

Comparative Study on the Seismic Performance of Integral and Conventional Bridges

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ABSTRACT: One of the most important aspects of design which can affect structure life and maintenance costs is the reduction or elimination of roadway expansion joints and associated expansion bearings. Integral bridges are bridges where the superstructure is continuous and connected monolithically with the substructure with a moment-resisting connection. In this study, the seismic performance of integral and conventional bridge is compared. For this purpose, one existing conventional bridge with eleven spans is selected and then an integral bridge with equivalent material properties and cross section is considered. The structural modeling and seismic analysis of integral and conventional bridges are done using the software SAP 2000. Response spectrum method is used for the analysis. The results of the analysis reveals that integral bridges has superior seismic performance compared to conventional bridges and by using integral bridges the cross section of members can be reduced thus resulting economy.

KEYWORDS: Integral Bridge, Conventional Bridge, Seismic performance, SAP 2000, Response spectrum method.

I. INTRODUCTION

Integral bridges are structures where the superstructure and substructure move together to accommodate the required translation and rotation. There are no bridge expansion joints and in the case of fully integral abutment bridges, no bearings. IBs are constructed continuous and monolithic with the abutment walls, thus enabling the superstructure and the abutment to act as a single structural unit and assuring a full moment transfer through a moment-resisting connection between them. Monolithic joints and redundancy of the structural system do result in savings in the cost of the construction and maintenance. Elimination of bearings improves the structural performance during earthquakes. Finally, integral form of construction will require lesser inspection and maintenance efforts. Several urban structures in India have been built with this concept. However no national standards or uniform policy regarding the permissible bridge length skews and design procedures have been clearly established, although certain general concepts become common in practice.

One of the most common problems associated with seismic performance of conventional bridge construction is movement of super structure from the support bearings. This problem is eliminated from the integral bridge construction because there are no support bearings [11]. However, the system of joints and bearings used in traditional construction allows super structure movements during a seismic event which result in decreased demand on the foundation. In integral bridge construction, the foundation piles and abutments must be able to accommodate these increased demands. There has been a general agreement that integral construction provides increased seismic resistance relative to traditional construction through increased redundancy and continuity. The behaviour of integral piers has been studied by some researchers; however detailed analysis of the earthquake resistance of this type of construction has not been conducted.

In recent years, various research has been conducted on the behaviour of integral bridges. Oesterle et al. [7] carried out a study on the Transverse Movement in Skewed Integral Abutment Bridges. Behaviour of Two-Span Integral Bridges

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unsymmetrical about the Pier Line was studied by Knickerbocker [8]. Christou et al. [9] carried out the soil structure analysis of Integral Abutment Bridges. A paper presented by Burdette et al. [10] studied the behaviour of pile supported Integral Abutments. A comprehensive report presented by Frosch et al. [11] examines the response of integral abutment bridges to seismic loading. A report presented by Laman et al. [12] revised and made more accurate integral abutment bridge design criteria based on observed structural behaviour and results of numerical parametric studies. Gentela et al. [14] studied influence of soil structure interaction on seismic behaviour of reinforced concrete integral bridge piers. According to Fateh et al. [15] several factors affected the Semi-integral bridge response under seismic excitations such as configuration of bridge and type of connection between members which play vital roles in determining response of bridge under seismic excitation. The behaviour of integral abutment bridge in different condition was reviewed by Tausif and Kalurkar [16].

For this study, an existing conventional bridge is selected and response spectrum method of analysis is carried out using SAP 2000. For the same site conditions, an integral bridge with equivalent cross section is analyzed, and results are compared.

II. MATERIALS AND METHODS

The existing bridge is a flyover at the Calicut, Kerala. It has eleven numbers of 25m centre to centre spans. Total length of the structure is 275m. It has the circular hammer headed piers and pile foundations. It has prestressed concrete girder deck slab system. The carriageway width is 9m with concrete crash barriers on either side (Total width 10m). The subsoil profile at the flyover location indicates a hard rock found at about 13.5m below ground level with a compressive strength of 100kg/cm². Cross section of the bridge is shown in Fig.1. Table.1 shows the cross sectional details of the bridge components.

