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Design and Analysis of Bridge Girders using Different Codes

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Abstract

There are different highway bridge design concepts and standards used in different countries. In the highways of India, different bridges are found designed based on different standards. Many of the bridges have been designed based on IRC and AASHTO standards. Indian Road Congress codehas adopted these two standards for highway and feeder roads. In this thesis some well-known codes are reviewed in detail for a survey of current code requirements and common practices under bridge design in several countries including India, United States and European Countries. By comparing code philosophy and detailed codified design procedures in these countries, similarities and differences in various parameters become apparent. This thesis discusses the seismic design and analysis of bridge structure subjected to load with three codes namely: Indian Road Congress code, AASHTO LRFD code, and Euro Code with observations in Highway loadings of Indian for the typical bridge. The study is focused on the loading pattern, design and overall analysis of bridge components with the three codes. The results discuss the cost effectiveness of codes that the number of reinforcement bars in the design with same dimensions. Required dimensions and reinforcements of the bridge are calculated depending on the data collected from the typical bridge. Parallel analysis is done by using the Structural Analysis program of finite elements based software many parameters are calculated. The maximum values of the design parameters are compared in a relative way. The best design standard is recommended for the reference of developing own standard for Indian.

Keywords: *Bridge Girder, Longitudinal Girders, Cross Girder, etc..*

1. Introduction

Bridge is a structure constructed to provide a passage over the obstacle such as road crossing, river crossing, railway crossing, valley etc. Design of bridge structure is depends upon the use of bridge or function of the bridge. It also depends upon the nature of the region where bridge to be constructed. It depends upon the site conditions, construction material used in the bridge construction, construction methods and financial conditions etc. Due to so speedy growth and development of the technology, the traditional bridges are replaced by the cost effective and new designer bridges. There structure designs are designed so that they has a new look or appearance and there cost of the structure is also economical. For the solution of this problem, structural engineers found these two structural systems of reinforced cement concrete. These are

- Girder bridges
- Prestressed Bridges
- Arc Bridges
- Rigid Frame Bridges

Because we are comparing Girders, so we talk about Girders. The geometry of girders is very simple and also easy in construction. Design of bridge structure is very important task for a structural engineer. It is also a complex task of structural engineers. There are some important factors in case of bridge designing such as span, live load, dead load, length and height. These factors affect the whole concept of the design and selection of the system ofstructure is always important and the scope of research. In this study we select the span of length 25 m. Therefore, these two factors are important i.e. codal provision and the design details.

The design of the girders is carried out with IRC codes, Euro codes and AASHTO specifications using STAAD Pro. This study compares the shear force, bending moment and area of steel in the design of bridge girders i.e. longitudinal girders and cross girders due to the application of different loading according to IRC codes, Euro codes and AASHTO specifications.

2. Literature Review

The study of different journals, thesis and design aspects were done. They consider IS codes, IRC codes, Euro codes, AASHTO specifications and ACI codes.An important research paper on “Analysis of Bridge girder-2 way Beams” has been published by Vijay Kumar, S.P. & Mohan K. (2017) found that when we are using cross beams or girders the deflection, bending moment & shear force will reduced as compare to the design of girder bridge without cross beams or girders.

Saxena A. & Dr. Maru S. (2013) publish an important research paper on “Comparative Study of the Analysis and Design o T-Beam Girder and Box Girder Super Structure” describe that the T- beam girder is economical than the box girder but box girder is more suitable for

long span bridges. Because of their close box sections they have high torsional rigidity.
Chu, K.H. (1971) published “Simply Supported Curved Box Girder Bridge” with the help of finite element method. A study of “Dynamic & Impact Characteristics of Continuous Steel Beam Bridge Decks and Slant-legged Rigid Frame Bridges” was carried out by Wang & Herang (1992). In 2011, N.K. Paul published “Three Dimensional Finite Element Model and Test Them with Loading System of Two Point” to check their behavior of structure of the longitudinal girders of RCC T-beam bridges.

3. Methodology

Along with hand calculations, The Bridge is modeled with finite elements as described in the computer program. The bridge deck is designed using piegauds curve method. The girders and cap beams are designed using different methods as recommended by each code. The corresponding nodes between deck and girder, girder and bearing, bearing and cap beam, and cap beam and top of the column are all connected with rigid elements. The abutment is modeled using beam elements.
The equivalent static analysis method is best suited for structures with well-balanced spans and supporting elements of approximately equal stiffness (Bridge Engineering seismic design, edited by Wai-fah chen and Lian Duan, 2003). For these structures, response is primarily in a single mode and the lateral force distribution is simply defined.

