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Comparative Structural Performance of Three-Span Continuous Precast RCC I-Girder and Cast-in-Situ T-Beam Bridges under IRC Loading Using MIDAS Civil

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Abstract: *Bridge construction technology has evolved significantly with the adoption of precast concrete structural systems, which offer advantages in construction speed, quality control and reduced site activities. This research investigates the comparative structural performance of three-span continuous precast reinforced cement concrete (RCC) I-girder and cast-in-situ T-beam bridge superstructures under Indian Road Congress (IRC) loading conditions. Three-dimensional structural modelling and analysis were conducted using MIDAS Civil. The bridge models were evaluated under dead load, wearing coat load, vehicular live loads, safety kerb loading and support displacement effects. The principal parameters considered were bending moments at mid-span and continuous supports, shear forces at supports and deflection under test vehicle loading. The comparative results indicate that the precast I-girder system experiences approximately 8–9% higher total design bending moments at mid-span than the cast-in-situ T-beam system. However, the precast configuration demonstrates 12–15% lower bending moments at continuous supports and 16–20% lower support shear forces. The maximum calculated deflection is also higher in the precast configuration. The findings indicate that precast I-girder construction can provide favourable structural response at continuous supports, although mid-span bending moments and serviceability behaviour require careful consideration.*

Keywords: *Precast RCC I-Girder; Cast-in-Situ T-Beam; Continuous Bridge; MIDAS Civil; IRC Loading; Bending Moment; Shear Force; Structural Analysis*

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I. INTRODUCTION

Bridges are essential components of transportation infrastructure, providing connectivity across rivers, railway lines, highways and other physical obstacles. Increasing traffic volumes and infrastructure development have created a demand for bridge systems that provide structural safety, durability, economy and faster construction.

Conventional cast-in-situ reinforced concrete T-beam bridges have been widely adopted for short- and medium-span applications. Their construction generally requires extensive formwork, scaffolding, reinforcement placement and concrete curing at the construction site.

Precast concrete I-girder bridges provide an alternative construction approach. In this system, longitudinal girders are manufactured under controlled conditions, transported to the construction site and erected using suitable launching equipment. A cast-in-situ deck slab and diaphragms are subsequently provided to establish structural continuity and transverse load distribution.

The structural behaviour of continuous bridge systems is influenced by girder geometry, material properties, support conditions, construction sequence and traffic loading. The present investigation compares the structural response of precast RCC I-girder and cast-in-situ T-beam bridge superstructures

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using MIDAS Civil, with particular attention to bending moments, shear forces and deflection.

II. OBJECTIVES OF THE STUDY

1. To develop analytical models of three-span continuous precast RCC I-girder and cast-in-situ T-beam bridge superstructures.
2. To evaluate bending moments at mid-span and continuous supports.
3. To investigate support shear forces under different loading conditions.
4. To compare the deflection behaviour of both bridge systems under test vehicle loading.
5. To evaluate the influence of dead load, wearing coat, vehicular live load and support displacement.
6. To identify the relative structural advantages and limitations of the two bridge construction systems.

III. LITERATURE REVIEW

Previous investigations have examined the structural performance, construction techniques and load distribution characteristics of precast and cast-in-situ bridge systems. The source dissertation refers to Newmark (1949) on the design of slab and beam components in highway bridges; Khaleel and Itani (1990) on live-load bending moments in continuous normal and skew slab-and-girder bridges; and Marí and Valdés (2000) on the long-term behaviour of continuous precast concrete girder bridges.

The reviewed material also discusses research on precast segmental bridge construction, bridge load distribution and finite element modelling. These studies collectively establish the importance of structural configuration, continuity, construction sequence and load effects in bridge design.

Research Gap

The source dissertation identifies the need for a direct comparative investigation of three-span continuous precast RCC I-girder and cast-in-situ T-beam superstructures under comparable loading and modelling assumptions. The present study addresses this requirement by examining bending moments, support shear forces and deflections using MIDAS Civil.

IV. RESEARCH METHODOLOGY

The research methodology consists of bridge geometry selection, structural modelling, material property definition, load application, analysis and comparative evaluation.

Bridge Configuration

Table 1: Geometric and material parameters of the bridge configuration

Parameter	Specification
Number of spans	3
Total bridge length	60 m
Span arrangement	20 + 20 + 20 m
Effective span arrangement	19.5 + 20 + 19.5 m
Overall carriageway width	12.9 m
Clear carriageway width	10.5 m
Number of main girders	4
Girder centre-to-centre spacing	2.8 m
Deck slab thickness	225 mm
Overall superstructure depth	1,875 mm
Girder depth	1,575 mm
Concrete grade	M35
Unit weight of RCC	25 kN/m³

Material Properties

M35-grade concrete was considered for the precast girders, deck slab and diaphragms. The unit weight of reinforced concrete was taken as 25 kN/m³.

