GUIDELINES FOR BRIDGE DESIGN

INDEX

FROM THE DESK OF SEDC(BR)

The Engineers, who join this organisation, have to study various codes and books for considerable time to bring themselves up to a desired level of knowledge, as many of them are not in touch with the requisite literature. They do not get proper references at the required moment. They do not precisely know the practices followed in the State P.W.D. as regards the design of bridges and buildings. It was, therefore, considered necessary to prepare guidelines, which will help the engineers to know our practices and also know some useful references for further study.

An effort has been made to discuss almost all aspects relating to the bridge design, which are necessary for preparing 'Bridge Project' and further preparing the detailed designs. One practical example is also enclosed as annexure to understand the process better. It may please be remembered that these guidelines are useful for the beginners in Bridge Design. The provisions are only guiding principles and hence the designer should also study Text Books, Codes, and Specifications etc. for preparing the Designs.

The first edition of these guidelines was published in the year 1997. The same are now being revised as per revisions in IRC codes and prelevant practices in State P.W.D.

Some new chapters on submersible bridges, innovative structures, bridge asthetics, and high performance concrete have been added. Also some additional information on hydraulics including Unit Hydrograph Method.Raft foundations and some informative sketches have been incorporated. Hence, it is felt that the second edition of these guidelines will be useful not only to the new entrants in the Designs Circle but also serves as guidelines to the Field Engineers of the Department.

AUGUST 2007

Superintending Engineer
Designs Circle(Bridges)
Konkan Bhavan, Navi Mumbai

FROM THE AUTHORS

The publication of this book could not have been possible but for the untiring efforts put in by a large member of individuals working in the Design Circle.

The efforts taken by Shri. P. M. Kide, S. E., P. W. C., Chandrapur and Dr. D. T. Thube SEDC(BR), Navi Mumbai in recasting these guidelines are acknowledged.

The contribution of Pradnya Walke, Executive Engineer (BR1), Designs Circle is specially acknowledged, who helped in making suitable corrections and additions in these guidelines in accordance with the latest references and editing the original text to confirm to the latest codal provisions.

We also thank staff members of Designs Circle namely R. B. Hake (Draftsman), U. H. Patil, B. D. Kamble, J. S. Shah, N. S. Kore (Tracers), Smt. P. P. Pable, Smt. J. U. Shenoy (Steno typists) and S. B. Gadave (Sr. Clerk) for their contributions.

The first edition of these guidelines was issued in 1997.Thereafter modifications to IRC codes have been issued. There also have been some changes in practices in designing/constructing bridges. In view of this it was desired to have modifications in the guidelines. Some new chapters are added, modifications are done in existing chapters.

This second edition of guidelines is expected to meet the demands of the bridge designer while planning for a new bridge

AUGUST 2007

Shri. S. B.Tamsekar
Chief Engineer,
PW Region,Pune

Shri. K. S. Jangde
Secretary(Roads), PWD
Govt. of Maharashtra

FOREWORD

Shri. P. D. Wani
Secretary (Works) P.W.D.
Govt.of Maharashtra

Bridges are an integral part of the road network,which serves as the lifeline of any state. Therefore construction of bridges across nallas, rivers, canals, creeks and railway lines has always been on priority in Maharashtra State PWD.

Maharashtra like all other states in the country, has a diverse geography and has constructed all types of bridges after independence, besides maintaining large number of bridges constructed during preindependence period.

The designs wing of the PWD is active since 1948.This wing is the backbone of the department in keeping with the pace of development in bridge field.

It was long felt need to prepare a guidebook for the newly appointed Deputy Engineers joined in the Designs Circle to orient with the design of bridges.This has been made possible due to the efforts of Shri. K. S. Jangde, Superintending Engineer and Shri. S. B. Tamsekar, Executive Engineer, BR-1. I am sure that this book will also be helpful to the engineers of the department in acquiring more knowledge of bridge engineering.

PREFACE

Shri. M. V. Patil
Secretary (Roads) P.W.D.
Govt.of Maharashtra

The variety of forms of bridges demonstrate the combination of art and technology.Maharashtra as other states of ancient and historical bridges.

With technological advancements, development of new and stronger materials and construction techniques, the state has advanced from stone masonry arches and substructure to long span prestressed concrete bridges and tall slender RCC piers. To keep pace with developments and to be self reliant, a Designs Wong was opened way back in 1948 and has continually grown.

This book has been conceived as a reference book for new entrants in the Bridge Designs Wing. After going through the book they can directly start with the job and thus can speed up the work. This will not only be useful to the new entrants in the designs wing but will also be reference book for all the engineers in the department.

Compilation of these guidelines has been possible due to the activeness of Designs Circle, Navi Mumbai. They deserve appreciation for their commendable efforts.

FEW WORDS

Shri. P. L. Bongirwar
Joint Managing Director,
MSRDC, Mumbai

The State PWD has taken progressive steps in furtherance and strengthening of knowledge and innovating in the field of bridges.

Information is essential for realistic planning and budgeting. Research and experimental studies throw light on the behaviour of structural components and give confidence in the adopted methods of analysis. Innovations lead to economy. Repairs and rehabilitation are unavoidable in some cases and yet in others present unnecessary expenditure on reconstructing the same bridges and saves financial resources for new bridges.

With all this aspects before it, PWD has set up its own designs wing way back in 1948,developed various type plans, collected the information of bridges and carried out research for specific cases.

This book is further step by PWD towards streamlined and more accurate design of bridges, with the advent of computers, the most critical part of the bridge design namely the analysis has become easy and accurate. Many user friendly programmes are already prepared in house, the list is attached in the book. The State would endeavour to evolve more computer programmes to make bridge designs easy.

I am glad to see the efforts of Superintending Engineer(Br) becoming useful to fellow engineers by way of this book. Wish him every success.

CONTENTS

GUIDELINES FOR BRIDGE DESIGN

CHAPTER - 1

INTRODUCTION

1.1 HISTORY OF DESIGNS CIRCLE

There was no separate designs organisation in Old Mumbai State up to 1948. In 1948 for the first time one Designs Division was opened at Poona. This division was then transferred to Mumbai in May 1954 with one more sanctioned Division. In 1959 one more Division of Building Projects was created to cope with the increased workload. In July 1958, considering the increased workload, specialised problems and the need for an expert organisation for dealing with designs and development, a separate Designs Circle was opened along with one Division. Thus by August 1958, with creation of 4 Divisions and One Circle, guidance and uniformity in the matter of Bridge and Buildings Designs was available in the old organised Mumbai State.

After formation of Maharashtra and Gujarat States on 01.05.1960, one Designs Division was transferred to Gujarat State. Thereafter the Designs Circle was strengthened from time to time as mentioned below :

(a) One Designs Division created on 17.06.1969.

(b) One Division (National Highways) with usual staff was created on 07.12.1970 due to large programme of bridge works on National Highways.

(c) Another building project division created on 24.12.1970.

In September 1971, new staffing pattern with separate wings for buildings and bridges were created. Thus from 01.10.1971 one Superintending Engineer and Seven Executive Engineers started functioning. Subsequently in October 1984, separate Superintending Engineer's post was created for Building wing. Pune unit of Buildings was created in June 1984, and two Bridge Units, one at Nagpur and one at Aurangabad started functioning from June 1984. Due to increased work load of bridge, one more Superintending Engineer's post was created at Nagpur with jurisdiction of Nagpur, Amravati and Aurangabad Regions with effect from 16.01.1997. One design unit is functioning at Nasik from 2003 and one bridge unit is functioning at Pune from 2006(by transferring 2 units from Konkan Bhavan Navi Mumbai)

1.2 PRESENT ORGANISATION

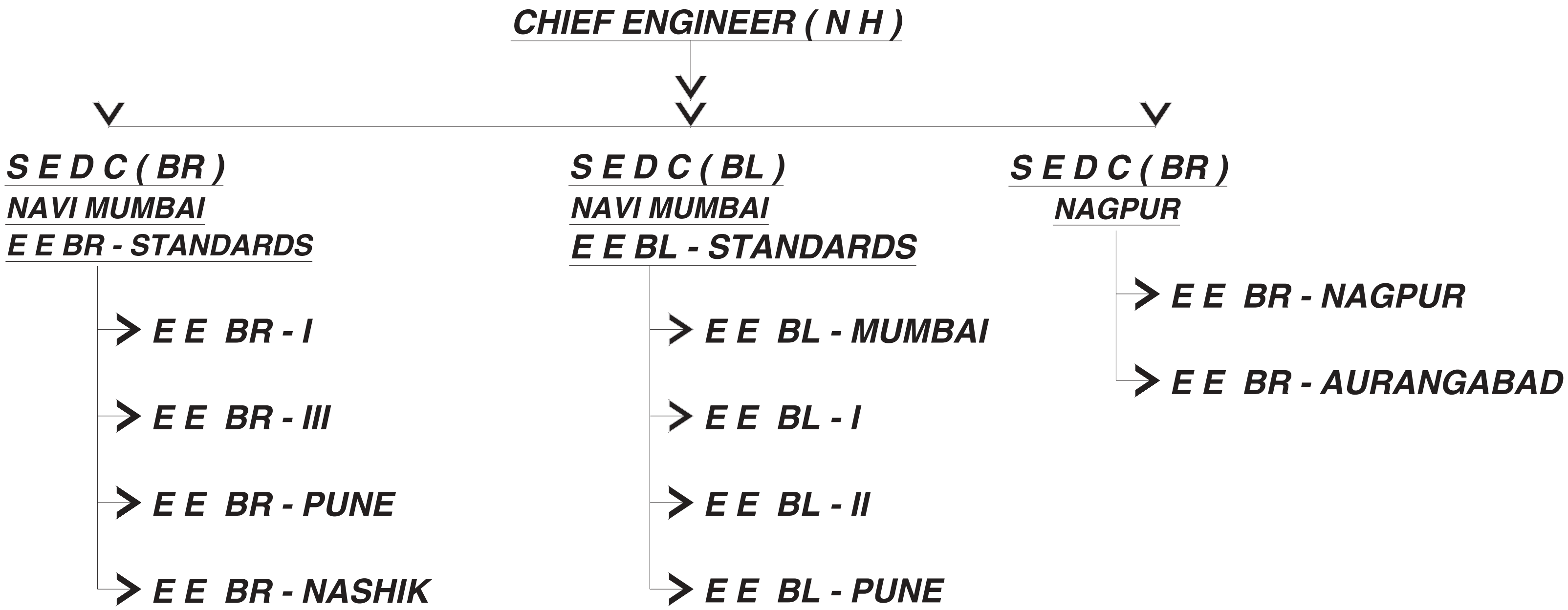
In order to give guidance to the three Designs Circle offices the Government of Maharashtra vide G.R. No. (Marathi) ईएसटी-२००२/प्रक्र-८६/प्रशासन १, दिनांक २४ एप्रिल २००३ brought the three offices of Superintending Engineer (BR.) Navi Mumbai, Superintending Engineer (BL.) Navi Mumbai and Superintending Engineer (BR.) Nagpur under the administrative and technical control of Chief Engineer (National Highways). At present there are 12 Executive Engineers and 62 Deputy Engineers working in the various units in this organisation.

1.3 ROLE OF SUPERINTENDING ENGINEER (DESIGNS CIRCLE)

Superintending Engineer (Designs) functions to fulfill two main objectives i.e. creation of new technical wealth in the Department and setting up of uniform technical standards and lending technical service. The Superintending Engineer has following role to perform:

1. Review research and technical literature.

D E S I G N S   O R G A N I S A T I O N



THERE ARE 51 DE'S UNDER S.E.D.C. (BR) AND (BL) NAVI MUMBAI AND 11 DE'S WORKING UNDER S.E.D.C.(BR) NAGPUR.

2. Analyze and synthesize useful existing practices.
3. Initiate research studies to be undertaken in research institutes such as MERI, CWPRS etc.
4. Participate as member of technical committee of I.R.C., I.S. etc.
5. Nurture the growth of central technical library.
6. Document and disseminate technical knowledge.
7. Identify structures for preparation of type designs and type plans.
8. Draw and issue technical notes and circular.
9. Provide direction in the preparation of projects & designs.
10. Approve bridge projects, building designs.
11. Select major bridge sites.
12. Co-ordinate design and construction.
13. Inspect work and issue technical advice and recommendations to field officers.
14. To guide field staff for selection of bridge sites and approve bridge designs with the help of proof consultants if necessary.

1.4 THE BOOK

The Engineers, who join this organisation, have to study various codes and books for considerable time to bring themselves up to a desired level of knowledge, as many of them are not in touch with the requisite literature. They do not get proper references at the required moment. They do not precisely know the practices followed in the State P.W.D. as regards the design of bridges and buildings. It was, therefore, considered necessary to prepare guidelines, which will help the engineers to know our practices and also know some useful references for further study. Hence, it is felt that these guidelines will be useful not only to the new entrants in the Designs Circle but also to the Field Engineers of the Department.

An effort has been made to discuss almost all aspects relating to the bridge design, which are necessary for preparing ‘Bridge Project’ and further preparing the detailed designs. One practical example is also enclosed as annexure to understand the process better. It may please be remembered that these guidelines are useful for the beginners in Bridge Design. The provisions are only guiding principles and hence the designer should also study Text Books, Codes, and Specifications etc. for preparing the Designs.

The first edition of these guidelines was published in the year 1997. The same are now being revised as per revisions in IRC codes and prelevant practices in State P.W.D.

1.5 INTRODUCTION

The need of bridge is felt by people and it is communicated to Government through Public representatives or the importance of bridge is felt by Govt. due to the increased traffic demand that may be due to various reasons viz. important road, tourist place, pilgrimage centre, industries etc. Government thus decides to construct a bridge at a particular location.

Road Project Division is required to carry out survey for the bridge location and collect requisite preliminary survey data that is required for bridge planning and design. Generally 2-3 cross sections at prospective sites are taken and the bridge length is decided for the purpose of preparing stage-I estimate needed for obtaining Administrative Approval. Depending on site conditions, particularly the foundation conditions (which could be a guess/ interpolation at this stage) the type of bridge viz. P.S.C., R.C.C., high level, submersible etc. is decided. Designs Circle is entrusted with the job of preparing projects for the bridges.

For bridges having length more than 60m, detailed estimate is required to be submitted to Govt. for obtaining Administrative Approval.(Refer Govt. Circular No.(Marathi) GEN-1096/C.No-14/N-3, dated 15.04.1997). It is, therefore, necessary that site is finalised by the Superintending Engineer, Designs Circle so that detailed soil explorations as may be necessary could be done by Road Project Divisions. The detailed proposal is then prepared by Superintending Engineer, Designs Circle. The detailed proposal would generally mean giving sufficient details for preparation of estimate after working out the stability of structures i.e. piers and abutments and deciding the tentative dimensions for superstructure and other components along with specifications.

The G.A.D. and Technical Note for bridges length less than 200 m is approved by Chief Engineer (National Highways) and Superintending Engineer Designs Circle (BR.) where as those having length more than 200 m require the sanction of Scrutiny Committee for bridges.

After General Arrangement Drawing and Technical Note is given to the field officers, it is necessary to take up the job of working out of detailed engineering by Designs Circle, if the tenders are to be invited on B-1/ B-2 form by field officers. In case the tenders are intended to be invited on lump-sum basis on contractors own design, then designs criteria required to be incorporated in N.I.T. should be prepared by Designs Circle. This will naturally depend on the decision informed by the Chief Engineer concerned.

1.6 LITERATURE

Deputy Engineers in the Designs Circle are expected to prepare proposal, undertake detailed designs and handle scrutiny of contractor's designs for bridges. Therefore a fresh hand should study the available literature and appropriate codes.

1.6.1 Codes and Specifications :

Section – I	I.R.C.:5-1998	General Features of Design. (Reprint April-2002)Seventh revision
Section – II	I.R.C.:6-2000	Loads and Stresses. (Reprint August-2004) Fourth revision

Section – III	I.R.C.:21-2000	Cement Concrete (Plain and Reinforced). (Third Revision). (Reprint November-2002)
Section – VI	I.R.C.:22-1986	Composite Construction. (Reprint November-2002) First revision
Section – V	I.R.C.:24-2001	Steel Road Bridges. (Second revision) (Reprint October-2003)
Section – VII	I.R.C.:78-2000	Foundations and Substructure (Second Revision) (Reprint August 2004)
Section – IX	I.R.C.:83-1999	Metallic Bearings (Part-I). (First revision December-1999) (Reprint May-2003)
Section – IX	I.R.C.:83-1987	Electrometric Bearings. (Part-II) (Reprint June-2003)
Section - IX	I.R.C.:83-2002	POT, POT-cum-PTFE, Pin and metallic guide bearings, (Part-III) First published March 2002
	I.R.C.:18-2000	Design Criteria for Prestressed Concrete Road Bridges (Post Tensioned Concrete) Third revision (Reprint Sept.2002)

I.R.C.:38-1988	Guidelines for Design of Horizontal Curves for Highways and Design Tables. (First revision – Sept. 1989)
I.R.C.:87-1984	Guidelines for the design and Erection of false work for Road Bridges. (Reprint March 2002)
I.R.C.:89-1997	Guidelines for Design & Construction of River Training & Control Works for Road Bridges. (First revision)Reprint October 2000
I.R.C.:SP 13-2004	Guidelines for the Design of small Bridges and Culverts .First revision June 2004
I.R.C.:SP 23–1983	Vertical Curves for Highways (Reprint Sept. 1989)
I.R.C.:SP 37–1991	Guidelines for Evaluation of Load Carrying Capacity of Bridges.(Second Revision 2001)
I.R.C.:SP 51–1999	Guidelines for Load Testing of Bridges
I.R.C:SP :64-2005	Guidelines for analysis and design of cast in place voided slab superstructure
I.R.C:SP :65-2005	Guidelines for design and construction of segmental bridges
I.R.C:SP :66-2005	Guidelines for design of continuous bridges

I.R.C:SP :67-2005	Guidelines for use of external and unbonded prestressing tendons in bridge structures
I.R.C:SP :70-2005	Guidelines for the use of high performance concrete in bridges
I.R.C:SP :71-2006	Guidelines for design and construction of precast pretensioned girder for bridges
I.S.:1893- (Part I)2002	Criteria for Earthquake Resistant Design of Structures. (Fifth Revision)June 2002
I.S.: 2911 – 1979 Reaffirmed Feb 2002	Code of practice for Design & Construction of Pile Foundations. (First Revision – June 1980)
I.S.: 13920-1993 (Reaffirmed July 2003)	Ductile Detailing of Reinforced Concrete Structures subjected to Edition 1.2 (2002-03) Seismic Forces- Code of Practice.

1.6.2 BOOKS FOR REFERENCE

(1) Open Channel Hydraulics - By Ven Te Chow

(2) Essentials of Bridge Engineering - By D.Johnson Victor

(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

1.7 SOME IMPORTANT DEFINITIONS

1.	Bridge	:	Bridge is a structure having a total length of above 6 m between the inner faces of the dirt walls for carrying traffic or other moving loads over a depression or obstruction such as channel, road or railway. These bridges are classified as : **Small bridge** - Overall length of the bridge between the inner faces of dirt walls is upto 30m and where individual span is not more than 10m **Minor bridge** - Total length upto 60m **Major bridge** - Total length greater than 60m
2.	Culvert	:	A cross drainage structure having total length of 6 m or less between inner faces of dirt wall.
3.	Foot Bridge	:	A bridge extensively used for carrying pedestrians, cycles and animals.
4.	High Level Bridge	:	A bridge, which carries the roadway above H.F.L. of the channel.
5.	Submersible Bridge/ Vented Causeway	:	A bridge designed to be overtopped during floods.
6.	Channel	:	A natural or artificial watercourse.
7.	Clearance	:	The shortest distance between boundaries at a specified position of bridge structure.
8.	Freeboard	:	The difference between H.F.L. (allowing afflux) and foundation level of road embankment on approaches.
9.	H.F.L.	:	Highest flood level is the level of highest flood ever recorded or the calculated level for design discharge.
10.	L.W.L.	:	Lowest flood level is the level of the water surface obtained in dry season.
11.	Length of Bridge	:	The length of a bridge structure will be taken as overall length measured along the center line of the bridge between inner faces of dirt wall.

12.	Linear Waterway	:	Width of waterway between the extreme edges of water surface at H.F.L. measured at right angles to the abutment face.
13.	Effective Linear Waterway	:	The total width of the waterway of the bridge at H.F.L. minus effective width of obstruction.
14.	Safety Kerb	:	A roadway kerb for occasional use of pedestrian traffic.
15.	Width of Carriageway	:	Minimum clear width measured at right angles to the longitudinal centreline of bridge between inside faces of roadway kerb or wheel grades.
16.	Super elevation/ Cant/Banking	:	The transverse inclination given to the c/s of a carriageway on a horizontal curve in order to reduce the effects of centrifugal force on a moving vehicle.
17.	Vertical clearance	:	The height from the design highest flood level with afflux of the channel to the lowest point of the bridge superstructure at the position along the bridge where clearance is denoted.
18.	Bearings	:	The part of the bridge structure which bears directly all the forces from the structure above and transmits the same to the supporting structure.
19.	Sliding Bearings	:	A type of bearing where sliding movement is permitted.
20.	Rocker Bearing	:	No sliding movement is permitted but which allows rotational movement.
21.	Sliding cum rocker Bearing	:	A type of bearing which in addition to the sliding movement either the top or bottom plate is provided with suitable curvature to permit rotation.
22.	Roller cum Rocker Bearing	:	A type of bearing, which permits longitudinal movement by rolling and simultaneously allows rotational movement.
23.	Elastomeric Bearing	:	A bearing consisting of one or more internal layers of elastomer boarded to internal steel laminates by the process of vulcanisation. The bearing cateress for translation and / or rotation of the superstructure by elastic deformation.

24.	Laminated Bearing	:	A bearing composed of alternate layer of elastomer and laminates integrally bonded during vulcanisation.
25.	Fixed POT Bearing	:	A type of POT bearing which along with vertical load bears and transmits horizontal force in any director and allows rotation about any axis in horizontal plane without permitting any movement in horizontal plane.
26.	True sliding type POT-cum-PTFE Bearing	:	A type of POT bearing which bears and transmit vertical load and allows movement in any direction in the horizontal plane and accommodates rotation about any axis in horizontal plane.
27.	Guided Sliding type POT cum PTFE Bearings	:	A type of POT bearing which along with vertical load bears and transmits horizontal force in one direction only and allows movement perpendicular to that direction and allows rotation about any axis in horizontal plane.
28.	Free PTFE Sliding Assembly	:	A type of PTFE sliding assembly, which along with vertical load bears and transmits horizontal force in one direction and allows movement perpendicular to that direction.
29.	Guided PTFE Sliding Assembly	:	A type of PTFE sliding assembly, which along with vertical load bears and transmits horizontal force in one direction and allows movement perpendicular to that direction.
30.	Pin Bearing	:	A bearing consisting of a metal pin provided within a metal cylinder to bear and transmit horizontal free along any direction in the horizontal plane and accommodating rotational movement about any axis. Pin bearing cannot bear or transmit any vertical load.
31.	Metallic Guide Bearing	:	A bearing consisting of a sliding assembly with restraint along a desired direction to bear and transmit horizontal force and capable of allowing movement in a direction and to the direction of horizontal force. Metallic Guide Bearings and capable of allowing rotation only about an axis perpendicular to the plane of sliding. Metallic Bearing cannot bear or transmit any vertical load.
32.	Abutment	:	The end supports of deck of bridge, which also retains earth, fill of approaches behind fully or partly.

33.	Box type Abutment and Return Wall	:	When the return walls on two sides are integrated with abutment and a back wall parallel to abutment is provided end of the returns with or without additional internal wall along or across length, this structure is called box type abutment and return wall or end block.
34.	Spill through Abutment	:	An abutment where soil is allowed to spill through gaps along the length of abutment such as column structure where columns are placed below deck beams and gap in between is free to spill earth.
35.	Afflux	:	The rise in the flood level of the river immediately on the upstream of a bridge as a result of obstruction to natural flow caused by the construction of bridge and its approaches.
36.	Bearing Capacity	:	The supporting power of a soil / rock expressed as bearing stress is referred to as its bearing capacity.
37.	Safe Bearing Capacity	:	The maximum pressure which the soil can carry safely without risk of shear failure and it is equal to the net Safe Bearing Capacity plus original overburden pressure.
38.	Cofferdam	:	A structure temporary built for the purpose of excluding water or soil sufficiently to permit construction or proceed without excessive pumping and to support the surrounding ground.
39.	Foundation	:	The part of bridge in direct contact with and transmitting load to the founding strata.
40.	Pier	:	Intermediate supports of the superstructure of a bridge.
41.	Abutment Pier	:	It is designed for a condition that even if one side arch span collapses it would be safe. Generally provided after 3 or 5 spans in multiple span arch bridges.
42.	Retaining Wall	:	A wall designed to resist the pressure of earth filling behind.
43.	Return Wall	:	A wall adjacent to abutment generally parallel to road or flared up to increase width and raised up to the top of road.
44.	Toe wall	:	A wall built at the end of the slope of earthen embankment to prevent slipping of earth and / or pitching on embankment.

45.	Wing Wall	:	A wall adjacent to abutment with its top up to R.T.L. near abutment and sloping down up to ground level or a little above at the other end. This is generally at 45 degrees to the alignment of road or parallel to the river and follows the profile of earthen banks.
46.	Substructure	:	The bridge structure such as pier and abutment above the foundation and supporting the superstructure. It shall include returns and wing walls but exclude bearings.
47.	Well foundations	:	A type of foundation where a part of the structure is hollow, which is generally built in parts and sunk through ground or water to the prescribed depth by removing earth through dredge hole.
48.	Tilt of Well	:	The inclination of the axis of the well from the vertical expressed as the tangent of the angle between the axis of the well and the vertical.
49.	Shift of Well	:	The horizontal displacement of the centre of the well at its base in its final position from its designed position.
50.	Skew angle of Bridge	:	It is the angle between the perpendicular to the flow of traffic direction and the flow direction of river.

■

GUIDELINES FOR BRIDGE DESIGN

CHAPTER - 2

ESTIMATION OF DESIGN DISCHARGE SCOUR DEPTH, LINEAR WATERWAY AND AFFLUX

2. The Deputy Engineer who joins the Designs Circle shall in the initial phase study the literature related with bridge engineering. Then the preparation of bridge project work should be taken in hand. Various stages in project preparation are described below. Following points need to be considered before preparation of project.

2.1 SCRUTINY OF SURVEY DATA

Scrutiny of survey data received from the field officers is the first step in Designs Circle. Survey data should be as per the checklist given in I.R.C. clause 102 and as per Designs Circle Circular, Dated 18.09.74. The guidelines for preparation of survey data are issued by Designs Circle under letter No.BC/CIR/93 dated 31.01.1961.

Any observations, certain clarifications, and/or additional data/information required are communicated to the concerned Executive Engineer.

Thereafter, the site inspection by the Superintending Engineer, Designs Circle for the bridges having length more than 60 m is arranged and bridge site is finalised. It is not necessary that site suggested by Road Project Division is approved. If some more study of better sites is necessary, Superintending Engineer, Designs Circle issues instructions for collecting additional data.

Some important points to be seen in survey data are detailed below:

(i) Alignment of the proposed road along with the new bridge. What are the alternatives tried and depending on the standard of road whether geometry of road is wisely proposed or otherwise. Previous practise of providing right angle crossing at the cost of deficient road alignment may not be insisted. Alternatively the alignment may be given priority over the angle of crossing. The most ideal site shall be reserved for permanent high level bridge if a submersible or temporary bridge is being planned at the moment.

Typical sketch of right angled and skew crossings are shown in fig 2.1

(ii) Cross sections at different proper locations are taken, drawn and L/S and R/S are correctly marked. For person standing in flow direction (facing d/s) his left is L/S.

(iii) Information about dams, weirs on u/s and d/s of the proposed bridge.

(iv) The possibility of subsequent changes in the catchments like aforestation, deforestation, urban development etc.

(v) The catchment area plan should be properly drawn and certified by the Executive Engineer, Road Project Division.

(vi) Contour plan is to be attached. This is very important since it gives better idea about site from consideration of outflanking, submergence of nearby village etc. Topo-sheets may be referred for feeling confident about the site.

(vii) Nearness of villages on u/s and d/s sides.

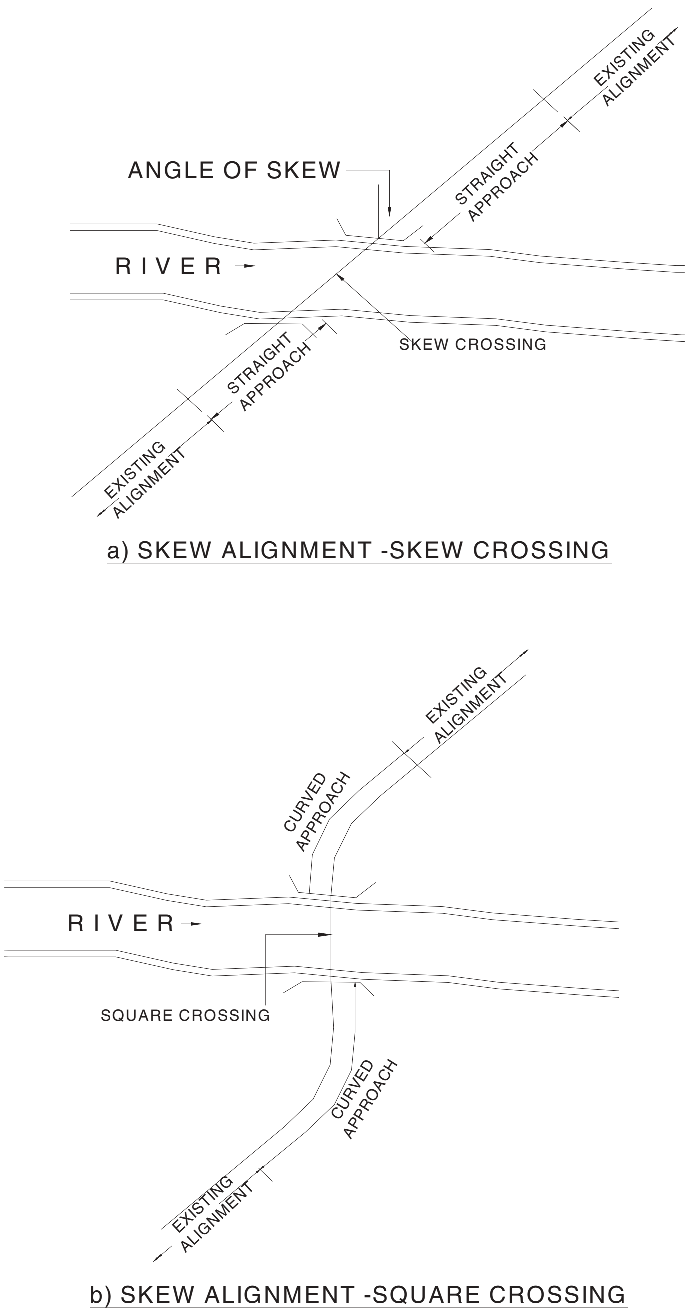


FIG.2.1 SKEW AND SQUARE CROSSING

(viii) The effect of afflux on areas in the vicinity. Limitation on afflux should be reported. Effect of submergence should be studied.

(ix) Generally trial pits are taken for a depth of 1.5m to 2m only which do not give true picture of the founding strata. Trial pits for sufficient depth or trial bores should be plotted to show different strata below bed to decide type of foundation.

(x) In case of navigational channels, the clearances (horizontal and vertical) reported by Maharashtra Meri-time Board.

(xi) H.F.L. from enquiry should be realistic. This may lead to unnecessary high bridge. Some times the discharge w.r.t. observed H.F.L. does not tally with Inglis discharge creating confusion.

(xii) O.F.L. is to be assessed properly for submersible bridges with due consideration to permissible interruptions to traffic as per IRC Codes.

(xiii) The rugosity coefficients are to be properly taken to depict the exact nalla characteristics for bed and bank.

(xiv) The value of silt factor reported from observations or by laboratory test. Laboratory test results should be considered more reliable.

Detailed survey data obtained from the Road Project Division is scrutinised, and clarification/ additional information sought. Thus the work of project preparation starts in Designs Circle.

While proceeding with the project, methodology proposed to be adopted for preparation of the project should be got approved from Superintending Engineer, Designs Circle. Certain assumptions, type of structures considered to be proposed, method of analysis and design etc. need be crystallised before detailed proposal is prepared. This would save time as corrections in the calculation and drawings can be minimised.

2.2 HYDRAULIC CALCULATIONS & HYDRAULIC DESIGN OF THE BRIDGE

Hydraulics is the essential feature of bridge design. Fair assessment of flood levels, maximum flood discharge expected to occur at bridge site during design life of bridge, and maximum scour levels are essential aspects of bridge hydraulics. Faulty determination of these parameters may lead to failure of structures.

While doing hydraulic calculations attention should be paid to the following-

1. The river cross section should be truly representative. The cross section should not be vitiated by artificial cuts etc.

2. If the bridge site is along the existing natural crossing, the cross section for hydraulics should be across the nearby natural undisturbed channel. The cross section within 100 m U/S or D/S may be quite useful.

3. Spill channels should be properly located, marked and catered for.

4. Appropriate coefficient of rugosity should be used. The same rugosity coefficient should not be used for bed and banks, as the nature of stream changes according to properties of material and vegetation growth etc.

5. The reasonableness of computed velocity should be judged in relation to bed material for e.g existence of boulders in the stream and low velocity of flow do not generally go together.

6. In tidal creeks the possibility of high tides and floods coinciding should be kept in view. In such cases discharge by usual ways i.e. by Manning's formula should be carefully worked out and tallied with Inglis discharge.

7. The adoption of either the observed H.F.L. obtained by local enquiry or the computed H.F.L. as design level should be done judiciously. The observed H.F.L. may be effected by obstructions like rice fields, bunds, blocking of spill channels etc. Higher of the two values be adopted as design H.F.L.

8. Details of various levels is explained as below.

HFL (observed)	Highest flood levels ever recorded. (50 years record)
HFL(Inglis)	Flood level giving Manning's discharge equal to Inglis discharge.
HFL(Modified Inglis)	Flood level giving Manning's discharge equal to Modified Inglis discharge.
O.F.L.	Ordinary flood level. This is level of flood when cleared by bridge (without submergence of bridge) that will not give more than permissible interruption to traffic during floods.

9. Maximum permissible interruptions for various standards of roads are as follows-

National Highways	–	No interruptions.
Bridges on SH, MDR	–	6 times a year and for a period not exceeding 12 hr at a time.
Bridges on ODR	-	6 times a year and not exceeding 24 hours at a time.
Bridges on VR	-	6 times a year and not exceeding 72 hours at a time.

2.2.1 ESTIMATION OF FLOOD DISCHARGE

Although records of rainfall exists to some extent, the actual record of rainfall is seldom available in such sufficiency (50 years) as to enable the Engineer to infer precisely the worst flood conditions for designing bridges.

2.2.1.1 The current practice generally followed for calculating the discharge at the bridge site is by using empirical formulae as detailed below for various regions.

(A) Inglis Formula (for Western Ghats and Tapi Valley)

$$Q = \frac{7000A}{\sqrt{A+4}}$$

Where Q = Discharge in cusecs (ft^3/s)

A = Catchment area in sq. miles.

(B) Modified Ingis Formula : (Upper parts of Western Ghats)

$$Q = \frac{4000A}{\sqrt{A+4}}$$

Where Q = Discharge in cusecs (ft^3/s)

A = Catchment area in sq.miles.

(C) Dicken's Formula (for Vidarbha & Marathwada Regions)

$$Q = C[A]^{3/4}$$

Where Q = Discharge in cusecs (ft^3/s)

A = Catchment area in sq. miles.

C = Constant whose value varies from 800 to 1600

= 800 to 1000 for rainfall 25" to 50"

= 1000 to 1400 generally this value taken in M.P can be adopted for Vidarbha adjacent to Madhya Pradesh

= 1400 to 1600 in Western Ghats.

The discharge is then calculated at the assumed H.F.L. by using Manning's formula. The discharge calculated by Manning's formula is tallied with the discharge obtained from above empirical formulae. By trial and error the H.F.L. is fixed.

The discharge calculated by the Manning's formulae is tallied with the discharge by above empirical formulae for the Catchments Area up to the bridge site. In the areas where 'Inglis flood' is not expected, the discharge calculated by Manning's formulae is tallied with either Modified Inglis formula or Dicken's formula. If the discharge calculated by Manning's formulae is less than the above empirical formulae discharge, the H.F.L. is raised suitably to get the 'designed H.F.L.' and vice-versa. The bridge is designed on the basis of H.F.L. so fixed with due consideration to observed flood level.

2.2.1.2 Discharge by Unit hydrograph Method

The Unit Hydrograph, frequently termed as the unit graph, is defined as the hydrograph of storm run-off at a given point in a river, resulting from an isolated rainfall of unit duration occurring uniformly over the catchment, and producing a unit run-off. The unit run-off adopted is 1 cm depth over a catchment area.

The term "Unit-Rainfall Duration" is the duration of rainfall excess resulting in the unit hydrograph. Usually, unit hydrographs are derived for specified unit durations, say, 6 hours, 12 hours. etc., and derived unit hydrographs for durations other than these are converted into unit hydrographs of the above unit durations. The duration selected should not exceed the period during which the storm is assumed to be approximately uniform in intensity over various parts of the catchment. A 6 hours unit duration is suitable and convenient for studies relating to catchments larger than 250 sq. km.

The unit hydrographs represents the integrated effects of all the basin constants, viz. drainage area, shape, stream pattern channel capacities, stream and land slopes.The derivation and application of the unit hydrograph is based on the following principles :

1) All the characteristics of the catchment of a river are reflected in the shape of the hydrograph of run-off.

2) At a given point on a river for all storms having the same duration of rainfall excess above this point and uniformly distributed with respect to time, the storm run-off. This implies that rainfall excess of say 2 cm within the unit of duration will produce a run-off hydrograph having ordinates twice as great as those of the unit hydrograph. Also, if individual hydrographs are obtained from separate periods of uniform rainfall excess that may occur throughout a storm discharge ordinates of the hydrograph are proportional to the total volumes of period, and these are properly arranged with respect to time, the ordinates of the individual hydrographs can be added to give ordinates representing the total storm run-off hydrograph for the entire storm period.

Three methods are generally available for giving unit hydrographs at any point in a river.

a) By analysis of rainfall and run-off records for isolated unit storms.
b) By analysis of the run-off compound hydrographs.
c) By computation of synthetic unit hydrographs when sufficient rainfall and run-off data are not available.

The determinations of design flood, after the unit hydrograph has been derived, involves the following steps :

a) Division of catchment into sub-areas, if necessary.

b) Derivation of design storm and its apportionment to sub-area.

c) Determination of minimum retention rate and calculation of rainfall excess of design storm.

d) Arrangement of design storm.

e) Application of rainfall excess to unit hydrographs for each sub-area.

f) Routing of flood for each sub-area to the point of collection of the whole catchment.

A rational determination of critical design storm for a catchment requires a comprehensive study of major storms recorded in the region and an evolution of effects of locals conditions upon rainfall rate. This is particularly necessary in the case if design storms covering a large area of several thousand square km.

In the case of areas less than a few thousand square km certain assumptions can be made regarding rainfall patterns and intensity variations without being inconsistent with meteorological causes. They simplify design-storm estimation, but would entail high degree of conservation.

2.2.1.3 Discharge by Mannings :

The discharge calculated as above from Inglis/Modified Inglis formula has to fairly tally with the discharge calculated by Manning's formula i.e. area-velocity method with use of hydraulic characteristics of stream.

Hydraulic characteristics of the channel influencing the maximum discharge are-

(a) Velocity of flow,

(b) Slope of stream,

(c) Cross sectional area of stream,

(d) Shape and roughness of stream.

$$\text{Mannings Velocity V (in m/s)} = \frac{1}{n} R^{2/3} \, S^{1/2}$$

Where n = Rugosity coefficient depending on roughness of bed & bank values shall be as given in table-2.1

R = A/P i.e. Hydraulic mean depth.

S = Hydraulic gradient

Q = Discharge m^3/s.

A = Area of cross section in m^2

V = velocities of respective compartments in m/s.

Variation in the velocity across the depth of Channel is indicated in the fig 2.2

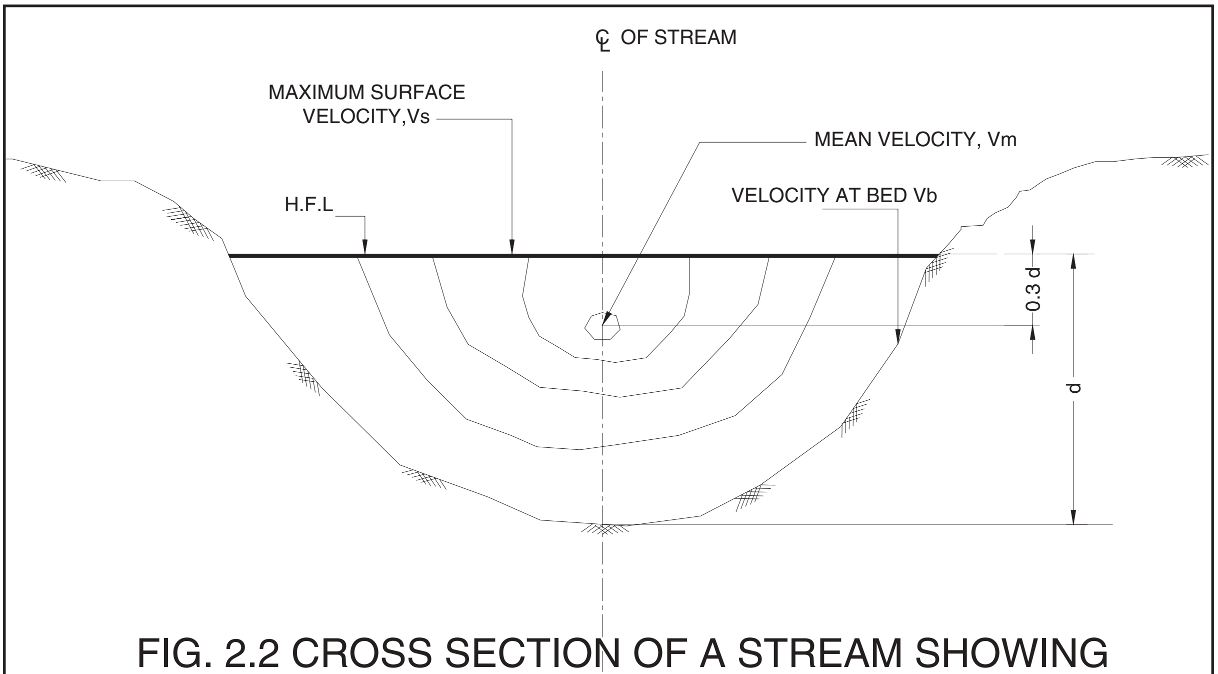


FIG. 2.2 CROSS SECTION OF A STREAM SHOWING VELOCITY CONTOURS

The discharge determined with Manning's formula at H.F.L. shall generally be within 2 %, variation with respect to Inglis or Dicken's or unit hydrograph discharge. The river cross section is divided into a number of compartments depending upon the bed characteristic and velocity and discharge is calculated for each compartment. Maximum velocity is then considered for design. Total discharge is taken as sum of all compartmental discharges. The discharge at O.F.L. may also be calculated from Mannings formula. Generally the O.F.L. discharge is 25 % to 30 % of the discharge at H.F.L. This may not, be true in all the cases.

Calculation of discharge in case of Creek Rivers is a very difficult job. It requires experience and good judgement. As river approaches sea, tidal variation plays an important role. Discharge over tidal level is actual discharge of river flow.

2.2.2 COEFFICIENT OF RUGOSITY

Coefficient of rugosity as indicated in IRC SP 13-2004 are indicated on table 2.1 shown below

TABLE 2.1

Sr. No.	Surface (Natural Stream)	Perfect	Good	Fair	Bad
1.	Clear, straight bank, no rift or deep pools	0.025	0.0275	0.030	0.033
2.	Same as (1) but some weeds & stones	0.030	0.0330	0.035	0.040
3.	Winding, some pools and shoals, clear	0.035	0.040	0.045	0.050
4.	Same as (3) but more ineffective slope and sections	0.040	0.045	0.050	0.055
5.	Same as (3) but some weeds and stones	0.033	0.035	0.040	0.045
6.	Same as (4) but stony sections	0.045	0.050	0.055	0.060
7.	Sluggish river reaches rather weedy.	0.050	0.060	0.070	0.080
8.	Very weedy reaches	0.075	0.100	0.125	0.150

Note : As per Chow's book, above values are applicable for minor streams having top width less than 100 ft. I.R.C. SP-13 also specifies the same values which may be adopted major bridges also. However, for more rigorous estimation Chow's book may referred to. These values are being used in the State over a period of time giving fairly reasonable discharge hence it is left with the designer to use appropriate values.Variation in surface from perfect to bad refers to regime channel having perfect surface and then disturbance in surface leads towards bad surface.This is depending on the intelligent judgement of the designer.

The effective height of irregularities forming the roughness elements is called the roughness height k.If roughness height is less than a certain fraction of the thickness of laminar sub layer, the surface irregularities will be so small that all roughness elements will be entirely submerged in the laminar sub layer. Under this condition the roughness has no effect upon the flow outside the laminar sub layer and the surface is said to be hydraulically smooth. For hydraulically smooth surface the roughness height must be less than a critical roughness expressed by

K_c=100v/V

Where v = kinematic viscosity

V = Mean velocity

If roughness height is greater than the critical value the roughness elements will have sufficient magnitude and angularity to extend their effects beyond the laminar sub layer and thus to disturb flow in channel. The surface is therefore said to be rough.

Smooth and rough surfaces are indicated in fig. 2.3 shown below

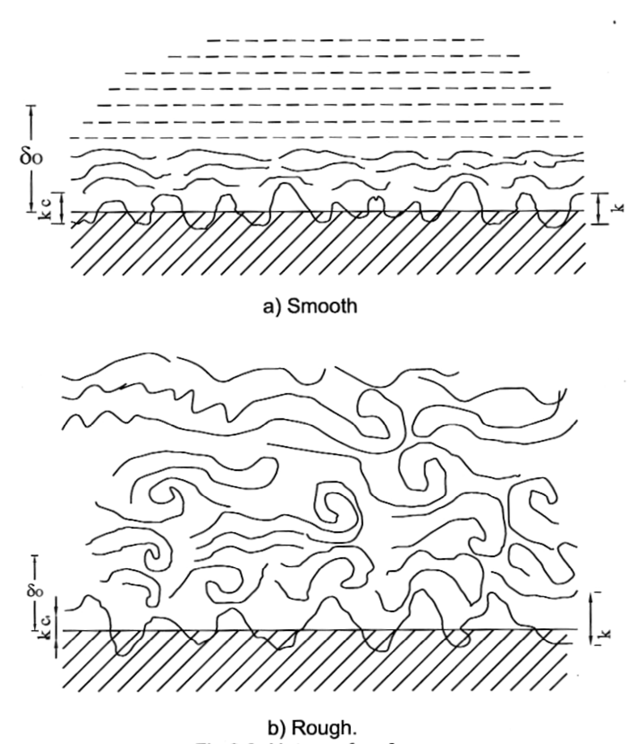


Fig.2.3 Nature of surface

2.2.3 OBSTRUCTION TO DISCHARGE

The bridge proposal should not normally cause obstruction to the discharge of more than 20% to 25% at H.F.L. This includes the obstruction caused by the approach roads and bridge structure itself. The percentage of obstruction to discharge should be calculated for design H.F.L., O.F.L. and flood level equal to road top level over bridge (for submersible bridges) in each case and normally the limits shall be satisfied. However, if the afflux and velocity are low then higher obstruction may not be objectionable.

