Fatigue Performance of Integral Bridges

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***Abstract*—Conventional construction, the superstructure typically consists of a series of simply supported spans separated by expansion joints and resting on bearings at the abutments and intermediate piers. In integral construction, the superstructure and abutments form a continuous, monolithic structure. In integral bridges, work of maintaining joints and bearings are eliminated as it is made integral with intermediate pier. In this project fatigue evaluation of integral bridge is carried out using finite element tool named ANSYS. Life assessment of the bridge is analyzed in this project. Dynamic analysis is also carried out for the bridge in two steps. First a real load history is applied to the bridge to obtain the transient response and then fatigue damage is evaluated**

Keywords— Integral bridge, bearing, expansion joints (key words)

I. INTRODUCTION

A Bridge is a structure built to span physical obstacles without closing the way underneath such as a body of water, valley or road for the purpose of providing passage over the obstacle. There are many different designs that all serve unique purposes and apply to different situations. Designs of bridges vary depending on the function of the bridges, nature of the terrain where the bridge is constructed and anchored, the material used to make it, and the funds available to build it.

Integral bridges are structures where the superstructure and substructure move together to accommodate the required translation and rotation. The integral abutment bridge concept is based on the theory that due to the flexibility of the piling, thermal stresses are transferred to the substructure by way of a rigid connection between the superstructure and substructure. There are no expansion joints and bearings in the case of integral abutment bridges. Integral bridges 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 bearing 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 structures in India have been built with this concept.

Bruno Briseghella ,*et.al*,[[10] introduced an innovative beam-to-pier joint and a theoretical and experimental study is conducted to overcome the durability problems of bearings and expansion joints. . M.Naji.*et.al* [1] were constructed two-dimensional model of an integral abutment bridge with soil springs around the piles and behind the abutments with finite element ANSYS. L.G.Kalurkar.*et.al*,[11] Studied the behaviour of integral abutment bridge in different condition. Shatirah Akib,*et.al*,[12] introduced an innovative countermeasure to prevent the impacts and consequences of scouring on integral bridge. Mahesh Tandon ,*et.al* [9]researched about economical earthquake resistant design of bridges .It includes the study of Plastic hinging and durability of bridge, Superstructure dislodgement prevention and integral bridges ,Base isolation, Energy dissipation and elastomeric bearings, Energy sharing. David Knickerbocker.*et.al.* [5] Studied the behaviour of two-Span integral bridges unsymmetrical about the Pier Line. Finite element modelling was used in the study using the software ANSYS V. 7.0 and the results are validated with experimental data from two integral bridges.

For this study, an existing conventional bridge is selected and transient analysis is carried out using ANSYS 15. For the same site conditions, an integral bridge with equivalent cross section is modelled, analysed, and results are compared.

II. GEOMETRY OF BRIDGE

The Mannathikkadavu Bridge is an existing bridge across Thootha River in Malappuram district, Kerala. It has five numbers of 22.32m centre to centre spans. Total length of structure is 111.6m. It has the circular hammer headed piers and open type foundations (600mm in hard rock). The road width is 7.5m with foot path 1.5m on both sides. Elastomeric bearing size of 500x360x99 mm shall be provided for all abutments and piers. For this project we consider only two spans of this bridge.

TABLE I GEOMETRY OF BRIDGE

Bridge Components	Description	Size(mm)
Deck Slab	Thickness	240
Girder	Flange	550 x 490
	Web	1440 x 240
Pier	Diameter	1800
Pedestal	Length	1500
	Breadth	800
	Thickness	300
Elastomeric bearing	Length	500

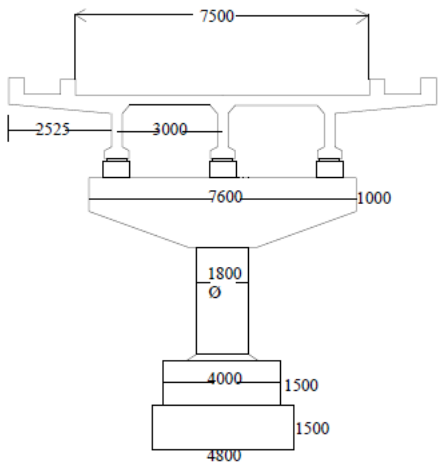

Fig.1.Cross section of bridge

III. MATERIAL PROPERTIES

Two materials are defined to model the bridge. They are reinforced concrete and neoprene .The properties of the materials are given in table 2.

TABLE II PROPERTIES OF MATERIALS USED

Material	Density (kg/m^3)	Modulus of Elasticity (MPa)	Poisson's ratio
Reinforced concrete	2500	50000	0.15
Neoprene	9.78E-08	6	0.499

IV. MODELLING OF BRIDGE

Figures show the models of integral and conventional bridges. The modelling of existing bridges is done using the software CATIAV5- which stands for **C**omputer **A**ided **T**hree-dimensional **I**nteractive **A**pplication - is the most powerful and widely used CAD (Computer Aided Design) software of its kind in the world.

