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A Comparative Study on the Impact of Moving Loads on a Reinforced Concrete Deck Bridge under IRC Class A and AASHTO HS-20 Loadings

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Abstract -
This thesis presents a comparative study on the effects of moving loads on a reinforced concrete deck bridge, examining two distinct loading standards, namely IRC Class A and AASHTO HS-20. The study's primary objectives were to evaluate the structural behavior, assess the performance, and compare the stresses and deformations experienced by the bridge under both loading conditions. Additionally, the research aimed to analyze the safety implications and identify potential vulnerabilities for each loading scenario while investigating critical points influenced differently by IRC Class A and AASHTO HS-20 loadings. The investigation involved analyzing various parameters such as bending moment, deflection, stress, torsional moment, and shear force in the bridge structure. conclusions offer valuable insights into the structural behavior and performance of steel girder deck bridges under various loading conditions and deck thicknesses. The findings can serve as essential guidelines for bridge design and optimization, ensuring the safety, durability, and efficient performance of the bridge structure. Engineers and designers can leverage this research to make informed decisions when selecting appropriate loading standards, ultimately contributing to the overall improvement of bridge infrastructure.
Key Words: *Bridge, IRC Loading AASHTO Loading*

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I. INTRODUCTION

Bridge design typically considers vehicular loads as the principal type of loading. Different countries have established their own standard specifications and codes for bridge design, such as IRC, AASHTO, and EURO codes. These standards take into account factors like traffic frequency, vehicle types, loadings, and logistical considerations for national emergencies.

Analytical modeling using Finite Element Method (FEM) allows engineers to obtain a comprehensive understanding of the responses of the bridge deck. It helps in assessing how the structure behaves under different loading conditions.

In many countries, bridge components are designed using specialized software. Designing large-span bridges through software is advantageous as it provides ease and accuracy compared to manual calculations, which can be time-consuming. Several software options are available for bridge analysis, including SAP, CSi Bridge Software, and Staad Pro. For the analysis of bridge decks in this project, Staad Pro will be utilized.

Traffic load models for the design of road bridges are defined in IRC 6: Section II and AASHTO LRFD. These models help engineers simulate and analyze the effects of traffic loads on bridge structures, enabling the design to meet necessary safety and performance requirements.

II. OBJECTIVE OF STUDY

The study aims to compare the effects of moving loads on a reinforced concrete deck bridge under two different loading standards, IRC Class A and AASHTO HS-20.

1. Evaluate the structural behavior of the bridge under IRC Class A loading conditions.
2. Assess the structural performance and response of the bridge when subjected to AASHTO HS-20 loading.
3. Compare the stresses and deformations experienced by the bridge under both loading standards.
4. Analyze the safety implications and potential vulnerabilities of the bridge for each loading scenario.
5. Investigate any critical points or sections that may be influenced differently by IRC Class A and AASHTO HS-20 loadings.

III. METHODOLOGIES

The following methodology was adopted to analyze the problem:

- Create a model in the XZ plane with dimensions of 12m x 10m, using a spacing of 0.5 along each axis to represent a slab with a constant width of 12m and a constant length of 10m.
- Use translational repeat to create beams along the X and Z axes and intersect them, resulting in the creation of 912 beams.
- Create a quadrilateral mesh and input the depth of the slab as 365mm.
- Input the modulus of elasticity of concrete as 21.7KN/mm2, the density of concrete as 23.5KN/m3, and Poisson's ratio as 0.17.
- Assign the properties to the model.
- Create four beams at spacing 0.5m, 4.5m, 7.5m, and 10.5m to represent the girders.
- In the section database, assign ISMB 600 steel to these beams, which will act as girders supporting the deck.
- Define the self-weight load in the negative Y direction and assign it to the entire model.
- Run the analysis.
- In the post-processing phase, check for the maximum node displacement and maximum plate moment.
- Access the Bridge Deck option.
- Create the deck and roadway.
- Assign the loading class as IRC CLASS A. Run the influence generator for loading class A.
- In the load generator, input the Indian code for class A and specify the maximum node displacements, reactions, and maximum bending moment.
- The software will generate the responses of the deck for loading class A, which can be checked in the post-processing option.
- Similarly, obtain the deck responses for loading class A and AASHTO HS-40 for deck thicknesses ranging from 415mm to 815mm.
- By following this methodology and utilizing the STAAD Pro software, the analysis of the bridge deck can be conducted for different deck thicknesses and loading conditions, providing valuable insights into the structural behavior and performance of the bridge.

IV. RESULTS

4.2 Analysis of Model by Finite Element method by Staad-Pro

The analysis of a simply supported reinforced concrete deck bridge with varying deck thickness (365mm to 815mm) is performed in this chapter. The bridge is subjected to Indian loading (IRC Class A) and AASHTO HS-20 loadings. The bridge is supported by four girders, consisting of I section concrete and ISMB 600 steel girder. The analysis is conducted using STAAD PRO software, which provides results in the X, Y, and Z directions. This comprehensive analysis allows for the evaluation of the bridge's structural behavior under different loading conditions.

