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Finite Element Analysis of slabs, cross girders and main girders in RC T-Beam Deck Slab Bridge

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Abstract - *Tee beam deck slab bridges are the principal type among the cast-place concrete bridges, and consists of main girders, cross girders which imparts lateral rigidity to the deck slab and deck slab which runs between T-beams continuously. There are many methods have been used for the analysis of Tee beam bridge, they are classical methods such as Courbon's method, Guyon-Massonet method, Hendry-Jaegar method for girder and pigeauds coefficient method for deck slab and Finite element method is a general method of structural analysis is approximated by the analysis of an assemblage of finite elements which are interconnected at a finite number of nodal points and represent the solution domain of the problem. The live load bending moment in a girder can be calculated by knowing the live load distribution among them. In this study the analysis of a single span two lane T-beam bridge is carried out by varying the span of 8m, 28m for analysis of girders and size of slab 3x2, 3.5x2.5, 4x3, 4.5x3.5, 5x4m by varying the spans of the bridges, deck slab depth as 200,225,250,275,300mm using software SAP 2000. In order to obtain maximum bending moment shear force and deflection, the bridge models are subjected to the IRC class AA Tracked, IRC class 70R and IRC class A loading system. The cross girders and deck slab of varying depth for different live loadings also presented in the study. It can be observed that with the increase in the span shear force, bending moment and deflection in the girder increases and also the models subjected to the IRC Class AA Tracked vehicle gives higher values of shear force, bending moment and deflection in comparison to those subjected to the IRC Class 70 R and IRC class A loadings.*

Key Words: T-Beam, Finite Element Method, IRC Loadings, courbon's method.

I. INTRODUCTION

T-beam, used in construction, is a load bearing structure of reinforced concrete, wood, or metal, 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.

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 4 to 5m interval.

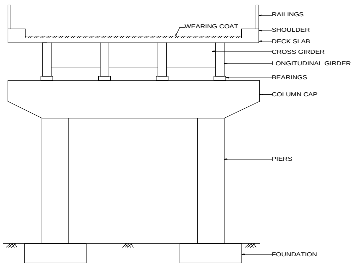


Fig 1: Components of T-Beam Bridge

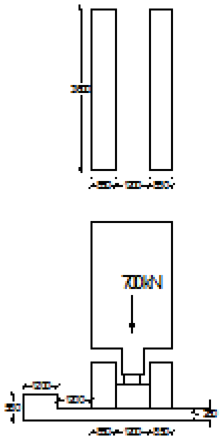
II. BRIDGE LOADING

A. Dead and Superimposed Dead Load

For general and building structures, dead or permanent loading is the gravity loading due to the structure and other items permanently attached to it. Superimposed dead load is the gravity load of non-structural parts of the bridge. Such items are long term but might be changed during the lifetime of the structure. An example of superimposed dead load is the weight of the parapet.

B. Live loads

Live Load (IRC Class AA T and IRC 70R T): The main live load on Highway Bridge is of the vehicles moving on it. Indian Roads Congress(IRC) recommends different types of standard hypothetical vehicular loading system in IRC 6:2000,for which a bridge is to be designed. The vehicular live load consists of a set of wheel loads which are distributed over small areas of contacts of wheels and form patch loads and treated as concentrated loads acting at centers of contact areas . In order to obtain the maximum response resultants for the design, different positions of each type of loading system as per IRC 6:2000 is tried on the bridge deck. IRC Class AA Tracked and IRC 70 R Tracked loadings systems (in mm) which are considered in this study are shown in figure 2 and 3.



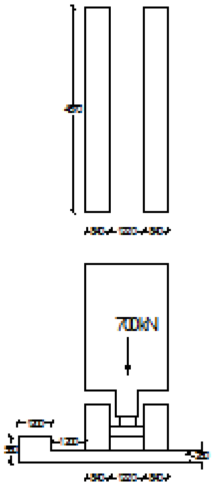


Fig -2: IRC Class AA T Vehicle **Fig -3**: IRC Class 70 R T Vehicle

III. METHODOLOGY

Bridge Data: In this study ,the varying span of two lane Tee beam deck slab bridge subjected to the IRC Class AA Tracked and IRC Class 70R Tracked loading having different slab size with different slab depth and 600mmx 300mm width and depth of the kerb is considered.