In case of raft foundations, it is reasonable to assume total cross sectional area (available as 30 cm)above top of raft slab for calculating discharge through vents and corresponding percentage obstruction and afflux.

2.2.4 DETERMINATION OF LINEAR WATERWAY

The area through which the water flows between nalla bed and bridge superstructure is known as the waterway of bridge. The linear measurement of this area along the bridge is known as linear waterway. This linear waterway equal to sum of all the clear spans is called as effective linear waterway. Roughly linear waterway can be determined as below.

(a) Linear waterway at HFL/OFL = A/D

Where A = Wetted area of the discharging sections at HFL/OFL

Where A_1, A_2, A_3 = Areas of compartments 1,2 and 3

Q_1, Q_2, Q_3 = Discharge of compartments 1,2,3

D = Maximum flood depth at HFL or OFL

= HFL/OFL - lowest bed level of central compartment.

A section of stream indicating compartments is indicated in fig.2.4

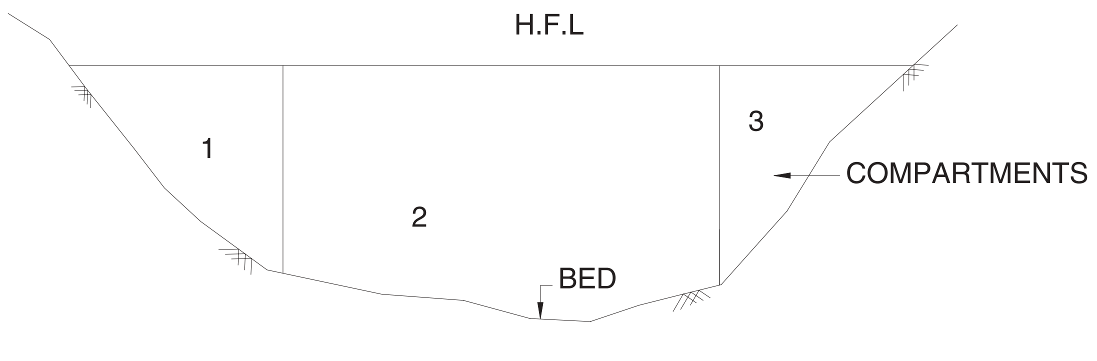


FIG. 2.4 SECTION OF STREAM SHOWING COMPARTMENTS

For natural channels in alluvial beds and having undefined banks, effective linear waterway can be determined from some accepted rational formula. One such formula as per I.R.C. for regime conditions is given below :

Linear waterway $W = C\sqrt{Q}$

Where Q = Design maximum discharge in m^3/s

C = A constant. Usually 4.8 for regime conditions but may vary from 4.5 to 6.3 according to local conditions.

2.2.5 SCOUR DEPTH

When the velocity of stream exceeds the limiting velocity, which the erodable particles of bed material can stand, the scour occurs. The normal scour depth is the depth of water in the middle of stream when it is carrying the peak flood discharge.

The probable maximum depth of scour to be taken for the purpose of designing foundations of abutment and piers shall be estimated after considering all local conditions. If possible the soundings for depth of scour shall be taken in the vicinity of bridge site during or immediately after the flood but before the scour holes had time to silt up appreciably. Allowance shall be made for increased depth resulting from

(a) The design discharge being greater than flood discharge.

(b) The increased velocity due to obstruction to flow caused by construction of bridge.

(c) The increase in scour in the proximity of piers and abutments.

Theoretically the scour can be estimated as below. This method is applicable for natural channel flowing in non-coherent alluvium.

Mean depth of scour $d_{sm} = 1.34 \left[\frac{Q_b{}^2}{K_{sf}}\right]^{1/3}$

Q_b = Discharge in cumecs per width.

K_{sf} = The silt factor for representative sample of bed material obtained up to the level of deepest anticipated scour.

$= 1.76\sqrt{d_m}$

d_m = Weighted mean diameter of bed material in mm.

The discharge per meter width (Q_b) shall be maximum of :-

(i) The total design discharge divided by effective linear waterway between abutments.

(ii) The value obtained taking into account any concentration of flow through a portion of the waterway assessed from the study of the cross section of river. However these, modification may be applied for bridge length more than 60m. The unit discharge (Q_b) for a high level bridge is obtained by dividing the total discharge by effective linear waterway. For submersible bridges the unit discharge should be worked out by considering two layers.

(1) Bed to R.T.L. (2) R.T.L. to H.F.L.

In case of submersible bridges, the scour depth and afflux calculations are to be done simultaneously and involve trial and error procedure. To provide for adequate margin of safety, the foundation shall be designed for a larger discharge which should be a percent as mentioned below over design discharge. (IRC:78-2000 clause 703.1) The discharge worked out by Empirical Formula be increased by

Catchment up to 3000 sq.km. - 30 %

3000 - 10000 sq.km. - 30 to 20 %

10000 - 40000 sq.km. - 20 to 10 %

More than 40000 sq.km. - 10 %

The value of K_{sf} for various grades of bed material is given in Table 2.2.

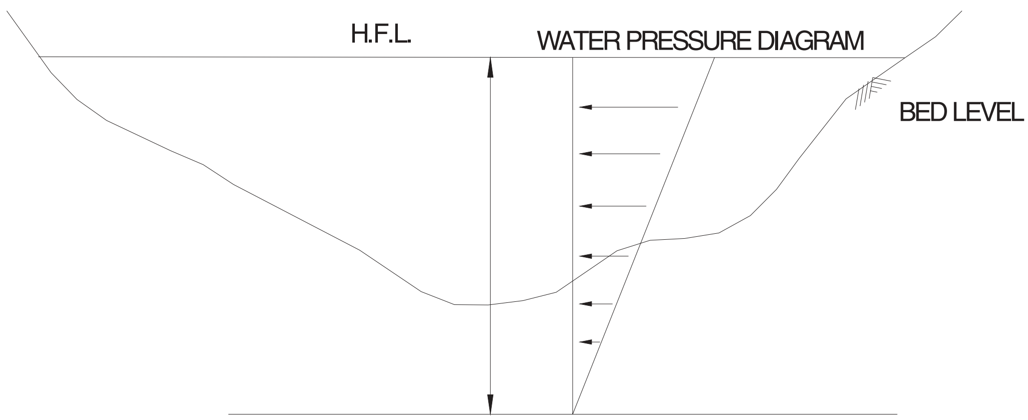
TABLE 2.2

Value of silt factor (K_{sf}) for various bed materials.

Sr. No.	Bed Material	Grain size in mm	Silt factor(K_{sf})
1. Silt	Fine	0.081	0.50
	Fine	0.120	0.60
	Fine	0.158	0.70
	Medium	0.233	0.85
	Standard	0.323	1.00
2. Sand	Medium	0.505	1.25
	Coarse	0.725	1.50
	Mixed with fine bajri 0.988	1.75	
	Heavy	1.290	2.00

2.2.6 MAXIMUM DEPTH OF SCOUR FOR FOUNDATION DESIGN

The maximum depth of scour below the highest flood level (H.F.L.) shown in fig 2.5 .shall be estimated from value of mean depth of scour (d_{sm}) in following manner :



MAXIMUM SCOUR LEVEL.
IS 1.27 Dsm FOR ABUTMENTS
2 Dsm IN THE VICINITY OF PIERS
FIG.2.5 **MEASUREMENT OF MAXIMUM SCOUR DEPTH.**

For the design of piers and abutments located in a straight reach and having individual foundations without any flood protection work.

(i) In the vicinity of pier - 2.00 d_{sm}

(ii) Near abutments - 1.27 d_{sm} when approach are retained.

- 2.00 d_{sm} when approaches are washed off.

(iii) Raft foundations - 1.00 d_{sm} (with u/s & d/s protection aprons)

For the design of protection to raft foundations, shallow foundations or flood protection the scour depth should be considered as follows:

(i) In a straight reach - 1.27 d_{sm}.

(ii) At a moderate bend - 1.50 d_{sm}.

(iii) At a severe bend - 1.75 d_{sm}

(iv) At a right angled bend - 2.00 d_{sm}

These above scour values can be suitably increased if actual observation data is available on similar structures in the vicinity. In the following abnormal conditions, special studies should be undertaken for determining maximum scour depth for the design of foundations.

(i) Bridge located in a bend of the river involving a curvilinear flow or excessive shoal formation.

(ii) Bridge located at a site where deep channel in the river hugs to one side.

(iii) Bridge having very thick piers inducing heavy local scour.

(iv) Where the obliquity of flow in the river is considerable.

(v) Where a bridge is required to be constructed across a canal, or across river downstream of storage works, with the possibility of the relatively clear water inducing greater scour.

(vi) Bridge in the vicinity of the dam, weir, barrage or other irrigation structures where concentration of flow, aggradations/degradation of bed, etc., are likely to affect behaviour of structure.

If a river is of flashy nature and the bed does not lend itself readily to the scouring effect of floods, the formula for d_{sm} given above shall not apply. In such cases the maximum depth of scour shall be assessed from actual observations.

For bridges located across streams having bouldary beds the formula given in above paragraph may be applied with a judicious choice of values for Q_b and K_{sf} and results may be compared with the actual observations at site or from experience on similar structures nearby and their performance.

2.3 VERTICAL CLEARANCE

It is the height from the design highest flood level with afflux of the Channel to the lowest soffit point of the bridge superstructure.

Clearance shall also be provided according to navigational or anti obstruction requirement. Where these considerations do not arise, vertical clearance in case of high-level bridges shall be as follows :

Discharge (m^3/s)	Minimum Vertical Clearance (in mm)
Up to 0.3	150
0.3 to 3.0	450
3.0 to 30	600
30 to 300	900
300 to 3000	1200
Above 3000	1500

In structures with metallic bearings, no part of the bearing shall be at a height less than 500mm above affluxed design highest flood level.

2.4 AFFLUX

When a bridge is constructed, the abutment and pier structures as well as approaches on either side cause the reduction of natural waterway area. The contraction of stream is desirable because it leads to tangible saving in the cost especially of alluvial streams whose natural surface is too large than that required for stability. Therefore to carry maximum flood discharge within bridge portion, the velocity under the bridge increases. This increased velocity gives rise to sudden heading up of water on the upstream side of stream. This heading up phenomenon is known as afflux. Fig.2.6 shows the afflux at bridge site.Greater the afflux, greater will be the velocity under downstream side of the bridge and greater will be depth of scour and consequently greater will be the depth of foundations required.

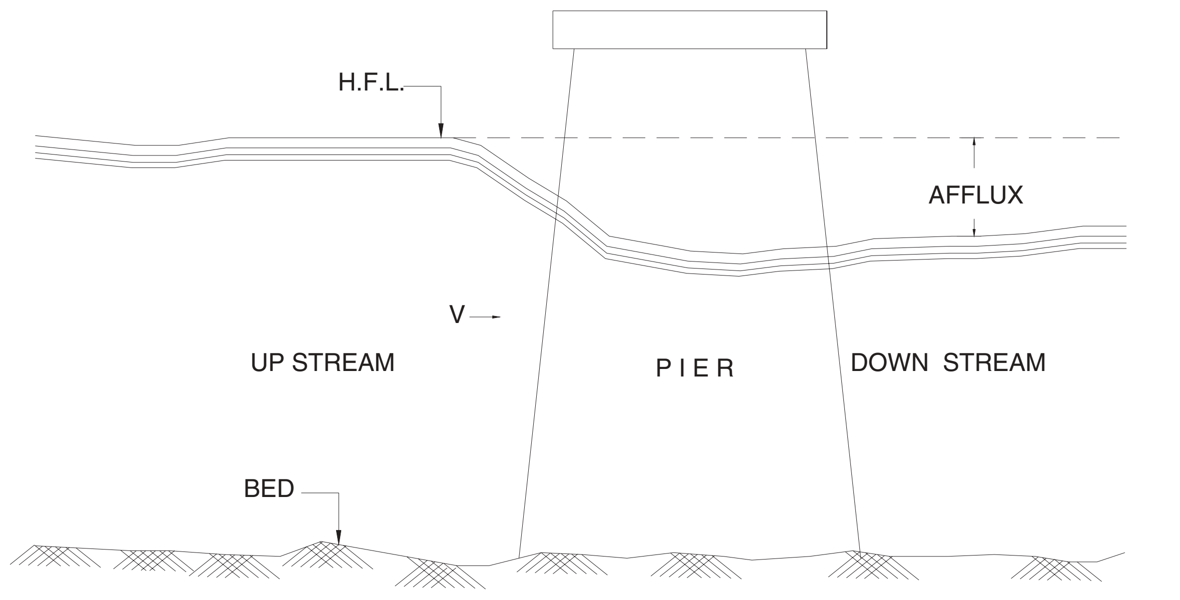


FIG.2.6 AFFLUX AT A BRIDGE

Afflux should be as small as possible and generally shall not exceed 0.6m. Where the floods spread over the banks is large, use of average velocity for calculating the afflux will give an erroneously low afflux. In such cases, the velocity in the main channel/ compartment should be used. The permissible afflux will be governed by the submergence effects on adjoining structures, fields etc. on upstream side.Afflux is calculated by the following formulae:

(a) Afflux at H.F.L. by Molesworth formula (In case of high-level bridge)

$$\text{Affluz } (h_a) = \left[\frac{V^2}{17.86} + 0.0153\right]\left[\left(\frac{Q}{Q_1}\right)^2 - 1\right]$$

Where V = Mean velocity in m/s

$$= \frac{\text{Total design discharge (Mannings)}}{\text{Total area of Channel (Mannings)}}$$

Q = Total design discharge in m^3/s

Q_1 = Unobstructed discharge in m^3/s

(b) Afflux at H.F.L. by submerged weir formula

(In case of submersible bridge)

Wetted area of channel at H.F.L. = W_a in m^2

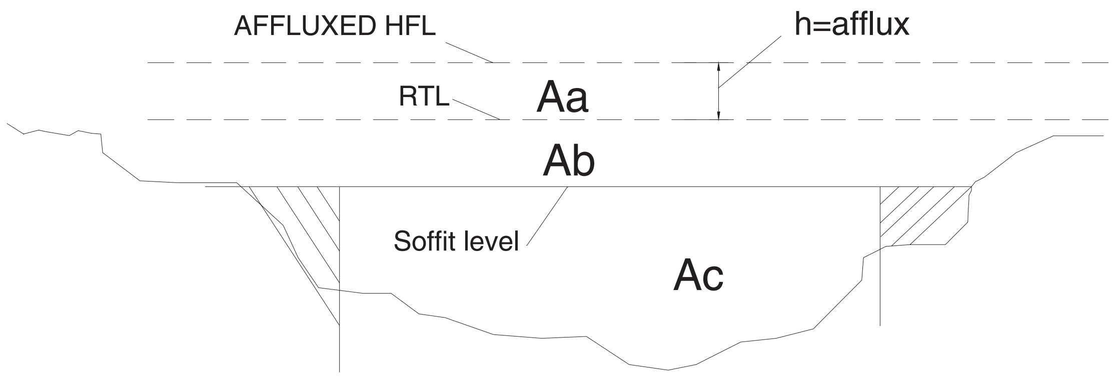


FIG. 2.7 AREA OF CROSS SECTION AT DIFFERENT LEVELS

Designed discharge (Mannings) = Q m^3/s

Assume afflux = h in m

Additional area due to assumed afflux = A_a in m^2

= Length at HFL x h

Total area = $W_a + A_a$

V_a = Velocity of approach

$$= \frac{W_a}{(W_a + A_a)} \times \text{Mean Velocity } (V_m)$$

Where $V_m = \frac{\text{Design Discharge}}{\text{Wetted area}} = \frac{Q}{W_a}$

Head due to velocity of approach = $h_a = \frac{V_a^2}{2g}$

Where g is 9.81 m/s^2.

Total head = $H = h + h_a$

$$Q_a = A_a \times 0.625 \times 2/3\sqrt{2}\, g \left(\frac{H^{3/2} - h_a^{3/2}}{h}\right)^{1/2}$$ .... (1)

$$Q_b = A_b \times 0.8 \times \sqrt{2}gH$$ .... (2)

Where A_b is unobstructed area above top of slab

$$Q_c = A_c \times 0.9 \times \sqrt{2}gH$$ .... (3)

Where A_c is unobstructed area of vent below soffit of slab

$A_{a,}$ $A_{b,}$ and A_c are shown in fig 2.7

Total $Q = Q_a + Q_b + Q_c$

Thus this arrived Q should tally with design discharge.

2.5 SELECTION OF TYPE OF FOUNDATION

Next step is deciding the type of foundations as per the site conditions and as per the trial pits and /or bore results and also on the type of river flow, scours depths etc.

2.6 SELECTION OF TYPE OF BRIDGE

Next step is to study all the aspects of bridge site and also what type of bridge is required to suit a particular site with respect to hydraulics on the basis of percentage obstruction and afflux.

2.7 GENERAL POINTS TO BE NOTED

While preparing the proposal following points should be studied carefully.

(I) The bridge should normally span the entire gorge from bank to bank. This is easy to determine in the case of defined gorges.

(II) Where floodwater carries tree trunks and branches a high level submersible bridge should not be proposed, nor should small span be proposed.

(III) All spill channels should be adequately bridged. If the cost of bridging spill channel is prohibitive then overflow sections should be properly protected. It may be possible to divert spill channels to mainstream in certain cases. If this is done the main bridge should be adequate to cater for this additional discharge. Discharge through spill should be judiciously decided. It is a good practice to allow the floodwater to flow in its natural course.

(iv) Where the river channel is flat and undefined it may not be possible to provide a high level or high-level submersible bridge without causing excessive obstruction. In such cases, either a causeway or a submersible bridge causing permissible obstruction to discharge may be provided. The obstruction to the discharge can be minimised by grading down the approaches to a level not higher than the soffit of the superstructure. This will reduce somewhat the serviceability of the bridge. Therefore, this practice should be adopted judiciously. Normally, the approach level could be the same as that of the road level over the bridge. In no case approach road should be higher than the road level over the bridge, nor lower than the soffit of the superstructure.

(v) In the case of submersible bridges the soffit of the superstructure should be such as to clear the affluxed O.F.L.

(vi) Where streams are swift, raft foundations should be provided with caution. The cut-off walls should be taken below the scour depth. Protective aprons should be constructed with heavier stones. The aprons should be extended on the sides to join with quadrant slope pitching.

(vii) On soft soils, box culverts and multi-cell monolithic boxes will cause less obstruction to discharge than the usual simple structure on raft foundations. Boxes should be provided with upstream and downstream cut-off walls.

(viii) In high-level single span bridges, masonry or plain C.C. abutments with front batters block major part of the vent and should therefore be avoided. This may also apply to the end span of multi-span bridges. The alternatives would be R.C.C. abutments or monolithic R.C.C. Box depending on foundation strata.

(ix) In deep gorges in hilly regions where currents are likely to be swift, locations of piers in the central gorge should be avoided as far as possible by adopting longer spans. In such cases unequal spans can also be adopted i.e. longer spans in the central portion and shorter spans towards ends.

(x) Where there are islands in the river channel, spans in front of them will not be fully effective. Therefore, such islands should be removed. Where this is not possible the reduced effectiveness of the spans should be taken into account while proposing the linear waterway and evaluating the % obstruction to discharge and afflux.

(x) Generally IRC describes submersible and high level bridges. High-level submersible bridge is another category introduced by the state. In this category clearance prescribed by IRC for high-level bridge is not given and nominal clearance only is provided. These should be provided judiciously and only in exceptional circumstances. Compromising on clearance means there is perfection about hydraulics carried out at said site and no trees/branches etc. are flowing in the channel that would require extra clearance is a precondition for these type of bridges..

■

GUIDELINES FOR BRIDGE DESIGN

CHAPTER - 3

COMPONENTS OF BRIDGE STRUCTURE

3. COMPONENTS OF BRIDGE STRUCTURE

Let us now study the bridge components and its adaptability and suitability in particular site conditions.

3.1 FOUNDATIONS

3.1.1 Depth of foundations : The foundation shall be taken to such depth that they are safe against scour, or protected from it. Apart from this, the depth should also be sufficient from consideration of bearing capacity, settlement, stability and suitability of strata at the founding level and at sufficient depth below it.

(A) Depth of foundations in soil (Erodible strata)

(a) Depth of shallow foundations : Foundations may be taken down to a comparatively shallow depth below the bed surface provided a good bearing stratum is available and the foundation is protected against scour.

R.L. of foundation	=	Designed H.F.L.(Tallied H.F.L.)
	-	Maximum scour depth
	-	Depth of Embedment (D.E.)
Where Depth of Embedment	=	Minimum 2.0 m for piers and abutments with arches.
	=	Minimum 1.2 m for pier and abutments, supporting other type of superstructure.

(b) Depth of deep foundations (in erodible strata)

R.L. of foundation = Designed H.F.L. (Tallied H.F.L.)- 1.33 * Maximum scour depth.

(B) Depth of foundations in rock

foundation R.L. in case of Hard Rock	=	R.L. of strata of Hard Rock - 0.60 m
foundation R.L. in soft rock / exposed rock	=	foundation R.L. in soft rock / Exposed rock - 1.50 m. (Scourable rock strata is not considered while taking R.L. of rock top)

Selection of a particular type of foundation is a very important job as it affects the entire proposal for the bridge. e.g. if the rock is not available at shallow depth, the tendency may be to adopt well foundation and as well foundations are costly the situation may lead to adoption of bigger spans, with P.S.C. structures. On the other hand if scour depth is less and flood depth is also reasonably small the raft foundation could be the choice. This will result in smaller spans, less height of bridge, may be a submersible bridge with permissible interruptions is felt sufficient.

Presence of soft/hard rock within 5m would attract open foundation depending upon the scour depth, the type of bridge and height of the bridge above and below the bed level. Situation with 5m depth of foundation below bed and 2m to 3m height of pier above bed may not sound good. Alternative should be thought of in such cases. So look for the strata where foundation can rest. Start with open foundation. If the depth of strata is deeper than 6m to 7m think of wells or piles. Simultaneously study scour depth and height of the bridge above bed level. If the scour depth is within 3.0 m and there is no problem of standing water, consider the possibility of raft foundations.

3.1.2 Important Points

The following points are to be noted while preparing bridge proposal.

(a) Span to height ratio for
  Raft foundation be kept as 1.00 to 1.25
  Open foundation be kept as 1.25 to 1.50
  Pile foundation be kept as 1.25 to 1.75
  well foundations it should be 1.50 to 2.00

The height of pier is measured from foundation to top of pier i.e. up to pier cap top.

(b) The dimensions of pier, abutment and well foundation to be taken from type designs or from the latest I.R.C. Codes.

(c) Proper uniform sitting of well foundation could be ensured by taking the foundation into rock by about 15 cm.

(d) The raft foundation details be taken from the type designs as applicable.

(e) Other similar designs prepared and approved by the Designs Circle should also be studied and referred to.

(f) Open foundations are comparatively easy to decide about.

(g) Anchorage of open foundation into the rock shall be as per IRC-78 i.e. minimum 0.60m into hard rock and 1.50 m into soft rock excluding scourable layers.

(h) Levelling course and annular filling should be proposed for open foundation. Annular filling should be done with M 15 concrete upto rock level.

(i) Stability of foundation should be worked out. The beginner should obtain the standard calculation sheets from office, and do the calculations manually to gain confidence. Further trials could be on computer. Software is available for checking the stability of the foundation.

(j) Area under tension as per IRC:78-2000 clause 706.3.3.2 is allowed up to 33 % for load combinations including seismic or impact of Barge and 20 % for other load combinations.

3.1.3 FOUNDATION TYPES

Generally two types of foundations are adopted for bridge structures.

(i)	Shallow foundations	-	Open foundations
		-	Raft foundations
(ii)	Deep foundations	-	Pile foundations
		-	Well foundations

3.1.3.1 Open

Open foundations are preferred over any other type. These are to be provided when good-founding strata is available at shallow depth and there is not much problem of dewatering. R.C.C. footings are preferred over P.C.C. footing in case of RCC piers.

3.1.3.2 Well

The shape of well can be, Single Circular, Double D-Type,Dumbell Type, Twin Circular as shown in fig.3.1.The typical components of well and various methods of starting well foundations are shown in fig.3.2 and fig. 3.3

Some important points to be noted regarding well foundations are as follows –

a. If the external diameter of single circular wells exceeds 12 m relevant provisions of clause 708.1.2 of IRC: 78-2000 shall apply.

b. The steining thickness of well shall not be less than 500 mm and shall satisfy the following relationship

$h = kd\sqrt{L}$

where h = minimum thickness of steining in m

d = external diameter of circular well in m

L = depth of wells in m below top of well cap or LWL whichever is more

K = constant(for wells in cement concrete 0.03,brick masonry 0.05 and twin D wells 0.39(For details refer to clause 708.2.3 of IRC: 78-2000).

c. In case of PCC wells the concrete shall not be learner than M-15. In case of conditions of severe exposure, steining shall not be leaner than M-20. The horizontal annular section of well steining shall be checked for ovalisation moments taking account of side earth pressure.

d. M.S. cutting edge shall not be less than 40 kg/m to facilitate sinking through all types of strata. In case of well curb the internal angle should be kept at about 30^0 to 37^0.Well curb shall not be leaner than RCC M-25.

e. The bottom plug provided should be such that the top is kept not lower than 300 mm in the centre above the top of the curb sump to be provided below the level of cutting edge. Well filling above the bottom plug shall be done generally with sand. Top plug of 300 mm in M-15 shall be provided over filling.

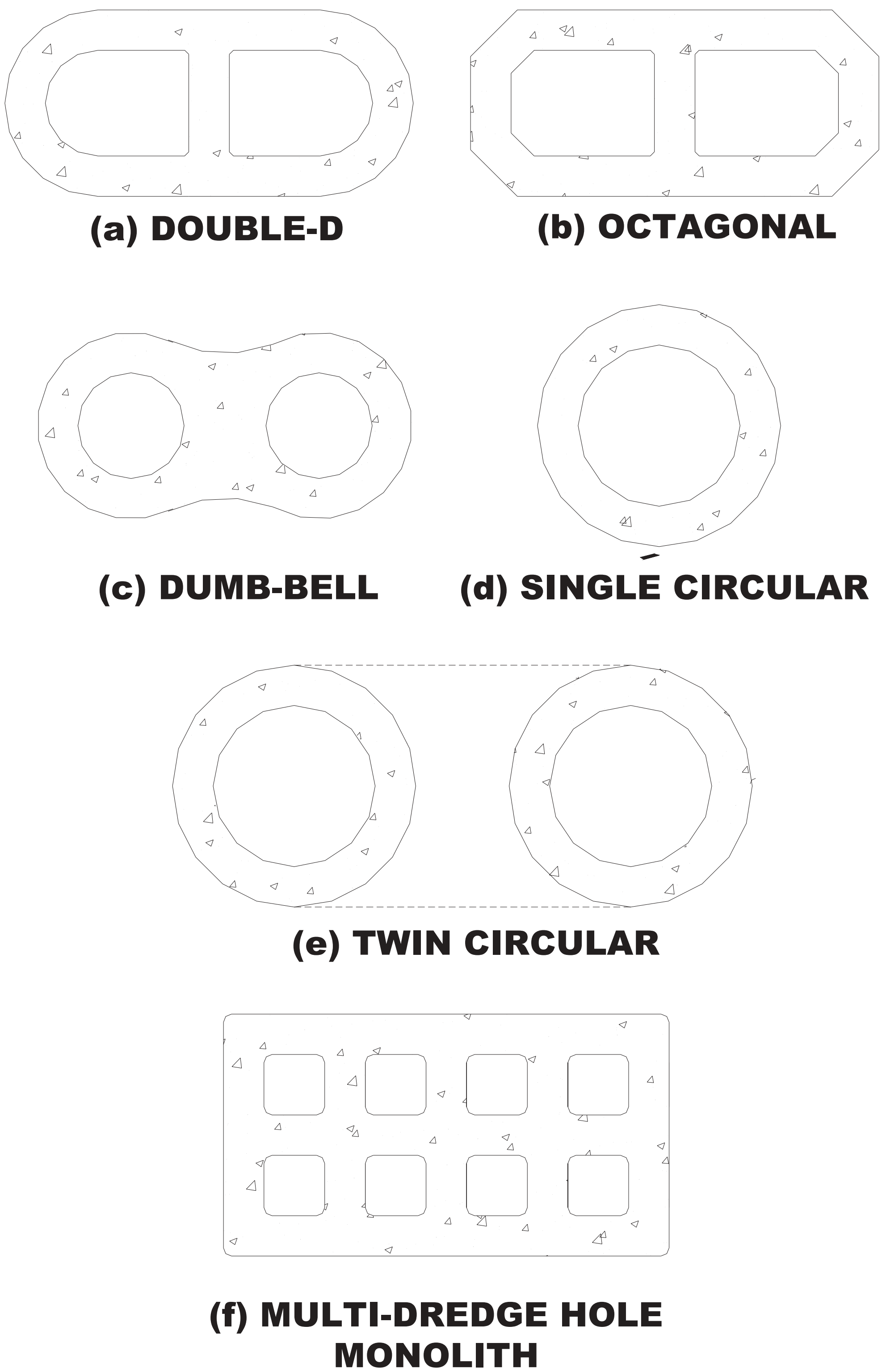


FIG. 3.1 VARIOUS SHAPES OF WELLS

UDAY PATIL, TRACER

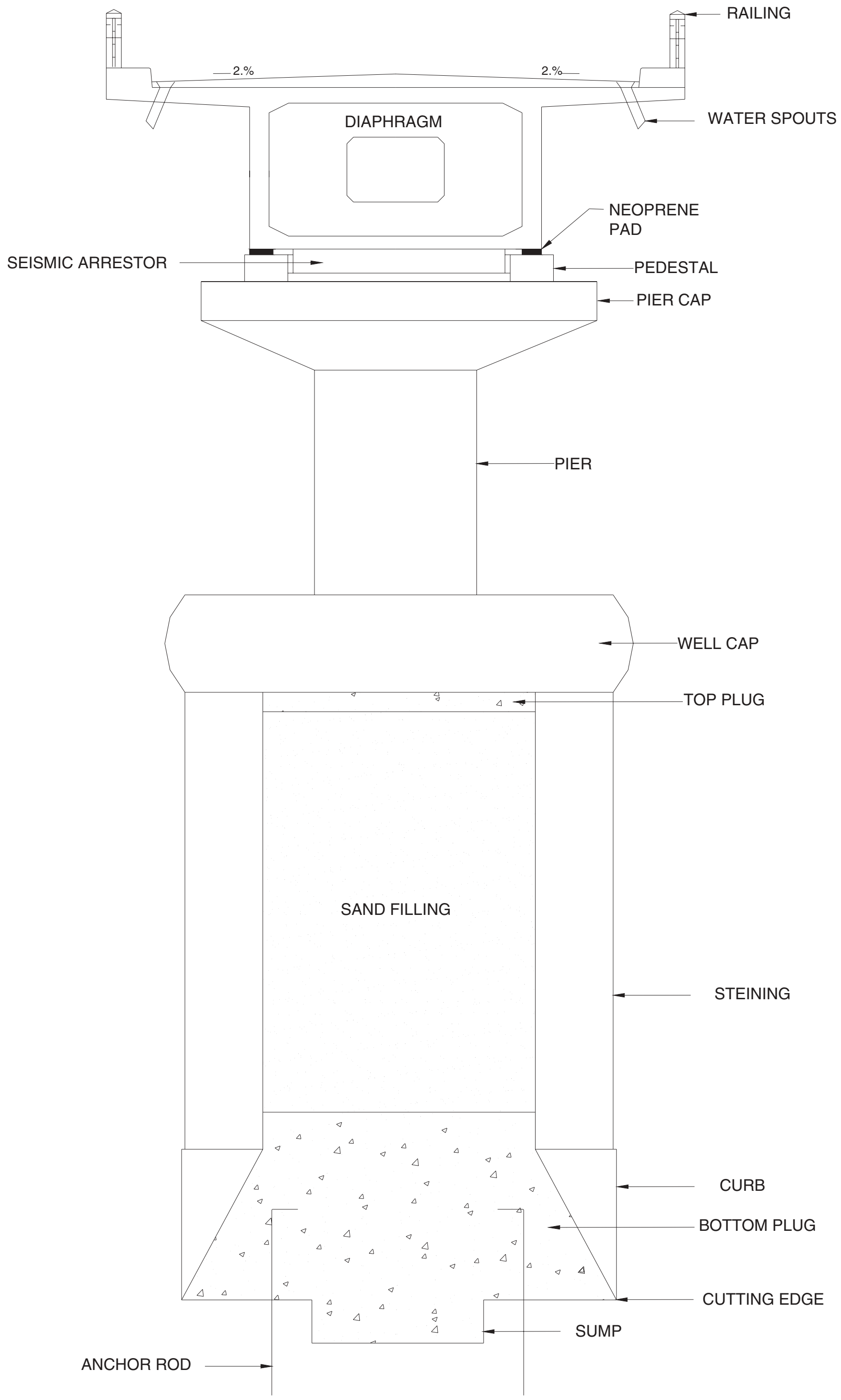


FIG 3.2 TYPICAL SECTION OF WELL

N. S. KORE, TRACER

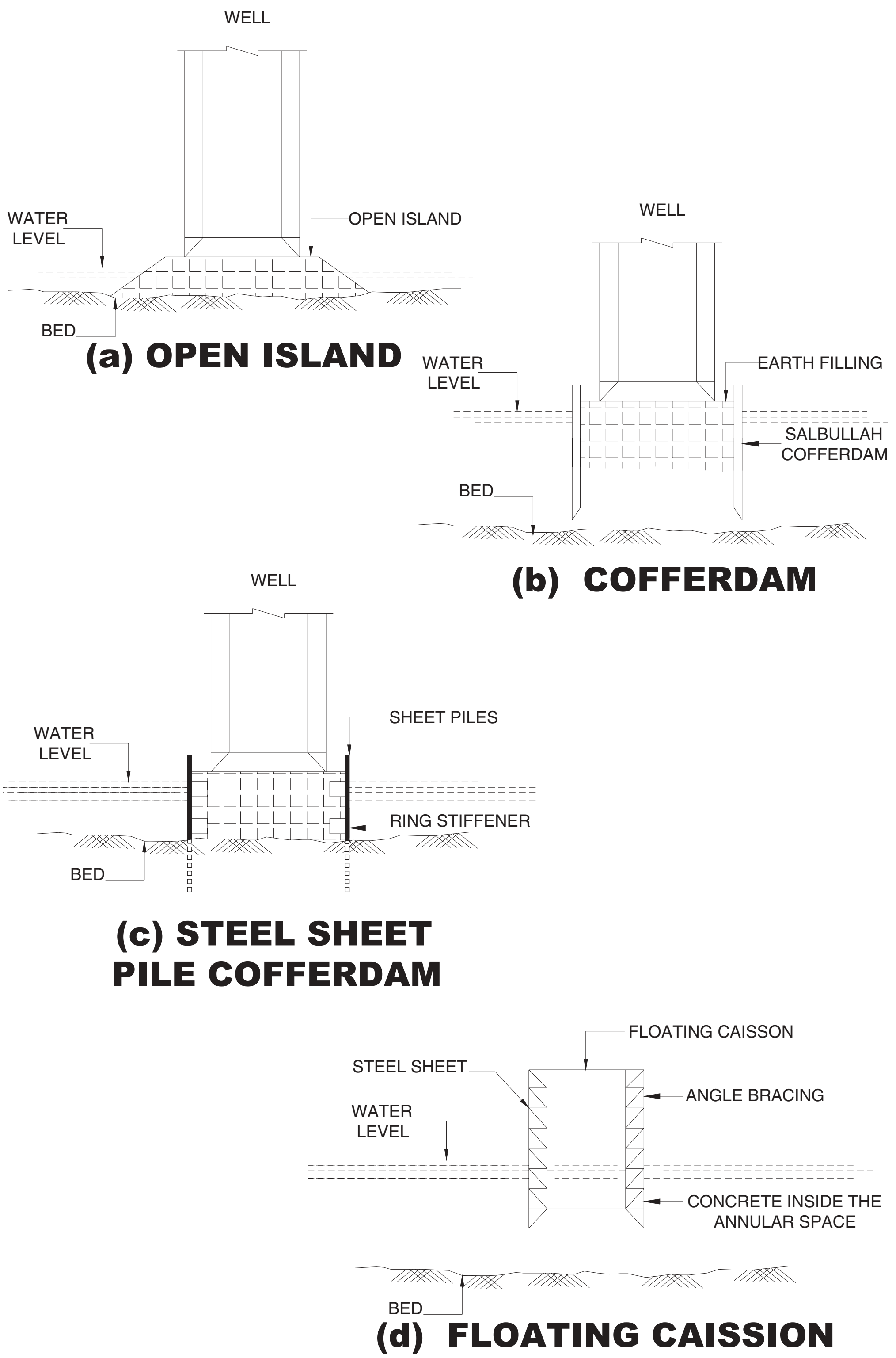


FIG. 3.3 VARIOUS METHODS OF STARTING WELL FOUNDATIONS

UDAY PATIL, TRACER

3.1.3.3 Piles

Although piles can be designed as end bearing or friction piles, only end bearing bored cast-in-situ piles drilled with rotary rig be preferred. Designs with single row of piles per substructure and annular piles filled or not filled should not generally be preferred.

TABLE 3.1

Type of Strata	Minimum Embedment	S.B.C.in T/m^2
Hard rock	1.5 x dia. of pile	400
	1.0 x dia. of pile	300
Soft rock	3.0 x dia. of pile	250
	2.0 x dia. of pile	200
	1.5 x dia. of pile	150

3.1.3.4 RAFT

(A) HISTORY OF RAFT FOUNDATION

In early 70s, P.W.D, designed raft foundation as R.C.C. solid slab.The additional component of cut off walls on both sides U/s and D/s was considered necessary to take care of seepage and possible undermining of the raft due to seepage and the scour due to floods . As the design approach was based on beams on elastic foundation, the entire bed was proposed to be provided with the flexible elastic media to ensure the elasticity of the bed. The raft was designed as one way slab spanning between two piers.

It was observed that the raft was showing signs of cracks between pier and cut off walls. The arrangement was, therefore, subsequently changed by resting pier on raft over the cut off walls.

The cut off walls when constructed monolithic with the raft, it was considered that the raft bed designed as two way slab (cut off walls on U/s & D/s and the piers provide fixity to the raft at all four edges). (Type designs issued in 1973).

The design of raft was then modified as channel type raft (entirely as a one structural component. In channel type raft, the entire channel formed by cut off and raft acts as a monolithic component. The cut off walls in this case resist most of the shear forces and bending moments and the slab is designed for local conditions. This resulted in reduced thickness of raft slab and also the cut off walls and resultant saving in concrete was found quite substantial.

If heavy dewatering is involved, the quality of concrete for cut off wall becomes doubtful. In case of channel type raft, cut off wall is an important component and its quality has to be excellent. If this is not possible to be achieved then it is desirable to go for detached P.C.C. cut off walls which are supposed to act only for increasing seepage path and keeping soil below foundation raft in tact. Such type designs are also evolved and issued by P.W.D. in 1996.

(B) SELECTION OF TYPE OF FOUNDATION

Raft foundation is, however, not recommended when

- Spans more that 10m raft being uneconomical.
- Bridge foundation that can not be inspected during its service life.
- Serious problem of dewatering due to large in flow of water/standing water.
- Where open foundations are feasible.

In other cases of small span bridges on weak soils, the raft foundations may be a most practicable solution.

(C) TYPES OF RAFT FOUNDATIONS

The raft foundation in vogue can be broadly classified in three categories.

- R.C.C. solid slab raft.
- R.C.C. Channel raft.
- Raft for box bridges.

Solid slab type raft is nothing but a slab resting on elastic bed, designed as one way (if cut off walls are detached) or two way if cut off walls are attached to the raft. The channel type raft is a monolithic unit designed and constructed as a channel cross-section. The third one for box bridges is unique type, since it is a part of the closed box with piers and superstructure. This can rightly be considered as a solid slab type raft, as the cut off walls should be detached from the raft, if not considered in analysis.

(D) IMPORTANT ASPECTS OF DESIGN OF RAFT

The raft foundation is designed with the assumption that it rests, on elastic bed. The analysis is based on Hetenyi's theory of beams on elastic foundations. The analysis considers the deflection pattern of the raft resting on elastic bed. Thus under the self weight of the bridge and the moving loads, the bending moments and shear forces are worked out at the desired sections in the raft.

Design of Slab Type Raft

For two lane bridges the width of the raft ranges between 8.50 m to 9.25 m for spans between 3 m to 10 m. In case of span to width ratio less that or equal to two, the Raft is designed as a two-way slab.

Due to the vertically upward reaction on the raft imparted by soil/strata below the raft, the same develops bending moments causing tension at top of raft, in addition, due to continuity etc., the rat slab is subjected to the moments causing tension at bottom at pier locations. Hence we find reinforcement at top and bottom both for the slab.

The channel type of raft is designed as a channel cross-section. The cut off walls takes the bending moments. Thus we find that the reinforcement required for resisting bending moment in longitudinal direction is all concentrated in the cut off wall and not in the raft slab

The cut off walls are designed to take all b.m. in longitudinal direction and also the shear forces. It is, therefore, important to note that the cut off walls are very important component of the raft foundation of this type.

The raft slab is designed for local effects of soil reaction from below as one way or two way reinforced slab. Hence we find the reinforcement pattern in this slab also similar to that in solid slab. The raft slab of box bridge is generally designed as one way as the box is analysed as a closed rectangular frame. Hence the main reinforcement in this raft is unidirectional.

(E) Analysis

The solid slab raft is analysed by using the elastic beam theory from Hetenyi's book 'Beams on Elastic Foundations[3] The bending moments in longitudinal direction are worked out and then apportioned in both the directions as per IS : 456 for two way slabs.

The channel type of raft is analysed by the same theory but in more elaborate way by solving differential equations involved in the analysis by using the 'Finite Difference Method' or "Finite Element Method' as a mathematical tool.

The box bridge raft is generally analysed as a closed box by 'Moment Distribution Method'. Any refined technique can be used for analysis of box.

(F) Wider and Narrow Rafts

The raft foundation is designed for 2 lane bridges. Considering the shape and batter given to the pier, the width of raft generally ranges between 8.55 m to 9.25 m. In case of minor bridges (length < 30 m) where the width of bridge is required to be kept equal to the specified formation width of the road, the raft width provided is 10 m to 12 m. Considering the width of the bridge with respect to span the raft becomes quite wide and need be analysed accordingly. Thus the type designs available for 7.5 m carriageway bridges should not be used for such wider foundations. Width of raft for single lane bridge is narrow. These are required to be designed accordingly as the bridge has to take only single lane of Class-A load.

(G) Placing the Raft Foundation

It is a common practice to keep the raft top 30 cm below the lowest bed level. However, if the lowest level does not tally with the average lower part of the bed, then the raft top may be suitable decided to be 30 cm below the average bed level. The sandy bed of the Nallah/River is expected to adjust itself due to the rigidity provided in the bed in the form of raft.

H U/s and D/s Approns

The aprons with toe wall need be provided both on U/s and D/s side the raft. These aprons are useful in increasing the seepage path below the raft. The concept of 1.0 d_{sm} (scour depth) works well with the raft foundation. Thus the aprons need be constructed and meticulously.

The aprons are designed as launching aprons and generally as per the guidelines given in IRC : 89, “Guidelines for design and construction of river training and control works”[6].

The length of U/s apron is taken as 1.5 times the depth of scour from bed level and D/s apron as 2.0 times the scour depth from the bed level,

The size of the stones to be used is of prime importance. It is the function of velocity of water in the stream, lest the apron gets washed away and endangers the raft foundation. Stone size and the thickness of apron need be carefully designed. If the stones of required size are not available economically, then concrete blocks, concrete or wire crates may be provided. The details of wire crates are available in IRC : 89, Appendix 1.

While deciding the size of stone, the velocity of flow at the bed level should be considered. If the maximum velocity which occurs at certain depth below the surface of the flow is considered, the size of the stone works out to be too large and is unnecessary. The minimum weight of stone to be used in apron shall not be less than 40 kg. It is desirable to provide bigger stones/concrete blocks near to the piers on D/s as the phenomenon of scour is predominant at this location.

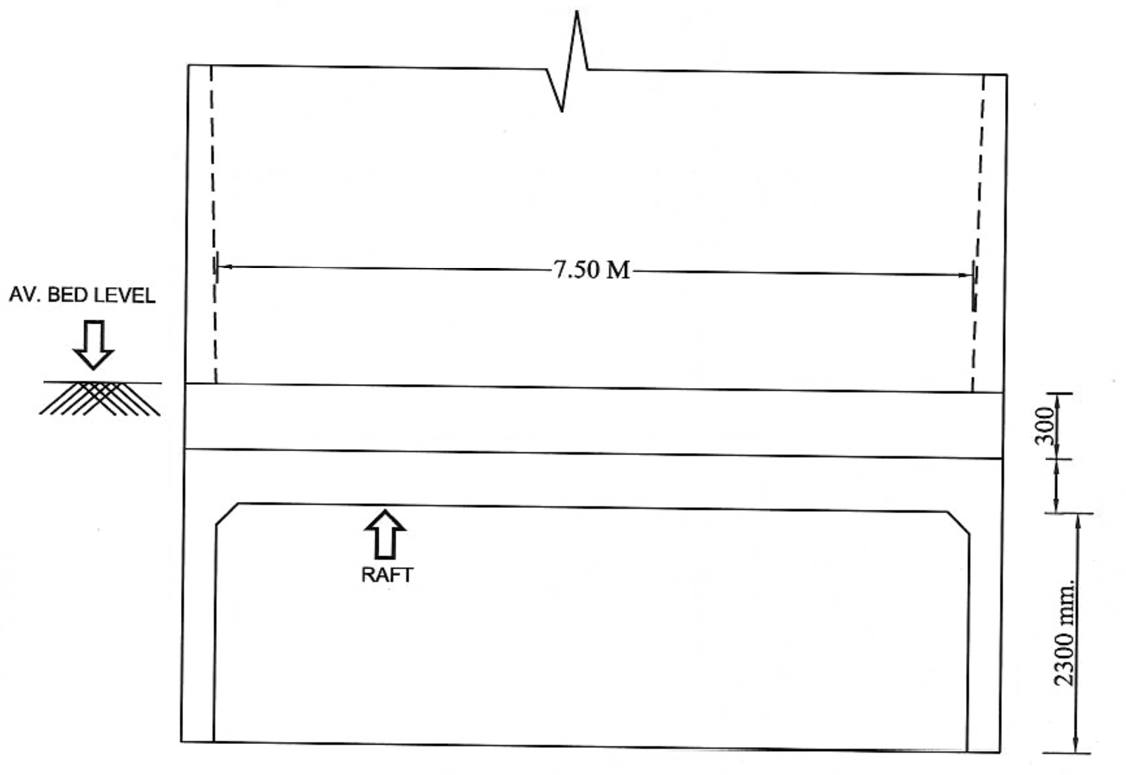
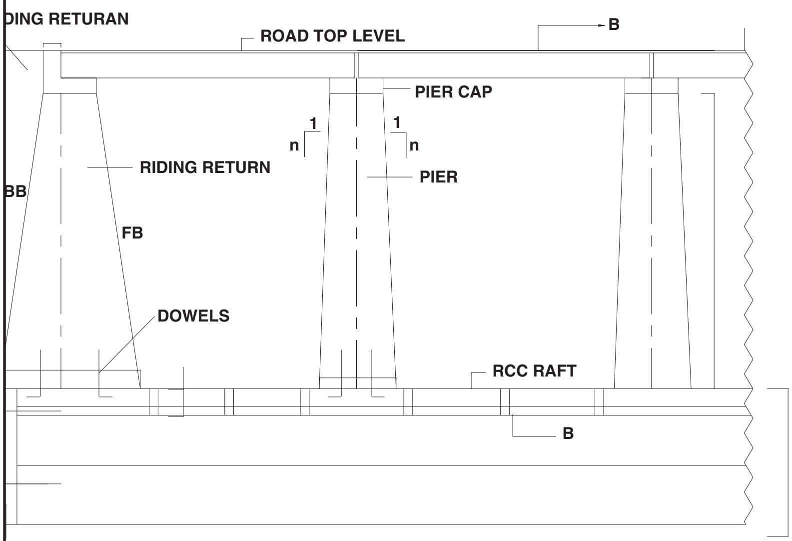
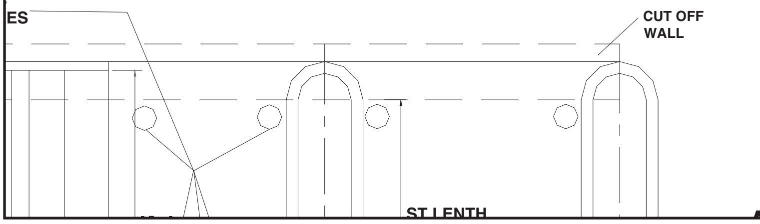


fig.3.5 Channel type raft

RIDING RETURN



SECTIONAL ELEVATION ALONG A-A



N. S. KORE, TRACER

Generally following size and weight of stone can be adopted for different velocities.

