Comparative study of T-beam Bridge Longitudinal Girder Design using IRC 112:2011 and IRC 21:2000

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Abstract— T-beam Bridge is composite concrete structure which is composed of slab panel, longitudinal girder and cross girder. Present study is mainly focuses design of longitudinal girder by IRC: 112-2011 and IRC: 21-2000. In India, till now girders are designed and constructed according to Indian road congress guidelines as per IRC: 21-2000 code in which working stress method is used. Recently Indian road congress has introduced another code IRC: 112-2011 for design of prestressed and RCC bridges using limit state method. In regards to this, present study has been performed to know how design of IRC-112 differs from IRC-21 and an attempt is made to study undefined parameters of IRC: 112-2011 such as span to depth (L/d) ratio. Present study is performed on design of longitudinal girder using “working stress method” using IRC: 21-2000 and limit state method using IRC: 112-2011 code specifications. It is observed that L/d ratio of 10 in working stress method and L/d ratio of 14 in limit state method is most preferable. Quantity of materials required in limit state method is compared with quantity of material required in working stress method and it is found that concrete can be saved up to 25 to 30% using limit state method.
Key words: T-Beam; IRC-Codes; Courbon’s Method; Deflection, Crack Width

I. Introduction

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

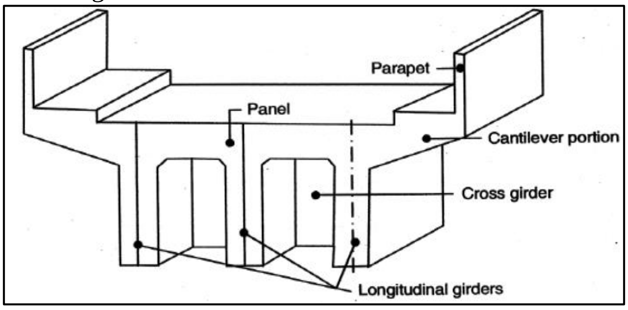


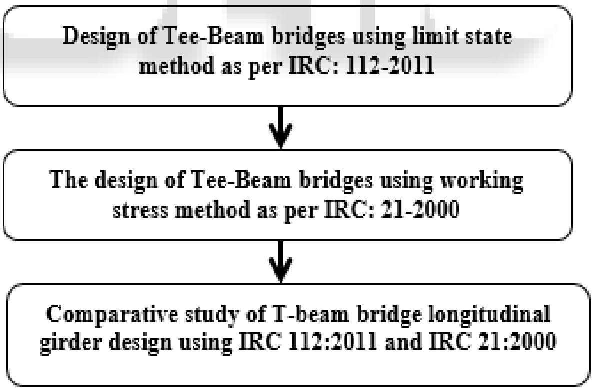
Fig. 1: components of T- beam bridge

A beam and slab bridge or T- beam bridge is constructed when the span is between 10 -25 m. The bridge deck essentially consists of a concrete slab monolithically cast over longitudinal girders so that the T-beam effect prevails. To impart transverse stiffness to the deck, cross girders or diaphragms are provided at regular intervals. The number of longitudinal girders depends on the width of the road. Three girders are normally provided for a two lane road bridge. T-beam bridges are composed of deck slab 20 to 25cm thick and longitudinal girders spaced from 1.9 to 2.5m and cross beams are provided at 3 to 5m interval. A bridge is a structure which is built over an obstacle and hence providing a passage without obstructing the way beneath. The passage may be for a railway, a road, a pipeline or a canal. The physical obstacle can be a road, railway, river, body of water or a valley. The T-beam Bridge is best suited when the span range is between 10 to 25 m. T-beam are so called because the longitudinal girders and deck slabs are cast monolithically to form a T shaped structure. The Superstructure consists of longitudinal girder, cross girder, deck slab, cantilever portion, footpath handrails and wearing coat.