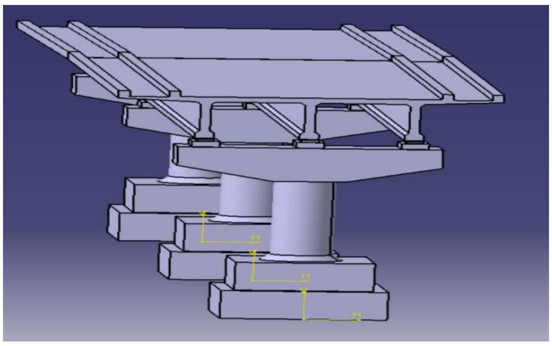

Fig. 2. Model of Integral Bridge (a)

V. LOADING CONDITIONS

As per IRC: 6 – 2014 , IRC Class 70R loading is considered for the analysis .Class 70R loading is applicable only for bridges having carriageway width of 5.3 m and above (i.e. 1.2 x 2 + 2.9 = 5.3). The minimum clearance between the road face of the kerb and the outer edge of the wheel or track shall be 1 .2 m.

VI. ANALYSIS RESULTS AND DISCUSSION

The selected bridges were analysed in ANSYS Workbench 15.Dynamic analysis is carried out for the bridges in two steps. First a real load history is applied to the bridge to obtain the transient response. Second, fatigue damage is evaluated.

TABLE III ANALYSIS RESULTS

	Integral Bridge	
	Maximum	Minimum
Deformation	2.048mm	0mm
Equivalent Strain	.0001	5.54E-9
Equivalent Stress	9.4738MPa	.00027437
Life	1E+6 Cycles	1E+6 Cycles
Damage	1000 cycles	1000 Cycles
Safety Factor	15	15

From the transient analysis it has been observed that integral bridge having maximum deflection of 2.048mm. The maximum strain value of integral bridge is negligible. Maximum stress value of integral bridge is 9.47MPa. Integral bridge shows maximum life span of 1E+06 cycles and maximum damage value of 1000 cycles and maximum safety factor of 15. Below figures represents the deformation, equivalent elastic strain, elastic stress, life, damage and safety factor of integral bridges

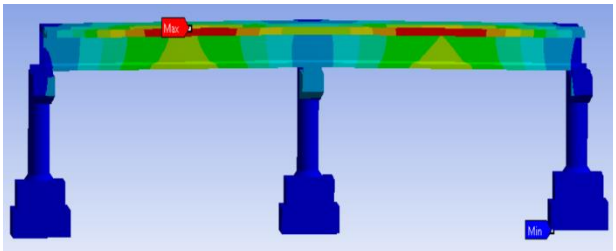

Fig.3.Total deformation of integral bridge

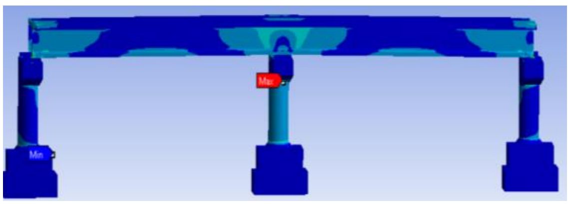

Fig.4.Equivalent elastic strain of integral bridge

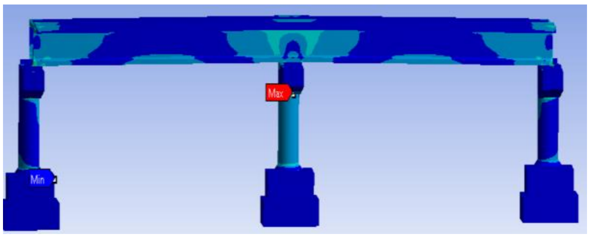

Fig.5.Equivalent stress of integral bridge

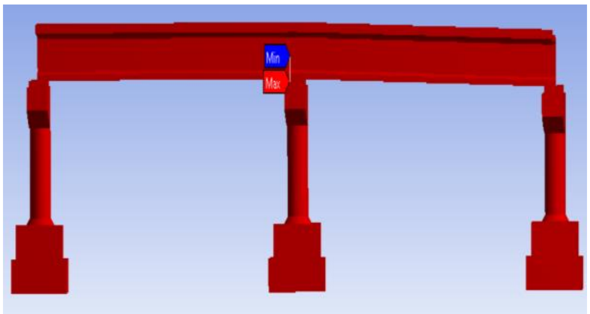

Fig.6.Life of integral bridge

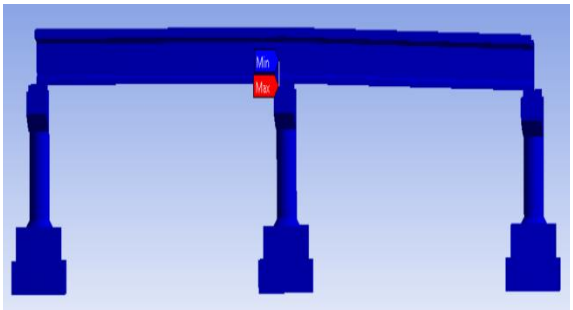

Fig.7.Damage of integral bridge

CONCLUSION

In this paper integral bridge was modelled in CATIA V5 and analysed in ANSYS Workbench 15. From the analysis result we understood that absence of expansion joints in integral bridge gives more durability. The maximum deformation of integral bridge is negligible. Due to the rigid nature of integral bridge, it is found that the value of stress and strain is very less. Integral bridges show maximum fatigue life of 1E+6 cycles. Due to the elimination of bearings and expansion joints in integral bridge, initial and maintenance cost is very low comparing with conventional bridge. So it is better to prefer integral construction over conventional type.

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