TABLE - 3.2

Mean Design Velocity in m/s	Dia. of stone in cm.	Weight of stone in kg.
Upto 2.5	30	40
3.0	38	76
3.5	51	184
4.0	67	417
4.5	85	852
5.0	104	1561

We find that when the velocity at bed level exceeds 4.0m/sec. the weight of stone required for apron is quite large. It may be difficult to get such large stones from quarries etc. We may, therefore think of concrete blocks or concrete stone blocks/crators

Note : For more details refer paper written by Shri.V.B.Borge and Shri.K.S.Jangde on "Innovative Bridge Foundations in Weak Soils-Experiment and Practice in Maharashtra"published in Journal of Indian Roads Congress Vol 66-3 October 2005.

3.2 SUB-STRUCTURE

3.2.1 Type designs available would provide sufficient information about the dimensions of the P.C.C. piers and abutments up to a height of 10m. These type designs available are for non-seismic zones only. For heights more than these R.C.C. pier of suitable dimensions will have to be considered.

3.2.2 As per IRC:21-2000 the Grade of Concrete as are specified below :

For bridges(Length > 60 m) :

Structural member	Conditions of Exposure	
	Moderate	Severe
P.C.C.	M 25	M 30
R.C.C.	M 30	M 35
P.S.C.	M 35	M 40
For other bridges or Culverts (<60m) :		
P.C.C.	M 15	M 20
R.C.C.	M 20	M 25

3.2.3 The proposed allowable compressive, tensile and shear stresses are as follows:

(i) Flexural compression scb = 0.33 fck for all grades of concrete

(ii) Flexural tension stb = 0.033 fck for all grades of concrete

(iii) Shear = As below

(a) The allowable shear stress for R.C.C. members subject to flexure, shear and members subject to axial compression, the allowable shear stress carried by the concrete (t_c) shall be as per following table. (Please refer IRC:21-2000, Table 12 B, Page 37.)

TABLE 3.3 : Permissible Shear Stress in Concrete

100 A_s bd	**Permissible Shear Stress in Concrete, t_c 14/mm2 Grade of Concrete**				
	M 20	**M 25**	**M 30**	**M 35**	**M 40 and above**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
0.15	0.18	0.19	0.20	0.20	0.20
0.25	0.22	0.23.	0.23.	0.23.	0.23.
0.50	0.30	0.31	0.31	0.31	0.32
0.75	0.35	0.36	0.37	0.37	0.38
1.00	0.39	0.40	0.41	0.42	0.42
1.25	0.42	0.44	0.45	0.45	0.46
1.50	0.45	0.46	0.48	0.49	0.49
1.75	0.47	0.49	0.50	0.52	0.52
2.00	0.49	0.51	0.53	0.54	0.55
2.25	0.51	0.53	0.55	0.56	0.57
2.50	0.51	0.55	0.57	0.58	0.60
2.75	0.51	0.56	0.58	0.60	0.62
3.00 and above	0.51	0.57	0.60	0.62	0.63

Note : 'A_s' is the area of longitudinal tension reinforcement (within the web in case of box sections), which continues at least one effective depth beyond the section being considered except at supports where the full area of tension reinforcement may be used provided the detailing conforms to Clause 304.6.2.2 of IRC:21-2000.

For slabs the allowable shear stress carried by concrete shall be Kt_c Where K has the values given below :

TABLE - 3.4

Overall depth of slab (mm)	300 or more	275	250	225	200	175	150 or less
K	1.00	1.05	1.10	1.15	1.20	1.25	1.30

3.2.4 Shear Reinforcement

(i) When the design shear stress t_v exceeds the shear stress carried by concrete t_c shear reinforcement shall be provided as per the following equation:

$$A_{sw} = \frac{V_{s.S}}{\sigma_s.d.(\sin\alpha + \cos\alpha)}$$

Where

A_{sw} = total cross-sectional area of stirrup legs or bent-up bars within a distances,

s = spacing of the stirrups or bent-up bars along the length of the member,

b = breadth of the member which for flanged beams, shall be taken as the breadth of the web,

σ_s = permissible tensile stress in shear reinforcement,

α = angle between the inclined stirrup or bent up bar and the axis of the member, not less than 45°, and

d = the effective depth

Where more than one type of shear reinforcement is used to reinforce the same portion of the beam, the total shear resistance shall be computed as the sum of the resistance for the various types separately. The areas of the stirrups shall not be less than the minimum specified in 304.7.1.5.

(ii) The type of shear reinforcement shall be in accordance with Cl.304.7.1.4 of IRC:21-2000.

Minimum Shear Reinforcement

The minimum shear reinforcement calculated as per the above equation shall not be less than :

TABLE - 3.5

	Grade of bars	
	S 240	S 415
Asw Min.	0.002 bs	0.001 bs

In no case design shear stress calculated shall exceed the maximum permissible shear τmax as given below.

τmax = 0.07 fck or 2.5 MPa whichever is less.

(Refer Table No. 12.A IRC:21-2000, Clause No. 304.7.1.2, Page 36)

3.2.5 P.C.C. piers need be provided with surface reinforcement to cater for effects of temperature variations in the structure. For P.C.C. substructure members surface reinforcement to be provided is 2.5 Kg/Sq.m. in both directions as per IRC:78-2000, Clause No. 710.1.1 and also the spacing should not be more than 200 mm. This reinforcement is also useful for having a good bond between two layers of concrete.

The top width of pier is dependent on type of superstructure i.e. solid slab, girder slab system, prestressed concrete etc. The same therefore, need be carefully decided. Span length plays important role in deciding the size of bearings and its pedestals and expansion gap, which also need be considered while deciding the top width of pier. Prestressed concrete construction warrants extra space for putting the prestressing jacks, which need be considered while deciding the top width of pier. Calculations are required with the help of properly drawn sketches. About 1.20 m clear space between the faces of end diaphragms of 2 spans resting on pier may be considered adequate for P.S.C. type of superstructures.

The batter given to the pier generally is 1:30, 1:25, 1:20, 1:18 and some times 1:15 and 1:12. This is as per the stability calculations. The batters 1:15 and steeper do not look aesthetically pleasing and also result in increased obstruction to flow of water and hence may be avoided if possible. It is prudent to have one shape of pier for a bridge from aesthetic point of view and also for ease of work and economy due to repeated use of centering.

3.2.6 Forces to be considered for stability of piers and abutments are given in IRC:6-2000 Loads & Stresses (Section-II). The permissible increases in stresses in the various members under different load combinations are also given in the code. The same is summarised as below:

TABLE – 3.6

Sr. No.	Load Combination	* Increase in permissible stresses.
1.	Dead + Live	NIL
2.	1 + Secondary + Deformation + Temperature	15%
3.	2 + wind + wave pressure	33 1/3 %
4.	2 + seismic + wave pressure	50%
5.	2 + barge impact + wind load	33 1/3 %
6.	Dead + water current + buoyancy +	33 1/3 %
	Earth pressure + erection + friction +	
	wind + grade effect 6 + Seismic - Wind	50%

(* These values are not applicable for working out the base pressure for piers, abutment, returns etc. The permissible base pressures are given in I.R.C.78 – 2000, Clause No. 706.3.)

Apart from above-mentioned combinations, following load combinations should generally be checked.

1. Dead + Live + wind in transverse direction

   (i) Wind acting perpendicular to deck.

   65 % perpendicular and 35 % along the deck. The wind velocity and method of computation of forces is given IRC: 6-2000. (Section-II).

2. One span dislodged (i.e. smaller span not in position) for pier and no span condition for abutment.

   One span dislodged condition with Class A one train on span.

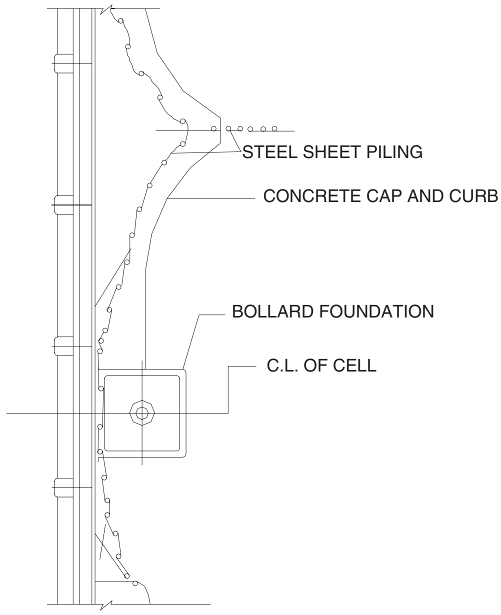
   While considering the water current forces it is also assumed that the water flows at an angle of 20° resulting in transverse force on the pier. This force is quite substantial and is important in the stability analysis.

   Differential water head of 250mm between opposite faces of the pier also need be considered in case of bridge with pucca floor or in-readable bed.

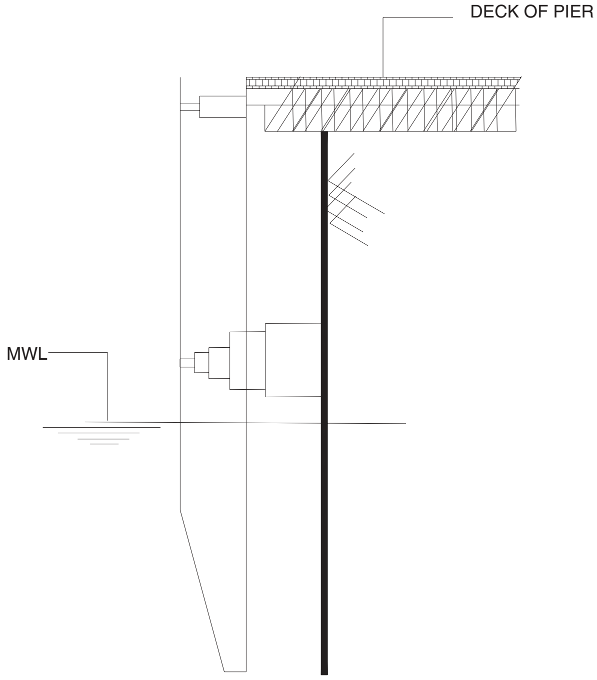
   The effect of live load surcharge on the abutments shall be as per IRC: 78-2000, Clause 710.4.4.

   It is further necessary to check the stability of pier for 'no-span' condition. The pier having no stabilising load from superstructure may be found unsafe under particular load combinations, e.g. water current.

   Barge impact (in case of navigational channels) is one of the important factors in substructure design. The values of barge impact load should be judiciously considered depending on the weight of the moving barge. The highest point on the pier where barge is likely to hit the barge need be defined and constructed accordingly. Typical arrangement is shown in fig 3.6.



PLAN



SECTION

FILLED CELLULER PIER

FIG.3.6

N. S. KORE, TRACER

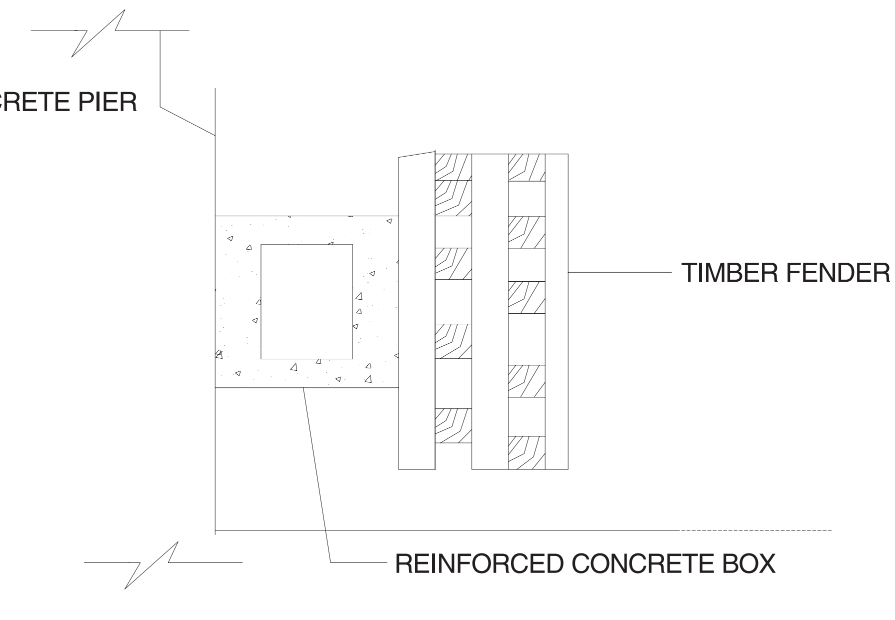


FIG.3.7 CRUSHABLE CONCRETE BOX FENDER ON THE FRANCIS SCOTT KEY BRIDGE

A typical pier with protective kerb for barge impact is shown in fig 3.8.

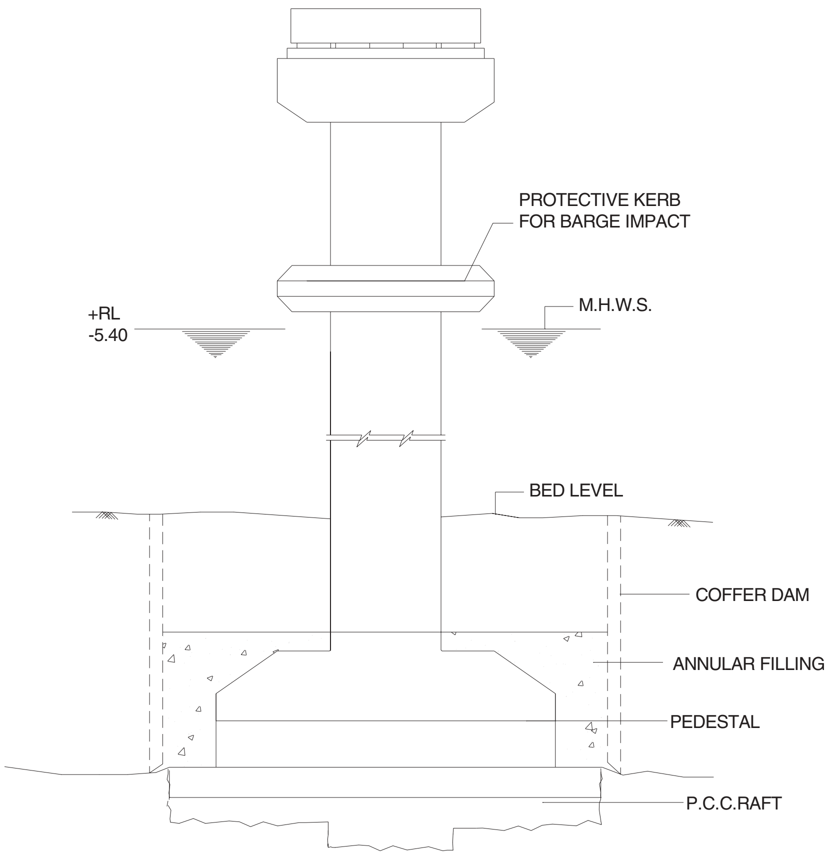


FIG.3.8 OPEN FOUNDATION (NEW THANE CREEK BRIDGE)

N. S. KORE, TRACER

All forces should be stated in a proper sequence. The combinations of load & permissible base pressures. Specific requirements for different types of foundations should be explained.

3.2.7 Piers

The various type and shapes of piers used by the Department are as indicated in fig.3.9 to 3.13.. The materials used for pier are Masonary, P.C.C., R.C.C.- Materials Shape - Solid wall type circular column, square column, rectangular, hollow circular twin or multiple column either or connected by diaphragm.

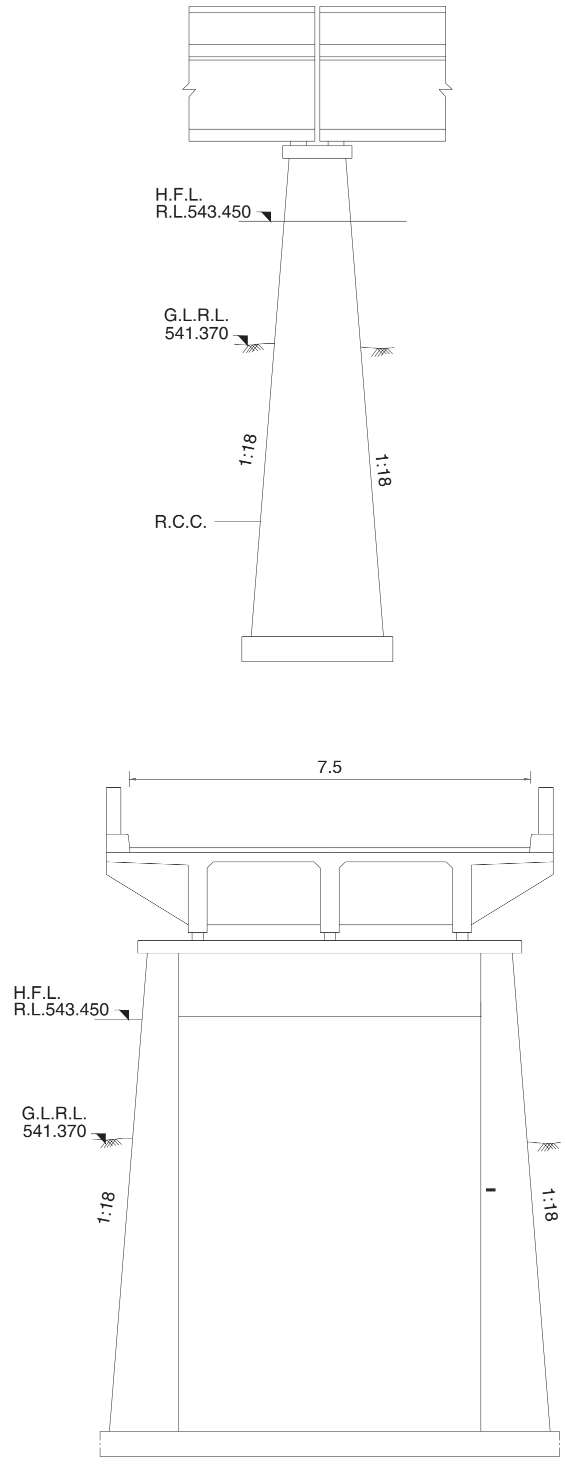
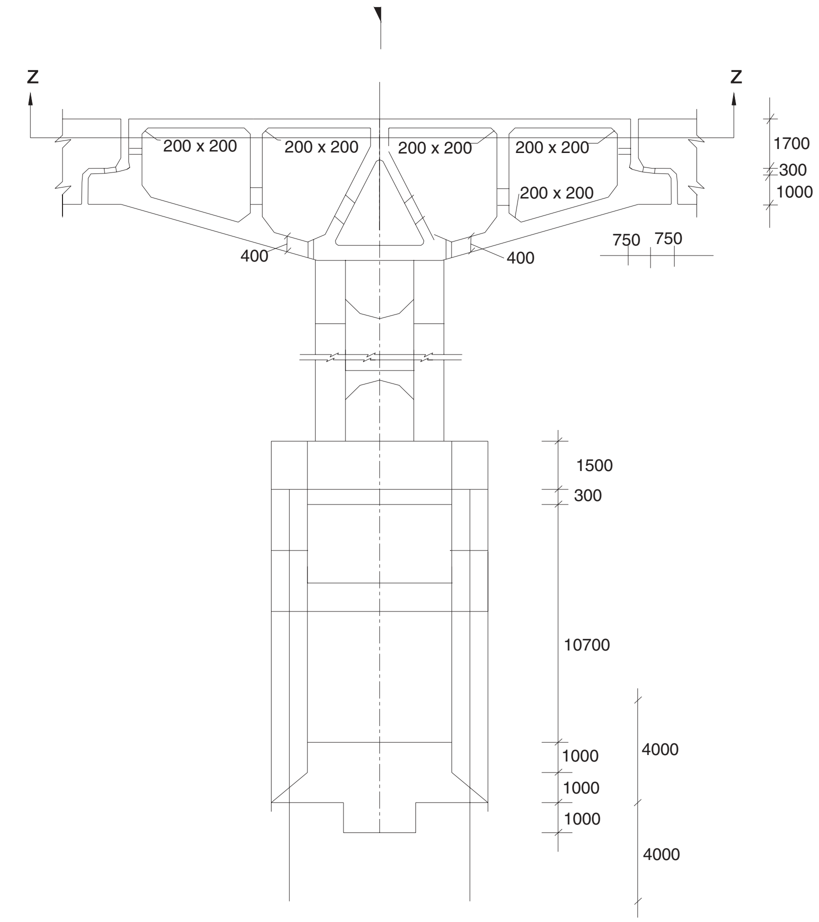


FIG.3.9 SOLID WALL TYPE PIER



HAMMER HEAD PIER

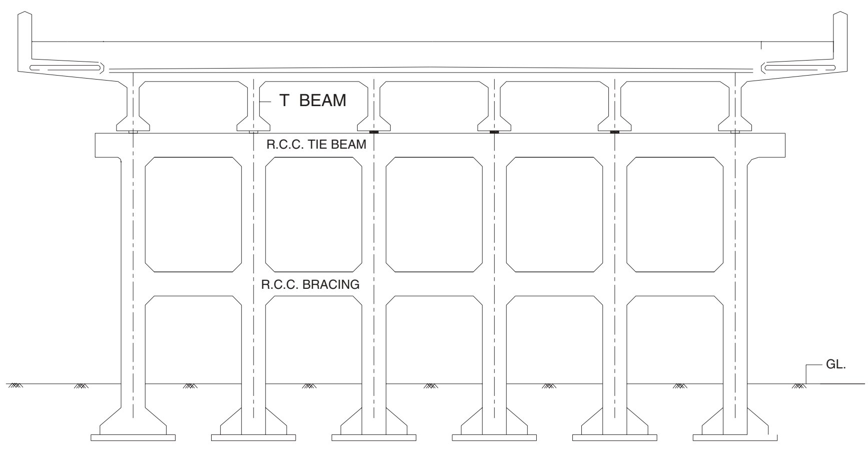


FIG.3.10 FRAME TYPE PIER

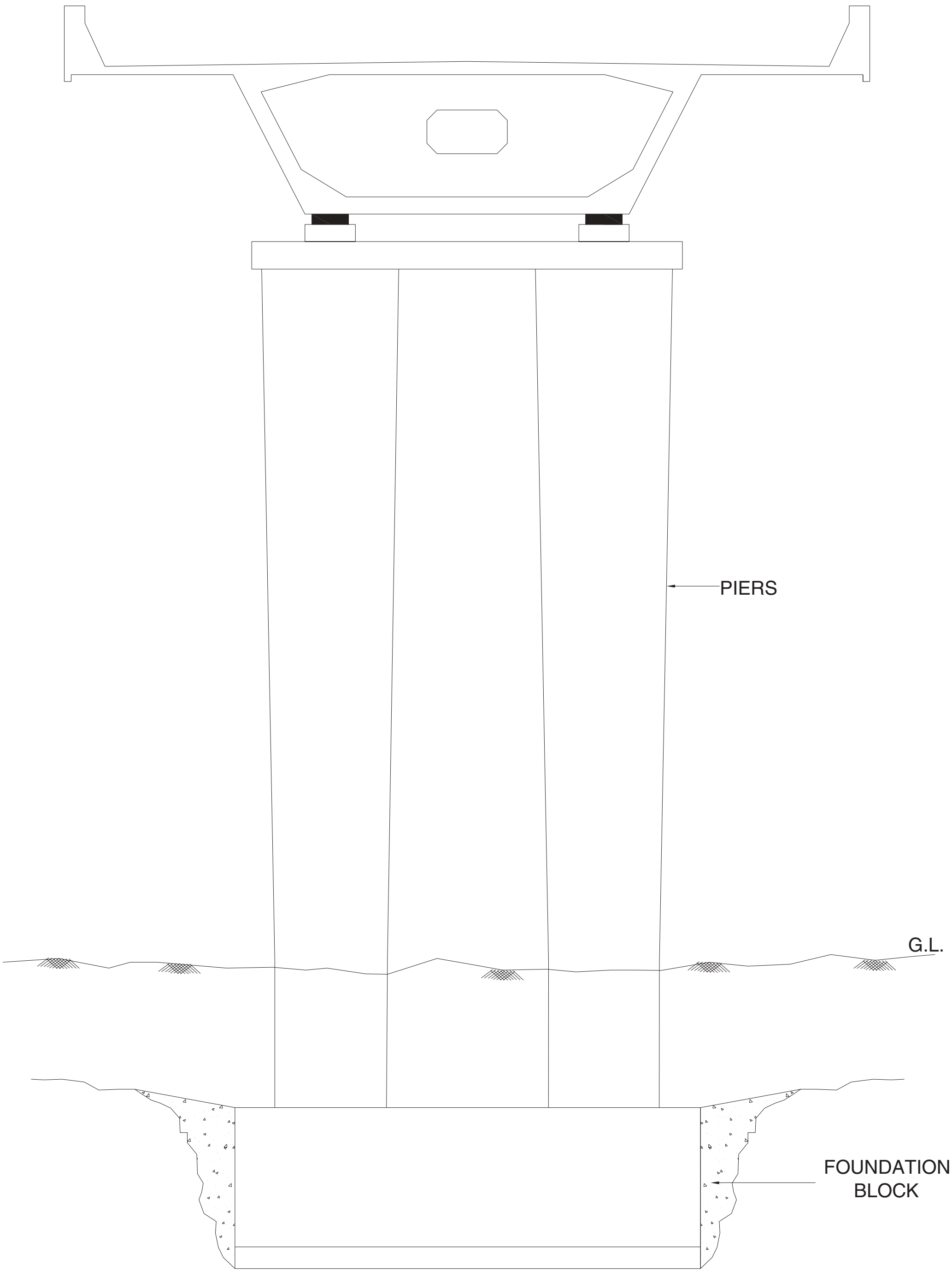


FIG. 3.11 TWIN CIRCULAR PIER

UDAY PATIL, TRACER

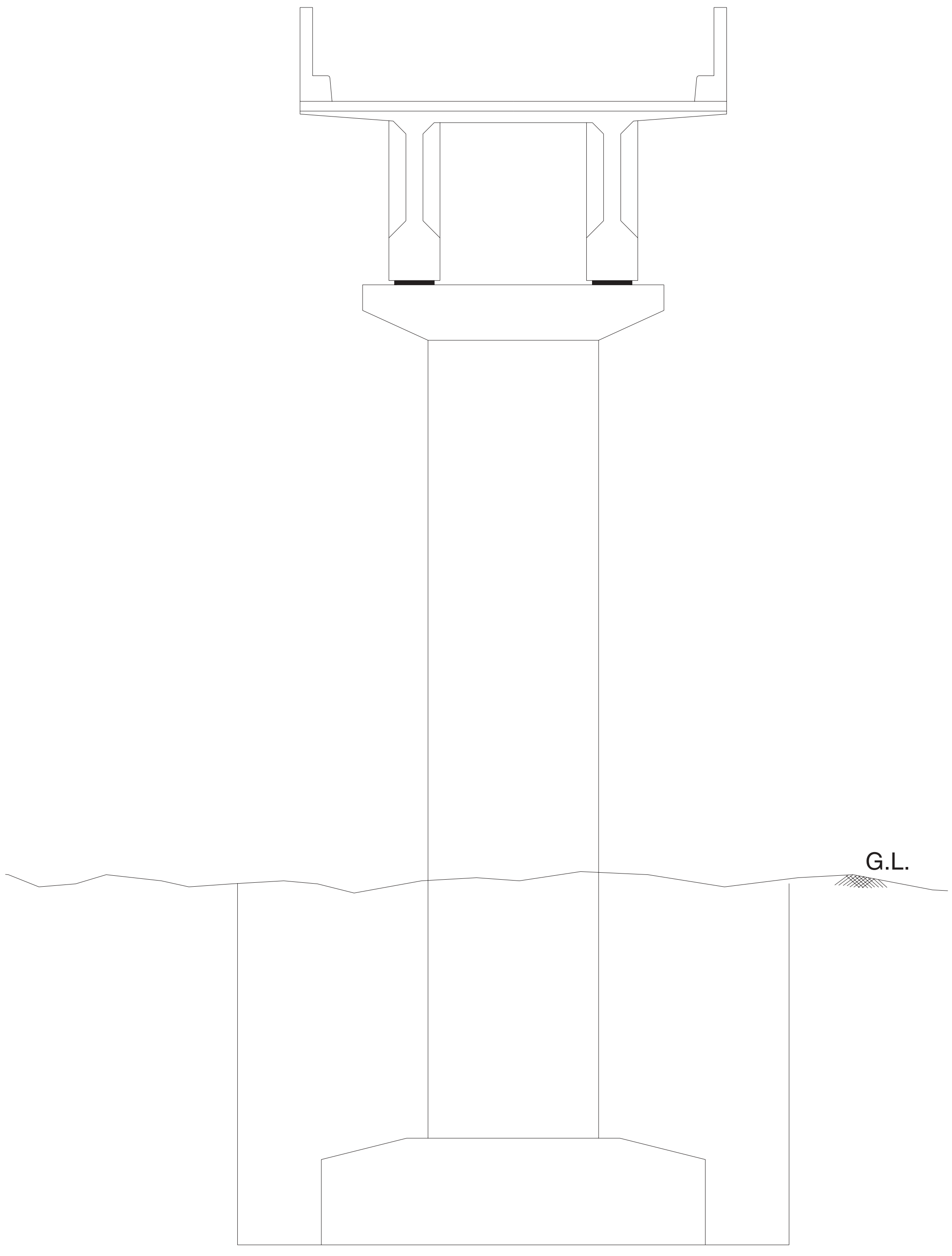


FIG.3.12 SINGLE CIRCULAR PIER

UDAY PATIL, TRACER

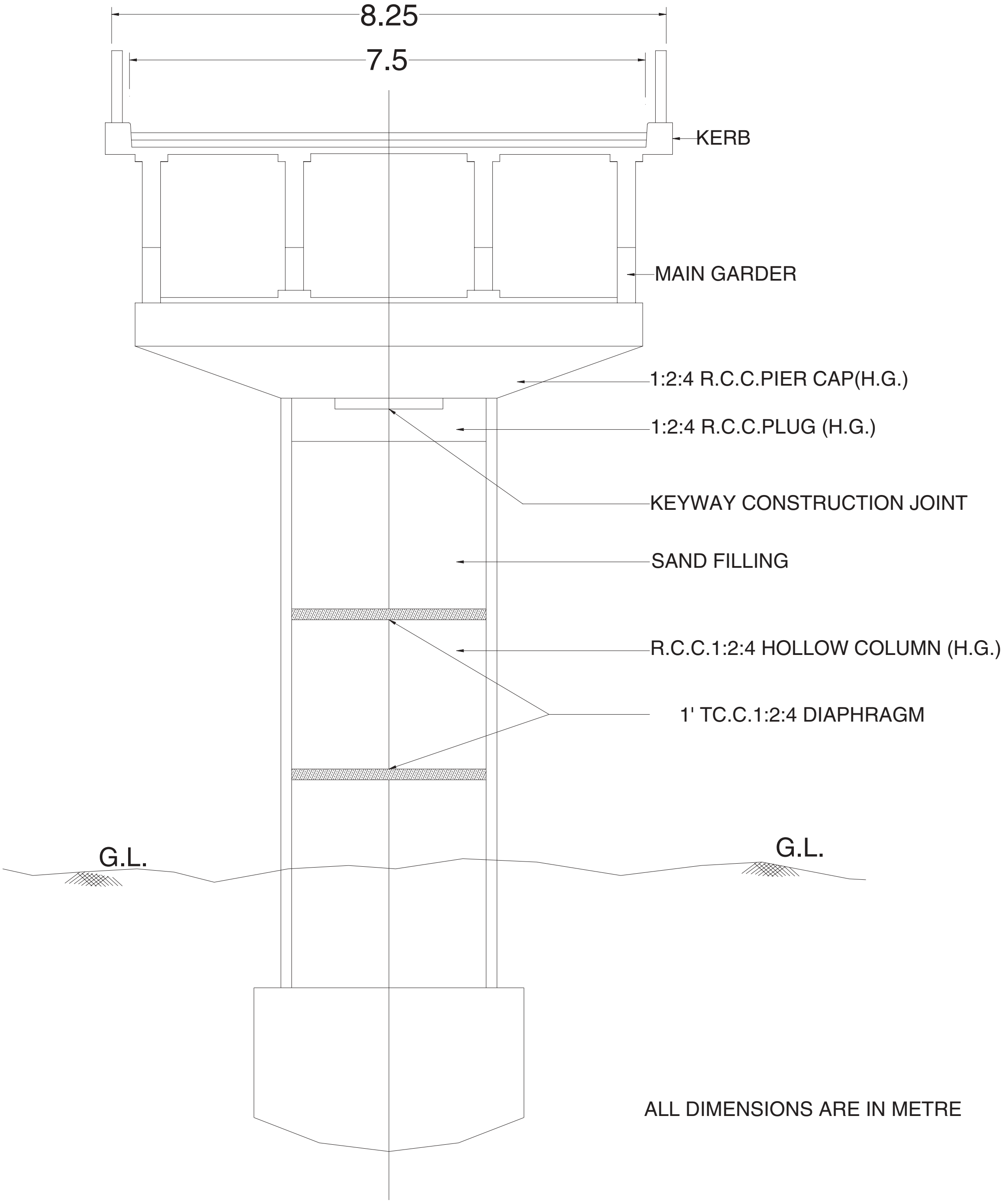


FIG.3.13 R.C.C. HOLLOW PIER

UDAY PATIL, TRACER

3.2.8 Abutment

Various types of abutments used are gravity type, spill through type, counter-fort type.Various types of abutments used in the department are shown in fig.3.14,3.15,3.16 Selection of a particular type of abutment depends upon the span , type of superstructure, height of substructure, magnitude of loads and forces to be transmitted, availability of type of construction material and construction equipment at site, time for construction and minimal cost. Solid abutments are proposed when height required is less than 10 m. Counterfort abutments are proposed when the height of abutment required is very high. Spill through abutment may be provided when the spilled earth is not subject to velocity more than 2 m/s and when solid and counterfort abutments are not feasible. Spill through material shall be suitably protected from wash out.

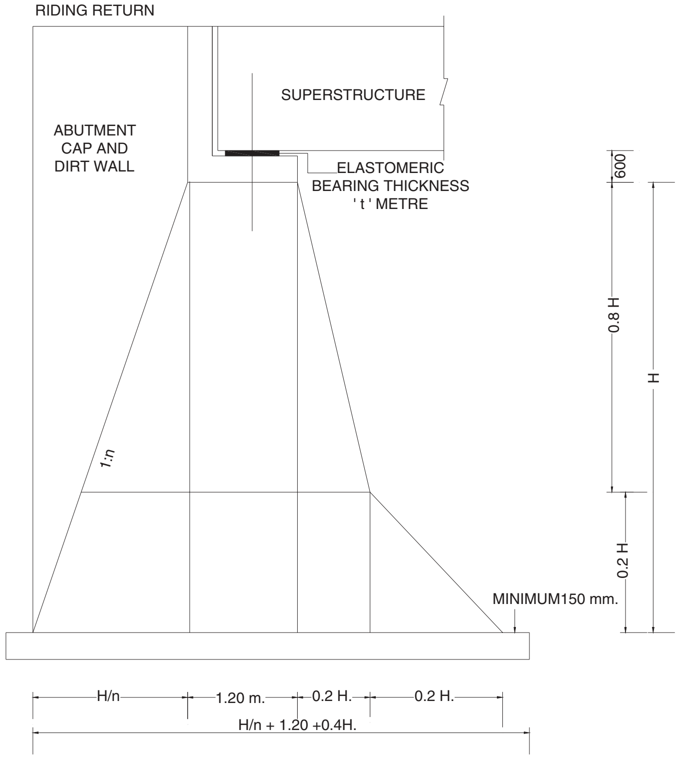


FIG.3.14 SOLID ABUTMENT

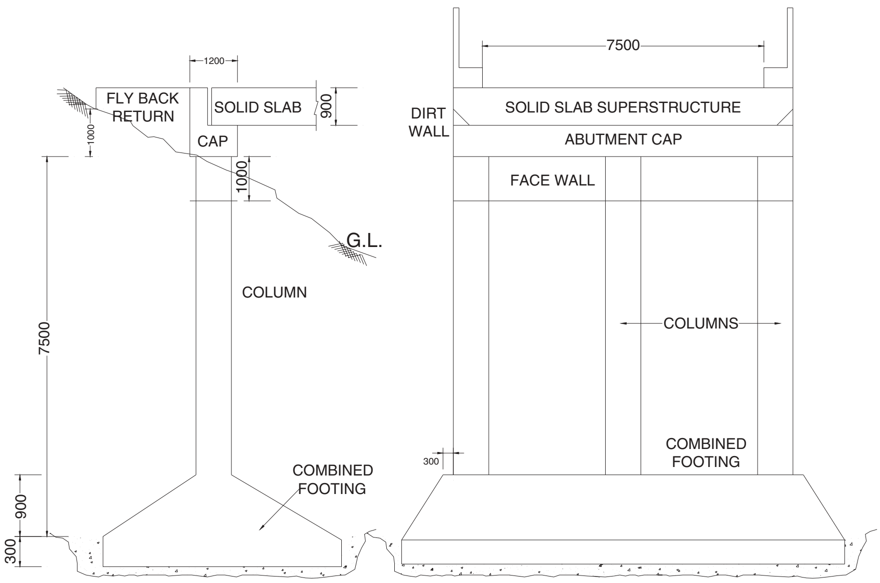


FIG.3.15 SPILL THROUGH ABUTMENT

UDAY PATIL, TRACER

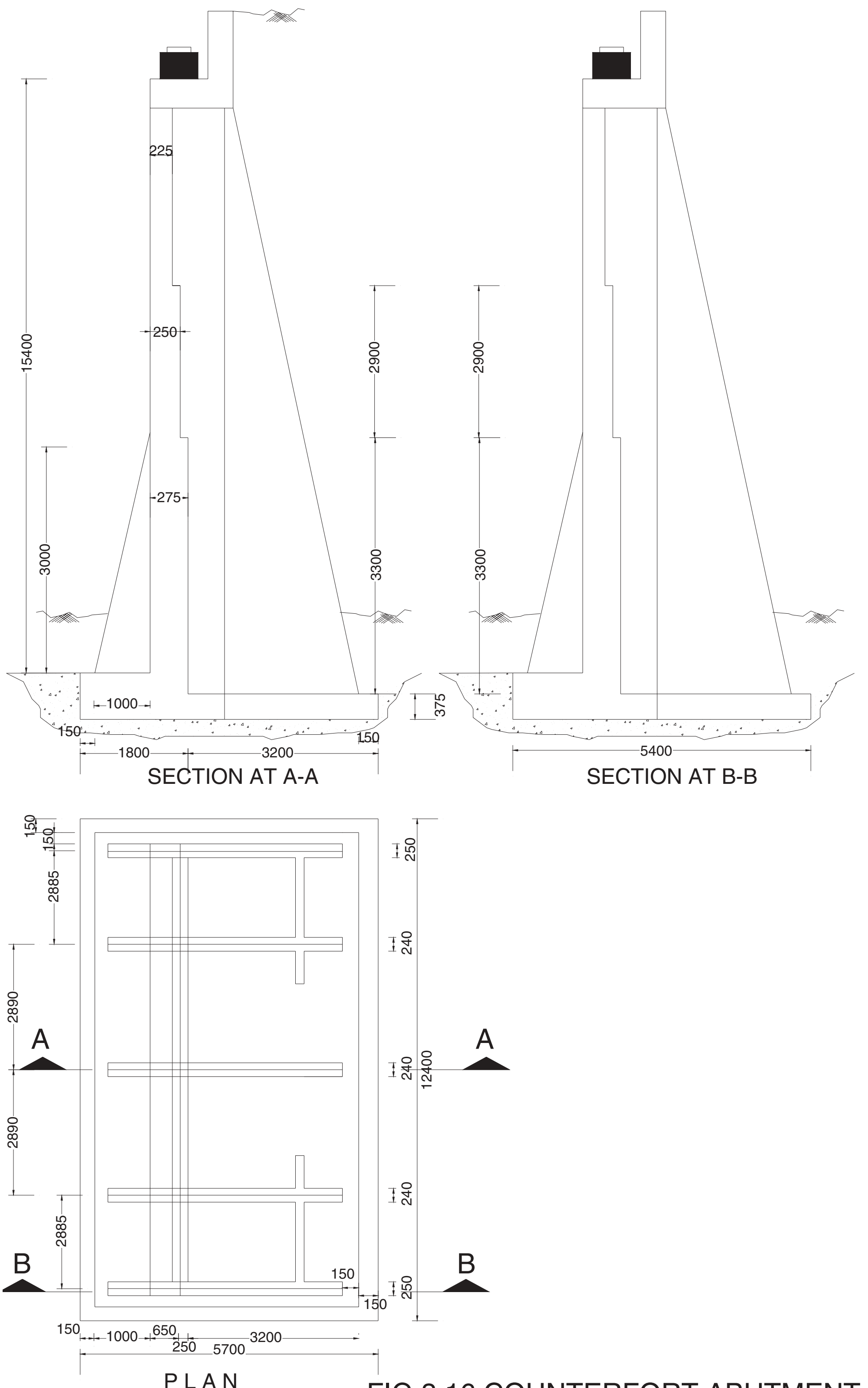


FIG.3.16 COUNTERFORT ABUTMENT

UDAY PATIL, TRACER

3.2.9 RETURNS

The types of returns used are solid gravity, R.C.C. box, Tied back or fly back type. Different shapes of recently used in the state are shown in fig 3.17,3.18 and 3.19.

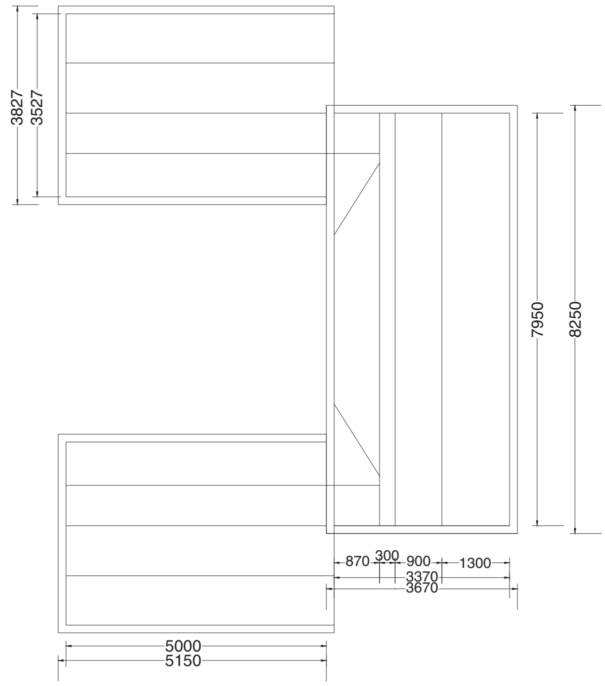


FIG.3.17 SOLID RETURN

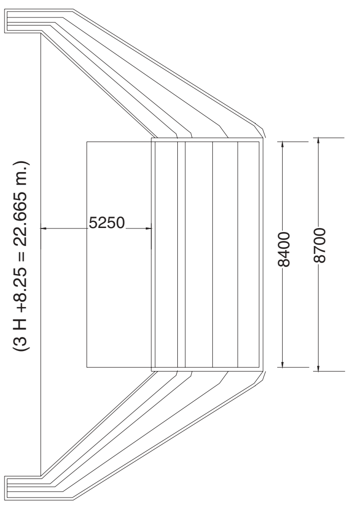


FIG. 3.18 SPLAYED RETURN

UDAY PATIL, TRACER

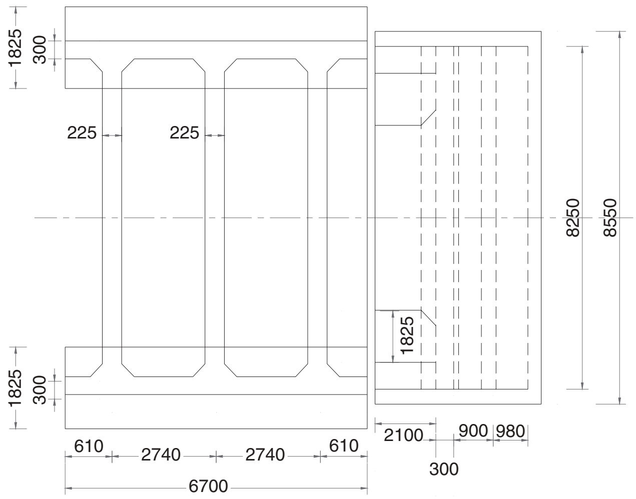
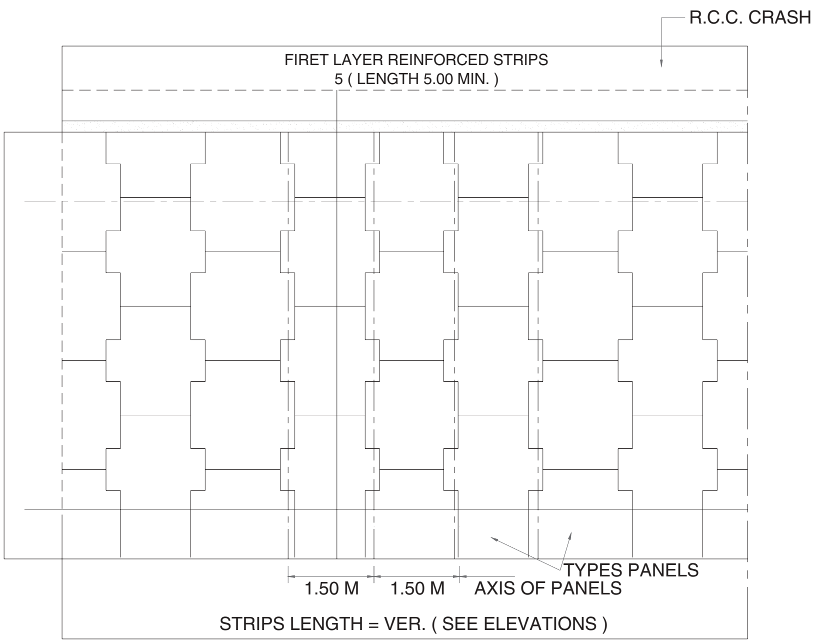


FIG.3.19 BOX RETURN

Now the department has decided to make use of reinforced earth embankments. Typical sketch is as shown in fig.3.20 and 3.21.



