COMPARATIVE ANALYSIS AND DESIGN OF T-BEAM AND BOX GIRDERS

Abrar Ahmed, [1] Prof. R.B. Lokhande[2]

[1] *Student of Master of Technology in Structural Engineering*
BLDEA's V.P. Dr. P.G Halakatti College of Engineering and Technology, Vijayapur - Karnataka, India.
[2] *Professor at Civil Engineering Department*
BLDEA's V.P. Dr. P.G Halakatti College of Engineering and Technology, Vijayapur - Karnataka, India.

---***---

Abstract: *The development of the nation is mainly from agricultural and industrial activities, so, it is required to facilitate the proper transportation by providing the Flyovers and Bridges. For constructing the flyovers or the bridges we find many types of section among which T-beam and box type are very popular. In order to find out the most suitable section, this project looks on the work of analysis, design and cost comparison of T-Beam and Box girders for different spans. The purpose of this study is to identify the suitable section for bridges of different spans. The Prestressed concrete sections have been considered in this case as the spans designed are more than 25 metres for which the Reinforced concrete sections are uneconomical. The aim and objective of the work is to analyse and design the sections for different Indian Road Congress, IRC vehicles. This has been done by analysing the structure by CSI bridge software and validating with manual results by developing the Microsoft Excel Sheets using Working Stress Method and by adopting Courbon's theory. It is found that the IRC 70R vehicle producing maximum effect on the sections. Cost comparison has shown that the T-beam girder is suitable for spans up to 30metre, as we go for higher spans the depth of T-beam girder increases drastically which makes it uneconomical. Therefore for higher spans the box girder is suitable. The result of this analysis can be used to find the suitable section for respective spans. From the obtained results we can conclude that the software results are acceptable and can be adopted for the design of substructures also.*

Key Words: - T-beam, Box Girder, Prestressed Concrete, CSI Bridge, Courbon's theory.

1. INTRODUCTION

In the present work the comparison between the 'Tee Beam Girder' and 'Box Girder' is carried out. This is helpful when we have two kinds for girder which can be used for same span; in that case the most economical one is to be selected. This comparison will give the clarity about selecting the deck type based on the span keeping economy in consideration. Deck slab is that part of the flyover which bears the load passing over it and transmits the forces caused by the same to the substructure. It is important to select the type of deck slab for different spans keeping aesthetic appearance and economy in consideration.

A Flyover is a structure which allows the Road or Railway vehicles to pass over existing Road or Railway lines. The construction of Flyover is necessary where there is a heavy traffic congestion which results in delay for the travellers. Construction of Flyover will reduce the delay and allow the vehicles to travel without interruption. As per the Indian standards IRC: 92-1985, the Flyover is preferred when the PCU [Passenger Car Unit] value at the intersection exceeds 10,000. The planning of these structures has two important parts viz., Traffic Assessment & layout design and Structural design. [1]

2. LITERATURE REVIEW

The analysis of T-beam girder by IRC specification showed that the results obtained by FEM method is economical than the one dimensional analysis. By: R. Shreedhar (2012). [2] The comparative design of T-beam and Box Girder for 25m Span shows that the T-Beam Girder is more economical section, but if span is more than 25 m, Box Girder is always suitable. The torsional rigidity is higher in box girders as they have closed section. By: Amit Saxena, (2013) [3]. Comparative design of I-Section and Box Section concludes that the Box girder is found to be Costlier for 16.3 m Span whereas for 31.4 m span the box girder is economical. It also provides the methodology for design of such sections. By: Vishal U. Misal, N. G. Gore, P. J. Salunke, (2014) [4]. Comparative design of RCC and PSC sections concludes that the Shear force and bending moments for PSC T-beam girder are lesser than RCC T-beam Girder Bridge. It is always suitable to adopt PSC sections rather than RCC, which is economical and Suitable for spans 24m and above. By: Rajamoori Arun Kumar, B. Vamsi Krishna (2014) [5]. The modelling and analysis of RC T-beam bridge superstructure can be efficiently performed using SAP-2000 and results in time saving. By: Mahantesh. S. Kamatagi, Prof. M. Manjunath (2015). [6]
Life span of Prestressed concrete structures is very more as compared to reinforced concrete structure sand Steel structures. By: K. Venkateswara Rao, Dr. M. Kameswara Rao (2015). [7]

