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Analysis And Design Of Straight Bridges Using Aashto Lrfd Hl-93

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Abstract

The main objective of this research is to study the effect of curvature on the shear distribution factor under the effect of AASHTO LRFD HL-93 live load for horizontally curved concrete box girder through an experimental program. The main variables considered in this study were the degree of curvature, the location of live load application and the number of the loadedlanes, under the variables the girder support reaction was measured by load cell connect to weigh indicator. The load cells and weight indicator allow calculating the shear distribution factor (SDF) according to the equilibrium method based on the girders support reaction under any load case and compared with AASHTO LRFD formulas for cast in place concrete box girder. The experimental results showed that the SDF does not affect with slight degree of curvature variation and the number of loaded lane under different radius of curvature for the exterior girder). The AASHTO formula overestimates the SDF for interior girder by 35 % for straight model and overestimate by 10% for model with (100) angle of curvature while the ASHHTO present conservative estimation for models with angle of curvature .

Keyword: Box Girder, Experimental Program, Shear Distribution Factor.

1.0 Introduction

Important aspects related to the construction and design of curved box girder bridges:

1.1Advantages of Box Girder Bridges in Curved Construction: Box girder bridges are preferred for curved construction in urban environments due to their high torsional rigidity. This additional curvature introduces torsion into the system, resulting in warping and distortion stress within the member cross-section. In curved bridges, secondary members that provide stability in straight bridges become primary load-carrying members due to these additional forces.

1.2 Load Distribution Factor (LDF): The load distribution factor (LDF) is a crucial tool for engineers to analyze bridge girder behavior by separating the effects of wheel loads in both the longitudinal and transverse directions. LDF simplifies the design process by allowing engineers to consider girder design (moment and shear) as the static result of the AASHTO HL-93 standard truck or design lane loads multiplied by the LLDF (Live Load Distribution Factor) calculated through AASHTO LRFD equations.

1.3 Shear Distribution in Box Girder Bridges: Several studies have been conducted to develop equations for shear distribution along box girder bridges. The text mentions the "lever rule" as an approximate solution for calculating the distribution factor. The lever rule assumes no transverse deck moment continuity at interior beams, implying that the cross-section of the deck in the transverse direction is statically determinate.

1.4 Shear Distribution Factor Trends: The text notes that the shear distribution factor for straight box girder bridges is almost uniform with increasing span length but decreases with an increase in the number of lanes from 2 to 3. This trend changes when the number of lanes increases from 3 to 5.

Overall, this information highlights the complexity of designing and analyzing curved box girder bridges and the importance of considering factors such as torsion, load distribution, and shear distribution in the design process. Provided outlines the key geometric and property specifications of the bridges used in the study. Here's a summary of the important points:

2.0 Literature Review

2.1 Advantages of Box Girder Bridges: Box girder bridges are chosen for their high torsional rigidity, making them suitable for curved constructions in urban environments.

2.2 Additional Curvature: The presence of additional curvature in these bridges introduces torsional forces, leading to warping and distortion stress within the cross-section of bridge members.

2.3 Role of Secondary Members: In curved bridges, secondary members that provide stability in straight bridges become primary load-carrying members due to the added curvature.

2.4 Load Distribution Factor (LDF): The text discusses the importance of the Load Distribution Factor (LDF) as a tool for analyzing bridge girder behavior. It separates the effects of wheel loads in the longitudinal and transverse directions.

2.5 Simplifying Design: LDF simplifies the design process by allowing engineers to consider girder design (moment and shear) based on the AASHTO HL-93 standard truck or design lane loads, multiplied by the Live Load Distribution Factor (LLDF) calculated through AASHTO LRFD equations.

2.6 Shear Distribution: The text mentions that studies have been conducted to develop equations for shear distribution in box girder bridges. The "lever rule" is noted as an approximate solution for calculating the distribution factor.

2.7 Trends in Shear Distribution Factor: It's mentioned that the shear distribution factor for straight box girder bridges behaves differently with varying span lengths and the number of lanes, highlighting the complexity of the design considerations.