ELEVATION
FIG.3.20 REINFORCED EARTH

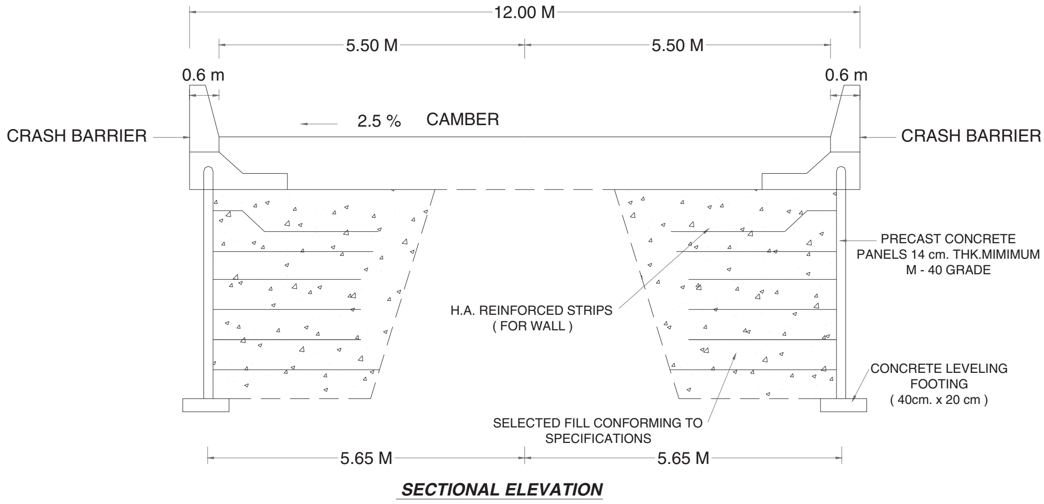


FIG.3.21 REINFORCED EARTH EMBANKMENT

3.3 BEARINGS

3.3.1 Types

Various bearings in use by the department are M.S. plate, cast steel rocker rollers, neoprene, and POT/ PTFE, R.C.C. Roller.

3.32 Selection

The selection of Bearings should be as follows :

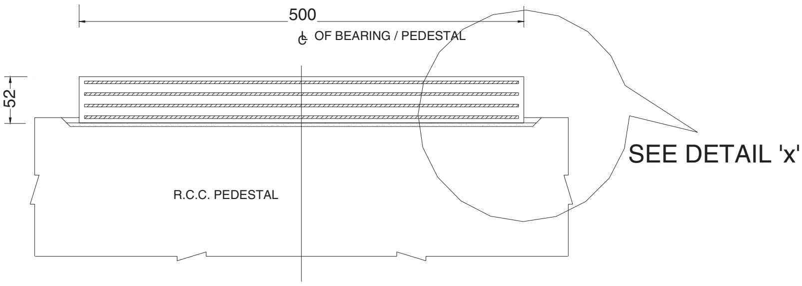
1	Spans upto and including 10 m for solid slab superstructure	Tar paper
2	Span > 10 m and < 25m	Neoprene
3	For larger spans	POT/PTFE

Reference should be made to

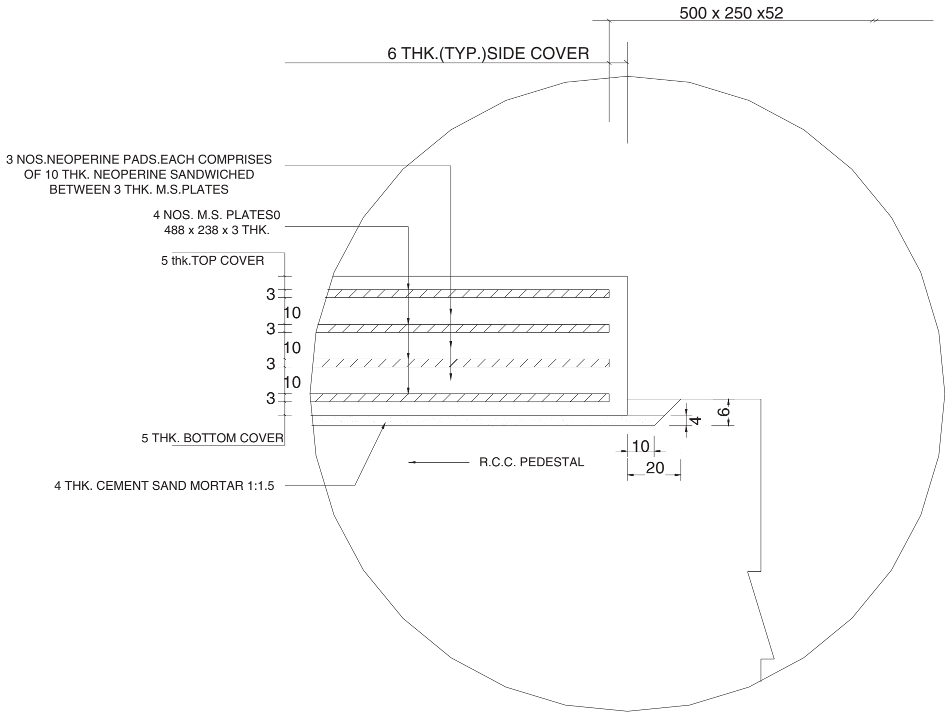
I.R.C.83 Section IX	Part I	Metalic Bearings
	Part II	Elastomeric Berings
	Part III	POT, POT/PTFE
		Pin and Metallic Guide Bearings.

3.3.3 Seismic arrestors

To prevent dislodgement of superstructure reaction blocks or other types of arrestors shall be provided and designed for twice the seismic force. For further details refer I.R.C.:6-2000, Clause 222.11.



SECTIONAL ELEVATION

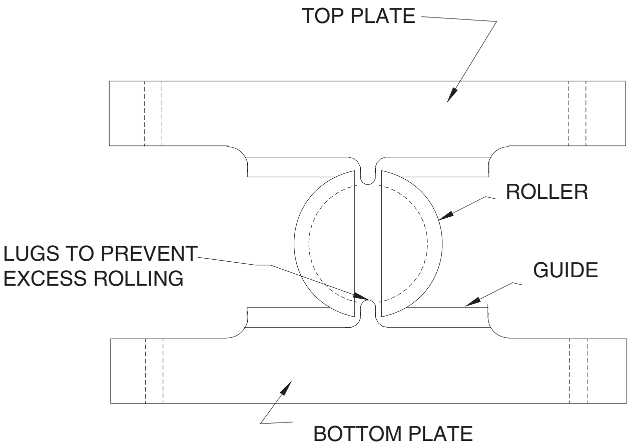


ENLARGED DETAIL AT 'x'

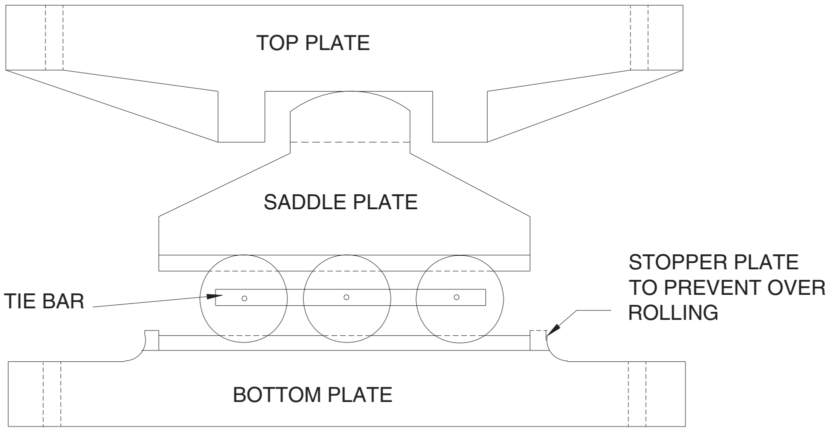
DETAIL OF NEOPRENE BEARING TYPE (A)
ON ABUTMENT / END PIER

FIG.3.22 TYPICAL SECTION OF NEOPRENE BEARING

UDAY PATIL, TRACER

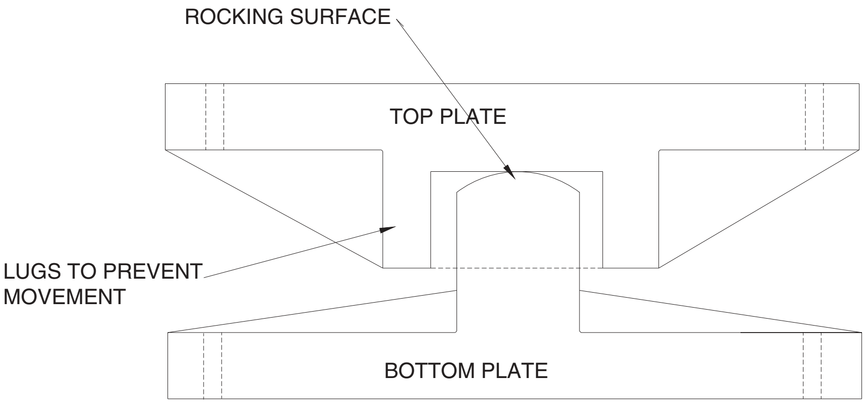


(a) SINGLE ROLLER

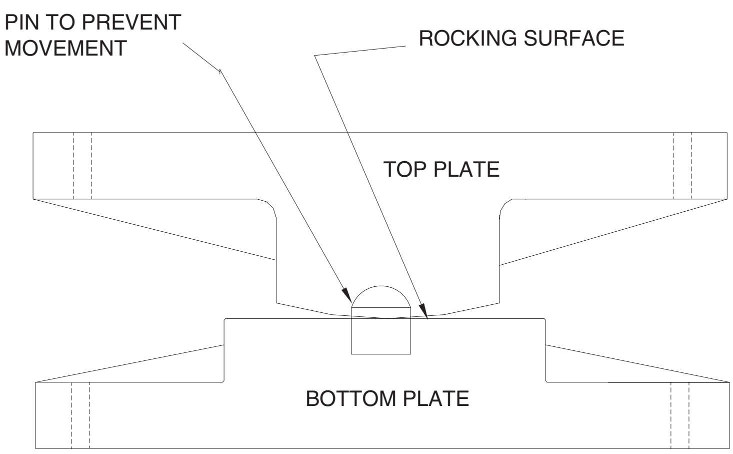


(b) MULTIPLE ROLLER

FIG.3.23 STEEL ROLLER BEARINGS



(a) FLAT SURFACE OVER CURVED SURFACE



(b) CURVED SURFACE OVER FLAT SURFACE

FIG.3.24 STEEL ROCKER BEARINGS[8]

N. S. KORE, TRACER

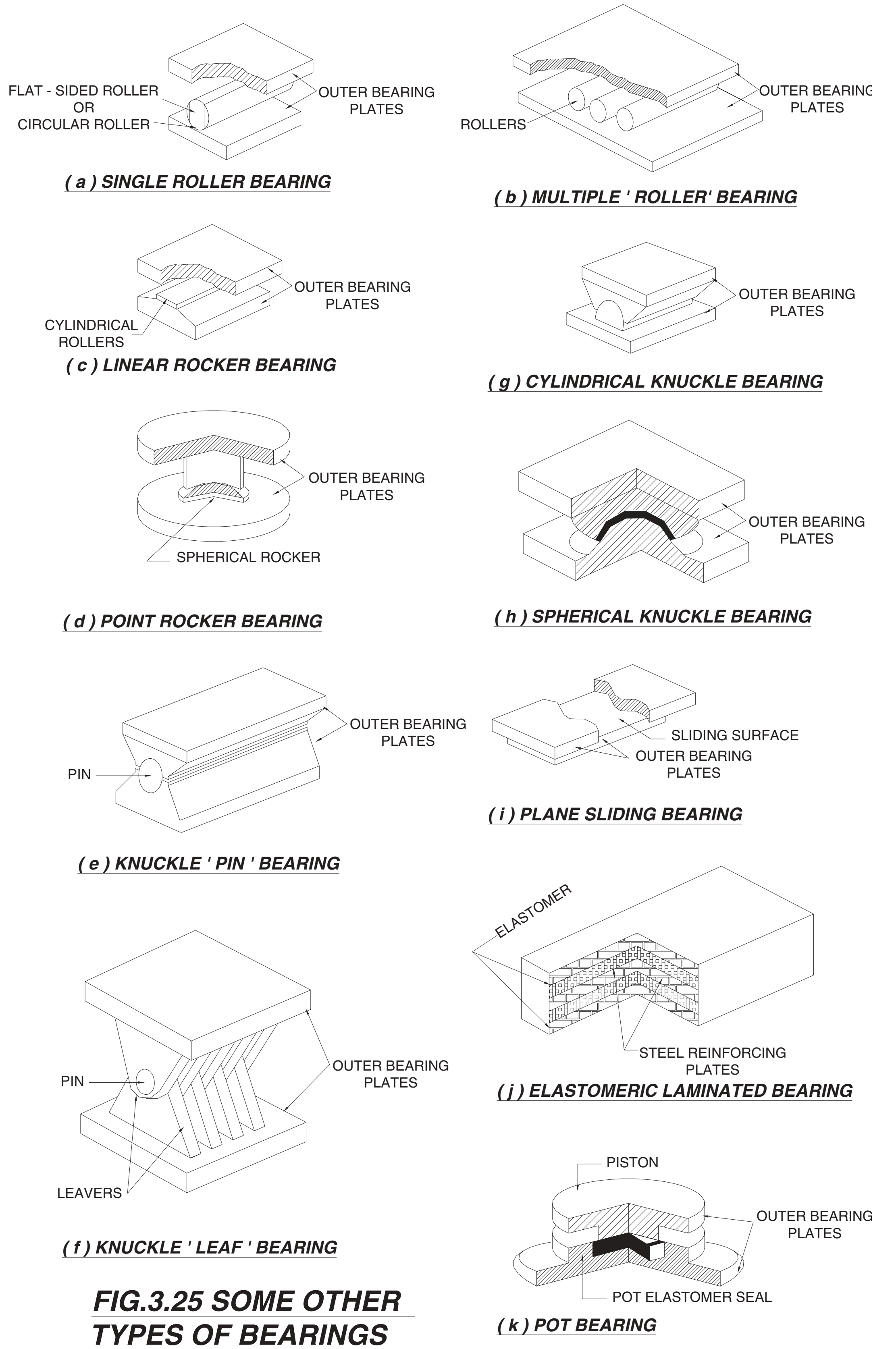
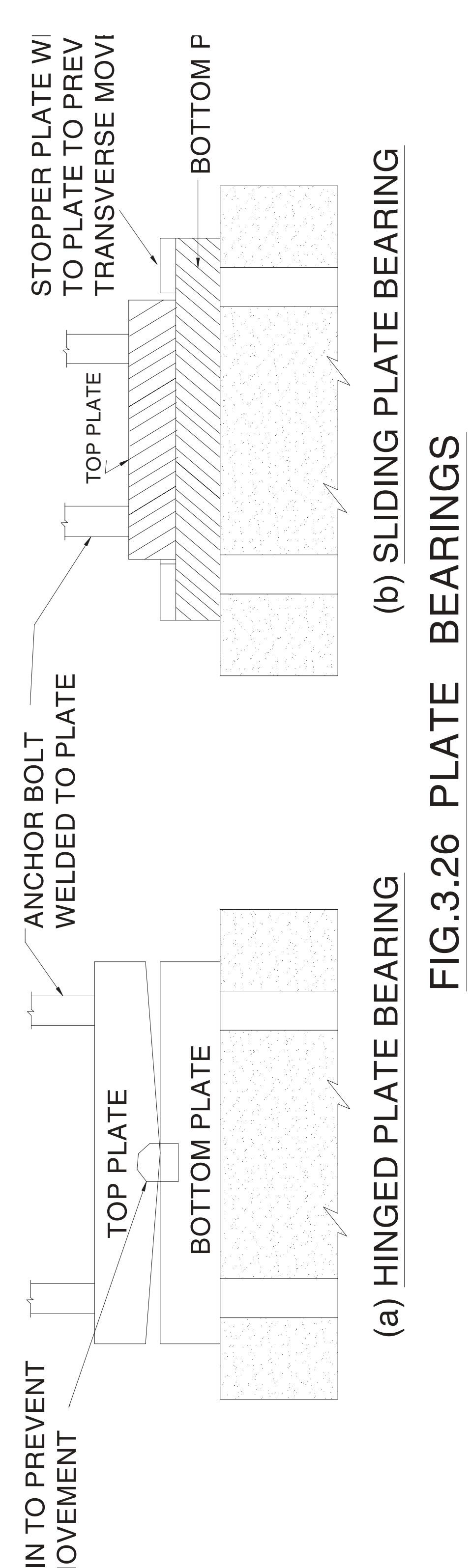


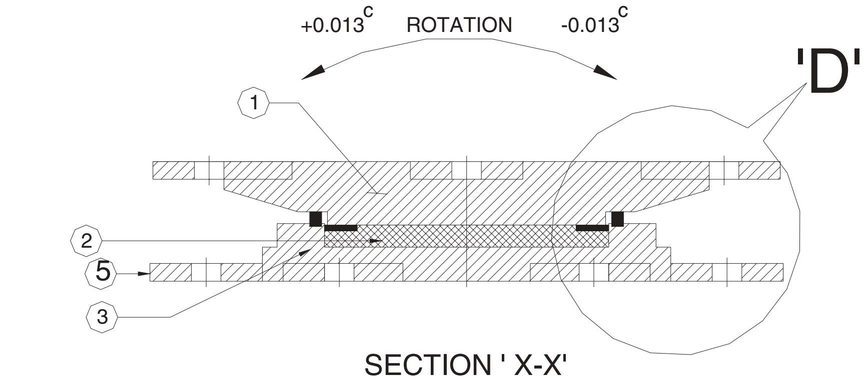
FIG.3.25 SOME OTHER TYPES OF BEARINGS



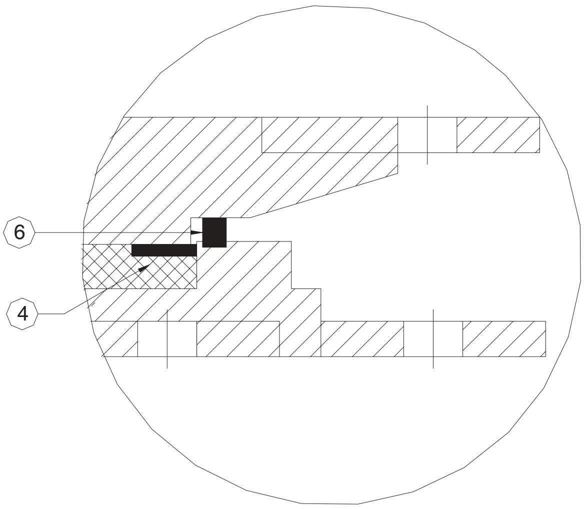
(a) HINGED PLATE BEARING

(b) SLIDING PLATE BEARING

FIG.3.26 PLATE BEARINGS



SECTION ' X-X'

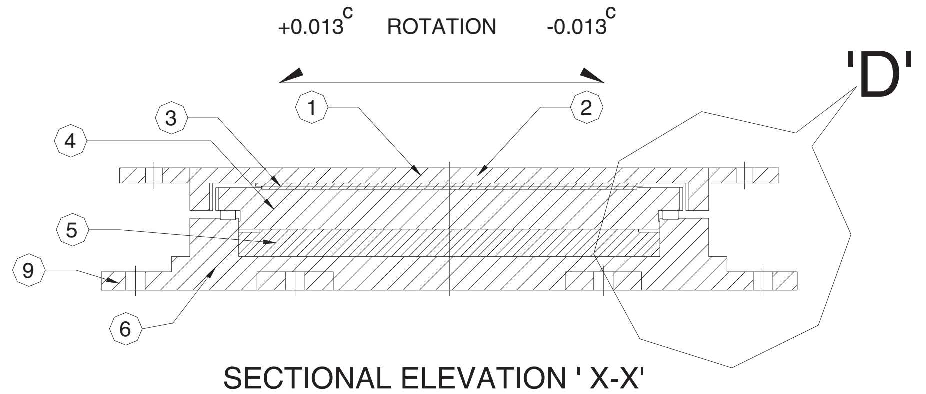


DETAILS AT 'D'

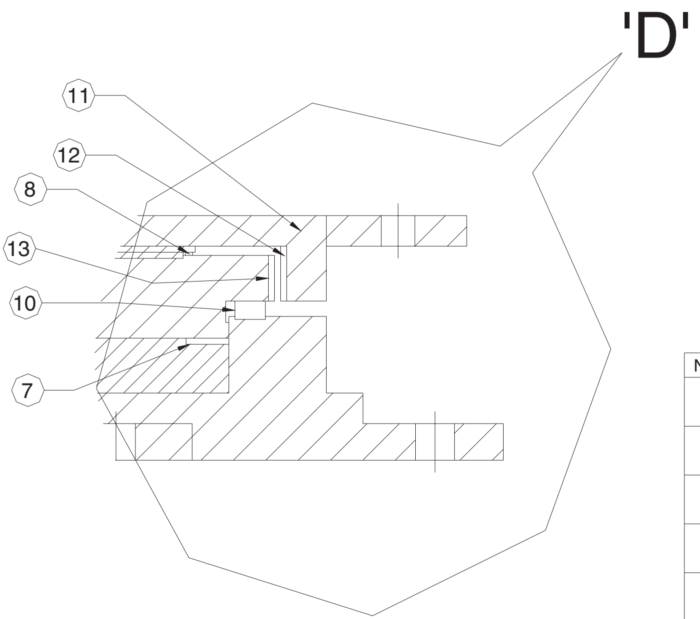
NO.	DESCRIPTION
1	TOP PLATE (B3Ø x DpØ x B6/B2)
2	ELASTOMERIC PAD (D5Ø x Nt)
3	POT (A1Ø / A7Ø x AH1/ A6/A2)
4	BRASS SEAL (D5Ø x D2Ø x 2 THICK)
5	LUGS (Ll x Ll x Lt)
6	EXTERNAL SEAL

FIG.3.27 DETAILS OF FIXED POT BEARING FOR 295 TON

B. D. KAMBLE, TRACER



SECTIONAL ELEVATION ' X-X'



DETAILS AT 'D'

NO.	DESCRIPTION
1	TOP PLATE (BL x BW x B2)
2	S.S.SHEET (SSPl x SSPw x SSPt)
3	P.T.E.F. (L x L x 4.5)
4	PISTON (C3 x C3 x DpØ x C2)
5	ELASTOMERIC PAD (D5Ø x Nt)
6	POT (A1Ø / A7Ø x AH1/ A6/A2)
7	BRASS SEAL (D5Ø x D2Ø x 2)
8	WIPER SEAL
9	LUGS (Ll x Ll x Lt)
10	EXTERNAL SEAL
11	END CONSTRAINT (El x Eb x Et)
12	S.S.STRIP (EL x ET x 3)
13	S.S.STRIP (C3 x 12 x 3)

FIG.3.28 DETAILS OF GUIDED SLIDING POT / PTFE BEARING FOR 295 TON

UDAY PATIL, TRACER

P.T.F.E. bearings are for sliding or rotational movements. Proper selection would be necessary. Sufficient margin should be kept for movement due to deflection in the structure. Stopper/Lugs need be provided to arrest excessive movements in lateral direction due to centrifugal force etc.

3.4 SUPERSTRUCTURE

Various types of superstructures are Arches, Masonry, C.C., R.C.C. Girder and deck slab, Solid Slab, R.C.C. T-Beam Slab, R.C.C. Box Beam, Voided Slab, P.S.C. Two Girder, Three Girder, Multi-Girder, Box Girder, Simply supported continuous Cantilever, Balance Cantilever, Hammer Head, Bow string girder, composite construction, cable stayed, suspension.

3.4.1 Selection of Proper Superstructure : Generally the following criteria should be followed for selection of superstructure depending on span length.

1.	Spans upto 10m.	R.C.C. solid slab.
2.	Spans- 10 to 15m	R.C.C. solid slab /Ribbed slab,
3.	Spans - 15m.to 20m	R.C.C. Multi-girder slab system.
4.	Spans - 20m.to 30m	P.S.C. Girder/Box type superstructure.
5.	Span - 30m to 60m	P.S.C. Box girder.

For spans more than 60 m the discussions should be held with Superintending Engineer, Designs Circle regarding selection of the type of superstructure.

2-girder system for two-lane superstructure should not be proposed unless other alternatives are considered unfeasible.

For spans up to 10m solid slab superstructures are found most suitable. As the span increases beyond 10m the thickness of solid slab poses difficulties during concreting. Lot of construction joints are created in the structure if proper programme of concreting is not prepared and insisted upon. It is, thus, desirable to go for ribbed slab or multi-girder system of deck slab. Spans between 10 m to 15 m could be conveniently covered in this manner.

Spans between 15m to 20m, multi-girder system would be desirable. Two-girder system should be avoided as far as possible. In case of single lane bridges two-girder system is natural choice. But this system should not be preferred in severe exposure conditions. There is a school of thought that damage to one girder makes the entire structure unstable and unsafe and hence multi girder system is to be preferred.

For spans between 20m and 30m R.C.C. box type superstructure is considered suitable. Use of R.C.C. girder and slab system might result in excessive deflections under live load. Box girder is a more desirable shape for the superstructure.

Beyond 30 m span, it is necessary to go for P.S.C. This enables us to somewhat restrict the deck height to the desired level. For spans greater than 60m discussions should be held with Superintending Engineer, Designs Circle for deciding the type of superstructure. The parameters influencing selection of superstructure need to be studied.

Typical cross-section of single box cell is shown in fig.3.29.Some other types in use in the department are shown in fig. 3.30 to 3.38.

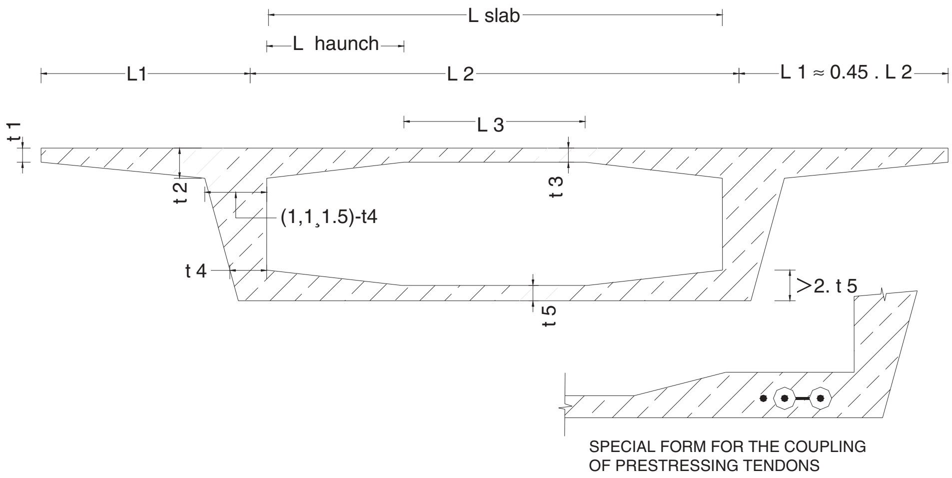


FIG.3.29 DESIGN AIDS FOR THE CROSS - SECTIONAL DIMENSIONS

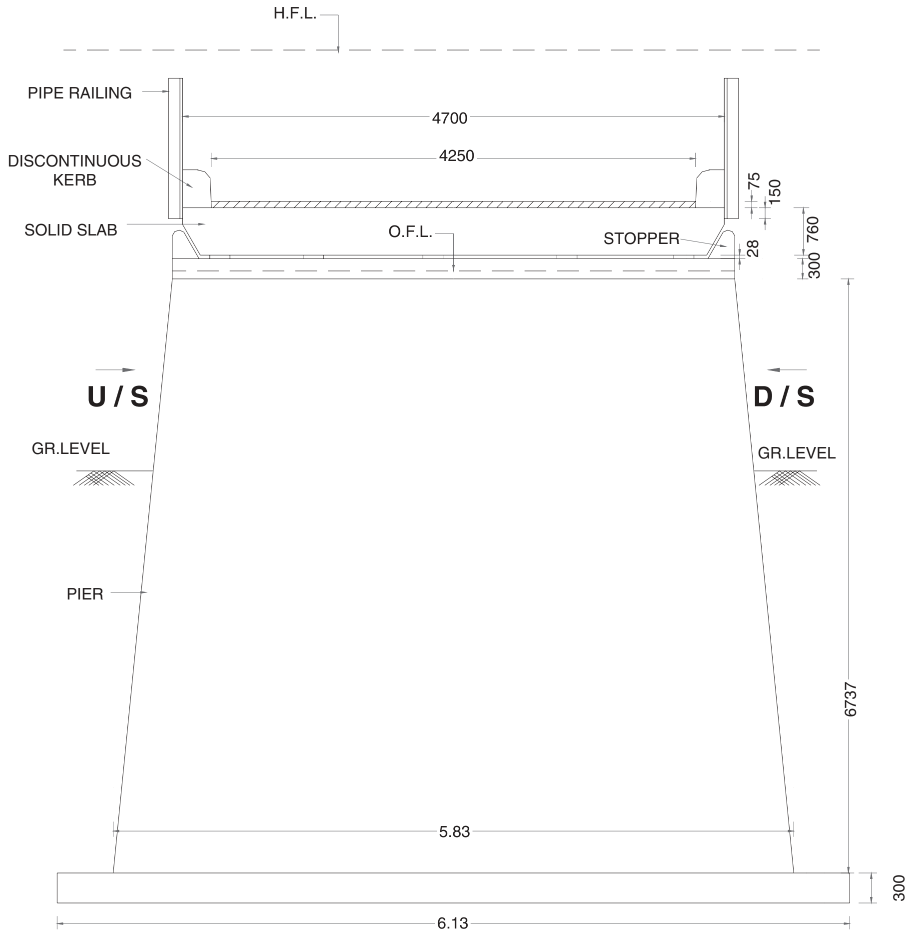


FIG.3.30 SOLID SLAB

J. S. SHAH, TRACER

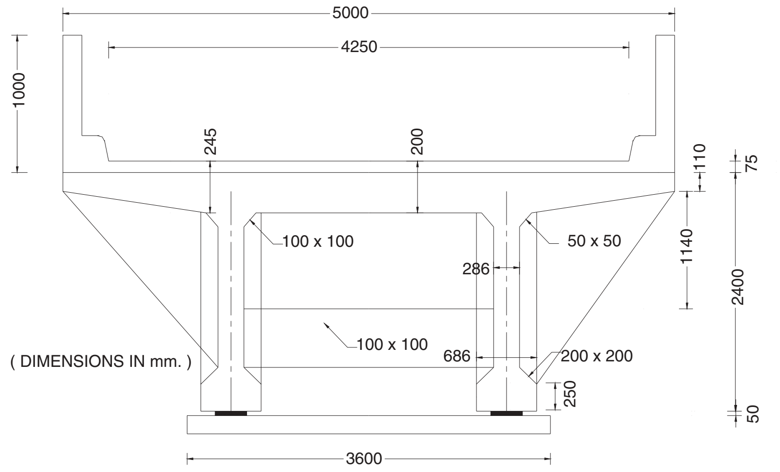


FIG.3.31 TWO - GIRDER SYSTEM (GENERALLY FOR FOOT BRIDGES)

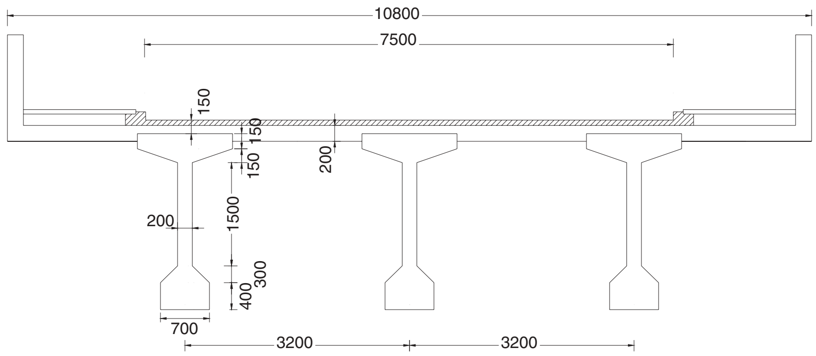
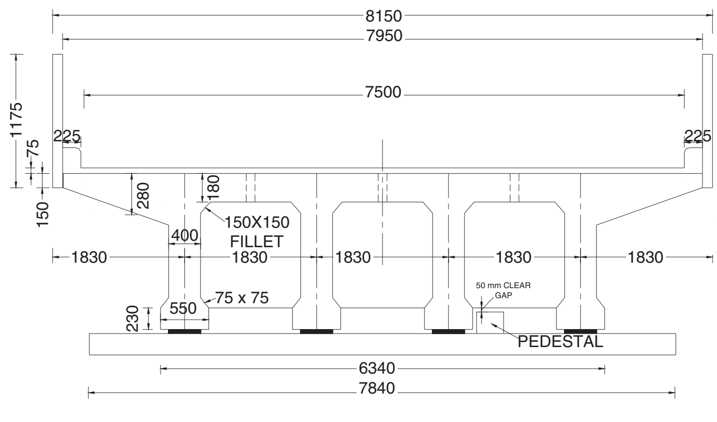


FIG.3.32 THREE - GIRDER SYSTEM



(DIMENSIONS IN mm.)

FIG3.33 FOUR - GIRDER SYSTEM

J. S. SHAH, TRACER

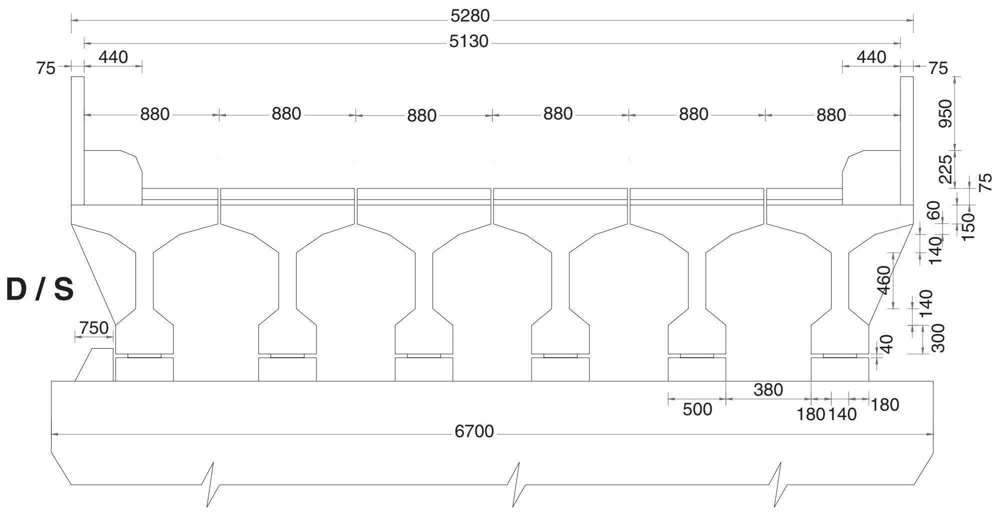


FIG.3.34 SIX - GIRDER SYSTEM

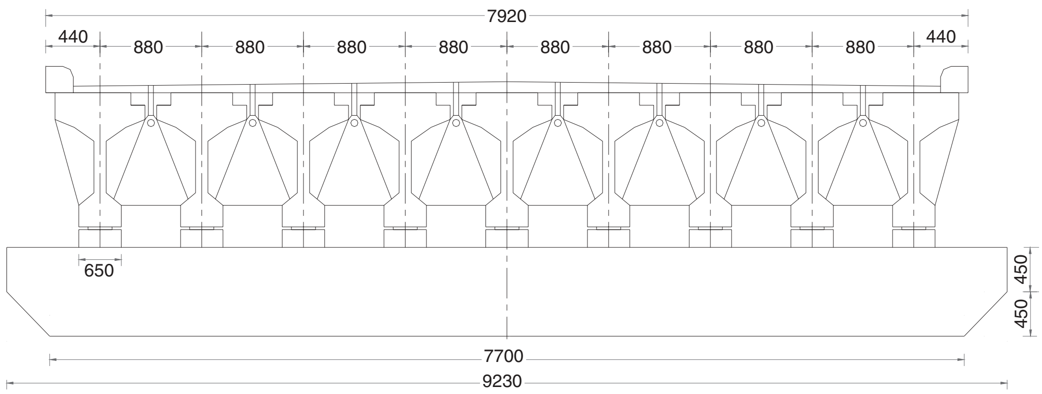


FIG.3.35 NINE - GIRDER SYSTEM

J. S. SHAH, TRACER

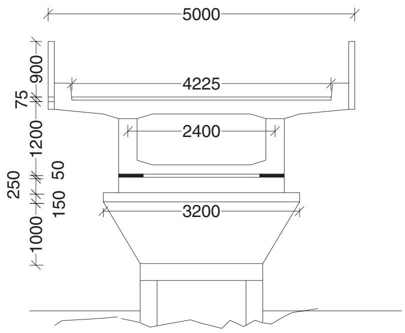


FIG.3.36 SINGLE CELL BOX

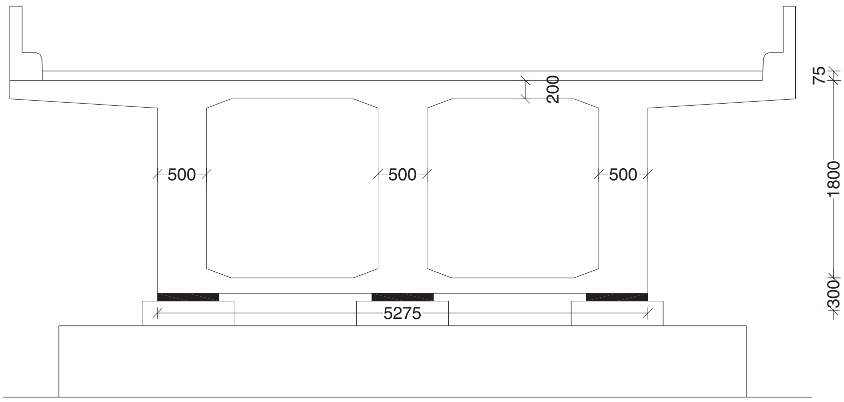


FIG.3.37 TWO CELL BOX

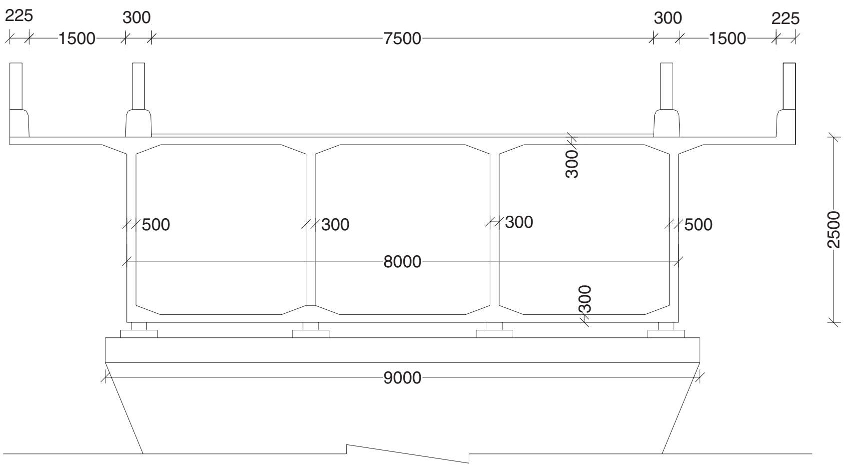


FIG.3.38 THREE CELL BOX

UDAY PATIL, TRACER

3.4.2 TYPE DESIGN

Type designs are available for solid slab and girder type superstructures. The type designs prepared by M.O.S.T. are also available for R.C.C. solid slab up to 10 m, R.C.C. Girder slabs upto 24 m and P.S.C. girder slab bridges upto 40 m spans.

For box superstructure, the type designs are to be done. However, reference could be made to already approved designs of similar nature.

3.4.3 Minimum thickness

Minimum thickness of deck slab shall not be less than 300 mm and 200 mm at tip of cantilever in transverse direction and minimum thickness of soffit slab shakll be 240mm irrespective of provisions elsewhere. In case of voided slab structure minimum thickness of concrete around void for deck shall be 300 mm. Minimum thickness of diaphragm where provided shall be 300 mm and that of end diaphragm is 500 mm. This thickness is essential from practical point of view regarding placement of reinforcement, concrete and its proper compaction.

Minimum web thickness for box girder shall be 300 mm, however this should be increased in case of severe exposure conditions. All the specified minimum thickness are from durability point of view.

3.4.4 Methods of Transverse Analysis

3.4.4.1 T-Girder Slab System

The longitudinal girders are connected by cross-girders at intermediate places and this arrangement supports the deck slab. Most complex problem in this case is determination of distribution of live loads between the longitudinal girders. When there are only two longitudinal girders, the reactions on the longitudinal girders can be found by assuming the supports of the deck slab as unyielding. With 3 or more girders, the load distribution can be estimated using any one of the rational methods discussed as below.

(a) Courbon's method : Main assumption in this method is linear variation of deflection in transverse direction. In view of simplicity this method is popular but it has its own limitation like

   i. Ratio of span to width shall be greater than 2 but less than 4.

   ii. Longitudinal girders are interconnected by symmetrically spaced cross girders of adequate stiffness.

   iii. Cross girders extend to a depth of at least 0.75 of the depth of main girder.

(b) Hendry Jaeger Method : Here it is assumed that cross girders can be replaced in the analysis by a uniform continuous transverse medium of equivalent stiffness.

(c) Morice - Little Method : Orthographic plate theory is applied to concrete bridge system. This approach has the merit that a single set of distribution coefficient for two extreme cases of no torsion grillage and a full torsion slab enable the distribution behaviour of any type of bridge to be found.

Designs Circle is having computer programme for these types of analysis. Refer 'Essentials of Bridge Engineering' by D.Johnson Victor.

3.4.4.2 Box Girder Bridge

Detailed transverse analysis for box girder bridge is difficult to perform. Exact finite element model will have to be generated to see the behaviour. In absence of rigorous analysis for the torsional moments and for forces due to restrictions of warping torsion at ends, design moments and shear in longitudinal direction are increased by 20% and transverse reinforcement steel by 5 % for simplicity and quick results.

Generally following procedure is followed for transverse analysis.

(i) Calculate bending moments in road way slab considering the slab, web and soffit slab as a closed frame.

(ii) Reinforcement in slabs, a web due to transverse moment is provided in addition to steel required for shear or torsion.

(2) Distortion of box girder due to transverse moment is to be considered in the design.

Now superstructure designs can be checked using STAAD-Pro software.

3.5 EXPANSION JOINTS

To cater for the expansion and contraction of superstructure suitable expansion joint is required to be provided. The expansion joint is also supposed to be leak proof so that the superstructure, bearings and piers do not get damaged due to such leakage of rainwater etc.

Designs Circle has issued some type designs for expansion joints, which are being used commonly on the small span bridges.

1. Copper plate expansion joints.
2. Sliding M.S. Plate expansion joints.

The sliding M.S. plate joint have been extensively used in past. The experience of its performance, however, is discouraging. The joint develops cracks in the bituminous wearing coat and during monsoon gets further deteriorated. It also creates lot of noise as the vehicles pass over it.

The copper plate expansion joint has given satisfactory results. (This joint is however susceptible to theft). Up to 25 mm gap, this type can be considered the best.

