Study on Integral Bridge with Composite deck for IRC Standards

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Abstract - *Integral Bridge as the name itself suggests is 'included as part of a whole rather than supplied separately' and may be defined as "a Bridge with no expansion joints or sliding bearings and the deck is continuous across the length of the bridge". Integral bridges are also referred to as integral abutment bridges, joint less bridges, integral bent bridges and rigid-frame bridges.*

The integral abutment bridge concept is based on the theory that due to the absence of bearings which constraints the deck movement there will be high intensity thermal stresses likely to be developed. And these thermal stresses are transferred to the substructure by way of a rigid connection between the superstructure and substructure.

The integral bridge concept even after being proven economical in initial construction for a wide range of span lengths as well as technically successful in eliminating expansion joint or bearing problems, it is susceptible to different problems that turn out to be geotechnical in nature. These are potentially due to a complex soil structure interaction mechanism involving relative movement between the bridge abutments and adjacent retained soil.

In this paper, the Composite Integral Bridge, which is a built-up steel girders and concrete deck slab, is developed using appropriate finite element software to study the behavior of the structure subjected to different loads.

Key Words: Integral Bridge, Composite Deck, FEM Analysis, IRC, SAP2000.

1. INTRODUCTION

Bridge is a means of connection or transition. It is a structure which is built over any physical obstacles such as water body, road/ railway track or valley or just to create a passage.

1.1 Integral Bridge System

Integral Bridge as the name itself suggests is "included as part of a whole rather than supplied separately" and may be defined as "a Bridge with no expansion joints or sliding bearings and the deck is continuous across the length of the bridge". Integral bridges are also referred to as integral abutment bridges (IAB), joint less bridges, integral bent bridges and rigid-frame bridges. The monolithic construction of abutment and the deck results in the low maintenance of the bridge as there will be no corrosion due to seepage of water through joints which in turn proves to be cost effective in terms of construction and durability.

1.2 Advantages of Integral Bridges over Conventional Bridges

The major advantage of Integral Bridge System is that it eliminates the use of expansion joints and bearings which are very expensive and can increase the initial construction cost. Also there is no special maintenance as such in IAB whereas Conventional Bridges requires maintenance at particular intervals.

The Elastomeric bearings can split and rupture due to unforeseen movements, or move out of position due to impact which is a common problem in Conventional Bridge system. Also Malfunctioning of bearings would lead to abrupt failure of the structure. Since the deck and the abutment are monolithically casted, Integral bridges leads to fast construction.

2. LITERATURE REVIEWS

2.1 Review of selected Literature

1) Akilu Muhammad, Redzuan Abdullah, Yusof Ahmad, 2012- This paper reviews different journal papers for Finite Element Model of IABs and its behavior. The study shows that the usual approach for modeling by most of the researchers is to use plate and shell element to model Slabs and Abutments and beam element to model beams, piers and piles. And spring element is used to model nonlinear soil behavior for soil-pile interaction. The major observant of most of the studies are that the factors affecting the behavior of the IABs are soil-structure interaction, temperature and time-dependent loading, geometry and curvature of IABs. However the studies also discovered that the Curved PSC girder under temperature and time dependent loading are not fully explored and counts for future studies.

2) Murat Dicleli , Suhail M. Albhaisi, 2004 - This paper deals with the performance of abutment backfill system under Thermal variations in IAB on clay for which a typical IAB structural model is built considering the nonlinear behavior of the piles and SSI effects. The study observes that if the backfill and foundation remains within the elastic limit which leads to small abutment displacements, then the pile's size and its orientation don't have significant effect on BM or SF. The study also shows that large backfill pressure, SF and BM in abutment is resulted due to compaction of the backfill. And accordingly use of non-compacted backfill in IAB is highly recommended.

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3. Scope of Work

The aim of the study is to contribute to the knowledge on the performance of Integral Bridges for Temperature load. It concentrates on Integral Abutment Bridge's response in Thermal loads and Seismic loads as per Indian Standards.

