IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⁜ Impact Factor 8.066 ⁜ Peer-reviewed / Refereed journal ⁜ Vol. 10, Issue 8, August 2023

DOI: 10.17148/IARJSET.2023.10824

Assessment of Load Carrying Capacity of RC Girder Bridge

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Abstract: This compilation of research endeavours covers a wide spectrum of bridge analysis and design studies, offering unique insights into various bridge structures and their behaviours under diverse conditions. These papers explore topics ranging from T-beam girder bridge evaluations to capacity assessments of aging T-beam bridges, dynamic responses of high-speed vehicles on bridges, and finite element analyses of deteriorated T-girder bridges under cyclic loading. Lastly, the paper on finite element failure analysis highlights the importance of accurately modelling support conditions in CSi Bridge software. Together, these studies significantly contribute to bridge engineering knowledge, benefiting designers, engineers, and researchers dedicated to enhancing the safety and integrity of diverse bridge types in various operational scenarios.

Keywords: FEM Analysis, Dynamic loading, Vehicular loading, CSi Bridge, T-girder Bridges.

I. INTRODUCTION

The field of civil engineering has witnessed remarkable advancements in recent decades, with the advent of sophisticated software tools that facilitate the analysis and design of complex structures. Among these tools, CSi Bridge software stands out as a versatile and powerful solution tailored for the analysis, design, and evaluation of bridge structures. This paper aims to introduce CSi Bridge software, outlining its capabilities, features, and applications in the realm of civil engineering. Bridges are integral components of modern infrastructure, connecting communities, facilitating transportation, and ensuring the safe passage of vehicles and pedestrians. Their design and maintenance require a deep understanding of structural engineering principles, along with advanced computational tools to meet the evolving demands of the 21st century. CSi Bridge software, developed by Computers and Structures, Inc. (CSI), has emerged as a pioneering software package that equips engineers with the tools necessary to meet these challenges.

In this paper, we delve into the key features of CSi Bridge software, highlighting its intuitive user interface, robust modelling capabilities, and comprehensive analysis tools. We explore its applications in the design of various bridge types, including highway, railway, and pedestrian bridges, and discuss how it assists engineers in optimizing structural performance while ensuring safety and compliance with industry standards.

Furthermore, we examine CSi Bridge's integration with Building Information Modeling (BIM) workflows, which streamlines the collaboration between architects, engineers, and contractors, enhancing project efficiency and accuracy. We also touch upon the software's ability to perform dynamic analysis, addressing the critical aspect of bridge response to seismic and other dynamic loads.

Parametric study of deteriorating precast concrete double-tee girder bridges using computational models: Junwon Seo, Brian Kidd

This paper's objective is to investigate the impact of various parameters on the live-load distribution factors (LLDFs) in precast concrete double-tee (DT) girder bridges by utilizing 3D computational models. These models were specifically created for two types of DT girder bridges, one with a depth of 584 mm and the other with a depth of 762 mm. The evaluation involved subjecting these bridges to a rating truck load using both solid and shell elements within the CSi Bridge software.

Initially, the LLDFs were calculated based on field tests. Subsequently, the computational models were fine-tuned to match these field-derived LLDFs, ensuring their accuracy. After this calibration step, various parameters were systematically modified to examine their individual effects on LLDFs. These parameters encompassed span length, concrete strength, deck width, diaphragm placement, and width-to-length ratio. Each of these parameters underwent thorough investigation within the context of DT girder bridges.

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The research findings indicated that the AASHTO LRFD (American Association of State Highway and Transportation Officials Load and Resistance Factor Design) interior LLDFs generally aligned well with the DT girder bridges, even when they exhibited significant joint damage. Notably, the study revealed that deck width, concrete strength, and diaphragm location had minimal influence on LLDFs. Conversely, span length and width-to-length ratio emerged as key factors significantly affecting LLDFs. Specifically, as the span length increased; both exterior and interior LLDFs exhibited a decrease. This trend was consistent with AASHTO LRFD specifications for interior LLDFs but not for exterior LLDFs, where the pattern differed from AASHTO LRFD LLDFs calculated using the lever rule and without factoring in span length. Finally, as the width-to-length ratio increased, LLDFs also increased.

Capacity assessment of older t-beam bridges by nonlinear proxy finite element analysis: Andrew P. Schanck, William G. Davids.

Older reinforced concrete T-beam bridges that were constructed in place often exhibit inadequate flexural rating factors, even though they continue to carry modern traffic without experiencing structural issues. To address this discrepancy, a field study was conducted on three such T-beam bridges subjected to high bending moments, and their strain responses were meticulously recorded. The outcomes of this study led to a significant revelation: for two of these bridges, their HL-93 flexural rating factors could be increased to values exceeding 1.0. This suggests that these bridges possess the capacity to handle larger loads than initially predicted.

To facilitate these assessments and bridge load ratings, a groundbreaking technique known as nonlinear proxy finite element analysis (PFEA) was developed. PFEA represents a computationally efficient method for predicting bridge responses up to the point of failure, accounting for crucial factors such as girder ductility and load redistribution within the three-dimensional bridge structure. This innovative approach relies on a genetic algorithm to optimize various parameters, both constitutive and geometric, which are applied to a shell element discretization of each girder. This discretization mimics the moment-curvature response found in solid reinforced concrete T-beam sections. The result is an elastic and elastic-plastic shell element representation that can be readily incorporated into a three-dimensional model of an entire bridge using commercially available finite element software.

The application of PFEA to the three field-tested bridges yielded load ratings that consistently surpassed those calculated by the American Association of State Highway and Transportation Officials (AASHTO) guidelines. These ratings were also in line with or exceeded those inferred from the field testing. Importantly, the PFEA technique accurately predicted the longitudinal and transverse load responses of the actual bridges, accounting for girder ductility, load redistribution, and even bridges with non-uniform geometry.

