Parametric study of flyover bridge based on Indian Road Congress [IRC]

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ABSTRACT

In Flyover Bridge, T beam deck slab comprises the important type of superstructure. The behavioural aspect of T beam deck slab is quite complicated which makes analysis difficult. Before the availability of computer programs more general methods were used to analyse the bridge decks such as Courbon’s method, Guyonmassonet method, Hendry jaegar method, which were based on unrealistic assumptions and were not suitable for analysing complex bridge under several loading conditions. In this paper the effort is being made to present an analysis based on advance finite element method software and the results are compared with the most general method used for manual analysis that is courbon’s method. This paper aims to provide accuracy and efficiency in the analysis of bridge by analysing T beam deck slab using CSI BRIDGE.

Keywords

courbon’s method, finite element method, IRC loading, CSI BRIDGE, T- beam deck slab

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Introduction

In the modern cities, the constructions of Flyovers are increasing day by day to reduce traffic congestion. Flyover bridges are the structures generally subjected to the moving load. The structural system used in superstructure of bridges is of several types namely T-beam girder, single box girder, double box girder etc. These structural systems as well as their behaviour are quite different from the buildings. This makes the methodologies adopted for the analysis of buildings unacceptable for the bridges. To design the bridge economically it is important that bridge structure should be analysed accurately. Most of the researchers have focused on the traditional methodology for analysis of bridges which includes Courbon’s method and grillage analogy method [1][2][3]. Former is a manual analysis procedure which tends to be uneconomical and time consuming and latter (though programmable) is based on idealized two dimensional model and cannot be used for complex geometry and loading patterns [2]. Today bridges are to be constructed in less time and hence these analysis procedures are not at all suitable. To overcome this issue a three dimensional finite element program (CSI BRIDGE) is used in this study which idealizes the model into three dimensional shell elements and also capable of analysing bridges with complex geometry thereby providing accuracy and economical solutions.

T beam bridges are the most common type of superstructure consists of following component:-

Table I Component of bridge

Components of bridge	
Sub structure	***Super structure***
Abutme	Deck slab
nts Piers	Girders
Wing	Approach
wall	slab
Footing	Bearing
Piles	Parapet

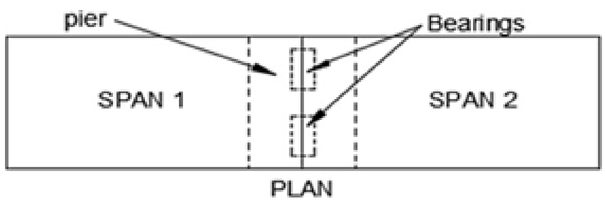
Always the arrangement of bearing rather than other components governs whether the bridge superstructure is continuous or simply supported. Notably the single bearing line indicates continuous bridge deck and in simply supported bridge deck double bearing line is used [4].

1. Single bearing line

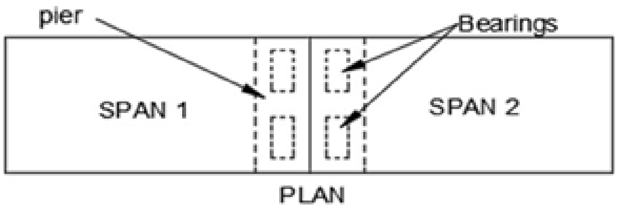
Single bearing line means two spans connected to only one centreline of the bearing. It reacts as a continuous span as shown in figure 1(a).

2. Double bearing line

Double bearing line means two spans connected to two different centreline of the bearing. It reacts as a simply supported span as shown in figure 1(b).



(a) Single bearing line



(b)Double bearing line

Fig. 1. Bearing arrangement. (a) Single bearing line (b) Double bearing line

Loading

For this paper Loading is based on IRC CODE [5]. Many types of load act on a bridge like dead load, live load, impact load etc.[5].

A. Dead load

Dead load is the gravity loading due to the structure. It means self-weight of slab, self-weight of wearing coat, self-weight of girders.

B. Live load

The main loading on highway bridges is due to the vehicles moving on it.

