IFERP
connecting engineers... developing research

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 2, Issue 3, March 2017

Analysis and Design of R.C.C. T-girder Bridge under IRC Class AA and Class A Loading

[1] Sudarshan Prabhakar Patil, [2] Kameshwar Rao Tallapragada
[1] Ex. P.G. Student, [2] Associate Professor,
Civil Engineering Department,
Shri Ramdeobaba College of Engineering and Management Nagpur-440012, Maharashtra, India

***Abstract:*— Reinforced concrete bridges with different types of deck slab have been widely used for both road and railway bridges. The most common type is the slab deck used for short span bridges. For medium span in the ranges of 12 to 25 m T- Girder and slab deck is widely used. In the case of T Girder and deck slab type, the slab span in two directions since it is cast integrally with main girder and cross girder. The deck slab is generally designed for either by 70 R loading or class AA Tracked wheel loading. IRC recommends bridge designed for class AA loading should also be checked for IRC class A loading. However in conventional analysis many of the important considerations are ignored by the various designers, which proved out to be somewhat unrealistic during the pragmatic conditions. For an assessment of the load carrying capacity of a bridge, one needs to know the maximum bending moment and the shear force included in the beams or girders of the bridge by vehicular loads. These maximum design load effect can be calculated by the conventional method such as Courbon's method. The main objective of study is to analyse super structure for IRC Class AA loading (Tracked vehicle) and IRC Class A loading to compute the values of bending moment, shear force and deflection for span range from 16 to 24 m. The analysis of super structure of different sections and spans is carried out by Courbon's method using MS Excel and by using STAAD.pro software. The bending moment and shear force results obtained by STAAD.pro were less up to 18 m span when compared to results obtained by MS Excel and vice-versa as the span increased. The safe design section is obtained by deflection criteria.**

***Index Terms*:-- Courbon's method, IRC class A loading, IRC class AA loading, T-girder Bridge**

I. INTRODUCTION

The T-beam Bridge is by far the most commonly adopted type in the span range of 12 to 25 m. The structure is so named because the main longitudinal girders are designed as T-beams integral with part of the deck slab, which is cast monolithically with the girders.
T beam bridges are very popular because of their simple geometry, low fabrication cost easy erection or casting and smaller dead loads. Usually I section or T section is used for the beam. But T section is found to be more efficient. T beams are economical where depth of section is a controlling factor from headroom considerations. The T beam bridge superstructure may consist of girders and slab or girders, slab and diaphragms at the supports or girders, slab intermediate cross beams and diaphragms. However, T Beams Bridge with cross beam extending into and cast monolithically with the

Deck slab are found to be more efficient and are recommended for adoption. Simply supported RC T beam is normally adopted for spans up to 25 m. The stem width is about 400 mm to accommodate a large number of reinforcement bars there as well as to take care of large shears occurring there.

A. Positive points

1. Simple geometry.
2. Easy to cast at site.
3. Most widely adopted.
4. Slab acts monolithically with beams.
5. Lesser number of longitudinal than I - girder bridges.
6. Can be usually made with locally available material.

B. Negative points

1. Cross - beam requirement gives less clean appearance.
2. Heavier than I - girder bridges

Figure 1: Cross section of T-beam bridge

II. OBJECTIVE OF STUDY

The main objective of this study is to analyse and design the T- beam section for finding out which T-beam sectional dimension is safe for particular span of the bridge

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 3, March 2017

for both the IRC class AA and IRC class A loading. The T-beam Bridge is analysed for span range 16 to 24m span.

In this study there are three longitudinal beams spacing at 2.5m centre to centre extending up to and cast monolithically with the deck slab. The panels of the floor slab are supported along the four edges by the longitudinal and cross beams. Hence the floor slab is designed as a two way slab. The provision of cross beams stiffens the structure to a considerable extent, resulting in better distribution of concentrated loads among the longitudinal girders. With two way slab and cross beams, the spacing of longitudinal girders can be increased, resulting in less number of girders and reduced cost of formwork.

The analysis and design of T- beam gives less amount of deflection and higher load carrying capacity as the T-beam bridge is analysed for both IRC class AA and class A loading.

III. BRIDGE LOADING AND DESIGN CONSIDERATION

The following is a list of the main forces whose effects should be analyzed to estimate the load-effects (moment's shears, etc.) at all critical sections in the structure. Only then the structure should be design for these load-effects to decide the section size, reinforcements, prestress force, etc., so as to resist these forces at the specified stress levels, and serviceability criteria (crack-widths, deflections, etc.)