3.1 Objective of work

1. To develop a numerical model using appropriate finite element software for Integral Bridge system using Indian standards.
2. To study the importance of Thermal effects in case of Integral Bridges considering Composite Deck system.
3. To check if the Integral Bridge behaves well with change in Temperature gradient for span of 45m.

4. Modelling and analysis

The commonly used model for composite bridge decks is Grillage Model as it is relatively easy to use.

- It is a 2D model which considers Structural behavior as linear elastic. The Beam members are laid out in a grid pattern in single plane, rigidly connected at nodes.
- Longitudinal members represent composite sections (i.e. main girders with associated slab).
- Transverse members represent the slab only, or composite section where transverse steel beams are present
- In Grillage method the Beam forces are calculated instead of Local stresses, since Beam forces can be used for strength design of structural components. Also the comparison of the calculated beam forces can be with strength formulae from the code of practices. In contradiction, there is less information about the stresses at a point in the code of practices.

Table -1: Basic Data for Modeling

Bridge Components	Details
Effective Span	45m
Width of the deck	15m
Girder to Girder spacing	3m c/c
Cross Bracings spacing	5m c/c
Inner Girders	2
Outer Girders	2
Main girder	Built up I section with concrete slab
Lateral Bracings	L angle- 100x100x6
Abutment type	Wall type
Abutment height	5m
Parapet height	1.2 m
Deck type	Composite (IRC 22:2008 guidelines)
Lanes	2
Width of carriage way	6.4m
Bridge type	Highway Bridge
Code Specifications	IRC 6:2014
Software	SAP2000

Table -2: Material Details

Concrete	
Mass per unit volume	2549.3 kg/m³
Weight per unit volume	25 kN/m³ (IS 875 part 1)
Modulus of elasticity	29.58 * 10^ 6 kN/m² (IS 456)
Poisson's ratio	0.2
Co-efficient of thermal expansion	1.20 * 10^-5
Concrete Compressive Strength, fc'	35 N/mm²

Steel	
Mass per unit volume	8002.019 Kg/m³
Weight per unit volume	78.50 kN/m³ (IS 875 part 1)
Modulus of elasticity	2 * 10^8 kN/m²
Poisson's ratio	0.3
Co-efficient of thermal expansion	1.175 * 10^-5
Minimum Yield stress	355 N/mm²

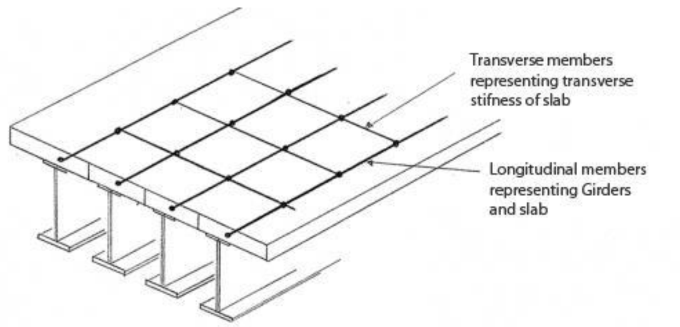

Fig 1: Isometric view showing Griallage model

Table-3: Composite Section Details

Conc. Grade	M	35	N/mm²		NA ( )	1197.435817	mm
E steel		200000	N/mm²		Ix	7.75E+10	mm⁴
E concrete	√	29580.4	N/mm²		Iy	8.42E+10	mm⁴
Modular ratio		6.76					
			Area	y	Ay	I_{xx}	I_{yy}
			mm²	mm	mm3	mm⁴	mm⁴
top slab dimensions							
b1	3000		110926.5	1625	180255556	20856340298	83194871950
d1	250						
top flange dimensions							
b2	500		25000	1475	36875000	1931255225	520833333.3
d2	50						
web dimensions							
b3	40		56000	750	42000000	20357800046	7466666.667
d3	1400						
bottom flange dimensions							
b4	500		25000	25	625000	34370351959	520833333.3
b5	50						
Total			216926.5		259755556	77515747528	84244005283