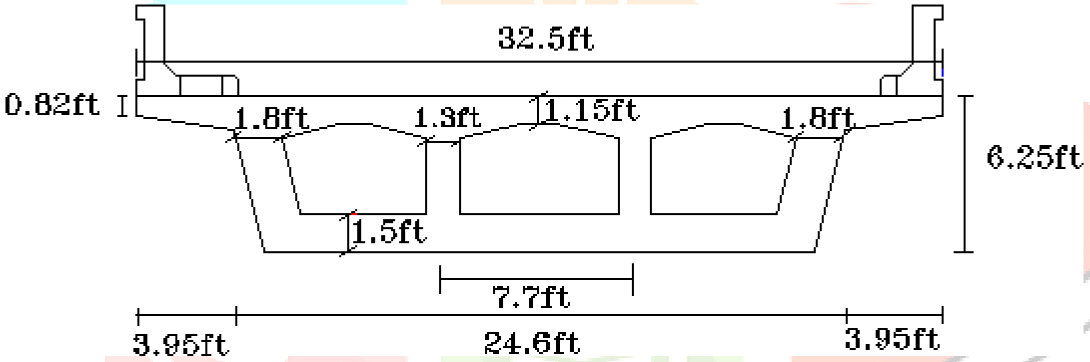

Figure 3.3: Real Geometry of the Box Girder for Span Length of 115 ft

3.0 Boundary Conditions of Bridge Bearings

Boundary conditions for bridge bearings are critical to ensure the proper functioning and safety of a bridge. Bridge bearings are structural components that provide support and allow for movement in various directions, accommodating thermal expansion, traffic loads, and other dynamic forces. Here are some key boundary conditions and considerations for bridge bearings:

3.1Vertical Support: Bridge bearings must provide vertical support to the superstructure, ensuring that the bridge can carry its own weight, as well as the live loads (such as vehicles and pedestrians) applied to it. Vertical support is typically achieved through the use of elastomeric or sliding bearings, depending on the bridge's design.

3.2 Transverse Movements: Bearings must allow for transverse movements, which occur due to thermal expansion and contraction, as well as lateral loads. This lateral movement prevents the bridge from being rigidly fixed and allows it to expand and contract with temperature changes.

3.3 Longitudinal Movements: Bridge bearings should permit longitudinal movements, which can result from factors like settlement, temperature fluctuations, and seismic forces. Expansion joints and sliding bearings are commonly used to accommodate these movements.

3.4 Rotation: Some bridge bearings are designed to allow for rotation, especially in curved or skewed bridges. This rotation helps distribute forces and ensures that the superstructure remains stable.

3.5 Restraint against Uplift: In some cases, it's essential to prevent the bridge from lifting off its supports due to uplift forces. Proper restraint against uplift is crucial to maintain stability.

3.6 Resistance to Horizontal Forces: Bearings should be able to resist horizontal forces, such as wind loads or seismic forces, to ensure the bridge's structural integrity during adverse conditions.

3.7 Durability: Bearings should be designed and constructed to withstand environmental conditions, including exposure to moisture, chemicals, and temperature extremes, to ensure long-term durability.

3.8 Maintenance: Regular inspection and maintenance of bridge bearings are essential to ensure they continue to function as intended. Maintenance practices may include cleaning, lubrication, and replacement of damaged components.

3.9 Compliance with Standards: Bridge bearings must comply with relevant industry and engineering standards and codes, such as those set by the American Association of State Highway and Transportation Officials (AASHTO) and local building codes.

3.10 Seismic Considerations: In earthquake-prone areas, special attention must be given to the design and installation of bridge bearings to ensure they can withstand seismic forces and prevent catastrophic failure during an earthquake.

3.11 Load Capacity: Bearings must be designed to support the expected loads, including both static and dynamic loads, such as those from heavy vehicles and dynamic factors like braking and acceleration.

The specific boundary conditions for bridge bearings can vary depending on factors like the bridge's design, location, purpose, and anticipated forces. Engineers must carefully consider these conditions during the design and construction phases to ensure the safety and functionality of the bridge throughout its lifespan.

4.0 Models of Bridge Construction

Modeling of bridge constructions is a critical aspect of modern bridge engineering and construction. It involves creating detailed and accurate digital representations of bridges and their components to aid in design, analysis, and construction processes. Here are some key points related to the modeling of bridge constructions:

4.1 3D Bridge Information Modeling (BIM): Bridge construction industry has adopted Building Information Modeling (BIM), which involves creating 3D digital models of bridges. BIM provides a precise numerical representation of bridge designs and drawings, enhancing the accuracy of construction plans and facilitating collaboration among project stakeholders [2].

