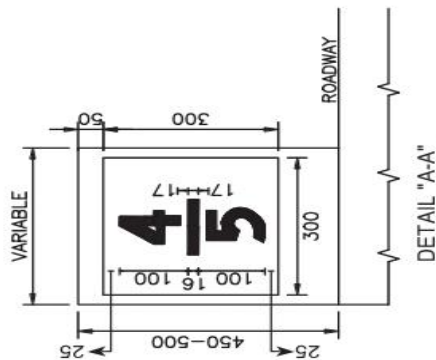
The structure numbers and information plate shall be updated whenever any change takes place affecting the existing position. They shall be kept clean well maintained and regularly painted.



NOTES:-

1. ALL DIMENSIONS ARE IN MM.

Fig. 2 Structure Number



NOTES:-

1. ALL DIMENSIONS ARE IN MM.

Fig. 1 Structure Number

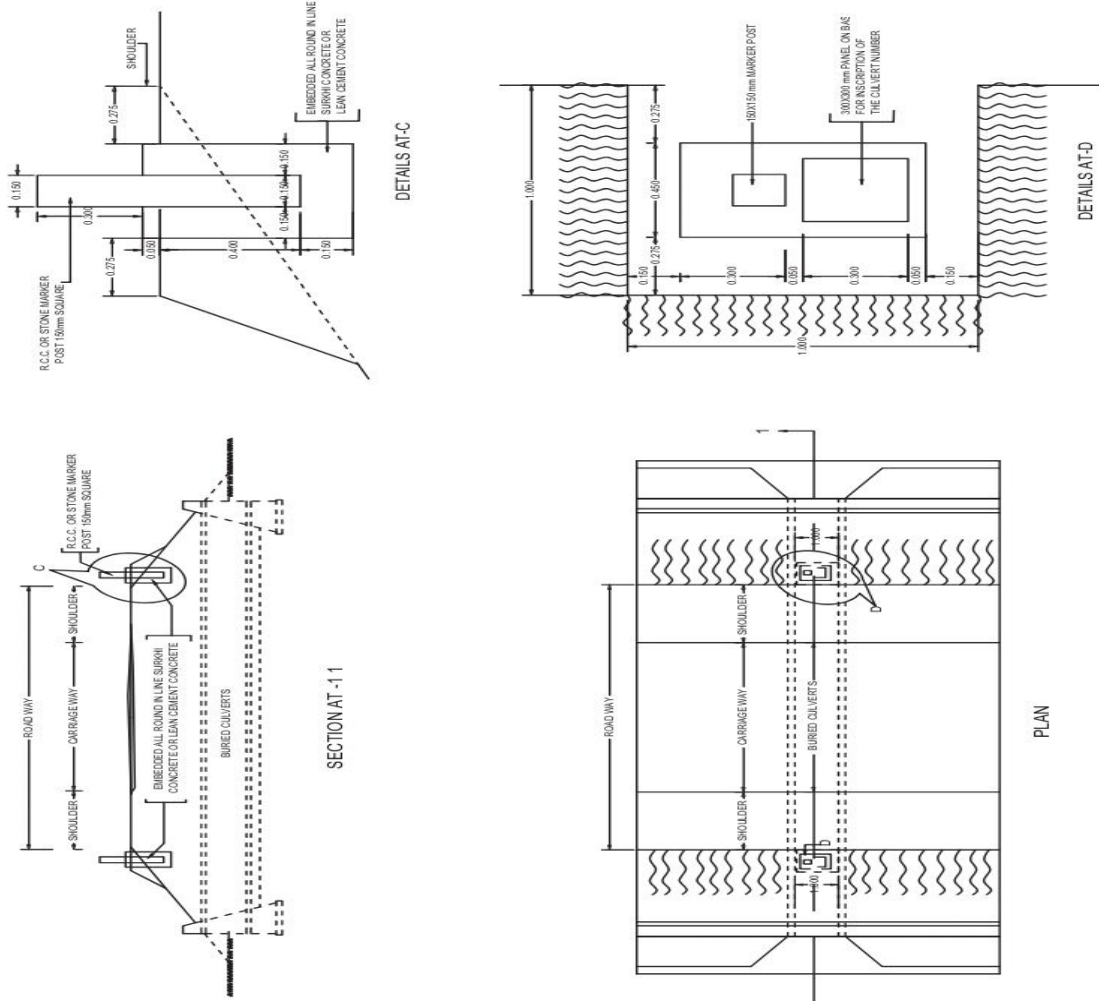


Fig. 3 Structure number for Pipe Culverts and other Structures without end Pillars

ALL DIMENSION IN mm

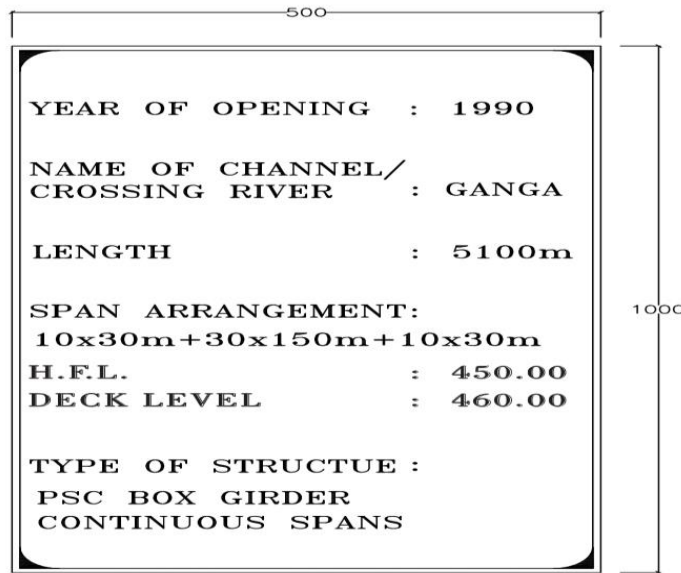


Fig. 4 Information Plate for Major Bridges and other Structures

8. STRUCTURAL HEALTH MONITORING (SHM) OF BRIDGES

8.1 Introduction

Structural Health Monitoring (SHM) involves the observation and analysis of a system over time using periodically sampled response measurements to monitor changes to the material and geometric properties of engineering structures such as bridges and buildings.

For long term SHM, the output of this process is periodically updated information regarding the ability of the structure to perform its intended function in light of the inevitable aging and degradation resulting from operational environments. After extreme events, such as earthquakes or blast loading, SHM is used for rapid condition screening and aims to provide, in near real time, reliable information regarding the integrity of the structure.

The SHM process involves selecting the excitation methods, the sensor types, number and locations, and the data acquisition/storage/transmittal hardware commonly called health and usage monitoring systems. Measurements may be taken to either directly detect any degradation or damage that may occur to a system or indirectly by measuring the size and frequency of loads experienced to allow the state of the system to be predicted.

SHM system implemented on bridges includes five operations of acquisition, validation, analysis, prognosis, and management of the system. The system and the sensors were developed to cover the parameters for the most important deterioration mechanisms: corrosion of reinforcement in bridges, carbonation of concrete, freeze-thaw cycles, alkali-silica reaction and mechanical damage, as well as the changes in the structures behavior and safety: static deformation, strains; crack widths and vibrations (frequencies, amplitudes, accelerations and vibration modes).

A SHM system can contribute to damage assessment in main five levels

- ❖ **Level I** - Damage detection when identifies that damage has occurred
- ❖ **Level II** - Damage location, when identifies that damage has occurred and determines the location of damage
- ❖ **Level III** - Damage typification, where identifies that damage has occurred, location of damage, and estimates the type of damage
- ❖ **Level IV** - Damage extent, where identifies that damage has occurred, location of damage, estimates the type of damage and evaluates the severity of damage
- ❖ **Level V** - Damage extent, where identifies that damage has occurred, location of damage, the type of damage, the severity of damage, and evaluates the remaining useful life of the bridge or viability state

8.2 Types of Monitoring

Health Monitoring can be subdivided into multiple types of categories. Both the time frame of monitoring and the scale of monitoring are necessary considerations that need to be addressed before choosing a type of monitoring system. A bridge owner may want to monitor the bridge health for a period of a year or a few months, while in other cases only a one-time short-term solution may be necessary. Conversely, a new structure may have an expected lifetime of 50 years and the owner would like a monitoring system that would last an extended period of time as well. Regarding the scale of monitoring, a specific joint or member in a bridge that has been problematic in the past may be the focus of the monitoring. On the other hand, an overall assessment of bridge response to loading may be the goal. The following definitions have been established to address the issues above.

8.2.1 Time Frame

Short-term – Monitoring to obtain bridge response information for a short-term objective. Examples include, but are not limited to load rating, tracking short-term fatigue growth, extending the life of a bridge for a year or less, or monitoring the response of a bridge for a permit vehicle.

Long-term – Monitoring of a new, retrofitted, or structurally deficient bridge to track response over an extended period of time, usually more than one year.

Inspection – Monitoring to assess the condition of the bridge or its components (e.g., the deck) as part of a regularly scheduled program (e.g., once every year or two).

Early Warning – Monitoring that offers alarm features which will provide notification automatically when certain pre-determined parameters are exceeded.

Collapse Warning – Monitoring that will close the bridge and warn motorists in the event of a bridge collapse.

