Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 4, Issue 6, June -2017

A Comparative Study of Conventional RC Girder Bridge and Integral Bridge

Mr. Kiranakumar V Arutagi[1], Prof. Ravichandra Honnalli[2]

[1]Post graduate student, Department of Civil Engineering, Basaveshwar Engineering College, Bagalkot.
[2]Assistant Professor, Department of Civil Engineering, Ballary Institute Of Technology & Management, Ballary

Abstract- *Integral bridges have been constructed all over the world including India; these are becoming very popular due to its low initial cost, elimination of bearings and less maintenance. To get a better understanding of the behavior of integral bridges in different situation, a comparative study is carried out on a typical integral bridge and a conventional simply supported RC girder bridge of same geometry and loading conditions. For modeling of bridges, 60 m length was considered. It was divided into 3 spans of 20 m each. The bridges were modelled and analyzed in SAP 2000. The seismic analysis was carried out by response spectrum method of analysis and the seismic responses of integral bridges were compared with the responses of conventional RC girder bridge. From the study it may be concluded that, integral bridges performs better than the conventional RC girder bridge under seismic loadings and also integral bridges requires minimum cross-sectional area as compared to conventional bridges.*

Keywords: *Conventional bridges, Integral bridges, Bearings, Expansion joints, Response spectrum, IRC loadings.*

I. INTRODUCTION

Bridges serve in the surface transport and carries water supply, electric lines across a stream. Apart from these day-to-day amenity services, during natural calamities such as earthquakes, it facilitates in providing the emergency services like supply of food, medicine etc. hence, the bridges are lifeline structures. For many decades, the majority of the research into the design of earthquake resistant structure has been concerned with building structures and relatively little attention was paid to bridge structures. This was presumably due to belief that social and economic consequences of earthquake damage to buildings were likely to be more serious than those resulting from damage to bridges. The relief and rehabilitation work is made possible only if bridges are saved from failures during earthquake events [1]. Highway bridges traditionally have a system of expansion joint, roller supports, abutment bearing and other structural releases to account for cyclic thermal expansion and contraction, creep and shrinkage.

There is an old saying that, 'a chain is as weak as its weakest link'. Bearings and expansion joints are the weak links in an, otherwise, robust and sturdy structure. Hence, interest about integral bridges or jointless bridges is increasing and their performance has gained international attention. Presumably, the primary reason for this interest is due to the acceptance of integral bridges by many transportation departments throughout the world. Integral bridges are constructed without any bearings or joints between spans or between spans and abutments.

II. INTEGRAL BRIDGE

Integral bridges are the bridges, where the superstructure is continuous and connected monolithically with the substructure with a moment-resisting connection.[1] Due to this continuity in the bridge the bridge have less expensive, esthetically pleasing appearance, safe riding, economical in construction and prevent the corrosion. However, simply supported bridges are still popular in India. The main reason for their popularity is that, these structures are simple to design and construct. The integral bridge concept is based on the theory that, due to the flexibility of the piles, thermal stresses are transferred to the substructure by way of a rigid connection between the superstructure and substructure. Integral abutment type bridge structures are single or multiple span bridges that have their superstructure cast integral with their substructure. With the superstructure rigidly connected to the substructure and with flexible substructure piling, the superstructure is permitted to expand and contract. Approach slab, connected to the abutment and deck slab with reinforcement, move with superstructure. Due to the elimination of the bridge deck expansion joints, construction and maintenance costs are reduced [1]. Some of the advantages of adopting integral bridges over that of the conventional bridge are summarized below:

- Simplified details for construction
- Reduced life cycle cost and long term maintenance
- Improved riding quality
- Added redundancy with improved seismic performance
- Elimination of water leakage on critical structural elements
- Lesser tolerance restriction due to elimination of bearings and expansion joints
- Faster construction

• Simplified widening and replacement detail
• Useful for strengthening existing bridges

III. DESCRIPTION OF STRUCTURE

The bridge under consideration is a conventional RC girder bridge and a RC integral bridge. The parameters specified below are applied to bridge structures. The modeling and analysis of both bridge structures was carried out in SAP 2000/Bridge software.