Structural Modelling

Both bridge configurations were analysed using MIDAS Civil finite element software. The modelling procedure included selection of three-span continuous bridge geometry; definition of material and cross-sectional properties; modelling of longitudinal girders, deck slab and diaphragms; definition of support conditions; application of dead, superimposed dead and vehicular live loads; definition of load combinations; and extraction of structural analysis results.

Loading Conditions

The loading conditions considered in the source study include self-weight of the superstructure, wearing coat, crash barrier, safety kerb, vehicular live loads, IRC Class 70R and Class A loading arrangements, support displacement effects and vehicle load test conditions.

The wearing coat thickness was taken as 65 mm, with a density of 25 kN/m³. The live-load impact and congestion factors were considered in accordance with the adopted IRC loading provisions. The impact fraction for a reinforced concrete bridge was calculated using IF = 4.5/(6 + L). For an effective span of 19.5 m, IF = 4.5/(6 + 19.5) = 0.176. The corresponding impact multiplier is 1.176. A congestion factor of 1.15 was also considered. The combined multiplier adopted for the live-load calculations was approximately 1.35.

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V. RESULTS AND DISCUSSION

The structural analysis results obtained from MIDAS Civil were compared for the precast I-girder and cast-in-situ T-beam configurations.

Comparison of Bending Moments at Mid-Span

Table 2: Comparison of Bending Moments at Mid-Span

Girder location	Cast-in-situ (kN-m)	Precast (kN-m)	Difference
Outer girder	5,045.536	5,430.247	+8%
Inner girder	4,180.201	4,558.272	+9%

The precast I-girder system experiences higher total bending moments at mid-span. The increase is approximately 8% for outer girders and 9% for inner girders. This indicates that the precast structural configuration requires particular attention to mid-span flexural design and reinforcement detailing.

Comparison of Bending Moments at Continuous Supports

Table 3: Comparison of Bending Moments at Continuous Supports

Girder location	Cast-in-situ (kN-m)	Precast (kN-m)	Reduction
Outer girder	6,173.310	5,217.000	15%
Inner girder	4,566.183	4,028.428	12%

The precast I-girder system demonstrates lower support bending moments compared with the cast-in-situ T-beam configuration. The reduction is approximately 15% for outer girders and 12% for inner girders.

Comparison of Shear Forces at Continuous Supports

Table 4: Comparison of Shear Forces at Continuous Supports

Girder location	Cast-in-situ (kN)	Precast (kN)	Reduction
Outer girder	1,692.654	1,424.637	16%
Inner girder	1,464.998	1,177.300	20%

The precast I-girder configuration exhibits lower total design shear forces at continuous supports. The reduction is approximately 16% for outer girders and 20% for inner girders.

Comparison of Deflection

Table 5: Comparison of Deflection

Girder location	Precast (mm)	Cast-in-situ (mm)
Inner girder	5.098	3.265
Outer girder	7.611	3.653

The maximum deflection occurs in the outer girder of the precast configuration. The results indicate that the precast bridge experiences greater deflection than the cast-in-situ bridge under the investigated vehicle loading conditions. Serviceability requirements and permissible deflection limits must therefore be carefully evaluated.

Overall Comparative Assessment

The comparative analysis demonstrates that neither structural configuration is superior for every response parameter. The precast I-girder system provides lower bending moments and shear forces at continuous supports, whereas the cast-in-situ T-beam configuration exhibits lower mid-span bending moments and deflections. Selection should consider the complete structural response rather than a single design parameter.

VI. CONCLUSION

1. The precast RCC I-girder bridge experiences approximately 8–9% higher total design bending moments at mid-span compared with the cast-in-situ T-beam bridge.
2. The bending moment at continuous supports is reduced by approximately 12–15% in the precast configuration.
3. The precast I-girder configuration demonstrates a 16–20% reduction in total design shear forces at continuous supports.
4. The maximum deflection in the precast outer girder is 7.611 mm, compared with 3.653 mm in the cast-in-situ configuration.
5. The precast configuration demonstrates favourable structural response at continuous supports, particularly in terms of bending moment and shear force.
6. The higher mid-span bending moments and deflections observed in the precast configuration require attention during flexural design and serviceability verification.
7. Precast construction may offer construction-related advantages through off-site manufacturing and faster erection; project-specific cost and construction assessments are necessary to establish overall economic suitability.

Overall, the findings indicate that the investigated precast RCC I-girder configuration offers a potential alternative for three-span continuous bridge construction, provided that its flexural and serviceability requirements are adequately addressed.

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VII. SCOPE FOR FUTURE RESEARCH

1. Parametric investigation of girder spacing, span length and girder depth.
2. Comparative analysis of reinforced and prestressed concrete I-girders.
3. Investigation of the influence of different concrete grades on structural behaviour.
4. Evaluation of seismic performance under different earthquake loading conditions.
5. Study of temperature, creep and shrinkage effects in continuous precast bridge systems.
6. Experimental validation of numerical results through laboratory testing.
7. Comparative assessment of construction cost, erection time and lifecycle performance.
8. Investigation of splitting resistance and durability characteristics of precast I-girders.

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