Table II Loading for live load

Categories of live load as per IRC-6		
Loading	***Types of vehicles***	***Load***
IRC class AA	Tracked	700 kN
	Wheeled	400 kN
IRC class 70R	Tracked	700 kN
	Wheeled [up to four wheels]	400 kN
	Wheeled with trains	1000 kN
IRC class A	Wheeled [truck with 2 trailers]	27 to 114 kN
IRC class B	Wheeled with trains	332 kN

C. Impact loading

Another major loading on the bridge super structure is due to the vibrations caused when the vehicles is moving over the bridge. Dynamic action can be included giving an incremented impact allowance as a fraction or percentage of the applied live load [5].

Table III Impact factor for IRC class AA and 70R loading

Impact factor for IRC class AA and 70R loading		
Span	***Vehicle types***	***Impact factor***
<9m	Tracked	25% up to 5m and linearly reducing to 10% for 5 to 9m
	Wheeled	25% up to 9m
>9m	Tracked [R.C.C. bridge]	10% up to 40m
	Wheeled [R.C.C. bridge]	25% up to 12m
	Tracked [steel bridge]	10% for all span
	Wheeled [steel bridge]	25% up to 23m

Table IV Impact factor for IRC class A and class B loading

Impact factor for IRC class A and class B loading	
Bridge type	***Impact factor fraction***
R.C.C	4.5/(6+L)
Steel	9/(13.5+L)
Note :- Here L is length of span in meters	

Methodology

There are many types of method to use analysis of bridge like courbon's method, finite element, grillage method, guyonmassonet method, finite strip method, effective width method etc. In this paper analysis of bridge is performed by courbon's method and finite element method.

A. Courbon's method

In this absence of more accurate analysis courbon's presented a method [6] to analysis the bridge deck. This method gain popularity due to its simplicity and is used extensively for T beam bridge.

Courbon's method states that "the load Ri on any girder i of a bridge consisting of multiple parallel girder is computed assuming a linear variation of deflection in transverse direction" [7]. The deflection will be maximum on the

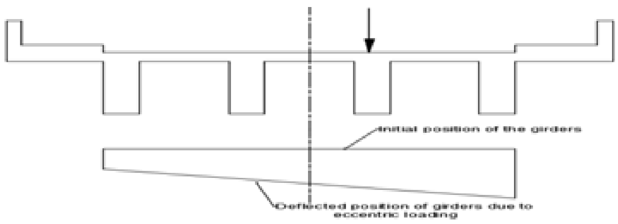


Fig.2. Deflection of girders owing to eccentric load

exterior girder located on the side of eccentric load and minimum on the other exterior girder. To obtain the load Ri

$R_i = [\Sigma W/n]\ [1 + (\Sigma I/\Sigma d\ 2.\ I)\ dx.e]$ (1)

In equation (1) R indicates the reaction factor for the ith girder depending upon eccentricity between C.G of L.L and C.G of girders system. As this method is based on simplified assumption, it has certain limitations, which needs to be satisfied before applying the method [7].

1. The span-width ratio is greater than 2 and less than 4.
2. At least five symmetrical cross girders connecting the longitudinal girders are present.
3. The depth of the cross girders is at least 3/4th of the depth of longitudinal girders.

B. Finite element method

In the last few decades, the development of numerous computational techniques has been evolved to solve the complex engineering problems such as finite difference method, finite volume method and boundary element method [3]. Two methods evolved rapidly for the analysis of bridge namely grillage analogy and finite element method. Former method was based on idealization of the bridge into

equivalent longitudinal and transverse girder and latter divides the bridge deck into small elements.
FEM as first proposed by Ray Clough based on the piecewise approximation of the problem and hence used in many disciplines including Engineering.FEM works by discretizing the domain into elements and gives a piecewise solution at each node. In this paper, three dimensional Finite elements modelling is done with the help of CSI Bridge which is capable to create spline, shell or solid object models
FEM gained more popularity because of the drawbacks in the grillage analogy method as listed below:-
1. It does not consider out of plane bending.
2. Grillage analogy seems to be inaccurate for the bridge decks with large cantilevers due to variations in location of Neutral axis [3].

Analysis Data

A simply supported single span of bridge with 15 spans has been analysed manually with following data and results has been compared with CSI BRIDGE.