II. Objective of the Study

1) The design of Tee-Beam bridges using limit state method as per IRC: 112-2011.
2) The design of Tee-Beam bridges using working stress method as per IRC: 21-2000
3) Comparative study of T-beam bridge longitudinal girder design using IRC 112:2011 and IRC 21:2000

III. Methodology



A typical tee beam bridge generally comprises the longitudinal girder, continuous deck slab between the tee beams and cross girders to provide lateral rigidity to the bridge deck. It is known that the bridge loads are transmitted from the deck to the superstructure and then to the supporting substructure elements. It is rather difficult to imagine how these loads get transferred. If a vehicle is moving on the top of a particular beam, it is reasonable to say that, this particular beam is resisting the vehicle or truckload. However, this beam is not alone it is connected to adjacent members through the slab and cross girders. This connectivity allows different members to work together in resisting loads. The supporting girders share the live load in varying proportions depending on the flexural stiffness of the deck and the position of the live load on the deck.

The distribution of live load among the longitudinal girders can be estimated by any of the following rational methods.

1) Courbon's method
2) Guyon Massonet method
3) Hendry Jaegar method

A. *Courbon's Method*

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

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

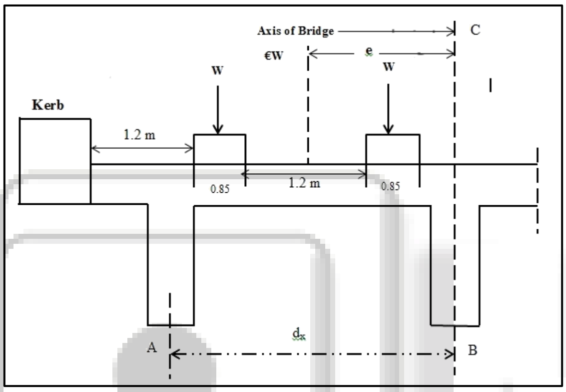


Fig. 2: Position of live loads

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 are increased or decreased depending upon the position of the girders. This is calculated by Courbon's theory by a reaction factor given by

$$R_X = \frac{\sum W}{n}\left[1 + \left(\frac{\sum I}{\sum dx^2 \times I}\right) \times dx \times e\right]$$

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
n = Number of longitudinal girders
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.

IV. Results & Discussions

The longitudinal girder of spans 12m, 14m, 16m 18m and 20m are analysed for various IRC loadings as per IRC 21-2000 for L/d ratio 9, 10 and 11 by working stress method and the same is analysed as per IRC 112-2011 by limit state method for L/d ratio 13, 14 and 15. Volume of concrete per girder is also calculated and presented. Since tracked vehicle is the critical loading in comparison to wheeled and trained is vehicle, it is taken as the critical case for the design.

