IRC:SP:66-2016

GUIDELINES FOR DESIGN OF CONTINUOUS BRIDGES (FIRST REVISION)

Published by:

INDIAN ROADS CONGRESS

Kama Koti Marg,
Sector-6, R.K. Puram,
New Delhi – 110 022

Price: ₹ 320/-
(Plus Packing & Postage)

IRC:SP:66-2016

First Published : **July, 2005**
First Revision : **December, 2016**

Printed by Intergraphic Reproductions Pvt. Ltd. New Delhi 110 020.
(1000 Copies)

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GUIDELINES FOR DESIGN OF CONTINUOUS BRIDGES

1.0 INTRODUCTION

1.1 IRC: SP:66 "Guidelines for Design of Continuous Bridges" was published by IRC in 2005. It is warranted to align these Special Publications of IRC with IRC:112 - "Code of Practice for Concrete Road Bridges", which is based on the Limit State approach.

1.2. Following is the composition of B-4 Concrete (Plain, Reinforced and Prestressed) Structures Committee (2015-17) of the Indian Roads congress:

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Nahar, Sajjan Singh	Secretary General, Indian Roads Congress

1.3. Mr. Alok Bhowmick, led the drafting team. The revised draft document was approved by Bridges Specifications and Standards (BSS) committee in its meeting held on 20.09.2016 and IRC Council at its 209th meeting held on 26.09.2016 at Kumarakom (Kerala).

2.0 SCOPE

2.1 Ministry of Road Transport & Highways (MoRT&H), Govt. of India in order to align itself with the globally best practices for economical, durable, speedy and aesthetic construction of "Bridge Structures", MoRT&H vide para 12 of the Circular No.RW/NH/-34072/1/2015-S&R(B) dated 18.08.2016, has decided that "due to assured quality, inherent economy, durability and low maintenance, precast and pre-stressed concrete may be used for various bridge components like box structures for culverts, deck slab, T-beam girder and box girders etc. These components may be procured by contractors or concessionaires from pre-casting factories, to be set up in all major states. Standard designs and drawings of any bridge components and their connections based on **Limit State Design philosophy as per IRC:112 (or other applicable international Specifications/ Standards) should be got approved by each factory owner from Ministry of Road Transport & Highways (M/o RT&H) before their usage in the construction of culverts and bridge structures on National Highways.........**" Further, MoRT&H in supersession of the MoRT&H's earlier Circular issued vide Circular No. RW-NH-35075/9/2006-S&R (B) dated 18.06.2014 (published at page No.42 of April 2012 edition of Indian Highways) vide which it was decided that the use of working loads/Allowable Stress methods as given in Annexure A-4 of IRC:112-2011 allowed to be followed till the end of year 2015 (i.e. upto 31.12.2015) in order to smooth transition and gradual acquaintance of practicing Engineers, has now vide Circular No. RW-NH-35075/9/2006-S&R (B) dated 02.09.2016 has decided that henceforth, all new bridges and its components shall be structurally designed strictly as per IRC:112 after following the "Limit State Design Philosophy" except those components for which IRC Codes and standards based on limit state philosophy are not available. Loading will be considered as per IRC:6 including 385 Tonnes Special Vehicle. Latest edition of the code notified/published either at the time of project consideration/ conceptualization or at least 60 days prior to the last date of bid submission need to be considered for this purpose.

2.2 However, owing to its merits being in line with the provisions of IRC: 112 besides the guidelines for Self-Compacting Concrete, various agencies other than national highways are warranted to follow these Guidelines/Norms for all bridge structures to be constructed on State Highways, Major District Roads, Rural Roads and Municipal roads etc.

2.3 The guidelines cover the analysis and design requirements for the following types of concrete bridges:

a) Continuous Bridges

b) Bridges made continuous through deck slabs.

The guidelines are applicable for the design of continuous type of bridges in reinforced concrete or in prestressed concrete or precast girder bridges made fully continuous for superimposed loads and live loads by providing in-situ concrete diaphragm at support or bridges with deck continuity. It shall be read in conjunction with the existing provisions in the relevant IRC codes. In case of any conflict with the present IRC:112, provisions of IRC:112 shall prevail over this document.

