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Comparative study of in-situ balanced cantilever and segmental girder bridge

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ABSTRACT

Structural engineers place a high value on bridge engineering. A balanced cantilever bridge is a structural engineering design and construction methodology in which the bridge construction is carried outward from supports, also termed piers, in a symmetrical manner, with cantilever arms extending equidistantly on both sides of each pier. This type of bridge construction is frequently used over obstacles such as rivers, valleys, or highways, where the implementation of temporary scaffolding is impracticable. There are two methods of balanced cantilever bridge and segmental bridge construction: in situ and precast. The in-situ balanced cantilever bridge construction method can be applied to spans of 200 m length or more using cable-stayed and precast segmental bridges, which are suitable for long spans of more than 100 m in length, where there are restrictions for accessing the site in land, and it is also very economical.

In India, bridge construction is performed using IRC codes, such as IRC: 5-2015 standard specifications and code of practice for road bridges[1], IRC: 6-2017 loads and load combinations of bridges[2], and for design purposes IRC: 112-2011 which is a code of practice for concrete road bridges[3]. This paper introduces and attempts to summarize a comparative study of in-situ balanced cantilever and precast segmental girder bridges.

Keywords: Balanced cantilever, in situ, segmental, bridge construction, IRC codes.

1 Introduction

In recent years, the growth of bridge construction has increased tremendously. As a fast growing infrastructure world the bridge are connecting one place to another and helps in developing economic growth of country. In-situ balanced cantilever bridge and segmental precast bridges are playing a major role in bridge construction technique which is frequently used over obstacles such as river, valley or highways as shown in Figure 1.

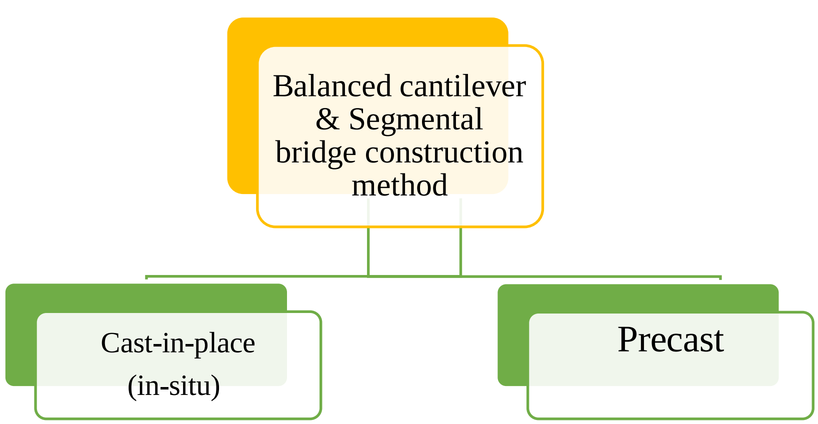


Fig.1. Balanced cantilever and segmental construction methods

The present study aims to examine the specific aspects of the analysis of in-situ balanced cantilever and precast segmental bridge. The work flow is shown in Figure 2. The bridge is design using IRC codes like IRC: 5-2015[1], IRC: 6-2017[2] and IRC: 112-2011[3]. The study will focus on two different bridge structures arrangement. The following types of bridge arrangement are in-situ balanced cantilever and precast segmental bridge. Comparison is done using Midas civil software.

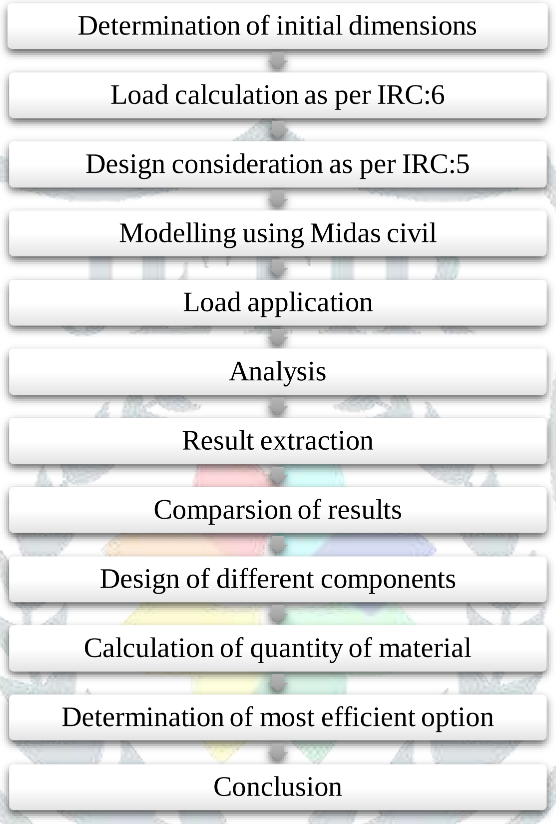


Fig.2. Workflow

2 Methodology

The present study focuses on a bridge with three spans, with middle span measuring 120 meters and side span measuring 60 meters each. The bridge's configuration and dimensions are visually shown in Figure 3 and Figure 4, which illustrate the structural elements and layout of the bridge.