Method: The analysis of T-beam bridge is performed by using Finite Element Method (SAP 2000 14th version software)

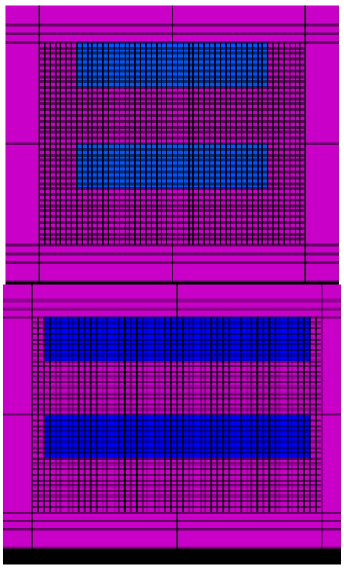


Fig -4: IRC Class AA Loading **Fig -5**: IRC 70R Loading

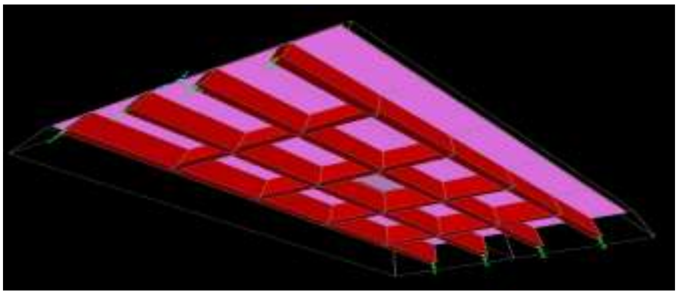
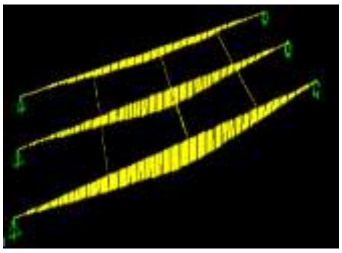


Fig -6: 3D Bridge model



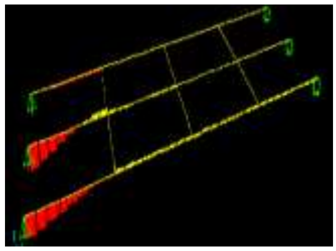
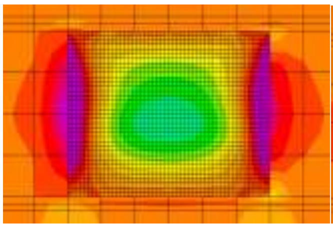


Fig -7: BM in Main girder(AA T) **Fig -8:** SF in Main girder(AA T)



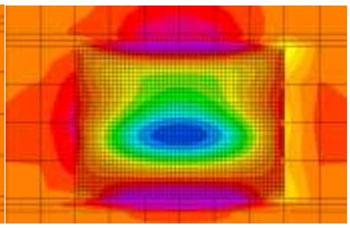
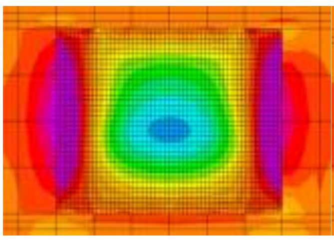


Fig -9: Max BM in X-dir in IRC Class 70R T Loading **Fig -10**: Max BM in Y-dir in IRC Class 70R T Loading



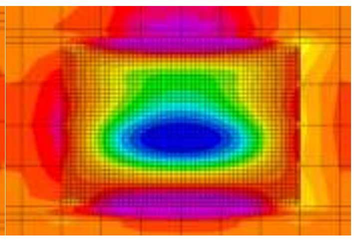


Fig -11: Max BM in X-dir in IRC Class AA T Loading **Fig -12**: Max BM in Y-dir in IRC Class AA T Loading

III. RESULTS AND DISCUSSION

Finite element analysis carried on behavior of T-beam deck slab bridge are presented. The influence different spans, live load and number of girders on flexural behavior of simply supported T-beam deck slab bridges are studied and presented here .also discusses about result of studies carried out on the influence of slenderness of cross girders on the behavior of T-beam deck slab bridge.