- The total length of bridge is 60 m measured between two dirt walls.
- Bridge is divided into 3 spans: each span is 20 m.
- The bridge deck is 300 mm thick.
- Carriage way width is 7.5 m.
- Total width of the bridge is 11 m in cross section (two lanes with footpath).
- Cross girders are 0.3 m in width, 1.25 m in depth and 5 m c/c.
- Soil is type II medium soil.
- Bridge is located in zone V.
- Portion of deck provided as a footpath is overhang for a clear length of 1.5 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.
- There are four longitudinal girders provided across the width of the bridge, each of them is spaced 2.5 m center to center from each other, and the longitudinal girders are 1.6 m top width, 0.45 m web thickness, provided with a bottom bulb of rectangular section with base width 0.75 m for conventional bridges. For integral bridges longitudinal girders are 1.0 m top width, 0.2 m web thickness, provided with a bottom bulb of rectangular section with base width 0.45 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 5 m it means there are three cross girders between two consecutive piers, and it is 300 mm wide and 1250 mm deep in section.
- The superstructure is supported by rectangular pier cap of 1.2 m in depth and 1.2 m width. There are two 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 superstructure rests on abutments, rigidly connected to the deck slab in integral bridge and simply supported in case of conventional bridge.

IV. DESIGN LOADS

The design loads considered for the analysis are dead loads, super imposed dead loads, live loads, earthquake loads and temperature loads. The brief description of these loads is given below.

4.1 Dead load

Dead load consists of various structural components of bridge superstructure and substructure. The dead load carried by the girders or the members consists of its self weight and the portions of the self weight of the superstructure and any fixed loads supported to the members. The dead load can be calculated accurately during design and can be controlled during construction and service.

4.2 Super imposed dead load

The weight of superimposed dead load consists of self weight of footpaths, earth-fills, wearing course, ballast, water-proofing courses, architectural ornamentation, pipes, conduits, cables and any other immovable materials installed on the structure.

4.3 Live load

Live loads are those produced by vehicles which pass over the bridge and are variable in nature. These loads cannot be estimated accurately, and the designer has very little control over the live loads once the bridge is opened to traffic movement. For 7.5 m carriage way width and for two lane bridge, the live load considered was two trains of class A (as per IRC 6-2000).

4.4 Seismic forces

Seismic forces were calculated by using IS 1893-2009 (Part 3). For seismic analysis of bridges response spectrum method was adopted.

Z = Zone factor = 0.36
I = Importance factor = 1.2
R = Response reduction factor = 4.0
$\frac{Sa}{g}$ = Average Acceleration coefficient for rock or soil sites = 2.5

V. MODELLING

Finite element method was adopted for analysis in the present study. The detailed finite element model of conventional RC girder bridge and integral bridge was created using SAP-2000 (computers and structures, Inc.) software. The bridge girders were modeled using the specified reinforced concrete with an ultimate compressive strength of 50 MPa. The cast-in-place concrete with ultimate compressive strength of 25 MPa was used to model the deck, abutments and bents. Once the finite element model was developed, design loads such as dead loads, live loads, earthquake loads and temperature loads are applied uniformly on the bridge structures.

5.1 Conventional RC girder bridge

Conventional RC girder bridge was modelled with expansion joints of 50 mm wide in deck slab at the support section as shown in Fig. 3.5. These expansion joints reduce the thermal stresses in the deck slab caused by the surrounding temperature variation. Due to the presence of expansion joints in the deck slab, the bridge acts as simply supported bridge. The girders rest on the bridge bearings and these bearings transmits loads from superstructure to substructure.