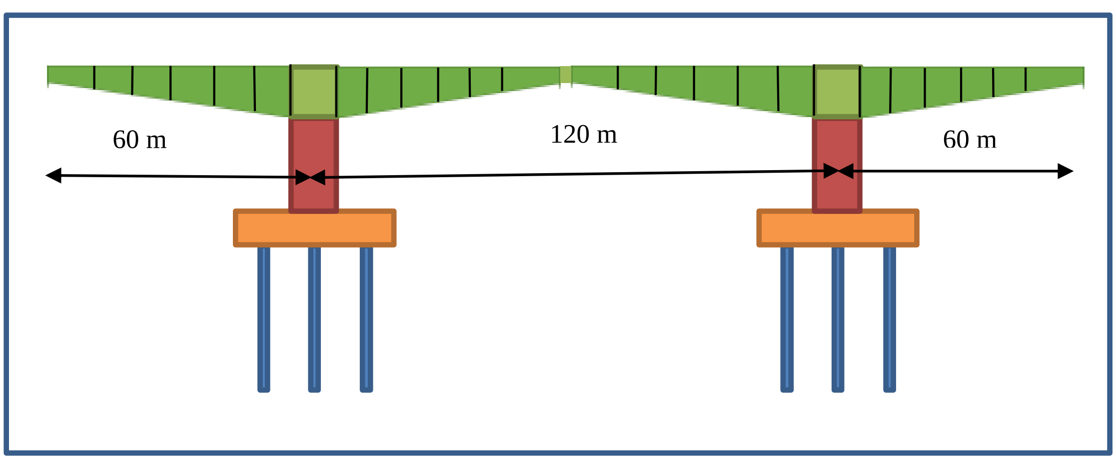


Fig.3. Span detail of in-situ balanced cantilever bridge

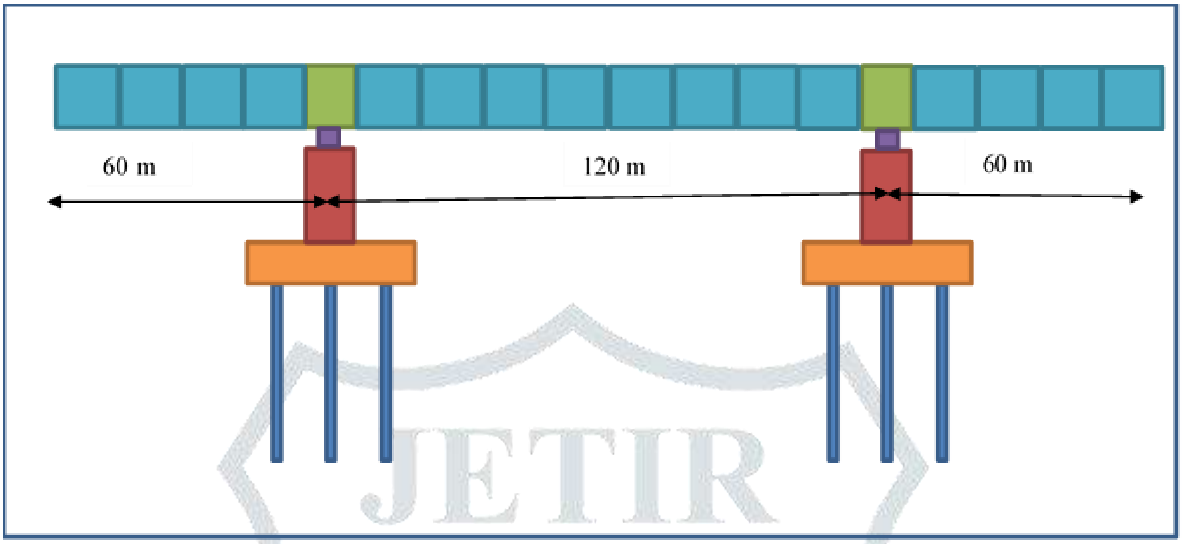


Fig.4. Span detail of precast segmental bridge

2.1 Details of bridge superstructure

The bridge superstructure comprises a deck that is 11.5 m wide and 0.250 m thick, supported by the box girder. The deck width includes the carriageway width of 7.5 m for 2 lane as per IRC: 5-2015[1] clause no.104.3.1 page no 14, 1.5m wide footpath on both sides and 0.5m wide crash barriers on both sides as shown in Figure 4 and Figure 5.The material properties of two different arrangement of bridges are present in Table 1.