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Dynamic behaviour of multi-span bridges under moving loads with focusing on the effect of the coupling conditions between spans: Hongan Xu, Wen L. Li.

This study delves into the dynamic behaviour of multi-span bridges when subjected to moving loads. The multi-span bridge model used in this study provides flexibility by allowing each span to be independently supported by as many as eight elastic springs. This approach offers a more comprehensive and realistic representation of the joints and intermediate supports commonly found in practical bridge designs.

What's particularly noteworthy is that this model no longer mandates that the displacement and its first derivative remain continuous at intermediate supports or span junctions. Instead, it accommodates possible discontinuities such as steps and skew angles at these locations. These aspects are crucial for studying the interactions between vehicles and bridges.

The study presents numerical findings that focus on how the coupling conditions between spans dynamically affect the bridge's behaviour. The results indicate a strong dependence of each span's deflection on its local coupling conditions, especially when stiffness values approach critical thresholds. Moreover, there is a notable variation in the response of each span across a wide range of stiffness values. This variability suggests significant potential for enhancing bridge performance through adjustments to joint parameters or coupling configurations.

Dynamic response of high speed vehicles and sustaining curved bridges under conditions of resonance: Qing Zeng, Y.B.Yang, Elias G. Dimitrakopoulos.

This paper explores the dynamic response of high-speed vehicles moving across horizontally curved bridges, whether they are simple, continuous, or multi-unit structures, when both the vehicle and the bridge enter a state of resonance. The study employs finite element simulations to model the bridge, while each vehicle is treated as a multibody system. The coupling forces at the contact points between the vehicle and the bridge are determined using a rigid contact assumption.

A notable aspect of this research is the three-dimensional (3D) simulation of a vehicle traveling along a horizontally curved path. This simulation enables the investigation of deformation modes within the 3D multibody vehicle model, including aspects related to lateral-rolling and yawing degrees of freedom. This is a novel approach as it considers the full 3D dynamics of the vehicle model, providing insights not previously explored.

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The paper validates its numerical results by demonstrating their agreement with relevant analytical solutions. The findings from the parametric study include:
Similar impact factor: The impact factors, which measure the effect of resonance, exhibit similar patterns in both the vertical and radial directions.
Damping effects: Suspension damping in the vehicle can mitigate the resonance response of the car body, even when the vehicle itself is in resonance.
Feedback effects: The Bridge's resonance has a substantial impact on the vehicle's response, but the vehicle's resonance effect on the bridge response is relatively small, particularly in the vertical direction.

Finite element failure analysis of reinforced concrete T-girder bridges: Ha-Won Song, Dong-Woo You, Keun-Joo Byun, Koichi Maekawa.

This paper focuses on investigating the failure behaviours of deteriorated reinforced concrete T-girder bridges under cyclic loading through experimental observation and the development of a finite element modelling technique to predict these behaviours. Here's a breakdown of the key points in this passage:
The study involves conducting full-scale destructive tests on in-situ bridges. These tests apply cyclic loads to the bridges until they fail. This empirical data collection forms the basis for understanding how these bridges respond to cyclic loading. The study also introduces a technique for creating non-linear finite element models to analyse the behaviour of deteriorated reinforced concrete T-girder bridges. These models are used to simulate and predict the behaviour of the bridges under various loading conditions.
Two specific types of in-situ reinforced concrete T-girder bridges are chosen for the failure tests and subsequent analysis: a symmetrically loaded bridge and a non-symmetrically loaded bridge. These represent different real-world scenarios. The analysis incorporates path-dependent in-plane constitutive laws of cracked reinforced concrete to accurately model the behaviour of the bridge materials.
Different modelling approaches are used for the two selected bridges. For the symmetrically loaded bridge, a two-dimensional finite element model with an RC zoning method is applied. For the non-symmetrically loaded bridge, a combination of frame elements using the fibre technique and layered shell elements in a three-dimensional model is used. Experimental results indicate that even in old reinforced concrete bridges with deterioration, a significant portion of their load-carrying capacity is retained. The manner in which degraded support conditions are modelled has a substantial impact on the predicted capacity and stiffness of the bridges. This highlights the importance of accurately representing support conditions in the analysis.

Evaluation of dynamic loads on a skew box girder continuous bridge Part I: Field test and modal analysis: Demeke B. Ashebo, Tommy H.T. Chana, and Ling Yua.

This paper details a comprehensive study aimed at evaluating dynamic loads on an existing continuous skew box girder bridge. The study encompasses a range of critical components, including the experimental procedure, the deployment of a data acquisition system, calibration testing, modal analysis, and the analysis of load distribution in the transversal direction. To calibrate the measurements, a three-axle heavy truck was utilized to induce both static and dynamic bending moments on the bridge, with a focus on establishing the correlation between measured strain and bending moments. The investigation into the bridge's dynamic behaviours relied on both experimental and theoretical modal analyses. Furthermore, the study explored the impact of skewness, or the angle of skew, on the bridge's static and dynamic characteristics, as well as its influence on load distribution for both the calibration truck and regular in-service vehicles. Surprisingly, the findings demonstrated that within the skew angle range of 0° to 30°, skewness had a negligible effect on both the static and dynamic behaviours of the bridge. Experimental study of the load-deformation behaviour of the precast post-tensioned continuous girder for straddle monorail: Full-scale load test under service and ultimate loading conditions: Athasit Sirisonthi, Suniti Suparp, Panuwat Joyklad, Qudeer Hussain, and Phongthorn Julphunthong.
This study reports the findings of an experimental investigation carried out on a newly designed Full-scale Precast Post-tensioned Continuous (FPPC) girder intended for a straddle monorail system, specifically the Yellow Line and Pink Line Monorail in Bangkok, Thailand. This innovative FPPC girder offers several advantages, including its lightweight nature, cost-effectiveness, and ease of rapid construction. The girder comprises three reinforced concrete (RC) hollow haunched girders, four piers or supports, two pier segments, four wet joints, and four bearings at each support. Construction took place at the Sino-Thai Engineering and Construction Public Company Limited (STECON) casting yard in Thailand. The girder underwent testing under various loading conditions, including service and ultimate loading scenarios, with both types applied as two-point loadings.