8.2.2 Scale

Local – Monitoring that focuses on a specific location in the bridge; examples include monitoring to assess growth of a known crack, local buckling, corrosion at specific locations, and strain measurements.

Member – Monitoring that focuses on a specific member or member-sized region of a bridge; e.g., strain distributions in or deflections of a particular member.

Global – Monitoring that focuses on the overall health of the entire bridge; examples include natural frequencies and mode shapes, bridge deflection distributions, acoustic emissions, temperature distributions, and wind profiles.

8.3 Monitoring Metrics

Monitoring metrics are a system of parameters intended to measure bridge condition and performance. Depending on the type of bridge and the needs of the bridge owner, different measurements should be taken in order to properly monitor bridge health. Some metrics can be measured for any type of bridge; however, there are some measurements specific to concrete and steel bridges. It is important to know how each metric applies to the bridge of interest and what will be useful in monitoring the health of the bridge.

8.3.1 General Metrics

8.3.1.1 Acceleration - The instantaneous rate at which the velocity of a point in a vibrating bridge is changing with time. Acceleration is the most common measure taken to characterize vibrations. It is possible to define the frequencies and shapes of the different modes of vibration from a single acceleration trace. The frequencies and modes can be compared to values obtained from previous acceleration measurements to determine if the bridge has deteriorated or has been damaged.

8.3.1.2 Climatic Conditions - Pertains to the environmental conditions in the area of the bridge that may relate to bridge performance. Parameters that can be measured include: air temperature, wind speed, wind direction, relative humidity, and solar radiation.

8.3.1.3 Curvature - The rate of change of slope along the length of a flexural member and produced by transverse loading (i.e., normal to the longitudinal axis). From principles of structural mechanics, curvature is known to be directly proportional to bending moment in the member.

8.3.1.4 Displacements - The overall linear movement (i.e., translation) of a bridge either in relation to its original position or on a global scale. It is possible to measure the displacement in one, two or three independent directions.

8.3.1.5 Load - The total load of objects passing over a particular area of a bridge. This measure can be useful to enforce weight restrictions, as well as to define the range (i.e., spectrum) of typical traffic loads.

8.3.1.6 Tilt/Slope -The angular change of components in a bridge. This is useful in determining distortion in bridge geometry. Slope is the rate of change of deflection of a flexural member with respect to length. Angle changes with respect to a vertical plane are also useful to assess 'out-of-plumb' elements. It is useful to know if there has been a large change in angle on an element.

8.3.1.7 Scour - The removal of soil around the piers of bridges due to fast moving water currents during flooding. Removal of soil can lead to instability of piers.

8.3.2 Concrete Metrics

8.3.2.1 Corrosion - It is possible to determine whether or not the steel reinforcement embedded in concrete is at risk of depletion from attack of chloride or carbon dioxide. Some corrosion monitoring

techniques determine the probability of corrosion occurring, while others determine the approximate corrosion rate. Different sensors and/or procedures may be required to monitor the corrosion of epoxy coated and non-epoxy coated rebar.

8.3.2.2 Cracking – The separation of concrete surfaces at the location of fractures is typically characterized by the width, length and number of cracks. Small-scale cracking (i.e., few, short, narrow cracks) is expected to take place in all concrete; however wider, longer and/or more numerous cracks are not expected. It is possible to detect the formation of these cracks through acoustic emission sensors. It is also possible to monitor known cracks using strain gauges placed over the area of interest.

8.3.2.3 Location of rebar/delaminations – The location of reinforcement in concrete can be determined using several non-destructive methods. These or similar techniques can be used to determine if the concrete above and below the reinforcement has begun to delaminate.

8.3.2.4 Strain – The relative elongation or shortening present in the concrete in specific locations of a bridge. In the service load range, the concrete behaves in a linear manner allowing the estimation of the stresses present at the particular location in the bridge.

8.3.2.5 Strength – The strength of concrete is typically characterized from tests of cylinder or cubes that are cast at the same time and from the same mix as the bridge member or component. For determining the initial in-situ strength of the concrete, measurements of concrete temperature can be taken while the member or component is curing and compared to previously obtained temperature-strength correlations for the particular concrete mix. This can be useful for quality control of the concrete during construction.

8.3.2.6 Tension (in rebar/tendons) – In post-tensioned systems, the tension in the cables is important to the overall strength of the concrete member. Also, if delamination occurs in reinforced concrete, the concrete cannot transfer forces to the rebar causing a reduction in stress. Thus, tension measurements can be used to assess the overall health of the structure.

8.3.3 Steel Metrics

8.3.3.1 Corrosion – The chemical reaction whereby steel loses electrons to water and oxygen and other corrosive materials (e.g., road salts). Monitoring is useful in order to determine extent and rates of corrosion within the structure.

8.3.3.2 Crack Growth – The elongation and/or widening of a known crack. Fatigue cracks may grow or remain static, with the former posing larger concerns than the latter regarding potential failure. Therefore, it is useful to a bridge owner to know if a fatigue crack is growing under the current loading conditions.

8.3.3.3 Cracking – The number, width and length of cracks in a steel member or component at locations of stress concentrations or fatigue loading. Such information is useful for predicting the remaining life in a steel bridge or for averting a sudden failure. Quantification of cracking is important because extensive cracking at a critical location or member in a steel bridge can cause large changes in stresses at other bridge locations.

8.3.3.4 Strain – The relative elongation or shortening present in the steel in specific locations of a bridge. In the service load range, the steel behaves in a linear manner allowing the estimation of the stresses present at the particular location in the bridge.

8.3.3.5 Tension (in cables) – Cables in suspension bridges are designed to handle tensile forces. Monitoring the magnitude of these forces is of interest, especially in cases where bridge loads have increased beyond design levels, or if deterioration of the cables is suspected or known.

8.4 Methods Used in Bridge SHM

8.4.1 Non-destructive testing methods

Testing can be an effective tool in the inspection and condition assessment of bridge structures. According to the degree of their invasiveness, testing methods can be divided into destructive, semi-destructive and non-destructive testing (NDT) methods. The destructive methods comprise tests normally performed in laboratory under more or less controlled conditions that may not mirror actual conditions experienced in the field. Additionally, these tests can be rather expensive as it is often necessary to damage the component or load it to failure. The NDT methods comprise a wide group of analysis techniques used to evaluate the properties of a material, component or system without causing damage. This advantage is particularly useful for evaluating in-service bridges, since the bridges can remain intact and open to traffic under the evaluation period minimizing the impact to the community and the travelling public. Table 8.1 lists some of the most well-known traditional NDT techniques used for damage detection.

Table 8.1 Non-destructive testing methods

| | |
|----------------------|---|
| Audio-visual methods | Visual inspection Chain drag Coin tap test |
| Stress-wave methods | Acoustic emission Impact echo testing Sonic testing Ultrasonic NDT |

| | |
|--------------------------|---|
| | Impulse response (IR) |
| Electro-magnetic methods | Ground penetrating radar (GPR) Conductivity Half-cell potential Electrical resistivity measurement |
| Deterministic methods | Proof load test Coring |
| Miscellaneous tests | Dynamic/vibration testing Infrared thermography Radiography |

8.4.2. Vibration-based damage identification methods

For a global assessment of the structure's integrity vibration-based damage identification (VBDI) methods can be used. Natural frequencies are the most fundamental vibration parameter and methods directly measuring shifts in natural frequency (or eigenvalue) can be used for identifying damage. Traditional VBDI techniques have been widely researched in the past decades and Cawley & Adams are likely to be the first researchers to give formulation for damage detection from frequency changes before and after damage is introduced. Since frequencies and mode shapes of the structure under vibration are a function of its mass and stiffness and, as mass generally remains constant, any changes in the dynamic behavior will be associated with stiffness variations, which implicitly point to the presence of damage in the structure. Thus, VBDI methods consist of measuring and evaluating the dynamic behavior of the structure often by comparing it to the behaviour simulated by numerical models, for instance by finite element (FE) models. Other times that comparison is based on times series data but in that case a large number of sensors need to be placed accurately in order to record the required data.

8.4.3. Model-based and data-based methods

The methods for assessment of structures can be split into two main classes, according to their approach. For a full understanding of the behavior of a particular structure, physics-based models are usually the most appropriate. As the name itself indicates, a physics-based approach typically presupposes a finite element (FE) model of the target structure. These models are often of gradually increasing complexity during the development stage, so as to make sure that the measured responses can be reproduced as much as accurate by the FE model. As such, the models evolve from simple conceptual system representations to physics-based high-fidelity models, which accurately represent the actual physical asset. Since many algorithms of damage detection are based

on the difference between the modified models before and after occurrence of damage, problems such as parameter identification and damage detection are closely related to model updating. The models can be updated in the presence of new collected data, provide feedback into the physical twin and simulate plausible scenarios for assessing risks and predicting structural performance. The data-based approach is free of geometrical and material information, allowing to circumvent the burden of having to develop a detailed FE model of the monitored structure, mostly by using Artificial Intelligence (AI) techniques. With this approach time series analysis or signal processing techniques are employed to extract damage-sensitive features from the measured signals. In these regards, choosing proper damage features is crucial for successful damage detection as these features are used to establish baseline statistics and to monitor change in structural behavior.