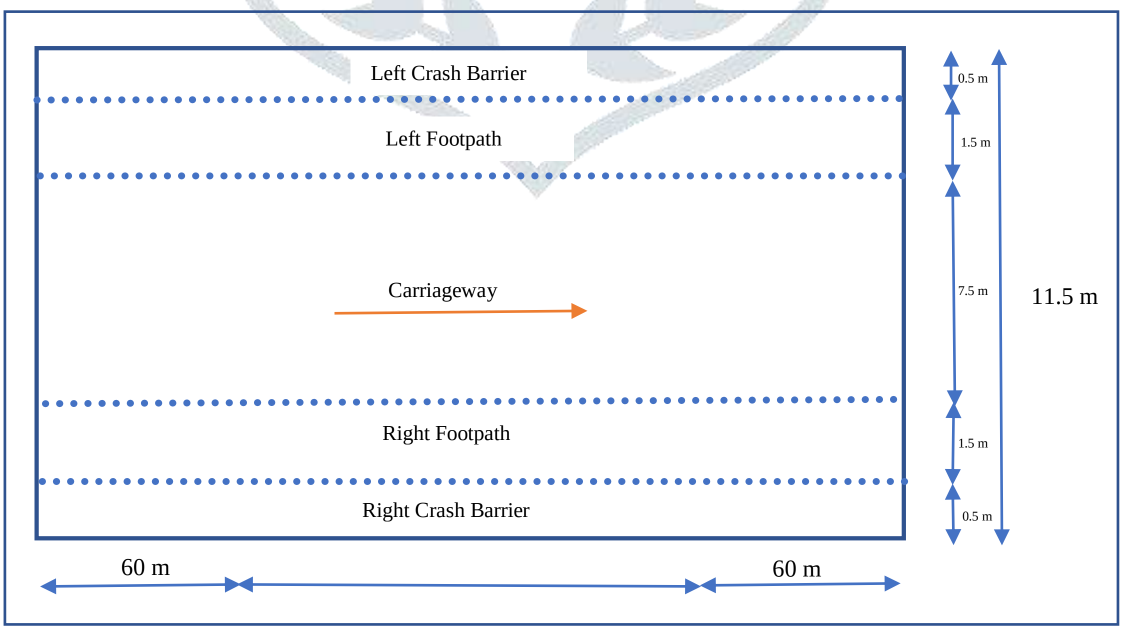


Fig.4. Plan of deck superstructure

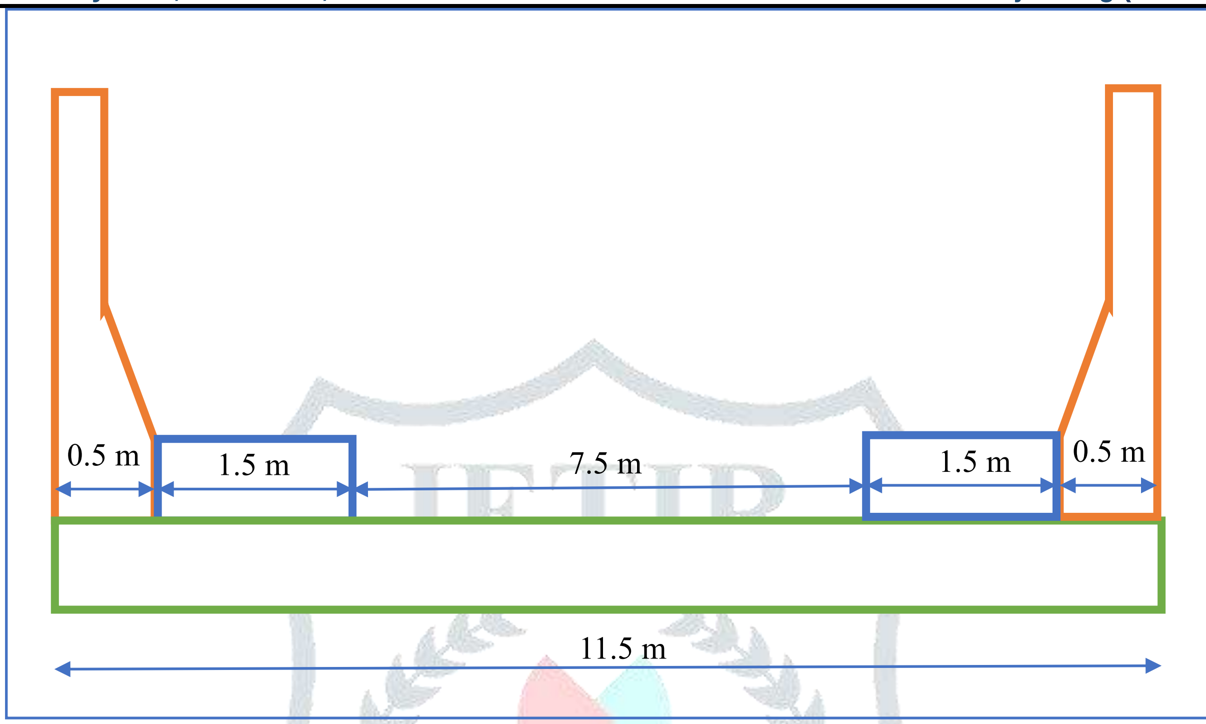


Fig.5. Cross section of deck superstructure

Material properties consider for modelling and analysis of two different arrangements of bridges:

Table 1. Properties of materials

Properties of materials

Grade of concrete for superstructure	=	M50
Grade of concrete for substructure	=	M45
Grade of steel for reinforcement	=	Fe540
Grade of steel for Prestressing	=	Fe1860
Density of concrete	=	25 kN/m^3
Density of wearing coarse	=	22 kN/m^3
Elastic modulus of concrete for girder	=	34000 MPa
Elastic modulus of concrete for deck	=	32000 MPa
Elastic modulus of concrete for pier	=	34000 MPa
Elastic modulus of concrete for abutment	=	34000 MPa
Elastic modulus of prestressing steel	=	195000 MPa
Elastic modulus for reinforcing steel		200000 MPa

3 Structural modelling and analysis

3.1 In-situ balanced cantilever bridge

Loads:

The design load calculation

Dead load as per IRC: 6-2017[2] clause no 203, page no 8.

Figure 6 provides a representation of a cross –section of single cell box at mid-section and Figure 7 provides at pier.

Deck slab (Thickness-0.25m) = 71.875KN/m

Box girder = 260 KN/m

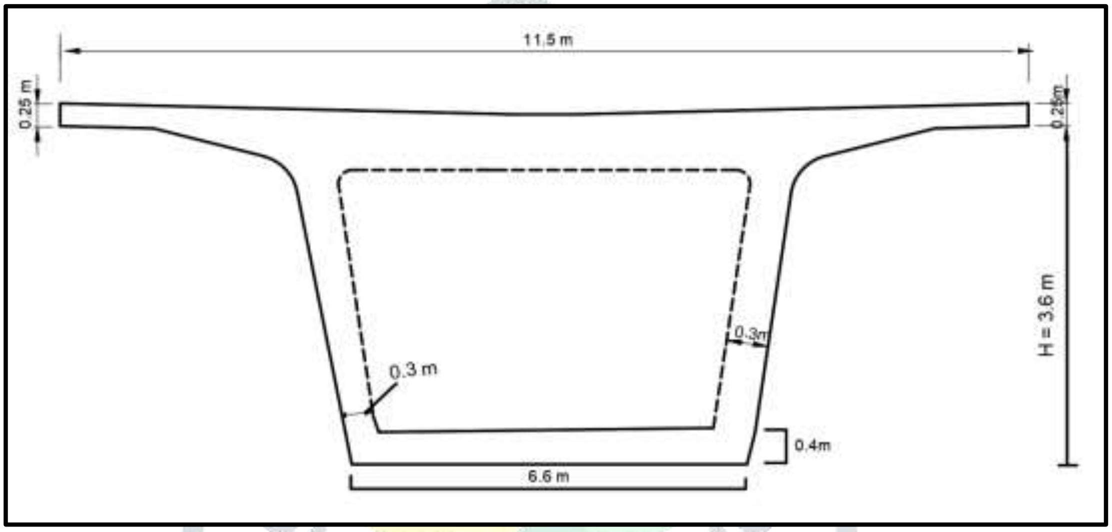


Fig.6 Cross-section of single cell box at mid-section

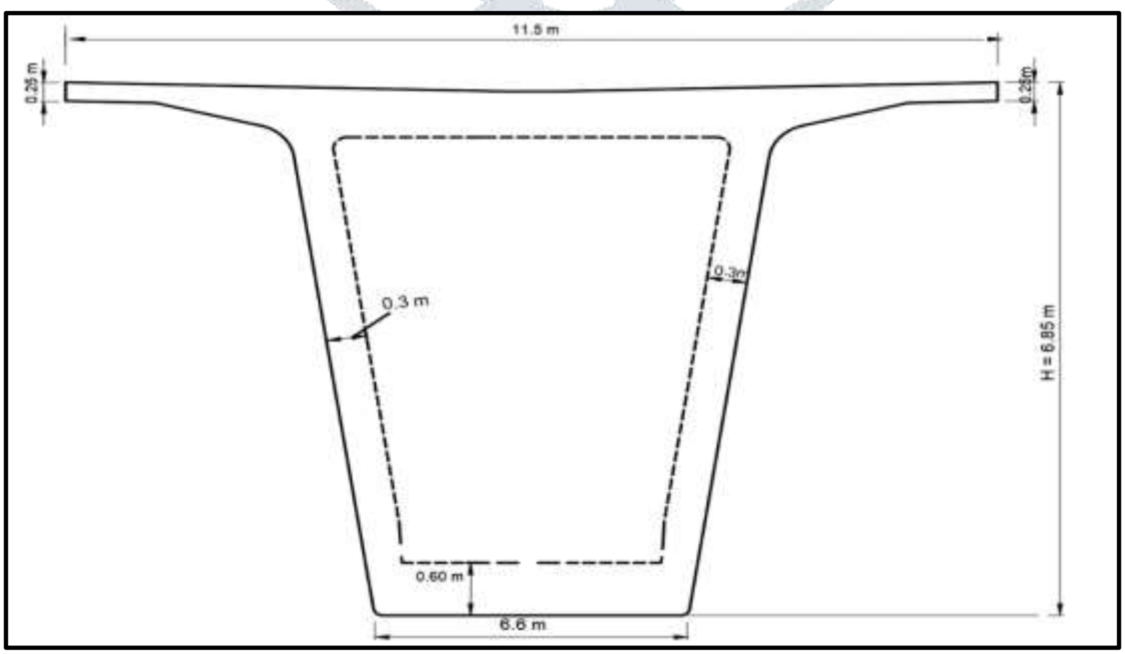


Fig.7 Cross-section of single cell box girder at pier

Superimposed dead load (SIDL) = 39.75 KN/m

Live load as per IRC: 6-2017[2] clause no 204.1.1, page no 10.
Class 70R loading = 153.2 KN/m
Seismic load as per IRC: 6-2017[2] clause no 218.2, page no 61.
Seismic base shear (V_B) site condition (New Delhi) = 89190 KN
Wind load as per IRC: 6-2017[2] clause no 209.3.3, page no 36.
Transverse wind force (Ft) = 95.9859 KN
Vertical wind force (Fv) = 47.99295 KN

Figure 10, Figure 11 and Figure 12 represent the modelling of in-situ balanced cantilever bridge in Midas civil:

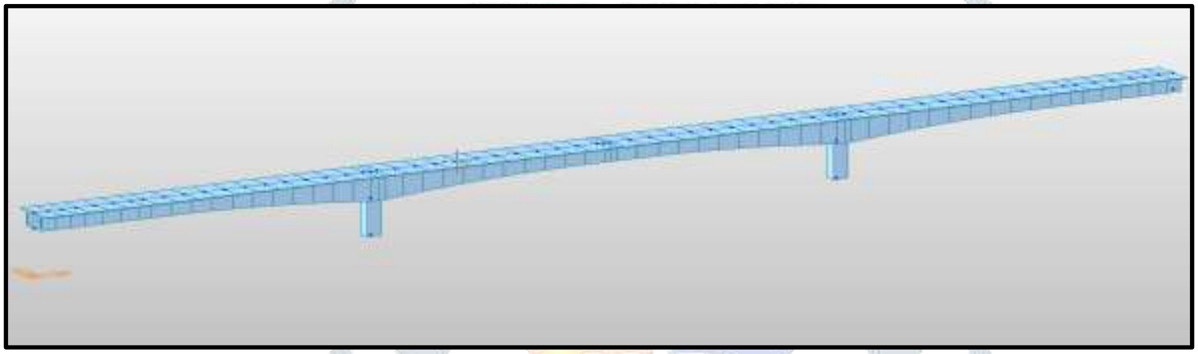


Fig.10 3D model of cast in place balanced cantilever bridge

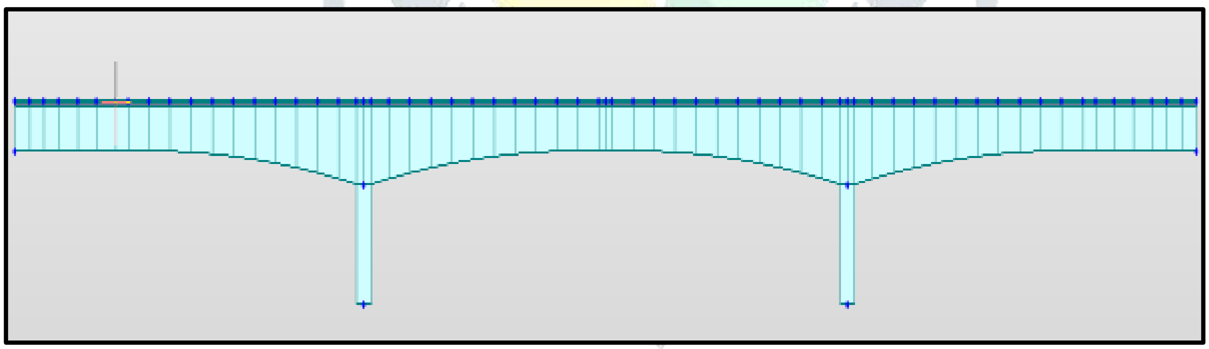


Fig.11 Front view of cast in place balanced cantilever bridge

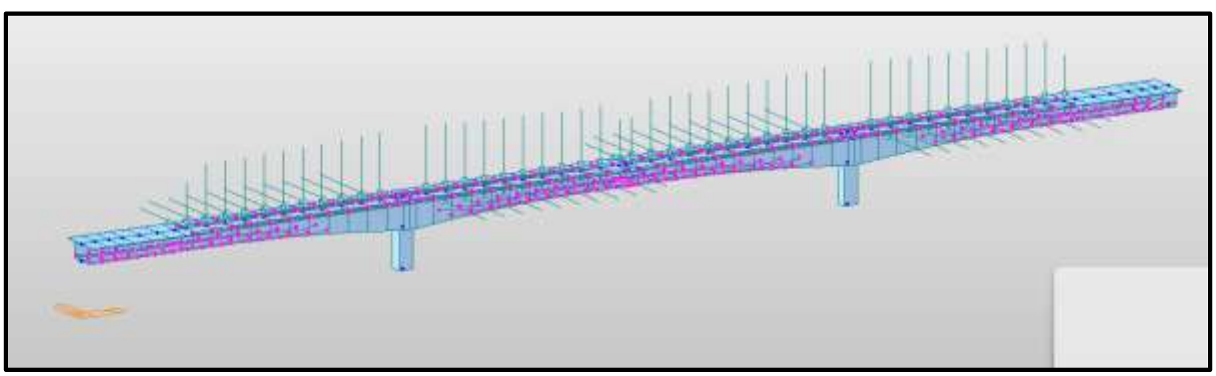


Fig.12 Point load due to form traveler and concreting

3.2 Precast segmental bridge

Loads:

The design load calculation

Dead load as per IRC: 6-2017[2] clause no 203, page no 8.

Deck slab (Thickness-0.25m) = 71.875KN/m

Box girder = 223.3 KN/m

Superimposed dead load (SIDL) = 39.75 KN/m

Live load as per IRC: 6-2017[2] clause no 204.1.1, page no 10.

Class 70R loading = 153.2 KN/m

Seismic load.

Seismic base shear (V_B) site condition (New Delhi) = 89190 KN

Wind load

Transverse wind force (Ft) = 95.9859 KN

Vertical wind force (Fv) = 47.99295 KN

Figure 12 and Figure 13 represent the modelling of precast segmental bridge in Midas civil:

