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Non-Linear Behaviour Analysis Of Rcc T Beam Bridge Girder At Different Span Levels

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Abstract: This dissertation presents a non-linear analysis of reinforced cement concrete (RCC) T-beam bridge girders across different span lengths. The study focuses on evaluating structural responses such as bending moment, shear force, axial force, torsion, and displacement under standard IRC loading conditions. Both manual calculations and STAAD.Pro simulations were performed to validate results and highlight the limitations of linear design assumptions. The findings indicate that span length has a significant effect on girder behaviour, with longer spans showing increased bending and deflection demands, requiring careful reinforcement and design optimization. The analysis also considers long-term effects such as creep and shrinkage, providing a realistic assessment of structural performance over service life. By comparing linear and non-linear responses, the study emphasizes the importance of advanced modelling for safe and economical bridge design. The outcomes contribute to improved understanding of T-beam girder performance, offering practical guidance for engineers in designing durable and efficient bridge structures.

Key Words: RCC T-beam, non-linear behavior, span length, STAAD.Pro, structural analysis.

1.INTRODUCTION

Reinforced cement concrete (RCC) T-beam girders are among the most widely used structural systems in bridge construction due to their efficiency in resisting bending and shear forces. With increasing transportation demands, accurate evaluation of their performance under varying loads and spans has become critical. Traditional linear analysis often fails to capture the true structural response, particularly when factors such as cracking, material non-linearity, and geometric effects are significant. Non-linear analysis provides deeper insights into load-deformation behavior, long-term durability, and safety, especially under seismic and dynamic conditions. This study investigates the non-linear performance of RCC T-beam girders across different span levels using advanced analytical methods.

1.1 T Beam

T-beam utilized as a part of construction, is a load bearing structure of reinforced concrete, wood or metal, with a t-formed cross area. The highest point of the t-molded cross segment fills in as a flange or pressure part in opposing compressive stress. The web (vertical area) of the beam beneath the compression flange serves to oppose shear stress and to give more noteworthy detachment to the coupled strengths of bending. T-beam girders are widely used in bridge construction, particularly in highway and railway bridges, due to their ability to span long distances while maintaining structural integrity. They are also common in multi-story buildings, where they serve as floor and roof supports. The advantages of T-beam girders include their efficient use of materials, allowing for lighter construction compared to traditional beam designs, and their versatility in design and application.

1.2 Girder

A girder in construction refers to a primary horizontal support member that carries loads and transfers them to piers or abutments. It can be constructed using materials such as reinforced concrete, structural steel, or composite sections. A girder bridge is one of the most common and fundamental bridge types, in which the deck slab rests directly on girders that span between supports. The girders typically used in such bridges include I-girders, named for their resemblance to the capital letter “I,” box girders, which have a hollow box-like form, and T-girders, whose cross-section resembles the letter “T.” These bridges are generally suitable for medium spans, ranging approximately between 10 m and 200 m, and are widely used in highways, rail overpasses, and pedestrian crossings. Notably, one of the world’s longest girder bridges is located in Brazil, extending about 700 m in length.

2. OBJECTIVE

- Analyse the effect of varying curvature on the non-linear behaviour of RC T-beam girders in curved bridges.
- Evaluate T-beam girder performance under dynamic loads like traffic and seismic activity.
- Study the influence of concrete non-linearities, including cracking and tension stiffening, on T-beam durability and load distribution.
- Compare load-carrying capacity and deflection control of pre-stressed versus non-pre-stressed T-beam girders under static and dynamic loads.
- Perform parametric analysis of seismic effects on T-beam girders, contrasting non-linear and linear models across spans and reinforcement layouts.
- Investigate reinforcement methods, such as steel plate bonding, for enhancing service life and capacity of existing T-beam bridges under non-linear and dynamic conditions.

3. METHODOLOGY

3.1 Courbon's Method

Courbon's method is a classical approach used to determine the distribution of live loads across girders in multi-girder bridges like T-beam or box-girder bridges. It assumes that transverse load distribution depends on girder stiffness and diaphragm positioning, which are taken as rigid. The method works on the principle that load sharing among girders varies with load location and girder spacing. It is especially suited for bridges with parallel, equally spaced girders under vehicular traffic. Courbon’s method calculates the moment on each girder by assuming uniform dead load distribution and considering live load eccentricity. The girders are treated as beams under uniform load, and simple equations are used for distribution. This makes it effective for bridges with moderate spans and straight, symmetric layouts. The key advantage of the method lies in its simplicity and quick manual application during preliminary design. Although not highly sophisticated, it provides sufficiently accurate results for many bridge types. Its accuracy, however, reduces in skewed or curved bridges, where advanced methods are preferable.