The few types of expansion joints are indicated in the sketches below :

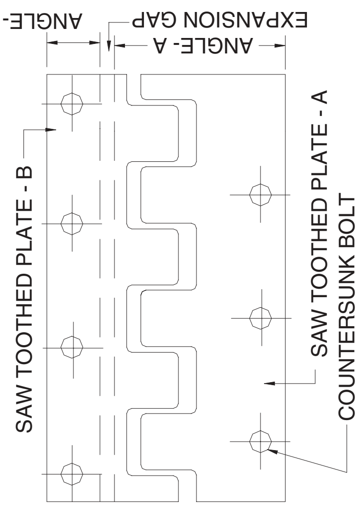


FIG.3.39(A) SAW - TOOTHED EXP.JOINT

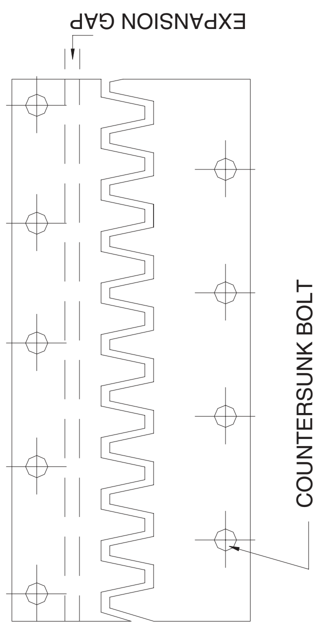
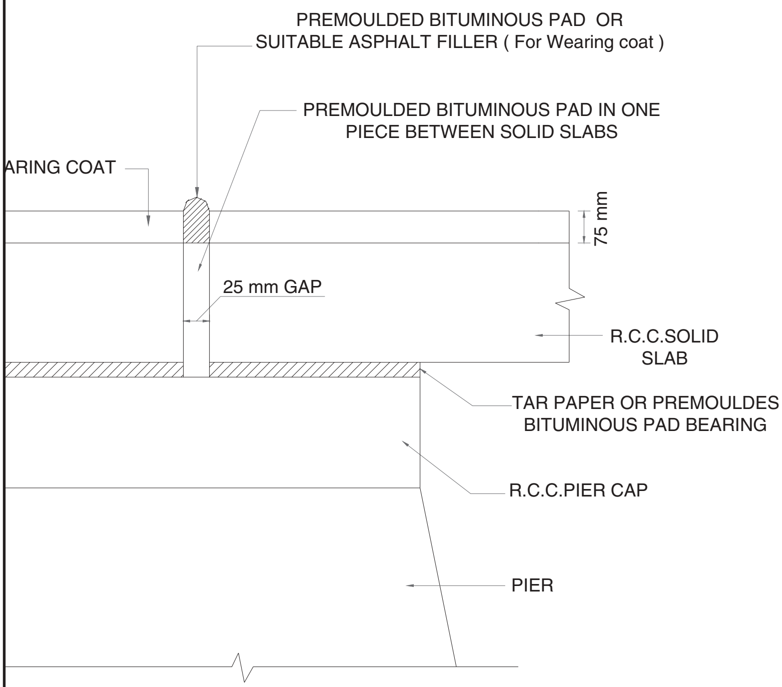


FIG.3.39(B) FINGER PLATE EXP.JOIN



ETAILS OF EXPANSION JOINT BETWEEN

J. S. SHAH, TRACER

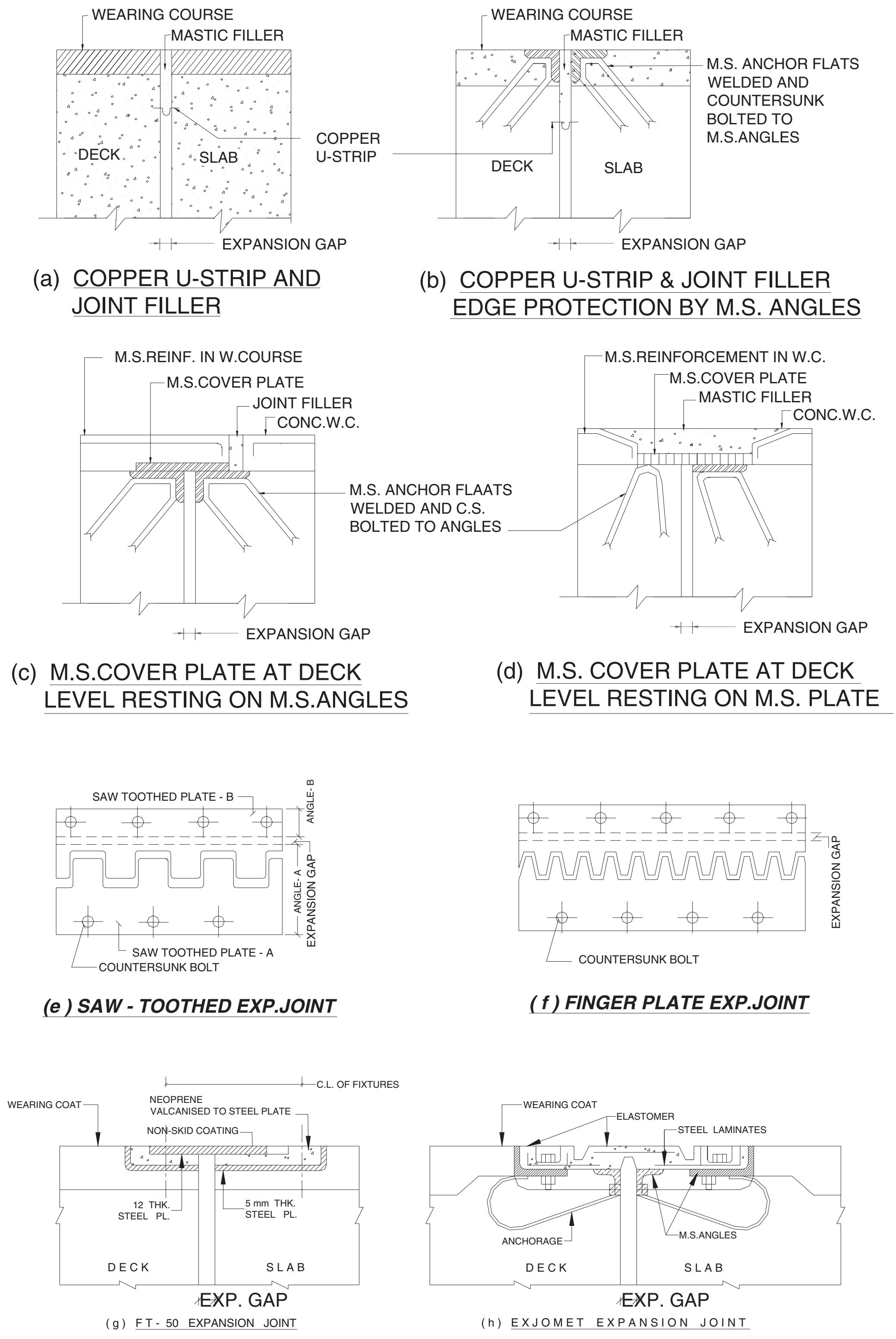


FIG.3.42 VARIOUS TYPES OF EXPANSION JOINTS

B. D. KAMBLE, TRACER

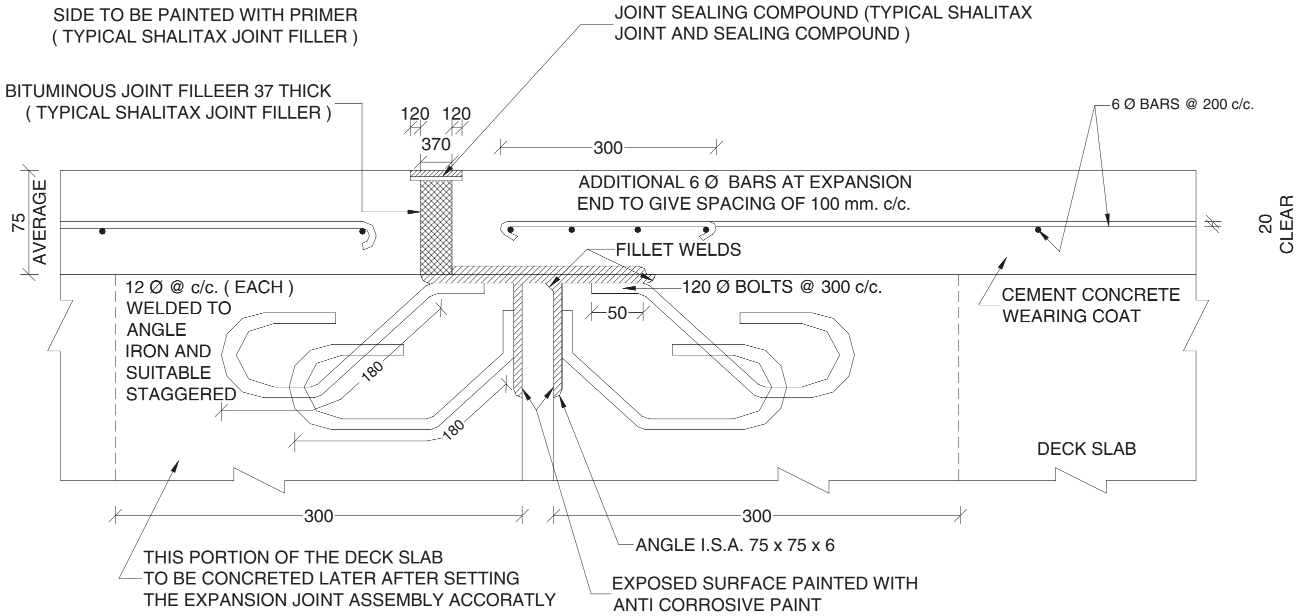


FIG.3.43 DETAILS OF M.S. PLATE EXPANSION JOINT AND CEMENT CONCRETE WEARING COAT

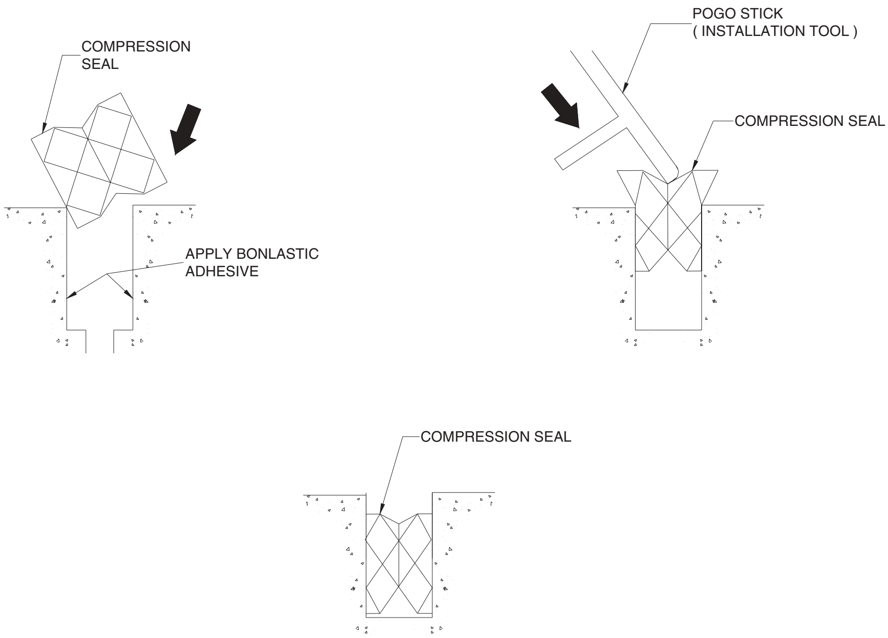


FIG.3.44 FIXING OF COMPRESSION SEAL JOINT

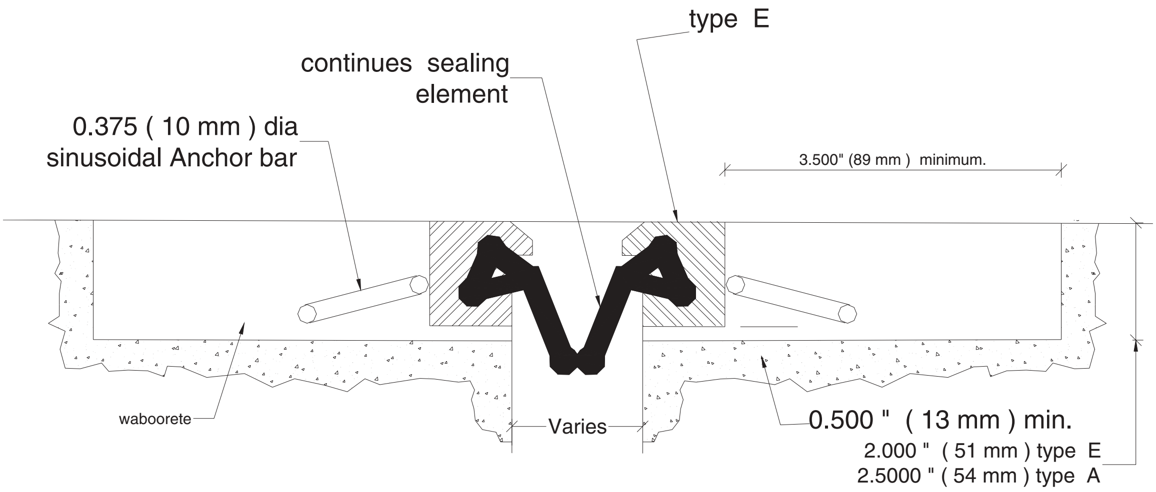
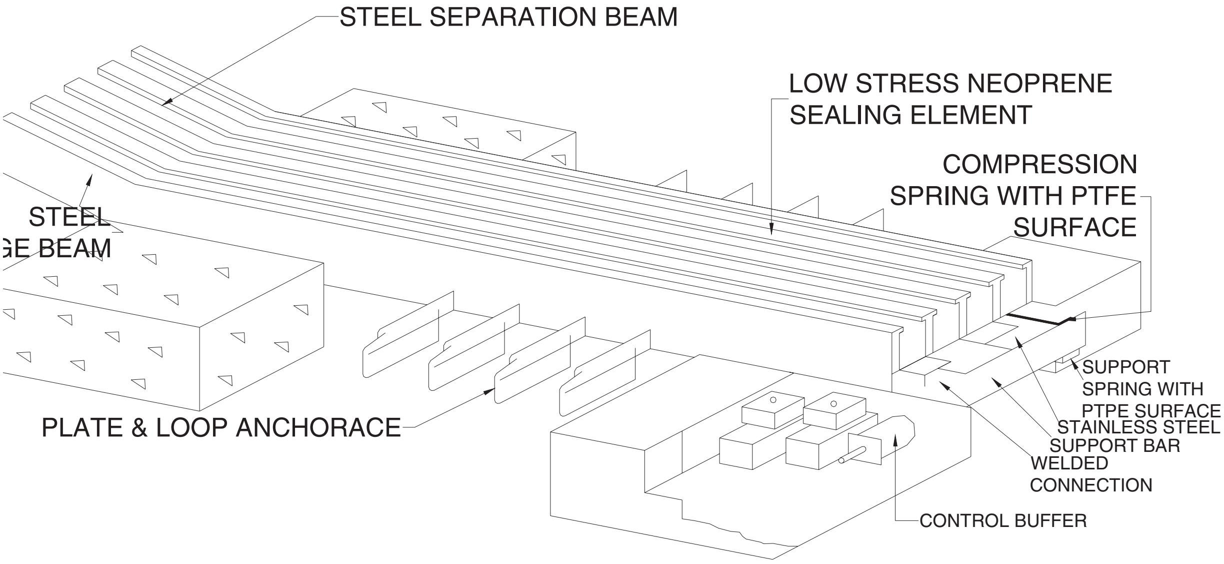


FIG.3.45 STRIP SEAL TYPE JOINT



.3.46 TYPICAL BOX SEAL MODULER EXPANSION JOINT

B. D. KAMBLE, TRACER

MOST under circular dated RW/NH/33059/1/96-S&R dated 13.01.1997 has prescribed different expansions joints suitable for particular expansion. The details are as per table below.

TABLE : 3.7

SUITABILITY CRITERIA FOR ADOPTION OF DIFFERENT TYPES OF EXPANSION JOINTS

Sr. No.	Type of Expansion	Suitable for adoption joint	Service Life	Special Consideration
1.	Buried	Simply supported spans up to 10m	10 years	Only for decks With bituminous asphaltic wearing coat.
2.	Filler Joint	Fixed end of simply supported spans with In-significant movement.	10 years	The sealant and joint filler would need replacement if found damaged.
3.	Asphaltic Plug Joint	Simply supported spans for right or skew upto (20 degree) moderately curved or wide deck with maxi- mum horizontal movement not exceeding 25mm.	10 years	Only for decks with bituminous /asphaltic wearing coat. Not suitable for bridge with longitudinal gradient more than 2% and cross camber/super-elevation exceeding 3%. Not suitable for curved spans and spans resting on yielding supports.
4.	Compression Seal Joint	Simply support of continuous spans right or skew (upto 30°), moderately curved with maximum horizontal movement not exceeding 40 mm.	10 years	Chloroprene/ closed Foam Seal may need replacement during service.
5.	Elastomeric slab seal joint	Simply supported or continuous spans Right or skew (less than 70 degree) moderately curved with maximum horizontal movement up to 50 mm.	10 years	Not suitable for bridges located in heavy rainfall area and spans resting on yielding support.
6.	Simple strip seal joint	Moderate to large simply supported.(cantilever/ continuous construction	25 years	Elastometric seal may need replacement during service.

Sr. No.	Type of Expansion	Suitable for adoption joint	Service Life	Special Consideration
		having right, skew or curved deck with maximum horizontal movement upto 70 mm.		
7.	Modular strip/ Box Seal Joint	Large to very large continuous/cantilever construction with right, skew or curved deck having maximum horizontal movement in excess of 70 mm.	25 years	Elastomeric seal may need replacement during service
8.	Special joints for special condition	For bridge having wide decks/span length of more than 120 m. or/and involving complex movement/rotations in different directions/ plans, provision of special type of modular expansion joints such as swivel joists joints may be made.	25 years	Elastometric seal may need replacement during service. Provision of these joints may be made with prior approval of competent authority.

These are proprietary items for which 10 years warranty shall be insisted upon from the suppliers.

For larger expansion gaps, of about 50mm and more the joint has to be designed suitably. Other types of joints are :

1. Finger type joint (Cast steel).
2. Strip seal joint (Elastomeric)
3. Compression seal joint (Elastomeric)
4. Slab seal joint (Elastomeric)
5. Modular joints. (Modules with Elastomeric)

The above joints are costly as compared to conventional joint described earlier. We are, however, left with no choice for long span bridges but for adopting them. For details of material properties refer latest M.O.S.T. specifications for Roads and Bridges.

The above item are presently patented and hence detailed design calculations are not generally made available. It should be insisted upon.

For details of these joints refer literature given by the manufacturers.

Extra care need be taken for maintaining line and level of the joint to match perfectly with the geometry of the deck surface.Expansion joint is the place wherein lies the comfort of the road users. Improper fixing invites criticism from public.

3.6 PARAPET AND KERB

Deciding the type of railing, kerb etc., as per the type of bridge i.e. high level or submersible.

(i) **For High Level Bridge :** Superintending Engineer Designs Circle's Type drawings or Sanchi Type parapet as mentioned in designs criteria can also be adopted.

(ii) **For Submersible Bridge :** Railing shall be removable type. Either pipe railing or collapsible type as shown in the type drawings.

3.7 WEARING COAT

(1) Earlier upto 1980 R.C.C. wearing coat was generally adopted. Now as per Govt. in P.W.D. Circular No.CEC/1179/50677/CR-225/D-29-A dated 12.08.80, following type of wearing coat are generally provided for bridges.

Conventional Practice

High Level Bridges	:	Bituminous 50 mm DBM + 25 mm AC/SDBC
Submersible Bridges	:	C.C. M-20 with temperature steel.
Long Span Bridges	:	Bituminous.

The performance of C.C. wearing coat on long span bridges (where deflections under live load are considerable) is not found to be satisfactory. It develops cracks and spoils the riding quality. The cracked surface also allows water to seep through and leads to correction in the main deck elements particularly in saline climates.

Bituminous wearing coat with 50 mm DBM + 25 mm. SDBC generally does not perform well during monsoon, particularly in high rain fall area (> 1000 mm per annum).

Better treatment considered today is –

12 mm Mastic Asphalt as leak proof layer.

\+ 50 mm DBM

\+ 25 mm Bituminous concrete / Mastic Asphalt

We may part with the 12 mm. thick Mastic Asphalt layer in areas where climate is not severe and that the rainfall is less than 1000 mm per annum.

3.8 WATER SPOUTS :

Waterspouts are required to drain out the rainwater from the deck surface quickly. The deck has camber or super elevation, which help rainwater get quickly towards kerbs. The waterspouts located near the kerb further disposes the water out.One water spout per 20 sq.m. of the deck area is considered adequate.Typical arrangement of rainwater disposal is shown in following figure

J. S. SHAH, TRACER, BR-III

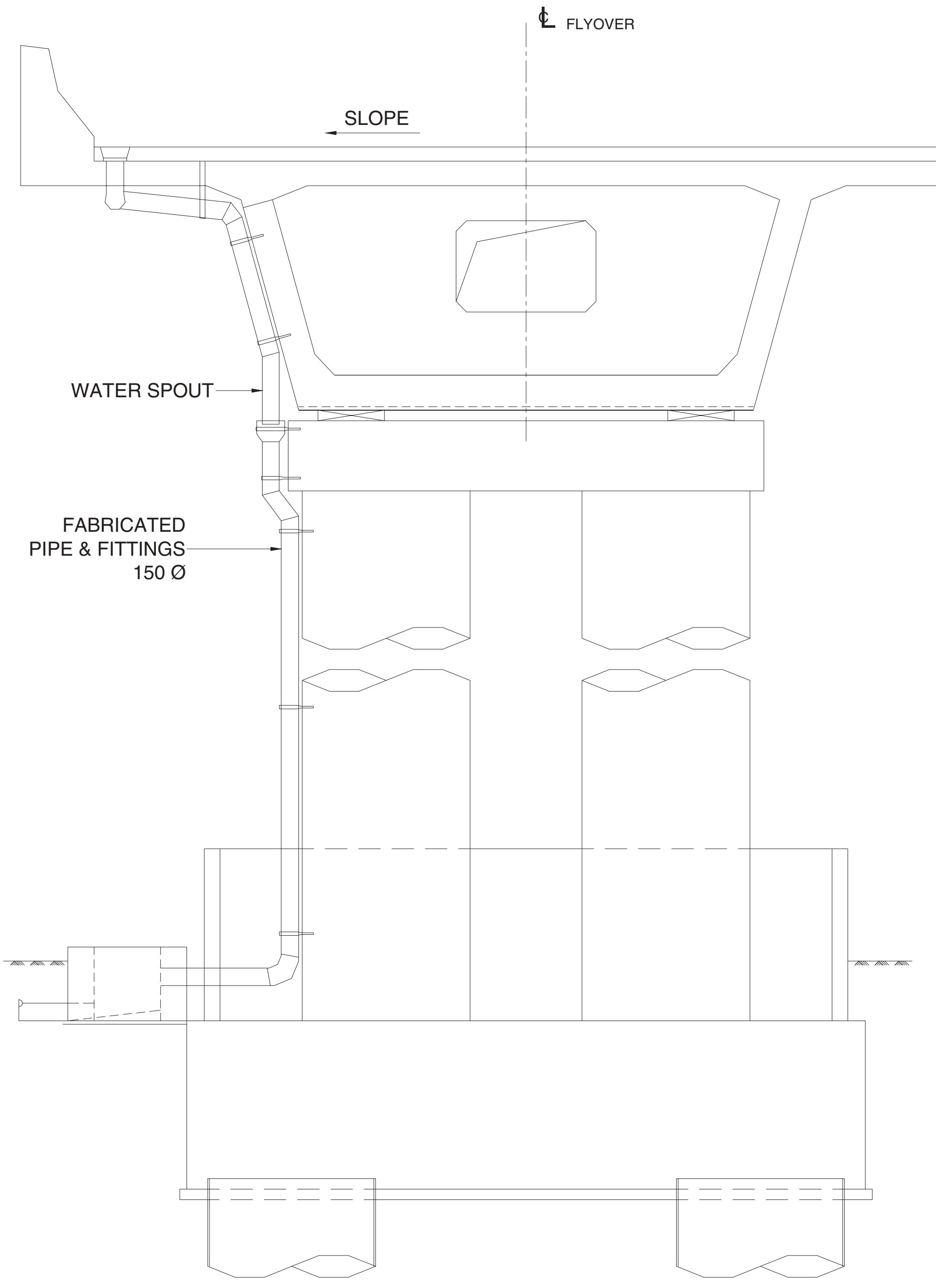


FIG.3.48 FLY OVERS IN URBAN AREA
(ARRANGEMENT OF WATER SPOUT)

B. D. KAMBLE, TRACER

GUIDELINES FOR
BRIDGE DESIGN

CHAPTER - 4

SUBMERSIBLE BRIDGES

4. NEED FOR SUBMERSIBLE BRIDGES

Construction of high level all-weather bridges on roads of lesser importance would cost millions of rupees.It is, therefore, necessary to adopt middle path to remove the deficiency of bridges on the roads to fit into the available budget and resources.

4.1 MECHANICS OF SUBMERSIBLE BRIDGES

The over all length of a submersible bridge and height of its piers is significantly less when compared to a high level bridge. These bridges, therefore , cost considerably less when compared to corresponding high level bridges.Submersible bridges can be accommodated into the natural gorge of the nallah / river.The approaches of the bridge do not need much of filling or cutting.The approaches of the submersible bridge can be kept at natural bank level, which does not disturb the geography of the area since there is no additional banking or cutting.

4.2. DESIGN CONSIDERATIONS

4.2.1 STANDARD OF ROAD

The district level roads MDR, ODR and VR may have submersible bridges though some MDR and ODR, depending on its strategic importance, could be considered fit for high level bridges.

4.2.2 GEOGRAPHY OF THE AREA

If the geography is such that a vast area is affected by the spread of floodwater submersible bridge would be a prudent choice because planning for high level bridge under such circumstances will require very long approaches, which will create obstruction to flow

Heading up of water on upstream of the bridge (afflux) due to embankments and obstruction to flow of water need be considered while planning for this type of bridge since such obstruction is responsible for increased exit velocity and the scour on downstream of the bridge.

4.2.3 VERTICAL GEOMETRY OF THE ROAD

Vertical geometry of the road many times dictate the road top level of the bridge, which results into selection of a type of bridge i.e. high level or submersible e.g. the nallah / river passing through habited area and it is not possible to go for approaches in banking or even to cut. Such situations necessarily warrant selection of submersible bridges.

4.2.4 FIXING BRIDGE TOP WHILE THE NATURAL BANKS ARE AT DIFFERENT LEVELS

If the natural banks are at different levels then it is desirable to fix up the RTL of the bridge matching with the lower bank level .This will help keeping obstruction to flow of water within permissible limits.. However, keeping the RTL at high bank level will necessitate approaches on other side in filling and flow of water will get obstructed which may result in damages to the approaches in bank.

4.2.5 FIXING LENGTH OF THE BRIDGE AND NALLAH TRAINING

Linear waterway requirement in case of high-level bridges is computed using relation W = CvQ given in IRC-5 General features of Design. The same formula can be used for linear waterway of submersible bridge but in this case Q shall be the designed discharge at OFL.

In case of defined channel where the flood is confined within the banks, fixing the length of bridge is easy since it may be almost same as that for High Level Bridge. Balancing of the obstructed area in the cross section of the channel by possible nallah training helps in deciding the length of submersible bridge. The percentage obstruction while flood level at RTL should be kept minimum while deciding the length of the submersible bridge.

4.3 HYDRAULIC DESIGN OF SUBMERSIBLE BRIDGES

4.3.1 DISCHARGE THROUGH SUBMERSIBLE BRIDGES

The bridges designed to pass about 25 percent to 30 percent of Inglis discharge are found to be quite efficient submersible bridges. The flood level at which the discharge is 30 percent of Inglis discharge decides the level of the bridge. It may, however , be noted that this can not be considered as the formula for fixing the bridge height, though it can be considered as governing factor for deciding the height of the bridge. The concept of OFL may be used for deciding the design flood level for submersible bridges. OFL is the flood level that occurs in the stream in normal monsoon. It is interesting to note that OFL generally tallies with 30 percent Inglis discharge in Maharashtra State. Though OFL is considered as design flood level, it is useful only for deciding the road top level and length of the bridge. Design calculations (hydraulic or structural) are, however, based on HFL and all intermediate critical conditions.

4.3.2 SCOUR DEPTH CONSIDERATION

The scour depth should, be worked out based on HFL corresponding to Inglis floods or Modified Inglis floods applicable to the area and also for critical condition like flood at bridge top.

4.3.3 OBSTRUCTION TO FLOW OF WATER

The bridge structure and its approaches obstruct the free flow of water in the stream. It is not practicable to design a bridge to allow 100 percent discharge. Some obstruction is, therefore, required to be allowed in the stream due to the structure as a practical approach to bridge planning.. In case of submersible bridges the obstructions could be limited to 20 percent at designed flood level (with 30 percent Inglis discharge). However, the obstruction at HFL should also be restricted to 20 percent.

The obstruction to flow of water causes afflux on upstream of the bridge site. This increases the area under submergence on up stream. It should be verified that such submergence does not adversely affect the nearby habitats and agricultural land etc.

4.3.4 HYDRAULIC FORCES

Submersible bridges are designed for hydraulic forces depending upon the applicability of Inglis or modified Inglis formula. The stresses in the structure need to be checked for at least 3 flood levels (i) flood at OFL, a condition that will occur frequently, (ii) flood at RTL, this condition, will give maximum obstruction to flood water, (iii) flood at HFL.

In case of bridges situated on immediate downstream of a dam the possibility of sudden opening of the floodgates shall also be considered in design. In such a situation stream carries extra discharge through gates in addition to the overflow through weir/spillway. This condition warrants the bridge to be checked for higher flood levels / discharge.

4.4 SPAN ARRANGEMENT

Height of submersible bridge from the bed level, in general, is about 5 m to 8 m. It is, therefore, desirable to have spans up to 10 m. Such span arrangement generally calls for solid slab superstructures, which impart stability to the bridge during floods. Longer spans call for girder and slab type arrangements, which are not desirable for submersible bridges, since they offer more obstruction to flow.

4.5 FOUNDATION FOR SUBMERSIBLE BRIDGES

An ideal situation would be to rest foundations on rock. The founding stratum being non-scourable poses no problem of stability, durability and maintenance.. Raft foundation may be a solution to the situation with weak soil and less scour depth. Furthermore, raft foundation provides more stability to the structure as it tries to bridge over the unevenness of the foundation.

4.6 STABILITY AGAINST OVERTURNING

It is necessary to check the superstructure against over-turning. Girder type bridges and box-girder types are susceptible to such forces since they offer more obstruction to flow of water, as they are lighter as compared to solid slab type superstructure. It is desirable to check all the types for stability against overturning. It should be remembered that submerged weight of superstructure is almost 60 percent of its original weight, thus reducing drastically the stabilizing forces. Girder and slab bridges should be considered with entrapped air between the girders, which might exert upward pressure on the superstructure reducing the stabilizing forces. The box type superstructure should be checked for stability with the condition that the box is not filled with water . This situation may occur when the rise in water level is sudden due to flash floods and also when the vents are choked and do not function efficiently. Single lane submersible bridge with slab and girder system or box superstructure shall be avoided.

4.7 STOPPERS ON DOWN STREAM SIDE

During floods there is a possibility that the superstructure may slide due to its buoyant weight and the water current forces. It is, therefore, necessary to provide downstream stoppers that will keep superstructure in its position. Downstream stoppers are provided on pier cap.

4.8 KERBS AND RAILINGS

Kerbs should be such that it offers less resistance to flow of water. The height of kerb should be limited to minimum required say 250 mm above slab. Discontinuous kerbs are desirable and railing should be collapsible or removable type otherwise it will obstruct the flow of water and debris generating forces in the bridge for which it is not designed.

4.9 WEARING COAT

For submersible bridges concrete wearing coat is preferred to bituminous wearing coat because under long submerged condition more damages are expected in case of bituminous wearing coat. Concrete wearing coat is, however, not desirable for longer span as it develops cracks due to deflection in superstructure. In such cases bituminous wearing coat is desirable though it needs continuous maintenance.

4.10 OUTFLANKING OF APPROACHES:

As the bridge along with approaches gets submerged the material / mass is subject to erosion. The junctions of bridge and approaches are vulnerable to erosion due to sudden changes in the characteristic of material. Such erosion cuts the approaches, particularly near the bridge and disrupts the traffic. Moreover, the returns gets damaged or dislodged .

In order to minimize this phenomenon, it is desirable to provide full width bituminous treatment to approaches. The side slopes of approaches in banking shall be stone-pitched with 40 to 60 kg stones. Pitching stones shall be adequately secured at the toe.

4.11 BETTER PRACTICES

An ideal submersible bridge should necessarily have following characteristics:

i. Open foundations keyed into rock.

ii. Firm and defined banks.

iii. Both banks at almost same level.

iv. Straight nallah / river.

v. O.F.L. 1.0 m below bank level.

vi. Height of bridge above bed level up to 6m.

vii. Spans up to 10m.

viii. Solid slab superstructure.

Note For more details on Submersible Bridges refer paper written by Shri.K.S.Jangde and Dr.N.P.Tongaonkar titled “Some Aspects of Submersible Bridges”

■

GUIDELINES FOR
BRIDGE DESIGN

CHAPTER - 5

INNOVATIVE STRUCTURES AND BRIDGE ASTHETICS

5.1 INNOVATIVE STRUCTURES

Large number of today's existing bridges have been built only during past sixty years or so. Rapid rate of growth in the science of analysis and design and the art of building bridges has led to numerous developmental experiences world over. Other existing activities (like in electronics, space technology, weaponry) had only short life span before it went obsolete. The poor bridge engineer's bridges must last up to half a century at least. This man who create technology- the engineer, with the aid of scientist, is the society's most radical revolutionary. He is the fundamental agent of all social changes, hence needs to make innovative ideas in bridge design and construction. Some forms of the modern day bridges are discussed now.

5.1.1 ARCH BRIDGE

The most beautiful bridge form is an arch as it expresses strength through shape. It is also most primitive form. One of the longest concrete arch is the bridge in Sweden with a remarkable span of 264 m. Even in India bridges having span greater than 100m have been constructed with arch form in Northern parts of India. Some of the arch shapes are shown in fig. 5.1 to 5.5

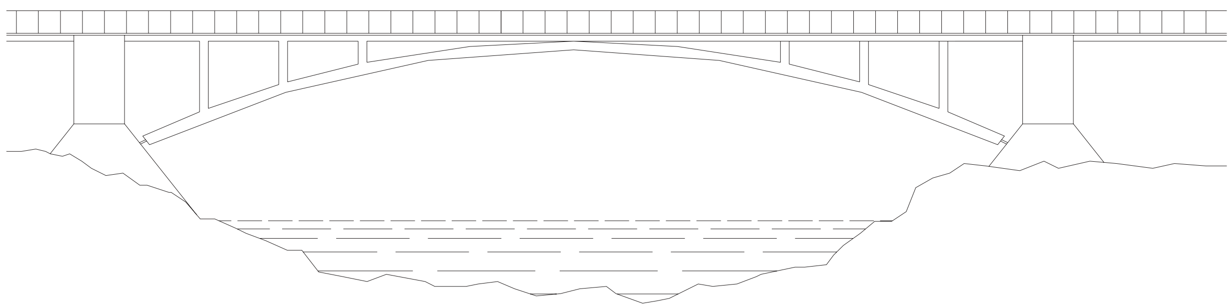


FIG.5.1 THE ELEGANT TWO-HINGED ARCH

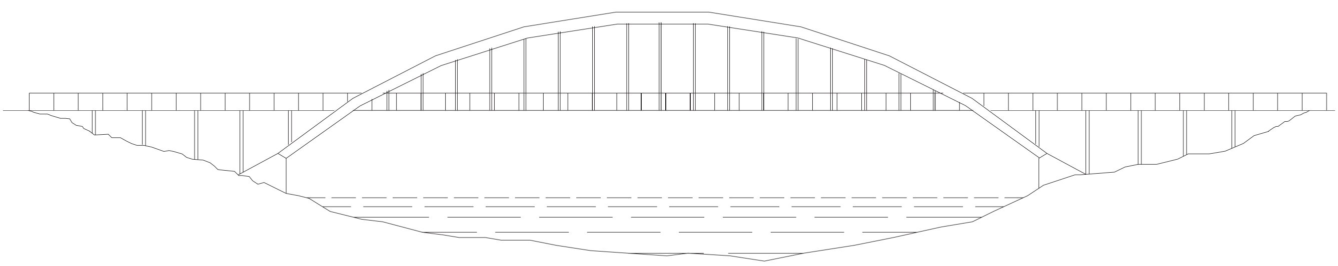


FIG.5.2 SICKLE-SHAPED ARCH WITH SUSPENDED DECK

UDAY PATIL, TRACER

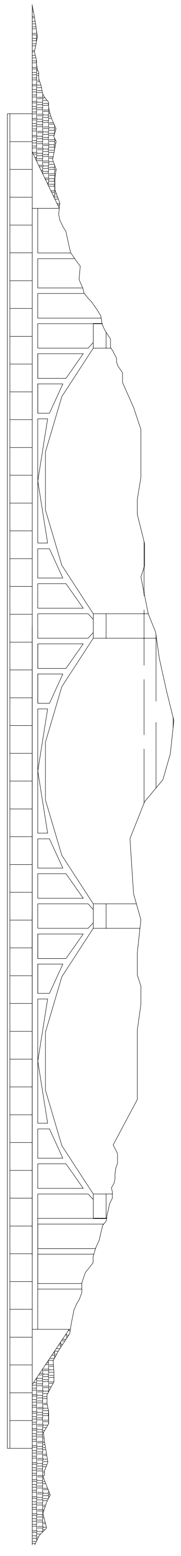


FIG.5.1 SEQUENCE OF FLAT TWO-HINGED ARCHES

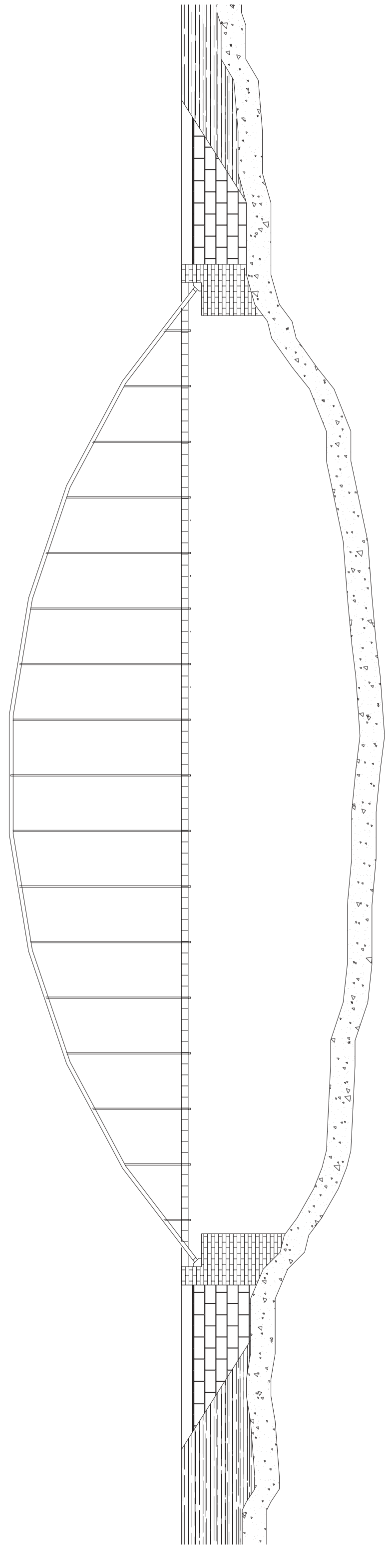


FIG.5.2 TIED ARCH, AND THIN SUSPENDED DECK

UDAY PATIL, TRACER

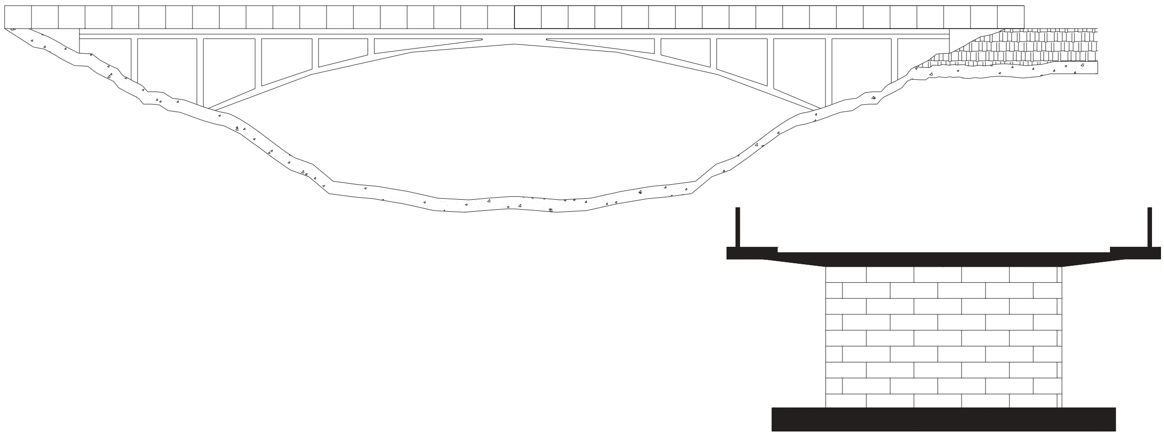


FIG.5.5 ARCH OVERPASS IN A CUT, BARREL WALLS AT ARCH SPRINGINGS.

UDAY PATIL, TRACER

5.1.2 SUSPENSION BRIDGE

Suspension bridge is somewhat like an arch form turned upside down. This form is much lighter than any other bridge form to carry the same loads over the same span. Uniformly distributed load of the deck in a suspension bridge gives a good looking parabolic shape to the suspension cables. Generally the side spans are restricted to about a third of the central span length. The suspended deck must look lighter and slender. A classical shape of suspension bridge along with a pylon is indicated in fig. 5.6

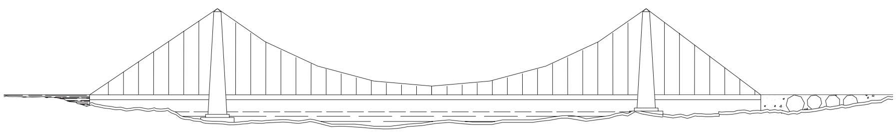


FIG.5.6 THE CLASSICAL SHAPE OF SUSPENSION BRIDGE

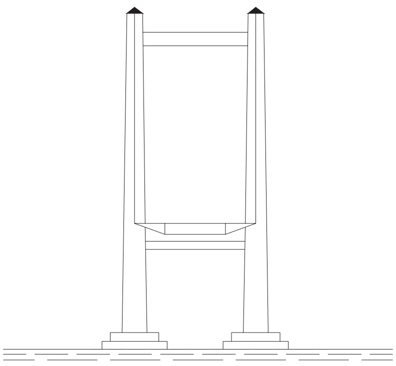


FIG.5.7 SHAPES OF PYLON FOR SUSPENSION BRIDGES

UDAY PATIL, TRACER

5.1.3 CANTILEVER TYPE

With the development of free cantilevering technology using prestressed concrete (segment by segment) more beautiful bridges are built at lesser cost. The free cantilevering technique, in which span is built by adding one segment at a time on either side of pier and stitching it back to developing cantilever by prestressing cable is relatively recent development. Classic example of these type of bridges are Thane creek bridge (new) at Navi Mumbai and Mohammad Ali flyover at Mumbai. Typical sketch is shown in fig.5.8

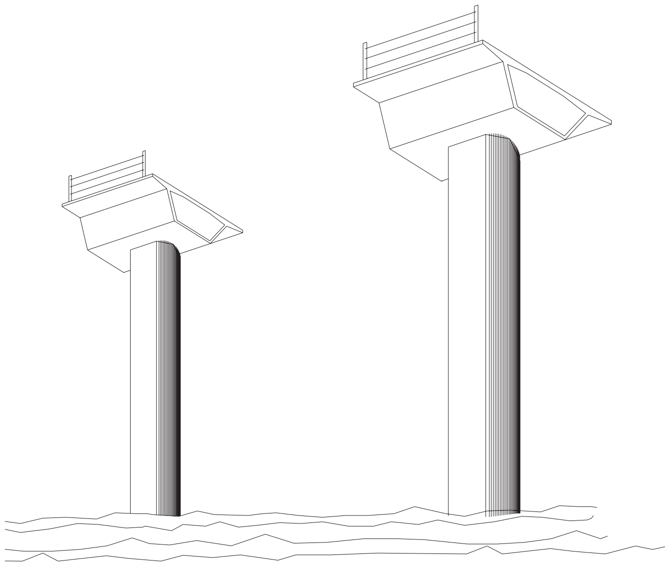


FIG.5.8 CANTILEVER TYPE BRIDGE CONSTRUCTION

5.1.4 MOVABLE BRIDGE

Movable bridge are those which can be some how change position or moved so as to open a clear passage for ships or boats. There are many different kind of movable bridges- grouped according to the manner in which they open. It may be a swing bridge, double swing span bridge or others are bascule and vertical lift type. Another useful movable bridge is Pontoon, a floating bridge form. These are generally in military use and an essential part of army equipment. Movable bridges are operated by electrical and mechanical machinery, so its responsibility of bridge engineer to oversee the design of mechanical equipment along with bridge design.

5.1.5 CABLE STAYED BRIDGE

A very recent bridge form is a cable stayed bridge wherein a very long beam is literally suspended from a tower (a pylon) by means of inclined stays which are essentially tension members. This type of bridge is in between cantilever and suspension type. Naturally its built like a modified cantilever construction and the ‘stays’ are wire cables. Arrangement of stays decide whether it is fan type, harp type or hybrid type i.e. combination of both.Typical arrangements are shown in fig .5.9 to 5.13.Various shapes of pylons are indicated in fis.5.14 and 5.15.

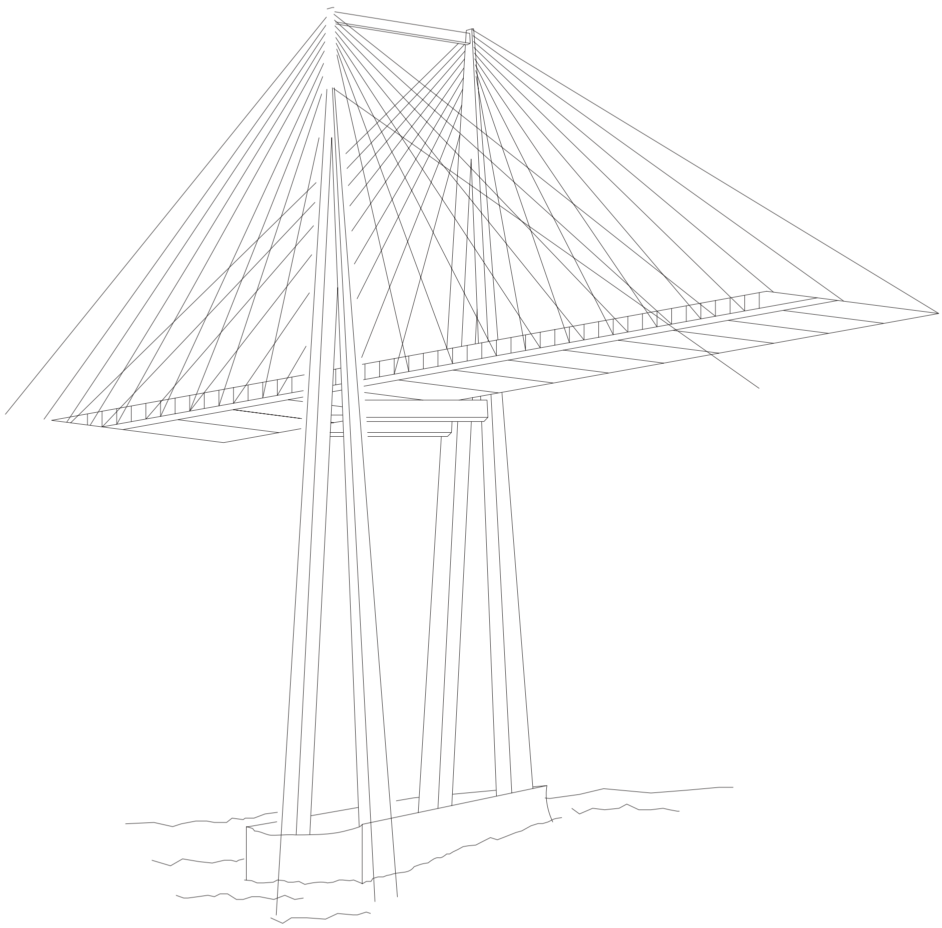


FIG.5.9 SIMPLE PYLON

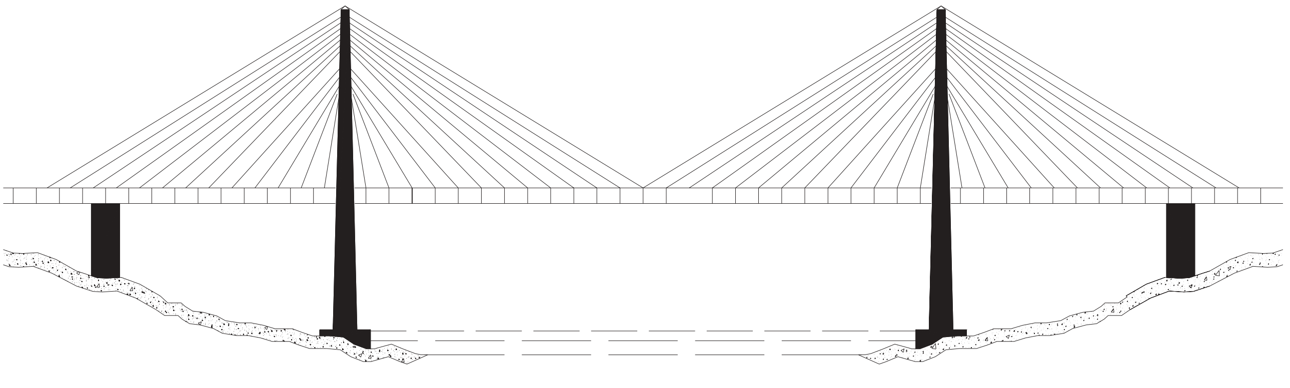


FIG 5.10 HYBRID ARRANGEMENT OF CABLES BETWEEN FAN AND HARP SHAPES

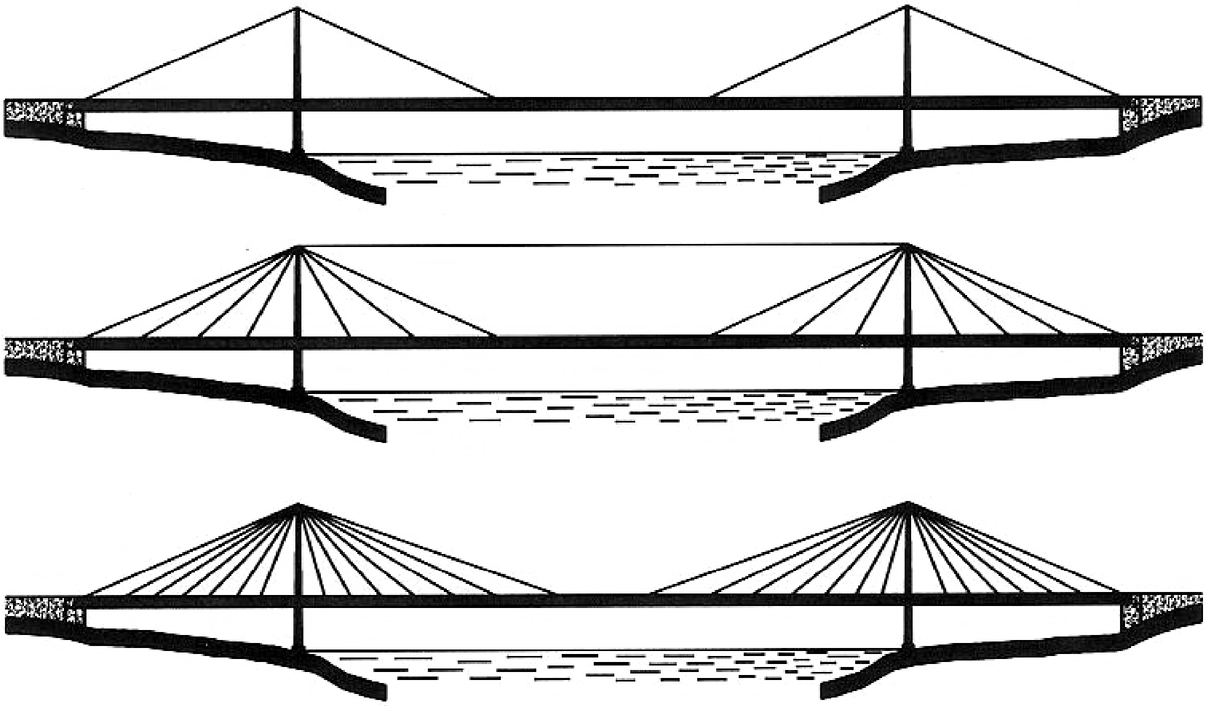


Fig.5.11 The more the cables, the thinner the beam, cables in fan shape.