Failure of concrete T-beam and box-girder highway bridges subjected to cyclic loading from traffic: Kent K. Sasaki, Terry Paret, Juan C. Araiza, and Peder Hals.

Concrete cast-in-place T-beam highway bridges often involve separate casting of girders and the deck, leading to a cold joint formation between the two components. This practice can, under specific conditions, result in undesired consequences such as cracking and noticeable slippage at the joint. These issues can even lead to the fracturing of the reinforcing steel that spans the joint, significantly diminishing the intended composite action between the flange and the web. An in-depth evaluation was conducted on 12 five-girder T-beam bridges located on Interstate 40 (I-40) in the south-western United States after observing movement at these joints and identifying a potential failure mechanism common to all. Additionally, considering the presence of alkali silica reaction (ASR) affecting bridges in the region, the study assessed whether ASR had played a role in these failures. Several contributing factors to the failure mechanism were pinpointed, including a lack of recognition in the original design standards regarding cyclic loading, a high volume of heavy truck traffic, and the generation of transverse moments due to unbalanced wheel loading. Following the investigation, recommendations were put forth for implementing special inspections of construction joints in similar existing bridges.

Free Vibration Analysis of RC Box-Girder Bridges Using FEM: Preeti Agarwal, Priyaranjan Pal and Pradeep Kumar Mehta.

The finite element method is employed to conduct a comprehensive analysis of the natural vibrations in simply supported box-girder bridges. This analysis extends to various configurations, including straight, skew, curved, and skew-curved box-girder bridges. The significance lies in understanding the interplay between skewness and curvature, as the behaviour of skew-curved box-girder bridges cannot be predicted simply by summing up the individual effects of skewness and curvature. Initially, an existing model is employed to validate the current methodology. A meticulous convergence study is undertaken to determine the appropriate mesh size for the finite element method. Furthermore, an extensive parametric investigation is carried out to ascertain the fundamental frequency of box-girder bridges under varying conditions, encompassing changes in skew angle, curve angle, span length, span-depth ratio, and the use of single or double cells. This study involves a total of 420 different bridge models, enabling a comprehensive examination. Additionally, the study presents mode shapes for skew-curved bridges and reveals that the fundamental frequency of skew-curved box-girder bridges exceeds that of straight bridges, making the former a preferable choice. Overall, this research offers valuable insights for the design of box-girder bridges.

Influence of reinforcement corrosion on shear resistance of RC bridge girder subjected to shear: Peter Koteš, Miroslav Brodňana, Martina Ivašková, and Kamil Dubala.

The quality and longevity of concrete structures can be significantly compromised by various deterioration processes. In the context of reinforced concrete (RC) structures, one of the most well-known degradation mechanisms is the corrosion of reinforcement. To meet the stipulations outlined in Euro code (specifically, STN EN 1992-1-1 and STN EN 1992-2), RC elements must adhere to specific criteria. Horizontal beams primarily endure forces related to bending and shear. This paper focuses on the corrosion of stirrups, which are a form of shear reinforcement, and examines its impact on the load-bearing capacity of existing bridge concrete structures. The study encompasses two distinct approaches: one involving passive stage calculation and the other involving active stage calculation.

LITERATURE REVIEW ON ANALYSIS & DESIGN GIRDER BRIDGE BY USING CSI BRIDGE: Mohd Junaid Mohd Zubair, Prof. Arvind B. Vawale, Prof. Nitin S. Vaidkar, Prof. Dr. Pradeep Sudhakar Bhalage.

The significance of bridge design has grown considerably due to compelling reasons. Bridges play a crucial role in enhancing our road networks, facilitating uninterrupted traffic flow, and ensuring road safety. It is essential to assess whether the chosen structural design will perform safely and effectively throughout its operational lifespan, particularly in varying weather conditions. This study involves a comparative analysis of bridge designs in accordance with different international design codes, with a focus on determining which approach offers superior performance and cost-efficiency. The research investigates how various combinations of loads and girder sections are employed to distribute the weight effectively. As the beam depth decreases, the pre stressing force also decreases, reducing the number of cables required for pre stressing. This approach not only harnesses the additional strength of concrete but also optimizes functionality and structural integrity.

Load Rating of a Reinforced Concrete T-Beam Bridge through Ambient Vibration Testing and Finite Element Model Updating: Abdou K. Ndong, Mehrdad S. Dizaji, Mohamad Alipour, Osman E. Ozbulut, and Devin K. Harris.

This paper addresses the critical need for accurate load rating procedures as the demand on highway bridges continues to rise. It emphasizes the limitations of conventional design office load rating techniques, particularly for bridges lacking structural plans, prompting the development of a more advanced approach. The methodology presented here offers a novel way to compute the live load-carrying capacity of reinforced concrete T-beam bridges, applicable to bridges with varying degrees of design information availability. This method employs modal identification through ambient vibrations and finite element model refinement based on vibration characteristics to estimate capacity. Field testing of a simply supported T-beam bridge in Virginia validates the proposed method, with accelerometers collecting vital data for analysis. The results highlight the capacity of the proposed approach to reveal the reserve capacity of bridges, setting it apart from traditional design office load rating procedures and underlining its potential significance in assessing existing bridge structures.

