Static and Dynamic Analysis of Tee Beam Bridge Deck

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Abstract— This bridge is a structure providing a passage over an obstacle may be for a road, a railway and pipeline etc., T beam bridges are one of the principle type of cast in place concrete decks. It consists of concrete deck slab monolithically cast over the longitudinal girders. Generally bridge structures are subjected to two types of loads i.e. static and dynamic loads. However in the design of structures they are designed based only upon the static loads. The drawback of neglecting the dynamic loads in design stage will affect the structure particularly during the seismic loading conditions. In this research work the bridge deck is modelled as a simply supported T beam bridge deck spanning in one direction with two lanes of span 20m by using rational methods with IRC loadings. T beam bridge design is analysed using Finite Element Analysis through ANSYS. Finally the serviceability of the bridge responses are obtained.
Key words: Bridge, Tee Beam Bridge Deck

I. INTRODUCTION

Beam bridges are the simplest form of bridges. The bridge is a structure providing passage over an obstacle without closing the way beneath. Tee-beam bridge decks are one of the principal type of cast-n-place concrete decks. This type of bridge decks consists of concrete slab integral with girders i.e. the girders are designed as beams integral with the part of the deck slab, which is cast monolithically with the girders. The beam bridge is by far the most commonly type in the span range of 10 to 25m. Simply supported Tee-beam span of over 30m are rare as the Dead load then becomes too heavy and widely used in both Railways and Roadways. This type of bridges carries the vertical load by flexure.

By using the traditional design method, the calculation of dynamic effects are taken into by increasing the Live load factors. Now a days the software's are very useful to determine the dynamic factors. Day to day development of the culture, the need of the dynamic calculations are also increased. Because, due to large vehicles the bridge experience a various deflections.

The objective of this study is to analyse the static and dynamic behaviour of the Tee-beam bridge deck using IRC live load with the help of influence line diagram.

II. LOADINGS

Generally, in design of bridges the loads are considered as a static and dynamic loads. Normally, all the civil engineering structures are only designed with the assumption of the static load only. But for bridge designing static load design is not enough because the vehicles are fastly moving in the bridges so we need to design with the assumption of Dynamic loads.

A. Static Load

Static load is the combination of Dead load and Live load applied in particular place. This force is often applied to engineering structures that peoples' safety depends on because engineers need to know the maximum force a structure can support before it will collapse. Any force applied steadily without moving an object is considered a static load, and the knowledge of how much loading a structure can handle is useful for setting safety margins for the structure. Limiting the loading to one half of a structure's maximum will give a factor of safety of two. These forces are either not dependent on time.

B. Dynamic Load

Dynamic load is the combination of dead load and live load that are act at a particular place at the small interval of time. They quickly change the magnitude or directions of the loads. Earthquake forces are also considered as the dynamic loads. In bridges, the moving vehicles are the dynamic loads. It is the time-dependent force and they are varies with time to time.

1) Dead Load

In a bridge the own weight of materials such as concrete, the gravity loading due to the structure and other in permanently attached to it. Dead loads are simply calculated by the product of volume and density of the material. In account we are also taking the self-weight of the non-structural parts of the bridge also such as handrails, guard stones, etc., this type of loads are termed as super imposed dead load. This type of load is particularly prone to increase during the bridge lifetime. For this reason, a particularly high load factor is applied to the pavement of road. Bridges are unusual among structures in that a high proportion of the total loading is attributable to dead and superimposed dead load. This is particularly true of long-span bridges.

