Behavior of Integral Bridge – State of Art Literature Review

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Abstract: Integral bridges become more popular among world. In conventional construction of bridges, the superstructure consists of a series of simply supported spans separated by expansion joints and resting on bearings at the abutments and intermediate piers. During service life of bridges, these joints and bearings become critical places for accumulation of debris and deicing chemicals, there by deteriorating concrete and corroding steel reinforcements that lead to high maintenance cost. Bearing needs periodic replacement result in high maintenance cost. Hence, to overcome this problem integral bridge is recommended which have monolithic connection between girder and pier cap to eliminate bearings and expansion joints. Maintenance cost of integral bridge is very less. The reviewed literature shows different aspect for behavior of Integral Bridge.

***IndexTerms* - Bearings, Conventional Bridges, Integral Bridges.**

I. INTRODUCTION

Integral bridges are defined as a class of rigid frame bridges without expansion joints. Arch bridges, rigid-frame bridges, culverts and modern integral bridges having a single row of steel H-piles at the abutments to provide the required lateral flexibility under thermal effects can be classified as Integral bridges. Integral bridges were first considered after observing the successful performance of older bridges within operative expansion joints under seismic and service loads. Since then, Integral bridges are usually considered as alternative to conventional jointed bridges. In the last two decades, Integral Bridges have become very popular in North America, Europe and other parts of the World as they provide many economical and functional advantages. A conventional bridge accommodates movement by means of free expansion at both ends. An integral bridge accommodates movement by its flexible foundation. One of the most common problems in the seismic resistance of traditional bridge construction is unseating of the superstructure from the support which is bearings. This problem can be eliminated in integral bridge construction as there are no support bearings. In integral abutment construction, the foundation piles and abutment must be able to accommodate increased demands due to restrained boundary condition.

II. Literature review

1)Shehab Mourad et al (1999) [1] study the deck slab stresses in integral bridge and compare with stresses associated with jointed bridge. Deals with the stress distribution in concrete deck slabs on composite steel beams used with integral abutment bridges. Bridges distribute the loads in the deck slab more uniformly than jointed bridge Transverse stresses are less. The reduction in the maximum positive moment in transverse direction in slab is 10 – 30%.The reduction in the maximum negative moment in transverse direction the slab is 20 – 70%.The reduction in the maximum longitudinal stress at the top of the slab is 1 – 15%.

2)Jonathan Kunin et al(2000)[2] A comparative survey was undertaken across North America, focusing on design and construction of both substructures and superstructures For further improvement of New York’s design practice. Integral abutment bridges have been gaining popularity among bridge owners as cost-effective alternatives to bridges with conventional joints. New York has been building them since the late 1970s, with a wide variety of details and they have been performing well.

3)Jonathan Kunin and Sreenivas Alampalli (2000) [3] did survey in United States and Canada. New York has been building them since the late 1970s, with a wide variety of details, and they have been performing well. For further improvement of New York’s design practice, a comparative survey was undertaken across North America, focusing on design and construction of both substructures and superstructures. In all, 39 states and Canadian provinces responded, including 8 who said they had no experience with these bridges. Responses are analyzed and summarized in this paper. Integral bridge performance included minor cracking, drainage at abutments, and settlement of approach slabs. Arizona was the only state with a negative opinion, having built 50 bridges. Max length of cast-in-place concrete bridges 290.4m.Most agencies keep skew of integral bridges to less than 30 degree, but two agencies set no skew limits. About half the designers report no distress related to thermal movement .Two agencies do not consider soil pressure within certain abutment size limits, and three do not consider earth pressure at all in their design.

4)Murat Dicleli et al(2005) [4] presents an analytical approach Which is used for predicting the length limits of integral bridges built on cohesive soils based on the flexural strength of the abutments and the low cycle fatigue performance of the steel H-piles at the abutments under cyclic thermal loading. It is found that the maximum length limits for concrete integral bridges range from 130 to 290 m and that for steel integral bridges ranges from 95 to 210 m.