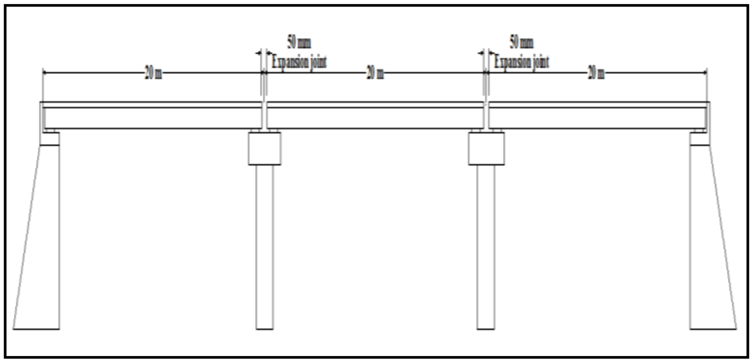

Fig. 1 Plan of conventional bridge

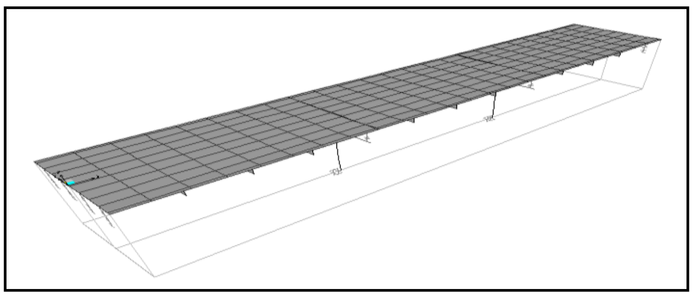

Fig. 2 Model of conventional bridge

5.2 Integral bridge

In this type of bridges, the bearing joints are eliminated and girders are monolithically connected to pier cap. The deck slab is continuous and it runs from start abutment to end abutment without any expansion joints. Due to this continuity of deck slab and fixed supports negative moment develops at the supports.

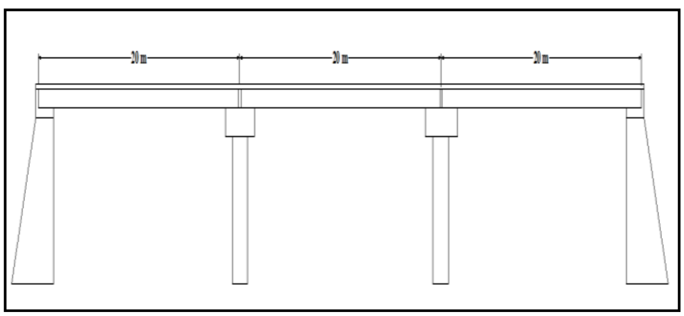

Fig. 3 Plan of integral bridge

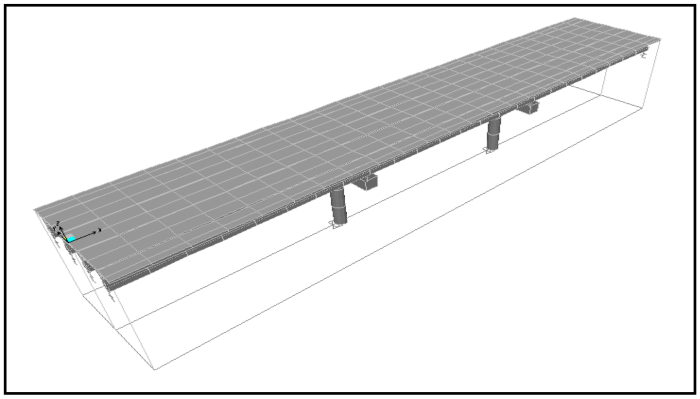

Fig. 4 Model of integral bridge

VI. RESULTS AND DISCUSSION

This includes the analytical results of the integral bridges under different load conditions. These results were discussed with comparison of conventional bridge results. The responses such as bending moment, shear force, vertical displacements, and lateral deflections are obtained in the analysis.

6.1 Bending moment and shear force

The conventional bridge was analyzed with simply supported condition and integral bridge was analyzed with fixed support condition. Figure 4.1 shows the comparison of bending moment in conventional bridge and integral bridge. This bending moment developed due to combination of dead load and live load. In conventional bridge the maximum bending moment was 17466.115 kN-m. In case of integral bridge, the maximum bending moment was 8186.69 kN-m. There is a negative moment developed in the support section of the integral bridge because of fixed supports and fixed connectivity between deck slab and substructure. Hence, negative moment is higher as compared to the positive moment and this negative moment was considered in the design of sections. But, in case of conventional bridges no negative moment developed because of simply supported structure. The reduction of bending moment in integral bridges is about 50% as compared to conventional bridges. Hence, the cross-sectional area of longitudinal girder reduced in integral bridges.

Fig. 4.2 shows the variation of shear force in conventional bridge and integral bridge. The variation of shear force is similar to the variation of bending moment. The shear force is more in case of conventional bridge as compared to the integral bridge. The shear force in the conventional bridge is 2333.022kN and in case of integral bridge it was decreased to 1740.726 kN because of fixed supports and fixidity between superstructure and substructure.The reduction of shear force in integral bridges is 25% as compared with conventional bridge.It was observed that, shear force is maximum at support sections and minimum at mid spans sections. The reduction of shear force in integral bridges is due to the some part of load will transferred to adjacent slabs because of continuity in the deck slab.

