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Analysis Of T-Beam Along With Deck Slab By Courbon'S Method

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***Abstract*—** Design of Bridge is most important as it involves major complexity, to analyze the loads and load distribution on the structural elements. Analysis of a simple T-beam bridge was by using IRC loadings using rational method approach and latest software STAAD Pro V8i version. The main aim of this project to analyze the T-beam of the bridge along with deck slab by applying **Courbon's method** and calculation of the value of bending moment, shear force and deflection for 18.72 m span range and compare the manual results with the software STAAD Pro V8i results.

STAAD.Pro is a general purpose structural analysis and design program with applications primarily in the building industry - commercial buildings, bridges and highway structures, industrial structures, chemical plant structures, dams, retaining walls, turbine foundations, culverts and other embedded structures etc. In software deck was analyzed for moments in different directions as plate elements which were quadrilateral in shape and the loading was applied on the plate elements by assigning co-ordinates discussed here.

Key words: T-Beam, IRC Loading, FEM, STAAD Pro 8vi, Courbon's method etc.

Introduction

A bridge is a structure providing passage over an obstacle without closing the way beneath underneath such as a road, valley or body of water etc. A bridge is an important elements in a transportation systems. The various type of bridges is used in all over world. The first reinforced concrete bridge was built by Adair in 1871 of 15 m span bridge across the Waveney at Homersfield, in England. The use of reinforced concrete for road bridges has becomes popular in India. T-beam bridges have been used widely in the span range of 10 m to 25 m. Various components of bridge which are taken into cognizance by designers before execution at site are of paramount importance and are as viz., - Superstructure , Substructure and Foundation which are considered as a composite structure when casted monolithically all together called a bridge.

T-beam bridge :

T beam bridges consist of the main longitudinal girders are designed as T-beam integral with part of the deck slab which is cast monolithically with the girders. The T-beam superstructure consists of the following components:-

I. Deck slab
II. Cantilever portion
III. Longitudinal girder
IV. Cross-beam / Cross girders or diaphragms
V. Wearing course
VI. Footpath, if provided, Kerb and Handrail.

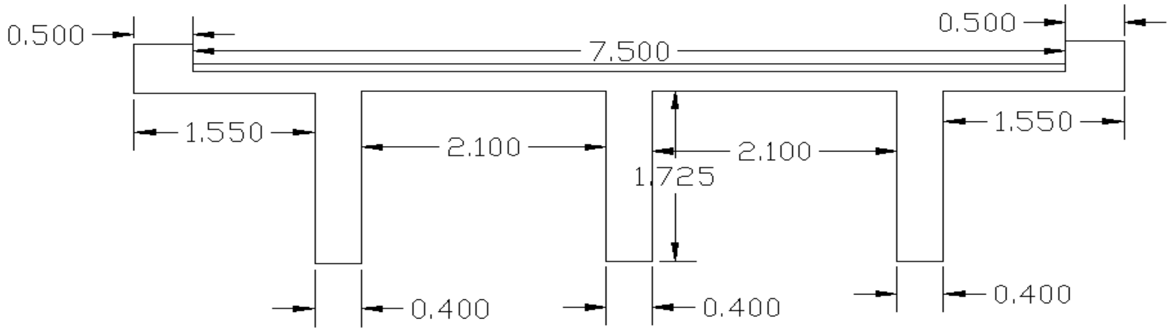

Fig 1 - Cross section of RC T beam bridge (m)