5)S. Hassiotis and E. K. Roman (2012) [5] summarize the research projects of the past ten years and the empirical knowledge gained by experienced bridge engineers. Although state agencies are surging ahead with the design and construction of longer integral bridges, it is evident that an accepted design process is not available and recommendations on design are made mainly on the basis of practical experience. In general, stub abutments supported on a single row of piles are used.

6)Alan G. Bloodworth et al (2012) [6] Studied that soil adjacent to integral bridge abutments experiences daily and annual temperature-induced cyclic loading owing to expansion and contraction of the bridge deck. This causes a particular soil response and complicated soil-structure interaction problem, with considerable uncertainties in design. Author describes a method of calculating the effects of thermal cycling by using the results of laboratory cyclic stress-path testing within a numerical model. Samples of stiff clay and sand were tested in the triaxial apparatus under stress paths that are typical behind an integral abutment. A numerical model was developed with a soil model reproducing the sand behavior at element level. Distinct behavior was observed for the two soils, with stiff clay showing relatively little build up of lateral stress with cycles,where as sand stresses continued to increase, exceeding at-rest pressure and approaching full passive pressures. Stiff clay reaches a resilient state quickly, with relatively little buildup of stress with cycles. For sand, there is a continual pressure buildup that may approach full passive in the long term due to progressive interlocking of particles by small rotations during each cycle.

7)Brent M. Phares et al(2013)[7] study the performance investigation of two approach slabs(a cast-in-place slab and a precast panel slab) integrally connected to two parallel bridges. No significant differences were measured between the precast and cast-in-place slabs.

8)Shelley A. Huntley and Arun J. Valsangkar(2014)[8] study the Behaviour of H-piles supporting an integral abutment bridge.Integral abutment bridges accommodate thermal superstructure movements through flexible foundations rather than expansion joints. While these structures are a common alternative to conventional design,the literature on measured field stresses in piles supporting integral abutment appears to be quite limited. Therefore, field data from strain gauges installed on the abutment foundation piles of a 76 m long; two-span integral abutment bridge are the focus in study. Axial load, weak and strong-axis bending moments of the foundation piles, as well as abutment movement and backfill response, are presented and discussed. Weak-axis moment variations indicate that the abutment piles are bending in double curvature to accommodate the thermal expansion and contraction of the bridge superstructure, while the strong-axis moment variations suggest the abutments are tilting in the lateral direction, causing torsion of the superstructure. It was found that the total stress measured in the abutment piles at the upper strain gauge locations ranged from 17% to 28% of the pile yield stress, and at no time did the total stress exceed the yield stress.

9)Mairéad Ní Choine et al(2015)[9] Over the past few decades, integral or joint-less bridges have become a popular alternative to conventional bridges designed with bearings and expansion joints. In the United Kingdom (UK) for example, designers are now required to consider the integral form for bridges up to 60 m [The Highways Agency, 2001]. This trend is also reflected in the United States (US) where at least 40 states are now building some form of joint-less bridges and although superstructures with deck joints still predominate, the trend appears to be moving towards the integral form .Author develops fragility curves for two bridge classes in order to draw comparisons between two design options the probability of the jointed bridge exceeding moderate damage is 60% greater than the probability of the integral bridge exceeding moderate damage.

10)Lakshmy Kakkanatt and Rajesh. A. K(2015)[10] modeled conventional, semi-integral and integral bridges and transient analysis is done using finite element tool ANSYS. Elimination of bearings improves the structural performance of integral bridges due to earthquake and it requires less inspection and maintenance efforts. It is found that integral bridge has smaller deflection and stress when compared to other bridges due to its rigid nature. Due to their increased stiffness, these bridges exhibits lower displacement demands. In integral bridges functional movements are maximized at the ends of the continuous deck. Unseating of superstructure from the support bearings can be eliminated. Therefore, integral bridges can be seen as a promising solution for the reduction of the seismic displacements.