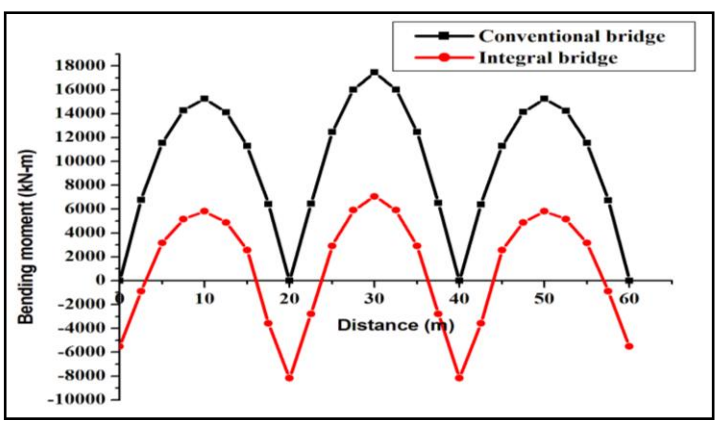

Fig. 5 Comparison of bending moment for DL+LL

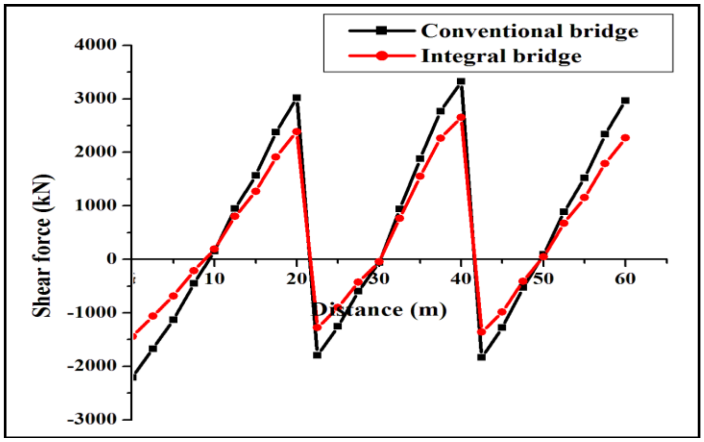

Fig. 6 Comparison of shear force for DL+LL

6.2 Vertical displacement

The moving load considered was two IRC class A vehicles: one in the forward direction and another in the backward direction. These two vehicles are meeting together at the center of the span. When these two vehicles met together maximum load will be applied on the deck slab. Hence, the maximum displacement found at the centre span of the bridge. Fig. 4.3 shows the variation of vertical displacement of deck slab due to combination of dead load and live load. The vertical displacement in the conventional bridge is about 10.8 mm but in case of integral bridge it was reduced to 6.15 mm. This reduction of vertical displacement is due to fixed supports in the integral bridges. This fixed support and fixed connectivity will not allow the deck slab to deflect in the downward direction. Due to fixidity the integral bridge becomes stiff and durable. The limitation of the vertical displacement in bridges as per IRC-112-201 is,

For vehicular loads = span/800

Span = 20 m

= 20000/800

= 25 mm

But maximum deflection observed was 10.8 mm.

Hence, the deflections are within permissible limit.

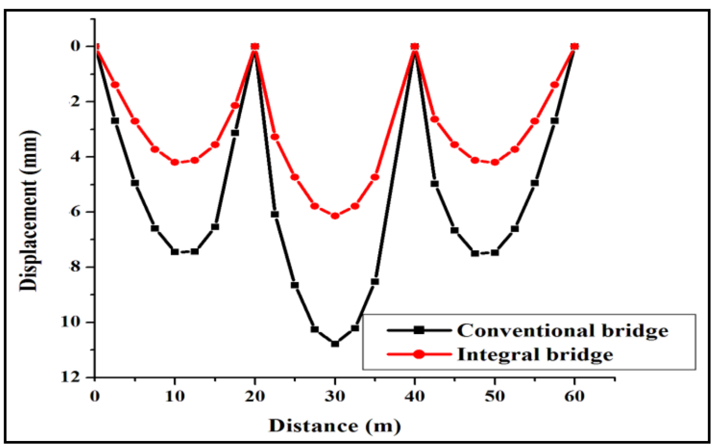

Fig. 7 Comparison of vertical displacement for DL+LL

6.3 Lateral deflection

Seismic analysis of both the bridges carried out by response spectrum analysis method. The bridges were analyzed separately for longitudinal and transverse directions. Table 4.1 and 4.2 shows variation of lateral deflection in longitudinal direction and transverse direction respectively. Conventional bridge experiences more deflection as compared to integral bridge in longitudinal and transverse direction. In longitudinal direction, the deflection is 3.75 mm for conventional bridge and it was reduced to 0.179 mm in integral bridges and this reduction is about 94%. But in case of transverse direction, the deflection was reduced from 38.6 mm to 5.9 mm and this reduction is about 96%. This is due to the presence of continuous deck slab and monolithic connection between deck slab and girders in the integral bridges. In case seismic forces the whole integral bridge acts as single unit due to fixity between the superstructure and substructure.

