# 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.

## 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/m$^3$ |
| Weight per unit volume | 25 kN/m$^3$ (IS 875 part 1) |
| Modulus of elasticity | 29.58 * 10^ 6 kN/m$^2$ (IS 456) |
| Poisson's ratio | 0.2 |
| Co-efficient of thermal expansion | 1.20 * 10^-5 |
| Concrete Compressive Strength, fc$^l$ | 35 N/mm$^2$ |

| Steel | |
|---|---|
| Mass per unit volume | 8002.019 Kg/m$^3$ |
| Weight per unit volume | 78.50 kN/m$^3$ (IS 875 part 1) |
| Modulus of elasticity | 2 * 10^8 kN/m$^2$ |
| Poisson's ratio | 0.3 |
| Co-efficient of thermal expansion | 1.175 * 10^-5 |
| Minimum Yield stress | 355 N/mm$^2$ |
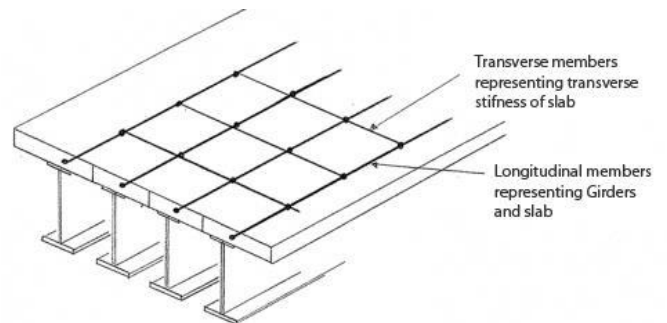


**Fig 1:** Isometric view showing Griallage model

**Table-3:** Composite Section Details

| Conc. Grade | M | 35 | N/mm$^2$ | | NA ( ) | 1197.435817 | mm |
|---|---|---|---|---|---|---|---|
| E steel | | 200000 | N/mm$^2$ | | Ix | 7.75E+10 | mm$^4$ |
| E concrete | √ | 29580.4 | N/mm$^2$ | | Iy | 8.42E+10 | mm$^4$ |
| Modular ratio | | 6.76 | | | | | |
| | | Area | y | Ay | I$_{xx}$ | I$_{yy}$ | |
| | | mm$^2$ | mm | mm3 | mm$^4$ | mm$^4$ | |
| 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 | |
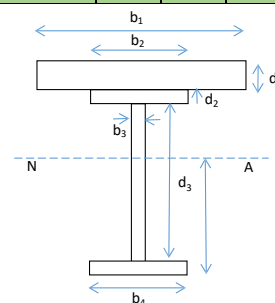


**Fig 2:** Built up Composite section

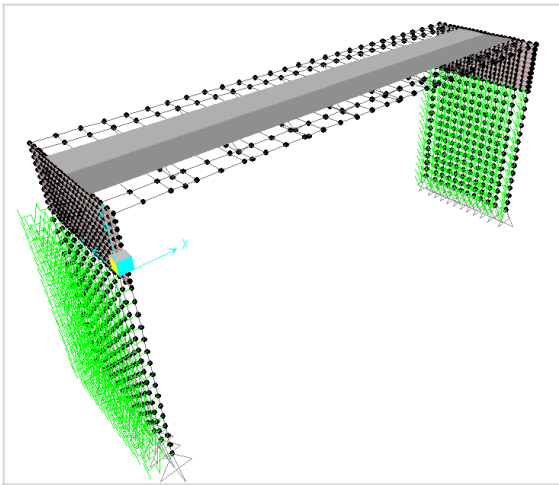**Fig -3**: Geometric model of Integral Bridge using SAP2000

## 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.
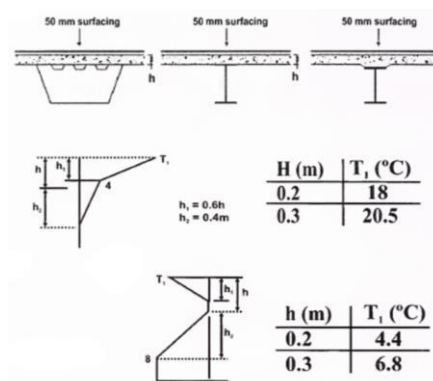


**Fig-4** : Temperature differences along composite deck section from IRC 6

### 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.
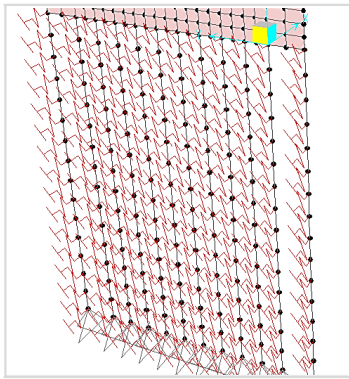


**Fig -5**: Soil Springs applied to the bridge model

### 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

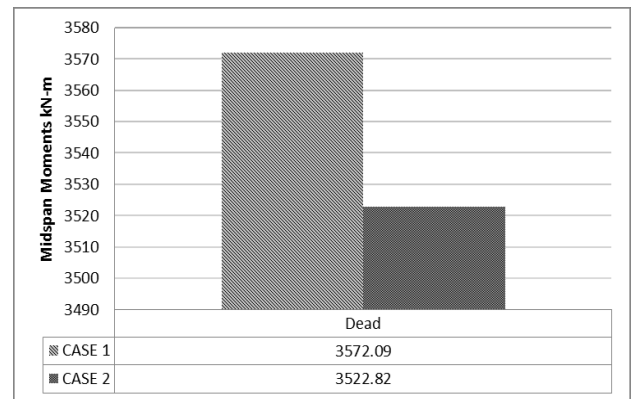| Midspan moments | | | |
|---|---|---|---|
| Loads | CASE 1 | CASE 2 | % decrease |
| | kN-m | kN-m | |
| | | | |
| Dead | 3572.09 | 3522.82 | -1.40% |