Model-assisted clustering for automated operational modal analysis of partially continuous multi-span bridges: Elisa Tomassini, Enrique García-Macías, Edwin Reynders, Filippo Ubertini.
This paper addresses an important gap in the field of structural health monitoring (SHM) and Operational Modal Analysis (OMA) for long multi-span bridges. While these bridges are commonplace in civil infrastructure, their condition-based maintenance using vibration-based SHM has received limited attention in the literature. The complexity arises from the quasi-periodic nature of these structures and the presence of weak inter-span coupling, even in designs following isostatic principles. This inherent coupling results in closely spaced frequencies and similar mode shapes, making it challenging to identify physical poles through stabilization diagrams. To tackle this issue, the paper introduces a novel model-based machine learning approach that leverages the analytical solution of the vertical free vibration response of multi-span girders with weak inter-span rotational coupling. This method enables the estimation of modal characteristics for a wide range of bridge configurations, from simply supported to perfectly continuous conditions. The study includes comprehensive parametric analyses and discussions on the correlation between inter-span rotational coupling, modal pole clustering, and the impact of various damage conditions. It also proposes a model-based cut-off distance threshold for hierarchical clustering to automate the OMA of multi-span bridges. The effectiveness of the approach is demonstrated through testing on a real-world seven-span reinforced concrete girder bridge, the Trigno V Bridge in Italy. Overall, this research presents a promising methodology to enhance the monitoring and maintenance of complex multi-span bridges, addressing a significant practical challenge in civil engineering.

Practical Approach for Estimating Distribution Factor for Load Rating: Demonstration on Reinforced Concrete T-Beam Bridges: F. Necati Catbas, M.ASCE; H. Burak Gokce; and Mustafa Gul, A.M.ASCE.
This paper introduces a practical and efficient methodology that combines straightforward analysis techniques with rapid experimental tests to determine distribution factors (DFs) for existing highway bridges. The approach is applied and demonstrated on a population of reinforced concrete T-beam bridges. The key innovation lies in establishing that the moment DFs for single-span T-beam bridges can be accurately derived by considering parameters such as skew angle, modal frequency, and the flexibility coefficient. These essential variables can be effectively identified through rapid impact testing, conducted using a tool like a falling weight deflectometer (FWD). The paper initially validates this novel approach using finite-element model (FEM) simulations, highlighting that the moment approximation using this method is remarkably precise, with just a 6% deviation from FEM results. In contrast, conventional beam line analysis specified in the AASHTO code results in a larger 30% approximation error. The efficacy of this new approach is further demonstrated by applying it to experimental data from four real-life bridges, enabling the computation of moment values and load ratings. The results indicate that this innovative approach conservatively estimates live load increases for these existing bridges. Overall, this research offers a valuable advancement in the assessment and analysis of bridge structures, with practical implications for bridge maintenance and safety.

II. METHODOLOGY

1) Modelling in CSi Bridge:

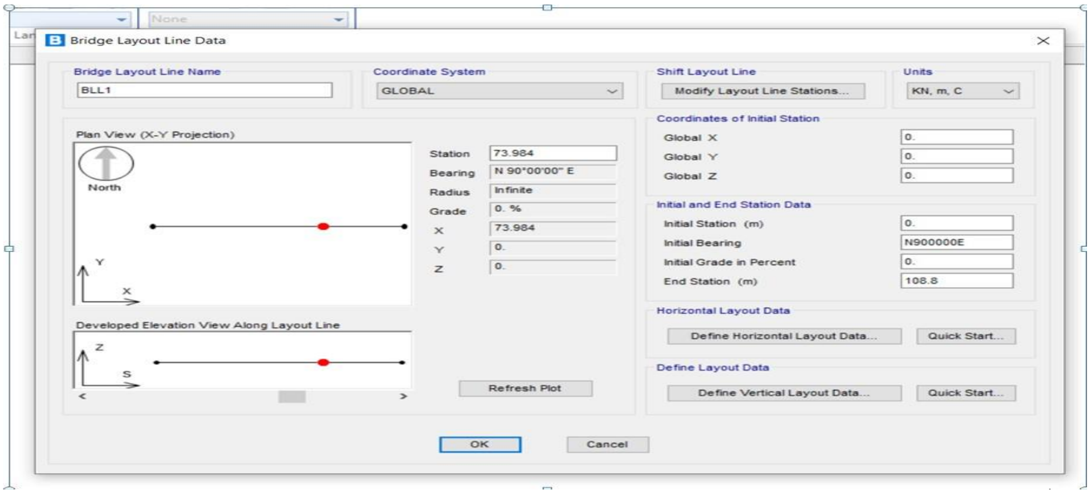
CSI Bridge employs a versatile array of modelling methods to accurately represent and analyse various bridge structures, tailored to the complexity and nature of the project at hand. For intricate and multidimensional bridge designs, Finite Element Analysis (FEA) is a go-to method, breaking down the structure into smaller elements for a comprehensive examination of stress, strain, and deformation. Simpler components like beams and columns are often modelled using line elements, while shell elements come into play for plate-like structures like bridge decks. For three-dimensional features such as piers and abutments, 3D solid modelling provides a complete representation. Beam modelling simplifies the analysis of linear members, such as girders and trusses. Furthermore, CSI Bridge accommodates nonlinear modelling when needed, accounting for material nonlinearity or large deformations. When it comes to simulating the construction sequence, staged construction modelling captures the bridge's behaviour throughout the construction process. This diverse toolbox of modelling techniques ensures that engineers can precisely and comprehensively simulate and analyse their bridge designs, catering to the specific demands of each project.
Modelling of Bridge involves following steps:

1) Bridge layout line data
2) Defining lane width

3) Material Specification:
4) Defining section properties:
5) Select bridge deck section type
6) Bridge section data-Concrete Tee beam
7) Bridge bent cap data
8) Defining load pattern
9) Bridge object data
10) Model 3d view
11) Extruded view

In Bridge layout line data we need to specify the overall length of bridge that is 108.8 m, after that we define lane width of 3.75 m each. In material specification we assigned M20 Grade of concrete and Fe415 steel. In defining section parameters we defined different sections based on requirement. After that we need to select bridge deck section of available configurations to define all parameters of bridge. After updating the model we will get rendered view as shown.