3. METHODOLOGY

The methodology used in this project is described briefly in points mentioned below:

i. Working Stress Method is being used for the Manual design whereas the CSI bridge for Software analysis.
ii. Excel Sheets are developed for manual calculations.
iii. Cost comparison is done by estimating the Concrete and Steel quantity for two different girders.
iv. Structural components are designed by selecting the trail section and checking for the adequacy of that section and stresses developed.

4. ANALYSIS USING CSI BRIDGE

CSI Bridge is analysis software used for bridges. It is adopted as it makes user convenient for layout of the deck sections and properties application.

4.1 Modelling

The Model of both T-beam and Box Girder is created and is as shown in below figures

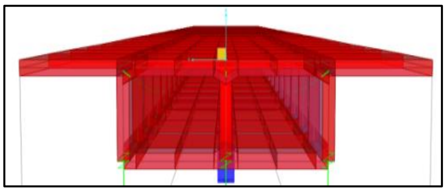

Figure 1: Front View of Box Girder

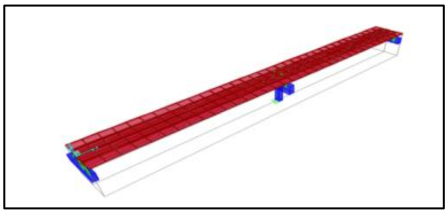

Figure 2: 3D View of Box Girder

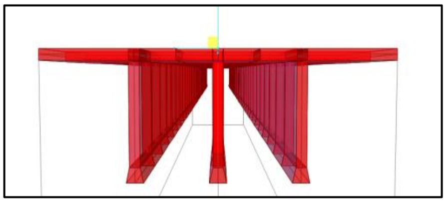

Figure 3: Front View of T- Beam Girder

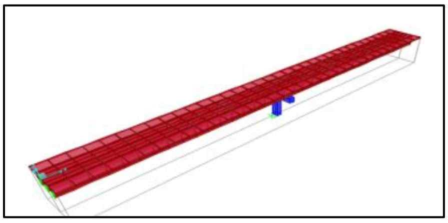

Figure 4: 3D View of T-Beam Girder

4.2 Analytical Results

The Shear Forces and Bending Moments of 50m span of both the sections are tabulated below: the results shown below are of IRC Class AA tracked vehicle which is said to produce the maximum moments in the span.

