A Review Article on Study Analysis of T-Beam Bridges by Finite Element Method and Courbon's Method

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Abstract — *T-beam bridge decks is one of the principal types of cast-in place concrete decks. It consist of a concrete slab integral with girders. A T-beam bridge was analyzed by using I.R.C. loadings as a one dimensional structure and also T-beam bridge is analysed as a three-dimensional structure by using finite element plate for the deck slab and beam elements for the main beam using software .Both models are subjected to I.R.C. Loadings to produce maximum bending moment. We are study from this result the finite element model are lesser than the results obtained from one dimensional analysis by Courbon's Method, that means the results obtained from manual calculations subjected to IRC loadings are conservative.*

Key Words —T-Beam, Finite Element Method, Courbon's Method

1. INTRODUCTION

A T-beam used in construction, is a load-bearing structure of reinforced concrete, wood or metal, with a t-shaped cross section. The flange (Horizontal Section) or compression member of the beam in resisting compressive stresses. The web (vertical section) of the beam below the compression flange serves to resist shear stress and to provide greater separation for the coupled forces of bending

In some respects, the T-beam dates back to the first time a human formed a bridge with a pier and a deck. After all, a T-beam is, in one sense, no more than a pillar with a horizontal bed on top, or, in the case of the inverted T-beam, on the bottom. The upright portion carrying the tension of the beam is termed a web or stem, and the horizontal part that carries the compression is termed a flange. However, the materials used have changed over the years but the basic structure is the same.

2. Lods acting on a Bridge

Various types of loads are considered for design of bridge structures. These loads and their load combinations decides the safety of the bridge construction during its use under all circumstances. Different design loads acting on bridges are explained below.

1. Dead load
2. Live load
3. Impact load
4. Wind load
5. Longitudinal forces
6. Centrifugal forces
7. Buoyancy effect
8. Effect of water current
9. Thermal effects
10. Deformation and horizontal effects
11. Erection stresses
12. Seismic loads

2.1 Dead Load

The dead load is nothing but a self-weight of the bridge elements. The different elements of bridge are deck slab, wearing coat, railings, parapet, stiffeners and other utilities. It is the first design load to be calculated in the design of bridge.

2.2 Live Load

The live load on the bridge, is moving load on the bridge throughout its length. The moving loads are vehicles, Pedestrians etc. but it is difficult to select one vehicle or a group of vehicles to design a safe bridge.

So, IRC recommended some imaginary vehicles as live loads which will give safe results against the any type of vehicle moving on the bridge. The vehicle loadings are categorized in to three types and they are

IRC class AA loading

IRC class A loading

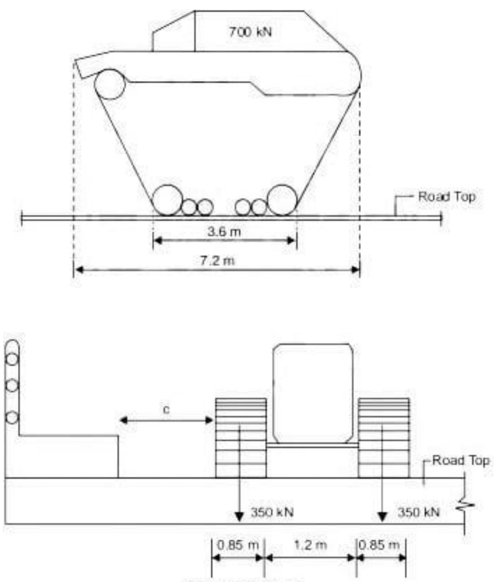
IRC class B loading

IRC Class AA Loading

This type of loading is considered for the design of new bridge especially heavy loading bridges like bridges on highways, in cities, industrial areas etc. In class AA loading generally two types of vehicles considered, and they are