The parameters and the cases according to which the analysis of the tee Beam Bridge is performed are shown in the following table

Table -1: List of parameters

Type of analysis	Slab	Girder
Span(m)	15,14,16,13.5,15	16,28
Lane of bridge	Two lane	Two lane
Carriageway width(m)	7.5	7.5
No. of longitudinal girders	3 or 4	3 and 4
Thickness of Slab(mm)	200, 225, 250, 275, 300	200
Thickness of girder(mm)	300	300
Depth of girder(mm)	At the rate of 10cm/per meter span	At the rate of 10cm/per meter span
Thickness of WC(mm)	80	80
IRC Standard Live Load	IRC AA T,IRC 70R T	IRC AA T,IRC 70R T
Size of the slabs (L x B)m Considered are	3x2, 3.5x2.5,4x3, 4.5x3.5,5x4.	4x2.5

Table -2: Variation of Maximum Bending Moment (kN-m) with the span (m) of IRC class AA T Vehicle

Depth of the Slab 250mm	Finite Element Method			
	IRC Class AA T BM			
Size of the Slabs(LxB)m	+VE BM		-VE BM	
	Mxc	Myc	Mxc	Myc
3x2	9.20	16.35	-17.14	-13.96
3.2x2.5	12.20	21.47	-24.00	-22.17
4x3	20.90	26.69	-29.70	-30.32
4.5x3.5	21.73	34.26	-36.00	-40.84
5x4	25.80	36.85	-38.60	-44.11

Table -3: Variation of Maximum Bending Moment (kN-m) with the span (m) IRC class 70R T Vehicle

Depth of the Slab 250mm	Finite Element Method			
	IRC Class 70R T BM			
Size of the Slabs(LxB)m	+VE BM		-VE BM	
	Mxc	Myc	Mxc	Myc
3x2	7.36	13.08	-13.71	-11.16
3.2x2.5	9.76	17.14	-20.06	-18.74
4x3	17.89	22.91	-23.76	-26.04
4.5x3.5	18.77	29.36	-34.03	-34.20
5x4	24.12	34.20	-36.38	-36.06

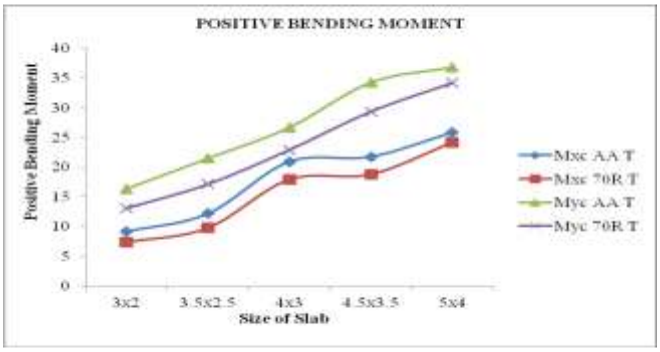


Fig -13: Variation of Maximum Positive Bending Moment (kN-m) in Slab

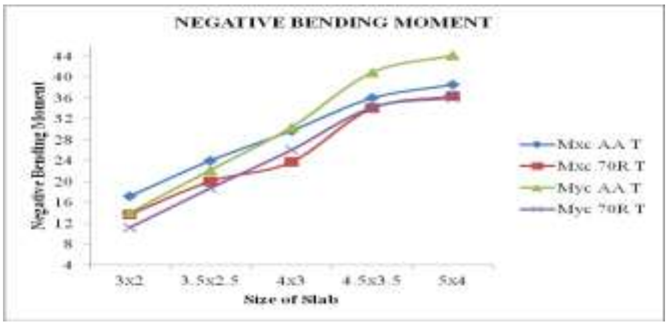


Fig -14: Variation of Maximum Negative Bending Moment (kN-m) in Slab

Table -4: Variation of Maximum Bending Moment (kN-m) in Main girder with the span (m) .