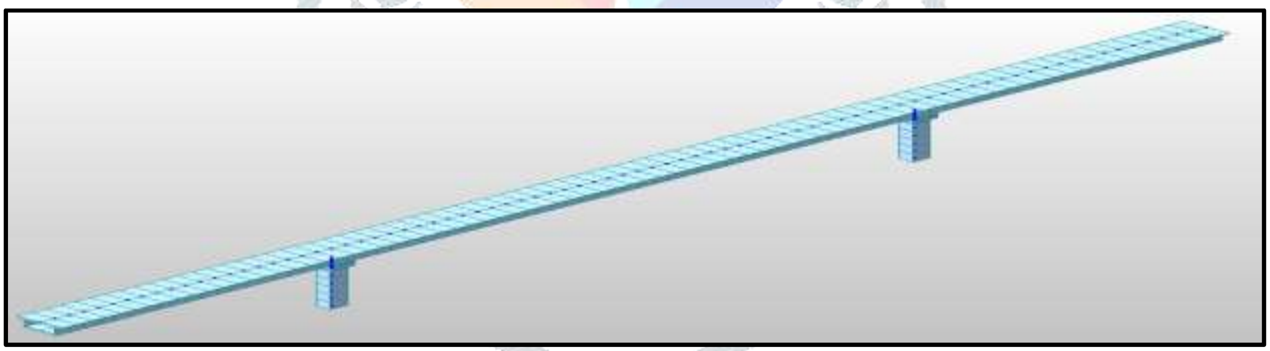


Fig.12 3D model of precast segmental bridge

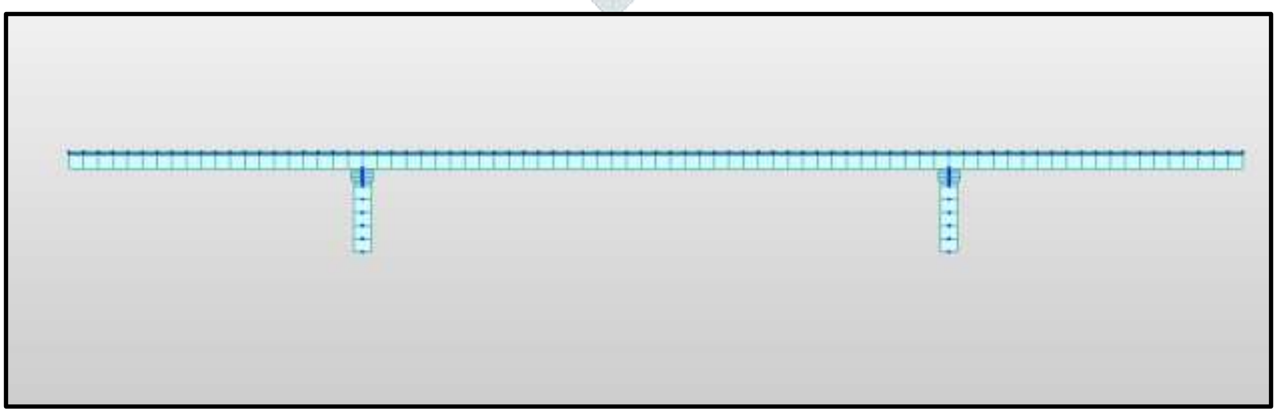
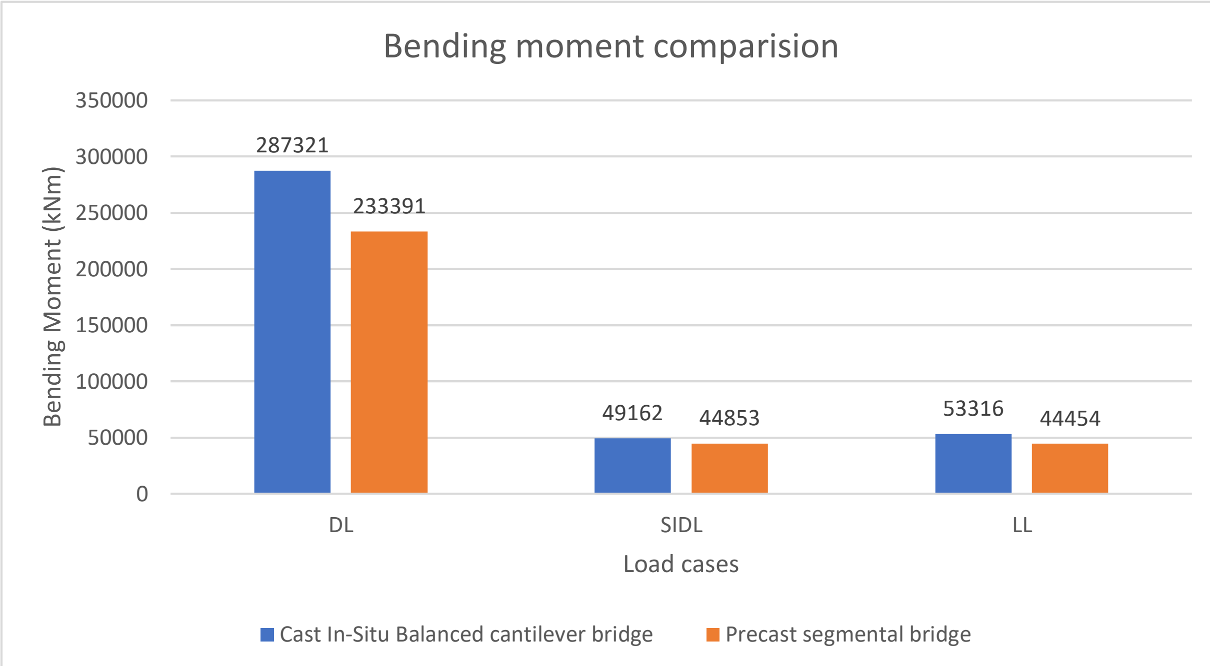