Table 1 Comparison of deflection in longitudinal direction

Type of bridge	Deflection in mm
Conventional bridge	37.5
Integral bridge	0.179

Table 2 Comparison of deflection in transverse direction

Type of bridge	Deflection in mm
Conventional bridge	38.6
Integral bridge	5.9

6.4 Base shear

Base shear is an estimate of the maximum expected lateral force that occurs due to seismic ground motion at the base of a structure. IS 1893-2009 (Part-3) gives the brief description of base shear for bridge structures. Table 4.3 shows variation of base shear in longitudinal direction and transverse direction for conventional bridge and integral bridge. The base shear is comparatively more in the integral bridges than the conventional bridges. This is due to more flexibility in the conventional bridges than the integral bridges. The base shear in conventional bridge was 676.132 kN in longitudinal direction and 634.300 kN in transverse direction. In case of integral bridges, the base shear in longitudinal direction was 803.895 kN and in transverse direction it increases to 1567.125 kN. The variation of base shear in longitudinal direction is about 16% and in transverse direction is about 60%. The values indicated that, integral bridges are comparatively stiffer than the conventional bridge. Furthermore, integral bridges are highly stiff in transverse direction than in the longitudinal direction….

Table 3 Variation of base shear

Type of bridge	Base shear (kN)	
	Longitudinal direction	**Transverse direction**
Conventional bridge	676.132	634.300
Integral bridge	803.895	1567.125

V. CONCLUSIONS

It may be concluded that, integral bridge shows improved behavior under seismic loadings compared with conventional bridges. Lateral deflection in the integral bridges reduced to 94% as compared to conventional bridges. Similarly, lateral deflection in transverse direction reduced to 96% in case of integral bridges. The bending moment of deck slab was reduced in integral bridges because of fixed supports. This results in reduction of cross-sectional area of girders. The base shear results show that, integral bridges are stiffer than the conventional bridges. The base shear in integral bridge was 16% more than the conventional bridge in longitudinal direction and 60% more in transverse direction.

REFERENCES

[1] Vasant A. Matsagar, Jungid R.S., "Seismic response of simply supported base isolated bridge with different isolators", International journal of applied science and engineering, pp 53-69, March-2006.

[2] Alok Bhowmick, "Design and detailing of integral bridges: suggested guidelines", Indian concrete journal, , pp 45-50. September 2005.

[3] ShaikhTausif, Kalurkar L G,"Behavior of integral abutment bridge with spring analysis", proceedings of 7th IRF international conference, 22nd June 2014.

[4] Shreedhar R, Vinod Hosur, IftikarChappu, "Behavior of integral abutment bridge with and without soil interaction", International Journal of scientific & engineering research, Volume 3, Issue 11, November 2012.

[5] Mahesh Tondon, "Economical design of earthquake resistant bridges", ISET journal of earthquake technology, Paper no. 453, Vol. 42, , pp.13-20.March 2005.
[6] Aslam Amirahmad, Rahman A, "Analysis of integral bridges by finite element method", 2nd International conference on rehabilitation and maintenance in Civil engineering, , pp 308-314,2013.
[7] Meldi Suhatril, Azlan Adnan, "The seismic performance comparison of integral bridge model by using finite element program and shaking table test", International journal of physical sciences, Vol. 7(6), ,pp 927-936, February 2012.
[8] ShaikhTousif, L.G. Kalurkar, "Review integral bridge behavior in different condition", International journal of engineering and advanced technology, Vol. 3, Issue 5, ,pp 109-111, June-2014.
[9] IRC 6-2010: Standard specification and code practice for road bridges, section II-loads and stresses.
[10] IS 21-2000: Standard specifications and code practice for road bridges, section: III cement concrete (plain and reinforced).
[11] IS 112-2010 Standard specifications and code practice for road bridges, Reinforced and pre-stressed concrete bridges.
[12] IS 1893-2002 (Part-1): Criteria of earthquake resistant design of structures, general provisions and buildings.
[13] IS 1893-2009 (Part-3): Criteria of earthquake resistant design of structures, Bridges and Retaining walls.