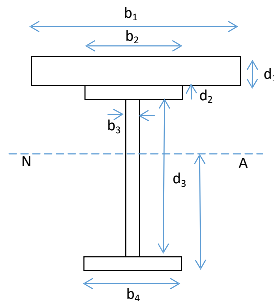

Fig 2: Built up Composite section

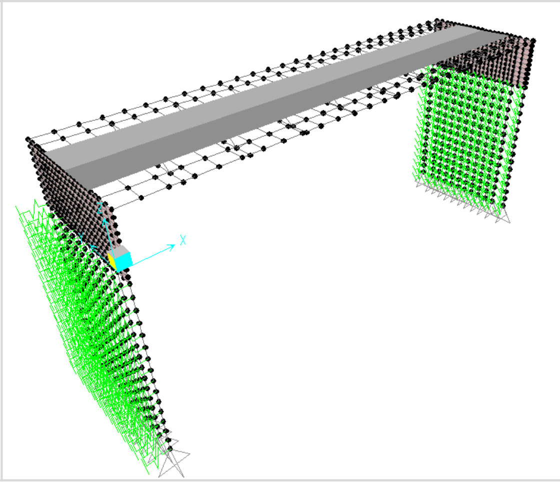

Fig -3: Geometric model of Integral Bridge using SAP2000

4.1 Loads Considered

The various loads considered for the present study are listed below, in which Temperature loads being taken as significant for this study.

4.1.1 Dead Loads

The dead load includes loads that are relatively persistent over time, including the weight of the structure itself and also superimposed dead weights such as load of wearing course, footpaths etc.

- Deck surfacing is taken as 200mm thick and with the density of 23 kN/m³.
- Barrier with 1100 mm height is considered which accounts for load of 10 kN/m.

Table-4: SIDL calculations

Super Imposed Dead Loads			
Thickness	**Width**	**Density**	**UDL**
m	**m**	**kN/m³**	**kN/m**
0.2	1.667	23	7.6682
0.2	0.8335	23	3.8341

4.1.2 Thermal Loads

The expansion and contraction of the concrete bridges are accommodated by bearings and expansion joints in case of Isolated Bridge system; however it results in the imposing of cyclic horizontal load on abutment in case of integral bridge. This in turn causes remarkably higher SSI which may lead to immoderate earth pressures behind the abutments and also possible failure of the soil and the structure.

In comparison with the effects of Live loads on Integral Bridges, the magnitude of the thermal loads should be given equal importance since there is restraint for the movement of the bridge deck and hence complex calculations with detailing of the inherent stresses should be taken care of.

The effective Bridge temperature is calculated as per IRC 6 Cl 215. As per fig. 8 and 9 from IRC 6, the highest maximum and lowest minimum temperatures shall be considered based on the zone.

Table-5: Temperature Load Calculations

Temperature Loads	
Thickness of the deck slab (h)	250 mm
	0.25 m
Zone	Delhi IV
Maximum Temp.	47.5 °C
Minimum Temp.	0 °C
Bridge effective temperature	
Temperature rise	33.75 °C
Temperature fall	13.75 °C
T_0	20 °C
T_{e1}	**13.75 °C**
T_{e2}	**-6.25 °C**
Temperature difference	
h1	0.15 m
h2	0.4 m
Positive Temperature	19.25 °C
Negative Temperature	5.6 °C

As a coexistence with the uniform temperature is a non-linear temperature gradient across the bridge deck i.e. there is a variation in temperature along the different levels throughout the depth of the deck. As per IRC 6 215.3, the postive and reverse temperature differences are specified which is to be reffered for temperature gradient assessment. Considering 50mm thick wearing course and 250mm composite deck thickness, the positive temperature and reverse temperature are shown in Figure 4.