8.5 Review of Case Studies of SHM of Bridges

8.5.1 Russia-Monitoring of Vintage Bridge - This bridge was constructed in 1936-37 over Moskova river in Moscow next to Kremlin. It is a Reinforced Concrete arched box girder bridge. It was declared a heritage building as it is more than 70 years old. Total length of bridge is 250m with 3 spans (43+92+43), 3 parallel arches. The SHM was started in 2003. Types of sensors used were 16 standard SOFO sensors in central arch plus 6 thermo couples. Numbers of sensors used were 22. Instrumentation was designed by SMARTEC SA, Switzerland and ZAO Triada holdings, Russia.

Purpose- To continuously monitor temperature and average strain along horizontal and vertical directions.

Results- Settlement of an abutment producing cracking of the stone lining and structural element. Another was chloride penetration into the structure leading to reinforcement corrosion.

8.5.2 Japan - Monitoring of Suspension Bridge

Hakucho bridge which is located at windy and seismically active area in northern part of Muroran, Hokkaido, Japan was opened on April 17, 1998. The main span of the bridge is 720 m installed with sensors placed at locations Z1 to Z19.

Purpose- The purpose of the monitoring is to understand the actual dynamic behavior and loading conditions, and to develop a health monitoring scheme using ambient vibration measurement which is readily available under service conditions

8.5.3 India- SHM of Naini Bridge (2001-2004)

Naini Bridge is 1510 meter long bridge for four lane traffic and with a footpath and a cycle track on each side of the traffic lanes. For crossing the deep channel of the river a 490 meter long cable stayed bridge is provided having a main span of 260 meter and side spans of 115 meter. On both sides of the cable stayed part approach bridges have been provided, one 365 meter long with typical spans of 25 meter and the other 515 meter long with typical spans of 60 meter.

The Structural Health Monitoring System (SHMS) for Naini Bridge was designed as a modern advanced monitoring system with the provisions for design verification, user safety support and optimization of maintenance planning. Also the system was designed to operate by a distributed data acquisition network based on standard data acquisition units and standard data acquisition software from US based National Instruments, in order to keep costs low.

Purpose- Building a high channel count SHM system to continuously scan the response of a large cable stayed bridge due to various changes in climate and operations.

So for the SHMS has through advanced GPS and Weigh in Motion monitoring proven able to detect the frequency of overloaded vehicles passing the bridge and to verify some design parameters concerning temperature movements.

APPENDIX 6 I
CHECKLIST FOR PREPARATION OF GAD

A. GENERAL

- 1 Title block, scales names etc. correctly written
- 2 Key plan indicated
- 3 North Line indicated
- 4 Chainage indicated
- 5 In notes, units of dimensions, levels and chainages indicated
- 6 In notes, Type of superstructure indicated
- 7 In notes, Type of substructure indicated
- 8 In notes, Type of foundation indicated
- 9 In notes, Type of expansion joints indicated
- 10 In notes, Type of bearings indicated
- 11 In notes, Type of wearing coat indicated
- 12 Grades of concrete for superstructure, substructure, foundation, approach slab, abutment, wing wall / return wall, toe walls, PCC below foundations etc. indicated
- 13 Details for arrangements at dirt wall given
- 14 Details for arrangements at expansion joints given
- 15 Section of abutments given clearly
- 16 Section of return wall along with fly wings given
- 17 Section of piers and foundations given clearly
- 18 All section marks and details numbering are tallying with the actual sections / details
- 19 No detail / section numbering is repeated / missed

B. PLAN

- 1 Directions %to___+in both sides indicated
- 2 Span arrangements with embankment lengths, viaduct lengths etc indicated
- 3 Expansion joints indicated
- 4 Crash barrier location shown
- 5 Handrails location shown
- 6 Piers, abutment, return walls / wing walls shown
- 7 Toe walls shown
- 8 Length of return wall / wing walls shown
- 9 Skew angles indicated and skew / square dimensions indicated
- 10 Centre line of bridge axis and piers / abutments indicated along with setout dimensions.
- 11 Median indicated and shaded
- 12 Median wall and connectivity / dry joint to existing structure shown
- 13 Drainage spouts indicated
- 14 Tapering of carriageways at approaches indicated
- 15 Approach embankment revetment, side slope pitching and bed pitching with toe walls indicated
- 16 Indicated the profile of river bed / railway tracks / roads
- 17 U /s and D / s sides indicated
- 18 Web lines indicated in dotted
- 19 Chainages indicated
- 20 Approach slab indicated
- 21 Hand rails / Crash barrier lines indicated
- 22 Railway chainage indicated and railway directions indicated

C. ELEVATION

- 1 Span arrangements with embankment lengths, viaduct lengths etc indicated
- 2 Directions %to___+in both sides indicated
- 3 Expansion Joints indicated
- 4 Crash barrier location shown
- 5 Handrails location shown
- 6 Piers, abutment, return wall / wing walls shown
- 7 Toe walls shown
- 8 Length of return wall / wing wall shown
- 9 Dimensions in square / skew indicated
- 10 Centre line of bridge axis and piers / abutments indicated along with setout dimensions.
- 11 HFL indicated
- 12 Chainages and FRL at deck level indicated
- 13 Bed level indicated
- 14 Approach embankment revetment, side slope pitching and bed pitching with toe walls indicated.
- 15 Foundations shown and levels indicated
- 16 Indicated the clearance from HFL / tracks / highest road level to soffit

D. SECTION

- 1 Title block, scales names etc. Correctly written
- 2 Crash barrier location shown
- 3 Handrails location shown
- 4 Piers, abutment, return walls / wing walls shown
- 5 Toe walls shown
- 6 Centre line of bridge deck with respect to existing bridge indicated
- 7 Drainage spouts indicated
- 8 HFL indicated
- 9 FRL at deck level indicated
- 10 Bed level indicated
- 11 Approach embankment revetment, side slope pitching and bed pitching with toe walls indicated
- 12 Section of piers indicated
- 13 Section of abutment indicated
- 14 Foundations shown and levels indicated
- 15 Indicated the clearance from HFL / tracks / highest road level to soffit
- 16 U / s and D / s indicated
- 17 Wearing coat indicated

Appendix – II**CHECKLIST FOR SUBMISSION OF GAD TO RAILWAY
DEPARTMENT FOR ROB_s**

- (i) Railway Boundary marked on GAD.
- (ii) Railway track existing and tracks proposed in future marked on GAD.
- (iii) A railway signal detail (if at point) is marked. LC no if level crossing is present marked.
- (iv) Railway chainage marked on drawings.
- (v) Minimum distance of Pile Cap / Pier Shaft / Abutment shall be minimum of 2360mm from the central line of track.
- (vi) For the distance between top of railway track and soffit level shall be
 - a. The minimum height is 6550mm for ROB (Road Over Bridge).
 - b. Where double Decker trains are likely to run height is 7300.

Appendix – III

Government of India
Ministry of Shipping, Road Transport & Highways
(Department of Road Transport & Highways)

Transport Bhawan,
 1, Parliament Street,
 New Delhi – 110 001.

No. RW/NH/33044/2/88-S&R(B)

24th March, 2009

To

1. Secretaries of all State Governments /UTs dealing with National Highways.
2. Engineer-in-Chief / Chief Engineer of all States Governments/ UTs dealing with National Highways.
3. Secretary, Transport of all State Governments and UTs.
4. Chairman, National Highways Authority of India.
5. Director General (Border Roads).

6. *All Roads/ETO*

Subject: Width of Bridges on 2-lane National Highways (with and without footpath).

Sir,

Instructions were issued vide this Ministry's letter of even number dated 9th May, 2000 regarding width of bridges to be provided on National Highways. The matter has been reconsidered in the light of concern for safety of vehicles/pedestrians using the bridges. The following revised guidelines are now issued in supersession of the earlier instructions for bridges on 2-lane NHs. These guidelines are applicable essentially to future cases.

2. GENERAL

The basic approach is that the width of carriageway of all bridges irrespective of their lengths or location / terrain (rural, urban, plain) shall be that:-

- a) for free flow of traffic from approaches to bridge, width of carriageway on bridge shall be equal to the carriageway width of immediate approaches plus paved shoulders even if presently not provided. For bridges on 2-lane NHs the carriageway width shall be 10.50m (paved shoulder and kerb shyness on either side taken as 1.50m and 0.25m respectively).
- b) Overall width of bridges will vary depending upon width of carriageway, footpath, safety kerbs, crash barriers, railings and provision for kerb shyness. Overall width of bridges for 2-lane NHs without footpath and with footpath are given in table in Annexure.
- c) Formation width of the immediate approaches shall be equal to overall width between outermost faces of the railing / crash barrier of the bridge. In case the formation width of approaches is different than the overall width of the bridge as stipulated in (b) above,

-1/6-

5.4 For bridges with footpath, having length more than 100m, half metre (0.5 m) wide opening in the crash barrier shall be provided at 50 m interval.

6. EXTRA WIDTH ON BRIDGES LOCATED ON CURVES:

Extra carriageway width of bridge located on curves shall be provided as per IRC codal provisions applicable for road section on curves.

7. Road over bridges on National Highways

The above provisions shall also generally apply to all road over bridges except where any deviations have to be made due to specific site constraints.

It is requested that the contents of this circular be brought to the notice of all officers in your department concerned with National Highways and other centrally sponsored schemes.