1) Bridge layout line data:



Bridge Layout Line Data

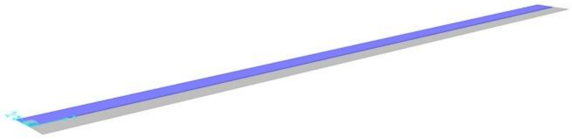
Bridge Layout Line Name: BLL1
Coordinate System: GLOBAL
Units: KN, m, C

Station: 73.984
Bearing: N 90°00'00" E
Radius: Infinite
Grade: 0. %
X: 73.984
Y: 0.
Z: 0.

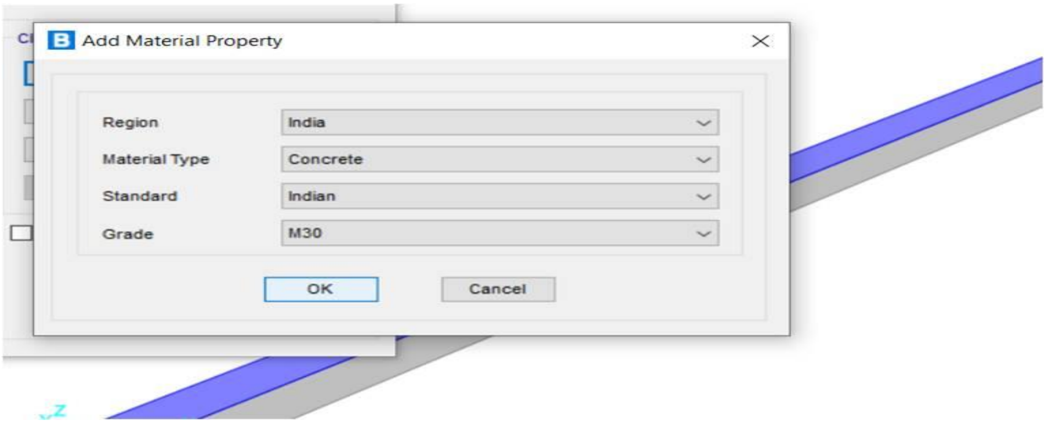
Coordinates of Initial Station
Global X: 0.
Global Y: 0.
Global Z: 0.

Initial and End Station Data
Initial Station (m): 0.
Initial Bearing: N900000E
Initial Grade in Percent: 0.
End Station (m): 108.8

2) Defining lane width:



3) Material specification:



Add Material Property

Region: India
Material Type: Concrete
Standard: Indian
Grade: M30

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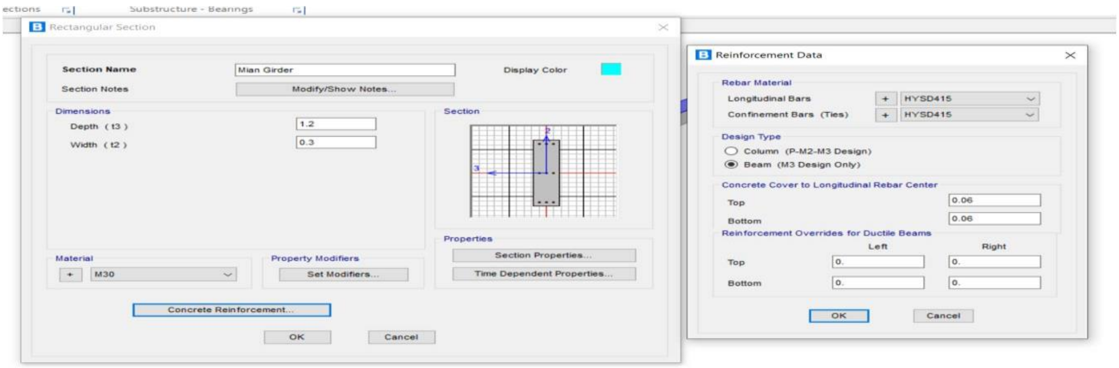
4) Defining section properties



Section Name: Mian Girder

Dimensions
Depth (t3): 1.2
Width (t2): 0.3

Material: M30

Rebar Material
Longitudinal Bars: HYSD415
Confinement Bars (Ties): HYSD415

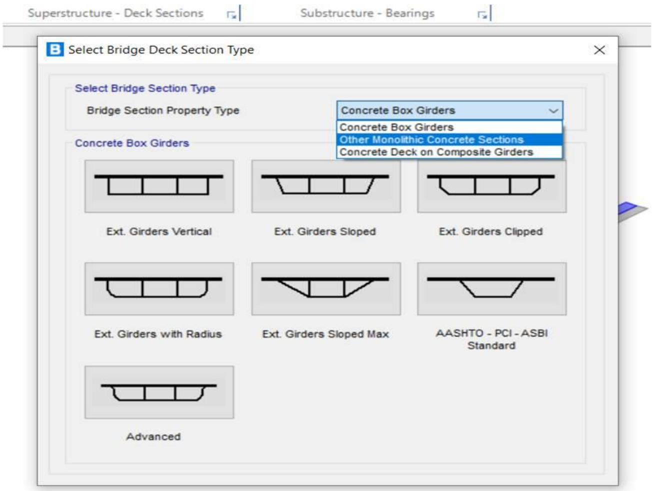
Design Type
○ Column (P-M2-M3 Design)
● Beam (M3 Design Only)

Concrete Cover to Longitudinal Rebar Center
Top: 0.06
Bottom: 0.06

Reinforcement Overrides for Ductile Beams

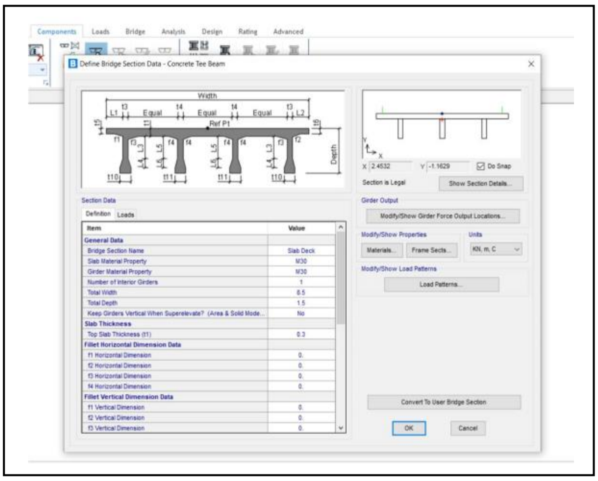
	Left	Right
Top	0.	0.
Bottom	0.	0.