Fig. 5.12 cables in harp shape.

B. D. KAMBLE, TRACER

B. D. KAMBLE, TRACER

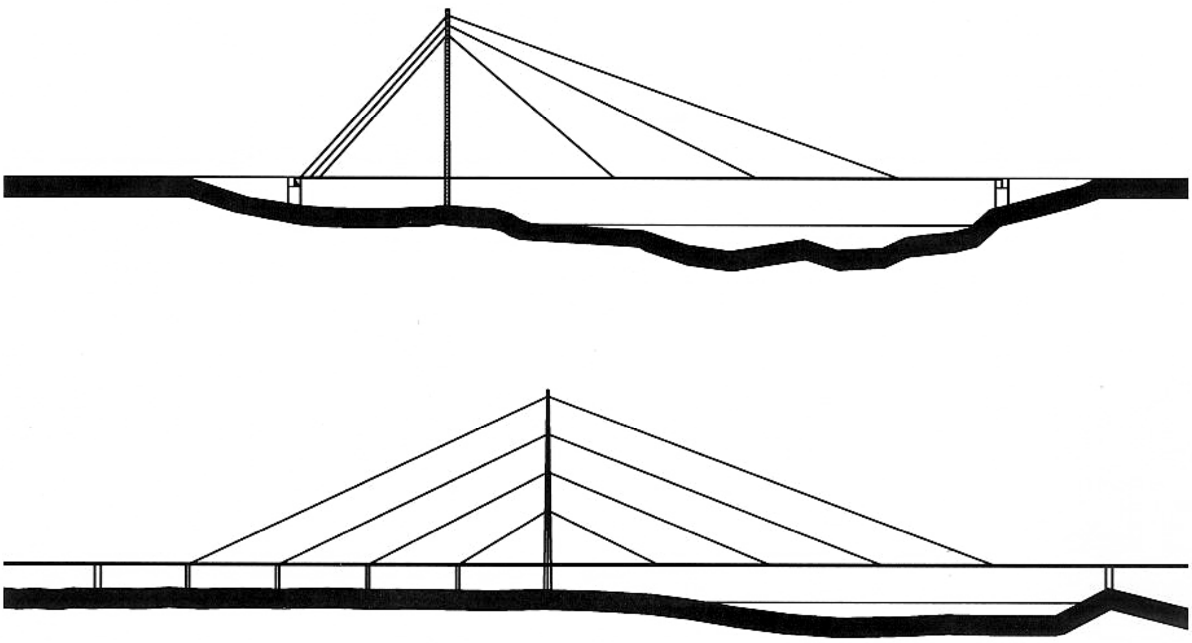


Fig.5.13 One side (one pylon) cable stayed bridges.

B. D. KAMBLE, TRACER

5.2 BRIDGE ASTHETICS

Aesthetics is essentially the quality of beauty and appeal to the senses. Some feel that in today's machine age bridge need only be functional one, on similar lines then house may be defined as 'Machine made for living in' Wherever possible at least some margin shall be kept for enhancing the aesthetic quality of bridge. Attempt should be made to integrate its form with its landscape.

The bridge form should represent a fusion of art and technology. In the innovative structure design by great engineer-architects,the structural form and dimension of each component portrays musical harmony with mathematical exaction. Ruskin said that all forms of beauty are composed exclusively of curves and this is equally applicable to most bridges. Light and shade determine the depth of object, hence surface treatment can enhance the expression of bridge.

Few characteristics / concepts discussed below comprise the principles of good aesthetic design.

5.2.1 PROPORTION

It is primary aesthetic objective. In relation to bridges, proportions may pertain to structure total, environment, elements of structure. Proportion between linear dimension like length, width, height, between masses / voids, areas in light / shadows are considered important. Choose optimal span / depth (L/D) ratio, choice is 5 to 20 or even 45 is feasible. In case of very flat, large, rectangular openings L/D > 20 may be opted. Preferably select odd spans with span length decreasing towards ends to give rhythm. Adopt wide cantilever width of deck slab for optimal ratio of areas lightened and in shadow.

5.2.2 CONTRAST

As opposed to harmony in proportions, it can lighten values of some elements in comparison with others. Contrast may be in volumes, material, colours, light, linear dimension etc.

5.2.3 SCALE

The absolute real dimension of structure defining its scale plays a dominant role in aesthetics. Scale of bridge is judged from different points of view.

5.2.4 ORDER

Order is key aesthetic quality in bridge. Order in lines is achieved by limiting their directions in space to the minimum practicable. Repetition of shapes leads an order which provides rhythm, however overdone repitions is to be avoided. Simplicity and cutting down unnecessary accessories leads to a good order. An uninterrupted line of fascia beam can emphasize the continuity of roadway flowing from one abutment to another. As far as possible, avoid intersecting lines.Multiplicity of colours for a pier and / or large number of piers for long bridge with small spans leads to disorder. Avoid large number of equal spans for long bridge as it leads to monotony and uneasiness. Avoid sudden increase in support section like large well showing out of water.

5.2.5 CHARACTER

Character is an element of man made environment and expressed by its effect on the human using it. The structures today need to reflect technological excellence and look modern. Use of uniform depth beam for long river bridge with low clearance above water level produces stiffness. This can be broken by curved soffit. However, highly curved soffit with depth at centre disproportionately reduced, is unpleasant.

5.2.6 COLOURS

Colours have a significant effect and can attribute to balance and tension. However in bridges concrete being the material, choice is limited.

5.2.7 FUNCTIONALISM

In bridges form follows function. Functional efficiency never conflicts with form. It generates simplicity in form and aesthetic quality. Ornamentation of larger surface of piers, abutments, retaining walls by suitable surface treatment for texturing can give heightened aesthetic quality and character to a bridge especially in an urban environment.

5.2.8 ENVIRONMENTAL INTEGRATION

Integration of bridge structure with environment is most important need of modern bridges. Simplicity in form may suit open rural lands. Wider river crossing may demand bridges compatible with majesty of river. Structures built in urban environment should have special quality because it has large impact on people and their habitat. Very slender beams with stiff parallel faces on tall thick piers are incompatible with high mountain backdrop. A long bridge in hilly terrain should never be in straight alignment. It has to pickup movement of terrain.

5.2.9 COMPLEXITY

It is part of second order aesthetics. Complexity results from a deliberate disregard for order, harmony and symmetry. In short the simplicity of form and proportion with load masses in locations where most effective , makes pleasing appearance of bridge structure.

5.2.10 HORIZONTAL AND VERTICAL GEOMETRY

Aesthetics is a matter of taste and therefore it is not possible to codify the rules, which are to be followed in the Designs of bridges. However, few criteria like alignment (horizontal and vertical) with proper geometrics can add to the architecture of bridge. The approach gradients either for a valley curve or a summit curve shall have a continuity without break. The change of slope should be gradual without any abrupt or sudden change. The approach to a bridge with a kink as shown below in fig 5.16 shall be avoided.

The approach gradients with two vertical curves at two ends with the bridge deck straight is preferable to the kink. But a convex curved bridge deck in the vertical plane having a single curvature will be most preferable.

a) SUMMIT CURVES

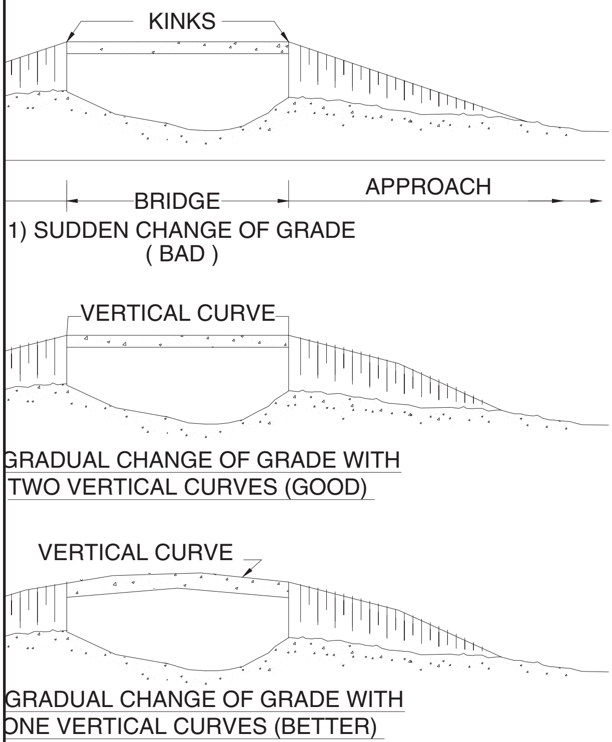


FIG. 5.15 b) VALLEY CURVES

SUMMIT CURVES

UDAY PATIL, TRACER

GUIDELINES FOR BRIDGE DESIGN

CHAPTER - 6

PREPARATION OF BRIDGE PROJECT

6.1. PREPARATION OF FIRST STAGE PROPOSAL FOR THE BRIDGE

The technical note of the proposal should cover following paragraphs.

(i)	Introduction	:	General site, area location and background should be mentioned here.
(ii)	Necessity	:	This should explain the necessity of bridge. How it will facilitate the communication between nearby villages and improve the road network. This also must state the requirement of high level or submersible bridge etc.
(iii)	Authority	:	If the work is approved administratively and if appearing in budget then its reference with amount should be stated. Or else priority given by the Chief Engineer should be mentioned.
(iv)	Site selection	:	Site selection is a very important aspect. As per G.R.BDG-1080/80838(394) Desk-2 dated 03.11.80 Designs Circle is supposed to prepare bridge proposals for length more than 30 m. For the length of bridge between 30m to 60m, territorial S.E. is to finalise the site. However, S.E. (Designs) has to finalise the site for bridge length more than 60m. Details of site inspection, alternatives studied and justification for the proposed site should be narrated in this Paragraph.
(v)	Hydraulics	:	This chapter should depict all the hydraulic characteristics of bridge site like catchment, discharge, surface characteristics, various water levels. The level to be cleared by the bridge with justification should be explained
(vi)	Foundations	:	This should explain the type of foundations adopted depending on trial pit or trial bore results with justification. The choice of type of foundations is also indicated.
(vii)	Proposal	:	This para should detail the proposed bridge whether submersible or high level. In some cases high-level submersible bridge is also proposed wherein the clearance over H.F.L. is nominal and not standard as per I.R.C. The exact chainages of abutments with length of bridge proposed is to be mentioned. How RTL/Soffit levels are worked out has to be mentioned as explained below :

H.F.L./O.F.L. (whichever is proposed to be cleared)	:	.... m.
+ Afflux (Assumed/actual)	:	.... m.
+ Vertical clearance	:	.... m.
Soffit of slab/girder of superstructure	:	.... m.
+ Girder height/Slab thickness/ superstructure depth	:	.... m.
+ Wearing coat thickness	:	.... m.
Road Top Level	:	.... m.

(viii) Standards : The Para should state the type of loading for which the bridge is proposed to be designed. In case of bridge with footpath, the loading should be mentioned. Generally two-lane bridge is designed for single lane of 70 R wheeled/tracked or 2 lanes of Class-A whichever produces worst effects. The single lane bridge is designed for one lane of class A only. Further the seismic zone of the bridge site with seismic coefficient, soil structure interaction factor and importance factor has to be clearly written.

(ix) Substructure : This chapter should indicate the dimensions of substructures like abutments and piers along with grades of concrete proposed. If the sections can be taken directly from type plans well and good or else the stability calculations for piers/abutments is required to be done with the aid of computer programmes .

(x) Superstructure : This para should inform about the type of superstructure adopted. Reference of type plan if adopted with grades of concrete and type of structure must be clearly given.

(xi) Miscellaneous : The miscellaneous item must spell out the provisions and details of wing walls/returns, bearings, expansion joints, parapets, wearing coat, filling behind abutment anti-corrosive treatment, special provisions with respect to inspection of bridges etc. The sites that are likely to be affected by the dewatering problem shall have specific mention so that proper provision can be made in the estimate.

(xii) Approaches : The approaches may need some specific treatment . In case of blocking of discharge in approach area, provision of vents or otherwise and its details are to be given. In case of submersible approaches the type plans shall be used. For the approaches exposed to wave action, proper design has to be obtained preferably from MERI/CWPRS.

(xiii) Special Points : The special points feature should include any points, which need special attention. If any data is to be re-verified or some approvals are to be obtained from competent authorities then it should appear here. Application of severe exposure, which has bearing on cost, must have special mention.Special provisions for formwork, centering, dewatering, slope protection etc. should be stated so that the same can be adequately incorporated in the estimate.

6.2 GENERAL ARRANGEMENT DRAWING (G.A.D.)

Apart from above description, the proposal should contain a general arrangement drawing. A drawing should necessarily contain L-section showing pier and abutment location, various levels, dimensions of pier/abutment, plan and a typical cross section. Further the notes about various assumptions of design should be written on the drawing. Typical Proforma of notes is attached as Annexure-2. Only applicable part of note has to be kept on drawing. Apart from this material table should appear on drawing. Thus drawing should be self-explanatory and to be easy for preparation of estimate at field level. General guidelines to be followed for preparation of material table are given in Annexure-5.

The G.A.D. so prepared should show sufficient details to enable preparation of detailed estimate. All dimensions and provisions should be clearly shown on the drawing.

Consider the whole proposal whether generally acceptable, workable, economical. A question should be asked at this stage whether there could be any better alternative. For reference of the new comers a sample technical note and general arrangement drawing is attached as annexure 7.

6.3. DETAILED ESTIMATE

After preparation of the proposal, estimate will be prepared by the field officers on the basis of this technical note and drawing. For the bridge length more than 60m, as per G.R.No.(Marathi)CEC-1083/(2008)/D-33 dated 5.4.83, the estimates are to be countersigned by the Designs Circle. Generally the measurements/ provisions are to be critically verified.

6.4 DESIGNS CRITERIA

Design Criteria is a guideline for contractor's designer to design the structure with good engineering practice and in conformity with codal and departmental specifications.

Separate criteria are devised for flyover and river/creek bridges. The department has restricted use of certain type of structures as mentioned below :

(1) Structures sensitive to unequal settlement of foundations indeterminate structures like continuous beams, partial beams etc. resting on yielding type of foundations.

(2) Abutments resting on approach embankments.

(3) Stability of overall structure endangered due to failure of one or more span/spans.

(4) Superstructure with joints at the tip of long cantilevers with hinges or gap slabs.

(5) Structures with continuity only in deck slab, in transverse direction.

(6) Piers in the form of multiple columns with isolated/separate footings resting on yielding type strata.

(7) Spill through type of abutments for river bridges where spilled earth is subjected to stream velocity is more than 2 m/s and tied back returns exceeding 3m in length.

(8) Square ended piers for river bridges.

(9) 2-girder slab system for superstructure in severe exposure.

(10) Piles in deep scour and navigational zone.

Apart from this various limitations are given in the Designs Criteria in view of practices followed in the state.

6.5. TRENDS AND PRACTISES FOLLOWED IN THE STATE

There are no hard and fast rules for good engineering practices. However, from the experience of the department in the State, these practices are listed in the designs criteria. The prominent ones are as below.

(1) There shall be minimum number of expansion joints for better riding surface.

(2) Reduced area of contact is allowed upto 75 % for load combinations II and III of I.R.C.:78.

(3) P.C.C. footings supporting R.C.C. columns are not permitted.

(4) The provision of sump for well foundations is made obligatory. Anchors bars 8 Nos., 32 diameter. are also made compulsory.

(5) Minimum diameter. for bored / driven cast-in-situ piles for river bridges is 1.2 m.

(6) Design with single row of piles is not accepted.

(7) Pile foundations are not provided in flood zones or areas with deep scour or at locations where navigation is allowed.

(8) Any dimension of any element of counter-fort type abutment is not to be less than 300mm.

(9) Hollow R.C.C. Piers shall have minimum thickness of wall as 300 mm in moderate exposure and 400 mm in severe exposure condition.

(10) The height of pedestal is limited to 500 mm.

(11) Minimum deck slab thickness shall be 300 mm and not less than 200 mm at the tip of cantilever.

(12) Minimum thickness of intermediate diaphragm wherever provided has to be 300 mm and that of end diaphragm 500mm.

(13) In the absence of rigorous transverse analysis for box, design live load moments and shear forces in longitudinal direction are increased by 20% and transverse reinforcement steel be increased by 5%.

(14) All prestressed members are provided with spare cables at 5% of total numbers required for designs. This is needed in case of shortfall in extensions of the designed cables.

(15) Provision for imparting 20% of design prestress at a future date is made in the deck and suitable anchorages, bulk heads are constructed for the purpose.

(16) In case of submersible bridge sufficient vent holes are provided in box superstructure to prevent entrapping of air inside and to get water into and out of box instantly.

(17) Bearings are to be provided preferably within external line of pier/abutment and below the web of box girders.

(18) Tar paper bearings are allowed up to 10m and restrained neoprene bearings are allowed up to 25m span only.

(19) Anti-crash barriers are provided in high-risk areas e.g. Intersections of important roads, tall bridges etc.

(20) Facilities for inspection of bridge are provided in case of tall bridges and those, which pose difficulties in inspection.

(21) The effective bridge temperature for the location of the bridge shall be estimated from the isotherms of shade air temperature given in fig 8 and 9 IRC:6-2000.Positive and reverse temperature difference for the purpose of design shall be assumed as shown in fig 6.1

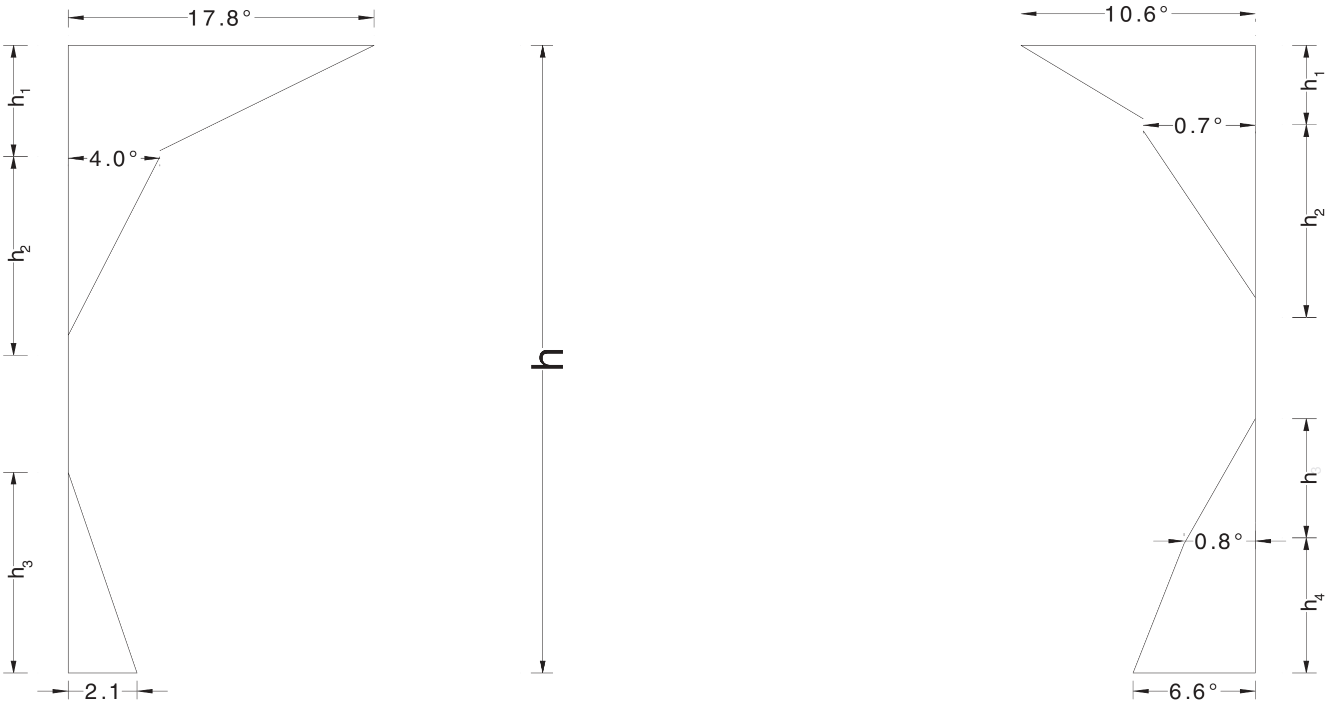


FIG.6.1 DESIGN TEMPERATURE DIFFERENCES

6.6. WORKING DRAWINGS

After this next stage is inviting tender. The tenders may be either on B-1/B-2 i.e. on departmental design or on C form i.e. on contractors own design. For B-1/B-2 type contracts the designs are to be prepared by Designs Circle & working drawings supplied to the concerned field officers. Generally for cost of the bridge more than Rs. 50 lakh, tenders are invited on lump-sum basis (i.e. form C). For these type of works the designs criteria is to be given by Designs Circle. On receipt of contractor's technical proposals with the tender, this is to be scrutinised with respect to the tender conditions and acceptability or otherwise need be communicated to field officers. Thereafter an important part is checking of contractors design after award of work.

6.7. PREPARATION OF WORKING DRAWINGS :

Based on the site condition i.e. foundation level etc., the detailed design with drawing is to be prepared for foundation substructure, superstructure etc.

6.8. CHECKING THE CONTRACTORS ALTERNATIVE DESIGN

(1) Design criteria for contractors alternative design is to be studied in detail.

(2) Contractors design are to be checked based on the design criteria.

■

GUIDELINES FOR
BRIDGE DESIGN

CHAPTER - 7

PRESTREESING
HIGH PERFORMANCE
CONCRETE
ANTICORROSIVE
TREATMENT

7.1. TYPES OF PRESTRESSING AND ITS PROPER USE

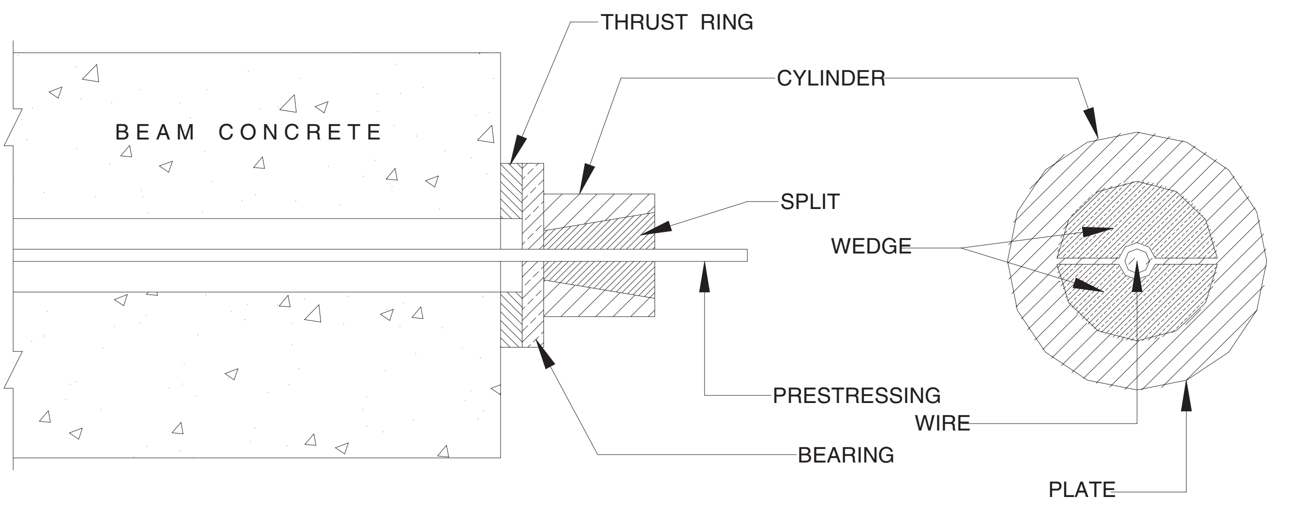
Basically two types of prestressing i.e. pretensioned and post tensioned are applied in bridge engineering.

Generally pretensioning is very rarely used in the state because of its limitations like proximity and availability of plant, size of member, number of units etc.

Post tensioning system is mainly used in the state. Various systems of prestressing are (a) Freyssinet, (b) Magnel-Blaton, (c) Gifford - Udall system.

Many of the post tensioning devices are covered by patents. In case of Freyssinet system, cable with a fixed number of wires e.g. 12-5f or 12-7f or 19-7f are used.Various systems are indicated in fig.7.1,7.2 and 7.3

The sheathing as specified in IRC:18-2000 is generally (CRCA)Mild Steel of bright metal finish or corrugated High Density Polyethylene(HDPE).



(a) SECTION THRO' WEDGE

(b) CROSS SECTION

FIG.7.1 ANCHORAGE FOR GIFFORD-UDALL SYSTEM

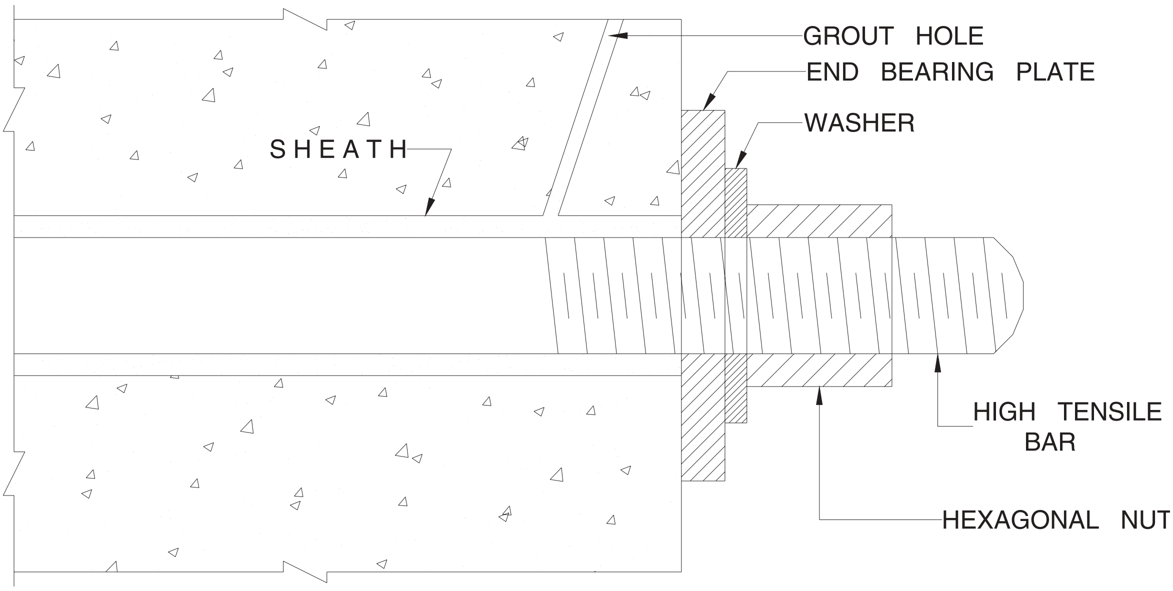


FIG. 7.2. ANCHORAGE FOR LEE - Mc CALL SYSTEM

B. D. KAMBLE, TRACER

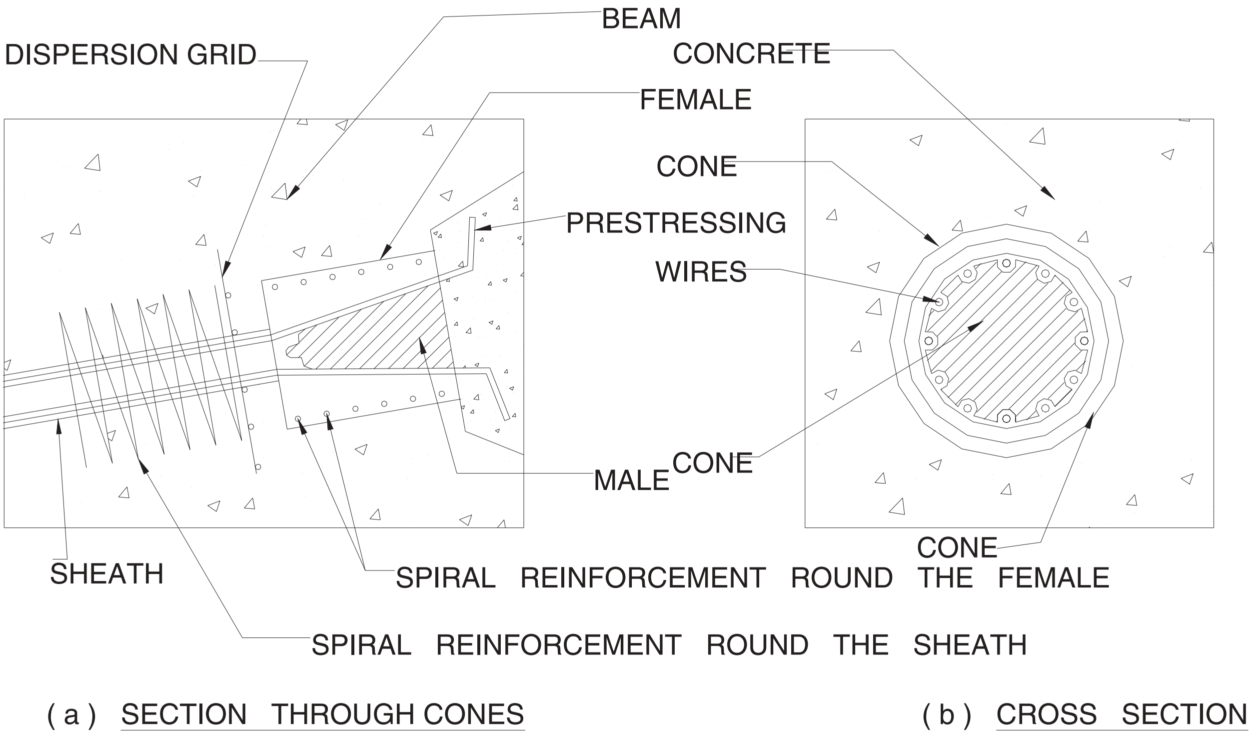


FIG. 7.3. ANCHORAGE FOR FREYSSINET SYSTEM

B. D. KAMBLE, TRACER

7.2 FUTURE PRESTRESSING ARRANGEMENTS

In case of prestressed concrete structures, located in severe/saline exposure conditions, provision of future prestressing arrangement is necessary and should be obligatory. In case of box structures, holes are kept in the end diaphragms at top portion. If intermediate diaphragms are provided then holes should be left in these also keeping in view the alignment of external cables. It is preferable to get the cable profile approved before approving the superstructure drawing. If the diaphragms are very wide/thick, then holes should be rectangular in size to adjust the profile of alignment.

For prestressed structure, suitable arrangement for external prestressing should be decided at design stage. Such arrangement should be for imparting about 20 % of the prestressing force originally applied.

7.3 HIGH PERFORMANCE CONCRETE

The last 10 or 20 years have seen an important evolution in materials and construction. The material concrete itself has changed a lot much. Until recently structural concrete was considered as a unique material, of course with some variation adopted to different possible applications.

Concrete can practically be designed for many different applications. Classical structural concrete has a characteristic strength ranging upto 50 MPa (500 kg/cm^2). More and more use of high performance concrete (HPC) with characteristic strength ranging from 60 MPa to 80 MPa is being used world over. The reason for using high performance concrete is to increase concrete strength driving important normal and bending forces. Major goal of specifying HPC is drastic increase of durability and a large compactness which comes with a high concrete strength is the best solution to limit penetration of corrosive agents like chlorides.

Self placing concrete which is a rather recent development, is more and more preferred to classical concrete.

Three main reasons for this are –

i) Placing is easier ; allows for reducing equipment and man power and finally produces financial benefits.

ii) When the reinforcement ratio is very high, when shape does not allow for easy vibration or when there is no access in some zones-or of segregation is more limited than with traditional concrete.

iii) It allows to give concrete structure more complex shapes, a serious advantage when considering some tendencies of modern architecture.

We have to evoke very high performance fiber concretes, which have been developed by some companies with a characteristic strength ranging from 150 to 200 MPa. Some structures have already been built in the world with such materials.

7.3.1 DURABILITY

Two types of concrete cancer, alkali reaction and sulphatic reaction, either external or internal have been experienced everywhere. Every effort will have to be made to avoid these problems which can produce disasters. High temperature during concrete hardening can have a detrimental impact. Massive piers build with concrete of rather high strength (more than 40 MPa) produce very high temperatures. Cement with low hydration and provisions shall be taken to limit temperature during concrete hardening. Serious and continuous control is very necessary. Second aspect of durability concerns reinforcement. Insufficient cover and lack of concrete compactness leads to corrosion. Therefore compact HPC is used even when high strength is not needed.

Another problem is about corrosion of prestressing strands. Improvement in grout quality, control injection, injection with oil wax for external tendons, greased and sheathed strands installed in wider ducts are some of the ways to prevent corrosion in prestressing strands.

7.3.2 NEW MATERIALS

Evolution of concrete in different forms along with steel reinforcement and prestressing steel has permitted designers and engineers world over to create and produce modern day bridges. Durability of reinforcement has increased over the years with characteristic tensile strength from 400 to 500 Mpa. This evolution has serious advantage for development of HPC, since it is necessary to maintain harmony between mechanical characteristics of steel and concrete.

Prestressing steel has not changed much during the last 10 to 15 years, characteristic strength ranging about 1770 to 1860 Mpa for strands. It seems difficult to increase strength over 200 Mpa.

Regarding plastic materials, Carbon fibers are now used to strengthen degraded structure. Glued carbon fibers completely replace previous technique of glued steel plates particularly in case of structures after natural calamities like earthquake.

At the end it can be said that new ideas are definitely more expensive than classical ones. One word for engineers that they should not live between codes and computers but within society. Elegant structure is result of serious education of deep comprehension of site, landscape and culture; of large capacity of analysis; of broad views of goals of construction and hard work to develop all details from a good concept. So let's start to build some such structures in our state.

7.4. ANTI CORROSIVE TREATMENT

Due to saline atmosphere, steel gets corroded due to electro-chemical action. Not only the reinforcing steel but also the standards/wires used for prestressing gets corroded. Adequate care, therefore, need to taken to protect the bridge structure from this dangerous phenomenon. The concrete as well as steel need to be provided with some anti-corrosive treatment. The bridges lying in coastal area are most affected by corrosion. At places the atmosphere may itself be corrosive due to heavy chemical industrialization. The channel may also carry waste produce from the industries, which may lead to corrosion.

The anticorrosive treatment is required to be applied to concrete and reinforcement steel in case of saline and severe exposure conditions.

7.4.1 REINFORCEMENT

Anticorrosive treatment to reinforcing steel shall be CPCC (Cement Polymer Composite Coating) developed by Karaikudi or FBEC (Fusion Bonded Epoxy Coating). The anchorage / bond length in case of FBEC Bars shall be increased by 50 % of normal values specified in I.R.C.

7.4.2 GALVANISATION

Recently galvanization to reinforcing bars is also considered as an alternative anticorrosive treatment

7.4.3 CONCRETE SURFACE

a. Over mild steel liner to piles : One coat of zinc rich epoxy primer and two coats of coal tar epoxy to the outside surface,

b. In case of part of substructure in contact with earth and upto H.T.L. + 0.9 m or H.F.L. which ever is higher one coat of primer and two coats of coal tar epoxy.

c. In case of part of substructure exposed to atmosphere water proof cement paint.

d. In case of parapets water proof cement based paint in three coats is applied.

e. In case of deck / girder / box epoxy based paint with one coat of primer and further two coats are applied,

7.5 USE OF COMPUTER FOR DESIGN OF BRIDGES

At present there are 41 stand-alone personal computers in the Designs Circle.

List of software developed by the Designs Circle is attached as Annexure-I. All these softwares have been developed in house. Efforts are being made to develop more and more soft wares. Recently purchased STADD-PRO software is found to be quite useful in analysis of structures. It is seen that for bridge structures, ready-made soft wares are not available in the market as a computer package. As soon as these become available, it should be purchased for office use. It must be kept in mind that computer should be used as a tool for helping the designs and its scrutiny. After all it is the feel of structure, judgement of the expert that will count in final decision. Before using any of the programmes, it is desirable that Design Engineer does the calculations with his own hands to get the feel of the problem.

■

GUIDELINES FOR BRIDGE DESIGN

ANNEXURES

ANNEXURE – 1

LIST OF COMPUTER PROGRAMMES AVAILABLE IN DESIGNS CIRCLE (P.W.D.), KONKAN BHAVAN, NAVI MUMBAI

(1) Hydraulic calculations.

(2) Stability calculation for pier.

(3) Stability calculation for abutment.

(4) Stability calculation for pier well.

(5) Stability calculation for abutment well.

(6) Properties of box girder.

(7) Design of neoprene bearings.

(8) Design of prestress concrete box superstructure.

(9) Design of well cap.

(10) Pile grouping and their design.

(11) Design of high embankment.

REVIEW OF SOFT WARES AVAILABLE WITH DESIGNS CIRCLE FOR BRIDGE DESIGN

1	Programme for BM & SF for superstructure	IL-1-99.1
2	Programme to calculate stresses in steel and concrete in rectangular column	FF-4-99.1
3	Programme to find stresses in steel and concrete in rectangular column subject to axial compression and uni-axial bending moment	RR-99.1
4	Programme to find stress in column in axial compression and Biaxial moment.	BI.2-99.1
5	Programme to find out stress in steel concrete of circular sections.	UNIAX-99.1
6	Programme to find the modified Inglis H.F.L. (M.F.H.L.) and Inglis H.F.L. (IHFL)	HYD.4-99.1
7	Abutment well stability	ABWELL-99.1
8	Abutment stability (open foundation)	ABUT-99.1
9	Programme to check parameters in design of neoprene bearing.	NEO-99.1
10	Programme to check stability of pier	STAB.98-99.1

ANNEXURE – 2

TYPE DESIGNS ISSUED BY THE DESIGNS CIRCLE

2.1 TYPE DESIGNS (I. FOUNDATIONS)

Sr. No.	Drawing No.	Description
1.	Drg.No.I/A-3/1/1972	Details of well steining and curb 3 m dia.
2.	Drg.No.I/A-3/2/1972	Notes and reinforcement schedule of well steining and curb for 3 m internal dia.
3.	Drg.No.I/B-1/1/1972	Well anchorage details for pier well 3 m (Twin well).
4.	Drg.No.BR-III/I/C-2/1/1972	Details of well steining and curb 4 m internal dia. steining thickness 0.7 m.
5.	Drg.No.BR-III/I/C-2/2/1972	Details of well steining and curb 5 m internal dia. steining thickness 0.85 m.
6.	Drg.No.BR-III/I/C-2/3/1972	Details of well steining & curb 6.20 m internal dia.
7.	Drg.No.BR-/I/C-2/4/1972	Details of well steining & curb 3 m internal dia.
8.	Drg.No.BR-/I/C-2/5/1972	Details of well steining & curb 5.60 m internal dia.
9.	Drg.No.BR-/I/C-2/6/1972	Details of well steining & curb 4.2 m internal dia. & steining thickness 0.9 m (TH) internal dia.
10.	Drg.No.BR-/I/C-2/7/1972	Details of well steining & curb 5.2 m internal dia.
11.	Drg.No.BR-/I/C-2/1/ 1974	Tentative details of well steining and curb (for Tapi Bridge at Indgaon)
12.	Drg.No.BR-I/D-1/1972	Details of well cap under abutment 6.20 m dia.
13.	Drg.No.BR-I/D-3/1972	Details of well cap and pier and abutment internal dia.3m steining thickness 0.60 m.
14.	Drg.No.BR-I/D-3/1972	Details of well cap under pier 3 m internal dia.
15.	Drg.No.BR-I/E-2/1/4/1972	General layout of type design for R.C.C. Rafts on shallow foundation (Two way rafts slab).
16.	Drg.No.BR-I/E-2/2/4/1973	Details of reinforcement for bars two way rafts slab.

Sr. No.	Drawing No.	Description
17.	Drg.No.BR-I/E-2/3/4/1972	Schedule of reinforcement for bars for R.C.C. Rafts on shallow foundations (Two ways rafts slab)
18.	Drg.No.BR-III/I/E-2/4/4/1973	Details of reinforcement for two way rafts on shallow foundations.
19.	Drg.No.BR-III/I/E-2/ 1/5/1979/T.P.	Type designs for R.C.C. rafts foundations for Bridges key plan.
20.	Drg.No.BR-III/I/2/5/ 1979/T.P.	Type designs for R.C.C. rafts foundations for bridges reinforcement arrangement.
21.	Drg.No.BR-III/E-2/3/5/ 1979/T.P.	Type designs for R.C.C. Rafts foundations for bridges schedule of two spans.
22.	Drg.No.BR-III/I/E-2/ 4/5/1979/T.P.	Type designs for R.C.C. Raft foundations for bridges schedule for more than two spans.
23.	Drg.No.BR-III/I/E-2/ 5/5/1979/T.P.	Type designs for R.C.C. Raft foundations for bridges schedule for single span.
24.	Drg.No.BRN/CDR/178/ 92037.	R.C.C. details of raft with cut off wall walls.

2.2 TYPE DESIGNS (II. SUB-STRUCTURE)

Sr. No.	Drawing No.	Description
1.	Drg.No.II/G-1/1972.	R.C.C. return 9 m height.
2.	Drg.No.II/G-2/1972.	R.C.C. box return 4.5m ht.
3.	Drg.No.II/G-3/1972.	R.C.C. box return 3 m ht.
4.	Drg.No.II/G-4/1972.	R.C.C. box return 13.5 m ht.
5.	Drg.No.II/G-5/1972.	R.C.C. box return 12 m ht.
6.	Drg.No.II/G-6/1972.	Schedule of reinf. for box return ht. 12 m & 13.5 m only.
7.	Drg.No.II/G-7/1972.	R.C.C. box return 6 m height.
8.	Drg.No.II/G-8/1972.	R.C.C. box return 7.5 m ht.
9.	Drg.No.II/G-9/1972.	R.C.C. box return 12 m & 7.5 m clear.
10.	Drg.No.II/G-10/1972.	Schedule of reinforcement for 3m, 6m, 9m & 12m deep box return and statement of concrete and steel for different.
11.	Drg.No.II/G-11/1972.	R.C.C. box return 10.5 m ht.
12.	Drg.No.II/K-1/1972.	Details of abutment cap with dirt wall and pier caps For T-beam and slab and R.C.C. solid slab (superseded)
13.	Drg.No.BR-III/II-K/75001/T.P.	Details of abutment cap with dirtwall & pier cap for solid slab
14.	Drg.No.BR-III/K-1A/1972	Details of abutment cap with dirtwall and pier cap for T beam and slab.
15.	Drg.No.BR-II/N-1/1973TP	Sketch showing surface reinforcement for pier and abutments with mass concrete or c.c. 1:3:6 with plums.
16.	Drg.No.BL-IV/II/A&B/74007/T.P	Type section for abutments (with solid slab deck)
17.	Drg.No.BL-IV/II/A&B/74008/T.P.	Type section for abutments (for T beam and slab deck).
18.	Drg.No.BL-IV/II/E&F/74009/T.P.	Type sections for return walls and wing walls.
19.	Drg.No.BL-IV/II-G/75025	R.C.C. box returns 13.5 m ht. (H.Y.S.D. & c.c. M 150)
20.	Drg.No.BL-IV/II-G/75026	R.C.C. box return 12 m and 13.5 m height (H.Y.S.D.)
21.	Drg.No.BL-IV/II-G/75027/T.P.	R.C.C. box return 12 m and 13.5 m height (sch. of reinf.)
22.	Drg.No.BL-IV/II-G/75028/T.P.	R.C.C. box return 10.5 m ht. Schedule of reinforcement)
23.	Drg.No.BL-IV/II-G/ 75029/T.P.	R.C.C. box return 9.0 m ht. (H.Y.S.D. and c.c 150 m)
24.	Drg.No.BL-IV/II-G/75030/T.P.	R.C.C. box return 7.5 m ht. (H.Y.S.D. and c.c. 150 m)
25.	Drg.No.BL-IV/IV-G/75031/T.P.	R.C.C. box return 6.0 m ht. (H.Y.S.D. and c.c.150 m)
26.	Drg.No.BL-IV/II-G/5032/T.P.	R.C.C. box return 4.5 m ht. (H.Y.S.D. & c.c. 150 m)
27.	Drg.No.BL-IV/II-G/75033/T.P.	R.C.C. box return 3.0 m ht. (H.Y.S.D. & c.c. 150 m)
28.	Drg.No.BR-II/C-79/T.P.	Piers for solid slab (non seismic)

2.3 TYPE DESIGNS (III. SUPERSTRUCTURE)

Sr. No.	Drawing No.	Description
1.	Drg.No.III/A-1/1972	Neoprene bearing for solid slab.
2.	Drg.No.III/A-2/1972	Neoprene bearing for T beam & slab 3 girder system clear span 10 m, 12 m, 15 m 20 m & 25 m only.
3.	Drg.No.III/A-1/1973	Restrained neoprene bearings for 20m span 4 girders system.
4.	Drg.No.III/A/74001/T.P.	Details of restrained neoprene bearing pads for 15 m clear span T beam slab decking with footpath.
5.	Drg.No.III/A/74002/T.P.	Details of neoprene bearing pads for 20 m span with foot path.
6.	Drg.No.III/A/74003/T.P.	Details of restrained neoprene bearing pad for 30 m span (with footpath)
7.	Drg.No.III/A/74004/T.P.	Details of restrained neoprene bearing pads for 10 m clear span T beam slab decking with footpath.
8.	Drg.No.BR-II/III-A/75001/T.P.	Details of restrained neoprene bearing pad for 15 m span 4 Girder system.
9.	Drg.No.III/B-1/1972	Details of M. S. curved plate bearing (capacity 40 to 90 tons)
10.	Drg.No.III/B-2/1972.	Cast steel roller and rocker bearing (capacity 60 to 300 tons)
11.	Drg.No.III/B-3/1972.	Cast steel rocker bearing (capacity 60 to 300 tons)
12.	Drg.No.III/B-4//1972	Notes and standard dimension of different cast steel bearings.
13.	Drg.No.III/C-1/1972	Details of R.C.C. solid slab (single lane and double lane)
14.	Drg.No.III/D-1/1972.	Details of R.C.C. deck slab span 16.5 m 3 girder 7.5 m clear roadway.
15.	Drg.No.III/D-2/1972	Details of inner girder 16.5 m span 7.5 m clear roadway.
16.	Drg.No.III/D-3/1972	Details of outer girder 16.5m.span 7.5 m clear roadway.
17.	Drg.No.III/D-4/1972	Details of cross girder 16.5 m span 7.5 m clear roadway.
18.	Drg.No.III/D-5/1972	Details of deck slab (without footpath) for span 11m, 13.5m, 26.5 m 3 girder system.
19.	Drg.No.III/D-6/1972	Details of inner girder 11.0 m span.