A. *Working stress method*

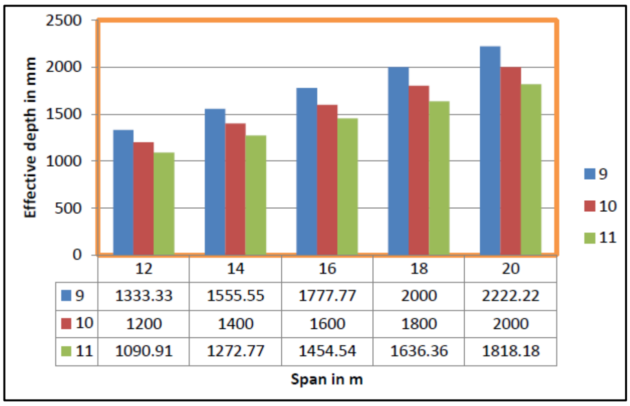


Fig. 3: Assumed effective depth in mm

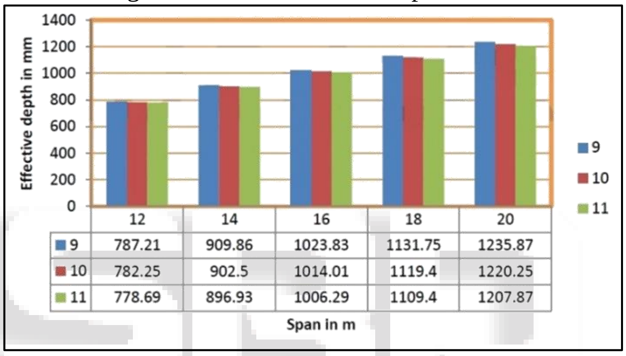


Fig. 4: Required effective depth in mm

Required effective depth is less than the assumed effective depth for all the spans and L/d ratios. Thus an efficient L/d ratio can be concluded from the nominal shear stress criteria.

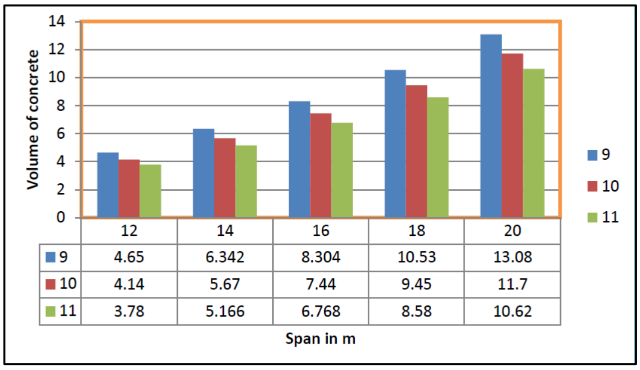


Fig. 5: Volume of concrete in m3

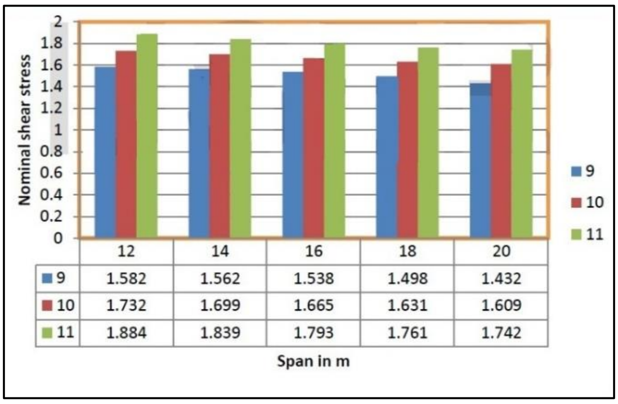


Fig. 6: Nominal shear stress in N/mm2

Permissible shear stress as per IRC-21:2000 for M-25 is 1.75 N/mm2. But for L/d ratio of 11 for spans varying from 12m to 18m, shear stress is more than the permissible value. Thus L/d ratio of 9 and 10 are adoptable. Most preferable L/d ratio is 10 because assumed depth for L/d ratio of 9 is uneconomical in comparison to assumed depth for L/d ratio of 10.