5) Select bridge deck section type



Bridge Section Property Type: Concrete Box Girders
Concrete Box Girders
Other Monolithic Concrete Sections
Concrete Deck on Composite Girders

6) Bridge section data-Concrete Tee beam



X 2.4532 Y -1.1629 ☑ Do Snap

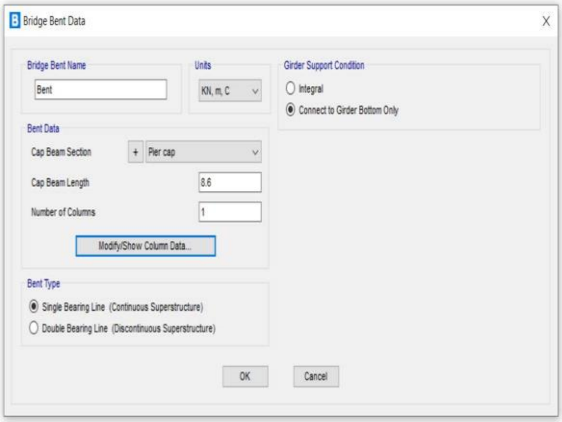
Section is Legal

Units: KN, m, C

Section Data — Definition | Loads

Item	Value
General Data	
Bridge Section Name	Slab Deck
Slab Material Property	M30
Girder Material Property	M30
Number of Interior Girders	1
Total Width	8.5
Total Depth	1.5
Keep Girders Vertical When Superelevate? (Area & Solid Mode...	No
Slab Thickness	
Top Slab Thickness (t1)	0.3
Fillet Horizontal Dimension Data	
f1 Horizontal Dimension	0.
f2 Horizontal Dimension	0.
f3 Horizontal Dimension	0.
f4 Horizontal Dimension	0.
Fillet Vertical Dimension Data	
f1 Vertical Dimension	0.
f2 Vertical Dimension	0.
f3 Vertical Dimension	0.

7) Bridge bent cap data



Bridge Bent Name: Bent

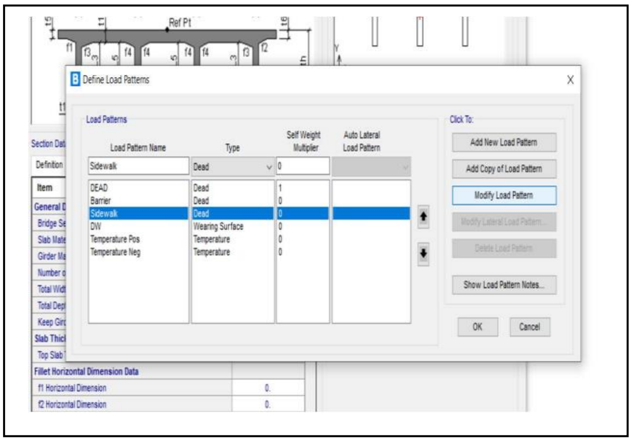
Units: KN, m, C

Girder Support Condition
○ Integral
● Connect to Girder Bottom Only

Bent Data
Cap Beam Section: Pier cap
Cap Beam Length: 8.6
Number of Columns: 1

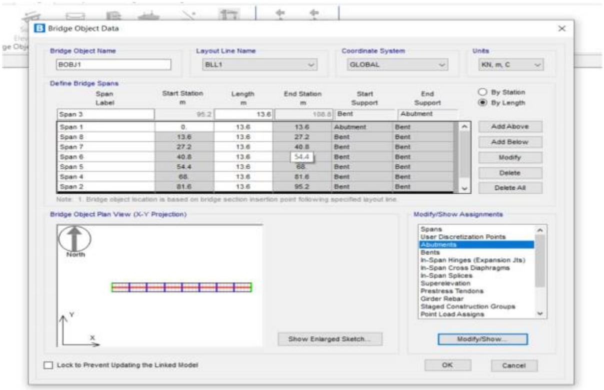
Bent Type
● Single Bearing Line (Continuous Superstructure)
○ Double Bearing Line (Discontinuous Superstructure)

8) Defining load pattern



Load Pattern Name	Type	Self Weight Multiplier	Auto Lateral Load Pattern
Sidewalk	Dead	0	
DEAD	Dead	1	
Barrier	Dead	0	
Sidewalk	Dead	0	
DW	Wearing Surface	0	
Temperature Pos	Temperature	0	
Temperature Neg	Temperature	0	

9) Bridge object data



Bridge Object Data

Bridge Object Name: BOBJ1
Layout Line Name: BLL1
Coordinate System: GLOBAL
Units: KN, m, C

