International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 - 5161

Research Article

Behavior of Integral Abutment Bridge by Different End Conditions

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Accepted 10 August 2014, Available online 25 Aug 2014, **Vol.4, No.4 (Aug 2014)**

Abstract

Integral Abutment Bridges (IAB) are defined as simple or multiple span bridges in which the bridge deck is cast monolithically with the abutment walls. IAB is also called as joint less bridge. The main purpose of constructing IAB's is to pre-vent the corrosion of the structure due to water seepage through joints. They improve aesthetics and earthquake resistance towards the traditional systems with expansion joints, roller supports, and other structural releases which permit thermal expansion and contraction, creep, and shrinkage. In this paper total four models are compared two with considering soil interaction and other without soil interaction and live load is applied using MIDAS CIVIL. First model is taken straight IAB without soil interaction and second straight model with soil interaction, third model curve IAB without soil interaction and fourth one curve with soil interaction. The paper motive is to study the trends in bending moment, shear force and deflection in central and end girders and deck slab due to dead load, live load with combination of thermal loads.

Keywords: *Integral Abutment Bridges, Thermal expansion, Contraction, creep, Shrinkage etc.*

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1. Introduction

As temperature change daily and seasonally, the lengths of integral bridges increase and decrease, pushing the abutment against the approach fill and pulling it away. As a result the bridge superstructure, the abutment, the approach fill, the foundation piles and the foundation soil are all subjected to cyclic loading, and understanding their interactions is important for effective design and satisfactory performance of integral bridges.

A bridge should be designed such that it is safe, aesthetically pleasing, and economical. Up to almost bridges in the world was built with expansion joints. These expansion joints often did not perform as well as intended. They required considerable maintenance, which undermined the economical operation of the bridges. Accident and vehicle damage caused by defective expansion joints raised safety concerns.

2. Important Terms

Abutment – A support at each end of a bridge.

Abutment Stem – Is comprised of a Pile Cap topped by a back wall.

Askew – The angle between the centerline of bearing and the centerline of the highway.

Back wall – Typically the second placement of concrete in an integral abutment. This segment of the abutment sets on top of the pile cap and is the segment the girders are embedded into.

Continuity Connection – A monolithic connection between two separate reinforced concrete components.

Flared Wing walls – Wing walls that extend from the abutment at an angle until the slope of the earth rising from the river or underpass meets the slope descending from the roadway. (See Figure 2.2.1-1)

Frame Action – Occurs when each end of a beam is fully embedded in its supports. Negative end moments from composite dead load and live load form along with positive mid-span moments.

In-Line Wing walls – Short extensions off the abutment at either end. These extensions are in line with the abutment or pile cap. (See Figure 2.2.1-1)

Integral Abutment – An abutment comprised of a pile cap with an embedded superstructure, supported by a single line of piles.

Leveling Plate – A steel bearing plate that supports one end of a girder –also called a sole plate. This plate is supported by two large anchor bolts on either side of the girder. The plate's elevation can be field adjusted by raising, or lowering the nuts supporting it.

Lower Zone – The lower portion of the pile that is fully supported by earth along its length where any deflection is negligible.

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Negative Moment Reinforcement – Requires steel reinforcement to resist the negative moment caused by deck loads at the abutments.

Nominal Axial Pile Resistance (NAPR) – The required strength of a pile, based on applied loads, adjusted by the resistance factor for axial strength in a pile.

Nominal Pile Driving Resistance (NPDR) – The required strength to drive a pile. Also called the geotechnical resistance of the pile.

Nominal Structural Pile Resistance (NSPR) – The axial structural strength of the pile defined by the pile section properties and the strength of the steel.

Pile Cap – A large prismatic volume of reinforced concrete topping a line of embedded piles.

Pile Head – The top of the pile as it becomes embedded into the pile cap.

Pile Orientation – The direction a pile will be driven to counteract lateral deflections at the pile head. A pile can be oriented for weak axis bending or strong axis bending.

Pile Tip – The bottom most point of the pile. Typically sets on bedrock.

Plastic Hinge – The state of a steel section when an applied moment causes permanent deformation at a specific point. At this state, the cross section is either in full compressive or tensile failure. The boundary of these two failure zones is the neutral axis. Compact sections can maintain this state at a constant resistance throughout a certain deflection before the resistance starts to diminish.

Pre-bore – This is the process of excavating the top strata of rocky or otherwise rigid earth by various means. The purpose of pre-boring is to control the soil condition surrounding the upper zone of the pile, allowing it to deflect as required without rigid soils seizing it up.