3.1 Bridge Geometry

The longitudinal sectional elevation of Bridge is shown in figure 3.1. It is RCC T-Girder double lane bridge. Effective length of each span is 25.00 m makes total length of 75.6 m. Carriage way width is 6.0 m and total width of deck is 7.2 m. Two intermediate reinforced concrete circular piers divide the total span into three equal individual spans. Abutments and piers are made of reinforced concrete. Open foundation has been used in this bridge.

Superstructure components and geometrical parameters

The plan view of single span deck slab is shown in figure. The cross section of super structure is as shown in figure. The super structure consists of three longitudinal girder of rectangular cross section with dimension 2000 mm x 350 mm. On each span there are seven numbers of cross girders of dimension 1500 mm x 250 mm joining the longitudinal girders at equal interval of 5.0 m. Deck slab of thickness 200 mm and total width 7.2 m is constructed monolithically with the longitudinal girders and cross girders. The grade of concrete used for superstructure is M25.

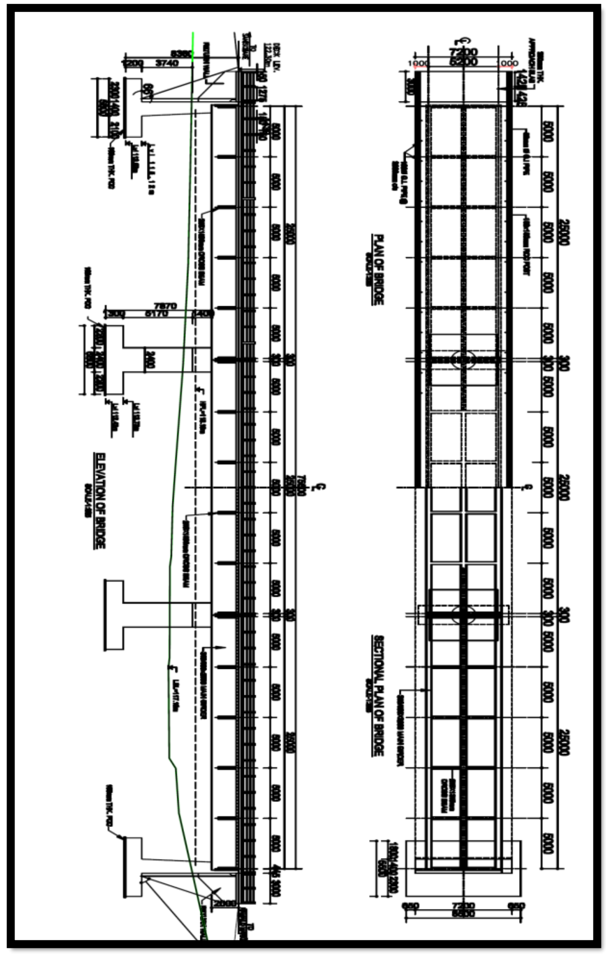

Figure 1: Sectional Elevation of Bridge