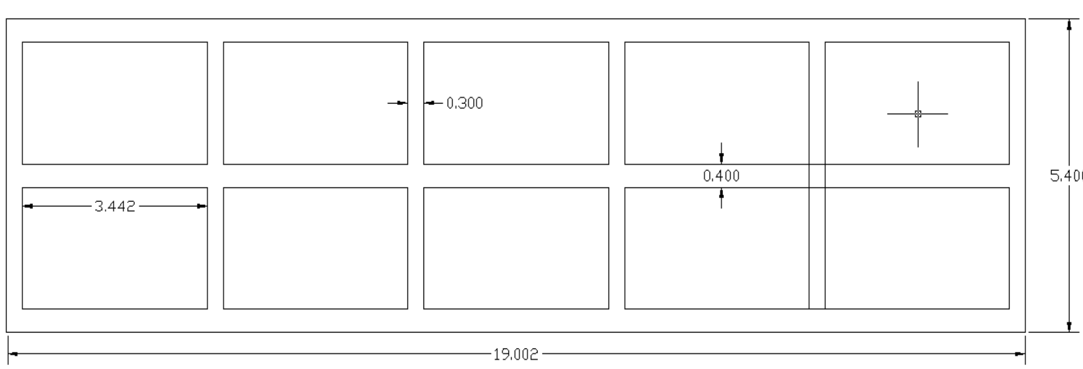

Fig 2 - Plan of RC T beam bridge girders (m)

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Volume 05 Issue 19
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LOADS

While designing the bridge for the road importance of following loads should be considered:-

DEAD LOAD

Structural Dead load: Structural dead loads are loads imposed on a member by its own weight and the weight of other structural elements that it supports including rail, sidewalks, slab and beam.

Superimposed dead loads: In addition to the structure Dead load, members should be designed to support the weight of superimposed dead load including footpath, wearing course, ballast, signs architectural ornamentation, pipes, cables and any other immovable appurtenances installed on the structures.

LIVE LOAD

The application of the normal live load is taken parallel to the supports. The Indian Road Congress (IRC) specified four classes of loads, designated as Class AA, Class 70 R, Class A, and Class B for the design of permanent bridges and all of them are followed in India.

IRC Class AA Loading: This Loading consists of either a tracked vehicle of 700 KN or a wheeled vehicle of 400 KN with dimensions as shown in fig. The tracked vehicle simulates a combat tank used by the army and ground contact length of the track is 3.6 m.

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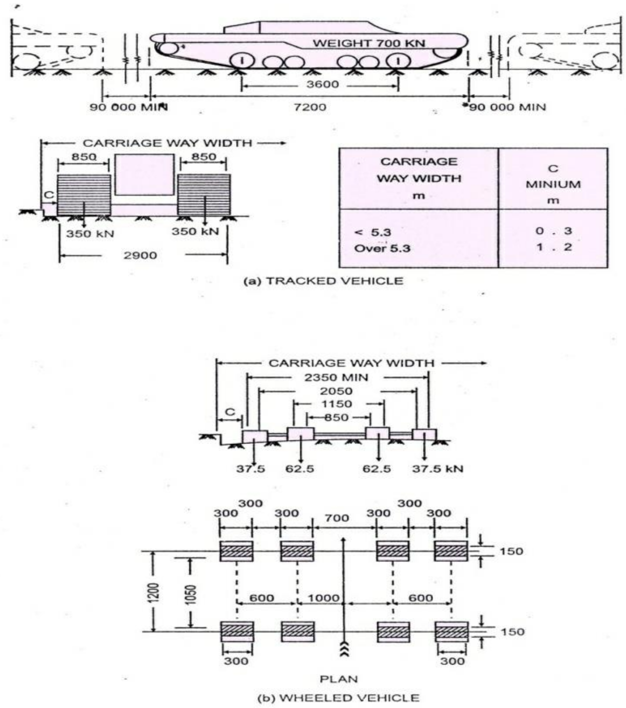

Fig 3 - IRC Class AA Loadings

IRC Class 70R Loading: This loading consists of a tracked vehicle of 700 KN or a wheeled vehicle of total load of 1000 KN. The wheeled vehicle is 15.22 m long and has seven axles with loads totaling to 1000 KN. In recent year, there is an increasing tendency to specify this loading in place of Class AA loading. All dimensions of the Class 70 R loading vehicles are shown in fig.