11)B. Kong, C.S. Cai and Y. Zhang(2016)[11] presents a numerical investigation on the thermal performance of bridge using ANSYS software. Based on the analysis studies, the numerical modeling including temperature loadings, backfill–abutment interactions, and soil–pile interactions, is validated by comparing the bridge response with the field measurements. The soils surrounding the piles show the most significant effects on the bridge responses. Changing the soft soils to the stiff soils generates a maximum of 1.5 times smaller bridge displacements and 20% smaller backfill pressures; but at the same time, it induces 70% larger pile positive strains and 48% larger slab negative strains.

12)Haymanmyintmaung and kyawlinnhtat(2016)[12] study, the integral bridge with various span length of 40m, 50m, 60m and 70m non-skew and skews angles of 15°, 30°, 45° and 60° were designed, and modeled in SAP2000 software. The parameters investigated in this analytical study were skew angle, span length and stress reduction methods. The geometric dimensions of the Integral Bridge and the loading used were in compliance with AASHTO standard specifications. Static analysis and dynamic nonlinear time history analysis were performed to assess the seismic performance of integral bridge. According to analysis result, integral bridge maximum skew angle can be extend up to 60° and span length up to 60 m can be extended using stress reduction method under extreme seismic loading.

13)MuratDicleli and O.FatihYalcin(2018)[13] work on the live load distribution in integral bridge component, no provisions exist for live-load distribution in the components of skewed integral bridges .Thus, in this study, skew correction factors were developed for the girders, abutments, and piles of SIBs to adjust the readily available live-load distribution formulae for integral bridges. For this purpose, two-dimensional and three-dimensional structural models of numerous skewed integral bridges were constructed and then analyzed to calculate the live-load distribution factors for skewed integral bridges components as a function of the skew angle and various structural parameters. The ratio of the live-load distribution factors for skewed integral bridges to those for the same bridges with no skew were then used to formulate skew correction factors. Live-load effects in SIB components were then simply obtained by multiplying the skew correction factors with the results obtained from the readily available live-load distribution formulae in the literature. The comparison of the results with those from structural analyses revealed that using the developed skew correction factors together with readily available live-load distribution formulae for regular integral bridges yields reasonably good estimates of Live-load moment and shear in skewed integral bridges components.

III.SUMMARY OF FINDINGS

From review of above papers, following findings are observed:

- United States begun construction of integral bridges in early 1940’s.
- Integral bridges are economical than bearing bridges. Initial cost of Integral Bridge is lesser compare to the bearing bridge.
- Earth pressure developed at abutment depends upon type of soil. In clay soil pressure is remain lesser than full passive pressure while in sand with number of cyclic movements due to inter granular locking full passive pressure is acting at abutment.
- In Earthquake event probability to damage bearing bridge is 60% higher than the integral bridge.
- Girder which is supported by bearing can unseat from its location leads to bridge failure. This type of failure can be prevented by integral approach.
- Integral bridge maximum skew angle can be extend up to 60° and span length up to 60 m can be extended using stress reduction method under extreme seismic loading.
- Stress distribution in slab deck is more uniform in integral bridge than conventional bridge.
- Negative moment and positive moments in deck slab are less in the integral bridge.
- Durability of integral bridge is higher because bearings and expansion joints which are weakest link of the bridge.
- Due to integrity in structure redundancy is increase which leads to durable structure in earthquake event.
- To retrofit the existing simply supported bridges the concept of integral bridge is useful. To convert in to integral bridge new reinforcement is introduced in the slab to resist negative bending moment at support.
- As per IRC-SP-115:2018; for integral bridge radius of curvature of bridge should be less than 100 m.
- Skew angle shall be less than or equal to 30 degrees.
- Wing wall of bridge shall not be connected to main structure of bridge.

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