Yours faithfully,



(Arun Kumar Sharma)

Chief Engineer (S & R) B

For Director General (Road Development) & S.S

Telephone: 011-23719850

Annexure : Width of bridge on two lane National Highway with and without footpath

To

All CE of Proj

-3/1-10

ANNEXURE

Width of bridge on two lane National Highway without and with footpath
(Reference para 2 and fig. 1, 2 & 3)

Dimensions in meters

| Description | Bridge without footpath | Bridge with footpath (1.5 footpath) |
|---------------|-------------------------|--|
| Carriageway | 10.00 | 10.00 |
| Kerb shyness | 0.50(2x 0.25) | 0.50(2x 0.25) |
| Footpath | - | 3.00 (2 x 1.50) |
| Safety Kerbs | 1.50 (2 x 0.75) | - |
| Crash Barrier | 0.90 (2 x 0.45) | 0.90 (2 x 0.45) |
| Railings | - | 0.40 (2 x 20) |
| Overall width | 12.90 | 14.80 |

Note:

(a) Carriageway width of 10.50m on bridges is planned to account for paved shoulders on approaches if provided later. Thus to arrive at the width of carriageway on bridges, the allowance for paved shoulders and kerb shyness has been made.

-4/6-

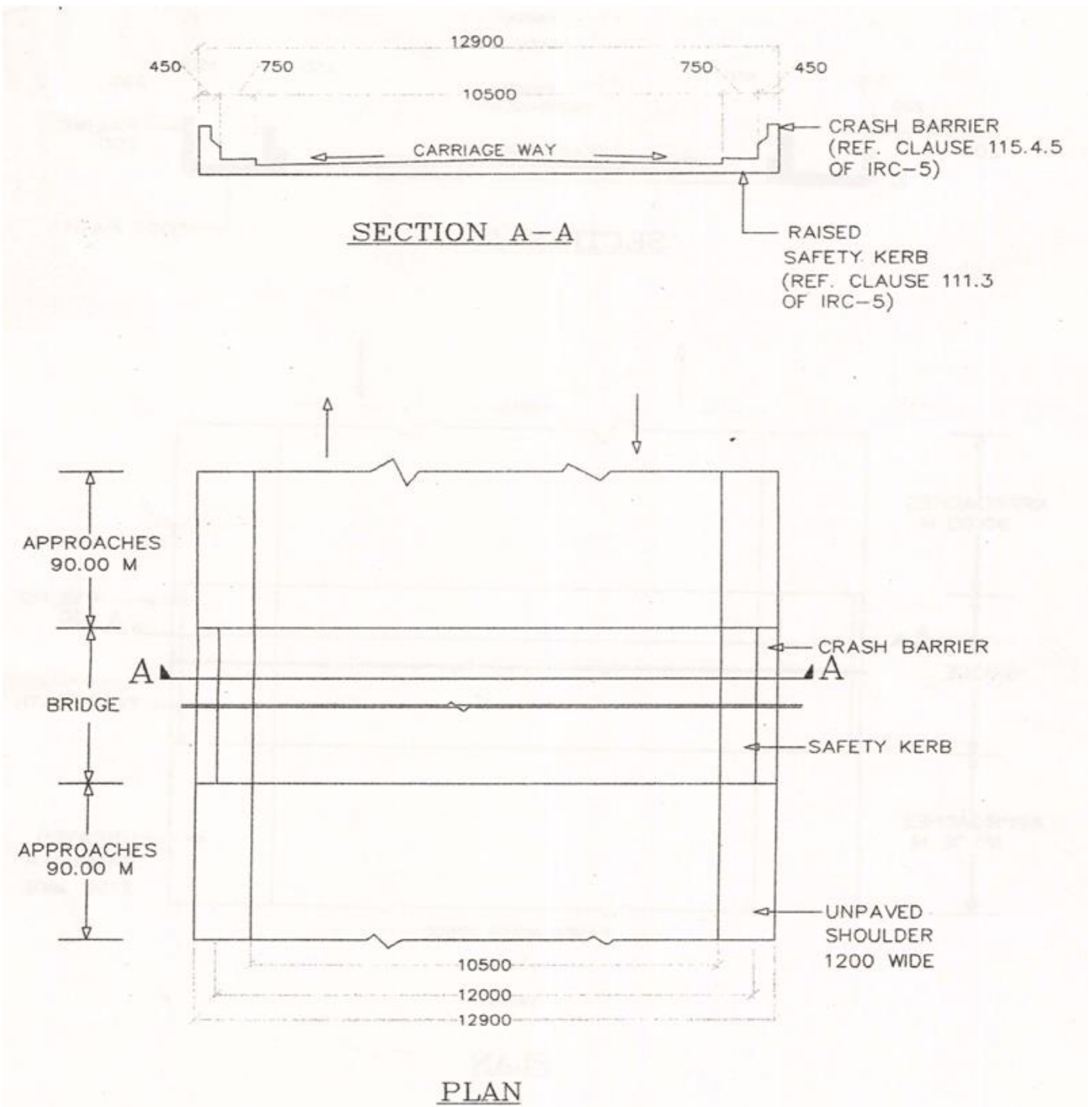
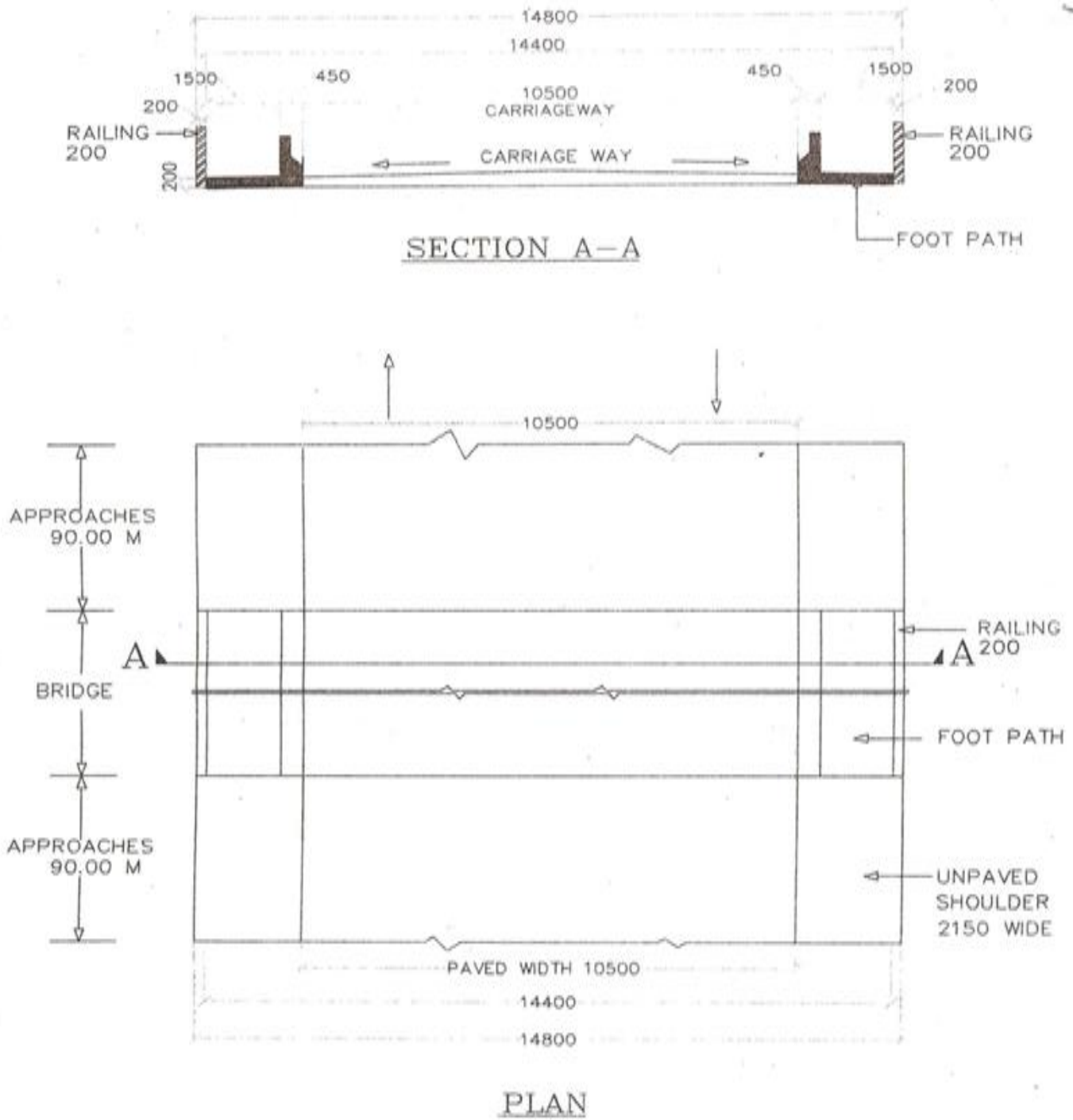


