International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Comparative Study on Construction Stage Analysis of Multi Span Conventional Bridge with Integral Bridge

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Abstract: ***Bridges are the important, useful and efficient civil engineering structure which decided the development of country. Bridges are of different types. They are designed based on the function of the bridge. Conventionally, bridges with bearing are most commonly used. The conventional bridges consist of simply supported spans separated by expansion joints and the bearings. During the service life of the bridge these expansion joints and the bearing, at the intermediate pier heads and abutments, are affected with rusting of steel reinforcement and deterioration of concrete due to the accumulation of debris and de-icing chemicals. This will lead high maintenance cost as well as the replacing cost. Hence engineers are recommended a new method for bridge construction i.e. integral bridge. Integral bridges are the bridges without joints which lead to the lower initial as well as the maintenance cost.This paper presents analytical comparative study on the construction stages of both conventional bridge and integral bridge in terms of moment and deflection by using SAP bridge software. From the above study it can be concluded that the variation in the moments and deflection during the construction stage has to be studied for a long span integral and conventional bridge. It is recommended that the integral bridges show more effectiveness than conventional bridges to avoid the accidents at the construction stages***

Keywords: conventional bridge, deflection, integral bridge, moment

1. Introduction

Bridge is a structure built to span and provide passage over a river, road, or any other physical hurdle. The function required from the bridge and the area where it is constructed decides the design of the bridge. Bridges are classified on the basis that how the four forces namely shear, compression, tension, and moment are distributed in the bridge structure.

Most commonly used bridge consists of bearings and expansion joints at the abutment as well as in the intermediate pier heads, which allows expansion and contraction of the bridge. During the service life of bridge these expansion joints and the bearing, at the intermediate pier heads and abutments, are affected with rusting of steel reinforcement and deterioration of concrete due to the accumulation of debris and de-icing chemicals. This will lead high maintenance cost as well as the replacing cost. In integral bridges there are no joints on the superstructure. Integral bridges are monolithic structures and constructed continuously, thus whole structure act as a single structural unit and moment transferred through the moment resistant connection between them. Structurally both conventional and integral bridges are different from each other and also are different from accommodation of movements. Conventional bridges accommodate movement through sliding bearing surface whereas an integral bridge accommodates movement by its flexible foundation.

The construction of bridge is very complicated and challenging process. Different methods and techniques exist for the construction of bridge super structure. When planning to build a bridge, engineers are required to come up with the most feasible way of erecting the structure in a safe and economic manner. Finding the optimum solution is based on comparing alternative techniques of erecting the bridge, along with the consideration of the different means and methods that can be employed and the implications on schedule and budget.

In this paper conventional bridge (bridge with joints and bearings) and integral bridge (bridge with no joints and bearings) with same cross sectional details are modeled and analysed in terms of construction stage analysis using SAP 2000 software .

2. Scope of Study

- To ensure the design calculation done by SAP 2000.
- To reduce the time involved in designing the structures.
- Results can be used for the future development and further construction of the bridges.
- Cost effective and effective material utilization of bridge

3. Objective of Study

- Compare and test the effectiveness of integral bridge with conventional bridge.
- To provide a new method of bridge construction technique for effective material utilization.
- Compare the deflection and construction stage moments of conventional and integral bridge.

- Construction stage analysis will provide future development of bridge analysis.

4. SAP 2000 Software

Sap 2000 software is integrated software for structural analysis and design purpose Bridge Designers can use SAP2000 Bridge Templates for generating Bridge Models, Automated Bridge Live Load Analysis and Design, Bridge Base Isolation, Bridge Construction Sequence Analysis, Large Deformation Cable Supported Bridge Analysis and Pushover Analysis. Advanced analysis - Options for nonlinear base isolators, dampers, gaps, large deflection, and plastic hinges for pushover analysis. Modal, response spectrum, linear or nonlinear time history dynamic analysis. No limit on use of springs, dampers, and other elements in dynamic analysis. It can be used other types of general structures like stadiums, water retaining tanks, airport hangers, chimneys etc., It has predefined templates for the ease of modeling such complicated structures

5. Specifications

a) Material

1) Steel

- Young's Modulus E=2.1 x 10^{11} N/m^2
- Poison's ratio v=0.3

2) Concrete

- Young's Modulus(super structures) E=4.5 x10^{9} N/m^2
- Young's Modulus(sub structures) E = 4.5 x10^{9} N/m^2
- Poison's ratio v=0.2
- density of concrete = 2.4x10^{-6}N/mm^3

b) Bridges

3) Bearing

- Neoprene pad bearings
- Young's Modulus E=6x 10^{11} N/m^2
- Poison's ratio v=0.5
- density of 9.65x10^{-7}N/mm^3

$$K_{eff} = \frac{G_{eff} \times A}{H_r} = \frac{680 \times 0.1575}{0.061} = 0.061KN/m$$

$$K_V = \frac{E_C \times A}{H} = \frac{617263 \times 0.1575}{0.085} = 1755\ KN/m$$

$$K_\theta = \frac{E \times I}{H_r} = \frac{617263 \times 0.0016}{0.061} = 16270KNm/m$$