Clear width of roadway=7.5m

Span (centre to centre of bearings) =30m Thickness of wearing coat=80mm Concrete mix: M-20 grade
Steel: Fe-415 grade HYSD bars, Loading: IRC class A wheels
Generally for manual analysis deck slab is analysed by pigeaud's curve which are shown below:-

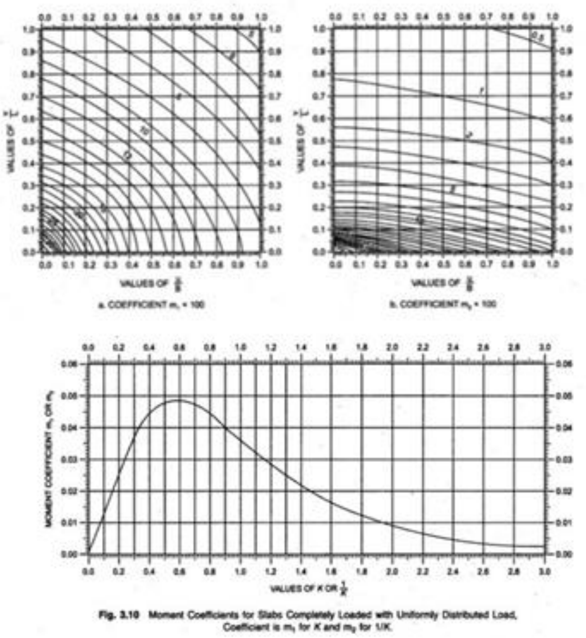


Fig. 3. pigeaud's curve

However pigeaud's curve does not offer any method or equation to analyse the girder hence girder is analysed by courbon's method which ignores torsional rigidity.
Results obtained from manual analysis are listed below:-

Table V Bending moment

Girders	D.L. B.M.	L.L B.M.
Exterior girder	3360.37kN *m	1579.25 kN*m
Interior girder	3360.37kN *m	1110.64 kN*m

Table VI Shear force

Girders	*D.L. S.F.*	*L.L. S.F.*
Exterior girder	438.15 kN	405.76 kN
Interior girder	438.15 kN	322.87 kN

Modelling of T-Beam Deck Slab by Finite Element Analaysis

The purpose of the analysis was to model and to know the rigorous distribution of the live load among the girders. The parametric study is carried out to determine behaviour of the girders due to moving load and gravity load.
Finite element model was prepared in CSI BRIDGE software with following details in below:-

Table VII Properties of T-Beam Bridge

Length of bridge	450 m
Numbers of span	15
Span length	30 m
Width of bridge	8.7 m
Numbers of lane	2
Deck types	T-Deck slab
Slab thickness	0.2 m
Loading	IRC class A
Cross girder	At every 5 m
Longitudinal girder	3 – 2.5 m interval
Grade	M20
Steel	Fe 415

