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Comparative Study of T Beam Bridge with Conventional Method and Finite Element Analysis

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Abstract: The most commonly and popular type of bridge used in Nepal is T beam bridge due to it's simple in design, construction and maintenance than other types. T-beam Bridge comprises of a concrete slab integral with girders. This type of bridges is more preferred when it comes to connectivity to short distances. So, it is necessary to update the analysis and design methods. Here, in this paper, there is an attempt to study the comparison of maximum bending moment due to live load in a girder and slab bridge for varying span length as 15m, 20m and 25m respectively of T Beam bridge using conventional method. The same bridge is analyzed as a three-dimensional model in finite element software as SAP2000, apply the same loading done for conventional methods and compared the results. The maximum bending moment results obtained from finite element model are lesser than Courbon's method which looks more conservative.

Keywords: T-Beam Bridge, Courbon's Method, IRC Live loadings, Longitudinal girder, SAP2000.

1. Introduction

A Bridge is a structure giving entry over a snag without shutting the route underneath [4]. The essential section can be used for street, pedestrian, railway, road, channel or pipe line. The snag cross may be for stream, street, railroad or valley [6,7]. A typical bridge consists of an upper part (superstructure), which comprises of the slab, the floor system, and the fundamental truss or girders, and a lower part (substructure), which are towers, columns, piles, footings, piers, and abutments [4,6]. The superstructure gives Horizontal spans, for example, deck and girders and effectively carries traffic loads. The substructure usually supports the horizontal spans, elevating over the ground surface. T- Beam bridge deck, is the most common type of bridge all over the world, it consists of several beams or girders. The span in the direction of the road way and connected across their tops by a thin continuous structural stab, the longitudinal beams can be made of several different materials, usually steel or concrete. T–Beam Bridge is generally adopted type of bridge for span range of 15 to 25m [4, 6].

The main longitudinal girders are designed as T-Beam which is integral part of deck slab cast monolithically with the deck slab. A typical T-beam bridge is shown in Fig. 1 and Fig. 2. Simply

Supported T-Beam spans of more than 25m are uncommon as the dead load on then turns out to be too substantial. T-Beam Bridge is the combination of superstructure (Deck slab with longitudinal girders & Cross girders) and Substructure (piers, abutment and foundations) [8].

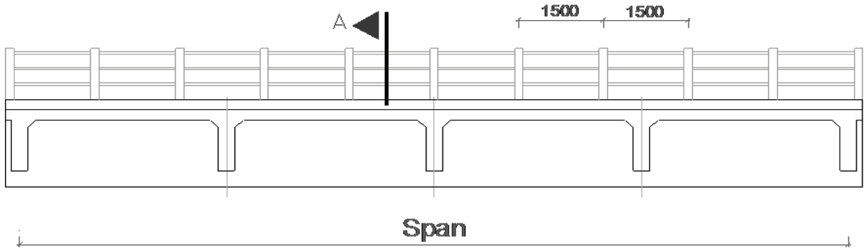

Fig. 1: Elevation of Longitudinal direction of bridge.

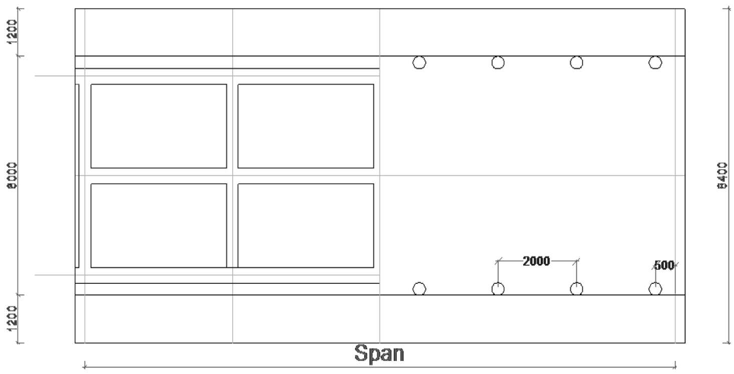

Fig. 2: Plan of T Bridge

A comparative study of three different spans was performed. They were ordinary deck on girders and T-Beam configurations of loadings considered for the analysis were FEM analysis is done using SAP2000. In this study, the objectives are achieved by underlying sequence:

- Validating FEM Analysis and comparing Conventional Method of analysis for span.
- Performing FEM Analysis on ordinary supported on girders and T-beam configuration by considering maximum bending moment for comparison.