4.2 Substructure Modeling: Accurate modeling of bridge substructures, such as piers and abutments, is essential. Various methods are used to model the support conditions, including fixed supports and reactions applied as forces on the substructure elements [3].

4.3 Advanced Technologies: The field of bridge construction benefits from advanced technologies, including advanced construction methods, materials, tools, and software. These technologies enhance the efficiency and safety of bridge construction projects [4].
3D and 4D Models: The use of 3D and 4D models is common in bridge design and construction. These models allow for the automatic generation of detailed bridge representations and can simulate construction processes using Virtual Reality (VR) capabilities [5].

4.4 Simulation: Simulation plays a crucial role in bridge construction. It allows engineers to study construction processes and optimize them for efficiency and safety. For example, simulation can be used to study the placement of beams on bridge piers using methods like the twin truss gantry launching method [6].

modeling of bridge constructions involves the use of advanced technologies, such as BIM and 3D/4D modeling, to create accurate representations of bridges and construction processes. These models improve design accuracy, aid in simulations, and enhance overall project efficiency and safety.

5.0 Straight Bridge Model

A straight bridge model is a representation of a bridge that has a linear, uncurved design. In the context of engineering and bridge analysis, creating a straight bridge model involves several key considerations and steps:

5.1 Geometry: Define the geometric parameters of the straight bridge, including its length, width, and height. Ensure that these dimensions accurately represent the physical bridge being analyzed.

5.2 Material Properties: Specify the material properties of the bridge components, such as concrete or steel. This includes parameters like material density, modulus of elasticity, and strength properties.

5.3 Loads and Load Distribution: Determine the loads that the bridge will be subjected to, including dead loads (the weight of the bridge itself) and live loads (traffic loads). Analyze the load distribution across the bridge structure.

5.4 Support Conditions: Define the support conditions at the bridge abutments and piers. These conditions can include fixed supports, pinned supports, or other types of boundary conditions.

5.5 Structural Analysis: Perform structural analysis using appropriate engineering software or methods to calculate stresses, deflections, and other structural responses under various load scenarios.

5.6 Code Compliance: Ensure that the bridge model complies with relevant engineering codes and standards, such as those provided by organizations like the American Association of State Highway and Transportation Officials (AASHTO).

5.7 Safety Factors: Apply safety factors to account for uncertainties in materials, loads, and other factors to ensure the bridge's safety and reliability.

5.8 Visualization: Create visual representations of the straight bridge model, including diagrams, drawings, and 3D models, to aid in understanding and communication.

It's important to note that straight bridge models serve as the foundation for more complex analyses and designs. Engineers use these models to evaluate the performance and behavior of bridges under various conditions, including static and dynamic loads. The results of such analyses inform decisions related to bridge design, maintenance, and safety.

6.0 The AASHTO LRFD Method

The AASHTO LRFD (American Association of State Highway and Transportation Officials Load and Resistance Factor Design) method is a widely used approach for the design of highway and transportation structures in the United States. It is a performance-based design method that takes into account various loads and factors of safety to ensure the safety and reliability of civil engineering structures. Here's an overview of the AASHTO LRFD method:

6.1 Load and Resistance Factors: AASHTO LRFD uses load and resistance factors to design structures. Load factors are applied to the loads (e.g., dead loads, live loads, environmental loads) to account for uncertainties and variations in these loads. Resistance factors are applied to the material and structural component strengths to account for uncertainties in material properties and construction quality.

6.2 Load Combinations: AASHTO LRFD specifies load combinations that include various load types, such as dead loads, live loads, wind loads, seismic loads, temperature effects, and others. These combinations are used to evaluate the structural response under different loading conditions.

6.3 Limit States: The method defines various limit states that a structure must satisfy to ensure safety and functionality. Common limit states include strength limit states (e.g., ultimate strength, serviceability limit states (e.g., deflections, vibrations), and fatigue limit states (related to repeated loading).

6.4 Resistance Factors: Resistance factors are used to reduce the nominal strength of structural components to account for uncertainties. These factors are typically less than 1.0, indicating a reduction in strength to provide a margin of safety.

6.5 Load Factors: Load factors are applied to the loads to account for variations and uncertainties in load magnitudes. These factors are typically greater than 1.0, indicating an increase in load to ensure a margin of safety.