FIG.1:—TWO LANE HIGHWAY BRIDGE WITHOUT FOOTPATHS
HAVING CRASH BARRIER AT THE EDGES

-5/6-



ALL DIMENSIONS IN mm

FIG.2:- TWO LANE HIGHWAY BRIDGE WITH FOOTPATHS HAVING CRASH BARRIER BETWEEN FOOTPATH AND CARRIAGEWAY

-6/6-

APPENDIX-IV
LIST OF IRC CODES AND SPECIAL PUBLICATIONS

| S. No. | Code/ Document No. | Title of the Publication |
|-----------|--------------------------|--|
| 1 | IRC:2-1968 | Route Marker Signs for National Highways (First Revision) |
| 2 | IRC:3-1983 | Dimensions & Weights of Road Design Vehicles (First Revision) |
| 3 | IRC:5-2015 | Standard Specifications and Code of Practice for Road Bridges, Section I . General Features of Design (Eighth Revision) |
| 4 | IRC:6-2017 | Standard Specifications and Code of Practice for Road Bridges, Section-II Loads and Load Combinations (Seventh Revision) |
| 5 | IRC:7-2017 | Recommended Practice for Numbering Culverts, Bridges and Tunnels (Second Revision) |
| 6 | IRC:8-1980 | Type Designs for Highway Kilometre Stones (Second Revision) |
| 7 | IRC:9-1972 | Traffic Census on Non-Urban Roads (First Revision) |
| 8 | IRC:11-2015 | Recommended Practice for the Design and Layout of Cycle Tracks (First Revision) |
| 9 | IRC:12-2016 | Unified Guidelines for Access Permission to Fuel Stations, Private Properties, Rest Area Complexes and Such Other Facilities Along National Highways (Fourth Revision) |
| 10 | IRC:14-2004 | Recommended Practice for Open Graded Premix Carpets (Third Revision) |
| 11 | IRC:15-2017 | Code of Practice for Construction of Jointed Plain Concrete Pavements (Fifth Revision) |
| 12 | IRC:16-2008 | Standard Specifications and Code of Practice for Prime and Tack Coat (Second Revision) |
| 13 | IRC:19-2005 | Standard Specifications and Code of Practice for Water Bound Macadam (Third Revision) |
| 14 | IRC:20-1966 | Recommended Practice for Bituminous Penetration Macadam (Full Grout) |
| 15 | IRC:22-2015 | Standard Specifications and Code of Practice for Road Bridges, Section VI . Composite Construction (Limit States Design) (Third Revision) |
| 16 | IRC:24-2010 | Standard Specifications and Code of Practice for Road Bridges, Steel Road Bridges (Limit State Method) (Third Revision) |
| 17 | IRC:25-1967 | Type Designs for Boundary Stones |
| 18 | IRC:26-1967 | Type Design for 200-Metre Stones |
| 19 | IRC:27-2009 | Specifications for Bituminous Macadam (First Revision) |
| 20 | IRC:28-1967 | Tentative Specifications for the Construction of Stabilized Soil Roads with Soft Aggregate in Areas of Moderate and High Rainfall |
| 21 | IRC:30-1968 | Standard Letters and Numerals of Different Heights for Use on Highway Signs |
| 22 | IRC:32-1969 | Standard for Vertical and Horizontal Clearances of Overhead Electric Power and Telecommunication Lines as Related to Roads |

| | | |
|----|-------------|--|
| 23 | IRC:33-1969 | Standard Procedure for Evaluation and Condition Surveys of Stabilised Soil Roads |
| 24 | IRC:34-2011 | Recommendations for Road Construction in Areas Affected by Water Logging, Flooding and/or Salts Infestation (First Revision) |
| 25 | IRC:35-2015 | Code of Practice for Road Markings (Second Revision) |
| 26 | IRC:36-2010 | Recommended Practice for Construction of Earth Embankments and Sub-Grade for Road Works (First Revision) |
| 27 | IRC:37-2018 | Guidelines for the Design of Flexible Pavements+(Fourth Revision) |
| 28 | IRC:38-1988 | Guidelines for Design of Horizontal Curves for Highways and Design Tables (First Revision) |
| 29 | IRC:39-1986 | Standards for Road-Rail Level Crossings (First Revision) |
| 30 | IRC:40-2002 | Standard Specifications and Code of Practice for Road Bridges, Section IV . (Brick, Stone and Cement Concrete Block Masonry) (Second Revision) |
| 31 | IRC:41-1997 | Guideline for Type Designs for Check Barriers (First Revision) |
| 32 | IRC:42-1972 | Proforma for Record of Test Values of Locally Available Pavement Construction Materials |
| 33 | IRC:43-2015 | Recommended Practice for Plants, Tools and Equipment Required for Construction and Maintenance of Concrete Roads (First Revision) |
| 34 | IRC:44-2017 | Guidelines for Cement Concrete Mix Design for Pavements (Third Revision) |
| 35 | IRC:45-1972 | Recommendations for Estimating the Resistance of Soil Below the Maximum Scour Level in the Design of Well Foundations of Bridges |
| 36 | IRC:46-1972 | A Policy on Roadside Advertisements (First Revision) |
| 37 | IRC:47-1972 | Tentative Specification for Built-up Spray Grout |
| 38 | IRC:50-1973 | Recommended Design Criteria for the Use of Cement Modified Soil in Road Construction |
| 39 | IRC:52-2019 | Guidelines for the Alignment Survey and Geometric Design of Hill Roads (Third Revision) |
| 40 | IRC:53-2012 | Road Accident Recording Forms A-1 and 4 (Second Revision) |
| 41 | IRC:54-1974 | Lateral and Vertical Clearances at Underpasses for Vehicular Traffic |
| 42 | IRC:55-1974 | Recommended Practice for Sand-Bitumen Base Courses |
| 43 | IRC:56-2011 | Recommended Practices for Treatment of Embankment and Roadside Slopes for Erosion Control (First Revision) |
| 44 | IRC:57-2018 | Recommended Practice for Sealing of Joints in Concrete Pavements (Second Revision) |
| 45 | IRC:58-2015 | Guidelines for the Design of Plain Jointed Rigid Pavements for Highways (Fourth Revision) (with CD) |
| 46 | IRC:60-1976 | Tentative Guidelines for the Use of Lime- Fly Ash Concrete as Pavement Base or Sub-Base |
| 47 | IRC:62-1976 | Guidelines for Control of Access of Highways |
| 48 | IRC:63-1976 | Tentative Guidelines for the Use of Low Grade Aggregates and Soil Aggregates Mixtures in Road Pavement Construction |
| 49 | IRC:64-1990 | Guidelines for Capacity of Roads in Rural Areas (First Revision) |

| | | |
|----|---------------------------|--|
| 50 | IRC:65-2017 | Guidelines for Planning and Design of Roundabouts (First Revision) |
| 51 | IRC:66-1976 | Recommended Practice for Sight Distance on Rural Highways (First Revision) |
| 52 | IRC:67-2012 | Code of Practice for Road Signs (Third Revision) |
| 53 | IRC:69-1977 | Space Standards for Roads in Urban Areas |
| 54 | IRC:70-2017 | Guidelines on Regulation and Control of Mixed Traffic in Urban Areas (First Revision) |
| 55 | IRC:71-1977 | Recommended Practice for Preparation of Notations |
| 56 | IRC:72-1978 | Recommended Practice for Use and Upkeep of Equipment, Tools and Appliances for Bituminous Pavement Construction |
| 57 | IRC:73-1980 | Geometric Design Standards for Rural (Non- Urban) Highways |
| 58 | IRC:74-1979 | Tentative Guidelines for Lean-Cement Concrete and Lean- Cement Fly Ash Concrete as a Pavement Base or Sub-Base |
| 59 | IRC:75-2015 | Guidelines for the Design of High Embankments (First Revision) |
| 60 | IRC:76-1979 | Tentative Guidelines for Structural Strength Evaluation of Rigid Airfield Pavements |
| 61 | IRC:78-2014 | Standard Specifications and Code of Practice for Road Bridges, Section VII- Foundations and Substructure (Revised Edition) |
| 62 | IRC:79-2019 | Recommended Practice for Road Delineators (First Revision) |
| 63 | IRC:80-1981 | Type Designs for Pick-up Bus Stops on Rural (i.e., Non-Urban) Highways |
| 64 | IRC:81-1997 | Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique (First Revision) |
| 65 | IRC:82-2015 | Code of Practice for Maintenance of Bituminous Road Surfaces (First Revision) |
| 66 | IRC:83-2015 (Part-I) | Standard Specifications and Code of Practice for Road Bridges, Section IX Bearings, Part I : Roller & Rocker Bearings (Second Revision) |
| 67 | IRC:83-2018 (Part II) | Standard Specifications and Code of Practice for Road Bridges, Section : IX . Bearings (Elastomeric Bearings), Part II (Second Revision) |
| 68 | IRC:83-2018 (Part III) | Standard Specifications and Code of Practice for Road Bridges, Section IX . Bearings, Part III: POT, PIN, Metallic Guide and Plane Sliding Bearings (First Revision) |
| 69 | IRC:83-2014 (Part IV) | Standard Specifications and Code of Practice for Road Bridges, (Section IX) . Bearings (Spherical and Cylindrical) |
| 70 | IRC:85-2015 | Recommended Practice for Accelerated Strength Testing & Evaluation of Concrete (First Revision) |
| 71 | IRC:86-2018 | Geometric Design Standards for Urban Roads and Streets (First Revision) |
| 72 | IRC:87-2018 | Guidelines for Formwork, Falsework and Temporary Structures for Road Bridges (Second Revision) |
| 73 | IRC:88-1984 | Recommended Practice for Lime Flyash Stabilised Soil Base/Sub-Base in Pavement Construction |
| 74 | IRC:89-2019 | Guidelines for Design and Construction of River Training & Control Works for Road Bridges (Second Revision) |