Simplified Design Method – A design methodology presented in this guide that simplifies the design process for integral abutments by using general assumptions in the way an integral abutment bridge performs. (See section 2.2.1)

Simply Supported – A beam supported by a pin at one end and a roller at the other end. The beam is supported vertically and laterally with no other restrictions. Beam ends pivot at their supports therefore forming moments towards the center of the beam.

Skew – The angle between the centerline of bearing and an imaginary transverse line 90° to the centerline.(See Askew)

Strong Axis Bending - Bending a section about the axis that provides the most bending resistance. For I sections (such as H-piles), this typically means bending in the axis parallel to the flanges.

3. Design Methodology

Simplified Design Method

The Simplified Design Method is provided to ease the design process of integral abutment bridges. To date, most integral abutment bridges built by the State of Vermont have complied with the Simplified Design criteria (see sections 2.2.1 and 4.2). The criteria have been developed from proven experience. From this experience, some general assumptions have been made such as:

- All loads are applied on a simply supported structure for superstructure load effects;
- All loads are applied on a frame for calculating the negative bridge end moments; skews 20° or less have no effect on the behavior of the structure; and small dead and live load rotations have minimal effects on the structure.

4. Research Work

The present work was done to observe the behavior of Integral Abutment Bridge while taking with and without spring analysis on the abutment wall and compare these two with the simply supported bridge, by using MIDAS CIVIL software.

5. Software Information

- Midas Civil is a new paradigm for engineering bridge and civil structures.
- It provides a distinctively easy user interface through its innovative graphics modules.
- Midas civil provides an optimal design solution, which analyses and designs all types of bridge structures in 3-D environments accounting for construction stages and time dependent properties.

6. Description of Structure

The bridge under consideration is an RCC Fly Over (T-beam) bridge of 150 m total length between two abutments excluding the length of approach slabs on either side. Further the bridge is divided into seven equal spans: each span is 21.5 m effective length i.e. center to center distance between two consecutive supports and 10.55 m wide in cross section (Two Lane Bridge with Footpath).

The bridge deck is 300mm thick for inner panels to resist the traffic load as per IRC Class AA single train or two trains of Class A (IRC 6-2000). Portion of deck provided as a footpath is over hang for a clear length of 1.45 m on either side from the face of external girder rib. Thickness of overhang portion of the deck is 300 mm at the face of external girder rib. Thickness of overhang portion of the deck is 300 mm at the face of external support which gradually reduces to 200 mm at free end. A parapet wall or anti crash barrier is provided at the free end of the footpath of 200 mm thickness and 900mm height while at the end of the overhang other side a median verge (divider) of 300 mm thickness and 240 mm depth is provided.

There are four longitudinal girders provided across the width of the bridge, each of them is spaced 2.45 m center to center from each other, and the longitudinal girder is a T-beam of 2.45 m flange width, 0.3 m web thickness, provided with a bottom bulb of trapezoidal section with base width 0.55 m. In addition to the longitudinal girders there are some cross girders provided to distribute the loads from the deck to the longitudinal girders. These cross girders are provided at a center-to-center distance of 3.75 m it means there are five cross girders between two consecutive piers, and it is 300 mm wide and 450 mm deep in section.

There are four circular piers of 1.2 m diameter provided to support the superstructure of the bridge, which rest on spread foundation. On either end of the bridge, the super structure rests on abutments, rigidly connected to the deck slab in Integral Abutment Bridge, and simply supported in case of conventional bridge.

Spring Analysis

Soil structure interaction was modeled using horizontal spring restraints the length of the bridge which were rigidly restrained at the ends of the abutment wall, because of the soil interaction with the end abutment the spring action is taken out in the ends of the bridge and the interaction provide the flexibility to the bridge.

7. Description of Various Load

Dead load: Dead load consists of weight of various structural components of the bridge superstructure and substructure.

Live Load: Live load consists of moving IRC Class A wheeled train+ dead load of structure.

Temperature forces: This load consists of stresses developed due to temperature variations in the vicinity of the bridge because of variation in top and bottom of the deck slab.

Backfill Pressure: This load consists of stresses developed due to soil placed behind the abutments to prevent the scouring of the abutments, and provide the support to the approach slab.

Spring Analysis: Soil structure interaction was modeled using horizontal spring restraints the length of the bridge which were rigidly restrained at the ends of the abutment wall.