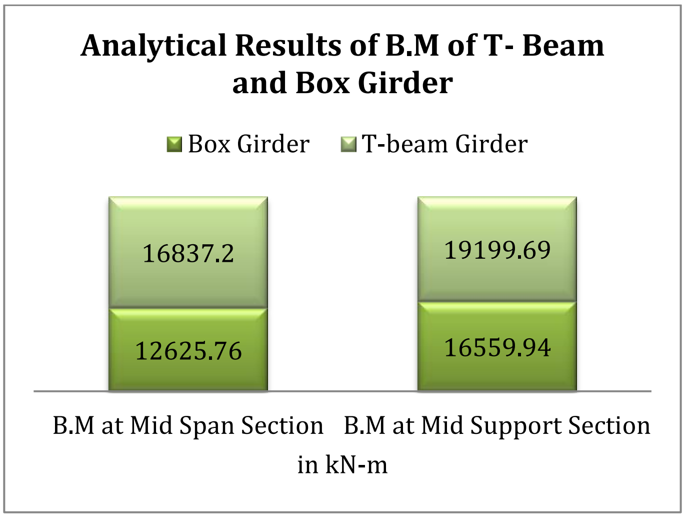

Figure 5: Analytical Results of B.M of T- Beam and Box Girder

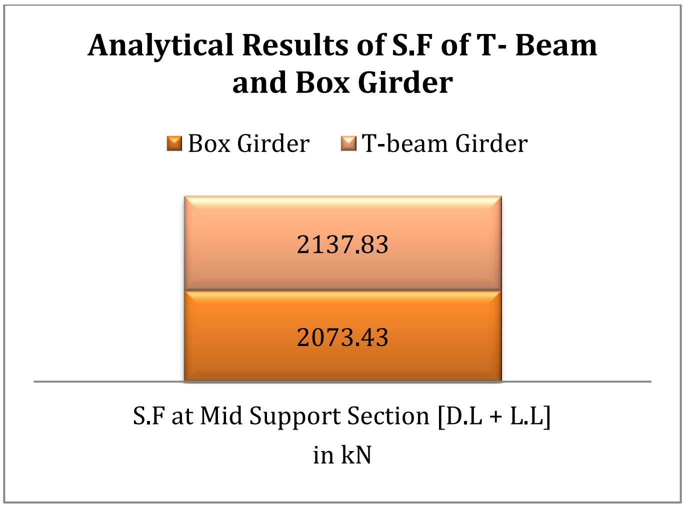

Figure 6: Analytical Results of S.F of T- Beam and Box Girder

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 07 | July -2017 www.irjet.net p-ISSN: 2395-0072

