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Comparative Analysis of Bridge Design Codes and Their Applicability in the Indian Context

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Abstract: *This research paper aims to compare and analyze the design provisions of three international bridge design codes: Indian Roads Congress (IRC), American Association of State Highway and Transportation Officials (AASHTO) LRFD, and Eurocode. The study focuses on a typical T-Girder RCC bridge and evaluates response behaviors and design philosophies according to these codes. Additionally, it explores the impact of actual Indian truck loading on bridge superstructure design. The major conclusions and recommendations highlight the potential applicability of Eurocodes in the Indian context and suggest areas for future research and guideline development.*

Keywords: *Indian Roads Congress, AASHTO, Highway, Bridge, Eurocode.*

1. Introduction

Bridges are vital components of transportation infrastructure and must be designed to withstand various loads and environmental conditions. This research aims to compare and analyze the design provisions of three prominent international bridge design codes, namely IRC, AASHTO LRFD, and Eurocode, and assess their applicability in the Indian context. By evaluating these codes and considering actual Indian truck loading, this study seeks to provide insights into optimizing bridge design practices in India.

2. Literature Review

Previous research on bridge design codes has highlighted the significance of adhering to appropriate design philosophies and standards. IRC, the Indian standard, provides guidelines tailored to the nation's unique conditions, while AASHTO LRFD and Eurocode are internationally recognized codes. Understanding the differences and similarities between these codes is essential for informed decision-making in bridge design.

3. Methodology

To conduct this comparative analysis, a typical T-Girder RCC bridge model is employed. The loading conditions considered include actual Indian truck loading, which reflects the real-world usage of bridges in the Indian transportation network. Structural analysis and design processes are implemented to assess how each code performs under these conditions.

3.1 Bridge Visualization

In addition to manual calculations, the bridge has been subjected to finite element modeling using specialized computer software. The design of the bridge deck follows the "pie gauds curve method," while the girders and cap beams have been designed using methods recommended by each respective code. To ensure structural integrity, nodes connecting the deck to the girders, girders to the bearings, bearings to the cap beams, and cap beams to the top of the columns have been linked with rigid elements. Furthermore, the abutment has been represented in the model using beam elements.

In terms of structural analysis, the equivalent static analysis method has been chosen as the most suitable approach. This method is particularly well-suited for structures characterized by evenly distributed spans and supporting elements with relatively uniform stiffness. In such cases, structural response typically occurs predominantly in a single mode, simplifying the lateral force distribution.

3.2 Bridge Geometry

The longitudinal sectional elevation of the bridge, as depicted in Figure 3.1, represents a Reinforced Concrete (RCC) T-Girder bridge designed to accommodate two lanes of traffic. Each span of the bridge has an effective length of 25.00 meters, resulting in a total bridge length of 75.6 meters. The carriage way, which serves as the road surface, is 6.0 meters wide, and the entire deck has a width of 7.2 meters.

To support the bridge structure, two intermediate reinforced concrete circular piers have been strategically positioned, dividing the total span into three equal individual spans. Both the abutments and piers are constructed using reinforced concrete, which provides the necessary strength and durability for withstanding the structural loads.

For the foundation of this bridge, an open foundation design has been employed. Open foundations typically involve excavating the ground to a suitable depth, ensuring proper soil compaction, and then constructing the foundation elements (in this case, for the piers and abutments) within the excavated area. This foundation type is chosen based on site-specific soil conditions and engineering considerations to ensure the stability and safety of the bridge.

4. Comparative Analysis

This section delves into a detailed comparison of the design provisions and philosophies presented in IRC, AASHTO LRFD, and Eurocode. It evaluates how each code addresses critical aspects of bridge design, including seismic considerations, loadings, and safety factors. Furthermore, it explores the responses of the bridge model under different design codes, providing insights into the code-specific behaviors.

Provisions	**AASHTO LRFD (U.S. Standard)**	**European standard (Euro codes)**	**Indian Standards (IRC codes) (Used in India)**
Design Standard	AASHTO LRFD Bridge Design Specifications, 5th edition.2010 Section 2: General design and Location features Section 3: Loads & load factors Section 4: Structural Analysis Section 5: Concrete structures Section 9: Deck & deck system Section 11: Abutment and Pier Section 13 & 14: Railings & Joint and bearing	Eurocode 0, EN 1990: Basis of structural design Euro code 1, Part 2 Traffic loads on bridges. Eurocode 2, part 2: concrete structures Eurocode 7, part 2: Geotechnical design Eurocode 8, part 2: seismic design of bridges	IRC 5-1998-section I- general features of design IRC 6-2010- section II-Loads and stresses IRC 21-2000-section III- / IRC 112-2011cement concrete (plain and reinforced) IRC 78-2000-section VII- foundations and substructures IRC 83-2002-section IX-Bearings-(part II)
Design Method	Load and Resistance Factor Design Method. (LSM)	Partial Factor Design Method.(LSM)	Working stress design method but transiting to Limit State Design
Live Load			
Truck Load	HL-93 Loading	Load Model 1	IRC class A Train of vehicle loading
Loading on Carriageway: B(m)	<u>1 lane</u> W≤3.65m Design truck + lane load or tandom + lane load **Design truck**: Three axles of 35.6KN, 142.3KN and 142.3KN are used. **Design tandom**: consists of a pair of 111.2KN axles spaced1.2m apart. **Lane loading**: 9.34 KN/m udl in the longitudinal direction and overa 3m width. <u>2 lane and more</u> 6.1m≤W≥7.3m & more Numbers axle loading of HL93per lane.	<u>1 carriageways</u> W<5.4m (300 KN axle load) Lane 1 ,UDL = 9kN/m^2 <u>2 carriageways</u> :5.4m<W<9m (300 KN axle load)Lane 1 ,UDL = 9kN/m^2 Lane 2 ,UDL = 2.5 kN/m^2 <u>3 carriageways</u> :9m<W<12m (300 KN axle load)Lane 1 ,UDL = 9kN/m2 Remaining lanes@2.5KN/m^2	1 lane, W<5.3m, one lane of width 2.3m with class A loading and remaining area loaded with 500kg/m2. 2 lane, 5.3m<W<9.6m, one lane of class 70R or two lane of class A. lane or more, Number of class A train loading per lane.
Live Load	2 @72.72KN contact area	2@150 kN	2@ 57 KN contact