2. Methodology

A typical tee beam deck slab usually consists of longitudinal girder integrated with slab between the tee beams and cross girders to provide lateral firmness to the deck. The transmission of loads takes place from deck slab to the girders then to the substructure. Depending on the position of the live load on the deck slab the distribution of live load on each girder takes place. The distribution of live load on the longitudinal girders can be estimated by any of the followings:

A. Conventional Method: Courbon's Method
B. Finite Elements Analysis from Software

2.1 Courbon's Method

This is one of the earliest forms of rational analysis of bridge decks and is very popular in view of its simplicity. The expression for reaction factor for individual longitudinal girders (share of the total load by the individual longitudinal girders) according to this method.

It is applicable when the following circumstances are fulfilled [4]:

- The deck span to width ratio is larger than 2 but with a reduction of 4.
- Minimum number of cross girders to be connected to longitudinal girders is at least five and should be symmetrically spaced.
- The depth of the cross girder can be taken as 0.75 times the longitudinal girders depth of the longitudinal girders.
- This method is renowned because of its computational ease.

Whenever LL are placed close to the kerb ares shown in Fig. 3.

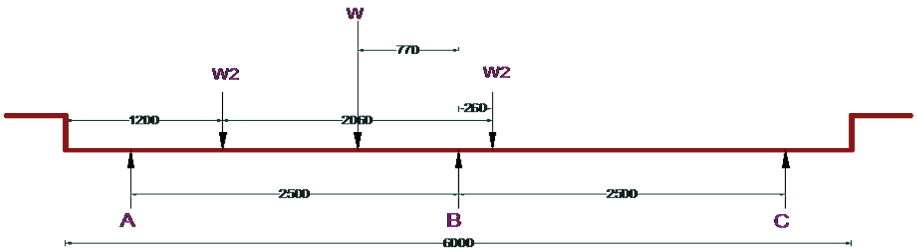

Fig. 3: Transverse deposition of IRC class 70R wheeled vehicle

The CG of LL is eccentrically with the CG of longitudinal girder system. Because of this eccentricity, there will be either increase or decrease in the loads of the girders. It can be estimated using Courbon's theory by a reaction factor given by equation (1),

$$R_x = \frac{\Sigma W}{n}\left[1 + \left(\frac{\Sigma I}{\Sigma d_x^2} . I\right) d_x . e\right] \quad (1)$$

where, R_x = Reaction factor for the girder under consideration

I = Moment of inertia of each longitudinal girder

d_x = Distance of the girder under consideration from the central axis of the bridge

W = Total concentrated live load

n = Number of longitudinal girders

e = Eccentricity of live load with respect to the axis of the bridge.

This helps to calculate the bending moments and shear forces on the longitudinal girders for the applied moving load. By adding the bending moments obtained due to the live load and dead load we can obtain the maximum design moments and shear forces are. With the usage of the maximum design moments and shear forces reinforcement design of the longitudinal girders can be obtained. For computing cross girders bending moments and shear forces a fairly accurate method can be used. It is assumed that the cross girders are equally placed between the longitudinal girders. Due to the above assumption the bending moment and shear forces computation becomes easier.

2.2 Finite Element Method

FEM is based on the principles of discretisation and numerical estimate to solve the technical and engineering difficulty facets of life. The FEM is a recognized device as an answer of intricate structural engineering difficulty, as it can solve any type of complex structure and accepts much complexity in obtaining the solution. We are using the help of software called SAP2000 to minimize the complexity.