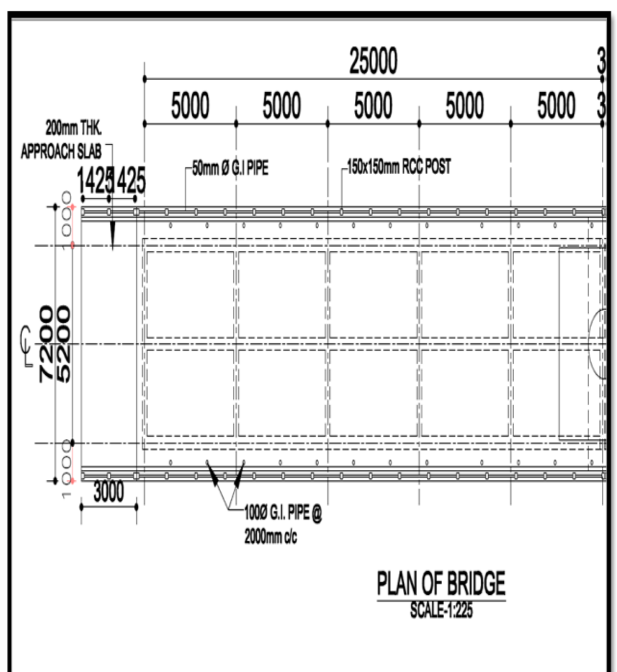

Figure 2 : Plan View of Single Span Deck Slab

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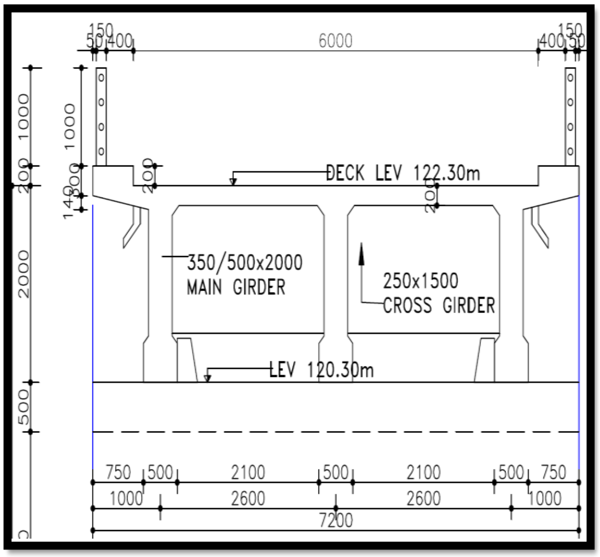

Figure 3: Cross section of Super Structure

Elastomeric Bearings

The bridge superstructure is rested over pier cap with the aid of elastomeric bearings. Each longitudinal girder support consists an elastomeric bearing. The pads are 500 mm x 300 mm in plan as in figure 3.4. The sectional view of it shows three elastomer of 10 mm thickness, four MS laminates of 3 mm thickness and cover of 5 mm thickness resulting total maximum thickness of 50 mm as in figure.

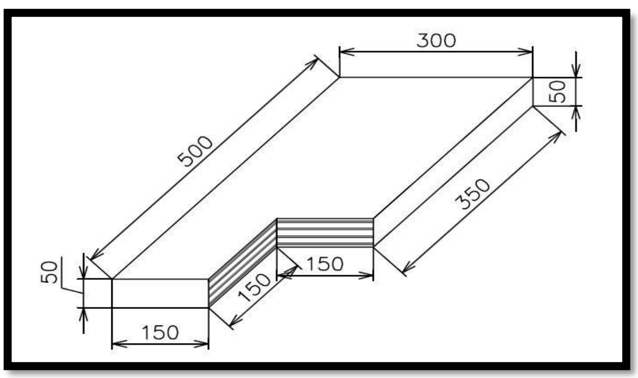

Figure 4: Global View of Elastomeric Bearing

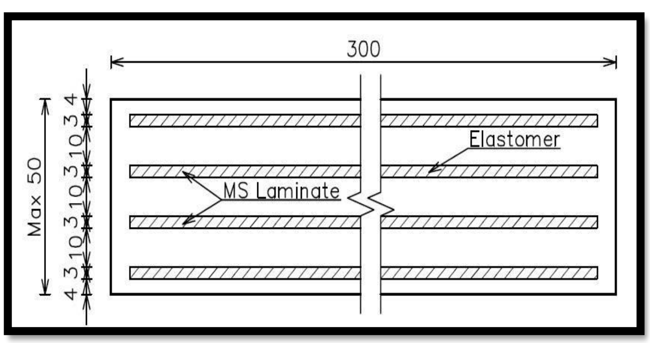

Figure 5 : Detail View of Elastomeric Bearing

Pier and Cap Beam

The Bridge consists of two single pier of circular cross section and height of 7.87 m including cap beam. The plan view of Pier is as shown in figure. The cap beam is rectangular cross section of 2400 mm x 1400 mm and length of 5900 mm. The Grade of concrete for pier cap is M25 and for pier column is M20.