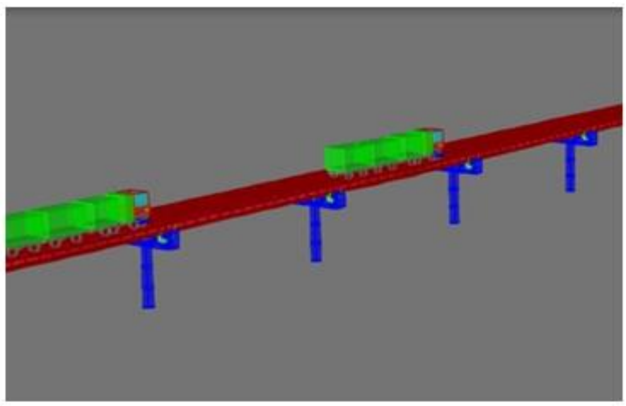


Fig.4. Finite element model of CSI BRIDGE

Result Comparision

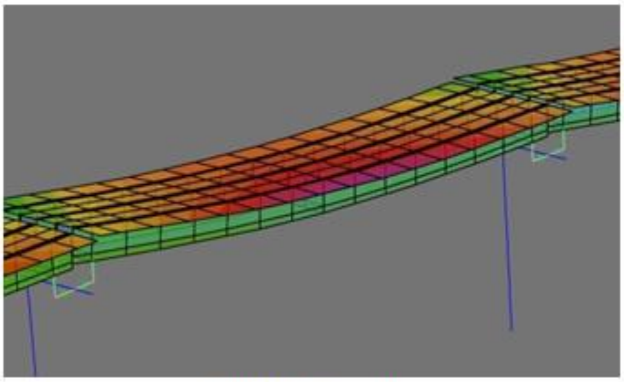
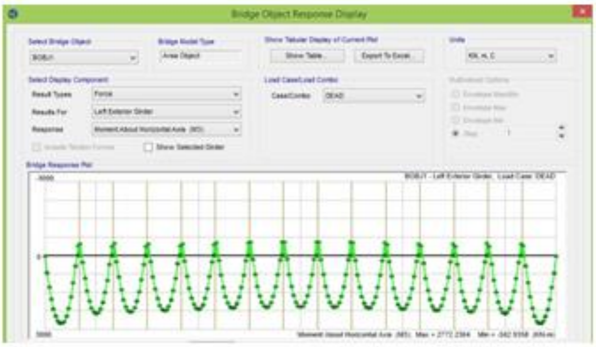
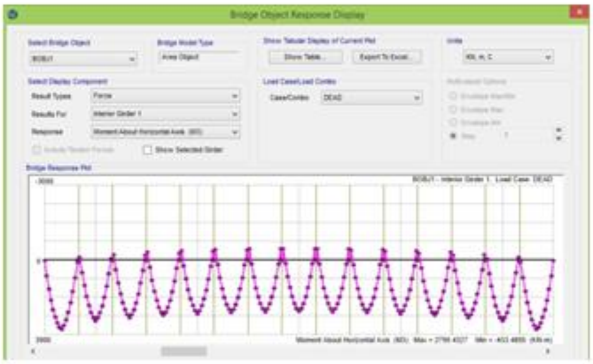


Fig.5. Shell stress diagram

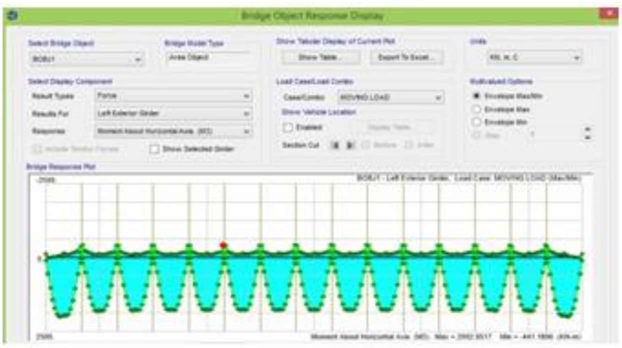


(a) Exterior girder



(b) Interior girder

Fig.6.Dead load moment for girder (a) Exterior girder (b) Interior girder



(a) Exterior girder

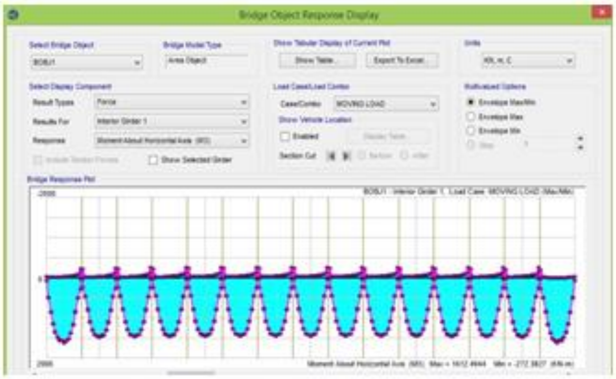
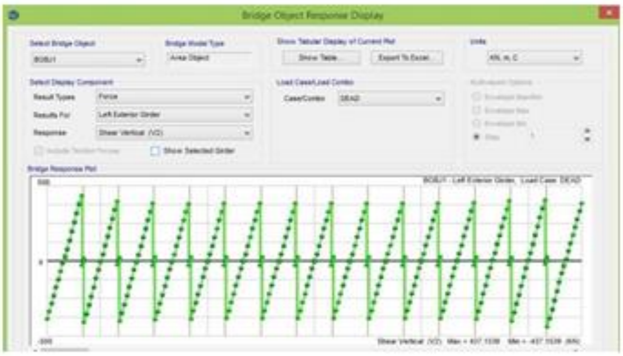
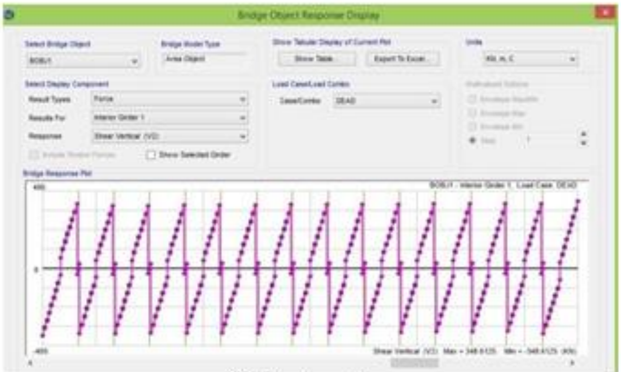