Tracked type

Wheeled type



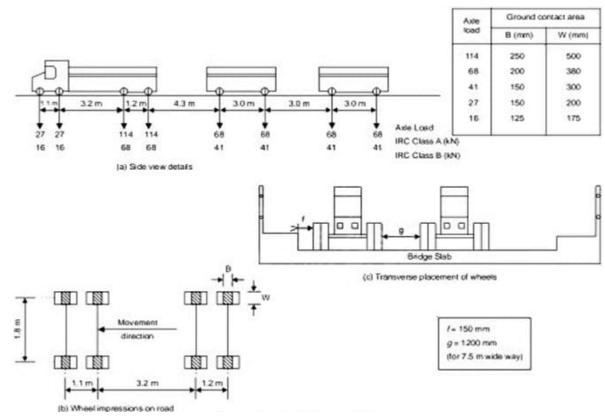
(a) Tracked Vehicle

IRC Class A Loading

This type of loading is used in the design of all permanent bridges. It is considered as standard live load of bridge. When we design a bridge using class AA type loading, then it must be checked for class A loading also.

IRC Class B Loading

This type of loading is used to design temporary bridges like Timber Bridge etc. It is considered as light loading. Both IRC class A and Class B are shown in below figure.



2.3 Impact Loads

The Impact load on bridge is due to sudden loads which are caused when the vehicle is moving on the bridge. When the wheel is in movement, the live load will change periodically from one wheel to another which results the impact load on bridge.

To consider impact loads on bridges, an impact factor is used. Impact factor is a multiplying factor which depends upon many factors such as weight of vehicle, span of bridge, velocity of vehicle etc. The impact factors for different IRC loadings are given below.

For IRC Class AA Loading and 70R Loading

TABLE 1 The impact factors for different IRC loadings

Span	Vehicle type	Vehicle type
Less than 9 meters	Tracked vehicle	25% up to 5m and linearly reducing to 10% from 5 m to 9 m.
	Wheeled vehicle	25% up to 9 m
Greater than 9 meters	Tracked vehicle (RCC bridge)	10% up to 40 m
	Wheeled vehicle (RCC bridge)	25% up to 12m
	Tracked vehicle (steel bridge)	10% for all spans
	Wheeled vehicle (steel bridge)	25% up to 23 m

If the length exceeds in any of the above limits, the impact factor should be considered from the graph given by IRC which is shown below.

For IRC class A and class B loadings

Impact factor If = A/(B+L)

Where L = span in meters

A and B are constant

TABLE 1 Impact factor

Bridge type	A	B
RCC	4.5	6.0
Steel	9.0	13.50

Apart from the super structure impact factor is also considered for substructures

1)For bed blocks, If = 0.5

2)For substructure up to the depth of 3 meters If = 0.5 to 0

3)For substructure greater than 3 m depth If = 0

2.4 Wind Loads

Wind load also an important factor in the bridge design. For short span bridges, wind load can be negligible. But for medium span bridges, wind load should be considered for substructure design. For long span bridges, wind load is considered in the design of super structure.

2.5 Longitudinal Forces

The longitudinal forces are caused by braking or accelerating of vehicle on the bridge. When the vehicle stops suddenly or accelerates suddenly it induces longitudinal forces on the bridge structure especially on the substructure. So, IRC recommends 20% of live load should be considered as longitudinal force on the bridges.

2.6 Centrifugal Forces

If bridge is to be built on horizontal curves, then the movement of vehicle along curves will cause centrifugal force on to the super structure. Hence, in this case design should be done for centrifugal forces also.

Centrifugal force can be calculated by C (kN/m) = (WV2)/(12.7R)

Where

W = live load (kN)

V = Design speed (kmph)

R = Radius of curve (m)

2.7 Buoyancy Effect

Buoyancy effect is considered for substructures of large bridges submerged under deep water bodies. Is the depth of submergence is less it can be negligible.

2.8 Forces by Water Current

When the bridge is to be constructed across a river, some part of the substructure is under submergence of water. The water current induces horizontal forces on submerged portion. The forces caused by water currents are maximum at the top of water level and zero at the bottom water level or at the bed level.

The pressure by water current is P = KW [V2/2g]

Where P = pressure (kN/m2)

K = constant (value depending upon shape of pier)

W = unit weight of water

V = water current velocity (m/s)

G = acceleration due to gravity (m/s2)

2.9 Thermal Stresses

Thermal stresses are caused due to temperature. When the temperature is very high or very low they induce stresses in the bridge elements especially at bearings and deck joints. These stresses are tensile in nature so, concrete cannot withstand against this and cracks are formed.