3.2 DEAD LOAD

The dead load response of a bridge structure can be evaluated by considering the loads arising from its various superstructure components, such as girders, slab, and deck. The longitudinal moments are determined by multiplying the support reactions with the longitudinal eccentricity, which represents the distance between the centerline of the pier and the bearing location. The total reaction on each bearing is calculated separately for different components of the structure, including girders, slab, and deck, to accurately capture their individual contributions. Additionally, the effects of superimposed dead loads (SIDL), such as the wearing coat, crash barriers, and other permanent fixtures, are also taken into account. By analyzing these loads independently and then combining them, a clear picture of the overall dead load distribution is obtained. This approach ensures that the structural design reflects both the self-weight of the bridge components and the additional permanent loads, thereby enhancing accuracy and safety in design

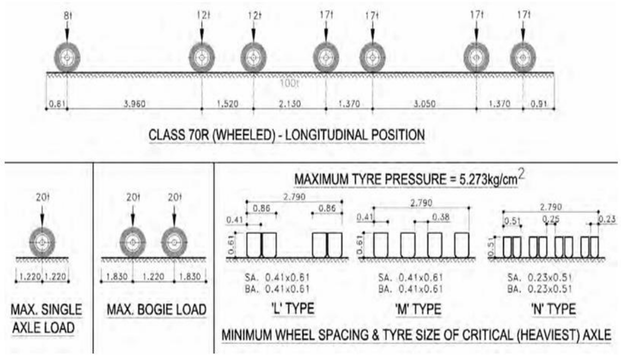
3.3 LIVE LOAD

A. IRC Class AA (Tracked) Loadings – The live load (LL) is considered as per IRC Class AA Tracked Vehicle loading in accordance with IRC:6-2017 guidelines. Fig 5.1 Class AA Tracked Vehicle is adopted for analysis, and appropriate impact factors are applied based on the span lengths, as specified by IRC provisions. This loading represents a heavy tracked vehicle and is primarily used for designing bridges in urban or industrial areas with high traffic density.

Create a Node on STAAD PRO. structure
↓
Create structure with Nodes and Beams
↓
Assign Section Properties
↓
Assign Material Properties
↓
Generate mesh of Deck slab
↓
Assign Supports
↓
Assign Load Definition
↓
Assign Load Cases Details
↓
Analysis
↓
Open Structure in Bridge Deck workflow
↓
Create Deck Slab
↓
Define Roadways
↓
Assign Support Reactions and Node Displacement
↓
Create Load Cases for Analytical Modelling
↓
Assingning THA (Time History Analysis) as load case
↓
Analysis

Fig 1. Class AA Tracked vehicle

B. IRC Class 70R (Wheeled) Loadings - The live load (LL) is considered as per IRC Class 70R Wheeled Vehicle loading in accordance with IRC:6-2017. Load Combination-1 is used for structural analysis, and the corresponding impact



WHEEL ARRANGEMENT FOR 70R (WHEELED VEHICLE)

factors recommended in the IRC code are applied based on the span lengths of the bridges.

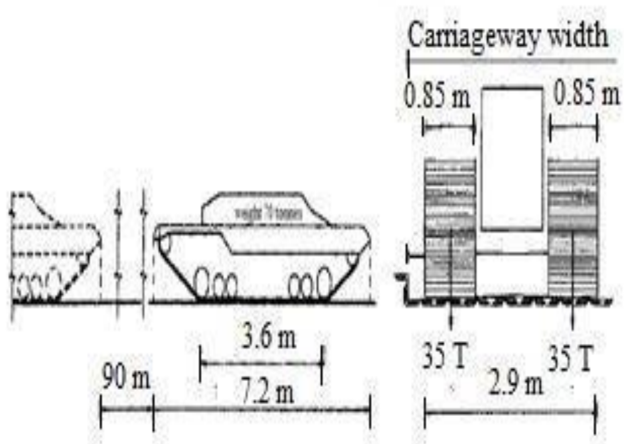


Fig.2 Class 70R Wheeled Vehicle

3.4 Procedure for Modelling in STAAD PRO.

4. DESIGN PARAMETERS

Bridge Type	T-Frame Slab Bridge Deck
Effective Span Length	15m, 20m, 25m and 30m
Height of T-Girder	2m
Lane of Bridge	Two lanes
Slab thickness	0.3m
Carriageway Width	5.2m
Total Width of Bridge Deck	7.66m
No. of longitudinal Girder	3
No. Cross girder	4, 5, 6 and 7
Distance Between Longitudinal Girder	2.6m c/c
Distance Between Cross Girder	5m c/c
Thickness of Girder	0.5m, 0.7m, 0.9m and 1.1m