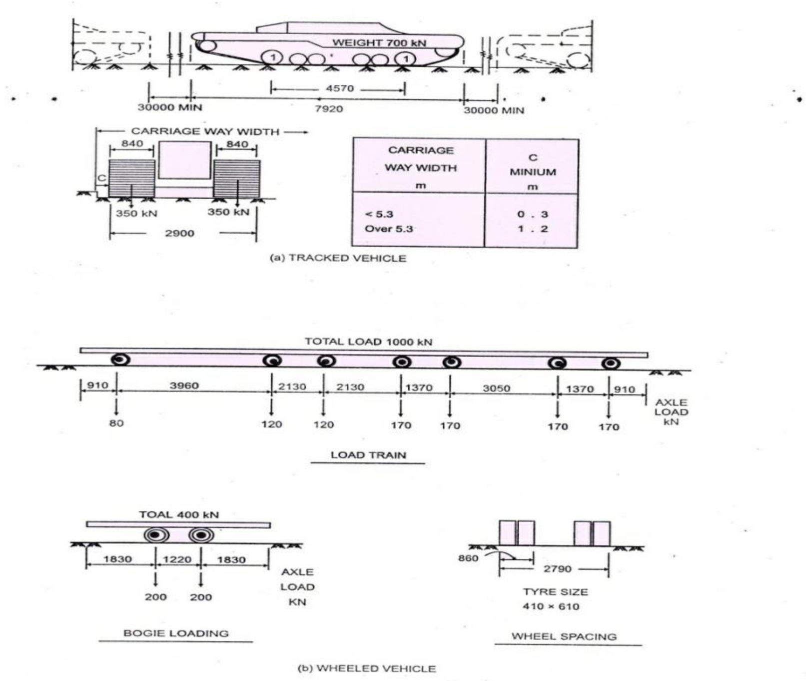

Fig 4 - IRC Class 70R Loading.

IRC Class A Loading: Class A loading is a 554 KN train of wheeled vehicle on eight axles. Class A loading normally adopted on all roads on which permanent bridges and culvert are constructed.

IRC Class B Loading: Class B loading comprises a train wheeled load similar to that of Class A loading but smaller axle loads.

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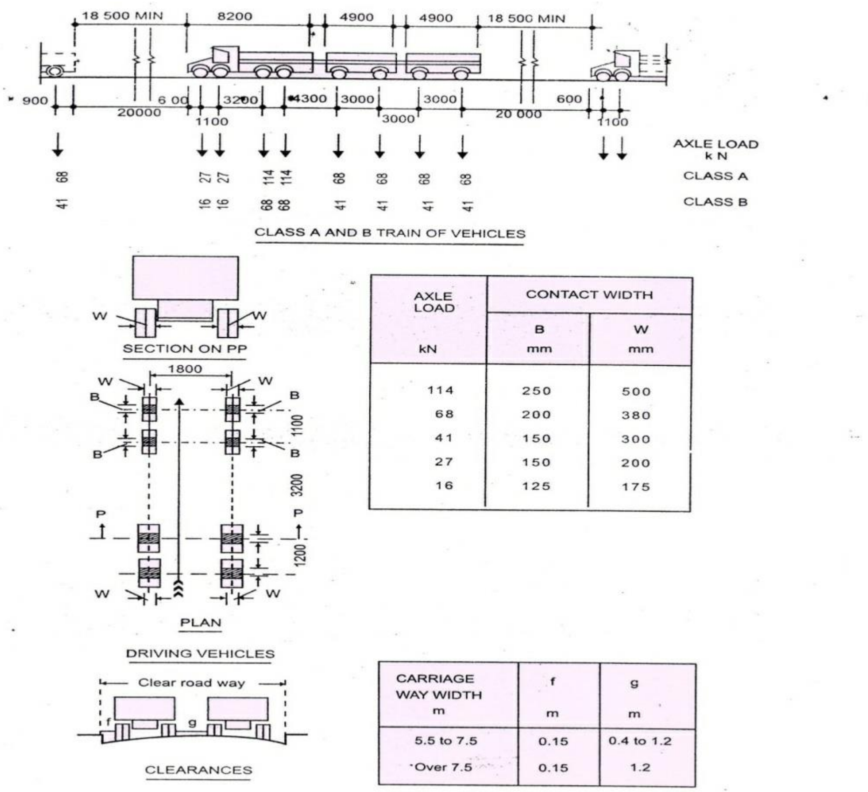