K_H K_V And K_θ denote the lateral, vertical, and rotational stiffnesses of the elastomeric pads used in this bridge

Table1: Elastomeric bearing properties

Properties	Size
Elastomeric bearing length L(cm)	35
Elastomeric bearing width W(cm)	45
Elastomeric bearing height H(cm)	8.5
Total Elastomer thickness h_r(cm)	6.1
Thickness of one elastomer layer h_{ri}(cm)	0.8
Thickness of one steel reinforcement layer h_s(cm)	0.3
Elastomer gross plan area A(cm2)	1575
Elastomer moment of inertia I(cm^4)	1600
Shape factor S	12.3
Amount of bearing n(at end of girder)	10

4) Meshes

- Mesh size= 20mm

Material specification of bridge shown in Table 2 and cross sectional details is shown in the fig.1 below.

Table 2: Bridge specifications

Bridge component	*description*	*Size(mm)*
Effective span	length	30000
Carriage way	width	7500
footpath	width	1500
Deck slab	thickness	240
Longitudinal girder	Top flange Bottom flange web	850x150 600x200 300x1750
Bent cap beam	Cross section Width	3200x2300 10000
Bent column	diameter	2000
Pile cap beam	Cross section	1800x1800
Pile	diameter	1200
Tendon	Type	19T13

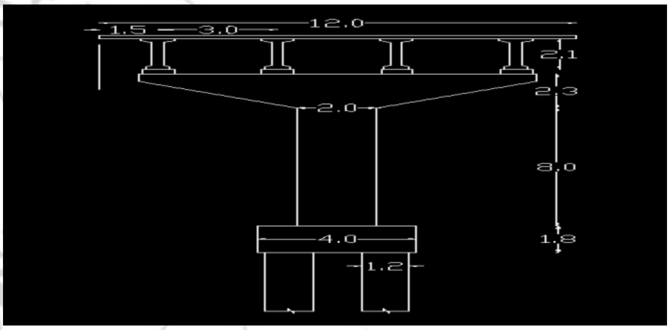

Figure 1: Cross section details of bridge

6. Modeling

For modeling of conventional bridge, five bridge spans each having 30m length and separated by means of expansion joints of 40mm are selected. Bearings are also provided between the superstructure and piers. Integral bridges are monolithic rigid structure, thereby eliminating the bearings and joints. The boundary conditions are set to restrain movement in vertical direction and accommodate movement in horizontal direction to maintain flexibility of the foundation. Other elements are modelled as same as that of conventional bridge

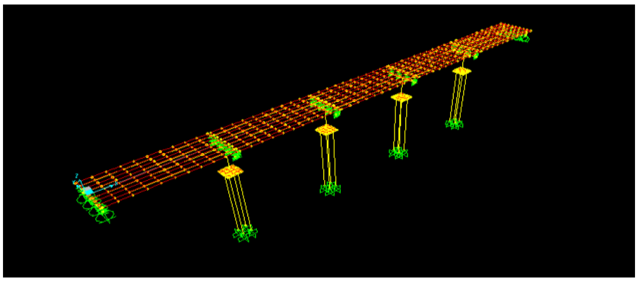

Figure 2: Schematic view of conventional bridge

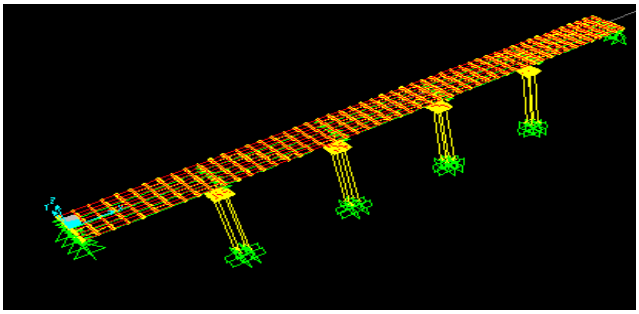

Figure4: Schematic view of integral bridge

7. Construction stage analysis

Staged construction is a static modeling, analysis, and design application which enables the definition of a sequence of construction stages in which structural systems and load patterns are added or removed, and time-dependent behaviors are evaluated, including creep, shrinkage, aging (change in elastic modulus with age), and tendon relaxation. Material and geometric nonlinearity may be applied to staged construction. Further, staged construction may be part of a sequence of nonlinear static or direct-integration time-history analysis load cases. For linear load cases, the structural stiffness at a given construction stage may serve as the basis for analysis. A structure such as a pre-stressed bridge requires separate and yet inter-related analyses for the completed structure and interim structures during the construction. Each temporary structure at a particular stage of construction affects the subsequent stages. Also, it is not uncommon to install and dismantle temporary supports and cables during construction. The structure constantly changes or evolves as the construction progresses with varying material properties such as modulus of elasticity and compressive strength due to different maturities among contiguous members. The structural behaviors such as deflections and stress re-distribution continue to change during and after the construction due to varying time dependent properties such as concrete creep, shrinkage, modulus of elasticity (aging) and tendon relaxation. Since the structural configuration continuously changes with different loading and support conditions, and each construction stage affects the subsequent stages, the design of certain structural components may be governed during the construction. Accordingly, the time dependent effects for construction stage analysis is required to examine each stage of the construction