2) Live load

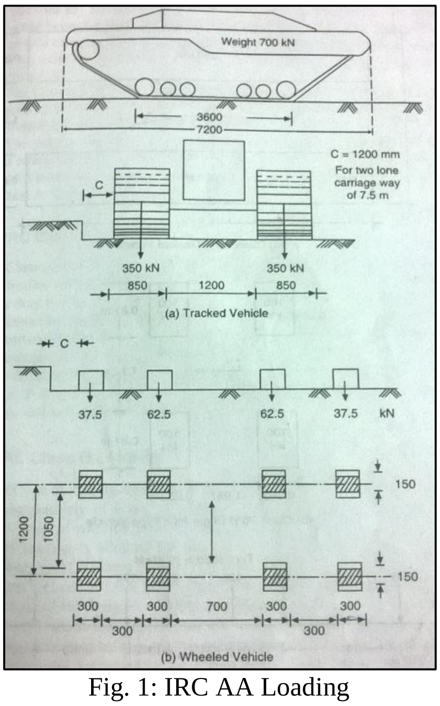

Fig. 1: IRC AA Loading

In India, Road bridge decks have to be designed to withstand the live loads specified by Indian Roads Congress (I.R.C: 6-2000 sec2). The different categories of loadings were first formulated in1958 and they have not changed in the subsequent revisions of 1964, 1966 & 2000.

IRC class AA loading consists of two different types of vehicles are specified under this category grouped as tracked and wheeled vehicles. The IRC class AA tracked vehicle (simulating an army tank) of 700kN and a wheeled vehicle (heavy duty army truck) of 400kN are shown in "Fig.1", All bridges located on National Highways and State Highways are have to be designed for this type of loading.

III. Methodology

The selection of the type of bridge is selected and span of the bridge is done and mainly type of loads acted on the bridge is studied. The bridge is initially theoretically designed by using the Rational methods. The analysis is carried out with the help of IRC loading conditions and ANSYS. The results are finally analysed and compared to produce the better results for Dynamic factors.

IV. Design & Analysis

A. *Rational Method of Analysis of Bridge*

A typical Tee beam deck slab generally comprises the longitudinal girder, continuous deck slab between the Tee beams and cross girders to provide lateral rigidity to the bridge deck. In order to compute the bending moment due to live load in a girder and slab bridge, the distribution of the live loads among the longitudinal girders has to be determined. When there are only two longitudinal girders, the reactions on the longitudinal can be found by assuming the supports of the deck slab as unyielding. With three or more longitudinal girders, the load distribution is estimated using one of the rational methods. Three of these are as below:

– Courbon's method,
– Guyon Massonet method and
– Hendry Jaegar method.

Among the three methods, Courbon's method is the simplest method and it is applicable only when the following conditions are to be satisfied:

– The ratio of span to width of deck is greater than 2 but less than 4.
– The longitudinal girders are interconnected by at least five symmetrically spaced cross girders.
– The cross girder extends to a depth of at least 0.75 times the depth of the longitudinal girders.

These conditions are usually satisfied for majority of modern Tee beam Bridges. In this project also, Courbon's method is used for the design and analysis.

According to Courbon's method, the reaction of the cross beam on any girder of a typical bridge consisting of multiple parallel beams is computed assuming a linear variation of deflection in the transverse direction. The deflection will be maximum on the exterior girder on the eccentric load and minimum on the other exterior girder.

When the live loads are positioned nearer to the kerb the centre of gravity of live load acts eccentrically with the centre of gravity of the girder system. Due to this eccentricity, the loads shared by each girder is increased or decreased depending upon the position of the girders. This is calculated by Courbon's theory by a reaction factor given by,

$$R_x = (\Sigma W/n)\,[1+ (\Sigma W/\Sigma d^2x.\ I)\ dx.\ e]$$

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 and

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

The live load bending moments and shear forces are computed for each of the girders. The maximum design moments and shear forces are obtained by adding the live load and dead load bending moments. The reinforcement in the main longitudinal girders are designed for the maximum moments and shears developed in the girders.

B. *Design*

1) *Design Details*

Clear width of roadway	= 7.5m.
Span (centre to centre of bearings)	= 20m.
Average thickness of wearing coat	= 80mm.
M25 Grade of concrete and Fe415 Steel used.	

Table 1: Design Details

2) *Cross section of Deck*

– Thickness of deck slab = 200mm.
– Wearing coat= 80mm.
– Width of main girders = 300mm.
– Breadth of cross girder = 300mm.
– Depth of main girder = 160cm at the rate of 10cm per meter of span.