Fig 5 - IRC Class A and B Loadings

FINITE ELEMENT ANALYSIS

Finite elements, referred to as finite elements, connected together at a number of nodes. The finite elements method was first applied to problems of plane stress, using triangular and rectangular element. The method has since been extended and we can now use triangular and rectangular elements in plate bending, tetrahedron and hexahedron in three-dimensional stress analysis, and curved elements in singly or doubly curved shell problems. Thus the finite element method may be seen to be very general in application and it is sometimes the only valid analysis for the technique for solution of complicated structural engineering problems. It most accurately predicted the bridge behavior under the truck axle loading.

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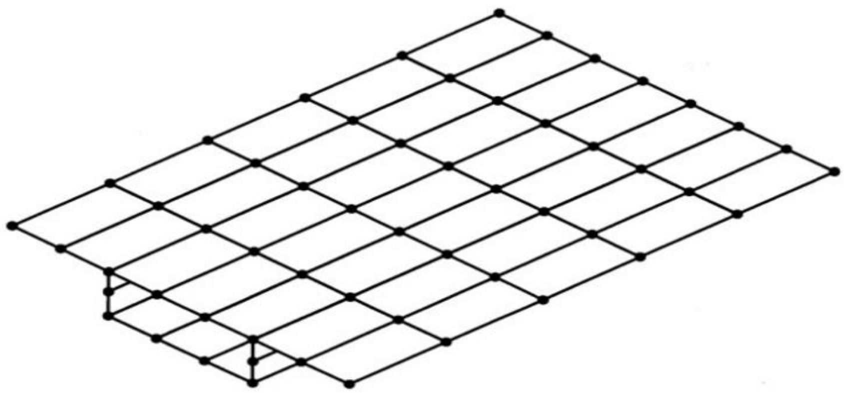

Figure 6 -Three- Dimensional Structures Composed of Finite Plate Elements

Analysis of T beam bridge by Courbon's method:

Courbon's method:

Among these methods, Courbon's method is the simplest and is applicable when the following conditions are satisfied:-

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

Courbon's method is popular due to the simplicity of computations as detailed below:-

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 load 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,

$$R_x = \frac{\sum W}{n}\left[1 + \frac{\sum I \times d_x e}{\sum d_x^2 I}\right]$$

Where,

Rx= Reaction factor for the girder under consideration.
I = Moment of Inertia of each longitudinal girder.
dx= distance of the girder under consideration from the central axis of the bridge.
W = Total concentrated live load.

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n = number of longitudinal girders.
e = Eccentricity of live load with respect to the axis of the bridge.

PROBLEM

Design a RCC T- beam girder bridge to suit the following data,

Clear width of the roadway = 7.5 m
Span (c/c of the bearing) = 18.72 m
Thickness of wearing coat = 75 m
Five Cross beams at 3.742 M interval
Three T-beams at 2.5M intervals
Live load = IRC tracked vehicle Loadings (for state highway)
Concrete mix M30 and Fe 415 grade HYSD bars and Clear cover = 40 mm
Using Courbon method, calculate the design moments and shears main girders and cross girders

Deck Slab

The Slab is supported on four sides by beams
Thickness of Slab, H = 225MM
Thickness of Wearing Coat, D = 75MM
Span in the transverse direction = 2.5M
Effective span in the Transverse direction = 2.5 - 0.4 = 2.1M
Span in the Longitudinal direction = 3.742M
Effective span in the longitudinal direction = 3.742 - 0.3 = 3.442M