6.6 Material Properties: AASHTO LRFD specifies the material properties and characteristics required for design, including concrete strength, steel yield strength, and other relevant material properties.

6.7 Computer-Based Analysis: Engineers often use computer-based analysis tools and software to perform structural analysis and design calculations based on the AASHTO LRFD method. These tools automate the complex calculations involved in the design process.

6.8 Code Provisions: The AASHTO LRFD method is detailed in the AASHTO LRFD Bridge Design Specifications, which provide comprehensive guidelines, equations, and provisions for designing various bridge components, including superstructures, substructures, and foundations.

6.9 Updates and Revisions: The AASHTO LRFD specifications are periodically updated and revised to incorporate new research findings and improve design practices. Engineers are encouraged to use the most current version for their projects.

Overall, the AASHTO LRFD method is a robust and widely accepted approach for designing transportation structures, ensuring they meet safety and performance standards. It considers the uncertainties associated with loads and materials, providing a reliable framework for the design and construction of bridges, culverts, and other transportation-related infrastructure. Engineers use this method to optimize designs while maintaining safety and reliability.

7.0 Analysis Of Straight Bridges

The analysis of straight bridges involves a comprehensive evaluation of the structural integrity, performance, and behavior of bridges with linear, uncurved designs. Here are the key steps and aspects involved in the analysis of straight bridges:

7.1Geometry and Dimensions: Begin by accurately defining the geometry and dimensions of the straight bridge. This includes parameters such as length, width, height, and span.

7.2 Material Properties: Specify the material properties of the bridge components, such as the type of material (e.g., concrete, steel), material density, modulus of elasticity, and strength properties. These properties are crucial for determining the structural response.

7.3Loads and Load Distribution: Identify and consider the various loads that the bridge will encounter during its service life. These loads include dead loads (the weight of the bridge itself), live loads (traffic loads), environmental loads (e.g., wind, temperature effects), and any special loads (e.g., earthquake forces).

7.4 Support Conditions: Define the support conditions at the bridge's abutments and piers. Determine whether the supports are fixed, pinned, or have other boundary conditions. Properly modeling these support conditions is critical for accurate analysis.

7.5 Structural Analysis: Utilize engineering analysis software or methods to perform structural analysis on the straight bridge model. This analysis calculates the stresses, strains, deflections, and other structural responses under various loading scenarios. Common analysis methods include finite element analysis (FEA) and analytical methods.

7.6 Code Compliance: Ensure that the bridge's design and analysis comply with relevant engineering codes and standards, such as those provided by organizations like the American Association of State Highway and Transportation Officials (AASHTO).

7.7 Safety Factors: Apply safety factors to account for uncertainties in materials, loads, and other factors. These factors help ensure the bridge's safety and reliability.

7.8 Dynamic Analysis: For bridges subjected to dynamic loads, such as heavy traffic or seismic events, conduct dynamic analysis to assess the bridge's response to these dynamic forces. This may involve modal analysis and response spectrum analysis.

7.9 Load Rating: Evaluate the load-carrying capacity of the bridge to determine its load rating. This rating indicates the maximum allowable loads the bridge can safely support.

7.10 Visualization and Reporting: Present the analysis results in a clear and understandable format. Create visual representations, diagrams, and reports to communicate the structural behavior and performance of the bridge to stakeholders.

7.11 Maintenance and Monitoring: Implement a plan for bridge maintenance and monitoring based on the analysis findings. Regular inspections and maintenance are essential to ensure the long-term safety and functionality of the bridge.

8.0 Analysis Of Straight Bridges

The analysis of straight bridges is a critical engineering process that helps assess their structural integrity, safety, and performance. It informs decisions related to design improvements, maintenance strategies, and load-carrying capacity. Engineers use advanced analysis techniques and tools to ensure that bridges meet safety standards and can withstand the demands of their intended use.

8.1 Negative Moment (HL-93S):

For one lane loaded by two trucks (HL-93S), you observed that the maximum LLDF for interior girders was 0.33, while AASHTO LRFD predicted 0.51, indicating a 35% difference.

Similar results were found when the right or left lane was loaded by two trucks.

When two lanes were loaded by two trucks, the percentage difference between AASHTO LRFD and finite element analysis was about 16% for an 80 ft span and 13.3% for a 140 ft span.