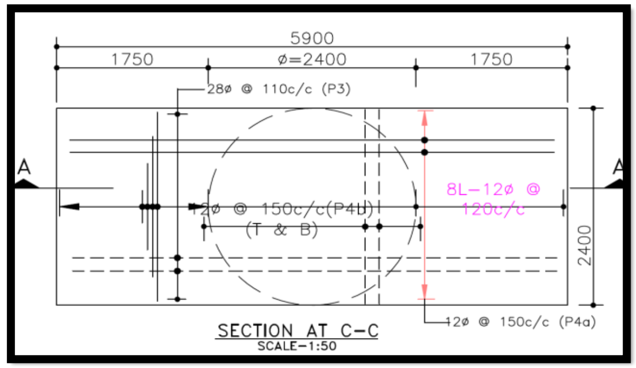

Figure 6: Plan View of Pier

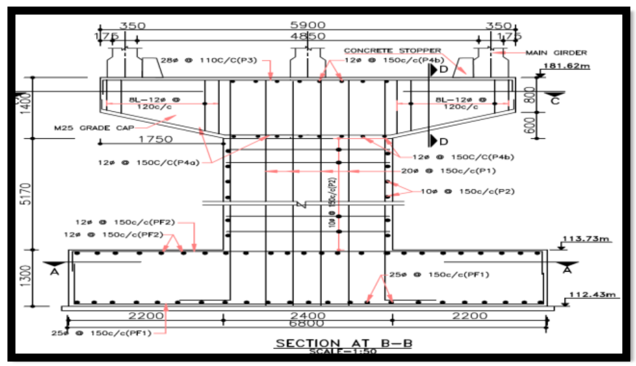

Figure 7 : Sectional details of Piers

Abutment

The abutment is also of reinforced concrete. The details of the cross section and front view of abutment is shown in figure below.

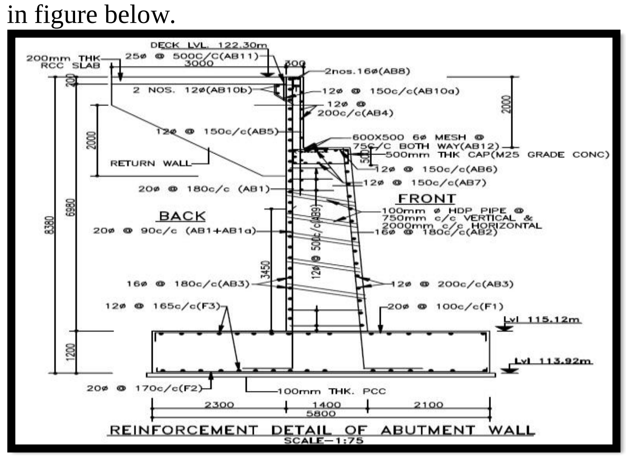

Figure 8 : Cross section and front view of Abutment

Material Properties

The properties of material used in the bridge structure are shown below.

Concrete

Modulus of elasticity (Ec) = 5000√ fck,

Characteristics strength of concrete (fck) = 20 Mpa and 25 Mpa Unit weight of concrete (γ) = 25 KN/m3, Poisson's ratio (ν) = 0.2 Reinforcing steel
Modulus of elasticity (Es) =200,000 Mpa
Specified minimum yield strength (fy) =415 Mpa

Ultimate tensile strength (fu) = 650 Mpa Poisson ratio (ν) = 0.3
Mass density (γ) =7850 kg/m^3

Finite Element Modeling

The basic finite element modeling objective in seismic bridge analysis is to provide the simplest mathematical formulation of the true bridge behavior. The most critical phase of structural analysis is to create a computer model with a finite number of mass less members and a finite number of nodes displacements that will simulate the behavior of the real structure. The mass of the structural systems, which can be accurately estimated, is lumped at the nodes (Wilson, 2002). Several commercial finite element programs are available. SAP 2000, general purpose finite element software is used for modeling the bridge in the current research. Global finite element model of the standard bridge is shown in figure 9.