Sr. No.	Drawing No.	Description
20.	Drg.No.III/D-7/1972	Details of outer girder 11.0 m span.
21.	Drg.No.III/D-8/1972	Details of cross girder 11.0 m span.
22.	Drg.No.III/D-9/1972	Details of centre girder 21.5 m span.
23.	Drg.No.III/D-10/1972	Details of outer girder 21.5 m span.
24.	Drg.No.III/D-11/1972	Details of cross girder 21.5 m span.
25.	Drg.No.III/D-12/1972	Details of inner girder 13.0 m span.
26.	Drg.No.III/D-13/1972	Details of cross girder 13.0 m span.
27.	Drg.No.III/D-14/1972	Details of inner girder 13.0 m span.
28.	Drg.No.III/D-15/1972	Details of inner girder 26.5 m span.
29.	Drg.No.III/D-16/1972	Details of outer girder 26.5 m span.
30.	Drg.No.III/D-17/1972	Details of cross girder 26.5 m span.
31.	Drg.No.III/D-18/1972	Details/data for estimate T beam and slab 3 girder system.
32.	Drg.No.III/D-19/1972	Details of R.C.C. solid slab (single lane) for 9 m span (with H.Y.S.D. bars) submersible bridge.
33.	Drg.No.BR-II/III/D-1/1974	R.C.C. deck slab 4 girder system 7.5m clear roadway for 15m, 18m & 30 m span.
34.	Drg.No.BR-II/III/D-2/1974	Details of inner girder 18.0 m span.
35.	Drg.No.BR-II/III/D-3/1974.	Details of outer girder 18.0 m span.
36.	Drg.No.BR-II/III/D-4/1974.	Details of cross girder 18.0 span.
37.	Drg.No.BR-II/III/D-5/1974.	Details of inner girder 20.0 m span c/c 4 girder.
38.	Drg.No.BR-II/III/D-6/1974.	Details of inner girder 20.0 m span c/c 4 girder.
39.	Drg.No.BR-II/III/D-7/1974.	Details of inner girder 20.0 m span c/c 4 girder.
40.	Drg.No.BR-II/III/D-8/1974.	Details of outer girder 20.0 m span c/c 4 girder.
41.	Drg.No.BR-II/III/D-9/1974.	Details of cross girder 20.0 m span c/c 4 girder.
42.	Drg.No.BR-II/III/D-10/1974.	Details of inner girder 20.0 m span (over all) c/c girder.
43.	Drg.No.BR-II/III/D-11/1974.	Details of outer girder 15.0 m span (over all) c/c girder.

Sr. No.	Drawing No.	Description
44.	Drg.No.BR-II/III/D-12/1974.	Details of cross girder 15.0 m span 4 girder.
45.	Drg.No.BR-II/III/D-13/1974.	General notes for 4 girder system 15 m span.
46.	Drg.No.III/G-1/1972	General layout of P. S. superstructure for 140'-0" span.
47.	Drg.No.III/G-2/1972	Cable profile for 140'-0" span
48.	Drg.No.III/G-3/1972	Details of end block and anchorage.
49.	Drg.No.III/G-4/1972	Details of M. S. reinforcement main girder and cross girder 40’-0”
50.	Drg.No.III/G-5/1972	Details of deck slab.
51.	Drg.No.III/G-6/1972	Stressing schedule and grouting specifications.
52.	Drg.No.III-A/1/1973/ TP/BL-IV	Typical drawing for lifting arrangement for solid slab.
53.	Drg.No.III-A/2/1/1973/ TP/BL-IV	Typical drawing for lifting arrangement for T beam & slab.
54.	Drg.No.BL-IV/III-C/74023/T.P.	Details of R.C.C. solid slab up to 20.0 m span (with H.Y.S.D.)
55.	Drg.No.BL-IV/III-D/75005/T.P.	R.C.C. beam and slab girder system without footpath span clear 10m main girder (H.Y.S.D. Bars)
56.	Drg.No.BL-IV/III-D/75006/T.P.	Details of cross girder for 10 m span R.C.C. T beam with H.Y.S.D. bars. Bridge without footpath.
57.	Drg.No.BL-IV/75007/T.P.	Details of main and cross Girder for 12 m clear span R.C.C. T beam bridge without footpath (with H.Y.S.D.)
58.	Drg.No.BL-IV/III-D/75008/T.P.	Details of main girder for 15m clear span R.C.C. T beam without footpath (with H.Y.S.D.)
59.	Drg.No.BL-IV/III-D/75009/T.P.	Details of cross girder 15 m clear span R.C.C. T beam with footpath (with H.Y.S.D.)
60.	Drg.No.BL-IV/III-D/75010/T.P.	Details of outer and central girder for 20 m clear span R.C.C. T beam without footpath (with H.Y.S.D.)
61.	Drg.No.BL-IV/III-D/75011/T.P.	Details of end & intermediate cross girder for 20.0 m clear span R.C.C. 20.1 M T beam without footpath (with H.Y.S.D.)
62.	Drg.No.BL-IV/III-D/75012/T.P.	Details of main and cross girder for 25 m clear span R.C.C. T beam without footpath (with H.Y.S.D.)
63.	Drg.No.BL-IV/III-D/ 75013/TP	Details of R.C.C. deck slab T beam without footpath for span 10 m, 12 m, 15 m 20 m (with H.Y.S.D.)

Sr. No.	Drawing No.	Description
64.	Drg.No.BL-IV/III-G/75036/TP	Cable profile for longitudinal girder and anchor details for 25 m span.
65.	Drg.No.III-G/75037/ T.P. (39"x21")	Details of un-tensioned reinforcement & main girder 25.0 m effect span.
66.	Drg.No.BL-IV/III-G/75038/T.P. (34"x13")	Details of cross girder for 25m effective span
67.	Drg.No.BL-IV/III-G/75039/TP (39"x29")	Details of R.C.C. deck slab for 25.0 m effective span
68.	Drg.No.BL-IV/III-G/75046/TP (56"x29")	R.C.C. details of prestressed concrete 3 girder system bridge of 25 m span c/c pier cable profile for longitudinal girder and anchor details.
69.	Drg.No.BL-IV/III-G/75047/TP (49"x21")	Reinforcement details of longitudinal girder 25 m span c/c of pier.
70.	Drg.No.BL-IV/III-G/75048/TP (13"x39")	Details of cross girder 25 m span c/c of pier.
71.	Drg.No.BL-IV/III-G/ 75049/TP (39"x29")	R.C.C. details of deck slab for 25 m span c/c of piers P.S.C. girder bridge.
72.	Drg.No.BL-IV/III-G/ 75063/TP (43"x27")	Details of end block and top anchorage of cables and schedule of cables 25 m span c/c piers.
73.	Drg.No.BR-II/(III))/ H-1/1/4/79/TP	General dimension drawing(submersible bridge)
74.	Drg.No.BR-II/(III)/ H-1/2/4/79/TP	Cable profiles for main and cross girder.
75.	Drg.No.BR-II/(III)/ H-1/3/4/79/TP	Reinforcement details in box girders.
76.	Drg.No.BR-III/1/5/91/TP	General arrangement of members of superstructure 30m span prestressed box girder.
77.	Drg.No.BR-III/2/5/91/TP	Details of cables.
78.	Drg.No.BR-III/3/5/91/TP	Details of shear reinforcement
79.	Drg.No.BR-III/4/5/91/TP	Details of cable anchorage.
80.	Drg.No.BR-III/5/5/91/TP	Reinforcement details of deck slab.

2.4 TYPE DESIGNS (IV. FIXED ITEMS)

Sr. No.	Drawing No.	Description
1.	Drg.No.BR-II/IV-A/77001/TP.	Details of wearing coat.
2.	Drg.No.IV/B-1/1972.	Details of R.C.C. parapet and kerb.
3.	Drg.No.IV/B-2/1972.	Details of R.C.C. parapet and kerb. prestressed box girder.
4.	Drg.No.IV/B-3/1972	Details of R.C.C. parapet (precast) and kerb.
5.	Drg.No.IV/B-6/1972®	Details of pipe railing for submersible bridge.
6.	Drg.No.IV/D-1/1972/TP	Details of expansion joints.
7.	Drg.No.IV/E-1/1972/TP	Details of R.C.C.approach slab.

2.5 TYPE DESIGNS (V. OTHER ITEMS)

Sr. No.	Drawing No.	Description
1.	Drg.No.V/F-1/1972.	Type cross section of submersible approaches.
2.	Drg.No.V/F-2/1973.	Type plan for sakav (foot bridge) span upto 6m superseded section drawing No.V/F-7/1973.
3.	Drg.No.V/F-3/1973.	Relationship with span Vs B.M. for various loading single supported span.
4.	Drg.No.V/F-4/1973.	Relationship with span Vs absolute maximum S.F. for various loading.
5.	Drg.No.V/F-5/1973.	Relationship with span Vs absolute maximum B.M. for various loading.
6.	Drg.No.V/F-6/1973.	Relationship graph for classification of bridges.
7.	Drg.No.V/F-7/1973.	Type plan for sakav (foot bridge) span upto 5m (see drawing No.V-F-2/1973.
8.	Drg.No.V/F-8/1973.	Type plan for temporary R.C.C. span pipe culvert.
9.	Drg.No.P-26/1973.	Sub-structure and foundations for piers & abutments for sakav.

Sr. No.	Drawing No.	Description
10.	Drg.No.BR-II/V-P-F/ 75001/TP	Details of vent holes(for girder with deck slab 15 m c/c of pier)
11.	Drg.No.BR-II/V-P/F/ 75002/TP	Details of vent holes for submersible girder and slab deck).
12.	Drg.No.BR-II/V/F-9/1976	Details of pylon and pilaster for bridges.
13.	Drg.No.BR-I/F-10/A 1976	A type plan for bridge and bandhara (for minor bridge)
14.	Drg.No.BR-II/F-10/1979	Details of pre-cast deck for bullock cart bridges.
15.	Drg.No.BR-II/F-11/1979	Details of type plan for foot bridge pre cast decking.
16.	Drg.No.BR-II/F-12/1979	Details of timber deck and pier.
17.	Drg.No.BR-II/V/F-13/ 1979.	Hand rail and anchorage details.

2.6 TYPE DESIGNS (V-D / R.C.C.BOX CULVERTS

Sr. No.	Drawing No.	Description
1.	Drg.No.BR-II-V/D-1/79/TP	Type plan of single cell R.C.C. square box culvert.
2.	Drg.No.BR-II/D-2/79/TP	Type plan of 5 cell R.C.C. Box culvert.
3.	Drg.No.BR-II-V/D-3/79/TP	Type plan of 5 cell R.C.C. Box culvert.
4.	Drg.No.V/D-4/79/TP.	Details of R.C.C. box culvert framed type (4 cell)
5.	Drg.No.V/D-4A/79/TP	Schedule of reinforcement for RCC box culvert framed type (4 cell)

2.7 TYPE DESIGNS FOR SAKAV BRIDGE

Sr. No.	Drawing No.	Description
1.	Drg.No.BR-II-V/F-15/1981/TP	Type designs for sakav (foot bridge) for pedestrains traffic 10 m span.
2.	Drg.No.BR-II-V/F-16/1981/TP BL-I/82048/TP BL-I/82049/TP	Type designs for sakav (foot bridge) for pedestrains traffic 15 m.span.
3.	Drg.No.BR-II-F-17/ BL-I/82054/TP BL-I/82054/TP	Type designs for sakav (foot supersedes bridge) for pedestrains traffic 15 m span.
4.	Drg.No.BR-II/V/F-18/1981/TP Size (30"x32")	Type designs for sakav (foot bridge) for pedestrains cum bullockcart traffic 10 m span.
5.	Drg.No.BR-II/F-19/TP BL-I/82041/TP BL-I/82041/TP	Type designs for sakav (foot Supersedes bridge) for pedest rains cum bullock cart traffic 15 m span.
6.	Drg.No.BR-II/V/F-20/1981/TP BL-I/82039/TP BL-82040/TP	Type designs for sakav (foot Supersedes bridge) for pedest-rains cum bullock cart traffic 20 m span.
7.	Drg.No.BR-II/V/F-21/1981/TP BL-I/82035/TP BL-I/82036/TP	Type designs for sakav (foot Supersedes bridge) for pedestrains traffic 30m span.
8.	Drg.No.BR-II/F-22/1981/TP supersedes BL-I/82024/TP BL-I/82025/TP	Type design for sakav (foot bridge) Supersedes cum bullock cart traffic 30 m span.
9.	Drg.No.BR-II/F-23/1981/TP	Type plan for piers for sakav.
10.	Drg.No.BL-I/82024/TP	Type designs for sakav for pedestrains cum bullock cart traffic. (span 30.00 m)
11.	Drg.No.BL-I/82035/TP	Type designs for sakav for pedestrians traffic (span 30.00 m)
12.	Drg.No.BL-I/82036/TP	Type designs for sakav for pedestrians traffic (span 30.00 m)

Sr. No.	Drawing No.	Description
13.	Drg.No.BL-I/82040/TP	Type designs for sakav for pedestrians cum bullock cart traffic (span 20.00 m)
14.	Drg.No.BL-I/82041/TP	Type design for sakav for pedestrians cum bullock cart traffic (span 15.00 m)
15.	Drg.No.BL-I/82041/TP	Type designs for sakav for pedestrians cum bullock cart traffic (span 15.00 m)
16.	Drg.No.BL-I/82048/TP	Type design for sakav for pedestrian traffic (span 15.00 m)
17.	Drg.No.BL-I/82049/TP	Type design for sakav for pedestrian traffic (span 15 m)
18.	Drg.No.BL-I/82054/TP	Type design for sakav for pedestrians traffic (span 20.00 m)
19.	Drg.No.BL-I/82055/TP	Type design for sakav for pedestrians traffic (span 20.00 m)
20.	Drg.No.BL-I/82039/TP	Type design for sakav for pedestrians cum bullock cart traffic (span 20.00 m)

ANNEXURE – 3

LIST OF TYPE DESIGNS ISSUED BY M.O.S.T.

M.O.S.T.'S TYPE DRAWINGS FOR BRIDGES

SLAB BRIDGES

(a) R.C.C. slab type right bridges

Sr. No.	Details of the Drawing	Drawing No.
1	Without footpath and effective spans from 3.37m to 8.37m	BD/1-74 A, BD/2-74
2	Without footpath and effective spans from 9.37m & 10.37m	BD/3-74 A, BD/4-74
3	With footpath and effective spans from 3.37 m to 8.37 m	BD/5-74 A, BD/6-74
4	With footpath and effective spans from 9.37 m to 10.37 m	BD/7-74 A, BD/8-74

(b) R.C.C. slab type skew bridges. Skew angle from 15° to 60°.

Sr. No.	Details of the Drawing	Drawing No.
5	With footpath and effective spans from 4.37 m to 6.37 m	BD/10-74A, BD/11-74
6	Without footpath and effective spans from 5.37 m to 8.38m	BD/12-74A, BD/13-74

(c) R.C.C. piers for slab bridges.

Sr. No.	Details of the Drawing	Drawing No.
7	Without footpath and effective spans from 3.37m to 10.37m	BD/8-75, BD/9-75
8	With footpath and effective spans from 3.37 m & 10.37m	BD/10-75A, BD/11-75

(d) Wearing Coat, Expansion joints and drainage spouts BD/1-69-9

(3) General details

1	General Notes	SD/101
2	General Arrangements	SD/102
3	Miscellaneous details	SD/103 & SD/104
4	Details of R.C.C. railing without footpath	SD/105
5	Details of R.C.C. railing with footpath	SD/106

(3) Reinforcement details and quantities for slab without footpath

1	Effective spans 3.0 m	SD/107
2	Effective spans 4.0 m	SD/108
3	Effective spans 5.0 m	SD/109
4	Effective spans 6.0 m	SD/110
5	Effective spans 7.0 m	SD/111
6	Effective spans 8.0 m	SD/112
7	Effective spans 9.0 m	SD/113
8	Effective spans 10.0 m	SD/114

(3) Reinforcement details and quantities for slab with footpath

1	Effective spans 3.0 m	SD/115
2	Effective spans 4.0 m	SD/116
3	Effective spans 5.0 m	SD/117
4	Effective spans 6.0 m	SD/118
5	Effective spans 7.0 m	SD/119
6	Effective spans 8.0 m	SD/120
7	Effective spans 9.0 m	SD/121
8	Effective spans 10.0 m	SD/122

PRESTRESSED CONCRETE BRIDGES

(3) General Details

1	General Notes	SD/301 sheets 1 & 2
2	General Arrangements	SD/302
3	Details of wearing coat and drainage system	SD/303
4	Details of R.C.C. railing for superstructure without footpath	SD/304
5	Details of R.C.C. railing for superstructure with footpath	SD/305
6	Details of barings	SD/306 sheets 1,2 & 3

(3) Details of 30 m span without footpath

1	Dimensions and anchorage details	SD/311
2	Prestressing cables	SD/312
3	Reinforcement in deck slab and kerbs	SD/313
4	Reinforcement in main girder	SD/314
5	Reinforcement in end cross girders	SD/315
6	Reinforcement in intermediate cross girders	SD/316
7	Schedule of reinforcement	SD/317 sheets 1,2 & 3

(3) Details of 30 m span with footpath

1	Dimension and anchorage details	SD/321
2	Prestressing cables	SD/322
3	Reinforcement in deck slab and kerbs	SD/323
4	Reinforcement in main girder	SD/324
5	Reinforcement in end cross girders	SD/325
6	Reinforcement in intermediate cross girders	SD/326
7	Schedule of reinforcement	SD/327 sheets 1,2 & 3

(3) Details of 35 m span with footpath

1	Dimension and anchorage details	SD/331
2	Prestressing cables	SD/332
3	Reinforcement in deck slab and kerbs	SD/333
4	Reinforcement in main girder	SD/334
5	Reinforcement in end cross girders	SD/335
6	Reinforcement in intermediate cross girders	SD/336
7	Schedule of reinforcement	SD/337 sheets 1,2 & 3

(3) Details of 40 m span with footpath

1	Dimension and anchorage details	SD/341
2	Prestressing cables	SD/342
3	Reinforcement in deck slab and kerbs	SD/343
4	Reinforcement in main girder	SD/344
5	Reinforcement in end cross girders	SD/345
6	Reinforcement in intermediate cross girders	SD/346
7	Schedule of reinforcement	SD/347 sheets 1,2 & 3

ANNEXURE – 4

STANDARD NOTES FOR BRIDGES DRAWINGS

(1) All dimensions are in metres except otherwise mentioned.

(2) Dimensions should not be scaled from the Drawing. Figured dimensions should be taken instead of scaled dimensions.

(3) The clear road width is 7.5 m unless stated otherwise. The clear road width shall be measured in a direction perpendicular to the direction of traffic.

(4) The bridge is designed for two lanes of I.R.C. Class-A, single lane of I.R.C. Class-AA, or 70R loading, whichever produces the worst effects.

(5) This designs and plans and estimates are based on survey data received from the Executive Engineer, Road Project Division under his no. ....dt....

Before starting execution, a working cross-section at the shall be taken by precision survey and abutment and pier positions shown on technically sanctioned drawings shall be verified on site. In case of any discrepancy or doubt, clarification shall be obtained from the concerned authority before hand.

(6) The temporary Bench Mark is located at .... and its values are............ (However, in case of doubt, the same should be got confirmed before execution from the Executive Engineer, Road Project Division ....)

(7) Angle of skew is .... However, the piers & abutments should be oriented parallel to flow direction at site and discrepancy, if any, reported to Designs Circle before hand.

(8) Rubble pitching should be done upto 0.50 m. above affluxed H.F.L. on both sides or approaches, in flood zone.

(9) Filling behind abutments and returns shall be as per Government of India Circular No.LB-9(3)/68 dated 17.08.1971.

(10) Adequate weep holes shall be provided in abutments, riding returns, solid returns and outer walls of box returns at not more than 2000mm centre to centre horizontally and 1000mm centre to centre vertically, regularly staggered. The weep holes shall be provided upto the bed level.

(11) Foundation levels shown on the drawing are tentative. Open foundation for abutments and piers shall be keyed into soft rock or exposed rock by a minimum of 1500mm or into hard rock by a minimum 500mm whichever gives a higher foundation level. Foundations for returns wings shall be keyed by a minimum of 500 mm into exposed rock.

ANNEXURE – 5 : MATERIAL TABLE

Accompaniment to S.E.D.C.'s Circular No.1004, Dated 21.03.1997.

Sr. No.	Component	CONCRETE GRADES				Quantity of steel per cum of concrete
		MINIMUM		AS PER SP-33		
		Moderate	Severe	Moderate	Severe	
1	2	3	4	5	6	7
1.	a. Parapet (R.C.C.)	M-20	M-25	M-20*	M-25*	As per T.P. (8.5-12g/m)
	b. Railings	Collapsible type for submersible bridges				11.1 kg/m (Structural steel including pipes) please see type designs.
2.	Kerb	M-20	M-25	M-20*	M-25*	As per T.P. (5.25 kg/n\m)
3.	Superstructure					
	(a) Solid slab span upto & 10 m	M-20	M-25	M-35	M-40	As per T.P. (85 to 105 kg/cum)
	(3) Girder & slab 10<span<20 m	M-20	M-25	M-35	M-40	Girder 250-400 kg/cum slab 160-190 kg/cum
	(4) R.C.C. box					
	i. Span 20m to 25m	M-20	M-25	M-35	M-40	150-175 kg/cum
	ii. Span 25n to 30m	M-25	M-30	M-35	M-40	175-200 kg/cum
	(5) P.S.C. box span 30 m to 60 m	M-35	M-40	M-35	M-40	H.T.S. 30-40 kg/cum HYSD 150-200 kg/cum (Untensioned steel)
4.	Pedestal	Next higher grade of superstructure		M-40	M-4-	80-100 kg/cum
5.	Abutment cap (fully resting)	M-25	M-25	M-35	M-40	85 kg/cum Solid Slab 185 kg/cum Girder System

Sr. No.	Component	CONCRETE GRADES				Quantity of steel per cum of concrete
		MINIMUM		AS PER SP-33		
		Moderate	Severe	Moderate	Severe	
1	2	3	4	5	6	7
6.	Pier cap (fully resting for cap width 0.75 to 1.2 m)	M-20	M-25	M-35	M-40	70-85 kg/cum Solid Slab 200 kg/cum Girder System
7.	Cantilever type cap for piers & abutments	M-20	M-25	M-35	M-40	230 kg/cum
8.	P.C.C. Pier/Abutments	M-10	M-15	M-25	M-30	Surface Reinforcement 5 kg/m2 (10 @ 200 mm c/c)
9.	P.C.C. returns	M-10	M-15	M-15	M-20	
10.	Solid R.C.C. Pier/ Abutment (Height 8 m to 15 m)	M-20	M-25	M-35	M-40	75 to 100 kg/cum
11.	Hollow Pier / Counter fort retaining wall type abutment	M-20	M-25	M-35	M-40	120 kg/cum
12.	Levelling course below Pier / Abutment	M-10	M-15	M-10	M-15	
13.	Well Cap / Pile Cap (Dia. 4.2 m to 8 m)	M-20	M-25	M-35	M-40	120-160 kg/cum (Pier resting on cap) 80 kg/cum (Pier resting on steining)
14.	Well steining (Dia. 3 m to 6.2 m & steining thickness 0.6 m to 1 m	M-10	M-15	M-25	M-30	14-20 kg/cum
15.	Top Plug	M-10	M-15	M-15*	M-20*	

Sr. No.	Component	CONCRETE GRADES				Quantity of steel per cum of concrete
		MINIMUM		AS PER SP-33		
		Moderate	Severe	Moderate	Severe	
1	2	3	4	5	6	7
16.	Bottom Plug	M-15**	M-20**	M-25	M-30	
17.	Well Curb (Dia. 6.2 m to 3 m)	M-20	M-25	M-35	M-40	70-80 kg/cum
18.	Box Returns (Height 3 m to 13.5 m end unit & intermediate units)	M-20	M-25	M-25	M-30*	52-78 kg/cum
19.	Raft Slab with cut off walls i.e. a channel section (Span 5 m to 10 m)	M-20	M-25	NOT RECOMMENDED		70-80 kg/cum
20.	Cut off walls (detached)	M-10	M-15	NOT RECOMMENDED		5 kg/m2 on each face
21.	Piers	M-20 (Min. cement content 400 kg/cum)	M-25 (Min. cement content 400 kg/cum)	M-35	M-40	75-100 kg/cum (Please refer IS:2911 Part-I:1979)
22.	R.C.C. Wearing Coat	M-20	M-25	M-35	M-40	6 @ 300 c/c both ways
23.	Cutting edge (Dia. Of well 4 m to 6.2 m thickness of steining = 0.6 to 0.9 m)	M.S.	Steel (structural)			58 kg/Rmt
24.	Expansion Joint					

Sr.No. 1,2,3 : For spans 10 m 1.		For solid slab upto M-10 m	Bituminous pad type
		1. For simply supported spans upto M-10 m	Burried type joint.
		3. Fixed end of simply supported spans upto M-10 m	Filler joint.
Sr.No. 4,5,6 : For spans between 10 m to 25 m.		4. Simply supported spans up to 25 m with maximum horizontal movement M-25 mm (Only for deck with bituminous. Wearing Coat Longitudinal Gradient < 2 % & cross camber < 3 %).	Asphaltic plug joint. Copper plate type
		4. Simply supported or continuous spans upto M-25 m with maximum horizontal movement less than M-40mm.	Compression seal joint. Copper plate type
		5. Simply supported or continuous spans upto M-25 m with maximum horizontal movement upto 50 mm.	Elastomeric slab seal joint. Copper plate type.
Sr.No.7 : For spans between 25 m to 50 m		6. Spans M-25 m to 50 m simply supported, cantilever construction with maximum horizontal movement upto 70mm	Single strip seal joint. Finger plate.
Sr.No. 8 : For spans more than 50 m		8. Large to very large continuous to cantilever construction with movement in excess of 70 mm	Modular strip / Box seal Joint Finger plate.
25.	Wearing Coat	1) For Annual rainfall > 1000 mm.	50 BM + 25 AC (75 average thickness)
		2) For Annual rainfall < 1000 mm.	12 Mastic + 50 DBM + 25 Mastic.

		3) a) For Annual rainfall > 1000 mm. For flyover and very important bridge work b) For Annual rain fall < 1000 mm	50 mm DBM + 25 mm Mastic.
26.	Water Spouts	As per MOST type design except dia. of pipe as 150 mm @ one no. / 20 sq.m. area of deck.	
27.	Bearings	1. Tar paper for solid slabs less than or equal to 10 m 2. Neoprene bearings for spans less than or equal to 40 m. 3. PTFE bearings – for spans more than 40 m.	

NOTES :

1. The grades specified in the table are minimum preferable. These can be changed as per design requirement.
2. The concrete grades for bottom plug are increased one step above the grades for top plug as this concrete is expected to prevent the seepage of water from bottom.
3. The reinforcement quantities given in the table are for estimate purpose only. These quantities may vary depending on the design requirement. Proper judgement should be used to choose appropriate steel reinforcement quantity per cum of concrete.

Sd/-

(K. S. JANGDE.)

Superintending Engineer (Bridges.),
Designs Circle, Konkan Bhavan,
Navi Mumbai 400 414.

ANNEXURE – 6

IMPORATANT CIRCULAR ISSUED BY THE DESIGNS CIRCLE

(3) Circular No. EC-MIS-8/1519,

(4) Circular No. BC-CIR/93,

(5) Circular No. BR-II/SD/4683 of 1974,

(6) Designs Circle (B&C) Survey for Major Bridges: Instructions for good bridge site,

(7) Designs Circle (B&C) Survey for Major Bridges: General Instructions,

(8) Designs Circle (B&C) Survey for Major Bridges: Instructions on trial pits, punch bores and bores,

(9) Designs Circle (B&C) Survey for Major Bridges: Standard Proforma for survey data for bridges.

ANNEXURE – 6.1

No.EC MIS.8/1519
Office of the Superintending Engineer,
Designs Circle, (B & C) Department,
Hutment No.4, C.C.I.,
Bombay - 1.
Dated : 19.11.1968.

To,

All Superintending Engineers of B&C, Circles
All Executive Engineers, B&C Divisions,& Zilla Parishads,
& Road Project Divisions, Designs Divisions No.I & II.
In accordance with the Irrigation and Power Department Bombay's No.MNS-1963-M.I(I). The flood discharge for catchments upto 20 sq. miles may be worked out as under :-

(i) For catchments less than or equal to 1 sq. miles.
Run off - 3 inches per hour per acre.

(ii) For catchments more than 1 sq. miles.

$$Q = \frac{C + A}{\sqrt{(A + 4)}}$$

Where A = Catchment in sq.miles.
& C = Values given in the table below

Sr. No.	Catchment area in sq.miles.	Value of C	Sr. No.	Catchment area in sq.miles.	Value of C
1.	2	4600	11.	12	6300
2.	3	4800	12.	13	6400
3.	4	5000	13.	14	6500
4.	5	5300	14.	15	6600
5.	6	5550	15.	16	6700
6.	7	5700	16.	17	6775
7.	8	5850	17.	18	6850
8.	9	6000	18.	19	6925
9.	10	6100	19.	20	7000
10.	11	6200			

(V. N. GUNAJI.)
Superintending Engineer,
Designs Circle, B&C,
Mumbai.

ANNEXURE – 6.2

NO.BR-II/SD/4683/OF 1974,
OFFICE OF THE SUPERINTENDING ENGINEER,
DESIGNS CIRCLE, B.& C. DEPARTMENT,
GOVT. HUTMENT NO.IV, OPPOSITE C.C.I.,
BOMBAY 400 020 (TEL.NO.296334)
DATED :- 18th Sept. 1974.

To,

The Superintending Engineer,
Road Project Circle,
Poona/Akola/Aurangabad.
The Coastal Engineer,
Bombay.

Subject : Survey data for bridges

In the past, for collection of survey data a circular was issued by Shri S.V.Natu the then Superintending Engineer, Designs vide No.BC/Circular/93, dated 31.01.1961. Subsequently a check list for submission of survey data to Designs Circle was prepared and circulated under this office No.T-19/1786, dated 29.12.1969. Further instructions regarding collection of survey data for bridges were issued under this office D.O. letter No.PB/2138, dated 20.04.1974.

2/- The Government has since issued different circulars as mentioned below :-

(a) Chief Engineer's Circular No.14 of 1971 issued under HBS-1970/94658(G)-C, dated 14.08.1971 in connection with construction of road and bridge works affecting railways.

(b) Government Circular No. BLN.1072/1197-P(I), dated 14.12.1973 issued in connection with the construction of bridge-cum bandhara type structures.

(c) Chief Engineer's Circular No.5 of 1974 issued under No.RRS.1074-2643-P(I), regarding C.F.L. for the survey data of major bridge works.

(d) Government Circular No.RRM-1074/6416-P(I), dated 9.8.1974 regarding co-ordination of road works and irrigation works affected by irrigation project.

3/- In view of the above Government Circulars it has become necessary to modify the previous circular instructions issued by this office for the information to be supplied along with the survey data for major bridges. I am enclosing herewith detailed proforma which should henceforth be completed and sent to this office along with the detail survey data of major bridges invariably. This should be filled in even for bridges whose S.D. is already sent by Plan & Estimate are yet to be prepared.

4/- Incidentally, a copy of instructions for selection of a good bridge site which were included in

Shri. Natu's circular, are again enclosed herewith for ready reference and guidance of all the field engineers working in Road Project Organisation.

D.A. : Copy of the proforma & instructions about bridge site.

(N. V. Merani)
SUPERINTENDING ENGINEER,
DESIGNS CIRCLE,
BOMBAY-20.

Copy submitted to the Chief Engineer, Road Project and joint Secretary to Government, Buildings and Communications Department, Sachivalaya, Bombay for favour of information.

D.A. : Copy of the proforma.

Copy forwarded to Executive Engineer, Road Project Division.

D.A. : Copy of the proforma & instructions about bridge site.

ANNEXURE – 6.3

DESIGNS CIRCLE (B&C)

SURVEY FOR MAJOR BRIDGES.

Instructions for selection of a good bridge site

(Reproduced from the brochure - "Bridging India's Rivers").

(1) WHAT IS A GOOD SITE ?

The characteristics of an ideal site for a bridge are –

10 A straight reach of the river;

11 Steady regime of the river and absence of serious whirls or cross currents;

12 A narrow and well defined channel

13 Suitable high bank above high flood level of each side;

14 Rock or other compact and fairly unerodable foundations close to the bed level.

15 Secure and economical approaches which should not be very high, long or liable to flank of the river and its spills during floods, nor should the approaches involve obstacles, e.g. hills, frequent drainage crossings, sacred places, graveyards, congested or built-up areas needing viaducts or troublesome land acquisition;

16 Reasonable proximity to a direct alignment of the road to be served, i.e. avoidance of long detours;

17 Absence of sharp curves in the approaches,

18 If it is unavoidable necessary for the approaches of a bridge to cross the spill-zone of a river face down-stream and not upstream.Facing upstream will cause heading up. Pocket foundation, and danger to the approaches

19 Absence of costly training works and, where such works are unavoidable, the possibility of executing them largely in the dry;

20 Avoidance of excessive construction work under water.

It is hardly necessary to mention that the "ideal"site never exists in reality. At every site, one or more of the ideal conditions is lacking and the object of a reconnaissance ("Recce" for short) is to select the least objectionable site. In making this selection, the relative importance to be attached to any one factor may very considerably according to the nature of the bridging problem. The best compromise is a matter of judgement but that judgement can only be applied after careful study of relevant data. It is the business of the "Racce" officer to collect that data and to record it.

(2) "REJECTION" PRECEDES SELECTION.

The officer deputed to reconnoitre for a bridge site should first study at home the largest available map of the area. He should tentatively fix the limits of the terrain within which his examination is to be conducted and make a tentative selection , on the map. of the sites and locations that seem to warrant inspection. The best method of doing this is by a process of "rejection" , i.e. by considering the topography of the reach of the river as a whole and rejecting such stretches where the chances of finding a suitable site for a bridge are negligible.

After eliminating unsuitable sites, the "Recce" Officer should concentrate upon the remainder, giving prior attention to the 'probable' site nearest to the line along which other things being favourable, the proposed road would run

Having decided the site or sites to which reconnaissance activities should be directed, the Recce officer should calculate the catchment areas at the probable sites from maps in his possession and get together any other information readily available with him about flood levels, discharges, waterway, etc. relating to the sites and to any bridges on the same river in the vicinity.

He should also take steps to collect meterological information like annual rainfall and seasonal distribution, storm data, direction of prevailing and strongest winds, range of temperature (seasonal and daily) and humidity conditions.

If there are existing road or railway bridges not very far upstream or downstream of the site he is to examine, he should write and ask for particulars of these bridges.

(3) F I X E D W O R K

Now the Recce office is ready to start his field work. His party should include, if possible, the officer who is to be responsible for carrying out the subsequent details investigation and preparation of the project.

Equipment : the equipment which the party will need during field work includes :-

10 Tapes and survey chains with plenty of arrows,half a dozen bamboo poles, each shod with steel, marked in black and white for feet, and carrying flages at the top

11 A clinometer or Abney level

12 A dumpy level with staff or, alternatively, a straight edge, and an ordinary mason's level

13 A prismatic compass or sextant

14 A stop watch or, in its absence, an ordinary watch with a second hand

15 A crowbar and one-inch diameter steel rod, about 12 ft. long, with one end pointed, and a sledge hammer

16 Pegs and mallets.

(4) WRITING THE REPORT

The report should be brief and to the point but must not omit anything relevant Clear, brief and crisp reports, accompanied by sketch maps, give a far better picture than do long narratives ;

10 The Recce officer will have to apply a broad vision and common sense to the problem taken as a whole.

11 If only one site is predominantly superior to all others, the Recce officer should recommend that any subsequent investigations be confined to that site only.

12 If several sites merit consideration, he should give this own order of their respective merits.

13 In either case he should recommend the scope of the subsequent detailed investigations and surveys needed to obtain the full data required for the design of the bridge.

14 The scope of the detailed investigation may vary from a very brief local survey for determining locations, reduced levels, and sections in the simpler cases, to fairly comprehensive investigation of topographical, hydrological, and geological data including Exploratory borings of the sub-soil, in the more complicated cases.

15 For economy as well as speed it is necessary that the scope should be limited to actual requirements and intelligently drawn up reconnaissance reports are a great help in this.

(5) POINTS THE RECEE OFFICER SHOULD REMEMBER.

10 He is concerned with selecting the best possible bridge site but this does NOT always mean the place where the cheapest bridge can be built. The best site is generally the one where the cheapest bridge with its approaches can be built.

11 He must think of the road and avoid long diversions if possible.

12 He must also think of the road needs of the traffic that is going to use the road for the next thousand years and avoid sharp curves, steep gradients, blind approaches, etc.

13 He must also think of the origin and destination of traffic that will cross the river after the bridge is built and locate his site as far as possible to suit the needs of present and, more important, future needs of traffic.

14 But he must not be influenced in his decision by local vested interests either in land, or in traffic.

15 In brief, the Recce officer is to select the best site, not only the best site technically but the best site having in view the long-term prosperity of the country. The Recce officer has a difficult and important task to perform.

(6) MISTAKES

It may help the Recce officer in his work and in writing his report to think of mistakes that have been made in the past by some of his predecessors. A few of the worst mistakes are listed below.

10 Bridge sited immediately downstream of a junction of two big rivers, (This mistake comes of looking only at a site and not upstream.)

11 Bridge undermined after construction owing to regression of soft rock in the river bed. (This mistake comes through the recce and survey officers not looking immediately downstream where there were a series of water-falls rapidly travelling up the softrock bed of a river.)

12 The designs of two bridges were interchanged and each was built over the stream for which the other was intended. (This extraordinary mistake occurred because the recce and survey officers did not take enough trouble to show the exact sites of the bridges on their plans with reference to neighbouring villages, the streams, themselves, and the approaches. The construction officer, of course, also acted without intelligence.)

13 Site involving deep foundations selected when there was a site with rock at no great depth only 700 ft. downstream. (This mistake would not have occurred had the recce officer sketched the course of the river downstream because there were surface indications (configuration of the banks and rocks on the banks on each side) that indicated the probable presence of rock at no great depth below the bed.)

14 Bridge much longer than necessary was built. (This mistake occurred because the recce officer did not notice that the wide spread of the river from bank to bank at the selected site was due to the presence of an old causeway which had frequently been outflanked and extended in the past. half a mile upstream and half a mile downstream the river has accepted a much narrower bed.)

15 Afflux caused by guide banks flooded some villages. (This mistake occurred because the recce, survey, and construction officers did not calculate probable afflux and did not examine the levels of the country in the immediate neighbourhood of the site.)

16 More money was spend on the approaches to a bridge than on the bridge itself. Had the bridge been built 200 ft upstream, the total cost would have been halved

The mistakes quoted are mistakes that have actually occurred in the past. The list could be made much longer. In nearly every case the mistake arose because, first, the recce officer and then the survey and construction officers, had their noses glued to a particular site and neither looked upstream nor downstream, nor did they look to the right or the left hand approaches to the bridge. They where obsessed with a particular BRIDGE SITE.Let the Recce officer look upstream and downstream of the river and to his right and left on the banks. Let him then make sketches of what he sees, putting in names of villages, a north point, direction of flow of his river, sketches of hills and nallas, temples and graveyards, in fact, of obstructions of all kinds. Let him (1) Use his eyes, and (2) Record what his eyes have seen.

ANNEXURE – 6.4

DESIGNS CIRCLE (B&C) SURVEY FOR MAJOR BRIDGES

CHECK LIST FOR SURVEY DATA FOR MAJAR BRIDGES

Issued vide SEDC ,Bombay letter no T-19 1736,29 Dec 1969
Incorporating the requirements as per I.R.C. Clause 101 and
modifications thereto as per our practice)

List of check points

The following is the list of the check points to be observed by local officers before submitting the survey data of major bridge work to Designs Circle.

10 Survey data should invariably be submitted in duplicate.

11 A Brief note explaining existing crossing and interruptions to the traffic it causes, necessity of the bridge, the area it will serve, the importance of the road and the urgency of work should accompany the survey data. Please mention separately if the work is budgeted, or included in the Plan etc.

The note should mention other bridges on the same river 100 km upstream and downstream of the site proposed, are under construction or investigation. Existing bridges rail and road on the same stream within 50 miles upstream and downstream of the proposed site should also be indicated.The note should explain the reasons for selection of bridge site. A suitable road level, as would not cause more than permissible interruptions to traffic, for a submersible bridge should also be indicated provided a submersible bridge would be sufficient to meet the requirements of traffic. If otherwise, a specific mention that a high level bridge is necessary should be made in the note.In case, there are any existing and or proposed road or railway bridges on the same river in the vicinity, the details of waterway and foundation condition should be mentioned in this note.

The note should also give the following details –

10 HYDRAULIC DATA

Size and shape of catchment.

Intensity of rainfall in cms per hour and per day and its frequency in the catchment.

Longitudinal and cross wise slope of catchment.

Nature of catchment - Whether under forests, under cultivation or urban etc.

Nature of soil crust in the catchment - Whether porous or rocky etc.

Storage, artificial or natural, in the catchment.

The possibility of subsequent changes in the catchment like aforestation, deforestation, urban development, extension of or reduction in cultivated area etc.

A chart of the periods of high flood levels for as many years as the relevant data are recorded. If no flood data exist max: H.F.L. should be determined with the help of flood marks and local inquiry. Opinion of the field officer as to the reliability of flood marks and information should also be given. Any other information affecting design, including geometric specifications.

Hydraulic calculations by channel formula. Preferably Manning's formula should be adopted.

$Q = (1.486/n) \times M^{2/3} \times I^{1/2}$ Where 'Q' is discharge in cusecs.

'n' is coefficient of rugosity

'M' is hydraulic mean depth

'I' is hydraulic gradient.

Discharge should be worked out for the max: HFL and compared with those obtained by empirical formulae such as Inglis' formula etc.

If the river section is divided into various compartment, the value of n, the rugosity, coefficient, for each compartment should be fixed with a good judgement and reasoning.

(B) GENERAL

The category of road along which the bridge lies. Mention if there are any chances of upgrading the road. Also state whether the road is existing or under construction. If under construction, furnish the detailed position and progress of work.

If the road is an O.D.R., state whether a single lane high level bridge or a double lane submersible bridge will be preferable.

If the bridge site is inspected by any higher officer, attach a copy of the Inspection Note.

State and give details if possible of any existing or under construction or contemplated Irrigation works on the same river or its tributary in the vicinity of the bridge (Both up-stream and down-stream) which are likely to affect the design of the bridge.

AVAILABILITY OF MATERIALS :

Complete and exhaustive information in respect of availability of materials useful for the construction of the proposed bridge should be given as per the accompanying statement.

(I) SURVEY DATA PLANS :

The following plans should be submitted for a complete and proper appreciation of the bridge project.

1. INDEX PLAN MAP

It should be plotted to scale of 1":1 mile and should extend to one important town (Preferably Taluka place or Municipal town) on either side of the proposed bridge.

It should show :

10 The existing bridges along the road.

11 The bridges under construction.

12 Other bridges under investigation.

13 The location of the proposed bridge.

14 Other unbridged crossings.

15 Alternative sites investigated for the proposed bridge under consideration.

16 The existing as well as proposed roads as per District Road Planning together with their classifications.

17 The general topography of the country.

18 Other important towns within the scope of the map.

19 North line (Which should be vertical).

2. CATCHMENT AREA PLAN

This should be prepared from topo sheets to a scale of 1":1 mile and should cover the entire catchment area showing the details of various streams. The plan should be prepared with North line pointing due North i.e. top of plan.

In case of catchment area above 200 Sq. Miles, the scale may suitably be changed to 1":4 miles.

A reference to all the topo-sheets covering the entire catchment should be given so as to facilitate independent checking of the C.A. This should be shown by a grid.

On this plan also show the positions of irrigation works on the upstream and or downstream side of the bridge, that are likely to affect its design.

3. A CONTOUR SURVEY PLAN

It should show all topographical features such as local high spots and depressions etc. that may influence the location and design of the bridge and its approaches. All sites for crossings worth consideration along with their approach alignment shall be shown on the plan. It shall extend to about 10' above and the highest flood level known or covering a portion of ground equal to twice the river width on either side of the river whichever is less. On the upstream and downstream side of the range of the river within which alternative sites have been recommended, it shall extend to the following limits.

(a) C.A. less than 3 sq.km-100m

(b) C.A. less than 15 sq.km-300m

(c) C.A. less than 250 sq.km-750m

(d) C.A. more than 250 sq.km-1500m

The contour plan should be based on cross sections to be taken as detailed further . The base line which should be an unclosed traverse following generally one bank or bed of the river course as may be convenient, and the various cross section line (which should generally be at right angles to the base line) should be clearly indicated on the contour plan. All spots levels taken should be shown correct to one place of decimal only.

It should also show :-

10 North line.

11 Direction of flow; H.F.L., O.F.L., L.W.L., H.T.L., L.T.L., etc.

12 Inactive river terraces.

13 Exact extent of exposed rock, located by offsets from base and cross section lines, positions of trial pits or bores.

14 Boundary of built up area and important buildings nearby and all other permanent stray structures and miles and furlong stones on the roads.

15 Existing road alignment.

16 Alternative bridge sites with their approach alignments.

17 Position of openings of the existing bridge or causeway, if any within the scope of the plan.

18 Angle of skew of proposed crossing (if any).

19 All important B.M.S., their location and values.

20 The general contour interval should be not more than 1 m. For rivers having shallow and wide basin with low banks, contour interval should be reduced suitably.

4. A SITE PLAN

(In case of stream with a C.A. of not more than 25 sq.miles this may be combined with contour plan only).

It shall be drawn to a scale of 1cm = 20m and should show all alternative alignment with approaches.This shall extend 100m on either side of the centre line for small stream and 500m for major crossings. It shall show the following details.

(a) The name of the stream or bridge and of the road and the identification number allotted to the crossing

(b) The approximate outlines of the banks, the high water channel (if different from the banks) and the low water channel.

(c) The direction of flow of water at maximum discharge and if possible, the extend of deviation of lower discharges

(d) The north line.

(e) The alignment of existing approaches and of the proposed crossing and its approaches.

10 The angle and direction of skew if the crossing is aligned on a skew.

11 The name of the nearest inhabited identifiable locality at either end of the crossing on the roads leading to the site

(h) References to the position (with description and reduced level) of the bench marks used as datum

12 The lines and identification numbers of the cross sections and longitudinal sections taken within the scope of the site plan. and the exact location of their extreme points.

13 The locations of trial pits or boring each being given an identification number.

14 The location of all nallas, buildings, walls outcrops of rocks, and outer possible obstructions to a road alignment.

15 The soil strata, the extent of exposed rock with their chainages along the bridge line etc.

16 The position of bores or trial pits.

In case of streams with a gorge width of 500' and more the following additional information shall be given.