Span	W C	Girder	AA T Total BM		70 R Total BM		A T Total BM	
			3MG	4MG	3MG	4MG	3MG	4MG
16	i	outer	2328	2196	1892	1843	1679	1529
		inner	2012	1838	1986	1744	1444	1310
	ii	outer	2154	2063	1718	1710	1505	1396

		inner	1834	1706	1808	1612	1266	1178
28	i	outer	6979	6545	6109	5885	6077	5610
		inner	6414	5962	6322	5821	5482	5118
	ii	outer	6430	6133	5560	5473	5528	5198
		inner	5866	5550	5774	5409	4934	4706

i=with wearing coat, ii=without wearing coat

Table -5: Variation of Maximum Shear Force (kN) in Main girder with the span (m).

Span	W C	Girder	AA T Total SF		70 R Total SF		A T Total SF	
			3MG	4MG	3MG	4MG	3MG	4MG
16	i	outer	504	456	355	324	347	300
		inner	526	513	457	403	308	297
	ii	outer	462	427	343	295	305	272
		inner	490	482	421	402	272	266
28	i	outer	916	846	747	699	700	623
		inner	937	900	878	929	723	689
	ii	outer	839	791	670	644	623	638
		inner	868	843	807	772	652	632

i=with wearing coat, ii=without wearing coat

Table -6: Variation of Maximum Deflection (mm) in Main girder with the span (m)

Span	Girder	AA T Total Deflection		70 R Total Deflection		A T Total Deflection	
		3MG	4MG	3MG	4MG	3MG	4MG
16	outer	33	31	27	26	25	22
	inner	29	26	29	25	21	19
28	outer	49	46	44	42	44	41
	inner	45	42	45	40	40	37

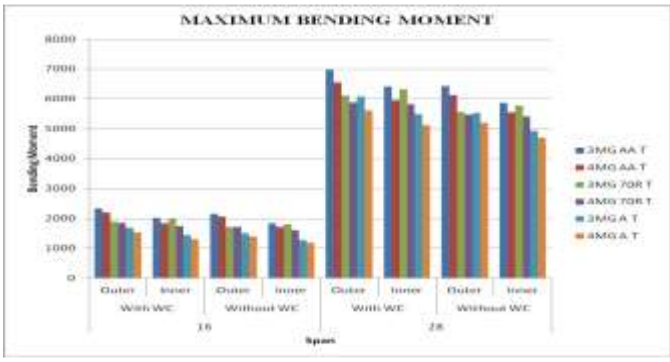


Fig -15: Variation of Maximum Bending Moment (kN-m) in outer and inner girders of Main girder with the span.

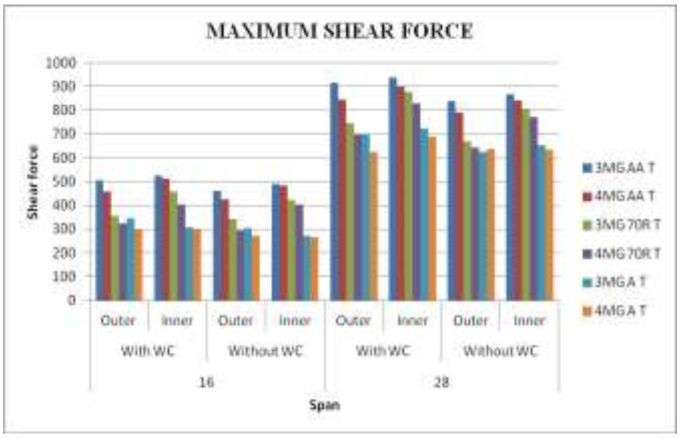


Fig -16: Variation of Maximum Shear Force (kN) in outer and inner girders of Main girder with the span.