5. MODELLING & RESULT

5.1 Models

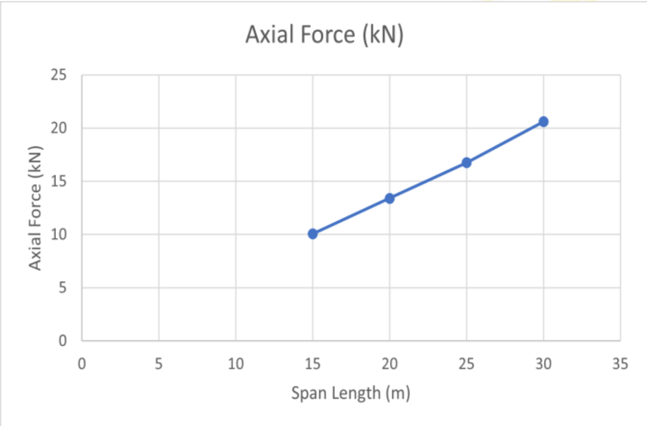
Fig 3. Analytical Model

5.2 Results

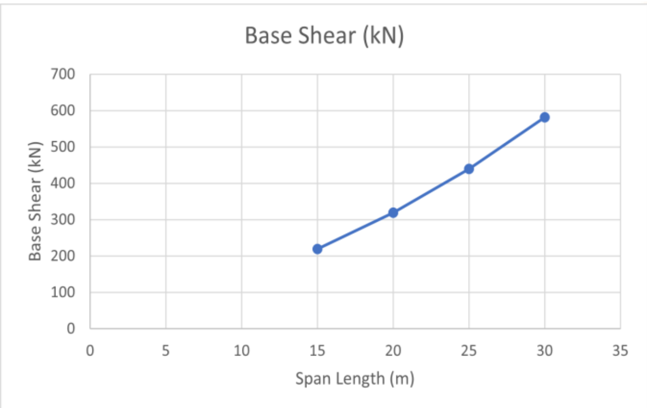
The following graphs will be divided into two types of IRC Live Load
1. IRC Live Load Class AA tracked vehicle
2. IRC Live Load Class 70R wheeled vehicle

A. Performance Parameters under IRC Live Load class AA tracked vehicle

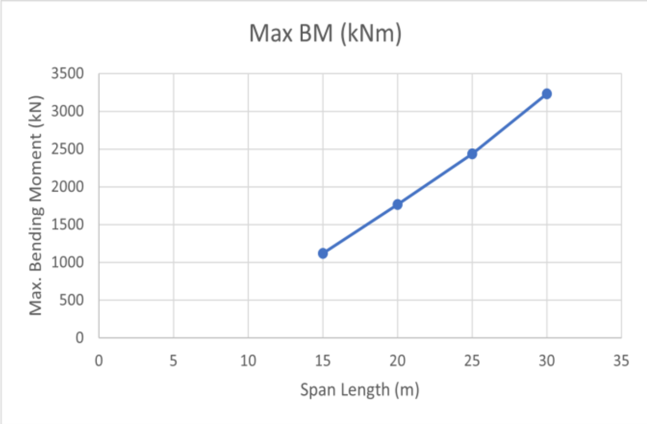
1. Variation in axial force against span length (15m, 20m, 25m, 30m)



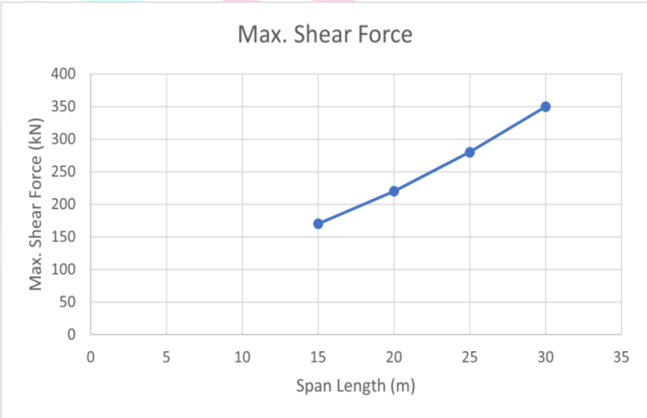
2. Variation in Base Shear against span length (15m, 20m, 25m, 30m)