| | | |
|-----|--------------|--|
| 75 | IRC:90-2010 | Guidelines of Selection, Operation and Maintenance of Bituminous Hot Mix Plant (First Revision) |
| 76 | IRC:92-2017 | Guidelines for the Design of Interchanges in Urban Areas (First Revision) |
| 77 | IRC:93-1985 | Guidelines on Design and Installation of Road Traffic Signals |
| 78 | IRC:98-2011 | Guidelines on Accommodation of Utility Services on Roads in Urban Areas (Second Revision) |
| 79 | IRC:99-2018 | Guidelines for Traffic Calming Measures in Urban and Rural Areas (First Revision) |
| 80 | IRC:101-1988 | Guidelines for Design of Continuously Reinforced Concrete Pavement with Elastic Joints |
| 81 | IRC:102-1988 | Traffic Studies for Planning Bypasses Around Towns |
| 82 | IRC:103-2012 | Guidelines for Pedestrian Facilities (First Revision) |
| 83 | IRC:104-1988 | Guidelines for Environmental Impact Assessment of Highway Projects |
| 84 | IRC:105-2019 | Specifications for Dense Bituminous Macadam and Bituminous Concrete for Airfield Pavements (First Revision) |
| 85 | IRC:106-1990 | Guidelines for Capacity of Urban Roads in Plain Areas |
| 86 | IRC:107-2013 | Specifications for Bitumen Mastic Wearing Courses (First Revision) |
| 87 | IRC:108-2015 | Guidelines for Traffic Forecast on Highways (First Revision) |
| 88 | IRC:109-2015 | Guidelines for Wet Mix Macadam (First Revision) |
| 89 | IRC:110-2005 | Standard Specifications and Code of Practice for Design and Construction of Surface Dressing |
| 90 | IRC:111-2009 | Specifications for Dense Graded Bituminous Mixes |
| 91 | IRC:112-2019 | Code of Practice for Concrete Road Bridges (First Revision) |
| 92 | IRC:113-2013 | Guidelines for the Design and Construction of Geosynthetic Reinforced Embankments on Soft Subsoils |
| 93 | IRC:114-2013 | Guidelines for use of Silica Fume in Rigid Pavement |
| 94 | IRC:115-2014 | Guidelines for Structural Evaluation and Strengthening of Flexible Road Pavements Using Falling Weight Deflectometer (FWD) Technique+(with CD) |
| 95 | IRC:116-2014 | Specifications for Readymade Bituminous Pothole Patching Mix using Cut-Back Bitumen |
| 96 | IRC:117-2015 | Guidelines for the Structural Evaluation of Rigid Pavement by Falling Weight Deflectometer (with CD) |
| 97 | IRC:118-2015 | Guidelines for Design and Construction of Continuously Reinforced Concrete Pavement (CRCP) |
| 98 | IRC:119-2015 | Guidelines for Traffic Safety Barriers |
| 99 | IRC:120-2015 | Recommended Practice for Recycling of Bituminous Pavements |
| 100 | IRC:121-2017 | Guidelines for Use of Construction and Demolition Waste in Road Sector |
| 101 | IRC:122-2017 | Guidelines for Construction of Precast Concrete Segmental Box Culverts |
| 102 | IRC:123-2017 | Guidelines on Geophysical Investigation for Bridges |
| 103 | IRC:124-2017 | Bus Rapid Transit (BRT) Design Guidelines for Indian Cities |

| | | |
|-----|----------------|---|
| 104 | IRC:125-2017 | Guidelines on Dozers for Highway Works |
| 105 | IRC:126-2017 | Guidelines on Wet Mix Plant |
| 106 | IRC-127-2018 | Guidelines on Skill Development of Workmen in Road Sector |
| 107 | IRC-128-2019 | Guidelines on Training of Highway Professionals |
| 108 | IRC-129-2019 | Specifications for Open-Graded Friction Course |
| 109 | IRC:SP:4-1966 | Bridge Loading Round the World |
| 110 | IRC:SP:12-2015 | Guidelines for Parking Facilities in Urban Roads+(First Revision) |
| 111 | IRC:SP:13-2004 | Guidelines for the Design of Small Bridges and Culverts (First Revision) |
| 112 | IRC:SP:14-1973 | A Manual for the Application of the Critical Path Method to Highway Projects in India |
| 113 | IRC:SP:15-1996 | Ribbon Development Along Highways and Its Prevention |
| 114 | IRC:SP:16-2019 | Guidelines on Measuring Road Roughness and Norms (Second Revision) |
| 115 | IRC:SP:18-1978 | Manual for Highway Bridge Maintenance Inspection |
| 116 | IRC:SP:19-2001 | Manual for Survey, Investigation and Preparation of Road Projects (Second Revision) |
| 117 | IRC:SP:20-2002 | Rural Roads Manual |
| 118 | IRC:SP:21-2009 | Guidelines on Landscaping and Tree Plantation |
| 119 | IRC:SP:22-1986 | Recommendation for the Sizes for each Type of Road Making Machinery to Cater to the General Demand of Road Works |
| 120 | IRC:SP:23-1983 | Vertical Curves for Highways |
| 121 | IRC:SP:24-1984 | Guidelines on the Choice and Planning of Appropriate Technology in Road Construction |
| 122 | IRC:SP:25-1984 | Gopi and his Road Roller-Guidelines on Maintenance of Road Rollers |
| 123 | IRC:SP:26-1984 | Report Containing Recommendations of IRC Regional Workshops on Rural Road Development (with Supplementary Notes) |
| 124 | IRC:SP:27-1984 | Report Containing Recommendations of the IRC Regional Workshops on Highway Safety |
| 125 | IRC:SP:28-1995 | Road Transport and Energy (First Revision) |
| 126 | IRC:SP:29-1994 | Directory of Indigenous Manufacturers of Road/ Bridge Construction Machinery & Important Bridge Components (First Revision) |
| 127 | IRC:SP:30-2019 | Manual on Economic Evaluation of Highway Projects in India (Third Revision) |
| 128 | IRC:SP:34-1989 | General Guidelines About the Equipment for Bituminous Surface Dressing |
| 129 | IRC:SP:35-1990 | Guidelines for Inspection and Maintenance of Bridges |
| 130 | IRC:SP:36-2018 | Guidelines for IRC Standards (First Revision) |
| 131 | IRC:SP:37-2010 | Guidelines for Evaluation of Load Carrying Capacity of Bridges (First Revision) |
| 132 | IRC:SP:38-1992 | Manual for Road Investment Decision Model |
| 133 | IRC:SP:39-1992 | Guidelines on Bulk Bitumen Transportation & Storage Equipment |
| 134 | IRC:SP:40-2019 | Guidelines on Repair, Strengthening and Rehabilitation of Concrete Bridges (First Revision) |
| 135 | IRC:SP:41-1994 | Guidelines for the Design of At-Grade Intersections in Rural & Urban Areas |
| 136 | IRC:SP:42-2014 | Guidelines on Road Drainage (First Revision) |

| | | |
|-----|----------------|--|
| 137 | IRC:SP:43-1994 | Guidelines on Low-Cost Traffic Management Technique for Urban Areas |
| 138 | IRC:SP:44-1996 | Highway Safety Code |
| 139 | IRC:SP:45-1996 | Time Series Data on Road Transport Passenger and Freight Movement (1951-1991) |
| 140 | IRC:SP:46-2013 | Guidelines for Design and Construction of Fibre Reinforced Concrete Pavements (First Revision) |
| 141 | IRC:SP:48-1998 | Hill Road Manual |
| 142 | IRC:SP:49-2014 | Guidelines for the Use of Dry Lean Concrete as Sub-base for Rigid Pavement (First Revision) |
| 143 | IRC:SP:50-2013 | Guidelines on Urban Drainage (First Revision) |
| 144 | IRC:SP:51-2015 | Guidelines for Load Testing of Bridges (First Revision) |
| 145 | IRC:SP:52-1999 | Bridge Inspector's Reference Manual |
| 146 | IRC:SP:53-2010 | Guidelines on Use of Modified Bitumen in Road Construction (Second Revision) |
| 147 | IRC:SP:54-2018 | Project Preparation Manual for Bridges (First Revision) |
| 148 | IRC:SP:55-2014 | Guidelines on Traffic Management in Work Zones+ (First Revision) |
| 149 | IRC:SP:56-2011 | Guidelines for Steel Pedestrian Bridges (First Revision) |
| 150 | IRC:SP:58-2001 | Guidelines for Use of Fly Ash in Road Embankments |
| 151 | IRC:SP:59-2019 | Guidelines for Use of Geosynthetics in Road Pavements and Associated Works (First Revision) |
| 152 | IRC:SP:60-2002 | An Approach Document for Assessment of Remaining Life of Concrete Bridges |
| 153 | IRC:SP:61-2004 | An Approach Document on Whole Life Costing for Bridges in India |
| 154 | IRC:SP:62-2014 | Guidelines for Design and Construction of Cement Concrete Pavements for Low Volume Roads+ (First Revision) |
| 155 | IRC:SP:63-2018 | Guidelines for the Use of Interlocking Concrete Block Pavement (First Revision) |
| 156 | IRC:SP:64-2016 | Guidelines for the Analysis and Design of Cast-in-Place Voided Slab Superstructure (First Revision) |
| 157 | IRC:SP:65-2018 | Guidelines for Design and Construction of Segmental Bridges (First Revision) |
| 158 | IRC:SP:66-2016 | Guidelines for Design of Continuous Bridges (First Revision) |
| 159 | IRC:SP:67-2005 | Guidelines for Use of External and Unbonded Prestressing Tendons in Bridge Structures |
| 160 | IRC:SP:68-2005 | Guidelines for Construction of Roller Compacted Concrete Pavements |
| 161 | IRC:SP:69-2011 | Guidelines & Specifications for Expansion Joints (First Revision) |
| 162 | IRC:SP:70-2016 | Guidelines for the Use of High Performance Concrete (Including Self Compacting Concrete in Bridges) (First Revision) |
| 163 | IRC:SP:71-2018 | Guidelines for Design and Construction of Precast Pre-tensioned Girders for Bridges (First Revision) |
| 164 | IRC:SP:72-2015 | Guidelines for the Design of Flexible Pavements for Low Volume Rural Roads+ (First Revision) |
| 165 | IRC:SP:73-2018 | Manual of Specifications & Standards for Two Lanning of Highways with Paved Shoulder (Second Revision) |
| 166 | IRC:SP:74-2007 | Guidelines for Repair and Rehabilitation of Steel Bridges |