Along the finally selected or recommended alignment a strip of 200' width (i.e. 100' on either side of the bridge centre line) should be completely charted by a chain and compass survey and plotted to a scale of 1"-40' showing the salient features falling within the strip such as exact rock exposures, pools or water, various soil strata, contours at 1' interval, bank lines(i.e. the position of effective gorge of the river), the H.F.L., L.W.L., etc. This strip should extend along the alignment to 5' above the H.F.L. and levels should be taken at very close intervals, say at every 10' or closer at obligatory points. Chainages along the alignment should also be marked on this plan.

5. A VILLAGE MAP

The village map should be prepared with North line so pointing that the diversion i.e. road alignment as chained and levelled, runs roughly left to right of the paper (i.e. chainage should be progressive from left to right).

This should extend to the same limits as those of the site plan or upto half a mile or existing road beyond diversion points on either side, with a minimum size showing an area 1 and 1/2 mile long along the road and 1 mile wide.

It should show the following details :-

10 Alternative bridge sites together with their approach alignments on both banks, Details of curves should specifically be given.

11 Name of stream direction of flow at maximum discharge.

12 Angle and direction of a skew crossing if any.

13 North point.

14 Exact extend and nature of built-up area along the approaches (e.g. Kutcha or pucca structures etc.)

15 Type of the land near the approaches showing the location of wells if any. (i.e.) Bagayat land or waste land etc.

16 The position of bores and trial pits.

6. A CROSS SECTION OF THE RIVER AT THE PROPOSED BRIDGE SITE AND ALONG APPROCHES.

This should be plotted to the scale of 1" = 100' horizontally and 1" = 10' vertically, and should include the following information :-

10 The name of the stream and the serial number allotted to the crossing if any.

11 The name of the road with mileage and chainage of the centre of the crossing.

12 The bed lines upto the top of banks and the ground line with levels at intervals sufficiently close, to give a clear outline of markedly uneven features of the bed and banks. On the banks, the levels should be taken at every 25' while in the active gorge portion of the stream, levels shall be taken at every

10' for the river width upto 200'

20' for the river width upto 500'

and 25' for the river width exceeding 500'.

The chainages marked on the cross section should be continuous from left end to the right end as far as possible. While looking towards the downstream side of the stream, the bank to the left shall be called the left bank and shall preferably lie on the left side of the drawing.

The practice of giving distances in between the two level points shall be totally discouraged.

(d) Low water level, ordinary flood level and the Highest flood level, known in human memory. L.W.L. should be that particular level generally obtained in the month of February. If the water level as observed on any subsequent data is shown the data should be indicated against it into brackets. The ordinary flood level may be defined as that flood level which is not exceeded by more than 6 times in a year, each time duration being not more than 72 hours.

If the bridge site is affected by back water, its details should be given i.e. the normal back water level and the highest back water level. In case of tidal rivers L.T.L. if above bed and H.T.L. should also be given.

Flood levels should be ascertained as correctly as possible with the help of gauge posts if any or from information locally available.

(e) The nature of the surface soil in bed, banks and approaches with trial pit and bore log sections showing the levels and nature of the various strata, suitable for foundations. The safe intensity of pressure on the proposed foundation soil should be indicated from local knowledge.

Fair weather flow in the river (during November to May) should also be reported.

(f) If a submersible bridge is tolerable with regard to traffic requirements a suitable road level which will give permissible interruptions as per I.R.C. clause 100.3 should also be shown on the cross section.

The cross section should be continued upto the point of diversion on the existing road and one furlong along it on either side showing on it the position of permanent features of the existing road such as mile and furlong stones, cross-drainage works with their distinctive number etc. etc.

The cross section shall extend to at least 5' above the maximum H.F.L. or back-water level which ever is higher. Whether this section is not at right angles to the river flow upto 5' above the H.F.L., an additional section exactly at right angles to the river and rising 5 feet above the H.F.L., should be taken and furnished, showing all the above information. This is required for hydraulic calculations.

7. VARIOUS OTHER CROSS SECTIONS

In addition to the cross section at the proposed bridge site, further cross-sections should be taken at alternative sites and also at suitable intervals both upstream and downstream of the proposed bridge, extending upto limits as indicated below :-

(a) For catchments upto 25, sq. miles c/s at 100' intervals upto 200' on u/s and d/s side.

(b) For catchments from 25 to 100 sq. miles c/s at 200' intervals upto 1000' on u/s and d/s side

(c) For catchments greater than 100 sq. miles c/s at 500' intervals upto 2500' on u/s and d/s side

The above cross sections should extend at least upto 5' above the H.F.L. or back water level whichever is higher and should indicate all such details as in the case of cross section at the proposed bridge, applicable site except the trial pit or bore results.

The scale of these cross sections should be 1' - 100' horizontally and 1' - 10' vertically, which may be suitably changed to 1" - 200' horizontal and 1" - 20' vertically in certain special cases.

8. A LONGITUDINAL SECTION OF THE STREAM

This should be plotted upstream on the left side.

This should show the following details :-

(a) The site of the bridge.

(b) The H.F.L., O.F.L., L.W.L., H.T.L., L.T.L., max. B.W.L. and bed levels at suitably spaced intervals along the approximate centre line of along the approximate centre line of the deep water channel.

The L-Section should extend to the same limits as those of the contour plans and should be drawn to the same horizontal scale as that of the contour plan. The vertical scale should be 1" - 10'.

If there is any existing road or railway bridge over the same stream within a distance of 1 mile on the upstream or downstream side, the L-Section should be extended to cover that bridge and all water levels as indicated above at this bridge should be given.

Hydraulic gradient if observed during floods should be clearly marked on this L-Section.

HYDRAULIC GRADIENT

Observation of hydraulic gradient need to be carried out with great attention by local observations without placing any reliance on local inquiry or on the bed slope of the river. Hydraulic gradient should be determined by simultaneously marking the flood levels either on a gauge post if already fixed or on a peg driver firmly for the purpose at two points at least 1/2 mile apart and then by connecting levels of these pegs. It will be desirable particularly in case of major rivers to fix five points in a length of 1 mile, one at the proposed site, and two each on up stream and downstream in order to get really representative and accurate figure for this very important items in the hydraulic calculations. Hydraulic gradients should be observed two to four times selecting normal, and high floods and the same given corresponding to each flood level for which it is observed.

9. RECORD PLAN OF THE EXISTING ROAD OR RAILWAY BRIDGE. ON THE SAME RIVER IN THE VICINITY.

In case, a record plan is not available, a cross section of the stream at that existing bridge should be taken and the following details shown thereon :-

(i) Total linear waterway between faces of abutments.

(ii) Number and clear size or sizes of spans maximum known H.F.L. ascertained from local enquiry, designed H.F.L. of the structure if available. Clearance available below bridge above maximum known H.F.L., Rail or road level, type of superstructure, foundation details (Open or wells or any other type) and such other information as may prove useful in the design of the proposed bridge.

In case of existing railway bridges the datum level for the same should be connected with that for bridge under survey.

SPECIAL NOTES

(a) In the case of a small project, it may be convenient to combine two or more drawing on one sheet.

(b) Every document shall contain the identification particulars of the crossing.

(c) Scale of scales shall be indicated on the drawings and all plans shall show the North point, bench marks, the direction of flow of the stream where necessary.

(d) The survey data should be connected to the nearest G.T.S.B.M. if easily available.

(R. T. Atre)	**(S. V. Natu)**
Executive Engineer	**Superintending Engineer**
Designs Circle (B & C),	Designs Circle (B & C),
Division No.II,	Bombay.
Bombay	

ANNEXURE 6.5

DESIGNS CIRCLE (B.& C.) SURVEY FOR MAJOR BRIDGES

Instructions on trial pits, punch bores, and bores

A. Trial Pits

I. Location

The spacing of the trial pits (on bore holes) should be such as to provide a full description of all substrata layers along the whole width of the gorge and the necessary width of crossing. Generally for small bridges, four trial pits would be sufficient - one on each bank if low or halfway the bank slope and two in the bed of the river approximately at ends of middle third.

The trial pits should be extended down to hard stratum. The nature of inflow of water at the time of taking trial pits (along with the date) should be reported. If necessary one or two pumps should be used in the trial pit to de-water the and their capacities and durations of working every day for initial dewatering and during excavation should be given also indicating the depth excavated every day.

When it is not possible to continue further with the work in trial-pits, further exploration may be done with probing.

Probing with 1 and 1/2" 0 pointed rock should extend upto 20' below the deepest bed of the river and the nature of strata within that margin should be reported. The penetration of such a crowbar at 20' depth (or earlier, if good soil is met with) when struck with a standard hammer (its weight and fall should be given). Should be reported.

10 Punch bores

This probing can be much more effectively done by the method of punch boring. Where bedrock is near, punch boring is sometimes used to secure information on the subsoil. The punch rod is of 7/8 or 1-in. steel with an enlarged point to make the hole slightly oversize (Fig.A). A set of these rods should be 4,8,12 and 16 ft. long. If it is necessary to go deeper than 16 ft. the rods should be made up with threaded ends. Punch boring have been made as deep as 40 ft.The rods are driven into the ground either with sledge hammers, or by weighting a removable cross arm clamped to the rod.

While two men rest their weight on the cross arm, two more men revolve the rod by pushing on the arms, thus twisting it into the ground. Every 4 feet, the rod is withdrawn. This can be done by slipping a ½ in. Plate over the rod and prying under one end of the plate as shown in (Fig.A.) or by making up an arrangement of two eccentrics as shown in (Fig.B) which allows two piers to be used at one time, giving straight lift. A soil sample is taken every 4 ft. by means of a “spoon” on the end of a ½ in. rod. Experienced punch bores claim they can detect by the sound of the rod, when the point is passing from the stratum to another. Similarly, there is a decided difference in sound when the rod strikes bed rock or a boulder.

BORES

Boring should only be resorted to in case of major rivers.If rock is exposed to a great extent, no bores be taken.Boring should be done with such a machine as to get a 4” 0 core.Two bores should necessarily be taken on banks - one on either side. In the river bed, the bores should evenly be spaced at 200’ intervals which may suitably be changed according to site conditions in each case.

The bores should extend at least 5’ in hard rock to offset the possibility of a boulder being mistaken for parent rock. If rock is not expected to be met with, the depth of bore shall be limited to 50’ or 1 and ½ times the flood depth whichever is deeper below the river bed level.

The cores should neatly be preserved in wooden boxes.

ANNEXURE – 6.6

STANDARD PROFORMA FOR SURVEY DATA FOR BRIDGE

(Length 30 m or more)

I. GENERAL

1 Road and its classification.

2 Name of the stream.

3 Road chainage at center line of the stream.

4 What arrangements exist for crossing river at present?

  10 During Monsoon.

  11 During dry season.

5 10 The existing road level connected to survey data of the crossing and details of interruptions

  11 Existing & expected traffic intensity on the bridge.

6 In which seismic zone the bridge site is located.

7 Authority for taking up the project.

8 Whether the bridge site is railway affecting work vide C.E.'s Circular No. HBS-1870/ 94658(0)–C, dt. 14.09.71.

9 Whether the bridge site is affected by any Irrigation Project and whether co-ordination with Irrigation Dept. as per Govt. Circular No. RR/174/6416-P(I), dated 9.8.74 is necessary.

10 Whether high level or submersible bridge is required.

11 If submersible bridge is proposed whether the OFL is reported taking into consideration CE's Circular no 5 of 74 vide no RRS 1074-26431-P(I) Dt-19.07.74

12 10 Whether details of existing or proposed road or railway bridges on the same river in the vicinity including details of waterway and foundation conditions and other details linked up with survey data are furnished.

  11 Give name & location of Bench Mark.

13 Whether the site is suitable for bridge cum bandhara as per Govt. Circular No. PLN-1072/ 119097-PI, dt. 14.11.73.

II. CATCHMENT AREA AND RUN-OFF

1 Catchment area.

10.1 In alluvial parts.

10.2 In plains.

10.3 Total Area in square km

2 Rainfall in cm per year in the region.

3 Maximum recorded intensity of rainfall in the catchment area.

4 Length of the catchment is km.

5 Width of the catchment in Km.

6 Longitudinal slope of the catchment.

7 Cross slope of the catchment.

8 Nature of catchment whether under forest, under cultivation or urban.

9 Are there any artificial or natural storage such as lake etc. In the catchment.

10 Nature of soil crust in the catchment, whether porous or rocky.

III. HYDRAULIC DETAILS

1 Is the stream

(a) Alluvial with erodible banks

(b) Quassi-alluvial with more or less fixed bed but erodible banks.

(c) Rigid with this erodible banks and bed.

2 Is the stream

(a) Perennial or

(b) Seasonable.

3 Is there any stagnant water pool near the site.

4 Does the stream change course and meander.

5 Are the banks at the proposed site.

10 Firm and steep.

11 Firm and gently sloping.

12 Does the stream confine itself within banks or overtop banks in floods.

6 Nature of stream in vicinity of the proposed site

10 Clean bed, straight banks no rifts or deep pools.

11 As in (a) but with some weed stones.

12 Winding, some shoals but clean.

13 As in (c) with weeds or stones.

14 Stones section with ineffective slopes and shoals.

15 Sluggish river reaches or weedy with deep pools.

16 With very weedy reaches.

7 What is the coefficient of rugosity in the bed and bank

8 Are there any active spills if so, what is the nature, cross section, and bed slope of the spills.

9 If there is considerable water spread, is the ground level low on u/s as well as d/and whether it is an effective decision charging section.

10 Details of various levels,

(a) Tide levels & distance from sea coast

M.H.W.S

M.H.W.S.

M.L.W.S.

L.L.W.S

(b) Flood levels.

H.F.L. (Observed)

H.F.L. (Inglis)

H.F.L. (Modified Inglis)

O.F.L.

(hydraulic calculations by Manning's formula should be attached.)

(c) Surface velocities.

At low water level.

At H.F.L.

At O.F.L.

11 Nature of river bed and strata below based on trial pits or bore results.

12 R.L. and location of maximum recorded scour (or cracks in case of clayey bed) if any.

13 R.L. of maximum anticipated scour (attach calculations separately.)

14 If tests are taken on samples of bores or pits for the strata available at different depths, state the type of test and properties ascertained. (give detailed results separately).

15 Allowable bearing capacity of the strata at foundation level in T/m^2

(i) Calculated theoretically.

(ii) Calculated by conducting a standard test.

16 Does the stream carry drifting materials in floods, if so, state the nature (such as bushes, trees, branches, boulders etc.)

17 Area the banks susceptible to scour if so, indicate the extent of cutting of banks that occurred in the past.

18 Is the stream navigable.

19 If so, the clearance required.

Horizontal clean spans/spans required.

Vertical clear above MHWS.

20 Are large scale river training works necessary.

IV. APPROACHES

Is the proposed alignment of the bridge skew or normal.

a) If skew give the angle of the skew.

b) Will the bridge be straight, if not give the radios of curves on right approach and lift approach.

c) Specify if there is any special requirement to be observed and approach gradients etc.

V. SUPERSTRUCTURE

10 Proposed clear roadway over the bridge.

11 Proposed width of footpaths if necessary.

VI. FOUNDATIONS

(a) what type of foundations feasible and recommended.

10 Open foundations.

11 Well foundations

12 Raft foundations.

13 Pile foundations.

(b) Probable cost of dewatering in case of open foundations/raft foundations.

VII. EXISTING STRUCTURES

Do any bridges exist on the stream? If so, have their positions been marked on index plan?

10 Size and No. of spans.

11 Type of substructure.

12 Type of superstructure.

13 Type and depth of foundations.

14 C/s area at H.F.L. under bridge.

15 Is the waterway found to be adequate or excess or inadequate.

16 Whether the foundations have been trouble free and depth provided is adequate or inadequate.

17 Any other information.

VIII. MISCELLANEOUS

(1) Name of nearest town and Railway station and its distance from site.

(2) Is space available at site or in the neighbourhood for construction purpose.

(3) Mention if any special considerations for effect of bridge on adjoining village etc. are to be taken into account.

(4) Lead at site of the following materials (give information in respect of items of materials applicable).

10 Masonry stones.

11 Sand for R.C.C. & Masonry work.

12 Aggregates for R.C.C. work.

(5) Have the following been enclosed duly completed? (Plans to be as per provision in clause 101 of I.R.C. bridge Code Section I).

10 Key map.

11 Index plan.

12 Contour survey plan.

13 Site plan.

14 At least three cross-sections.

15 Longitudinal Section & Hydraulic gradient.

16 Trial boring and pit charts.

The size of the drawing sheets (outside dimension) may be any one of the following but all drawing sheets for one project should be of the same

841 mm x 1189 mm.

594 mm x 841 mm

420 mm x 594 mm

297 mm x 420 mm.

Size at sr. no 3 is preferable as it is approximately equal to drawings prepared for IDA projects

Deputy Sub Divisional Engineer	**Executive Engineer** R. P. Division

Proposed site for the bridge has been by

Other remarks considered worth mentioning by Superintending Engineer.

Superintending Engineer,
P.W. Circle

ANNEXURE – 7

TYPICAL EXAMPLE OF PROJECT PREPARATION

Name of Work

Construction of single lane submersible bridge across Gadhi River on Panvel- Vichumbe Road.

INDEX

10 General Description

11 I.R.C. paper clause 101

12 Standard proforma for Survey Data for Bridge

13 Discharge calculations

14 Discharge calculations by Mannings formula.

15 Plans

Name of work

Construction of single lane submersible bridge across Gadhi River on Panvel- Vichumbe Road.

GENERAL DESCRIPTION

Introduction :

The villages Vichumbe and Usaroli are very near to Panvel Taluka.These villages are at present connected to Panvel Via.Bhingari village.The road length is 14.00 km.There is a Municipal Road from Panvel upto village Podi and beyond about 2 km.length.The village Podi is on one side and villages Vichumbe and Deod are on the other side of the Gadhi River.At present people of these villages cross the river by Railway Bridge of Panvel-Roha Railway line on foot.The villagers have demanded the bridge.If this bridge is constructed, the people of village Deod and Vichumbe village will have direct contact with Panvel Town and also will be in position to go to Industrial area for work.The people of these two villages will be benefited having population of about 1500 Nos.The work is proposed to be included in 1992-93 Budget list.

Necessity :

At present the people are crossing the river on foot through Railway Bridge.If this bridge is constructed about 8 to10 km.Distance will be saved and people will be a position to go for work in Panvel Industrial Area.

Selection of Site :

As such three sites have been surveyed for the construction of the bridge, the merits and de-merits are given below :

Site No.1 near Mahadeo Tample at Ch.0 : This site is proposed by the villagers.The open foundations are there and the width of gorge is about 66 m.This site is on the nose of the curvature of River.This site is also having larger depth of water at the centre.Hence is not suitable for the bridge. Scouring has taken place at U/s and D/s of this site.

Site No.2 180 M.on D/s of Site No.1 : This site is having straight crossing but is at the end of curvature of the river.This site will have no land acquisition problem.Exposed rock is seen in the bed.

Site No.3 at 215 m. D/s of Site No.1 : This site is having straight crossing.C.I.D.C.O. Road coming from Panvel side meets this Bridge on Podi side bank.The banks are firm and straight.This site may cause some land acquisition problem for only 60 m. length.But this site is suitable for construction of bridge.

Proposal :

It is proposed to construct a single lane submersible bridge clearing O.F.L. R.L.97.946 m.The length of bridge of about 60 m. would be required.Open foundations are proposed since exposed rock is seen in the bed.

Catchment Area :

The catchment area of the river is observed from Topo sheets and is about 161.08 sq.km.The shape of the catchment is almost oval shaped comparing partly in hilly area, partly in paddy fields.

Rain Fall Data :

The annual rail-fall data for the last 6 years as collected from the records of statistical office, Alibag is as under :

1987	2159 mm
1988	3169 mm
1989	2520 mm
1990	4187 mm
1991	2847 mm
Average	2900 mm

Hydraulic Data :

The hydraulic details of the river at 300 m. D/s of site No.1 are given below :

Catchment Area	161.08 sq.km
Discharge by Inglis Formula	1540 cumecs
Dischare by Run Off Formula	3464 cumecs
Discharge by Mannings Formula at H.F.L.R.L.98.620 m.	1005 cumecs
Discharge by Mannings Formula at O.F.L.R.L.97.945 m.	715 cumecs
Hydraulic Gradient	1 in 600
Maximum Velocity of Water	3.45 m./s
H.F.L.R.L	98.620 m.
O.F.L.R.L.	97.945 m
Lowest Water Level	
Nature of Bed	Rocky in main Gorge portion
Line or Waterway required	60 m.
Line or waterway required by Lacey's formulae.	189 m

Plans :

The following Plans are submitted herewith.

10 Key Map

11 Index Map

12 Site Plan

13 Cross-section at proposed site No.1.

14 Cross-section at proposed site No.2.

15 Cross-section at proposed site No.3.

16 Cross-section at proposed at 50 m. u/s.

17 Cross-section at proposed at 300 m. u/s

18 Cross-section at proposed at 50 m. d/s.

19 Cross-section at proposed at 300 m. d/s.

20 Cross-section at proposed at existing Railway Bridge

21 L-section of the river bed.

The detailed hydraulic calclulations alongwith questionnaire as per I.R.C.Paper Clause-101 and Standard Proforma for Survey Data for bridges are also submitted.

Sd/-	Sd/-
Sub-Divisional Engineer,	Executive Engineer,
Road Project Sub-Dn.,Mahad.	Road Project Dn.Mahad.

Name of work :

Construction of single lane submersible bridge across Gadhi River on Panvel-Vichumbe Road.

Preliminary Data for Major Bridge.

I.R.C. Paper Clause 101

Questionnaires	Reply
1 An Index Map	Yes. To a scale of 1"=1 Mile and a Key Map to a scale of 1" = 4 mile showing portion of bridge site is given
2 A Contour Survey Plan	--------------
3 A site plan with the following details	
a. The name of stream and road	Yes. Gadhi River on Panvel Vinchure Rd. V.R.No.55.
b. Approximate outline of the bank	Yes. Shown
c. Direction of Water flow	Yes. Shown
d. North Point	Yes. Shown
e. The alignment of approaches and of the proposed crossing.	Yes. Shown
f. The angle & direction of skew, if any	Square crossing
g. The name of the nearest inhabitated identifiable facility at either ends of the crossing on the roads leading to the site	Village Vinchumbe on east side and existing Panvel Adal Rd VR 38
h. Reference to the position with description of the Bench mark used as Datum	Arbitory Bench Mark on Mahadeo Temple plinth & on CIDCO C.D.Work
j. Location of trial pits or bores each bearing identification	Exposed rock is seen at the site
k. The location of Nalla, Building walls and the possible obstructions to the road alignment.	Yes. One small nalla crossing in alignment no.2 and 3
4 A cross section of the river at the proposed bridge site with the following information	
a. Name of the stream	Gadhi River
b. Name of the Road with mileage and chainage at centre of crossing	Panvel-Vichumbe Road

Questionnaires	Reply
c. The bed line up to toe of banks and the ground line to a sufficient distance beyond the edges of the stream	Yes. Shown
d. Low water level	Yes. Shown
e. Ordinary flood level	Yes.Shown
f. Nature of surface in bed, bank and approaches with trial pits or bore holes sections	Bed- Rocky bed Bank - Soil & Gravel. Approaches - B.C.Soil
g. High flood level	Yes. Shown.
h Catchment area discharge and average velocity	Catchment area 161.08 sq.km Discharge1540 Cumecs. (as per Inglis Formula) Discharge: 3464 Cumecs (as per RunOff-formula) Discharge: 1005 Cumecs (by Mannings Formula)
5 Estimated depth of scour If scour depth has been observed the description or any other special causes responsible for the same.	
6 L-Section of the stream	Yes. Given. The bed gradient is worked out as 1 in 345.
7 The following details to be furnished	
a. The size of the catchment	
b. Shape of the catchment	Oval shape
c. Intensity and frequency of the rainfall in the catchment	2400 m
d. Slope of the catchment both longitudinal and cross-section	Section across the nalla and along the nalla are submitted
e. Nature of the catchment whether under forest under cultivation,urban etc	Partly under forest partly under cultivation & partly under Urban area

Questionnaires		Reply
f.	Possibility of subsequent changes in the catchment area like aforestation, extention or reduction in cultivated area.	No such possibility
g.	Storage artificial or natural in the Catchment. A chart of the period of HFL for as many years as the relevant data are recorded	---------
h.	Important details of the bridge crossing on the same river within a reasonable distance	Yes. Existing Railway bridge at D/s 580 m of the proposed bridge site and about 2 km D/s existing on Mumbai-Pune National Highway
i.	Maximum permissible vertical channel clearance and the basis of special requirement for navigation	No such case
j.	Liability of the site for any Earthquake disturbance	Area falls under seismic Zone No.III
k.	Brief description of reasons determining particular site selection for crossing accompanied if necessary with alternatives of suitable crossings on u/s and d/s	The site is having square crossing exposed rock and is near to the CIDCO Road on Panvel side, hence site No.2 or 3 are feasible
l.	The live load for which the bridge is to be designed	For I.R.C.Class-AA loading
m.	Any other information affecting design including geometrical specification	
n.	Is there any tidal effect	

Sd/-
Sub-Divisional Engineer
Road Project Sub-Division
Alibag

Sd/-
Executive Engineer
Road Project Division
Mahad

Name of work

Construction of a single lane submersible bridge across Gadhi River on Panvel-Vichumbe Road.

Standard Proforma for Survey Data for Bridge

I	**GENERAL**	
1	Road and its classification	Panvel Podi Vichumbe Deod Rd.V.R.No.55.
2	Name of stream	Gadhi river
3	Road chainage at centre of stream	Panvel Pune Rd NH4 ch. 3/00
4	What arrangements exist for crossing river at present	
	a. During monsoon	For pedestrians From railway over bridge For vehicles From bridge on N.H.4 to Bhingari and Bhingari to Vichumbe which is a longer route.
	b. During dry season	
5	a. The existing road level connected to survey data of the crossing and detail of interruptions	On Mahadeo temple plinth assumed as 100m Railway bridge abutment top
	b. Existing and expected traffic intensity on the bridge	300 to 600 MT/day
6	In which seismic zone the bridge is located	Seismic zone III
7	Authority for taking up the project	GOM letter no.plan/3290/27914/(648)/no 1/ dated 13.12.90
8	Whether the bridge site is a railway affecting work vide CE's circular no. HBS-1870/94658(O)-C,dt 14.09.71	No
9	Whether the bridge site is affected by any Irrigation Project and whether coordination with I and PD dept as per Govt. circular no.RR/174/6416-P(I) dated 9.8.74 is neccesary	No

10	Whether high level or submersible bridge is required	Single lane submersible bridge would be sufficient
11	If submersible bridge is proposed whether the OFL is reported taking into consideration CE's circular no.5 of 74 vide no.RRS 1074-26431-P(I),dt 19.07.74	Yes
12	a Whether details of existing or proposed road or railway bridges on the same river in the vicinity including details of waterway and foundation conditions and other details linked up with survey data are furnished	Existing railway bridge is there at 600m d/s of proposed bridge side having 6 spans of 13.5 m c/c with open foundation. Road bridge is also there at about 3 km d/s of proposed bridge on NH 4.Details will be submitted in due course
	b Give name and location of bench mark	TBM is located on Mahadeo Temple by the side of the river having value as 100m
13	Whether the site is suitable for bridge cum bandhara as per Govt circular no. PLN-1072/119097-PI,dt 14.11.73	Yes.But there is Kolhapur type Bandhara at 2 km from the site

II CATCHMENT AREA AND RUNOFF

1	Catchment area	
	a In Alluvial parts	61.08
	b In Plain	100.00
	c Total area in sq.km	161.08 sq. km
2	Rainfall in mm per year in the region	2400 mm
3	Maximum recorded intensity of rainfall in the catchment area	4187 mm
4	Length of the catchment in km	10.50 km
5	Width of the catchment in km	17.50 km
6	Longitudinal slope of the catchment	1 in 600
7	Cross-slope of the catchment	
8	Nature of the catchment whether under forest,under cultivation or urban	

9	Are there any artificial or natural storage such as lake etc.in the catchment	Only Kolhapur type Bandhara is on d/s at 2 Km.
10	Nature of soil crust in catchment. Whether porous or rocky.	In alluvial rock and in plain paddy fields
III	**HYDRAULIC DETAILS**	
1	Is the stream	
	a Alluvial With erodible banks	
	b Quasi- alluvial with more or less fixed bed but with erodible banks	Yes. Gorge Alluvial with more or less fixed but errodible banks
	c Rigid with erodible banks and bed	Exposed rock is seen in the 75% width of the Gorge the remaining 25% sand in the bed.
2	Is the stream	
	a Perennial	Perrenial
	b seasonal	
3	Is there any stagnant water pool near the site	No. Back water effect is there due to tidal variations.
4	Does the stream change its course or meander	Yes
5	Are the banks at the proposed site	
	a Firm and steep	Yes
	b Firm & gently slopping	—
	c Does the stream confine itself within banks or over tops banks in floods.	Over tops when flooded
6	Nature of the stream in the vicinity of the proposed site	
	a Clean bed, straight banks no rifts or deep pools	Clean and straight banks
	b As in (a) but with some weeds, stones	
	c Winding some pools and shoals but clean	
	d As in ©with weeds or stones	

	e	Stony sections with ineffective slopes and shoals	Stony sections with ineffective slopes and shoals
	f	Sluggish river reaches and weedy with deep pools	
	g	With very weedy reaches	
	h	What is the coefficient of rugosity in bed and banks	Compartment no. 1- 0.030 Compartment no.2 –0.035 Compartment no.3 –0.025
7		Are there any active spills? If so what is the nature of cross section and bed slopes of the spills.	The additional discharge of sewage disposal of some of the area of New Panvel by CIDCO is done
8		If there is considerable water spread, is the ground level low on u/s as well as d/s and whether it is an effective discharging section	Water spreads in 100m u/s and d/s section,but does not effect the discharging section
9		Details of various levels Tide levels and distance from the sea coast (MHWS,MLWS)	No considerable effect is there of tidal variation
		Flood levels	
		HFL(observed)	98.6
		HFL(Inglis)	99.00
		HFL(Modified Inglis)	
		OFL	97.945
		Hydraulic calculations by mannings formula should be attached	Attached herewith
		Surface velocities	
		At LWL	2.00 m/s
		At HFL	3.43 m/s
		At OFL	2.75 m/s
10		Nature of the river bed and strata below based on trial pits or bore results	Exposed rock is seen in 75 % bed portion
11		RL and location of maximum recorded scour(or cracks in case of clayey bed) if any	No record is maintained

12	RL of maximum anticipated scour (attach calculations separately)	6.74 m below HFL RL 98.60 m
13	If tests are taken on samples of bores or pits for the strata available at different depths state the type of the test and properties ascertained(give detailed results separately)	No tests are taken.
14	Allowable bearing capacity of the strata at foundation level in Calculated theoretically T/m^2 Calculated by conducting standard test	 200 T/m^2
15	Does the stream carry drifting materials in floods.If so , state the nature (such as bushes,trees,branches,boulders etc)	Bushes ,trees and branches
16	Are banks susceptible to scour if so indicate the extent of cutting of banks occurred in the past	Yes scouring of banks has taken place, but is very less
17	Is the stream navigable If so the clearance required Horizontal clear spans required Vertical clearance above MHWS	Yes Not required Not required
18	Are large scale river training works required	No
IV	**APPROACHES**	
	Is the proposed alignment of the bridge skew or normal If Skew give the angle of skew	Normal
	Will the bridge be straight, if not give the radius of curves on the right and left approach	Straight
	Specify if there is any special requirement to be observed and approach gradients	For 30 m on either side of the bridge pitching will be required to the approaches
V	**SUPERSTRUCTURE**	
	Proposed clear road way over the bridge	4.25 m

	Proposed width of footpaths if necessary	—
VI	**FOUNDATIONS**	
	What type of foundations are feasible and recommended	
	Open	Open foundations
	Well	
	Raft	
	Pile	
	Probable cost of dewatering in case of open foundations/raft foundations	Cofferdam Rs.20000/- for each pier and abutment Dewatering Rs.20000/- for each pier and abutment
VII	**EXISTING STRUCTURES**	
	Do any bridges exist on the stream?	Yes
	If so have their positions been marked on the index plan?	Railway bridge at 600m d/s Road bridge at 3 km d/s
	Size and no.of spans	For railway bridge 7 spans of 13.5 m c/c
	Type of substructure	PCC for piers and abutments
	Type of superstructure	RCC girders and slabs
	Type and depth of foundations	Open foundation 1m below bed level
	Cross sectional area at HFL	attached
	Is the linear waterway found to be adequate or excess or inadequate	Adequate
	Whether foundations have been trouble free and depth provided is adequate or inadequate	Yes,trouble free
	Any other information	
VIII	**MISCELLENEOUS**	
	Name of the nearest town and railway station and its distance form the site	Panvel town at 4 km from the site
	Is space available at the site or in the neighbourhood for construction purpose	Yes,available at site only

Mention if any special considerations for effect of bridge on the adjoining village etc are to be taken into account	
Lead at the site of the following materials (Give information in respect of items of materials applicable	As per quarry chart attached
Masonry stones	
Sand for RCC and masonry work	
Aggregates for RCC work	
Have the following been enclosed duly completed(IRC clause 101)	
Key map	Yes
Index plan	Yes
Contour survey plan	Yes
Site plan	Yes
At least three c/s	Yes
Longitudinal section and hydraulic gradient	Yes
Trial boring and pit charts	No trial bores are taken as exposed rock is seen on the foundation
Proposed site is inspected by SEDC	No,site is not yet inspected by SEDC

Sub-Divisional Engineer	**Executive Engineer**
Road Project Sub-Div.No.2	Road Project Division
Alibag	Mahad

Name of work : Construction of single lane submersible bridge across Gadhi River on Panvel Vichumbe Road in Raigad District.

Discharge Calculations

Catchment area

Discharge as per Inglis Formula as per I.R.C. 13/1978

$$Q = \frac{125}{M+10}$$

$$= \frac{125 \times 161.08}{161.08}$$

= 1539.37 Cumecs.

say = 1540 Cumecs.

Discharge by Run-off Formula.

Q = 0.028 X 0.6 X 161.08 X 10 x 12.80

= 3463.86 Cumecs.

Say 3464 Cumecs.

Maximum velocity = 3.43 m/s.

$$\text{Ventway required} = \frac{\text{Discharge by Manning's Formula}}{\text{Velocity}}$$

$$= \frac{1005}{293 \ \text{sq. m.}}$$

Diff.between H.F.L.& Sill level = 98.00 – 93.170 = 5.43 m

$$\text{Linear waterway required} = \frac{293.00}{5.43}$$

= 53.95 m.

Linear waterway required by Lacey's formula.

W = 4.8 Q ½

= 4.8 x 1540 ½

= 188.36 m.

Say = 189 m.

Scour depth calculations

Normal depth of scour

$$R1 = \frac{0.473 \times 1005^{1/3}}{2.1}$$

$= 3.62m$

D = Q/WV = 1005/(54x2.76) = 6.74m

Sd/-
Sub Divisional Engr.
Road Project Dn.No.2,
Alibag.

Sd/-
Executive Engr.,
Road Project Dn.
Mahad.

Name of work : Construction of major bridge on Gadhi river near Vichumbe village in Panvel Taluka.

Discharge calculations by Mannings formula H.F.L.98.600 M.

Chainage	Bed level	Depth below in m	Mean depth in m.	Diff. In depth between two success-ive level(D)	length in m (L)	Area 4 x 6	Wetted Perimeter P = L2+D2 = (5)2+(6)2	Discharge
1.	2.	3.	4.	5.	6.	7.		8.
Comp.I								A/P = $\frac{36.785}{13.935}$ = 2.64
15	98.600	—						
22	95.250	3.350	1.675	3.350	7	11.720	7.76	V1 = (1/n1)$R^{2/3}$ $S^{1/2}$
25	94.210	4.390	3.870	1.040	3	11.610	3.175	= (1/0.03)x $2.64^{2/3}$ x 0.0016 ½ = 2.55 m/s
28	94.020	4.580	4.485	0.190	3	13.455	3.00	Q1 = 36.785 x 2.55
						36.785	13.935	= 93.80 Cumecs.
Comp.II								
28	94.020	4.580						A/P = $\frac{239.872}{46.06}$ = 5.20
31	93.570	5.030	4.805	0.450	3	14.415	3.03	
34	93.520	5.080	5.055	0.050	3	15.165	3.00	V2 = (1/0.035) 5.20 $^{2/3}$0.0016 ½
37	93.570	5.030	5.055	0.050	3	15.165	3.00	= 3.43 m/s
40	93.320	5.280	5.155	0.250	3	15.465	3.01	Q2 = 239.872 x 4.4
43	93.220	5.380	5.330	0.100	3	15.990	3.00	= 822.75 cumecs.
47	93.220	5.380	5.380	-	4	21.520	4.00	
50	93.170	5.430	5.405	0.050	3	16.215	3.00	
53	93.170	5.430	5.430	-	3	16.290	3.00	
56	93.320	5.280	5.355	0.170	3	16.065	3.00	
59	93.370	5.230	5.255	0.050	3	15.765	3.00	

Chainage	Bed level	Depth below in m	Mean depth in m.	Diff. In depth between two success-ive level(D)	length in m (L)	Area 4 x 6	Wetted Perimeter P = L2+D2 = (5)2+(6)2	Discharge
1.	2.	3.	4.	5.	6.	7.		8.
62	93.345	5.255	5.242	0.025	3	15.726	3.00	
65	93.370	5.230	5.242	0.025	3	15.726	3.00	
68	93.355	5.245	5.237	0.015	3	15.711	3.00	
71	93.420	5.180	5.213	0.065	3	15.639	3.00	
74	93.770	4.830	5.005	0.350	3	15.015	3.02	
						239.87	46.06	
Com.III								
74	93.770	4.830	4.620	0.420	3	13.86	3.03	$A/P = \frac{37.78}{21.76} = 1.74$
77	94.190	4.410	3.157	2.205	5	11.03	5.47	
82	96.395	1.905		0.990	3	4.36	3.16	$V3 = (1/0.025) \times (1.75)^{2/3} \times 0.04$
85	97.385	1.215	1.453	-	3	3.64	3.00	= 2.31 m/s
88	97.385	1.215	1.215	0.510	3	3.32	3.04	Q3 = A3 V3
91	97.895	0.705	1.107	0.450	3	1.44	3.03	= 37.78 x 2.3
94	98.345	0.255	0.480	0.255	1	0.127	1.03	= 87.27 Cumecs
95	98.600	-	1.127			37.780	21.76	Total discharge
								= Q1+Q2+Q3
								= 93.80+822.75+87.27
								= 1003.82 Cumecs.
								Say 1005 Cumecs.

Name of work : Construction of major bridge on Gadhi river near Vichumbe village in Panvel Taluka.

Discharge calculations by Mannings formula O.F.L.97.945 M.

Chainage	Bed level	Depth below in m	Mean depth in m.	Diff. In depth between two success- ive level(D)	length in m (L)	Area 4 x 6	Wetted Perimeter P = L2+D2 = (5)2+(6)2	Discharge
1.	2.	3.	4.	5.	6.	7.		8.
Com.I								A/P = 29.22=-2.29
16	97.945	—						12.76
22	95.250	2.695	1.345	2.695	6	8.09	6.58	V1 = (1/.03)x $2.29^{2/3}$ x $0.0016^{1/2}$
25	94.210	3.735	3.215	1.040	3	9.64	3.18	= 2.32 m/s
28	94.020	3.925	3.830	0.190	3	11.49	3.00	Q1 = A1 V1
						29.22	12.76	= 29.22 X 2.32
								= 67.79 cumecs.
Comp.II								
28	94.020	3.925						A/P = 210.34
31	93.570	4.375	4.15	0.45	3	12.45	3.03	46.06
34	93.520	4.425	4.40	0.05	3	13.20	3.00	= 4.566
37	93.370	4.575	4.50	0.05	3	13.50	3.00	V2 = (1/0.04) x $4.566^{2/3}$x
40	93.320	4.625	4.60	0.25	3	13.80	3.01	$0.0016^{1/2}$
43	93.220	4.725	4.67	0.10	3	14.01	3.00	= (1/0.04)x2.75x 0.04
47	93.220	4.725	4.725	—	4	18.90	4.00	= 2.75 m/s.
50	93.170	4.775	4.750	.050	3	14.25	3.00	Q2 = 210.34 x 2.75
53	93.170	4.775	4.775	—	3	14.32	3.00	= 578.43Cumecs.

Chainage	Bed level	Depth below in m	Mean depth in m.	Diff. In depth between two success-ive level(D)	length in m (L)	Area 4 x 6	Wetted Perimeter P = L2+D2 = (5)2+(6)2	Discharge
1.	2.	3.	4.	5.	6.	7.		8.
56	93.320	4.625	4.70	0.170	3	14.10	3.00	
59	93.370	4.575	4.60	0.050	3	13.80	3.00	
62	93.345	4.600	4.59	0.025	3	13.77	3.00	
65	93.370	4.575	4.59	0.025	3	13.77	3.00	
68	93.355	4.590	4.58	0.015	3	13.74	3.00	
71	93.420	4.525	4.56	0.065	3	13.68	3.00	
74	93.770	4.175	4.35	0.350	3	13.05	3.02	
						210.34	46.06	
Comp.III								R = A/P = 30.74 / 18.69 = 1.645
74	93.770	4.175						
77	94.190	3.755	3.965	0.42	3	11.89	3.03	V3 = (1/0.025)x1.645 $^{2/3}$ x0.04
82	96.395	1.550	2.650	2.205	5	13.25	5.46	= 2.22 m/s
85	97.385	.560	1.275	0.990	3	2.97	3.16	Q3 = 30.74 x 2.22
88	97.385	0.560	0.560	—	3	1.68	3.00	= 68.36 cumecs.
91	97.895	0.050	0.305	0.510	3	0.92	3.04	Q = Q1 + Q2 + Q3
92	97.945	—	0.025	0.050	1	0.03	1.00	= 67.79 + 578.43 + 68.36
						30.74	18.69	= 714.48 Cumecs.

NAME OF WORK : Construction on of single lane High level major Bridge across Gadhi river near village Vichumbe in Tal.Panvel Dist. Raigad.

June 1997

TECHNICAL NOTE

1. Introduction & Authority :

10.1 This proposal is for the construction of single lane High Level major bridge across Gadhi river near village Vichumba in Tal. Panvel Dist Raigad.

10.2 The village Vichumbe & Usaroli are very near to Panvel Taluka. These villages are at present connected to Panvel via Bhingari village. The road length is 14.00 km. There is Municipal Road from Panvel upto village Podi & beyond about 2 km. in length. The village Podi is on one side and village Vichumbe & Deod are on the other side of the Gadi river. At present people of these villages used to cross the river by Railway bridge of Panvel Roha Railway line on foot. The villages have demanded the bridge. If this bridge is constructed the people of village Deod & Vichumbe will have direct contact with Panvel town.2.

2. Selection of Site :

10.1 The proposed bridge site has been selected by the Superintending Engineer P.W.Designs Circle, Navi Mumbai during site visit on dated 24.1.94.

10.2 The proposed site is right angle to the river bed and c/s of the site is sent by Executive Engineer, Alibag (P.W.) Division Alibag vide letter No.AD/DB-I/12493 dated 23.12.96. The river bed is having exposed rock hence trial bores are not taken.

3. Hydraulics :

3.1 Hydraulics is done at the c/s proposed by Executive Engineer, Alibag (P.W.) Division, Alibag.

3.2 Hydraulic data submitted by Executive Engineer, Alibag (P.W.) Division, Alibag is detailed as below.

1	Catchment area	62.91 sq. miles
2	Discharge by Inglis Formula	1524.4490 cum/sec
3	Discharge by Manings formula at HFL RL 98.50	1508.889 cum/sec
4	O.F.L. R.L.	98.16
5	H.F.L. R.L.(Reported)	98.71
6	H.F.L. R.L. (Designed)	99.51
7	No. of compartments	3 nos
8	Rugosity Coefficient	
	For Bank on Panvel side	0.035
	For Bed	0.030
	For Bank on Vichumbe side	0.035
9	Maximum Mean compartmental velocity	4.27 m/s

3.3 H.F.L. R.L. is reported as 98.71 m. However, the discharge by Manning's formula fairly tallies with that by Inglis discharge at H.F.L. R.L. 99.51 m. Hence R.L. 99.51 m is considered for the design purpose.

3.4 The bridge is proposed to be designed as single lane high level bridge as requested by field officers.

4. Foundations :

10.1 The Executive Engineer Alibag (P.W.) Division Alibag reported that exposed trap rock is in the river bed hence open foundation is proposed. The foundation should be taken 2 m below the G.L. for pier and at abutment location and anchored in rock for minimum 1.50 m depth.

5. Proposal :

10.1 It is proposed to construct single lane high level bridge in between ch. 90 m to 150 m. having total length of bridge 60 m.

5.2 It is proposed to provide 6 span of 10.0 m c/c. With above proposal, the R.T.L. work out as below.

(i)	H.F.L. R.L.	.....	99.51 m
(ii)	Afflux (Assumed)	.....	0.600 m
(iii)	Vertical clearance (I.R.C.cl.106.2.1)	.....	1.200 m
	Soffit R.L. .	.....	101.31 m
(iv)	Depth of superstructure (for 10 m span s.s. M 25 grade)	.....	0.660 m
(v)	Wearing Coat	.....	0.075 m
	Road Top Level	.....	102.045 m

10.2 With the above proposal the percentage obstruction and afflux at H.F.L. works out to 19.70 % & 0.52 m respectively.

5.4 The bridge is to be designed for single lane of I.R.C. Class A loading.

6. Sub Structure :

6.1 It is proposed to provide solid type of piers and abutment as per Designs Circle type drawings.Piers and abutment are proposed in M 10.The top width of pier and abutment is 0.90 & 1.20 m respectively.The batter for piers is 1 in 25.

6.2 Solid returns in M 10 as per type plan are proposed for required length.

6.3 Surface reinforcement @ 5 kg/m2 is proposed for piers and abutments.

7. Superstructure :

7.1 Superstructure is proposed in M 25 as per Designs Circle's type plan of solid slab of 10 m c/c.

7.2 Tar paper bearing are proposed below the solid slab.

7.3 R.C.C. parapet is proposed as per type design.

8 Standards :

8.1 The bridge is proposed to be single lane high level bridge with clear roadway 4.25 m without footpath.

10.1 The bridge site lies in seismic zone III. However, the seismic design is not to be done as length of bridge is 60 m.

9. Miscellaneous :

9.1 The wearing coat is proposed of 75 m (avg) thickness with 50 BM + 25 AC.

9.2 The bituminous pad expansion joints are proposed.

9.3 The provision of water spout, should be as per MOST type design with 150 mm diameter pipes. Filling behind abutment & return shall be as per Appendix 6 of I.R.C.-78-1983.

10. Special Points :

10.1 The coefficient of rugosity for bed & banks are 0.03 & 0.035 respectively. This shall be confirmed.

10.2 The angle of skew is assumed to be zero degree which shall be confirmed.

10.3 Approach on both (left & right) side should be suitably protected by providing pitching against flood zone.

(D. P. Hadole)
Sub-Divisional Engineer,
Bridge Wing Unit-I,
Designs Circle,
Konkan Bhavan, Navi Mumbai.

(S. B. Tamsekar)
Executive Engineer,
Bridge Wing Unit-I,
Designs Circle,
Konkan Bhavan, Navi Mumbai.

(K. S. Jandge)
Superintending Engineer (Bridges),
Designs Circle, Konkan Bhavan,
Navi Mumbai