3.0 DEFINITIONS

3.1 Continuous Bridges

Continuous bridge is a bridge with the superstructure longitudinally continuous over intermediate supports. There are several methods of achieving the continuity in Superstructure. **Fig.1** shows some of such methods. This guideline do not cover continuous precast prestressed segmental bridges and continuous spliced girder bridges, for which reference may be made to other special publications of IRC.

3.2 Bridges made continuous through deck slab

These are bridges built using girders, which are simply supported, and made continuous through cast-in-situ deck slab.

4.0 IMPACT FACTOR

For continuous bridges, the live load impact factor shall be calculated in accordance with IRC:6.

5.0 ANALYSIS, DESIGN & DETAILING

5.1 Analysis

5.1.1 Method of analysis for determination of the forces and deformations, taking into account all aspects of response of the structure to loads and imposed deformations shall in general conform to provisions of Section 7 of IRC:112.

5.1.2 The effects of creep and shrinkage of concrete, temperature difference and differential settlements need not be considered while checking the safety against ultimate stage failure.

5.1.3 Secondary effects due to hyperstatic reactions of prestress shall be taken into account while analyzing the structure. For ultimate stage checks, the load factor for prestress (including the hyperstatic effects) shall be taken as 1.0.

5.1.4 Due account shall be taken of the change in nature of the structural system and in material properties that occur during the construction sequence of a continuous bridge. The behavior at any stage of the construction sequence shall be analyzed, duly taking into account the loading sequence as well as effect of redistribution due to creep, shrinkage and relaxation.

5.1.5 For continuous bridges construction using balanced cantilever technique, arrangement shall be made at the construction stage to accommodate asymmetric loads causing longitudinal bending moments due to load of unbalanced segments. This can be either in the form of temporary support to the deck during construction or temporary / permanent fixity of deck with pier.

5.1.6 The design for shear and torsion shall conform to provisions of Section 10 of IRC:112.

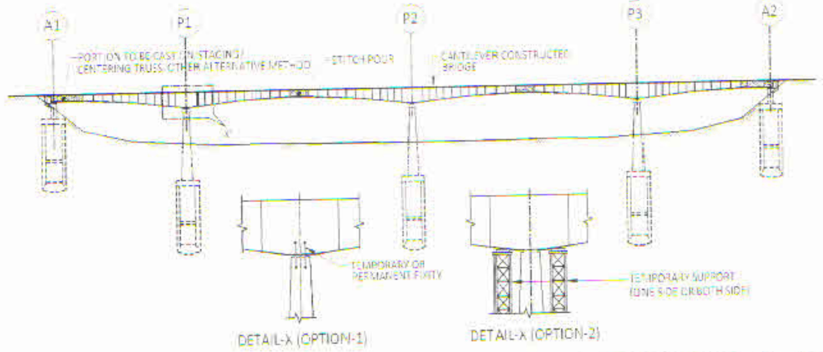
5.2 Design

5.2.1 The design bending moment over an intermediate support of a continuous deck, monolithic / supported on bearings may be calculated by equation :

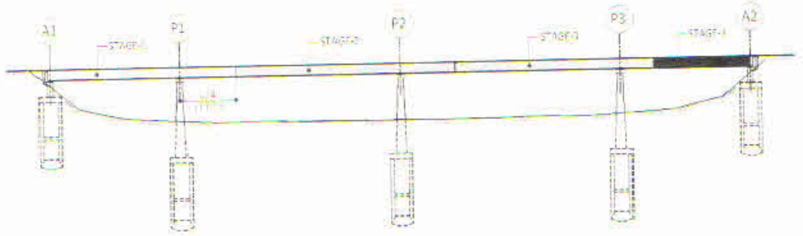
M_1 = $(M - q.a^2/8)$ or 0.9M, whichever is greater, where

M_1 = Design bending moment.

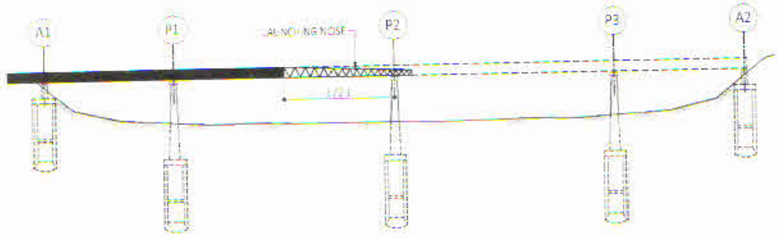
M = Analysed Bending moment at centerline of intermediate support.