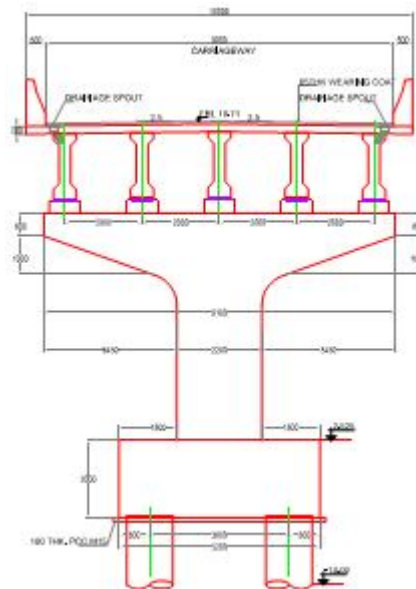


Fig.1. Cross section of the bridge

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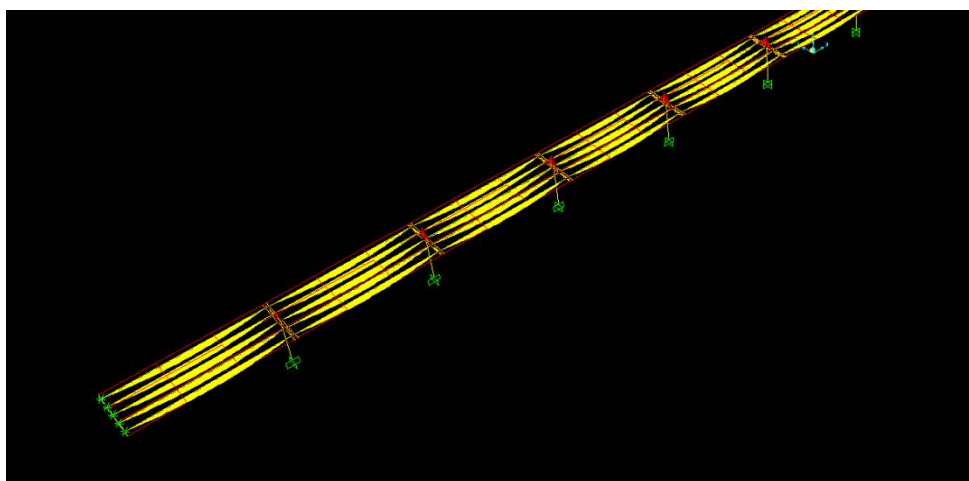
Table.1. Cross Sectional Details of the Bridge Components

Bridge component	Description	Size (mm)
Deck slab	Thickness	250
Longitudinal girder	Top flange	600 x 300
	Bottom flange	600 x 400
	Web	300 x 1000
Cross girder	Cross section	600 x 1300
Bent cap beam	Cross section	2000 x 1700
	Length	8600
Bent column	Diameter	2200

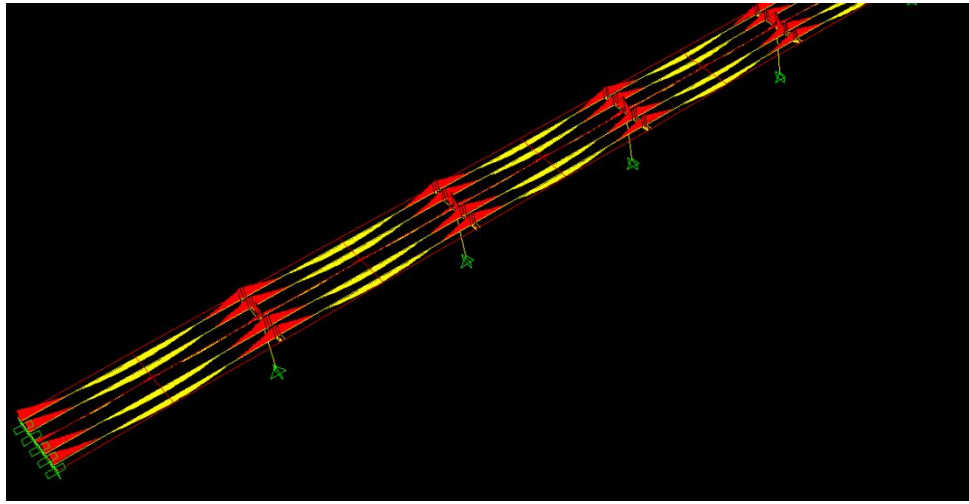
M45 grade concrete is used for the superstructure and M30 concrete for the substructure. Elastic properties of these materials are taken as per IS456 [2000]. Poisson’s ratio of concrete is taken as 0.2. The live load applied is IRC class AA loading. The seismic analysis of the existing bridge and equivalent integral bridge is carried out using SAP2000.

III. MODELLING AND ANALYSIS

A three dimensional (3D) finite element model (FEM) of the bridge was created using the software SAP2000. For FE models, finite element mesh was used to model deck and soffit. On the other hand, girders, diaphragms and bent columns were modelled using 3-D frame elements. The finite element model of bending moment diagrams are shown in Fig.2. As per IS 1893 (2002), Seismic zone III and Type II soil is used in the seismic analysis.