1) Dead load of the structure(self weight come in stages)
2) Live load (on roadway)
3) Impact effect (of moving load)

A. Dead Load

Dead load of the structure considered can be accounted at the start of the design or in some cases self-weight may come in stages as is there in the design of prestressed bridge decks. The dead load of the structure depends upon the following factor:

a) Live load
b) Type of design
c) Working stresses employed
d) Length of span
e) Character of details

On the basis of above factor the approximate weight of the structure is roughly estimated using Empirical formulae for R.C.C. Bridge-T-beam bridges. The formula is applicable only for 6-15m span T-beam bridges

Here, W=415+80L

W=total weight in kg/m2, L=clear spam in meters

B. Live load

(a) IRC Class AA loading (Tracked vehicles)

The IRC Class AA loading corresponds to the Class 70 loading and is based on the original classification methods of the Defense Authorities. This loading is to be adopted for design of bridges within certain municipal limits, in certain existing or contemplated industrial area, in other specified areas and along National Highway and State Highways.

This loading consists of tracked vehicle, the loading of which is 70 tonnes loading. Bridges designed for Class AA loading should be checked for class A loading also. As under certain conditions heavier stress may be obtained under class A loading.

i. The nose to tail spacing between two successive vehicles shall not less than 90m.
ii. For multi lane bridges and culvert, one train of class AA tracked or wheeled vehicle whichever creates severer conditions shall be considered for two traffic lane width. No other live load shall be considered on any part of said 2-lane wide carriageway of the bridge when above mentioned train of vehicles is crossing the bridge.

The details of these loading are as shown in Figure 2.

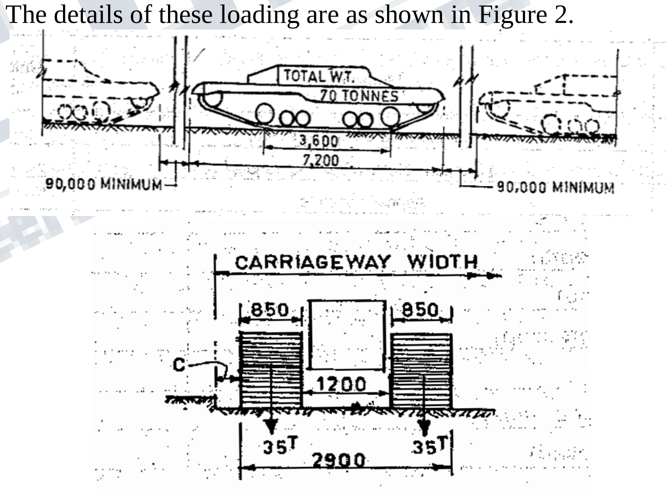

Figure 2: IRC class AA laoding (Tracked Vehicle) details

(b) IRC Class A Loading

The Class A loading was proposed by IRC with the objective of covering the worst combination of axle loads and axle spacing likely to arise from the various types of vehicles that are normally expected to use the road.. The loading consists of a train of wheel loads that is composed of a driving vehicle and two trailers of specified axle spacing's and loads. This loading in bridge designing is generally

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 3, March 2017

adopted on all roads on which permanent bridges and culverts are constructed.

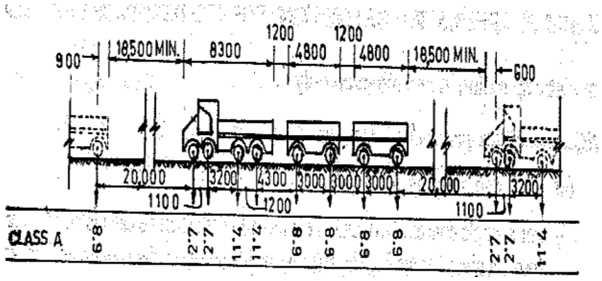

Figure 3: IRC class A laoding details

i. The nose to tail distance between successive trains shall not be less than 18.4m.

ii. No other live load shall cover any part of carriageway when train of vehicle (or trains of vehicle in multi Lane Bridge) is crossing the bridge.

iii. The ground contact area of the wheels shall be as under:

iv. The minimum clearance 'f', between outer edge of wheel and the roadway face of the kerb, and the minimum clearance 'g', between the outer edge of passing or crossing vehicles on multi-lane bridge shall be as given below.