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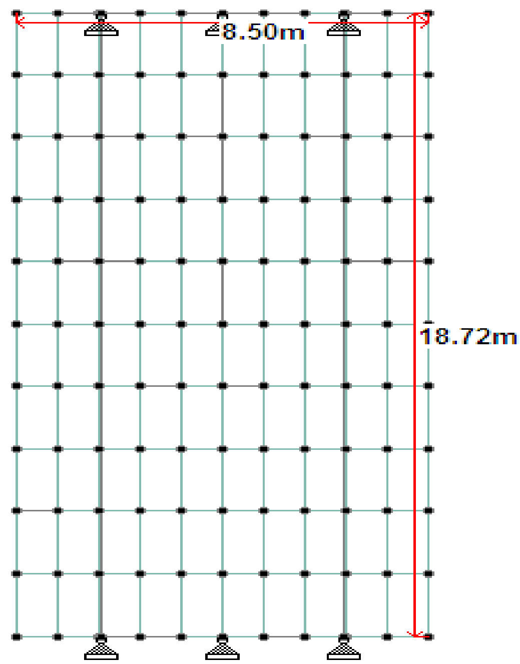
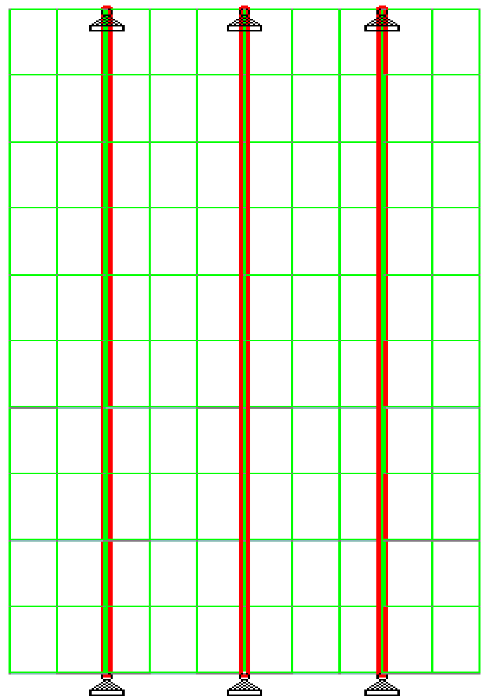


Fig 7 - Plan Of Deck Slab



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p-ISSN: 2348-795X
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August 2018

Fig 8 - Plan Of longitudinal girder of T beam

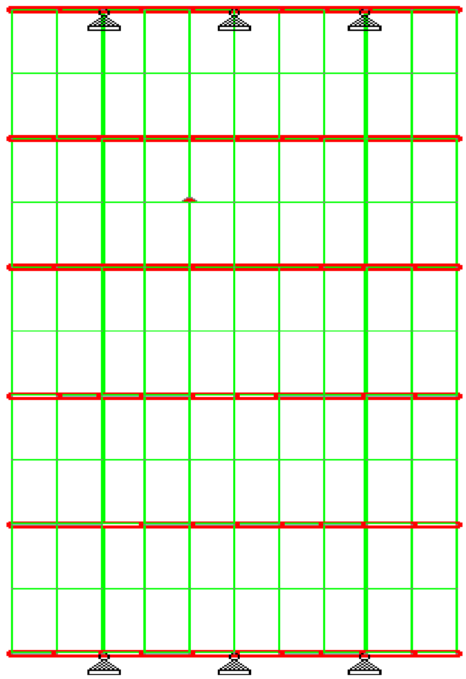

Fig 9 - Plan Of Cross girder of T beam

Comparative analysis of results obtained from manual design- by Working Stress Method verses Finite Element Method- by using Staad Pro (Manual design v/s Staad Pro).