8. Notations

IAB: - Integral Abutment Bridge

SSB: - Simply Supported Bridge

IAB WSA: - Integral Abutment Bridge with Spring Analysis

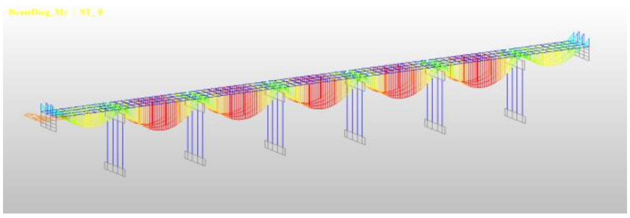

Fig 1 Simply Supported Bridge Bending Moment Diagram

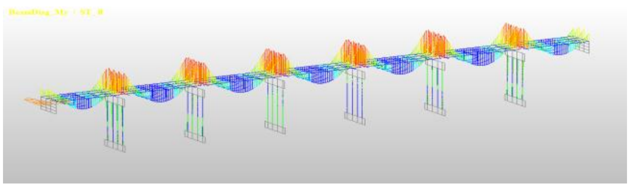

Fig 2 Integral Abutment Bridge Bending Moment Diagram

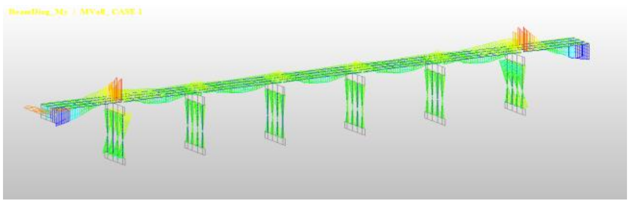

Fig 3 Integral Abutment Bridge (Spring Analysis at Both End Abutments Bending) Moment Diagram **(IAB WSA)**

9. Results

Span	Load Case		SSB	IAB	IAB WSA
			M(Km)	M(KN)	M(KNm)
Inner	Dead Load	Max -Ve	0	1782.5	1183.5
		Max+Ve	2582.5	898.8	797.6
	Live Load	Ma -Ve	0	193.6	126.7
		Max+Ve	288.9	99.6	62.1
	Load case 50	Max -Ve	0	2045.48	1845.67
		Max+Ve	2467	0	1060.89
	Load case 96	Max -Ve	0	2123.48	1600
		Max+Ve	2932.60	0	1956.55
	Temperature	Max -Ve	0	0	0
		Max+Ve	192.66	257.23	210.2