3. Modeling of T Beam Bridge

A finite element analysis of a single span with variable lengths of 15m, 20 m, 25m long, 8.4m wide [1] as shown in the Fig. 4 was performed to know the live load distribution along the longitudinal girder. The assumption is made that the bridge superstructure includes three uniformly spaced girders integrated with a 220mm thick deck slab and cross girders at equal intervals. The bridge is a concrete bridge with M25 grade concrete and Fe 500 rebars [3] are used for reinforcement. The Bridge properties assigned and the material properties used in the present study are summarized in the Table 1. The finite element program is used to perform the analysis. The purpose of the analysis was to model to know the rigorous distribution of live load among the girders. The parametric study is carried out to study behavior of longitudinal girders due to the gravity and moving loads.

Table 1: List of Parameters used in Bridge

Type of Bridge	T-Beam Deck Slab Bridge
Span (m)	15, 20 and 25
Lane of Bridge	Two lanes
Carriageway width (m)	6
No. of longitudinal girders	3
Thickness of girders (mm)	400
Depth of girders (mm)	1500, 1800, 2000
Spacing of cross girders	2.5 m c/c
Depth of deck slab (mm)	220
Thickness of wearing coat (mm)	80

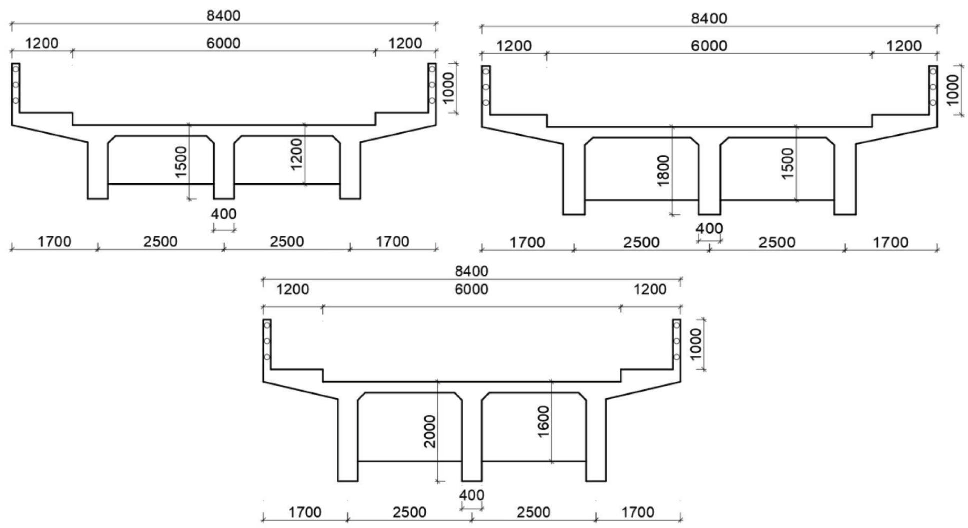

Fig. 4: Variation of dimensions of girder depth in span 15 m, 20 m and 25 m bridges respectively.

4. Results and Discussions

All the analysis has performed using SAP2000 with loads taken from Indian standard codes and particularly Courbon's method was used to come up with class 70R wheeled vehicle loading [2]. Validation was done at the start of every analysis procedure using excel sheets and manual calculations.

Comparison of conventional method and FEM analysis.

4.1 Dead Load Cases

The dead load carried by a girder or member shall consist of the portion of the weight of super-structure which is supported entirely or in part by girder or member including its own weight. In Table 2, values of mending moments due to dead load using different methods are shown. Fig. 5 shows the comparison of dead load bending moments of different span bridges using FEM analysis and manual calculation.

Table 2: Bending moment of dead load cases for span 15m, 20m and 25m respectively.

Span, m	Manual Calculation (kN-m)	FEM Analysis (kN-m)
15	1082.00	1072.03
20	2073.55	2060.35
25	3409.19	3403.51