Fig.13 Front view of precast segmental bridge

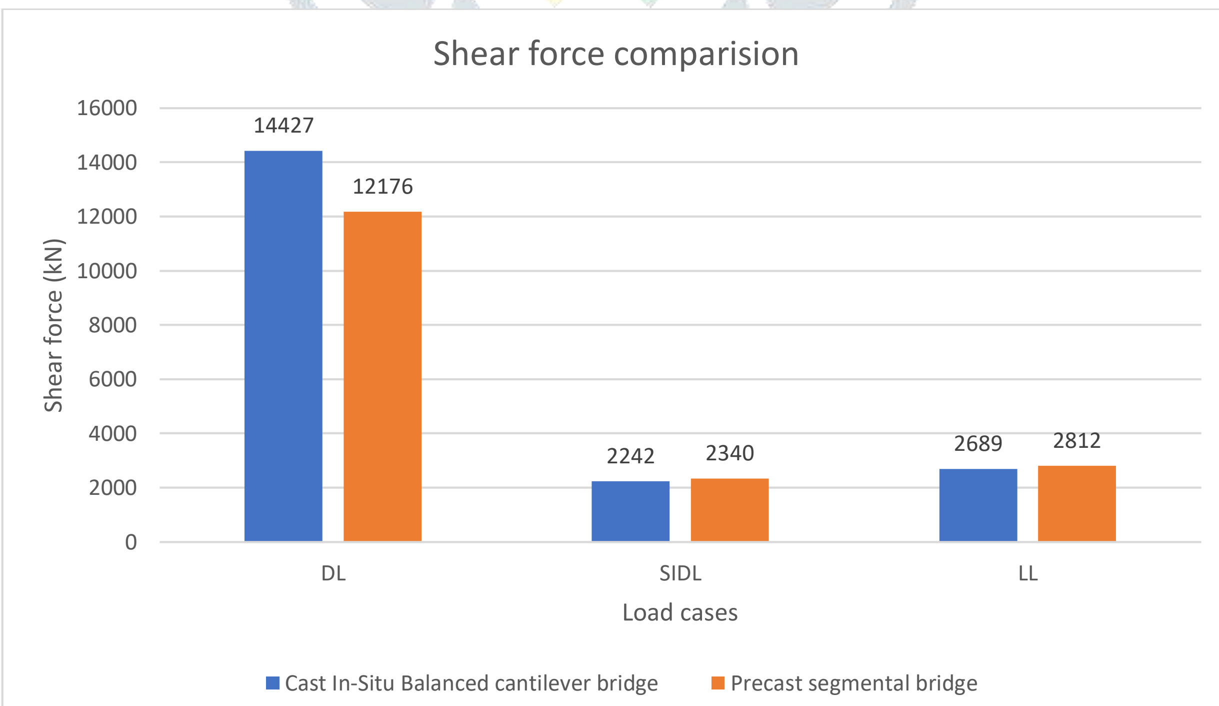
4 Results

4.1 Analysis results

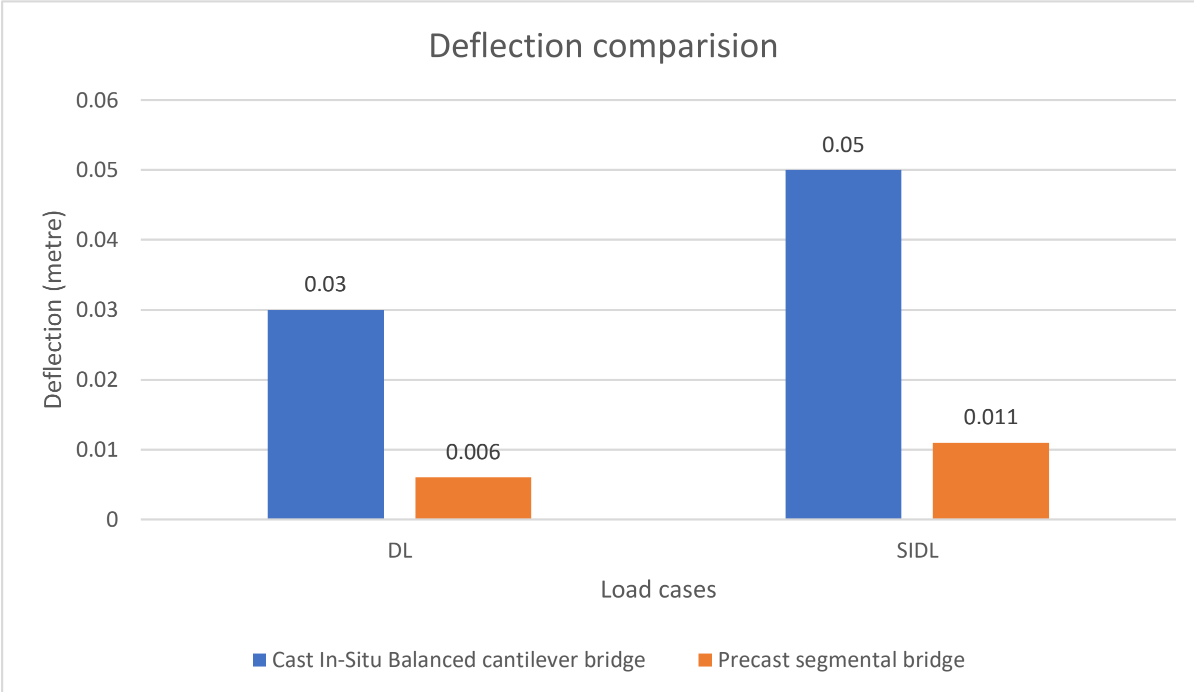
Figure 14 represents the comparison of structural behaviour for the chosen sections for deformation and stresses.



(a)



(b)



(c)

Fig.14 Structural behaviour for the chosen section (**a**) Comparison of bending moments (**b**) Comparison of shear force (**c**) Comparison of deflection

5 Conclusion

In conclusion, the study demonstrates a detail comparison between cast in situ balanced cantilever bridge and precast segmental bridge with respect to structural behaviour and deflection performance.

1. It is evident that precast segmental bridges offer superior control over deflection, owing to their controlled fabrication environment.
2. In contrast, cast-in-situ balanced cantilever bridges typically require greater quantities of reinforcement and prestressing to resist the higher moments that arise during staged construction.
3. The cast-in-situ method proves more adaptable for complex geometries, curved alignments, or locations where transporting and installing precast segments is challenging**.**
4. Precast segmental bridges enable faster construction**,** as segments can be produced simultaneously and assembled efficiently, leading to a shorter overall project timeline**.**

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STATEMENT & DECLARATION

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Consent to participate declaration

Not applicable

Ethics declaration

Not applicable

Competing Interest Declaration
The author declare that there are no competing interests related to this paper.

Author’s Contribution
All authors contributed to the study. The conceptualization, material preparation, data collection, analysis and manuscript writing were carried out by Sajid Daud Tamboli. Adjunct Prof. M.R Shiyekar supervised the work, provided guidance and reviewed the manuscript. All authors read and approved of the final manuscript.