To resist this, additional steel reinforcement perpendicular to main reinforcement should be provided. Expansion joints are also provided.

2.10 Seismic Loads

When the bridge is to be built in seismic zone or earthquake zone, earthquake loads must be considered. They induce both vertical and horizontal forces during earthquake. The amount of forces exerted is mainly depends on the self-weight of the structure. If weight of structure is more, larger forces will be exerted.

2.11 Deformation and Horizontal Effects

Deformation stresses are occurred due to change is material properties either internally or externally. The change may be creep, shrinkage of concrete etc. similarly horizontal forces will develop due to temperature changes, braking of vehicles, earthquakes etc. Hence, these are also be considered as design loads in bridge design.

2.12 Erection Stresses

Erection stress are induced by the construction equipment during the bridge construction. These can be resisted by providing suitable supports for the members.

3. Analysis of Girders:

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. The longitudinal girders are spaced at interval so 2 to 2.5 m and cross girders are provided at 4 to 5 m Intervals. The distribution of live loads among the longitudinal girders can be estimate by any of the following rational methods.

- Courbon method
- GuyonMassonet method
- Hendry Jaegar method

3.1 Courbon's Theory:

In Courbon's theory, the cross-beams or diaphragms are assumed to be infinitely stiff. Due to the rigidity of the deck, a concentrated load, instead of making the nearby girder or girders deflected, moves down all the girders the relative magnitude of which depends on the location of the concentrated load or group of concentrated loads.

In case of a single concentric load or a group of symmetrical load, the deflection of all the girders becomes equal but when the loads are placed eccentrically with respect to the centre line of the deck, the deflection of all the girders does not remain the same but the outer girder of the loaded side becomes more deflected than the next interior girder and so on but the deflection profile remains in a straight

The behaviour of the deck is similar to a stiff pile-cap and the method of evaluation of load sharing or load distribution over the piles may be utilised in the evaluation of load coming on each girder.

Courbon's method is valid if the following conditions are satisfied:

(i) The longitudinal girders are connected by at least five cross-girders, one at centre, two at ends and two at one-fourth points.

(ii) The depth of the cross girder is at least 0.75 of the depth of the longitudinal girders.

(iii) The span-width ratio is greater than 2 as specified in clause 305.9.1 of IRC: 21-1987. The Author, however, recommends that to get realistic values, the span-width ratio shall be greater than 4 as was shown by the Author in an article published in the Indian Concrete Journal, August, 1965.The use of Courbon's method in finding out the distribution coefficients is illustrated by an example. It may be mentioned here that although the span-width ratio of the deck under consideration is not such as to make the theory valid but just to make, a comparative study of the results by the other method viz. Morice and Little's theory, this is illustrated.

3.2 Finite Element Method

The finite element method is a well known tool for the solution of complicated structural engineering problems, as it is capable of accommodating many complexities in the solution. In this method, the actual continuum is replaced by an equivalent idealized structure composed of discrete elements, referred to as finite elements, connected together at a number of nodes. Thus the finite element method may be seen to be very general in application and it is sometimes the only valid form of analysis for difficult deck problems. The finite element method is a numerical method with powerful technique for solution of complicated structural engineering problems. It is mostly accurately predicted the bridge ehavior under the truck axle loading. The finite element method involves subdividing the actual structure into a suitable number of sub-regions that are called finite elements. These elements can be in the form of line elements, two dimensional elements and three-dimensional elements to represent the structure. The intersection between the elements is called nodal points in one dimensional problem where in two and three-dimensional problems are called nodal lines and nodal planes respectively. At the nodes, degrees of freedom (which are usually in the form of the nodal displacement and or their derivatives, stresses, or combinations of these) are assigned. Models which use displacements are called displacement models and models based on stresses are called force or equilibrium models, while those based on combinations of both displacements and stresses are called mixed models or hybrid models .Displacements are the most commonly used nodal variables, with most general purpose programs limiting their nodal degree of freedom to just displacements. A number of displacement functions such as polynomials and trigonometric series can be assumed, especially polynomials because of the ease and simplification they provide in the finite element formulation. This method needs more time and efforts in modeling than the grillage. The results obtained from the finite element method depend on the mesh size but by using optimization of the mesh the results of this method are considered more accurate than grillage. Fig. 6 below shows the finite element mesh for the deck slab and also for three-dimensional model of bridg