Define Bridge Spans

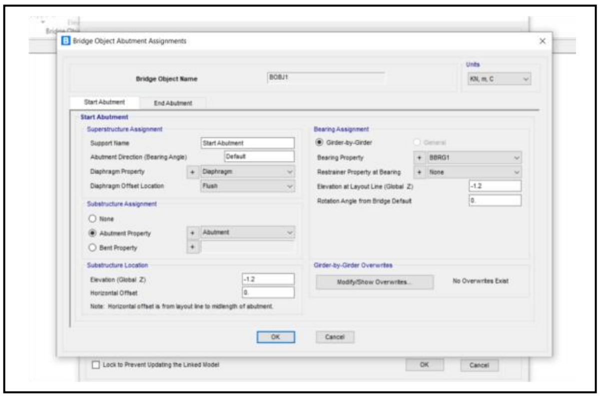
Span Label	Start Station m	Length m	End Station m	Start Support	End Support
Span 3	95.2	13.6	108.8	Bent	Abutment
Span 1	0.	13.6	13.6	Abutment	Bent
Span 8	13.6	13.6	27.2	Bent	Bent
Span 7	27.2	13.6	40.8	Bent	Bent
Span 6	40.8	13.6	54.4	Bent	Bent
Span 5	54.4	13.6	68.	Bent	Bent
Span 4	68.	13.6	81.6	Bent	Bent
Span 2	81.6	13.6	95.2	Bent	Bent

○ By Station
● By Length

Note: 1. Bridge object location is based on bridge section insertion point following specified layout line.

☐ Lock to Prevent Updating the Linked Model

10) Bridge Object Abutment Assignment



Bridge Object Abutment Assignments

Bridge Object Name: BOBJ1
Units: KN, m, C

Start Abutment

Superstructure Assignment
Support Name: Start Abutment
Abutment Direction (Bearing Angle): Default
Diaphragm Property: Diaphragm
Diaphragm Offset Location: Flush

Substructure Assignment
○ None
● Abutment Property: Abutment
○ Bent Property

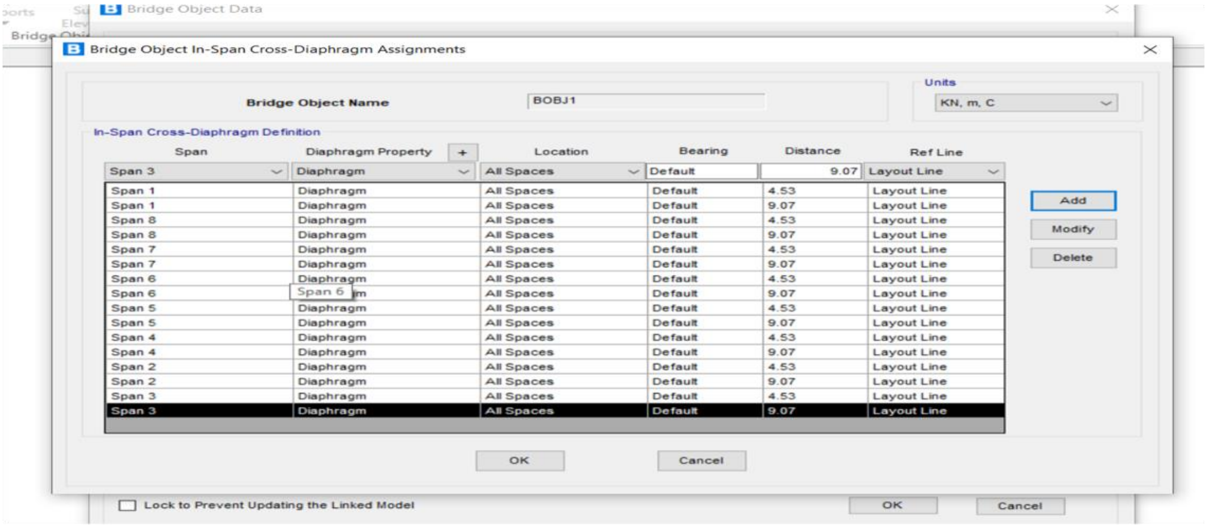
Substructure Location
Elevation (Global Z): -1.2
Horizontal Offset: 0.
Note: Horizontal offset is from layout line to midlength of abutment.

Bearing Assignment
● Girder-by-Girder ○ General
Bearing Property: BBRG1
Restrainer Property at Bearing: None
Elevation at Layout Line (Global Z): -1.2
Rotation Angle from Bridge Default: 0.

Girder-by-Girder Overwrites
No Overwrites Exist

☐ Lock to Prevent Updating the Linked Model

11 in span Cross Diaphragm Assignment



Bridge Object In-Span Cross-Diaphragm Assignments

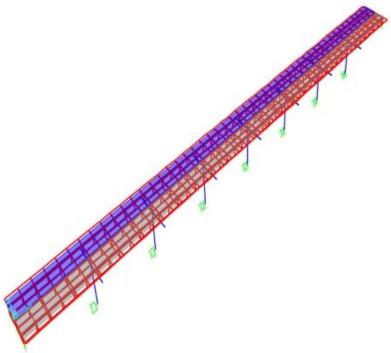
Bridge Object Name: BOBJ1
Units: KN, m, C

In-Span Cross-Diaphragm Definition

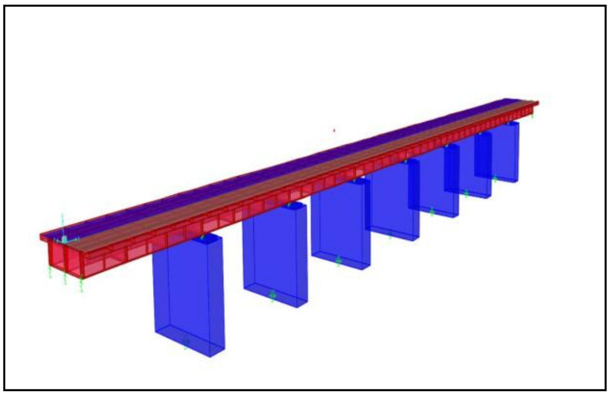
Span	Diaphragm Property	Location	Bearing	Distance	Ref Line
Span 3	Diaphragm	All Spaces	Default	9.07	Layout Line
Span 1	Diaphragm	All Spaces	Default	4.53	Layout Line
Span 1	Diaphragm	All Spaces	Default	9.07	Layout Line
Span 8	Diaphragm	All Spaces	Default	4.53	Layout Line
Span 8	Diaphragm	All Spaces	Default	9.07	Layout Line
Span 7	Diaphragm	All Spaces	Default	4.53	Layout Line
Span 7	Diaphragm	All Spaces	Default	9.07	Layout Line
Span 6	Diaphragm	All Spaces	Default	4.53	Layout Line
Span 6	Span 6 m	All Spaces	Default	9.07	Layout Line
Span 5	Diaphragm	All Spaces	Default	4.53	Layout Line
Span 5	Diaphragm	All Spaces	Default	9.07	Layout Line
Span 4	Diaphragm	All Spaces	Default	4.53	Layout Line
Span 4	Diaphragm	All Spaces	Default	9.07	Layout Line
Span 2	Diaphragm	All Spaces	Default	4.53	Layout Line
Span 2	Diaphragm	All Spaces	Default	9.07	Layout Line
Span 3	Diaphragm	All Spaces	Default	4.53	Layout Line
Span 3	Diaphragm	All Spaces	Default	9.07	Layout Line