Three main girders are provided at 2.5m center.

Kerbs 600mm wide by 300mm deep are provided.

Cross girders are provided at every 4m interval.

The depth of cross girder is taken as equal to the depth of main girder to simplify the computation.

The bridge is analysed as follows: The Bridge is first analysed using I.R.C. specifications. The beam is considered as one dimensional element subject to dead load and live loads.

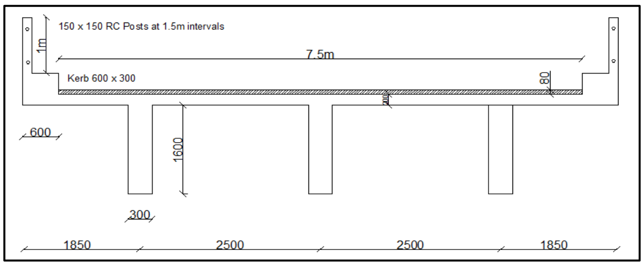

Fig. 2: Cross section of Deck

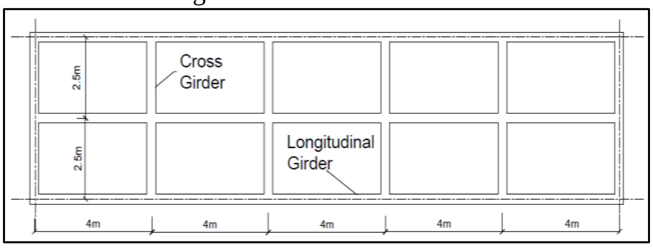

Fig. 3: Plan of Bridge Deck

3) Bending Moment

- Maximum Bending Moment due to Dead Load
- Weight of Deck Slab = 0.200 X 24 = 4.80 kN/m^2
- Weight of Wearing Course = 0.08 X 22 = 1.76 kN/m^2
- Total Weight = 6.56 kN/m^2

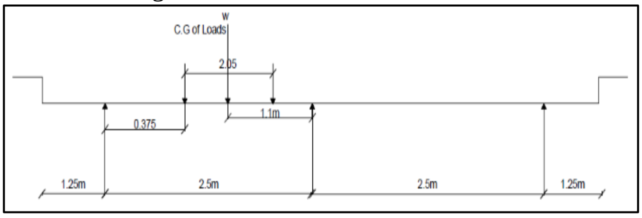

Fig. 4: Transverse position of IRC Class AA Tracked vehicle

Minimum Clearance Distance: 1.2 + 0.85/2 = 1.625m

$e = 1.1m$, P =w/2

$\Sigma x^2 = (2.5)^2 + (0)^2 + (2.5)^2 = 2(2.5)^2 = 12.5m$

For outer girder, x = 2.6m, for inner girder x = 0

Therefore,

$R_A = \Sigma P / [1 + nex/\Sigma x^2]$

$R_A = 4P/3[1 + 3 \times 1.1 \times 2.5/2(2.5)^2]$

$R_A = 0.5536W$ and $R_B = 0.3333W$

a) Dead load from slab for girder

Dead load of deck Slab is calculated as follows weight of

- Parapet Railing = 0.700 kN-m
- Wearing Coat = (0.08 x1.1x22) = 1.936 kN-m
- Deck slab = (0.2x1.1x24) = 5.280 kN-m
- Kerb = (0.5x0.6x1x24) = 7.200 kN-m
- Total = 15.116 kN-m
- Total Dead load of Deck = (2x15.116) + (6.56x5.3) = 65 kN-m

It is assumed that dead load is shared equally by all girders Therefore, DL/girder =21.66KNm

b) Live load BM in girder

- Span of girder = 16m
- Impact factor (For class AA Loads) = 10%
- Live load BM 0.5(4+3.1) = 2485 kN-m