Fig. 7. Live load moment for girder (a) Exterior girder (b) Interior girder

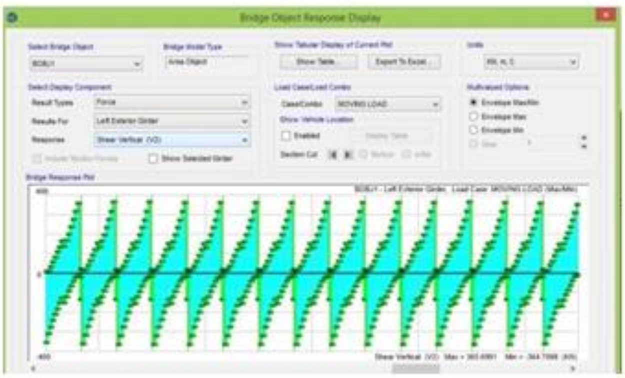


(a) Exterior girder

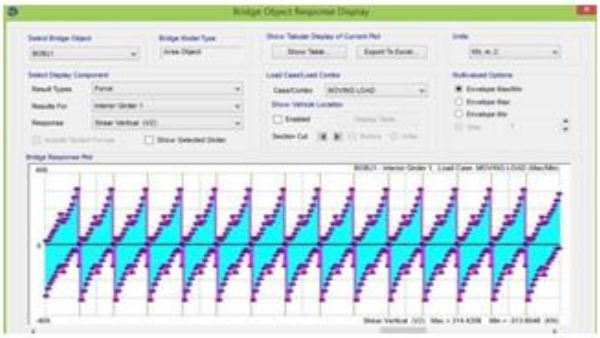


(b) Interior girder

Fig. 8. Dead load shear force for girders (a) Exterior girder (b) Interior girder



(a) Exterior girder



(b) Interior girder

Fig.9. Live load shear force for girders (a) Exterior girder (b) Interior girder

Table VIII Bending movement comparison

(a) Dead load bending moment

B.M	Dead load bending moment	
	Courbon's method [Manually] kN*m	***FEM [Software] kN*m***
exterior girder	3360.37	2772.23
interior girder	3360.37	2790.43

(b) Live load bending moment

B.M	Live load bending moment	
	Courbon's method [Manually] kN*m	***FEM [Software] kN*m***
exterior girder	1579.25	2002.95
interior girder	1110.64	1612.49

Table IX Shear force comparison

(a) Dead load shear force

S.F.	Dead load shear force	
	Courbon's method [Manually] kN	***FEM [Software] kN***
exterior girder	438.15	437.15
interior girder	438.15	348.61

(b) Live load shear force

S.F.	Live load shear force	
	Courbon's method [Manually] kN	***FEM [Software] kN***
exterior girder	405.76	365.87
interior girder	322.87	314.42

Table X Results comparison

(a) D.L + L.L bending moment

B.M	D.L + L.L bending moment	
	Courbon's method [Manually] kN*m	***FEM [Software] kN*m***
exterior girder	4939.62	4775.18
interior girder	4471.01	4402.92
Total	9410.63	9178.10

(b) D.L + L.L shear force

S.F.	D.L + L.L shear force	
	Courbon's method [Manually] kN	***FEM [Software] kN***
exterior girder	843.91	803.02
interior girder	761.02	663.03
Total	1604.93	1466.05

CONCLUSION

In this paper simply supported bridge is analysed and importance conclusions are listed below:-

1. Courbon's method is simple but not suitable for programming and complex geometry.
2. CSI BRIDGE has good correlation with the manual analysis method as the obtained difference in B.M. is 2.47% and S.F. is 8.65% which is acceptable.
3. It is easier to consider geometric and parametric variation in CSI BRIDGE which enables incorporating centrifugal effects in curved bridge.
4. The finite element technique using CSI BRIDGE can be used for more accurate future studies such as response of bridge structure considering vehicle structure interaction.

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