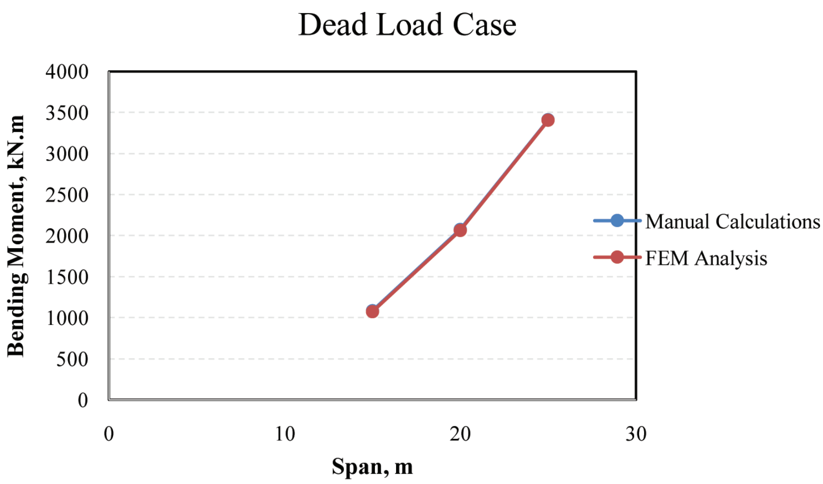

Fig. 5: Bending moment vs Span curve for dead load cases

In this case, the Bending moment for both ways' analysis give much more accuracy (less than 1% variation) for span 15m, 20m and 25m bridges. This results from manual calculations and from FEM analysis shows that the FEM has good precisions. These comparisons verify the reliability of the numerical model in simulating the dead load. The validated numerical models are used to systematically investigate the influences of different factors. Fig. 6 shows the dead load bending moments of different span bridges using FEM analysis.

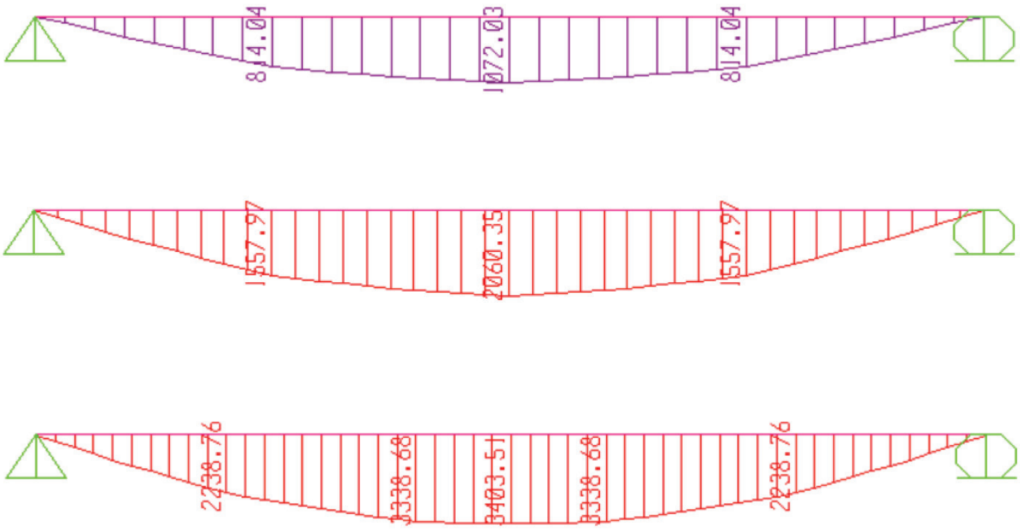

Fig. 6: Bending moment diagram for dead load cases of span 15 m, 20 m and 25 m respectively.

4.2 Live Load Cases

Live loads are induced by the movement of the vehicles over the bridge and they are transitory in nature. These live loads can't compute accurately, and the designer has very little organized over them till the bridge is opened for traffic flow. The standard loadings are of four types namely IRC class AA, IRC class 70R, IRC class A and IRC class B loadings [2]. In this paper only, IRC class 70R wheeled loading is considered as shown in Fig. 7.