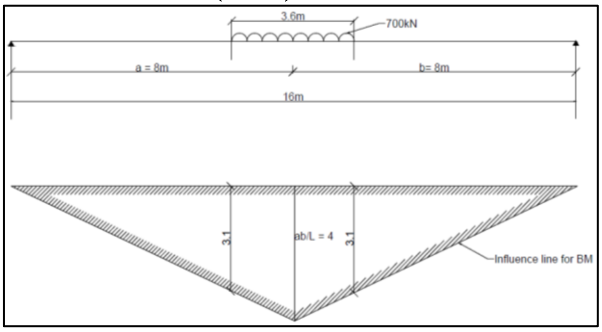

Fig. 5: Influence line for Bending moment in Girder

Bending Moment including Impact and reaction factor for outer girder is = (2485x1.1x0.5536) =1513 kN-m

Bending Moment including Impact and reaction factor for outer girder is = (2485x1.1x0.3333) = 912 kN-m

c) Live load shear

For estimating the maximum Live load shear in the girders, The IRC Class AA Load are placed

Reaction of W_2 on Girder B = 63kN

Reaction of W_2 on Girder A = 287kN

Total load on Girder B = (350+63) = 413kN

Maximum reaction in girder B = (413x14.2)/16 = 366kN

Maximum reaction in girder A = (413x14.2)/16 = 255kN

Maximum live load shears with impact factor in
inner girder= (366x1.1) = 402.6kN
outer girder = (255x1.1) = 280.5kN

d) Dead load BM and SF in main girder.

The depth of the girder is assumed as 1600mm

Depth of rib = 1.4m

Width = 0.3m

Weight of rib/m= (1x0.3x1.4x24) = 10.08kNm

Reaction on Main girder= (10.08x2.5) = 25.2kN

Reaction from deck slab on each girder = 21.66kNm

Total dead load/m on Girder= (21.66+10.08) = 31.74kNm

M_{max}= (31.74X20^2)/8+ (25.2X20)/4+ (25.2X20)/4 = 579kNm

Dead load Shear at Support: (31.74X20)/2+ (25.2) + (25.2/2) = 355kN

e) Design BM and SF are shown in tables

Sl. No	Live load	Dead Load	Total
B.M	1513 kN-m	1579 kN-m	3092 kN-m
S.F	280 kN	355 kN	

Table 2: Results of Bending moment and Shear Force

C. Finite Element Model

The T-Beam bridge deck is modelled using the ProE Software. The dimension of the deck is followed in the design. The structural details of the slab is given and it meshed. The slab consist of 108474 elements and 204702 nodes. Each node having the six degrees of freedom.

The applied loading for the static and dynamic (transient) analysis consists of the IRC Class AA loadings. For static analysis the loadings are applied throughout the structure and for the dynamic analysis loads are applied on the centre of the deck. For dynamic analysis, the loads are varying place to place because its time dependent.

V. Results

A. Static Analysis

"Fig .6 & 7", shows the deflected pattern of the bridge deck in the static loading condition. "Fig .6 & 7", shows the stress and strain deformations. The maximum deformations are occurred in the top middle of the deck. The values obtained are under the serviceability conditions.

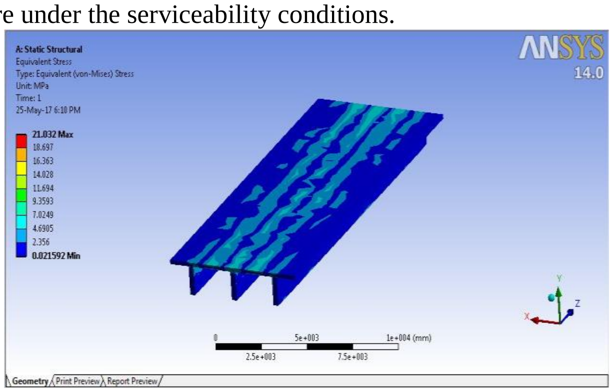

Fig. 6: Isometric shape of the Tee Beam Deck – Stress Deformation (Static)