- The analysis was conducted on a model consisting of 1489 beams, 480 plates, and 525 nodes. The size of the quadrilateral shell elements used in the analysis was 0.5m x 0.5m.
- In Case 1, the model was supported by four I-section concrete girders, and deck thicknesses ranging from 365mm to 815mm were considered. The loading classes applied to this model were IRC Class A and AASHTO HS-20.
- In Case 2, the model was supported by four ISMB steel girders, and the same range of deck thicknesses was considered. The loading classes applied to this model were also IRC Class A and AASHTO HS-20.
- The analysis was performed using the full 3D elastic Finite Element Analysis capabilities of STAAD Pro v8i.

The table presents various structural data and properties related to a deck bridge:

1. Modulus of Elasticity: The modulus of elasticity is 21.7 kN/mm2, representing the measure of stiffness of the material used in the bridge construction.
2. Poisson's Ratio: The Poisson's ratio is 0.17, indicating the ratio of lateral to longitudinal strain in the bridge material under loading conditions.
3. Length of Deck: The length of the deck is 10 meters, denoting the longitudinal dimension of the bridge surface.
4. Width of Deck: The width of the deck is 12 meters, representing the transverse dimension of the bridge surface.
5. Girder Length: The girder length is 10 meters, specifying the longitudinal length of the girders used in the bridge construction.
6. Girder Specifications: The girder used is ISMB 600, which is an I-section concrete girder, indicating the type and size of the girder elements.
7. Vehicle Loads (AASHTO): The bridge is designed to withstand AASHTO HS-20 vehicle loads, which are standardized loads specified by the American Association of State Highway and Transportation Officials.

8. Vehicle Loads Indian: The bridge is designed to support Indian Class A vehicle loads, which are specified by the Indian road and transportation authorities.

9. This table provides essential information about the bridge's structural characteristics, material properties, and the type of vehicle loads it is designed to accommodate.