**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

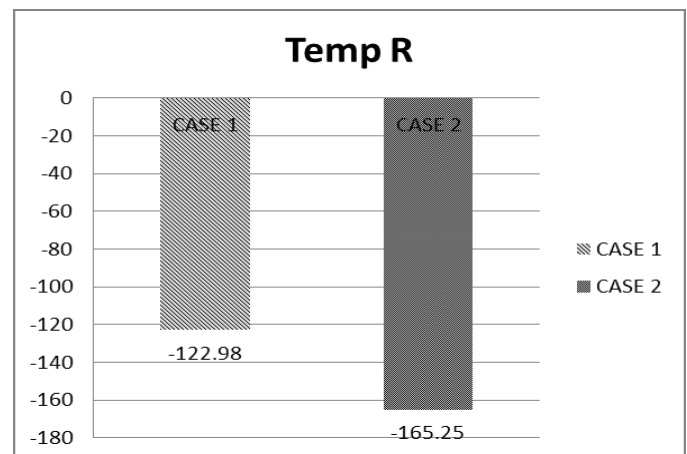| Moments at Pile Tip | | | |
|---|---|---|---|
| Loads | CASE 1 | CASE 2 | % decrease |
| | | | |
| Temp R | -122.98 | -165.25 | 25.58% |
| Temp F | 55.903 | 75.11 | 25.57% |



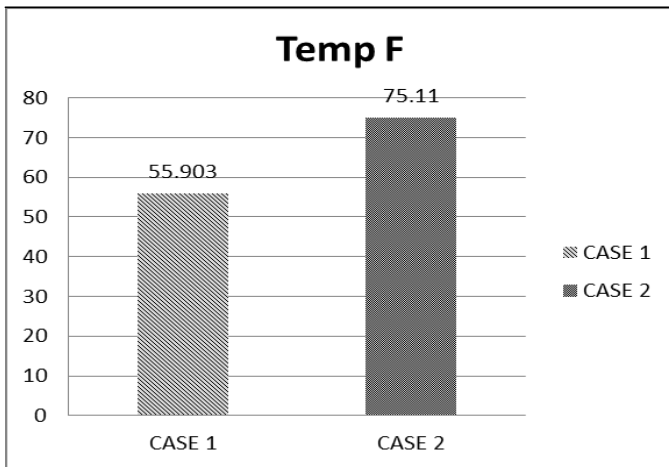**Fig-7:** Moments at Pile Tip for Temperature Rise

**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

| Depth | CASE-1 | | CASE-2 | |
|---|---|---|---|---|
| | 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 |
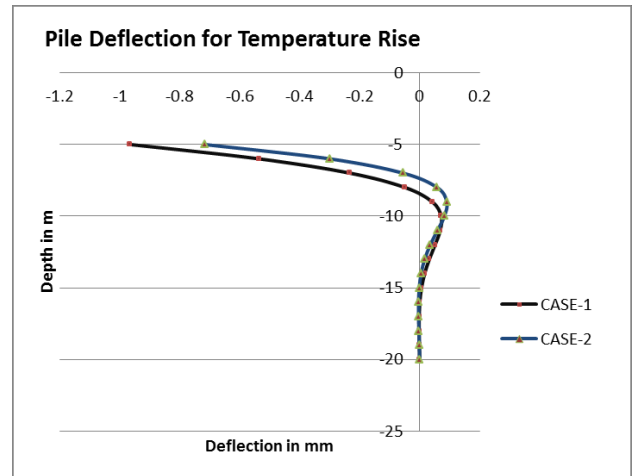


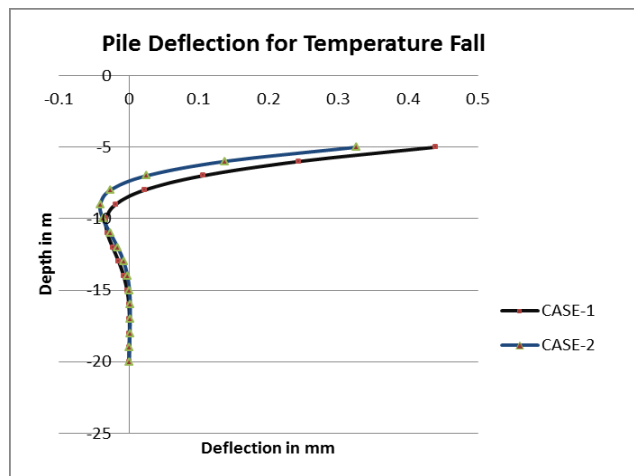**Fig-9:** Pile Deflection for Temperature Rise



**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.

## ACKNOWLEDGEMENT

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