8.2 Positive and Negative Moments (HL-93K):

For positive moments, when one lane was loaded, the LLDFs from AASHTO LRFD were approximately 39-40% higher than those obtained from analysis for interior girders and 44% higher for exterior girders.

For two lanes loaded, AASHTO LRFD predicted bending moments about 16% higher than those from analysis for interior girders and 20% higher for exterior girders.

For negative moments, when one lane was loaded, AASHTO LRFD resulted in LLDFs about 35% higher for interior girders and 37.5% higher for exterior girders.

For two lanes loaded, the percentage difference was 14% for interior girders.

It's evident that AASHTO LRFD tends to predict higher LLDFs compared to the finite element analysis for various loading conditions and span lengths. These findings will be valuable for evaluating the accuracy and suitability of AASHTO LRFD equations in practical bridge design scenarios.

mentioned that you calculated the maximum Live Load Distribution Factors (LLDF) for entire girders (the entire bridge) for straight bridges. You provided tables and figures showing the LLDF for various loading conditions and span lengths.

However, you didn't specify the exact values or details from these tables and figures in your text. If you have specific questions or if you would like to discuss the results in more detail, please provide the relevant values, and I'll be happy to assist you further or answer any questions you may have.

Table 1: LLDF for Negative Moment Due to HL-93S- One Lane Loaded

Span Length (ft)	**Interior Girder 1**	**AASHTO LRFD**	**Interior Girder 2**	**AASHTO LRFD**	**Left Exterior Girder**	**AASHTO LRFD**	**Right Exterior Girder**	**AASHTO LRFD**
80	0.30	0.51	**0.33**	0.51	0.16	0.46	**0.30**	0.45
90	0.29	0.49	**0.32**	0.49	0.17	0.45	**0.29**	0.45
100	0.28	0.47	**0.31**	0.47	0.18	0.45	**0.29**	0.45
115	0.26	0.45	**0.3**	0.45	0.19	0.45	**0.28**	0.45
120	0.26	0.44	**0.29**	0.44	0.2	0.44	**0.28**	0.44
140	0.25	0.42	**0.28**	0.42	0.21	0.44	**0.27**	0.43

Table 2: LLDF for Negative Moment Due to HL-93S- Two Lanes Loaded

Span Length (ft)	**Interior Girder 1**	**AASHTO LRFD**	**Interior Girder 2**	**AASHTO LRFD**	**Left Exterior Girder**	**AASHTO LRFD**	**Right Exterior Girder**	**AASHTO LRFD**
80	**0.58**	0.69	**0.58**	0.69	**0.42**	0.56	**0.42**	0.56
90	**0.57**	0.67	**0.57**	0.67	**0.45**	0.55	**0.45**	0.55
100	**0.56**	0.65	**0.56**	0.65	**0.46**	0.55	**0.46**	0.55
115	**0.55**	0.63	**0.55**	0.63	**0.47**	0.55	**0.47**	0.55
120	**0.54**	0.62	**0.54**	0.62	**0.47**	0.54	**0.47**	0.54
140	**0.52**	0.60	**0.52**	0.60	**0.48**	0.54	**0.48**	0.54

providing additional information about the results and the comparison between LLDF obtained from AASHTO LRFD and finite element analyses for straight bridges. It's clear that you've conducted a thorough analysis of the LLDF for different loading scenarios and span lengths. If you have specific questions about the results or if there's anything specific you'd like to discuss or analyze further in these figures, please let me know, and I'd be happy to assist you.