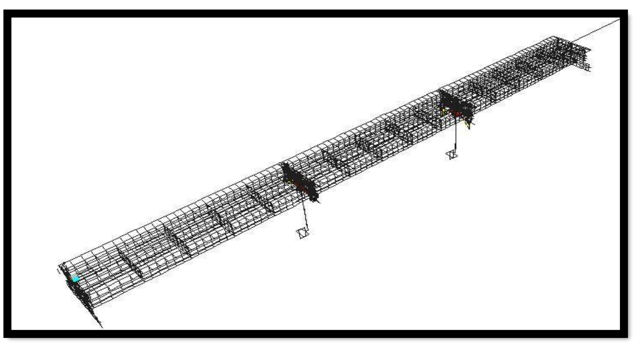

Figure 9 : Global Finite Element Model of Bridge

The mass source used to generate the seismic loads includes the superstructure dead load, the superimposed dead loads and 1/3 of the column weight. The superimposed dead loads include 50 mm wearing coat, and two barriers. The dead load used in the model is distributed over the length of the bridge, and nodal load placed on the top of the column. The uniform dead load includes an allowance for the weight of light posts, cables and future asphalt overlays. The load on the pier is used to develop the nominal flexural resistance of the single column pier using the Sap 2000 program.
To establish a common basis for comparing the seismic design provisions of the examined codes, the following assumptions are undertaken:

1. The pier properties and the unfactored dead load on the two single column piers will be used to develop the flexural capacity.
2. The seismic loads and deflections will be based solely on the effective flexural rigidity of a single column pier.
3. The effect of the vertical seismic loads on the bridge is ignored. The seismic loads in the two orthogonal horizontal directions will be considered only (i.e., along the longitudinal axis of the bridge and transverse to it).
4. The analysis is based on applying the design spectra to the bridge, and comparing the resulting seismic design moments, shears and ductility demands.
5. The bridge belongs to the "Other" bridge classification, and has an Importance factor of I = 1.0. This assumption was necessary because it is the only common Importance category in all the codes being studied (e.g. the AASHTO LRFD provisions do not address critical/essential bridges specifically). Also, the Eurocode treats the Importance category differently by using different return periods for different Importance categories.
6. The strength analysis of all codes is based on a rare earthquake event.
7. The probability of a high live load during an earthquake is low. The dynamic analysis mass source is based solely on the dead load.
8. To overcome the incompatible design philosophy undertaken by the AASHTO LRFD provisions and that of the other codes, the force based capacity design provisions will be assumed. The response modification factor used will be that of the IRC codes. In addition, the displacements obtained were compared with the limits specified in the AASHTO guidelines.
9. Linear dynamic analysis will be used in all cases, even if an Equivalent Static method maybe applicable or the seismic design code approach does not require checking the bridge for seismic loads.
10. The pier is designed to the required detailing for ductile elements as stipulated in all the design codes considered.

Due to the presence of neoprene bearings at the top of the column, the connection between the superstructure and the pier is assumed to be simply supported. The pier is therefore modeled with a fixed support at its base (i.e., at the footing) and a pinned connection at its top (i.e., at the superstructure). The bearings at the abutments consist of multi-directional and unidirectional sliding bearings, permitting movement in the longitudinal direction of the bridge, with shear keys to resist lateral movements of the bridge. Hence, the earthquake resisting system is based solely on the pier in the longitudinal direction (i.e., along the bridge's longitudinal axis), and on the single column piers and abutments in the transverse direction (i.e., at 90 degrees to the longitudinal axis of the bridge). The bridge piers will therefore dissipate energy in the longitudinal direction through the action of the concrete column only, and will participate along with the abutments in resisting transverse movements. The inertial load is transferred from the superstructure's centre of gravity to the rock or soil by shear in the abutments and piers. The bridge is modeled as a 75 m long structure pinned at the supports (i.e., rotations are released), with the exception of allowing for longitudinal movement at both abutments. The seismic response spectrum is applied independently in each direction. The vibration periods and shapes for each vibration mode is determined by, and later summed up using the CQC method. The reinforced concrete column will crack under cyclic seismic loading, and its stiffness will consequently decrease. The decrease in stiffness results in a reduction in the energy dissipating capabilities of the column. Cracked section properties are therefore used to model the reinforced concrete column.

4. Conclusion

Different loadings are taken from IRC codes, AASHTO specifications and Euro codes. The conclusion of above analysis is as follows

1. In comparison of all three codes, Euro code designs are over reinforced as compare to the other two i.e. IRC codes and AASHTO specifications.
2. In design of bridge girders with Euro codes shear forces, bending moment and deflection are almost double as compare to the other two i.e. IRC codes and AASHTO specifications. Design of bridge girders (up to 25m) using IRC codes are most economical and safer as compare to the other two i.e. AASHTO specifications and Euro codes.
3. IRC codes have the best combination of loading and design methods as compare to the other two i.e. AASHTO specifications and Euro codes.
4. Since the design of bridge girder using IRC codes acquire minimum value of deflection and bending moment so therefore IRC Class A loading is the most economical and optimum loading for the design of bridge girder in INDIA.