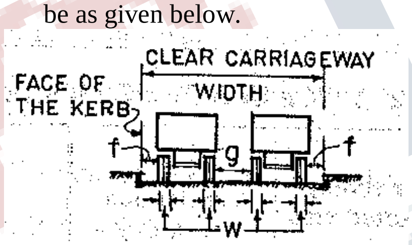

Figure 4: IRC class A laoding distance between kerb and wheel edge

C. Impact effect (of moving load)

A vehicle moving across a bridge at a normal rate of speed produces greater stresses than a vehicle that remains in a static position on the structure. This increment in stress can be called as the stress due to dynamic action of the moving load, which in bridge designing terminology is referred to as impact. Thus it can be said that impact factor is equivalent static effect of loading.

The provision for impact effect in bridge designing is made by an increment of live load by an impact allowance expressed as a fraction or a percentage of the applied live load. This allowance varies for different loadings e.g.:

For Class A loading the value of impact factor is:

- For reinforced concrete bridges, impact factor = 4.5/(6+L)
- For steel bridges, impact factor = 9/(13.5+L)

For Class AA & Class 70R loading the value of impact factor is

1) For span less than 9m:
- For tracked vehicle: 25% for span up to 5m linearly reducing to 10%for span of 9m.
- For wheeled vehicle: 25%

2) For span of 9m or more:
- Reinforced concrete Bridge for tracked vehicle: 10% up to span of 40m.
- Reinforced concrete Bridge for wheeled vehicle: 25% up to span 12m.

It is to be noted that the effect of impact is considered only while designing the superstructure, bearings, abutment or pier caps. For designing the substructure this effect is not considered.

IV. METHODOLOGY

The complete analysis of the T-girder Bridge consist of the analysis of the following components,
(a) Analysis of Deck slab
(b) Analysis of Longitudinal slab

a. Analysis of Deck slab:-

The analysis of deck slab is done by Pigeaud's curves method. Pigeaud's curves are used for computing bending moment in panel freely supported along four edges with restrained corners and carrying symmetrically placed load distributed over some well defined area. Pigeaud's derived these curves for him thin plates, using elastic theory of flexure, and assuming Poisson's ratio of 0.15.

$$V = a + 2h$$
$$U = b + 2h$$

The bending moments in the slab are given by the following expressions:

Short spam B.M

$$M_b = W(m_1 + 0.15m_2)$$

Long spam BM

$$M_l = W(0.15m_1 + m_2)$$

The values of the moment coefficient m_1 and m_2 are given in the pigeaud's curves for various values of spam ratio k = B/L and ratio u/b and v/l figures give the coefficient m_1 and m_2.

b. Analysis of Longitudinal slab

All the components of the bridge are connected to each other monolithically, a point load acting on any one of the longitudinal girders or cross girder is distributed on the other girder due to transverse strength of the deck slab. Thus the design load considered for the loaded beam is less than the actual magnitude of the point load acting on the beam.

When longitudinal girder are connected together by transverse member like deck slab, cross girder, diaphragm, and soffit slab etc., the distribution of the bending moments between longitudinal shall be calculated by Courbon's method.

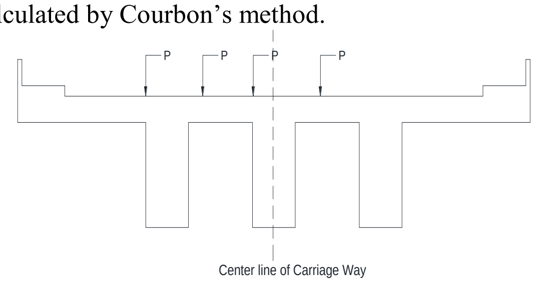

Figure 4: Transverse Position of Load

When the live loads are positioned nearer to the kerb, the C.G. of the loads acts eccentrically with the C.G. of the deck system as shown in figure below thus due to the eccentricity the live load on each girder will vary depending upon the positions of the girder. The reaction factors for the bending moments in such cases can be calculated by Courbon's method.

This method is simply and widely adopted for the analysis of T- Girder Bridge.

The method can only be adopted when the following conditions exist.

- The effective width of the deck slab is less than half the span and the span width ratio is less than 4.
- There are at least five symmetrical cross girder or diaphragms integrated with longitudinal girders.
- The depth of the cross girder or diaphragms is at least 3/4th of the depth of the longitudinal girders.