(a)



(b)
Fig.2. Bending moment diagrams (a) Conventional bridge (b) Integral bridge

IV. ANALYTICAL RESULTS

Bending moments and modal information is considered and compared. Modal information for the bridges are tabulated and presented in Table.2.

Table.2. Modal information for integral and conventional bridges

Mode	Conventional bridge		Integral bridge	
	Period (Sec)	Frequency (Cyc/Sec)	Period (Sec)	Frequency (Cyc/Sec)
1	0.357	2.79	0.204	4.89
2	0.204	4.89	0.201	4.97
3	0.202	4.93	0.192	5.21
4	0.195	5.12	0.177	5.66
5	0.180	5.54	0.176	5.68
6	0.159	6.26	0.156	6.37

From the modal analysis it has been observed that the Integral bridge vibrates in transverse direction in the 1st mode, vertical direction in the 2nd mode, torsional direction in the 4th mode and longitudinal direction in the 5th mode. The Conventional bridge vibrates longitudinal direction in the 1st mode, transverse direction in the 2nd mode, vertical direction in the 4th mode and torsional direction in the 5th mode. Some of the mode shapes of the Conventional and Integral bridges are presented in Fig.3 and Fig.4.

Structures with higher natural frequencies and a short natural period, tend to suffer higher accelerations but smaller displacement. In the case of structures with lower natural frequencies and long natural period, the structure will experience lower accelerations but larger displacement. From Table.1, it has been observed that for integral bridge, the maximum period of vibration is 0.204 seconds with a frequency of 4.89 Cycles per second. The maximum period of

vibration of conventional bridge is noted as 0.357 seconds with a frequency of 2.79 Cycles per second. Therefore, the displacement will be larger for conventional bridge when compared to the integral bridge.

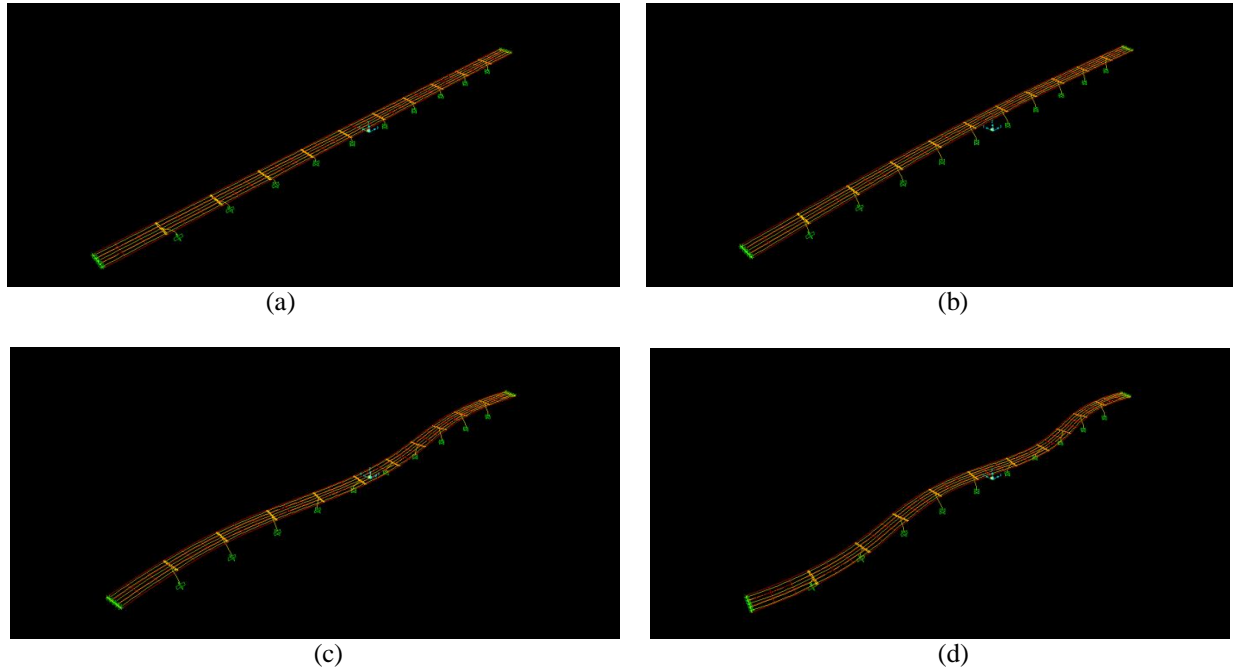


Fig.3. Mode shapes of the Conventional bridge (a) Mode1 (b) Mode 2 (c) Mode 4 (d) Mode 5