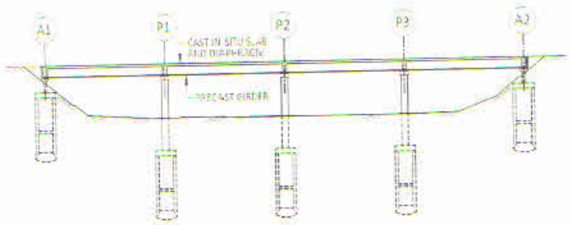
A) BALANCED CANTILEVER CONSTRUCTION TECHNIQUE (CAST-IN-PLACE)



B) SPAN BY SPAN METHOD



C) INCREMENTAL LAUNCHING METHOD



D) PRECAST GIRDERS MADE CONTINUOUS BY IN SITU SLAB & DIAPHRAGM (CONTINUOUS FOR SIDL & LL)

FIG. 1. METHODS OF ACHIEVING CONTINUITY IN BRIDGE SUPERSTRUCTURE

q = R/a

R = Reaction at the intermediate support

a = Width of Bearing / Support in the direction of span (Refer **Fig.2**).

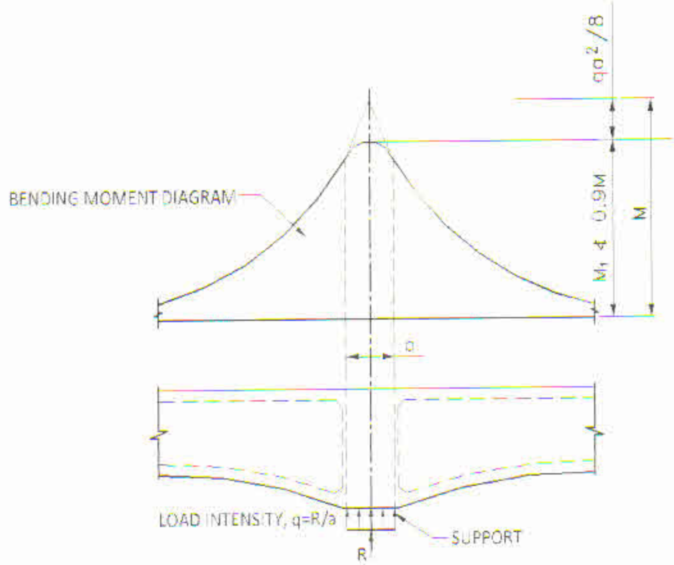


Fig. 2. design bending moment over an intermediate support

5.3 Detailing

5.3.1 Bearing Layout & Movements

The selection of the bearing type and the bearing layout in a continuous structure is an important task, which shall be established during the initial design process itself. The layout of the bearings shall correspond to the structural analysis of the whole structure. The expected bearing movements and rotations shall be determined taking into account the sequence of construction. In case of stage by stage construction, stability of the partially completed unit shall be ensured by suitable means, which shall be clearly spelt out by the designer in the working drawings. Some of the typical layout of bearings for continuous bridges with straight, curved and skewed alignments are shown in Figs. 3, 4 & 5 respectively.

The arrangement shown in Figs. 3, 4 & 5 are only indicative and any other layout / arrangement of bearings can also be adopted. Methods of analysis, shall take into account the bearing orientations to determine the bearing movements and corresponding forces transferred to the substructure.

5.3.2 The horizontal earthquake forces that are being transferred through the fixed bearing in a continuous bridge is usually large. There is a concentration of stress at the joint and suitable tie back reinforcement may be necessary at the junction of fixed bearing with deck. Additional reinforcement may be required to be provided within the influence width, in concrete adjoining the fixed bearing, which shall be designed to resist the horizontal force that is transferred through the bearings. These reinforcements shall be of length sufficient to ensure proper transfer of force. **Fig. 6** shows a typical detail of such reinforcement.

5.3.3 When couplers are used for extending prestressing cables, not more than 50% of the longitudinal post tensioning tendons shall be coupled at any one section.