| | | |
|-----|-------------------------|--|
| 167 | IRC:SP:75-2008 | Guidelines for Retrofitting of Steel Bridges by Prestressing |
| 168 | IRC:SP:76-2015 | Guidelines for Conventional and Thin White-topping+(First Revision) |
| 169 | IRC:SP:77-2008 | Manual for Design, Construction & Maintenance of Gravel Roads |
| 170 | IRC:SP:78-2008 | Specifications for Mix Seal Surfacing (MSS) Close-Graded Premix Surfacing (CGPS) |
| 171 | IRC:SP:79-2008 | Tentative Specifications for Stone Matrix Asphalt |
| 172 | IRC:SP:80-2008 | Guidelines for Corrosion Prevention, Monitoring and Remedial Measures for Concrete Bridge Structures |
| 173 | IRC:SP:81-2008 | Tentative Specifications for Slurry Seal and Microsurfacing |
| 174 | IRC:SP:82-2008 | Guidelines for Design of Causeways and Submersible bridges |
| 175 | IRC:SP:83-2018 | Guidelines for Maintenance, Repairs & Rehabilitation of Cement Concrete Pavements (First Revision) |
| 176 | IRC:SP-84-2019 | Manual of Specifications and Standards for Four Laning of Highways (Second Revision) |
| 177 | IRC:SP-85-2011 | Guidelines for Variable Message Signs |
| 178 | IRC:SP-86-2010 | Guidelines for Selection, Operation and Maintenance of Paver Finishers |
| 179 | IRC:SP-87-2019 | Manual of Specifications & Standards for Six Laning of Highways (Second Revision) |
| 180 | IRC:SP-88-2019 | Manual on Road Safety Audit (First Revision) |
| 181 | IRC:SP-89-2010 | Guidelines for Soil and Granular Material Stabilization Using Cement, Lime and Fly Ash |
| 182 | IRC:SP-89(Part II)-2018 | Guidelines for the Design of Stabilized Pavements (Part-II) |
| 183 | IRC:SP-90-2010 | Manual for Grade Separators and Elevated Structures |
| 184 | IRC:SP-91-2019 | Guidelines for Road Tunnels (First Revision) |
| 185 | IRC:SP-92-2010 | Road Map for Human Resource Development in Highway Sector |
| 186 | IRC:SP-93-2017 | Guidelines on Requirements for Environmental Clearances for Road Projects |
| 187 | IRC:SP-95-2011 | Model Contract Document for Maintenance of Highways |
| 188 | IRC:SP-96-2012 | Guidelines for Selection, Operation and Maintenance of Concrete Batching and Mixing Plants |
| 189 | IRC:SP-97-2013 | Guidelines on Compaction Equipment for Roads Works |
| 190 | IRC:SP-98-2013 | Guidelines for the use of Waste Plastic in Hot Bituminous Mixes (Dry Process) in Wearing Courses |
| 191 | IRC:SP-99-2013 | Manual of Specifications and Standards for Expressways` |
| 192 | IRC:SP-100-2014 | Use of Cold Mix Technology in Construction and Maintenance of Roads Using Bitumen Emulsion |
| 193 | IRC:SP-101-2019 | Guidelines for Warm Mix Asphalt |
| 194 | IRC:SP-102-2014 | Guidelines for Design and Construction of Reinforced Soil Walls |
| 195 | IRC:SP-103-2014 | Guidelines on Tree Plantation along Rural Roads |
| 196 | IRC:SP-104-2015 | Guidelines for Fabrication and Erection of Steel Bridges |
| 197 | IRC:SP-105-2015 | Explanatory Handbook to IRC:112-2011: Code of Practice for Concrete Roads Bridges |

| | | |
|-----|-----------------|--|
| 198 | IRC:SP-106-2015 | Engineering Guidelines on Landslide Mitigation Measures for Indian Roads |
| 199 | IRC:SP-107-2015 | Guidelines for Gap Graded Wearing Course with Rubberised Bitumen-(Bitumen Rubber) |
| 200 | IRC:SP-108-2015 | Guidelines on Preparation and Implementation of Environment Management Plan |
| 201 | IRC:SP-109-2015 | Guidelines for Design and Construction of Small Diameter Piles for Road Bridges |
| 202 | IRC:SP-110-2017 | Application of Intelligent Transport System for Urban Roads |
| 203 | IRC:SP:111-2017 | Capacity Building of Road Agencies In Charge of Implementation of Road Projects in Urban Areas |
| 204 | IRC:SP:112-2017 | Manual for Quality Control in Road and Bridge works |
| 205 | IRC:SP:113-2018 | Guidelines on Flood Disaster Mitigation for Highway Engineers |
| 206 | IRC:SP:114-2018 | Guidelines for Seismic Design of Road Bridges |
| 207 | IRC:SP:115-2018 | Guidelines for Design of Integral Bridges |
| 208 | IRC:SP:116-2018 | Guidelines for Design and Installation of Gabion Structures |
| 209 | IRC:SP:117-2018 | Manual on Universal Accessibility for Urban Roads and Streets |
| 210 | IRC:SP:118-2018 | Manual for Planning and Development of Urban Roads and Streets |
| 211 | IRC:SP:119-2018 | Manual of Planting and Landscaping of Urban Roads |
| 212 | IRC:SP:120-2018 | Explanatory Handbook to IRC:22-2015 Standard Specifications and Code of Practice for Road Bridges, Section VI-Composite Construction |
| 213 | IRC:SP:121-2018 | Guidelines for Use of Iron, Steel and Copper Slag in Construction of Rural Roads |
| 214 | IRC:SP:124-2019 | Model Contract for Maintenance of Roads (Based on single Percentage Rate) |
| 215 | IRC:SP:125-2019 | Guidelines for Cement Grouted Bituminous Mix Surfacing for Urban Roads |
| 216 | IRC:SP:126-2019 | Guidelines for the Design and Construction of Low Volume Rural Roads Using Jute Geotextiles |

REFERENCES

| S. No. | Code/ Document No. | TITLE |
|--------|-----------------------|-------|
|--------|-----------------------|-------|

1. IRC CODES

| | | |
|----|--------------------------|---|
| 1 | IRC:5-2015 | Standard Specifications and Code of Practice for Road Bridges, Section I . General Features of Design (Eighth Revision June, 2015) |
| 2 | IRC:6-2016 | Standard Specifications and Code of Practice for Road Bridges, Section II . Loads and Stresses (Seventh Revision December, 2016) |
| 3 | IRC:18-2000 | Design Criteria for Pre stressed Concrete Road Bridges (Post Tensioned Concrete) (Third Revision) |
| 4 | IRC:21-2000 | Standard Specifications and Code of Practice for Road Bridges, Section III . Cement Concrete (Plain and Reinforced) (Third Revision) |
| 5 | IRC:22-2015 | Standard Specifications and Code of Practice for Road Bridges, Section VI . Composite Construction (Limit States Design) (Third Revision January, 2015) |
| 6 | IRC:24-2010 | Standard Specifications and Code of Practice for Road Bridges, Steel Road Bridges (Limit State Method) (Third Revision). |
| 7 | IRC:38-1988 | Guidelines for Design of Horizontal Curves for Highways and Design Tables (First Revision) |
| 8 | IRC.:45-1972 | Recommendations for Estimating the Resistance of Soil Below the Maximum Scour Level in the Design of Well Foundations of Bridges |
| 9 | IRC:78-2014 | Standard Specifications and Code of Practice for Road Bridges, Section VII . Foundations and Substructure (Revised Edition January, 2014) |
| 10 | IRC:83-2015 (Part I) | Standard Specifications and Code of Practice for Road Bridges, Section IX . Bearings, Part I : Metallic Bearings (Second Revision) |
| 11 | IRC:83-2018 (Part II) | Standard Specifications and Code of Practice for Road Bridges, Section IX . Bearings, Part II: Elastomeric Bearings (Second Revision, May 2018) |

| | | |
|----|---------------------------|---|
| 12 | IRC:83-2018 (Part III) | Standard Specifications and Code of Practice for Road Bridges, Section IX . Bearings, Part III: POT, POTCUMPTFE, PIN and Metallic Guide Bearings (First Revision May, 2018) |
| 13 | IRC:87-2018 | Guidelines for the Design and Erection of False work for Road Bridges (Second Revision) |
| 14 | IRC:89-1997 | Guidelines for Design and Construction of River Training & Control Works for Road Bridges (First Revision) |