8. Results

- **Variation in the moments at different construction stages**

The following results were obtained from SAP2000 for the moments at different construction stage on the pier. The following graph shows the moment variation on the support pier element no 2

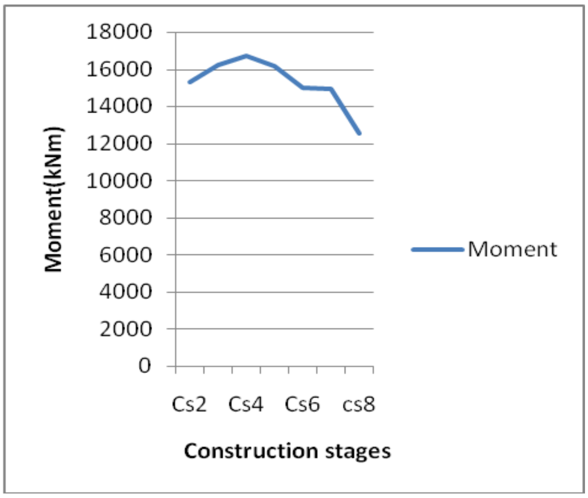

Figure 5: Moments of conventional bridge

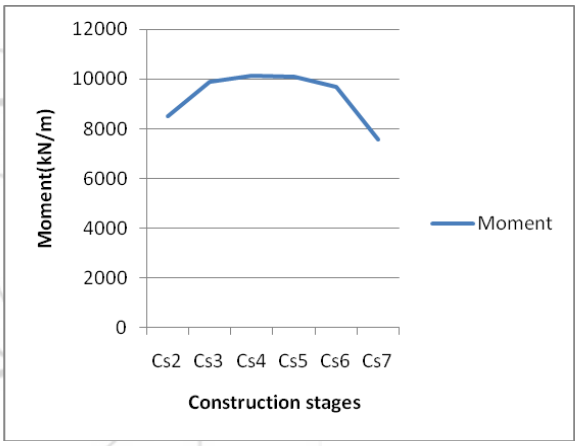

Figure 6: Moments of integral bridge

- **Deflection Variation at different construction stages**

The bridge deflection at the various construction stages are graphically shown in below.

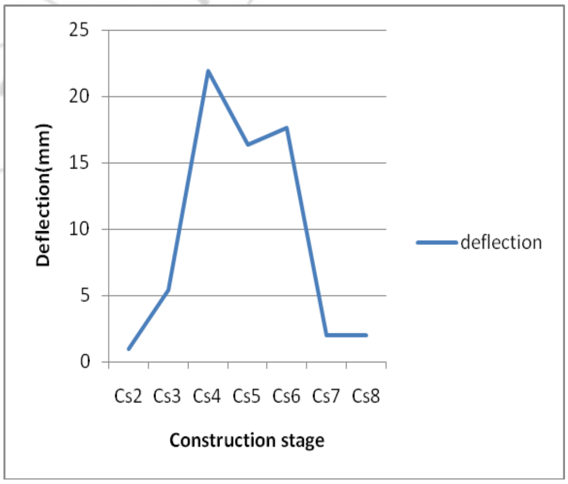

Figure 7: Deflections of conventional bridge

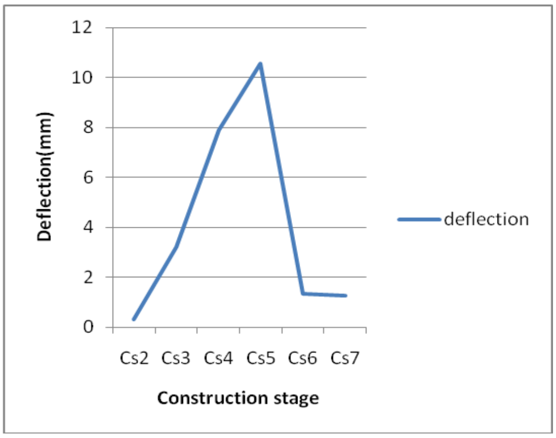

Figure 8: Deflections of integral bridge

9. Comparison of static analysis results

Maximum bending moments coming over the conventional bridges are 16733kNm and the deflection is 21.89mm. in the case of integral bridges 10124.856kNm is the maximum bending moment and 10.57mm are the deflections. Integral bridges shows lesser deflection and bending moments in the construction stages, it is because of the monolithic construction and the lesser number of joints and other accessories.

10. Conclusions

The above study shows the comparative study on construction stage analysis of integral and conventional bridge. From the above results it can be concluded that the variation in the moments and deflection during the construction stage has to be studied for a long span pre stress integral and conventional bridge. It is recommended that the integral bridges show more effectiveness than conventional bridges to avoid the accidents at the construction stages.

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