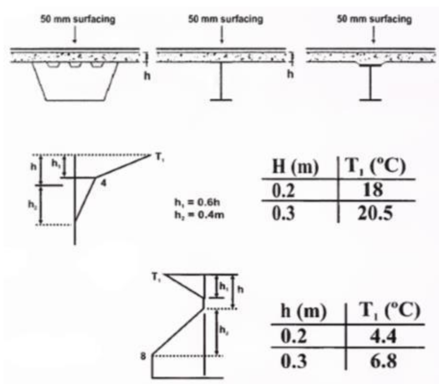

Fig-4 : Temperature differences along composite deck section from IRC 6

4.1.3 Soil Spring Idealization

The behaviour of the bridge structure is likely to be altered with the interaction between bridge structure, its foundation and the surrounding soil medium. As the Behaviour of IAB is associated with its structural components and as well as its soil medium, it's very important to ascertain the appropriate parameters of soil and thus represent its behaviour. The soil being non-linear (force- displacement characteristics), heterogeneous and anisotropic leads to a complex behaviour which needs to be included in the modelling. Therefore the soil properties have to be modelled as "Soil Spring Constants" to assess the flexibility and stiffness of the soil.

Laterally loaded Piles of single row were chosen for the present study. The lateral resistance of the soil helps in the transfer of lateral loads to the surrounding soil. In case of lateral loading of the piles, the piles tries to displace horizontally as a whole or a part in the applied load's direction, which leads to translation/rotation of the pile. The Pile which is pressed against the soil creates shear stresses and strains in the soil from which the pile movement is resisted.

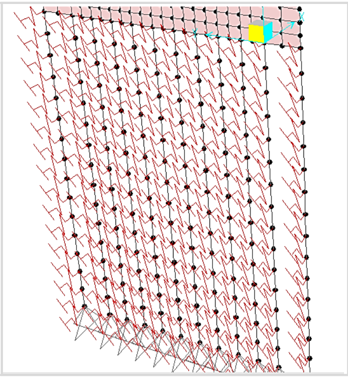

Fig -5: Soil Springs applied to the bridge model

4.1.6 Variation of soil parameters

Two combinations of soil layers are considered for the present study.

CASE 1- Combination 1: Medium to Dense Sand<< Hard Stiff Clay<< Sandy Clay with Pebbles<<Rock.

CASE 2- Combination 2: Sandy Clay with Pebbles<< Medium to Dense Sand << Hard Stiff Clay<< Rock.

5. Analysis results and discussion

In this chapter results are extracted from SAP2000 software after the analysis of the model is done. The results are presented in the form of tables and graphs to interpret and conclude.

5.1 Moment Variations

Table-6: Midspan Moments for Dead load

Midspan moments			
Loads	**CASE 1**	**CASE 2**	**% decrease**
	kN-m	kN-m	
Dead	3572.09	3522.82	-1.40%

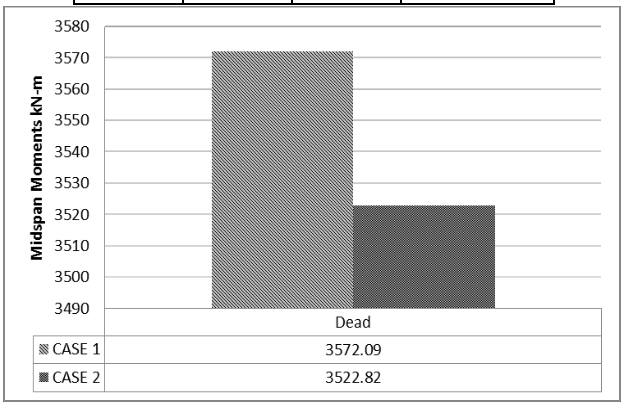

Fig-6 : Midspan Moments for Dead load cases

From the above graph it can be observed that the mid span moment values of CASE-2 combination is than that of CASE-1 for Dead load. This shows the variation in the structural behavior with variation in the soil type.