Distribution of the live loads on the longitudinal girder for the bending moment based on the Courbon's theory when the live loads are eccentrically placed with respect to the C.G. of the girder system, the reaction factor Rx for any girder can be calculated by the equation,

$$R_X = \frac{\sum P}{n}\left\{1 + \frac{\sum I \times e\; x_x}{\sum I \times e \times e}\right\}$$

Where,

Rx = Reaction factor for the girder under consideration

P = total concentrated girder

n = number of inertia of each girder

I = moment of inertia of each girder

e = eccentricity of the live load with respect to the axis of the bridge

x = distance of the girder under consideration from the centre line of Bridge

V. DESIGN EXAMPLE

Effective span(c/c bearing) =16m,18m,20m,22m,and 24m.

Width of road=7.5m

Width of main and cross girder = 400mm.

Kerb=600mm on each side

Footpath=1.5m wide on each side

Thickness of wearing coat=80mm

Depth of deck slab = 200mm (up to 18m),

=230mm (above 18m)

Live load=IRC class AA tracked vehicle and IRC class A

Grade of concrete =M_{25} (Slab), M_{20} (Beam),

F_e415 grade HYSD bars

Above example data considered for analysis and design for T-girder Bridge for span ranges from 16m to 24m and various main girder cross sections. The analysis is done using M. S .Excel manually and STAAD.pro software and design to be checked for deflection criteria.

VI. ANALYSIS AND DESIGN OF RESULTS

TABLE I. Maximum bending moment & shear force using MS Excel (Courbon's method) for IRC class AA loading

SR. NO.	SPAN OF GIRDER (m)	MAX. B.M. (kN-m)	MAX S.F. (kN)	MAIN GIRDER SIZE(B x D)
1	16	2766	705	400×1500
2	18	3112	744	400×1500
3	20	3571	809	400×1600
4	22	4045	876	400×1800
5	24	4536	947	400×2000

TABLE II. Maximum bending moment & shear force using MS Excel (Courbon's method) for IRC class A loading

Sr. No.	Span Of Girder (m)	MAX. B.M. (kN-m)	MAX S.F. (kN)	Main Girder Size (B x D)
1	16	2538	648	400×1500
2	18	2890	689	400×1600
3	20	3459	759	400×1800
4	22	4025	822	400×2000
5	24	4605	889	400×2200

IFERP connecting engineers... developing research

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 2, Issue 3, March 2017

TABLE III. Deflection check for IRC class AA loading

SR. NO.	Span Of Girder (m)	Allowable Deflection (mm)	Max. Deflection (Mm)	Main Girder Size (BXD)	Remark
1	16	42.67	33.14	400×1500	SAFE in design
			28.67	400×1600	SAFE in design
2	18	48.00	41.20	400×1500	SAFE in design
			41.50	400×1600	SAFE in design
3	20	53.33	53.68	400×1500	UNSAFE in design
			51.70	400×1600	SAFE in design
4	22	58.67	63.00	400×1600	UNSAFE in design
			52.37	400×1800	SAFE in design
5	24	64.00	65.29	400×1800	UNSAFE in design
			55.29	400×2000	SAFE in design

TABLE IV. Deflection check for IRC class A loading

SR. NO.	Span Of Girder (m)	Allowable Deflection (Mm)	Max. Deflection (Mm)	Main Girder Size (B X D)	Remark
1	16	42.67	37.49	400×1500	SAFE in design
			37.84	400×1600	SAFE in design
2	18	48.00	55.28	400×1500	UNSAFE in design
			47.82	400×1600	SAFE in design
3	20	53.33	60.60	400×1600	UNSAFE in design
			51.96	400×1800	SAFE in design
4	22	58.67	73.75	400×1800	UNSAFE in design
			58.58	400×2000	SAFE in design
5	24	64.00	78.35	400×2000	UNSAFE in design
			63.94	400×2200	SAFE in design

TABLE V. Comparison of Max. deflection of T-Beam for IRC class AA loading and class A loading

Sr. No.	Span Of Girder (m)	Maximum Deflection (mm)	
		Class AA	Class A
1	16	33.14	37.49
2	18	41.20	47.82
3	20	51.70	51.96
4	22	52.37	58.58
5	24	55.29	63.94