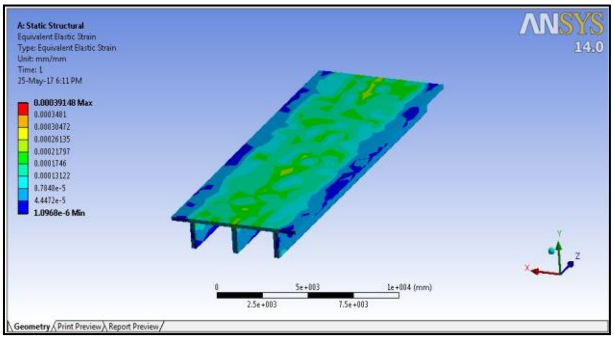

Fig. 7: Isometric shape of the Tee Beam Deck – Strain Displacement (Static)

B. Dynamic Analysis

"Fig .8 & 9", shows the deflected pattern of the bridge deck under the dynamic loading condition. "Fig .8 & 9", shows the stress and strain deformations. The maximum deformations are occurred in the top middle of the deck. In this analysis the loading conditions are movable from one place to another place. And also the dynamic loading conditions the values obtained are comes under the safe and serviceability conditions.

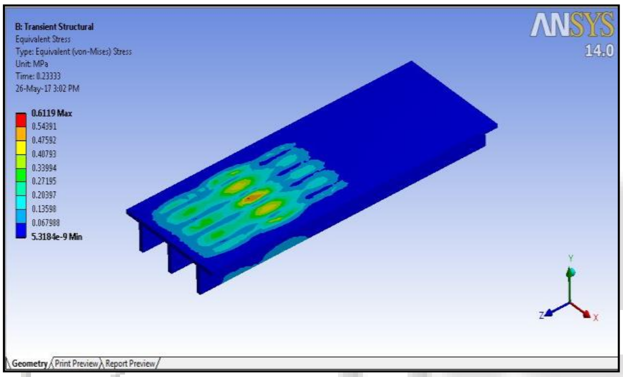

Fig. 8: Isometric shape of the Tee Beam Deck – Stress Displacement (Dynamic)

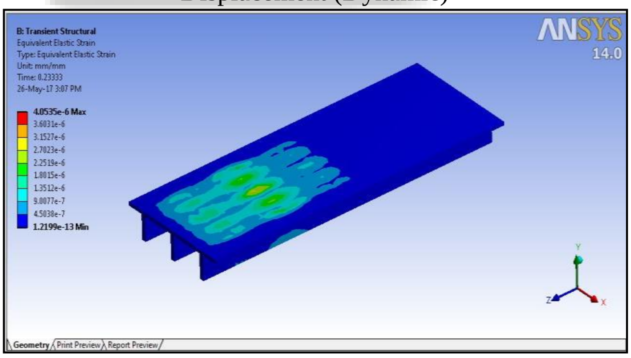

Fig. 9: Isometric shape of the Tee Beam Deck – Strain Displacement (Dynamic)

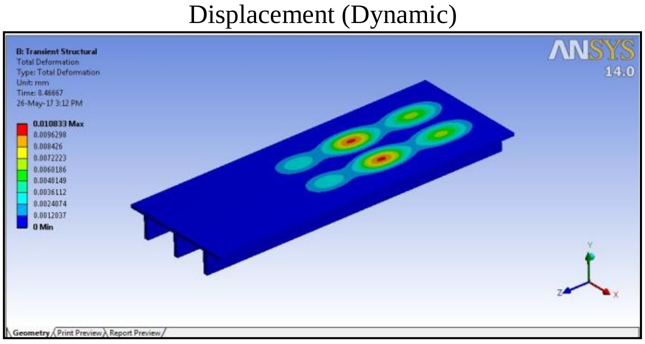

Fig. 10: Isometric shape of the Tee Beam Deck – Total Deformation (Dynamic)

VI. Conclusion

The dynamic response of the bridge deck of 20m span and 7.5m width of the Tee beam bridge for IRC class AA loading is analysed using ANSYS. From the analysis it was found that the model designed in this research work gives positive results and also the results are satisfied with the standard values of IS Codes.

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