OG=outer girder , IG=inner girder

Fig -17: Variation of Maximum Deflection(mm) in outer girder and inner girder of Main girder

Table -7: Variation of Maximum Bending Moment (kN-m) in Cross girder with the span (m) .

Span	W C	AA T Total BM		70 R Total BM		A T Total BM	
		3MG	4MG	3MG	4MG	3MG	4MG
16	i	317	448	356	421	167	334
	ii	300	438	339	411	150	324
28	i	385	502	371	472	172	394
	ii	368	493	354	463	155	385

i=with wearing coat, ii=without wearing coat

Table -8: Variation of Maximum Shear force (kN) in Cross girder with the span (m).

Span	W C	AA T Total BM		70 R Total BM		A T Total BM	
		3MG	4MG	3MG	4MG	3MG	4MG
16	i	169	176	146	152	76	127
	ii	165	170	142	146	72	121
28	i	193	198	167	167	89	149
	ii	189	193	163	163	85	144

i=with wearing coat, ii=without wearing coat

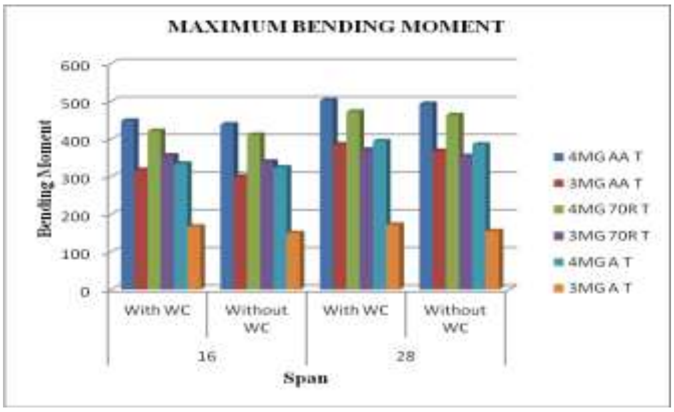


Fig -18: Variation of Maximum Bending Moment (kN-m) in Cross girder with the span.

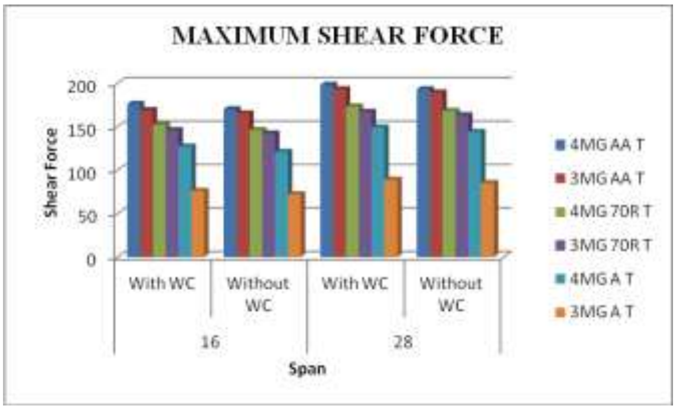


Fig -19: Variation of Maximum Shear Force (kN) in Cross girder with the span.

III. CONCLUSIONS

The following are the conclusions made from this study.

-In case of deck slab

- As the size of the slab increases bending moment and deflection increases.
- As the depth of the deck slab increases bending moment decreases .
- The bending moment obtained from the models which are subjected to the IRC CLASS AA Tracked loading are more than Those subjected to the IRC CLASS 70R loading.

-In case of girders

- As the span of the bridge increases ,the shear force ,bending moment and deflection increases
- The bending moment obtained from the models which are subjected to the IRC CLASS AA Tracked loading are more than Those subjected to the IRC CLASS 70R loading.

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