3. Variation in Maximum Bending Moment against span length (15m, 20m, 25m,30m)

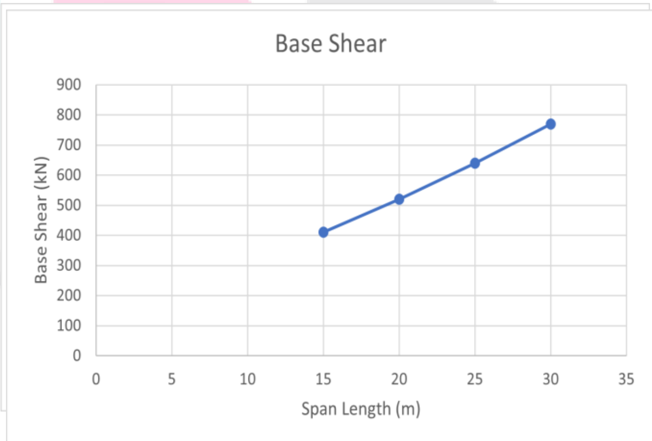


4. Variation in Maximum Shear Force against span length (15m, 20m, 25m, 30m)



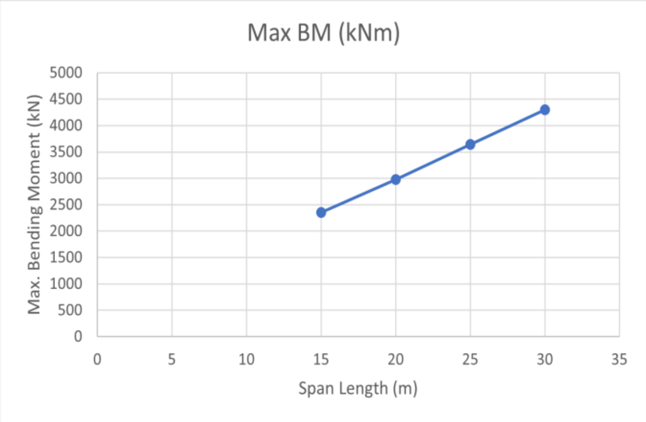
B. Performance Parameters under IRC Live Load class 70R wheeled vehicle

1. Variation in axial force against span length (15m, 20m, 25m, 30m)

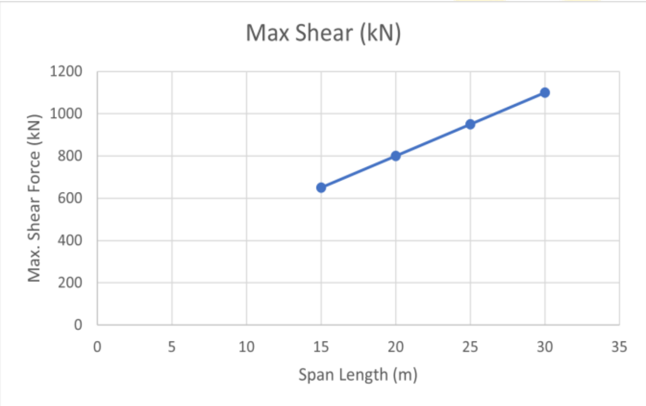


2. Variation in Base Shear against span length (15m, 20m, 25m, 30m)

3. Variation in Maximum Bending Moment against span length (15m, 20m, 25m, 30m)



4. Variation in Maximum Shear Force against span length (15m, 20m, 25m, 30m)



6. CONCLUSIONS

The investigation demonstrates that span length has a significant impact on the structural response of T-beam girder bridges under IRC Live Load Class AA tracked vehicle and Class 70R wheeled vehicle. Axial force, shear force, bending moment, and base shear increase consistently with span, demanding stronger foundations, deeper or prestressed girders, and enhanced reinforcement. Seismic effects become more pronounced in longer spans due to higher base shear, residual displacements, and longer fundamental periods, emphasizing the need for robust lateral load–resisting systems and precise seismic detailing. Although energy dissipation capacity improves with span, indicating enhanced ductility, careful detailing is necessary to prevent excessive deformations and maintain serviceability. Overall, longer spans approach structural capacity limits more rapidly, requiring optimized design strategies, high-performance materials, and balanced integration of strength, ductility, and serviceability.

Future Scope

This study has examined the non-linear behaviour of RCC T-beam girders at selected span levels; however, future research could extend the analysis to longer spans and varied girder configurations for broader applicability. The inclusion of curved and skewed geometries would address limitations of simplified methods such as Courbon's approach. Consideration of dynamic and fatigue loading due to high-volume traffic is also essential to assess long-term performance. Advancements in materials, including high-performance concrete, fibre-reinforced composites, and hybrid girders, may enhance structural capacity and durability. Furthermore, experimental validation using scaled or full-scale models would strengthen the reliability of numerical results. The adoption of advanced computational tools such as ANSYS and ABAQUS for refined 3D nonlinear simulations can provide deeper insights into stress distribution and failure mechanisms.

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