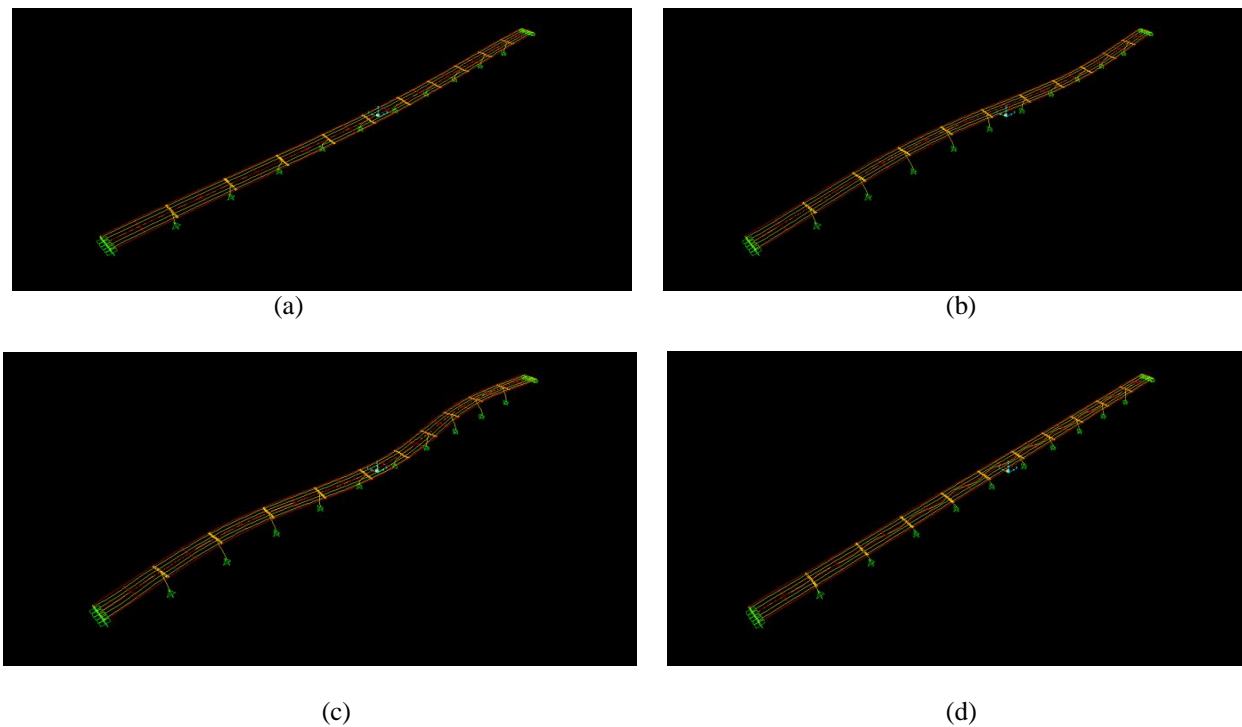


Fig.4. Mode shapes of the Integral bridge (a) Mode1 (b) Mode 2 (c) Mode 4 (d) Mode 5

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Inner span bending moments of Integral and Conventional bridges are tabulated and presented in Table.3.

Table.3. Inner span bending moment

Dead load BM (kN-m)	Integral bridge	Conventional bridge
Max -ve	1019.31	0
Max +ve	436.63	1367.58
Live Load BM (kN-m)	Integral bridge	Conventional bridge
Max -ve	1612.20	0
Max +ve	891.15	1971

From Table.2, it has been observed that maximum positive bending moments at the girders of integral bridge is low as compared to the conventional bridge. This is due to the continuity of the structure so that the cross section of members of integral bridges can be comparatively reduced. In that sense also integral bridges are economical as compared to conventional bridges

V. CONCLUSION

In this study, inner span bending moments and modal information are taken and compared. From the modal analysis, it has been seen that for integral bridge, the maximum period of vibration is 0.204 seconds with a frequency of 4.89 Cycles per second. The maximum period of vibration of conventional bridge is noted as 0.357 seconds with a frequency of 2.79 Cycles per second. Therefore it is found that larger displacement occurs in conventional bridge as compared to integral bridge. From inner span bending moments, it is noted that the value of positive bending moment is more in the case of conventional bridge. Positive bending moment is comparatively less in integral bridge so that as an advantage we can reduce the cross section of the members economically.

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