IRC 70R Wheeled Live Loadings

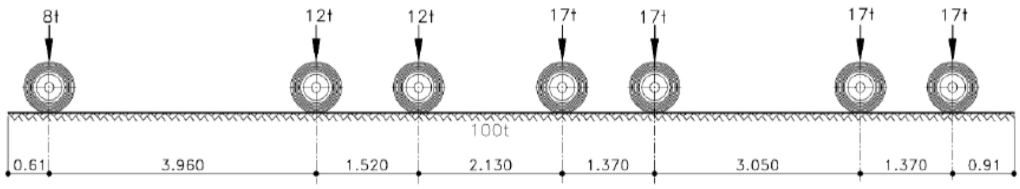

Fig. 7: Live load position as per IRC codes

Live loading should be placed on outer and inner girder as per IRC code. Here, the bending moment calculation has done through conventional method as well as FEM analysis for both inner and outer separately of varying span length. The results coming from both methods are compared below.

i. Outer Girder

Table 3 shows the values of bending moments of live load due to Class 70 R wheeled loadings on outer girder of different spans bridges.

Table 3: Bending moment of live load cases (outer girder) for span 15m, 20m and 25m respectively.

Span, m	Courbon's Method (kN-m)	FEM Analysis (kN-m)
15	1253.88	1169.39
20	1923.42	1854.74
25	2575.24	2424.27

Comparison of live load bending moments using FEM analysis and Courbon's method are shown in Fig. 8.

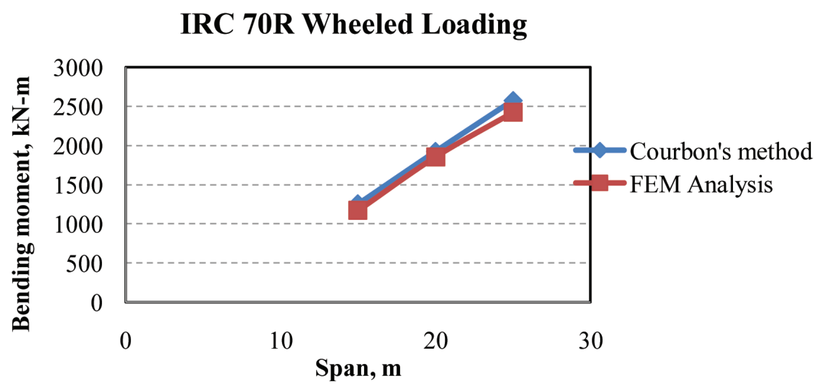

Fig. 8: Bending moment vs span curve for live load case (outer girder)

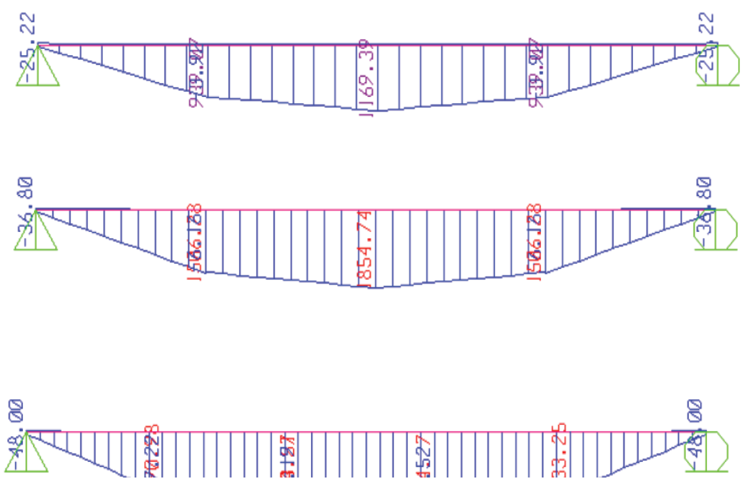

Fig. 9: Bending moment diagram for outer girder of span 15m, 20m and 25m respectively

The bending moment (FEM analysis) has reduced up to 5.4% as compared to courbon's method as shown in Fig. 9.

ii. Inner Girder

Table 4 shows the values of bending moments of live load due to Class 70 R wheeled loadings on inner girder of different spans bridges.

Table 4: Bending moment of live load case (Inner girder) for span 15m, 20m and 25m respectively

Span, m	Courbon's Method (kN-m)	FEM Analysis (kN-m)
15	857.65	820.43
20	1315.61	1308.57
25	1761.45	1751.7

Comparison of live load bending moments using FEM analysis and Courbon's method are shown in Fig. 10.