Advantages of Finite element Method

- The finite element method has a number of advantages; they include the ability to Model irregularly shaped bodies and composed of several different materials.
- Handle general load condition and unlimited numbers and kinds of boundary conditions.
- Include dynamic effects.
- Handle nonlinear behaviour existing with large deformation and non- linear materials.

Disadvantages of Finite Element Method

¬ Commercial software packages the required hardware, which have substantial price reduction, still require significant investment

¬ FEM obtains only approximate solutions.

¬ Stress values may vary by 25% from fine mesh analysis to average mesh analysis.

4. LITERATURE REVIEW

R. Shreedhar (2012) The object of the paper the simple span of T-beam bridge was analyzed by use I.R.C. loadings as a one dimensional structure and same analyzed as a three- dimensional structure using finite element plate for the deck slab and beam elements for the main beam using software STAAD ProV8i. Both models are subjected to I.R.C. Loadings to produce maximum bending moment. The results obtained from the finite element model are lesser than the results obtained from one dimensional analysis, that means the results from manual calculations subjected to IRC loadings are conservative.

Soumya S1, (2015) :- In this study Paper we study the design of superstructure of a RC T-beam bridge by using varying spans. The finite element method is a very common technique for the analysis of complicated structure. a simple span T-beam bridge was analyzed by using I.R.C.loadings as a one dimensional structure and same analyzed as a three- dimensional structure using finite element software. Both models are subjected to I.R.C. Loadings to produce maximum bending moment. The results obtained from the finite element model are lesser than the results obtained from Courbon’s method, that means the results obtained are conservative

Praful N K (2015) In this paper we studied that bridge is a structure providing passage for a road, a railway, pedestrians, a canal or a pipeline. . A simple span T-beam bridge was analyzed by using I.R.C. loadings as a one dimensional structure using rational methods and same T-beam bridge is analyzed as a three dimensional structure using finite element plate for the deck slab and beam elements for the main beam using software , three different span of 16m, 20m and 24m was analyzed. Both FEM and 1D models where subjected to I.R.C. Loadings to produce maximum bending moment, Shear force and similarly deflection in structure was analysed. The results obtained from the finite element are lesser than the results obtained from one dimensional analysis, that means the results obtained from manual calculations subjected to IRC loadings are conservative.

S. Basilahamed (2018):- In this paper we study The T beam bridge deck is a structural element composed of deck slab rigidly integrated with main longitudinal girders. In structural analysis, the finite element method is a numerical procedure for modeling of complex geometry and irregular shapes as easier as varieties of finite elements are interconnected at different nodes provides the solution domain of problem. In this study, a simple span T-beam bridge was analyzed using courbon’s method by considering IRC loadings. And the same model is analyzed by finite element method for both deck slab and T beam integral with girders using STAAD V8i SS6 software for four different spans of 25m, 30m, 35m and 40 m. All analysis is carried out with suitable IRC Vehicular Loadings. Both FEM and Courbon’s analysis are subjected to IRC class AA and IRC 70R tracked vehicular loading system in order to obtain maximum bending moment and shear force. From analysis it is observed that the results obtained from courbon's method are greater than the results obtained from finite element analysis, this shows that the rational computations are conservative and staad values impart reasonable design. The value of shear force in rational method is less than that of finite element analysis due to load combinations and maximum SF occurs in IRC class AA Tracked vehicle.

Conculsion

After the review of previous researches, it becomes clear that Bending Moment and Shear force results were analyzed and it was found that the results obtained from the finite element model are lesser than the results obtained from courbon's method, which means that the results obtained from one of the rational method i.e. courbon's method is conservative and from FEM using staad pro provides reasonable design of bridge deck & more economical design method for transverse reinforcement in concrete bridge deck slab is obtained in Finite element Method.

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