Table-7: Moments at Pile Tip for Temperature Loads

Moments at Pile Tip			
Loads	**CASE 1**	**CASE 2**	**% decrease**
Temp R	-122.98	-165.25	25.58%
Temp F	55.903	75.11	25.57%

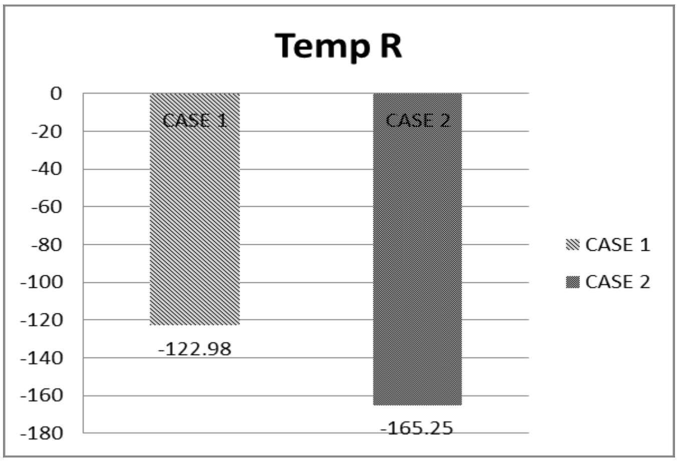

Fig-7: Moments at Pile Tip for Temperature Rise

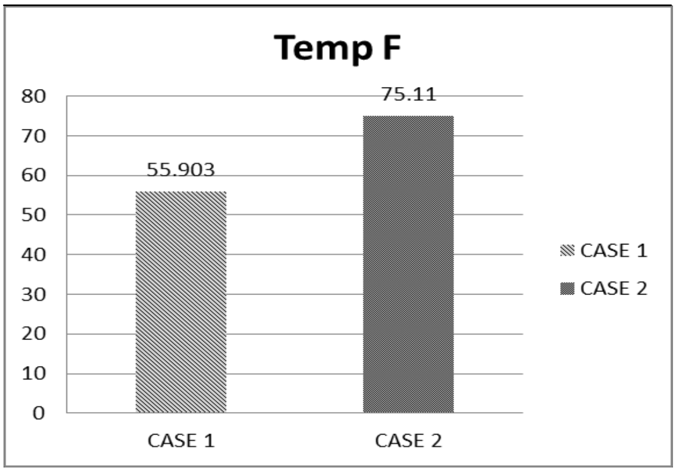

Fig-8: Moments at Pile Tip for Temperature Fall

It can be observed from the above graphs that the moments at the tip of the Pile for Temperature loads turns out to be slightly higher for the CASE-1 combination compared to CASE-2 combination. Due to the restricted movement of the bridge deck, the Temperature loads have to be transferred through the abutment to the pile.

Integral Bridge is affected by Daily and seasonal changes in the temperature. A complete cycle of expansion and contraction occurs on daily variation in temperature and the cycle repeats.

5.2 Deflection Variations

Table-8: Pile Deflection for Temperature Loads

	CASE-1		CASE-2	
Depth	Temp Rise	Temp Fall	Temp Rise	Temp Fall
m	mm	mm	mm	mm
-5	-0.966167	0.439167	-0.717783	0.326265
-6	-0.536042	0.243656	-0.300731	0.136696
-7	-0.232567	0.105712	-0.055421	0.025191
-8	-0.048952	0.022251	0.058064	-0.026393
-9	0.041769	-0.018986	0.090474	-0.041124
-10	0.071675	-0.03258	0.082459	-0.037481
-11	0.068388	-0.031085	0.05932	-0.026964
-12	0.051377	-0.023353	0.035241	-0.016019
-13	0.032209	-0.01464	0.01657	-0.007532
-14	0.016465	-0.007484	0.004701	-0.002137
-15	0.005939	-0.0027	-0.001447	0.000658
-16	0.000291	-0.000132	-0.003682	0.001674
-17	-0.001855	0.000843	-0.00365	0.001659
-18	-0.00195	0.000886	-0.002572	0.001169
-19	-0.001106	0.000503	-0.001237	0.000562
-20	0	0	0	0