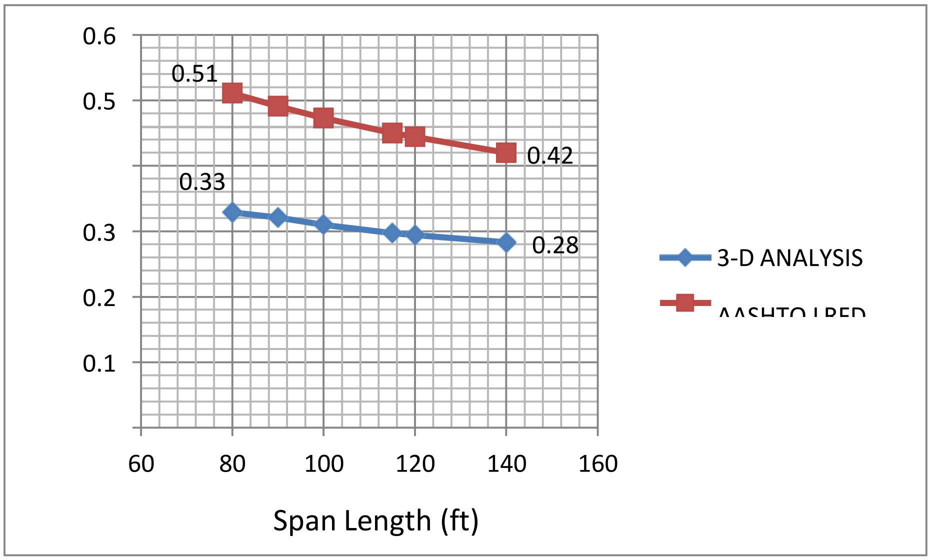

Figure 2 : HL-93S- One Lane Loaded- Interior Girder

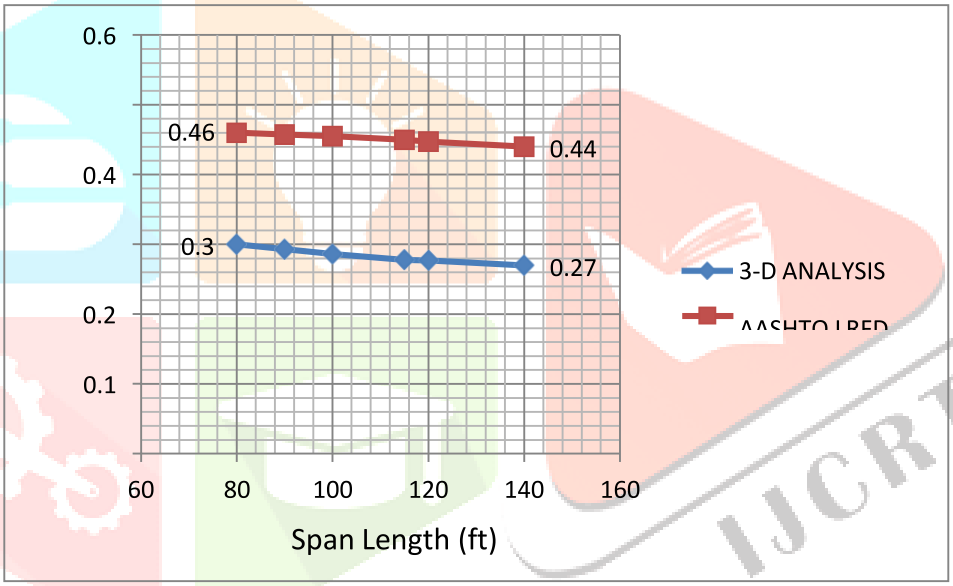

Figure 3: HL-93S- One Lane Loaded- Exterior Girder

9.0 Conclusion

The study related to bridge support reactions, shear distribution factors (SDF), and the effects of curvature. Let's break down the main points in your conclusion:

Correct Measuring Processor: The support reactions measured for both the left and right girders under the HL-93 live load were found to be equal to the applied loads. This suggests that the measuring processor used in the study is accurate and reliable. The experimental results indicated that the shear distribution factor (SDF) did not significantly change with slight degrees of curvature variation under load case (I) for the exterior girder (G1) compared to straight models (0%, 0%, 17%).The SDF was found to change with the number of loaded lanes under different radii of curvature for the exterior girder (G1), with an increase of 19%, 24%, and 49% compared to straight models.The experimental results revealed that the SDF increased as the curvature of the bridge increased for the exterior girder (G1). The AASHTO equation used for estimating the SDF for the interior girder (G2) was found to overestimate the SDF by 35% for straight models and overestimate by 10% for models with a 100-degree angle of curvature. However, it presented a conservative estimation for models with angles of curvature of 130 and 180 degrees.

The study observed that a simple girder tilting (uplift) occurred under load case (I) in the right side, measuring 0.5 kN at the inner edge girder (G4) for each 1-ton load under load case (I).

These findings provide valuable insights into the behavior of bridge girders under different conditions, including the impact of curvature and load distribution. It also highlights the performance of the AASHTO equation in estimating shear distribution factors for interior girders. These observations can inform bridge design and construction practices to ensure structural integrity and safety.

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