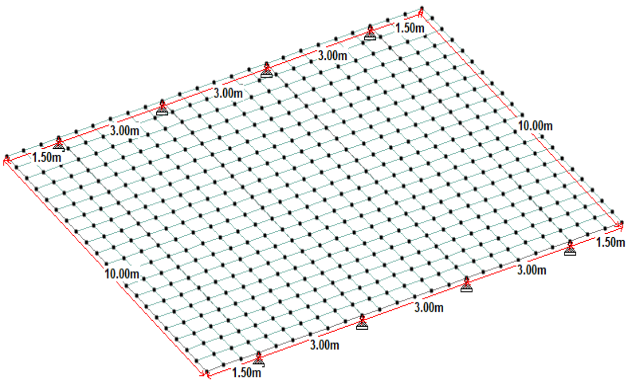

Figure 1 Deck Slab designing using Mesh generation

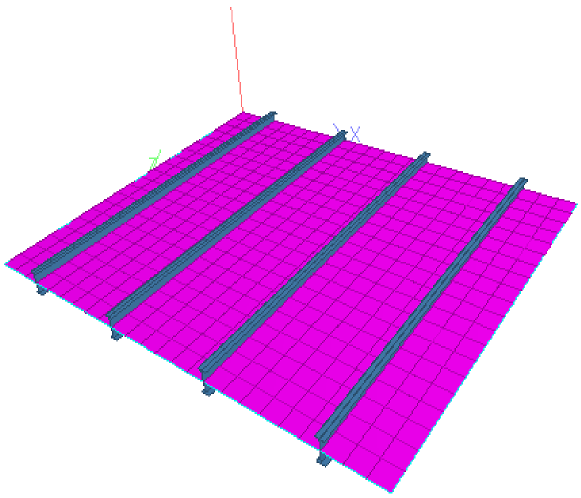

Figure 2 3D render view of Deck Slab

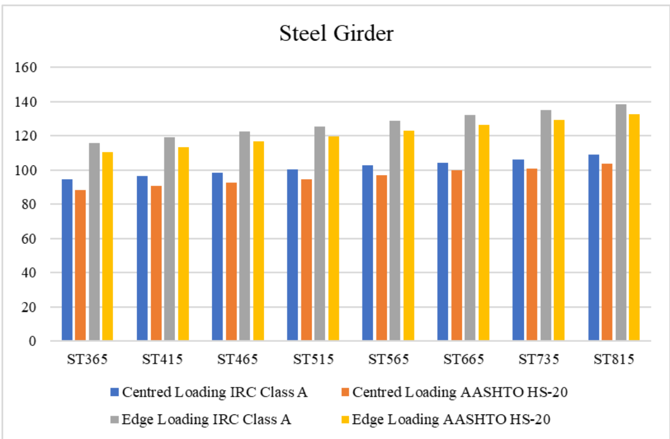

Figure 3 Slab thickness Vs Bendinging Moment for Steel girder

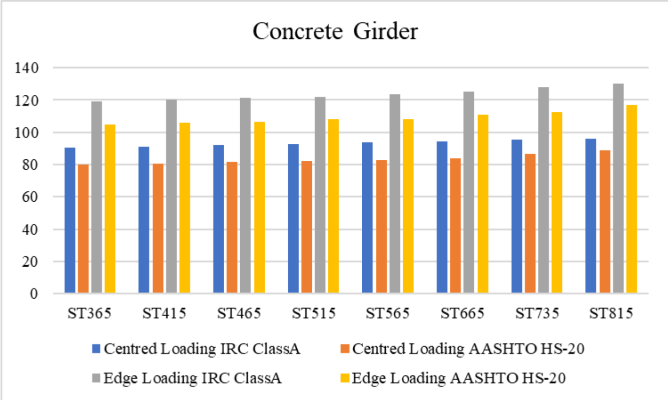

Figure Slab thickness Vs Bendinging Moment for Concrete girder

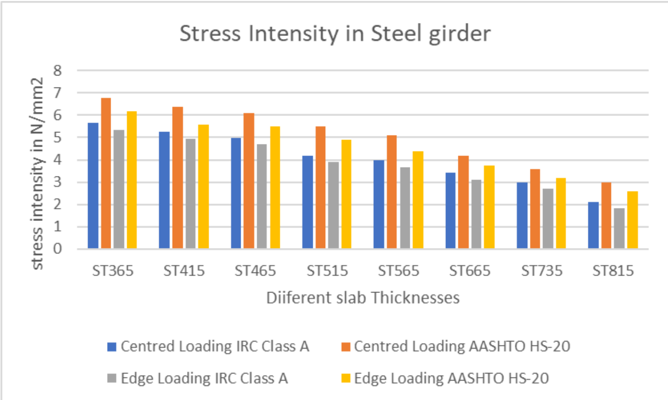

Figure 4 Slab thickness Vs Stress intensity in steel girder

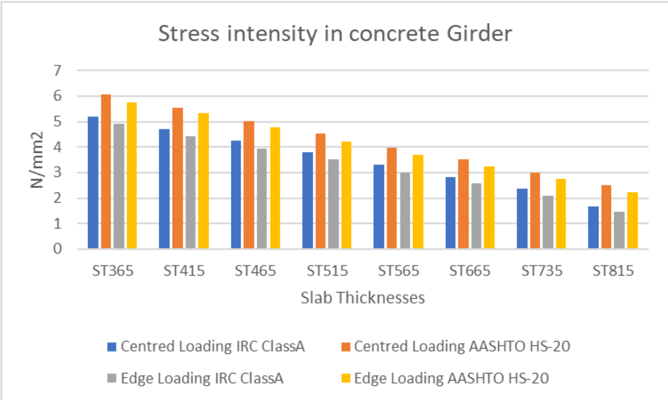

Figure 4 Slab thickness Vs Stress intensity in Concrete girder

V. CONCLUSION

This chapter presents the conclusions drawn from the entire study, based on the investigations conducted through finite element analysis. The following conclusions can be derived:

1. The maximum bending moment values caused by IRC Class A and AASHTO vehicle loadings show a difference of less than 5%.
2. The bending moment values increase with the increasing thickness of the deck slab.
3. For ISMB-600 steel girders, center loadings result in higher bending moment values compared to edge loadings.
4. The effect of standard loadings on steel girder deck bridges, in terms of deflection, is approximately 4.5% higher for IRC Class A loading compared to AASHTO loadings.
5. The stress values are approximately 13.7% higher for AASHTO loadings.
6. Increasing the thickness of the deck slab leads to a decrease in live load deflection values and maximum deck stress.

7. AASHTO loads result in a slightly higher torsional moment (approximately 16.8%) compared to IRC loads, mainly due to differences in wheel configurations.
8. The maximum shear force in beams significantly depends on the magnitude of loadings. Since the wheel load of AASHTO loadings is higher than IRC Class A loading, the shear force values produced by AASHTO loadings are approximately 17% higher.
9. The thickness of the deck slab plays a significant role in carrying and distributing vehicle loads. Increasing the deck thickness helps in achieving an even distribution of deck live loads to the girders, thereby enhancing durability and deck service life.
10. These conclusions provide valuable insights into the structural behavior and performance of steel girder deck bridges under different loading conditions and slab thicknesses. They can serve as guidelines for bridge design and optimization, ensuring the safety, durability, and efficient performance of the bridge structure.

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