2. IRC SPECIAL PUBLICATION , DESIGN CODES

| | | |
|----|-----------------|---|
| | IRC:SP:13-2004 | Guidelines for the Design of Small Bridges and Culverts (First Revision) |
| 15 | IRC:SP:18 1978 | Manual for Highway Bridge Maintenance Inspection |
| | IRC:SP:19-2001 | Manual for Survey, Investigation and Preparation of Road Projects |
| 17 | IRC:SP:23-1983 | Vertical Curves for Highways |
| 18 | IRC:SP:29-1994 | Directory of Indigenous Manufacturers of Road/ Bridge Construction Machinery & Important Bridge Components (First Revision) |
| | IRC :SP:30-1993 | Manual on Economic Evaluation of Highway Projects in India (First Revision)† |
| 19 | IRC:SP:33-1989 | Guidelines on Supplemental Measures for Design, Detailing & Durability of Important Bridge Structures |
| 20 | IRC:SP:37-2010 | Guidelines for Load Carrying Capacity of Bridges |
| 21 | IRC:SP:47-1998 | Guidelines on Quality Systems for Road Bridges (Plain, Reinforced, Prestressed and Composite Concrete) |
| 22 | IRC:SP:51-2015 | Guidelines for Load Testing of Bridges (First Revision) |
| 23 | IRC:SP:52-1999 | Bridge Inspector's Reference Manual |
| 24 | IRC:SP:54-2018 | Project Preparation Manual for Bridges (First Revision) |
| 25 | IRC:SP:56-2011 | Guidelines for Steel Pedestrian Bridges (First Revision) |

| | | |
|----|----------------|---|
| 26 | IRC:SP:60-2002 | An Approach Document for Assessment of Remaining Life of Concrete Bridges |
| 27 | IRC:SP:64-2016 | Guidelines for the Analysis and Design of Cast in Place Voided Slab Superstructure (First Revision) |
| 28 | IRC:SP:65-2018 | Guidelines for Design and Construction of Segmental Bridges (First Revision) |
| 29 | IRC:SP:66-2016 | Guidelines for Design of Continuous Bridges (First Revision) |
| 30 | IRC:SP:67-2005 | Guidelines for Use of External and Unbonded Prestressing Tendons in Bridge Structures |
| 31 | IRC:SP:69-2011 | Guidelines & Specifications for Expansion Joints (First Revision) |
| 32 | IRC:SP:70-2016 | Guidelines for the Use of High Performance Concrete in Bridges (First Revision) |
| 33 | IRC:SP:71-2018 | Guidelines for Design and Construction of Pretensioned Girder of Bridges (First Revision) |
| 34 | IRC:SP:75-2008 | Guidelines for Retrofitting of Steel Bridges by Prestressing |
| 35 | IRC:SP:82-2008 | Guidelines for Design of Causeways and Submersible bridge |
| 36 | MORT&H | Standard Plans for 3.0 m to 10.0 m Span Reinforced Cement Concrete Solid Slab Structure with and without Footpaths for Highways, 1991 |
| 37 | MORT&H | Standard Plans for Highway Bridges R.C.C. T-Beam & Slab Superstructure . Span from 10 m to 24 m with 12 m width, 1991 |
| 38 | MORT&H | Standard Plans for Highway Bridges PSC Girder and RC Slab Composite Superstructure for 30 m Span with and without Footpaths, 35 m Span with Footpaths and 40 m Span without Footpaths, 1991 |
| 39 | MORT&H | Standard Drawings for Road Bridges . R.C.C. Solid Slab Superstructure (15° & 30° SKEW) Span 4.0 m to 10.0 m (with and without Footpaths), 1992 |
| 40 | MORT&H | Standard Drawings for Road Bridges R.C.C. Solid Slab Superstructure (22.5° Skew) R.E. Span 4m to 10m (with and without Footpath), 1996 |

| | | |
|----|---|---|
| 41 | MORT&H | Standard Plan for Highway Bridges . Prestressed Concrete Beam & RCC Slab Type Superstructure Volume - II |
| 42 | MORT&H | Standard Plans for Single, Double and Triple Cell Box Culverts with and without Earth Cushion |
| 43 | HRB SR No.20, 2004 | State of the Art : Development of Bridge Bearings |
| 44 | Paper Nos.109 & 112, 1946 | Standard Specifications & Code of Practice for Road Bridges, Sections I & II (with Explanatory Notes & Discussions) |
| 45 | Paper No.238, 1996 | Considerations in the Design and Sinking of Well Foundations for Bridge Piers (B. Bal want Rao & C. Muthuswamy) |
| 46 | International Journal of Civil Engineering Research. ISSN 2278-3652 Volume 8, Number 1 (2017), pp. 33-38 | Structural Health Monitoring Case Study Review Shekhar verma, Dr. Vijay Raj |
| 47 | Science Direct Procedia Engineering 199 (2017) 2054. 2059 | Structural health monitoring system of bridges Cristian-Claudiu Comisu, Nicolae Taranu, Gheorghita Boaca, Maria-Cristina Scutaru |
| 48 | Report by Minnesota Department of Transportation 395 John Ireland Boulevard Mail Stop 330 St. Paul, Minnesota 55155 | Bridge Health Monitoring and Inspection . A Survey of Methods Andrew Gastineau, Tyler Johnson, Arturo Schultz Department of Civil Engineering University of Minnesota |
| 49 | IS 210 : 2009 | Grey iron castings - Specification (First Revision) |
| 50 | IS 269 : 1989 | 33 Grade Ordinary Portland Cement |
| 51 | IS 280 : 2006 | Mild Steel Wire for General Engineering Purposes |
| 52 | IS 383 : 2016 | Coarse and Fine Aggregate for Concrete - Specification (Third Revision) |
| 53 | IS 458 : 2003 | Precast Concrete Pipes (With and Without Reinforcement) |
| 54 | IS 516 : 1959 | Methods of tests for strength of concrete |
| 55 | IS 784 : 2001 | Prestressed Concrete Pipes (Including Fittings) |
| 56 | IS 812 : 1957 | Glossary of terms relating to welding and cutting of metals |

| | | |
|----|-----------------------------|--|
| 57 | IS 883 : 2016 | Design of Structural Timber in Buildings - Code of Practice (Fifth Revision) |
| 58 | IS 1785: PART 1 | Plain Hard-Drawn Steel Wire for Prestressed Concrete: Part 1 Cold drawn stress-relieved wire |
| 59 | I.S: 1893 . 2016 (Part . I) | Criteria for Earthquake Resistant Design of Structures. (Sixth Revision) December 2016 |
| 60 | IS 2090 : 1983 | Specification for high tensile steel bars used in prestressed concrete (First Revision) |
| 61 | I.S: 2911 . 2010 | Code of practice for Design & construction of Reaffirmed Feb 2002 Pile Foundation. (Second Revision May, 2011) |
| 62 | IS 6003 : 1983 | Indented Wire for Prestressed Concrete |
| 63 | IS 6006 : 1983 | Uncoated Stress Relieved Strand for Prestressed Concrete |
| 64 | IS 12269 : 1987 | 53 Grade Ordinary Portland Cement |
| 65 | IS 12594 : 1988 | Hot - Dip zinc Coating on Structural Steel bars for Concrete Reinforcement - Specification |
| 66 | I.S: 13920 . 2016 | Ductile Detailing of Reinforced (Revised July 2016) Concrete Structures |
| 67 | IS 14268 : 1995 | Uncoated Stress Relieved Low Relaxation Seven ply Strand for Prestressed Concrete |

3. BOOKS FOR REFERENCE

| | |
|---|--|
| 1 | Open Channel Hydraulics . By Ven Te Chow |
| 2 | Essentials of Bridge Engineering . By D. Johnson |
| 3 | Bridge Engineering . By K.S. Rakshit |
| 4 | Concrete Bridge Design & Practice . By Dr. V.K. Raina |
| 5 | Foundation Design . By Wayne C Teng |
| 6 | The World of Bridges . By Dr. V.K. Raina |
| 7 | Bridge Inspection and Maintenance . Published by Indian Railways Institute of Civil Engineering, Pune 411001 |

ACKNOWLEDGEMENT

This Bridge Manual framed by PW(R&B) Department through DIQC provides necessary guidelines in designing and construction of bridges to give greater guidance and valuable references for all the engineers involved in design and construction.

Er. Ishfaq Mohammad Beg, Er. Aijaz Masood Bhat, Er. Arif Mohammad Iqbal, Er. Syed Izhar Ahmad Rizvi, Er. Safina Sheikh, Assistant Executive Engineers, Er. Muzamil Mushtaq Khanday, Assistant Engineer and Er. Subzar Ahmad Bhat, Junior Engineer were the core team in formulating and compiling the Bridge Manual. The whole process was carried out under the supervision of Er. Mohammad Hanief Lone, Chief Engineer, DIQC, J&K.

The team was all along guided by Er. Sami Arif Yasvi, Development Commissioner Works, JK PWD who supported the team at every step during the process of framing this manual.

Able leadership and vision of Sh. Shailendra Kumar, Principal Secretary PW(R&B) Department, Jammu and Kashmir Government was the main source of inspiration in creating this manual.