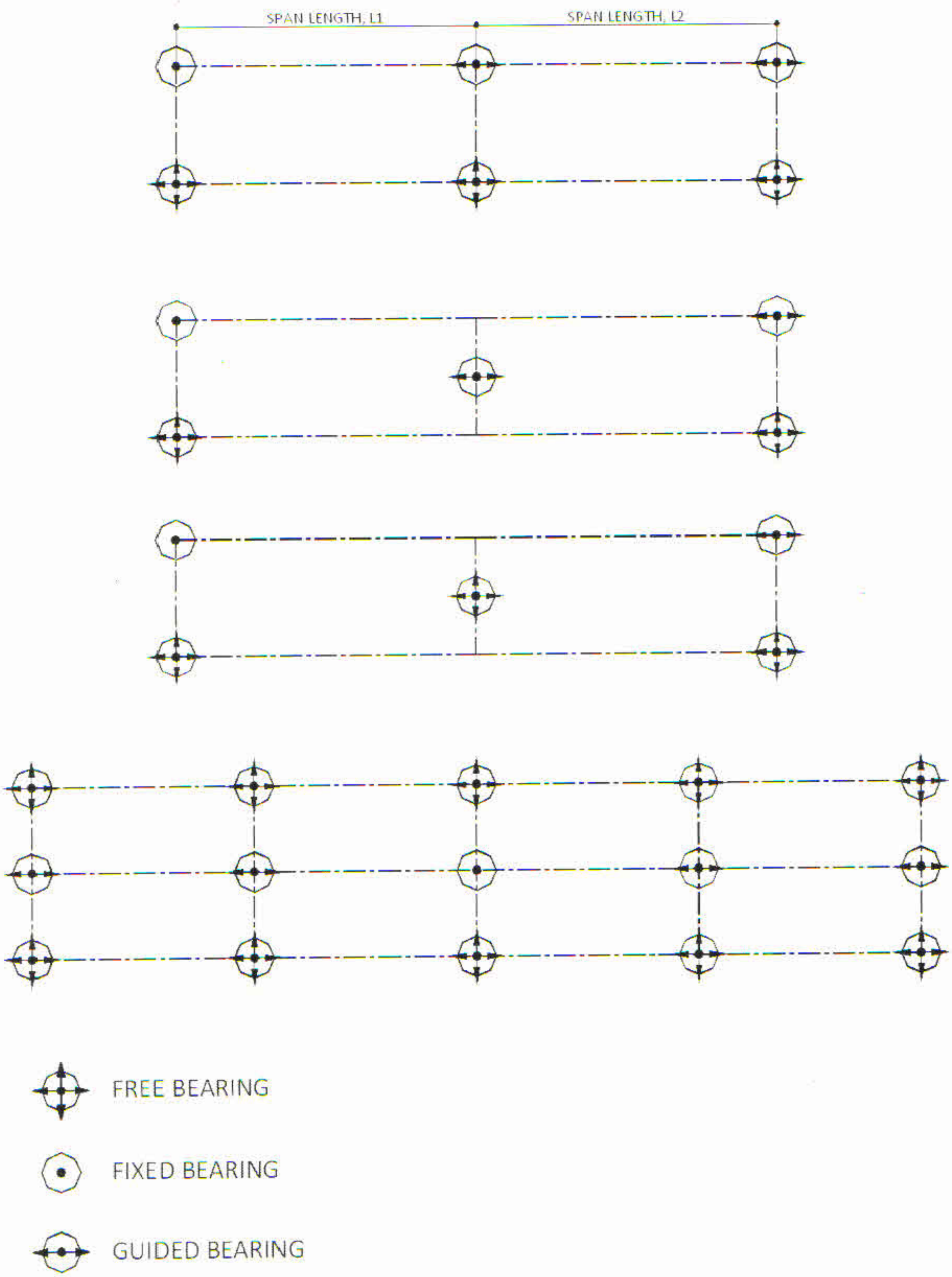


FIG. 3. TYPICAL BEARING LAYOUTS FOR STRAIGHT CONTINUOUS BRIDGES

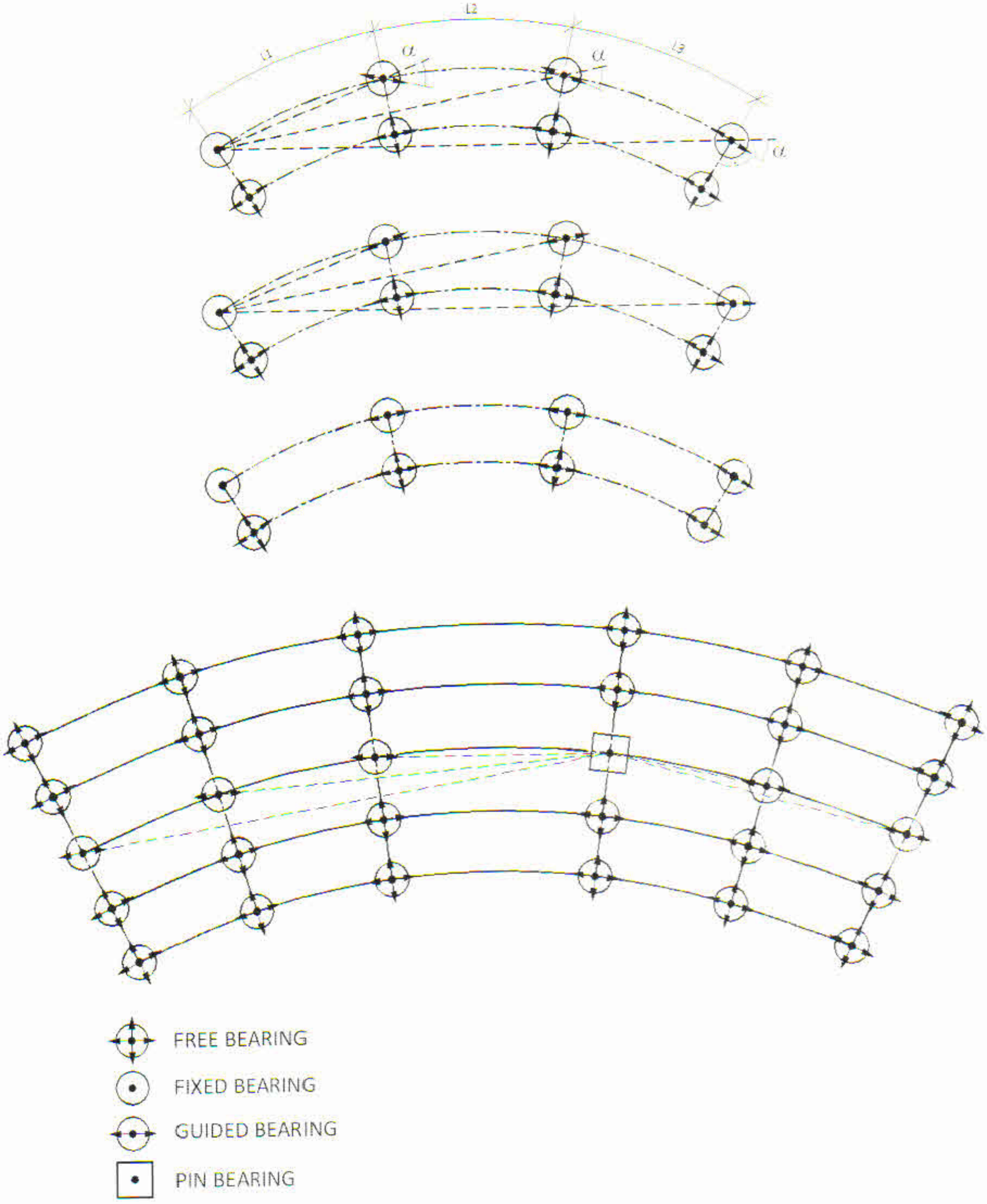


FIG. 4. TYPICAL BEARING LAYOUTS FOR CURVED CONTINUOUS BRIDGES

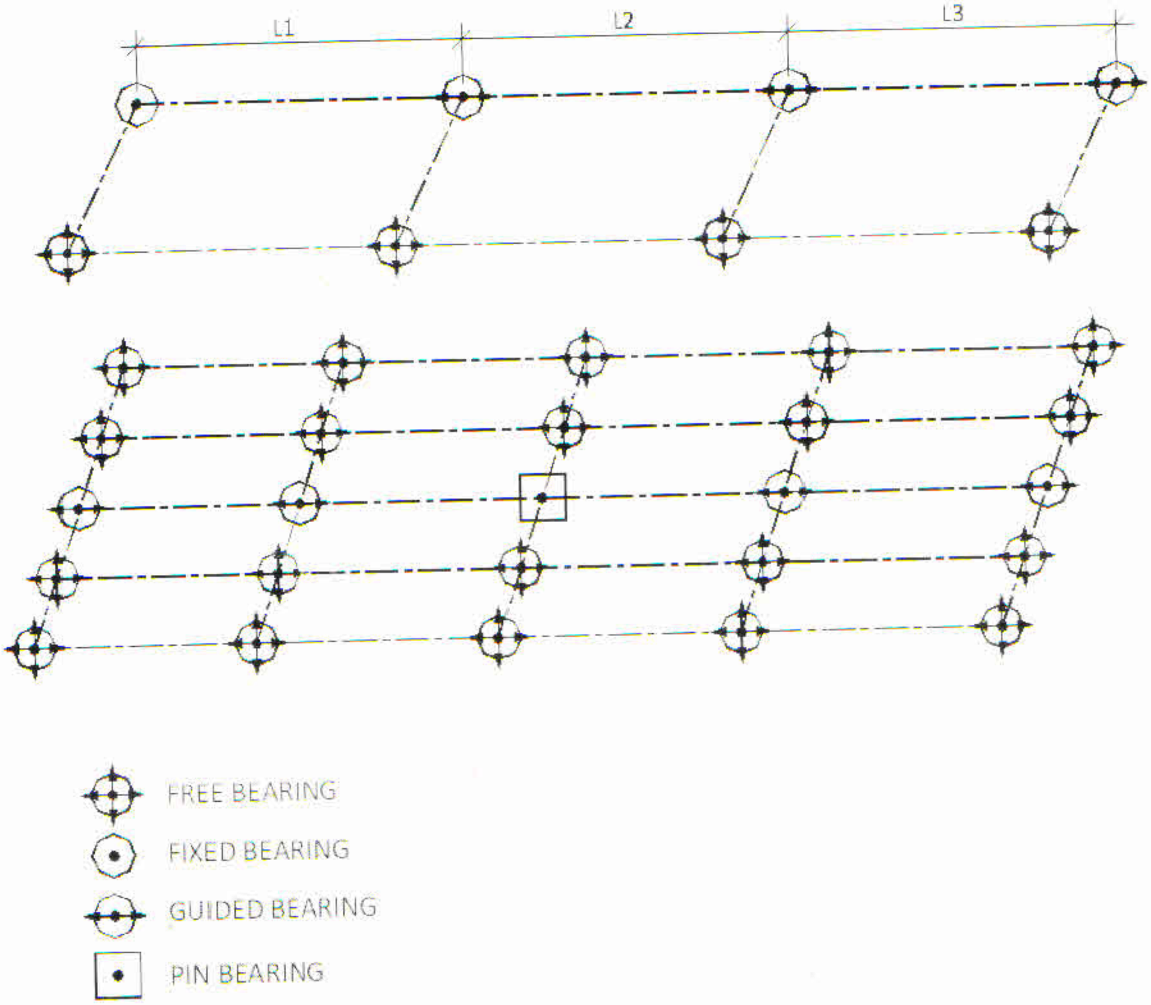


FIG. 5. TYPICAL BEARING LAYOUTS FOR SKEWED CONTINUOUS BRIDGES

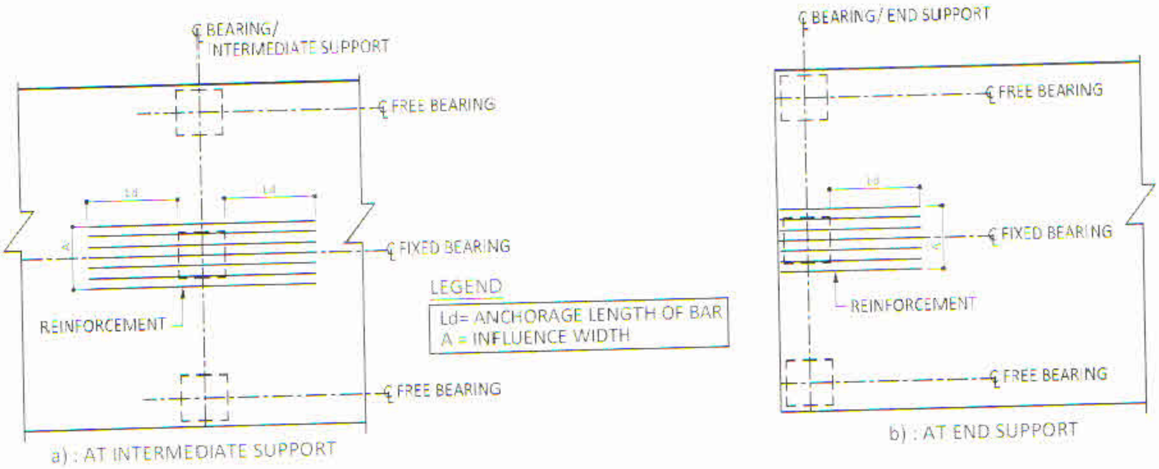


FIG. 6. ARRANGEMENT OF TIE BACK REINFORCEMENT AT FIXED BEARING

6.0 BRIDGES MADE CONTINUOUS THROUGH DECK SLAB

For bridges made continuous through deck slab, two generic type of connections normally adopted for different situations are as described below:

Type 1 : **Continuous separated deck slab with wide gap between girders,** in which the deck slab is continued monolithically over the intermediate piers, without