B. Limit state method

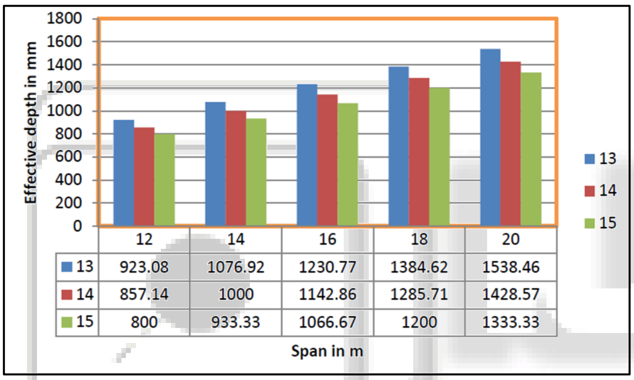


Fig. 7: Assumed effective depth in mm

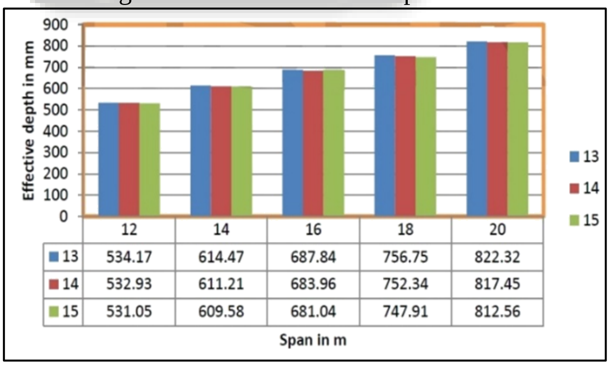


Fig. 8: Required effective depth in mm

Required effective depth is less than the assumed effective depth for all spans and L/d ratios. Most preferable L/d ratio is judged based on the deflection criteria.

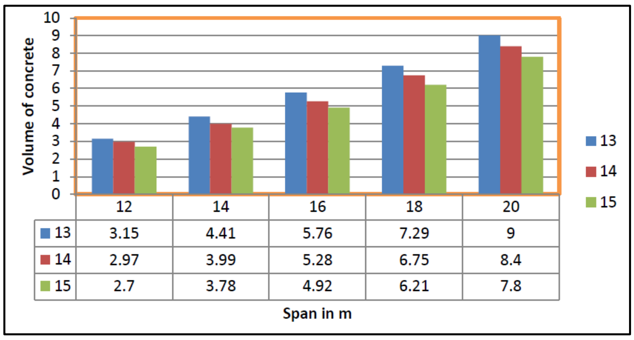


Fig. 9: Volume of concrete in m3

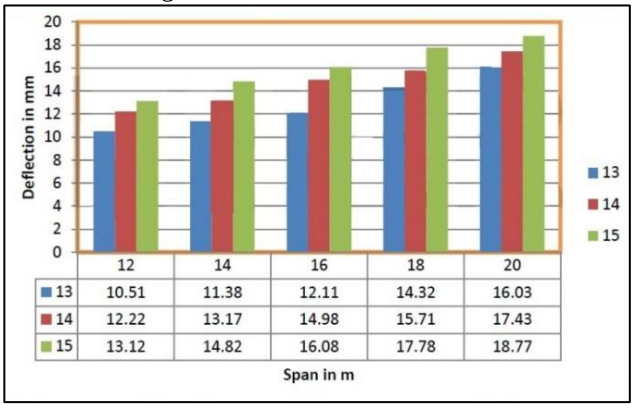


Fig. 10: Deflections in mm

For spans 12m, 14m and 16m for L/d ratio of 15, deflections are more than the permissible value i.e. (span/1000) as per IRC-112:2011. For L/d ratios of 13 and 14, deflection for each span is less than the permissible value. Thus L/d ratio of 13 and 14 are adoptable. Most preferable L/d ratio is 14 because assumed depth for L/d ratio of 13 is uneconomical in comparison to assumed depth for L/d ratio of 14.

V. CONCLUSIONS

1) In case of the design of Tee-Beam bridges using limit state method as per IRC: 112-2011, L/d ratio of 12 to 14 can be adopted. Preferable L/d ratio is 14.
2) In case of the design of Tee-Beam bridges using working stress method as per IRC: 21-2000, L/d ratio of 9 and 10 can be adopted. Most preferable L/d ratio is 10.
3) In case of Tee Beam Bridge using working stress method the nominal shear stress for L/d ratio of 11 is not satisfying for spans 12m to 18m.
4) Deflections are within the limiting value as mentioned in IRC: 112-2011 for L/d ratios of 13 and 14. Whereas for L/d ratio of 15 is not satisfying the deflection criteria.
5) In case of the design of Tee-Beam bridges for L/d ratio of 14, quantity of concrete can be saved up to 25 to 30% using limit state method.

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