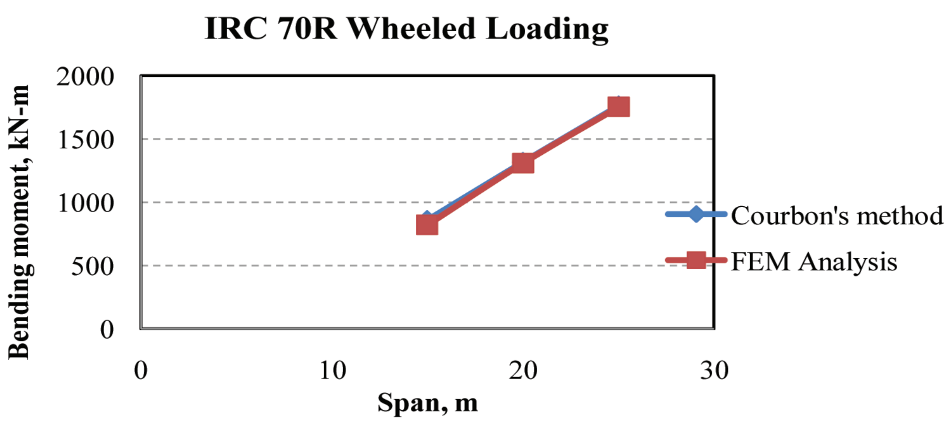

Fig. 10: Bending moment vs span curve for live load case (Inner girder)

Bending moment (FEM analysis) has reduced less than 5% with courbon's method (Fig. 11). That means FEM analysis is assumed to be more ease way for doing analysis from conclusion made from above study. The value of bending moment from FEM analysis is lesser than the bending moment from Courbon's method. This result shows that the Courbon's method is conservative [5].

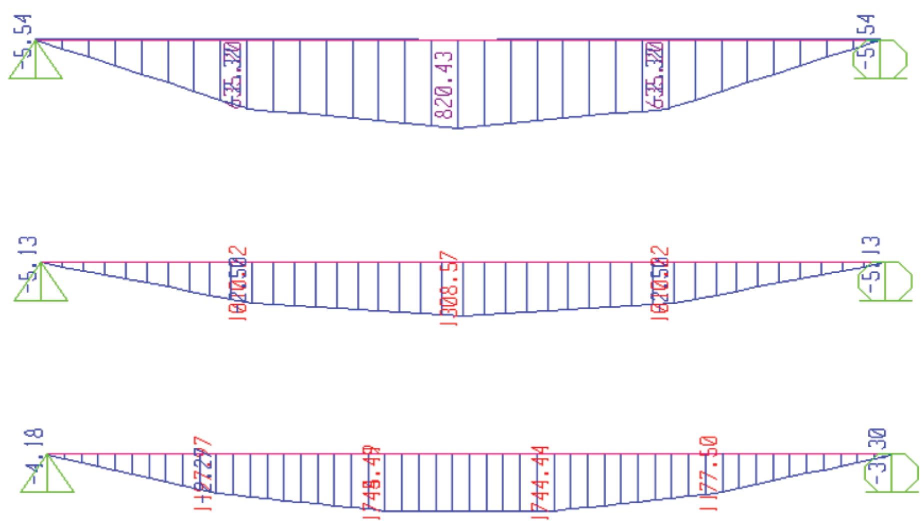

Fig. 11: Bending moment diagram for inner girder of span 15 m, 20 m and 25 m respectively

5. Conclusions

This paper discussed analysis of T Beam Bridge using manual calculation and to verify the results, FEM software as SAP2000 is incorporated. The following conclusions can be made from the present comparative study.

- The Bending moment given by Courbon's method for the longitudinal girders is more when compared with the bending moment obtained by the Finite Element analysis.
- The Values obtained by the SAP 2000 almost matches the results obtained by the Courbon's method when subjected to IRC 70R wheeled vehicle. Using the finite element software (SAP 2000) results are reduced by 5.39% as compared to Courbon's method for bending moment.
- The values obtained by the finite element analysis give more economical structure compared to conventional method.

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