continuing the girders. The length of the separated deck slab between the inner faces of girders shall be sufficient to provide both short term and long term flexibility required to accommodate rotation of the girders. (**Fig. 7a**).

This type of connection is simple in design and construction. However it does not provide moment continuity at the supports.

Type 2 : **Continuous separated deck slab with narrow gap between girders,** in which the deck slab is continued monolithically over the intermediate piers, without continuing the girders. A compressible filler material is placed in between slab and precast beam (6mm thickness minimum) for sufficient length along the span, to provide flexibility to the connecting slab. The length of the separated deck slab shall be sufficient to provide both short term and long term flexibility required to accommodate rotation of the girders. (**Fig. 7b**).

This type of connection is also simple in design and construction and it does not provide moment continuity at the supports.

It should be noted that bridges made continuous through deck slab do not provide moment continuity and thus in terms of structural action for vertical loads, the bridge can be considered as simply supported for the design of girders. Hence specific clauses pertaining to continuous structure do not apply for these bridges. For lateral loads however, the bridge is to be treated as continuous. The continuity slab over pier shall be designed for the forces arising out of the effect of such continuity, duly taking into account the effect of rotation of the girders subsequent to casting of the continuity slab. For the purpose of design of continuity slab, the permissible reduction in allowable stress in reinforcement shall be considered as 80% under SLS checks to account for fatigue. Under ULS checks, the partial material factor of safety, g_s for reinforcement in the connecting slab shall be taken as 1.4 (~ 1.15/0.8)

In case of bridges with deck continuity, the detailing of crash barrier for the continuity slab portion shall be done carefully. Gaps shall be left in crash barrier at the ends of continuity slab to allow for flexing of the slab.

7.0 REFERENCES

7.1 Codes & Specifications

a. IRC:112-2011 CODE OF PRACTICE FOR CONCRETE ROAD BRIDGES

b. AASHTO LRFD Bridge Design Specifications : 1999 Interim.