Working stress method:-

Design forces due to dead load on deck slab:

Bending moment along shorter span = 4.45 kN-m

Bending moment along longer span = 2.23 kN-m

Shear force = 7.45 kN

Finite Element Method:-

Design forces due to dead load on deck slab:

Bending moment along shorter span = 4.05 kN-m

Bending moment along longer span = 1.52 kN-m

Working stress method:-

Design forces due to Live load on deck slab due to IRC Class AA Tracked vehicle:

Bending moment along shorter span = 30.30 kN-m

Bending moment along longer span = 14.81 kN-m

Shear force = 47 kN

Shear force = 58.75 kN (due to impact factor)

Finite Element Method:-

Design forces due to Live load on deck slab due to IRC Class AA Tracked vehicle :

Bending moment along shorter span = 24.47 kN-m

Bending moment along longer span = 12.45 kN-m

Design B.M. and S.F. on Longitudinal girder for Class AA Tracked Loadings :-

Working stress method:-

At mid span

Bending moment at outer girder = 1800 kN-m

Bending moment at inner girder = 1083 kN-m

Shear force at outer girder = 173 kN

Shear force at inner girder = 105 kN

Finite Element Method:-

At mid span

Bending moment at outer girder = 1845.92 kN-m

Bending moment at inner girder = 1123.25 kN-m

Shear force at outer girder = 152.17 kN

Shear force at inner girder = 85 KN

Design B.M. and S.F. on Longitudinal girder for Class A Tracked Loadings :-

Working stress method:-

At mid span

Bending moment at outer girder = 1506 kN-m

Bending moment at inner girder = 1023 kN-m

Finite Element Method:-

At mid span

Bending moment at outer girder = 1325 kN-m

Bending moment at inner girder = 1085 kN-m

Shear force at outer girder = kN

Shear force at inner girder = kN

Design of Outer Girder

1. Total Bending Moment at centre of span = $1513(DL) + 1800(LL) = 3313\ KN - M$
2. Total Shear at support = $317.53 + 287 = 605KN$
4. Total Shear at Mid span = $173 + 0 = 173KN$

Design of Outer Girder (By Finite Element Method)

1. Total Bending Moment at centre of span = $555.59(DL) + 1845.92(LL) = 2401.51\ KN - M$

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2. Total Shear at support = $262\ DL + 239\ LL = 501\ KN$

4. Total Shear at Mid span = $152.17 + 0 = 152.17 KN$

Design of Inner Girder

1. Total Bending Moment at centre of span = 1513 + 1083 =2596 kN-m

2. Total shear at support = 620 kN

Design of Inner Girder (BY Finite Element Method)

1. Total Bending Moment at centre of span = 555.59 + 1123.25 = 1678.85 kN-m

2. Total shear at support = 410.35 kN

Design of cross-girder

Total Bending Moment = LL BM +DL BM

$$= 270 + 26.12 = 297\ kN - m$$

Total shear force = LL + DL SF

= 183 + 31 = 214 kN

Design of cross-girder (By Finite Element Method)

Total Bending Moment = LL BM +DL BM

= 260.27 + 25.50 = 285.77 kN-m

Total shear force = LL + DL SF

= 177.03 + 11.24 = 188.27 kN

CONCLUSIONS

The analysis and design of Deck slab and T-Beam of a Bridge has been carried out manually as per IRC guidelines and the following results have been noted.

1. Live Load due to Class AA Wheeled Vehicle produces the severest effect.
2. Shear Force due to Class AA Wheeled Vehicle is very high.
3. Bending Moment in the Inner girder is lesser than the Outer girder hence lesser reinforcement in inner girder when compared to outer girder.
4. The design of the deck slab and T- beam has been manually done keeping in view the above results.

With the advancement and recent development in bridge construction technologies now we have several options to select bridge from different types , different methods of analysis and also which full fills different parameters viz. economy, safety, stability and aesthetic view of sub-structure. Introduction and different types of bridges considered in this review and the selection of different type of bridges in construction technologies in civil engineering. Among all methods, Courbon's method is the simplest and is applicable when the conditions are satisfied

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