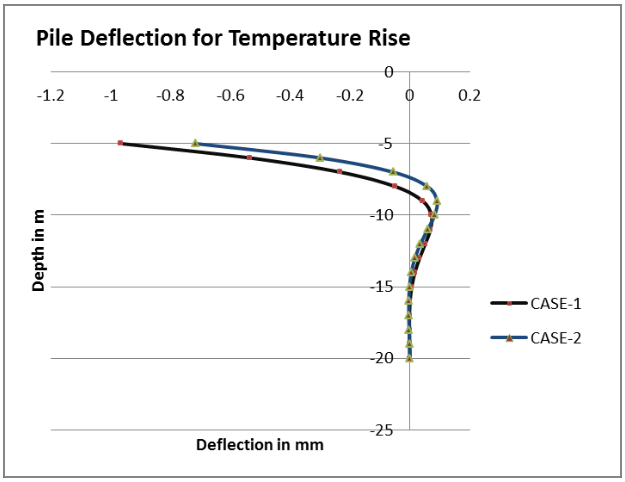

Fig-9: Pile Deflection for Temperature Rise

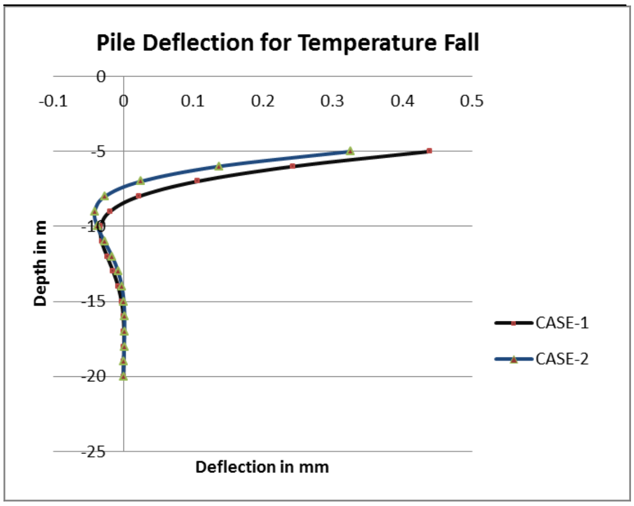

Fig-10: Pile Deflection for Temperature Fall

From the above graphs it can be noticed that the CASE-1 soil combination possesses a slightly higher deflection at the pile head for temperature loads compared to the CASE-2. The integral abutment bridge will be monolithic with the deck, causing it to be stiffer than the soil surrounding it or the pile itself and therefore there is constraint in the motion. Hence the soil parameter alters the behavior of the structure and soil pile interaction aswell.

6. CONCLUSIONS

Following conclusions can be made from the analysis.

1. Integral Bridge is affected by Daily and seasonal changes in the temperature. A complete cycle of expansion and contraction occurs on daily variation in temperature and the cycle repeats.

2. Therefore Temperature load is the most significant load which is to be considered while analyzing an Integral Bridge.

3. Also the integral abutment bridge will be monolithic with the deck, causing it to be stiffer than the soil surrounding it or the pile itself and therefore there is constraint in the motion. Hence the soil parameter alters the behavior of the structure and soil pile interaction aswell.

4. The study shows that change in Soil Condition directly affects the performance and response of the Integral Bridge.

5. Due to the restricted movement of the bridge deck, the Temperature loads have to be transferred through the abutment to the pile. And because of the continuity the load transfer can happen better.

6. Therefore it can be concluded that the Integral Bridge model behaves well with Temperature loading.

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