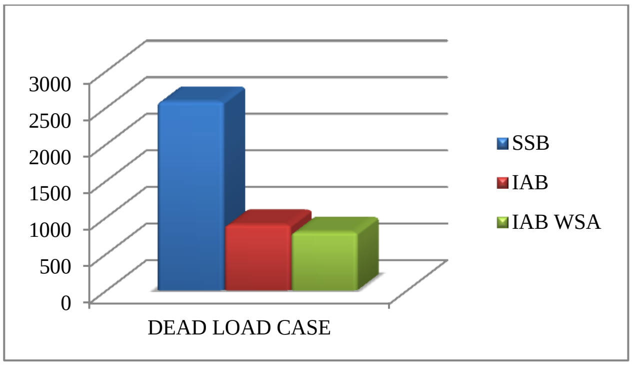

Fig 4 Dead Load Hogging Bending Moment

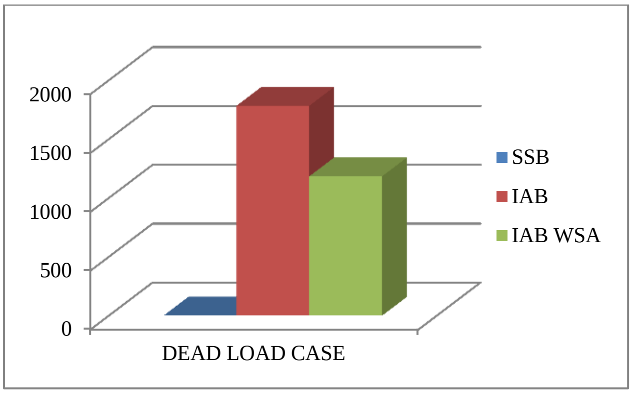

Fig 5 Dead Load Sagging Bending Moment

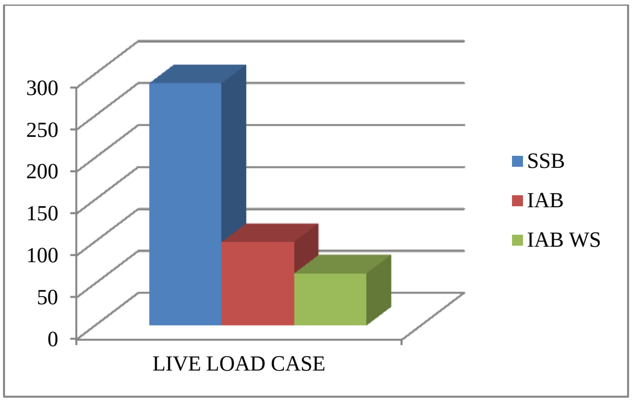

Fig 6 Live Load Hogging Bending Moment

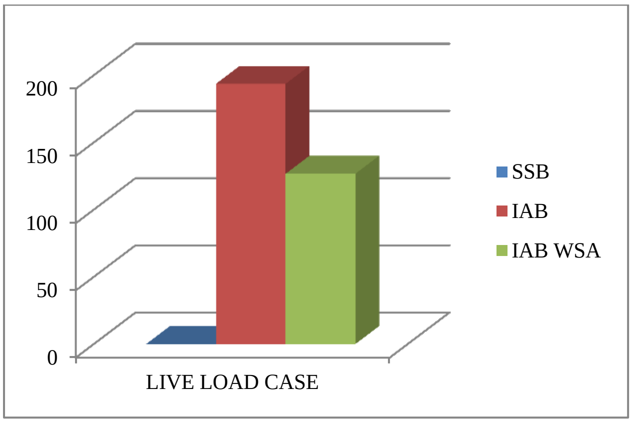

Fig 7 Live Load Sagging Bending Moment

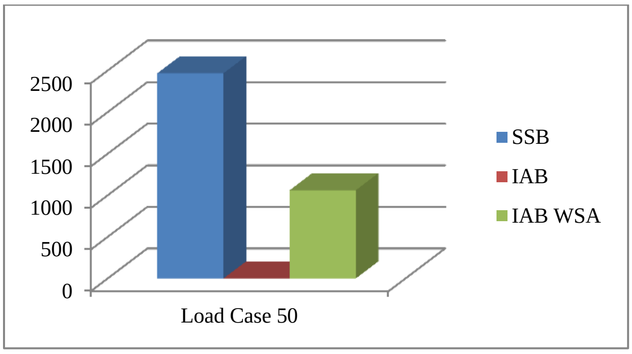

Fig Load Case 2 Hogging Bending Moment

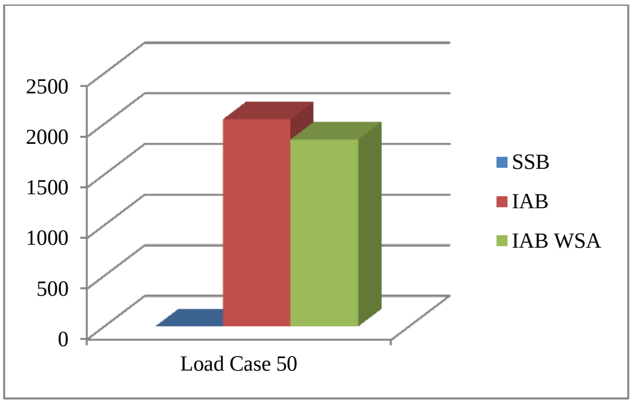

Fig Load Case 50 Sagging Bending Moment

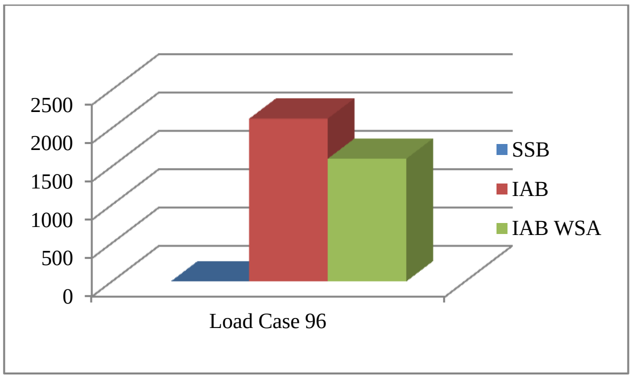

Fig Load Case 96 Hogging Bending Moment

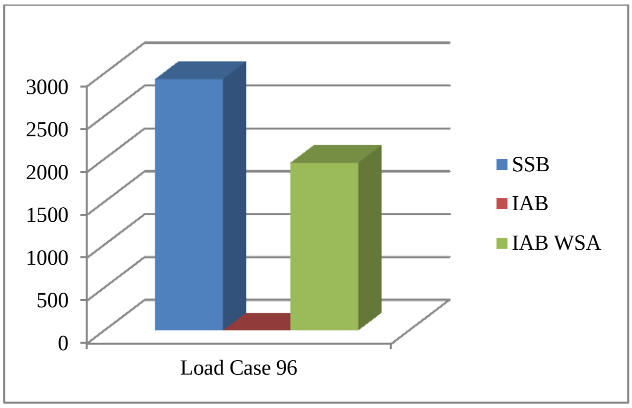

Fig Load Case 96 Sagging Bending Moment

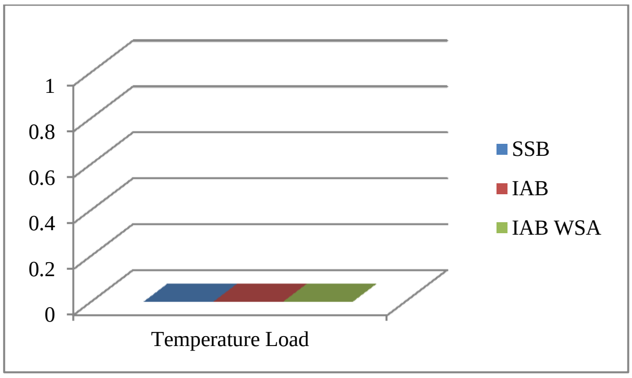

Fig Temperature Hogging Bending Moment

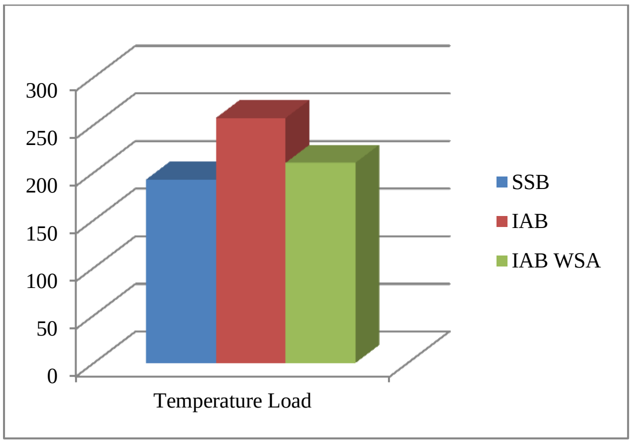

Fig Temperature Sagging Bending Moment

10. Future Scope

There is much scope for further work in the area of IAB, Some of which are as below.

Nonlinear material models of concrete need to be implemented to study the long term effects of cyclic loading during the lifespan of the IAB. This will help in understanding cracking of concrete deck, girders and piles.

IAB could be analyzed for longer and number of traffic lanes, considering skew ness of the substructure, it can be analyzed for bridges with horizontal curves because many times it is not possible to have straight bridges especially in urban areas.

11. Applications

Integral Abutment Bridge can be easily used in place of small bridges and culverts because of its strength, faster rate of construction, lower maintenance cost, improve driving and aesthetic conditions and resistance to seismic forces. It can also be used for rehabilitation of existing bridges. IAB can be constructed as Structural steel, RCC, or Composite bridge.

Conclusions

Near the junction of deck slab and abutment IAB has lesser stresses than SSB, because of rigid connection between abutment and deck slab, there is transfer of stresses, but in case of IAB WSA (Integral Abutment Bridge With Spring Analysis) the stresses is more as compare to SSB and less as compare to IAB because at ends abutments a spring force is develop.

Bending moment is more in SSB as compare to IAB and bending moment is less in IAB WSA as compare to both. Overall we can say that moment and shear stress developed in various components of IAB is higher than SSB, so it can be concluded that moments, stresses and forces developed in IAB is higher than the equivalent SSB because of monolithic connection between various components of the bridge, but if we provide spring analysis at both ends of the end abutment then the shear force, bending moment and forces will reduce as compare to IAB.

Acknowledgements

The authors wish to thank the Management, Principal, Head of Civil Engineering Department and Staff of Jawaharlal Nehru Engineering College and Authorities of DR .Babasaheb Ambedkar Marathwada University for their support.

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