References

[1] Kumar R Ajith. , Dr. J. K. Dattatreya (2015):- "Study on the Structural Behavior and Design of a Typical Single Cell Post Tensioned Concrete Box Girder Bridge". Journal of Civil Engineering and Environmental Technology, Volume 2, Number 11; April – June, 2015

[2] Saxena Amit, Dr. Savita Maru (2013):- "Comparative Study of the Analysis and Design of T-Beam Girder and Box Girder Superstructure". IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 1, and Issue 2, April-May, 2013.

[3] B. Paval (2015):- "Analysis of Multi-Cell Prestressed Concrete Box-Girder Bridge". International Journal of Engineering Technology Science and Research IJETSR, ISSN 2394 – 3386 Volume 3,

[4] Bhadauria D. S. and Dr. Rakesh Patel (2017):- "Comparative Study of RCC Bridge for Central Zone of India for Different Sections of Girder". International Journal for Scientific Research & Development, Volume 5, and Issue 4, 2017.

[5] Eurocode 1(EN 1991-2(2)) Action on structures part 2: Traffic loads on bridges.

[6] Eurocode 2(EN 1992-2) Design of concrete structures part 2: Concrete bridges design and detailing rules.

[7] AASHTO (2010), "AASHTO LRFD Bridge Design Specifications", 5th Edition, American Association of State Highway and Transportation Officials, Washington DC.

[8] Chu, K. H. and Pinjarkar, S. G. (1971) "Analysis of Horizontally Curved Box-Girder Bridges," Journal of the Structural Division, Vol. 97, No. 10.

[9] Schlaich, J., and Scheef, H. (1982) "Concrete BoxGirder Bridges", International Association for Bridge and Structural Engineering, Zurich, Switzerland

[10] Sami M. Fereig (1994),"Preliminary Design of Precast Prestressed Concrete Box Girder Bridge." PCI Journal

[11] 25. M. Qaqish, Al-Balqa Applied University, JORDAN (2008), "Comparison between One Dimensional and Three Dimensional Models of Two Continuous Spans of Box Girder Bridges" ICCBT 2008 - C - (42) – pp463-482

[12] Chan, T.H.T., and O'Connor, C. (1990a). "Wheel Loads from Highway Bridge Strains: Field Studies." Journal of Structural Engineering, ASCE, Vol. 116, No. 7.

[13] Chan, T.H.T., and O'Connor, C. (1990b). "Vehicle Model for Highway Bridge Impact." Journal of Structural Engineering, ASCE, Vol. 116, No. 7.

[14] Wang, T.L., and Huang, D.Z. (1992). "Computer Modeling Analysis in Bridge Evaluation." Report No. FL/DOT/RMC/0542(2)-4108, Structural Research Centre, Florida Department of Transportation, Tallahassee.

[15] Dr.Maher Qaqish, Dr.Eyad Fadda and Dr.Emad Akawwi (2008), "Design of T-Beam Bridge by Finite Element Method and AASHTO Specification" KMITL Sci. J. Vol.8 No.1.

[16] N. K. Paul, S. Saha (2011), "Improvement of Load Carrying Capacity of a RCC T-Beam Bridge Longitudinal Girder by Replacing Steel Bars with S.M.A Bars" World Academy of Science, Engineering and Technology 51

[17] D Johnson Victor (2007), "Essential of Bridge Engineering"6th edition

[18] V. K. Raina, (2007)"Concrete Bridge practice analysis, Design and Economics", 2nd edition

[19] N. Krishna Raju, (2010), "Design of Bridges", 4thedition

[20] T. R. Jagadeesh & M. A. Jayaram, (2010), "Design of Bridge Structures", 2nd edition

[21] IRC 6-2010, "Standard Specifications and Code of Practice for Road Bridges", Section II, loads and stresses, The Indian Roads Congress, New Delhi, India, 2010.

[22] IRC: 21-2000, "Standard Specifications and Code of Practice for Road Bridges, Section III, Cement Concrete (Plain and Reinforced)", The Indian Roads Congress, New Delhi, India, 2000.

[23] IRC:SP: 54-2000 "Project Preparation Manual for Bridge", The Indian Roads Congress, New Delhi, India, 2000.