TABLE VI. Comparison of M. S. Excel results & STAAD.pro results IRC class AA loading

Sr. No.	Span Of Girder (m)	M.S.EXCEL RESULT		STAAD RESULT	
		MAX. B.M. (kN-m)	*MAX S.F. (kN))*	*MAX. B.M. (kN-m)*	*MAX S.F. (kN)*
1	16	2766	705	2553	710
2	18	3112	744	3007	743
3	20	3571	809	3637	805
4	22	4045	876	4370	868
5	24	4536	947	5005	906

TABLE VII. Comparison of M. S. Excel results & STAAD.pro results IRC class A loading

Sr. No.	Span Of Girder (m)	M.S.EXCEL RESULT		STAAD RESULT	
		MAX. B.M. (kN-m)	*MAX S.F. (kN))*	*MAX. B.M. (kN-m)*	*MAX S.F. (kN))*
1	16	2538	648	2154	501
2	18	2890	689	2684	551
3	20	3459	759	3400	625
4	22	4025	822	4176	707
5	24	4605	889	5054	873

VII. DISCUSSION

(a) According to bending moment criteria:

The bending moment of T-beam Bridge depends upon the position of vehicle over the span. The length of Class A vehicle is 18.8m and length goes beyond the span length of 18m. So bending moment up to 18m span is less and there after it increases as the whole vehicle occupies entire span length which is shown in Table I, Table II and Table VII.

(b) According to Deflection criteria:

The serviceability criteria i.e. deflection depends upon the span and depth of the section. IRC recommended a particular deflection/span ratio 1/375. The permissible deflection limit varies with the span length. Some of the sections have failed due to over deflection than the permissible deflection limit. The Table III and Table IV shows computed and permissible deflection values of section of members with span length for IRC class AA loading and Class A loading respectively.

(c)According to limitation of section:

For an assumed span length there is limitation of beam section. As the span increases there is section failure as it is not safe under deflection check criteria. Also the width of the web T Girder section is increased from 300 mm to 400 mm to take care of large shear and to accommodate large number of reinforcement bars.

VIII. CONCLUSION

1. Maximum bending moment for both IRC class A loading and IRC class AA cases increases in MS Excel result up to 18 m when compared to STAAD.pro results. Beyond 18 m bending moment values decreases in MS Excel results when compared to STAAD.pro results which is shown in Table VI and Table VII.
2. The maximum deflection values are more for IRC class A loading case when compared to IRC class AA loading case as shown in Table V.
3. The maximum deflection for 20 m span is nearly same for both IRC Class loading cases.
4. There is limitation of T-beam section for particular span length for both IRC loading cases.
5. As per IRC guide lines T-beam section should be safe for both IRC class AA loading and class A loading.

REFERENCE

[1] A.M.David Jawad and A.K.Anis Mohamad-Ali (2010),"Analysis of Dynamic Behavior of T-Beam Bridge Deck Due to Heavy Weight Vehicle", Emirates Journal foe Engineering Research, Vol15, No.2, pp 29-39.

[2] B.C. Punmia, Ashok K Jain, Arun K. Jain, "Reinforced Concrete Structure", volume1 and volume 2, Laxmi Publication Pvt. Ltd.

[3] IRC: 6-2000, "Standard Specification and Code of Practice for Bridges section: II, Loads and Stresses", Indian Road Congress New Delhi, pp10-14, and pp22-24.

[4] IRC: 21-2000, "Standard Specification and Code of Practice for Bridges", section: III, Indian Road Congress New Delhi, pp20-21, pp35-38, and pp52-55.

[5] IS 456:2000, "Indian Standard Plain and Reinforced Concrete Code of Practice (Fourth Revision)", BIS, New Delhi, pp37-38, pp75-76, and pp88.

[6] K.I.Gajjar and N.K.Arora (October 2011), "An Analytical Aid for Analysis of Two Lane Bridge", International Journal of Earth Sciences and Engineering, Vol.4, No.6, pp 741-743.

[7] N.Krishna Raju, "Deign of Bridges", Fourth Edition, Oxford and IBSH publishing company.

[8] R.Shreedhar, Spurti Mamadapur (2012), "Analysis of T-Beam Bridge Using Finite Element Method", International Journal of Engineering and Innovative Technology (IJEIT), Vol.2, No. 3.

[9] Sushil kumar, "Treasure of RCC Design", Rajsons Publication Pvt. Ltd.