for SlabDesign	(50.8*25.4) cm^2	contact (40 x 40)cm^2	area (50 x 25) cm^2
Impact Factor (I)	33% of static wheel load for all limit states.	Impact is included inthe loading.	For spans 3 to 45m I=4.5/(L+6)—for concrete I=9/(L+13.5) --------- for steel

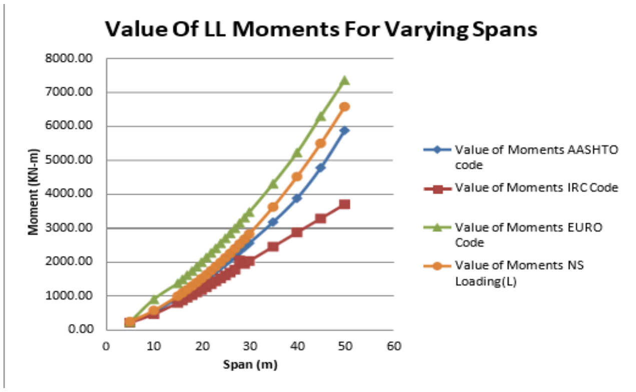

Figure 1: Value of Moments according to four codes with varying

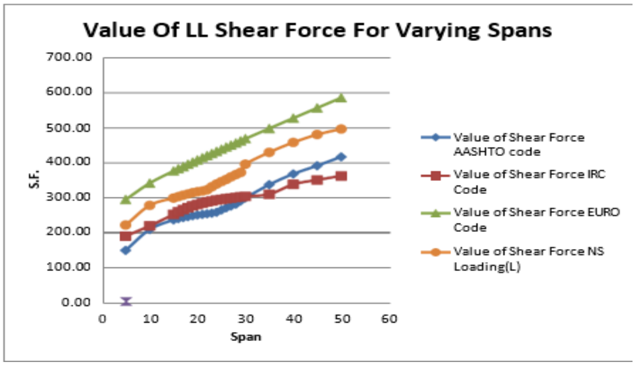

Figure 2: Value of Shear Forces according to four codes with varying spans

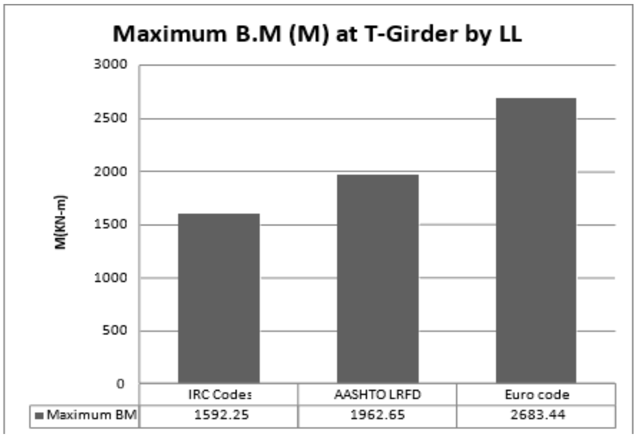

Figure 3: Maximum Bending Moment at T-Girder by Live Load

5. Recommendations and Future Work

This section outlines recommendations and areas for future research:

1. Expanding the study to encompass comprehensive bridge design guidelines independently, considering various loading conditions and design philosophies.
2. Broadening the study by selecting suitable adjustment factors for Eurocodes that are compatible with Indian environmental conditions.
3. Considering the inclusion of nonlinear behavior in pier and abutment design to provide more realistic results.
4. Incorporating soil-structure interaction for improved modeling accuracy and seismic response prediction.

6. Conclusion

The following conclusions and recommendations have been derived from the comparison of design provisions among the investigated design codes. The study encompasses the general design and analysis of a typical T-Girder RCC bridge, evaluating responses and design philosophies as per three international codes: IRC, AASHTO, and Eurocode. Additionally, it incorporates the actual loading conditions of Indian trucks to assess bridge superstructure design.

Major Conclusions:

- **Eurocode Conservatism**: Eurocode exhibited the most conservative design among all the codes investigated. This conservatism may be attributed to the use of characteristic loads without any adjustment factors. To adapt Eurocodes for Indian applications, suitable nationally determined parameters or factors should be considered.
- **Applicability of Eurocodes**: Eurocodes are designed for broad applicability and coverage, suggesting that they can be referenced for bridge design in India. The development of nationally determined parameters specific to India would enhance their usability.
- **Indian Standard Loading**: Indian Standard loading demonstrated reasonable responses, aligning well with

IRC loadings and AASHTO LRFD. This suggests the potential for the development of additional design guidelines tailored to Indian conditions.

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