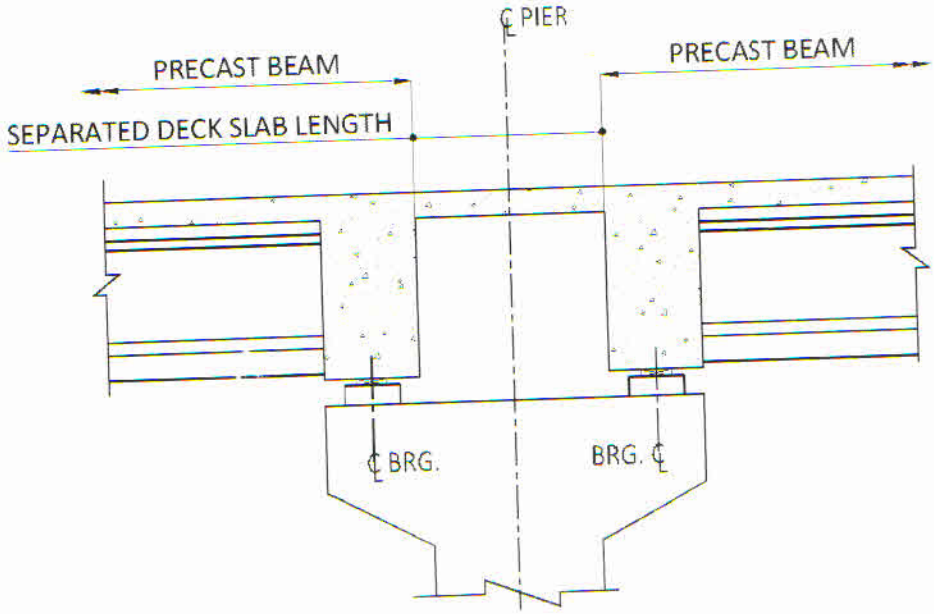
c. BS 5400 : Part 4 : 1984 : Code of practice for design of concrete bridges

d. SPECIFICATION FOR HIGHWAY BRIDGES, JAPAN ROAD ASSOCIATION

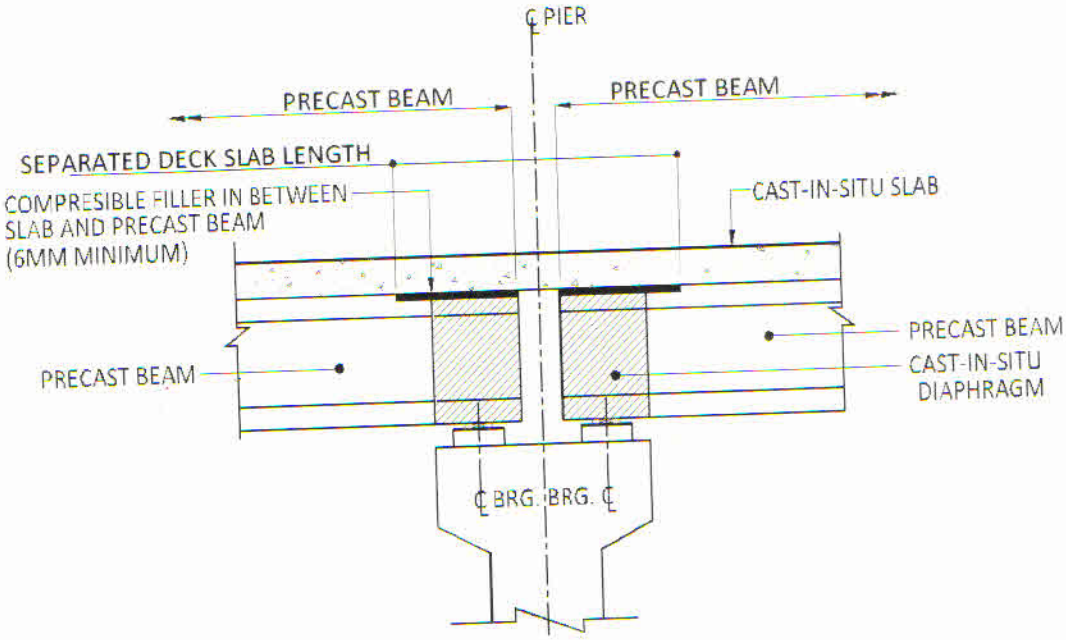
7.2 Papers & Publications

a. Brian Pritchard, BRIDGE DESIGN FOR ECONOMY & DURABILITY – Concepts for new, strengthened & replacement bridges"

b. Gunter Ramberger, Structural Bearings and Expansion Joints for Bridges, SED6 published by IABSE



a) : WITH WIDE GAP BETWEEN SUPPORTS OVER PIER



b) : WITH NARROW GAP BETWEEN SUPPORTS OVER PIER

FIG. 7. CONNECTION TYPE 1 : CONTINUOUS SEPARATED DECK SLAB

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual etc. from the date specified therein)