☐ Lock to Prevent Updating the Linked Model

12) FEM Model



13) Rendered View



Loading and Analysis:

After defining bridge object data, software will automatically generate the model load cases as per model specification requirements, we have to define vehicle class and speed to which vehicle need to be passed over bridge. For seismic analysis we need to define seismic function with available data input such as soil type, zone, reduction factor, and importance factor.

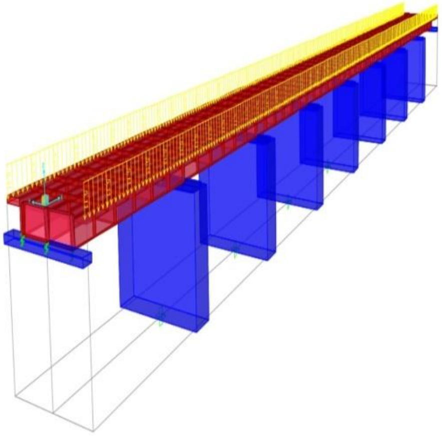


Figure 1 Railing load assignment

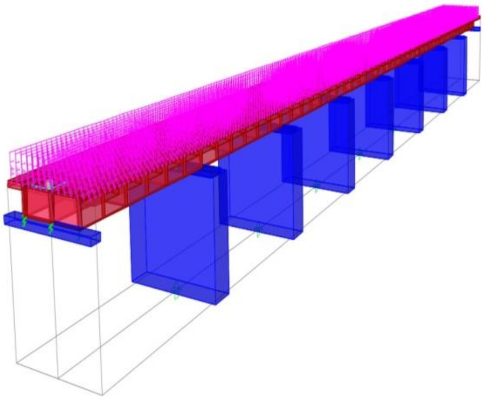


Figure 2: Wearing surface load

III. RESULTS AND DISCUSSION

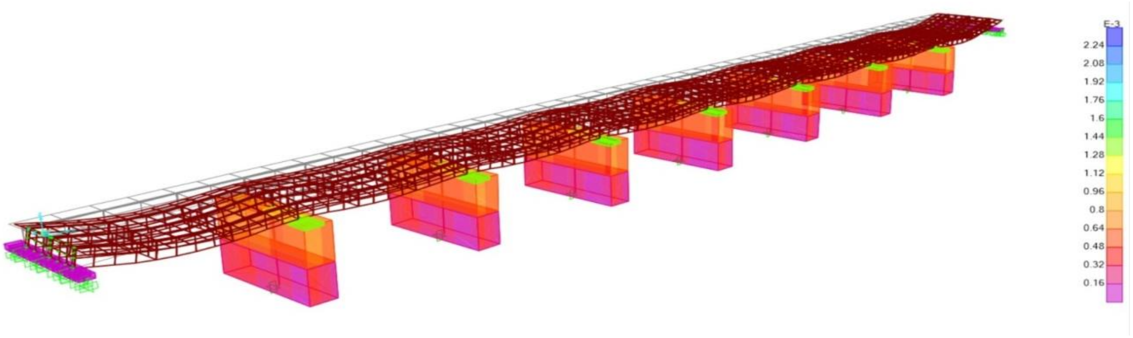


Figure 3 Deformed shape DL

IV. CONCLUSION

The literature presented here covers a wide range of studies related to the analysis and behaviour of various types of bridges, offering valuable insights into their structural performance. The first set of studies explores the load distribution and capacity assessment of different bridge types. Seo and Kidd investigate the impact of parameters on live-load distribution in precast concrete double-tee girder bridges, emphasizing the importance of span length and width-to-length ratio. Gupta, Kaushal, and Ranjan focus on T-beam girder bridges, highlighting the skew angle as a critical factor affecting bending moments and shear forces. Schanck and Davids introduce a novel proxy finite element analysis technique to assess older T-beam bridges more accurately, challenging conventional rating factors. Meanwhile, Xu and Li delve into the dynamic behaviour of multi-span bridges under moving loads, emphasizing the significance of span count and coupling conditions. Zeng, Yang, and Dimitrakopoulos explore the resonance dynamics of high-speed vehicles on curved bridges, offering insights into damping and feedback effects. Song, You, Byun, and Maekawa investigate the failure behaviours of deteriorated T-girder bridges under cyclic loading, presenting a valuable finite element modelling technique. Lastly, Ashebo, Chana, and Yu evaluate dynamic loads and skewness effects on box girder bridges, emphasizing the negligible influence of skew angle on bridge behaviour. Agarwal, Pal, and Mehta provide a comprehensive analysis of free vibrations in box-girder bridges, considering various configurations and

DOI: 10.17148/IARJSET.2023.10824

parameters. These studies collectively contribute to our understanding of bridge performance, design, and assessment across different types and conditions, ultimately enhancing the safety and sustainability of transportation infrastructure.

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