4.3 Data Validation

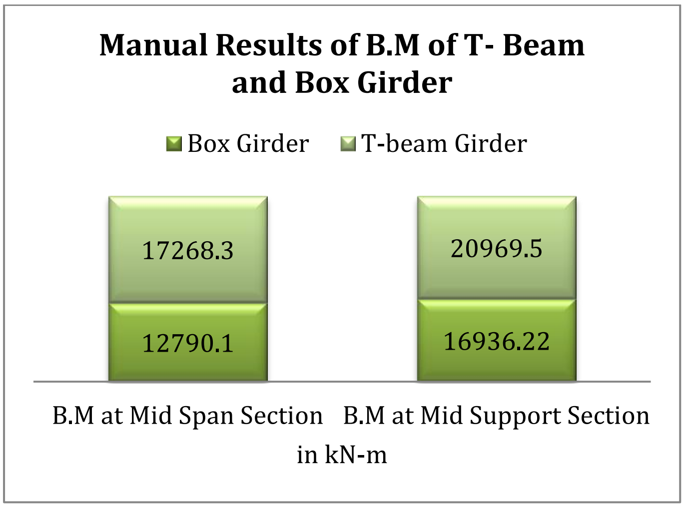

Figure 7: Manual Results of B.M of T- Beam and Box Girder

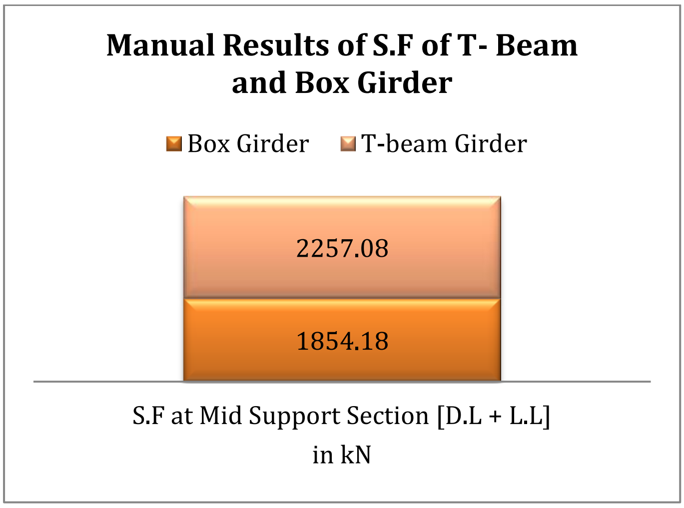

Figure 8: Manual Results of S.F of T- Beam and Box Girder

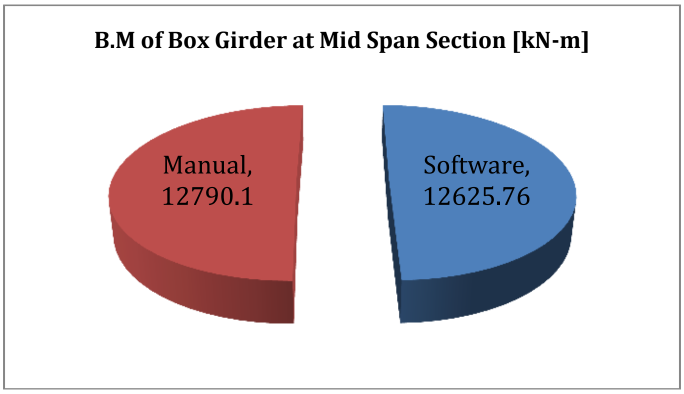

Figure 9: B.M of Box Girder at Mid Span Section [kN-m]

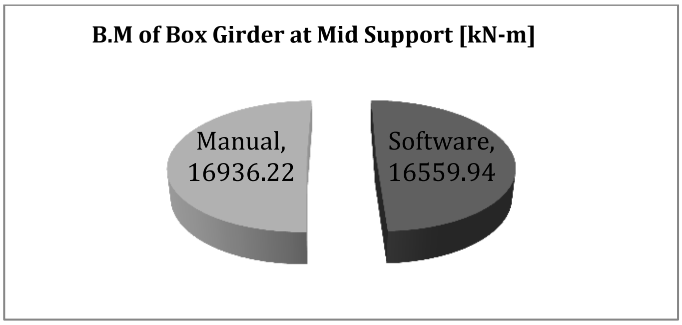

Figure 10: B.M of Box Girder at Mid Support Section [kN-m]

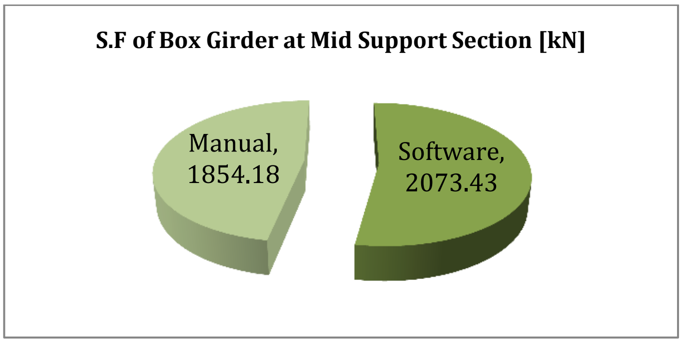

Figure 11: S.F of Box Girder at Mid Support Section [kN]

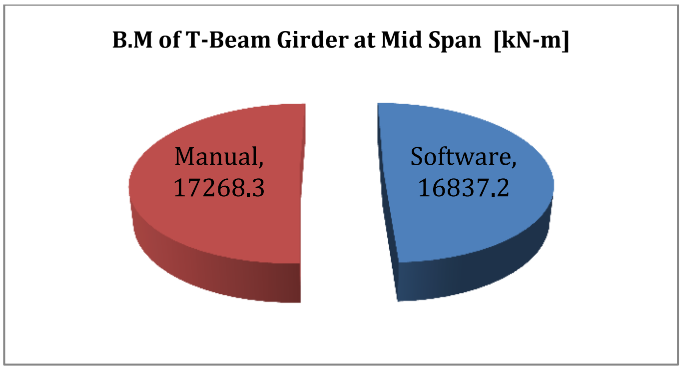

Figure 12: B.M of T-Beam at Mid Span Section [kN-m]

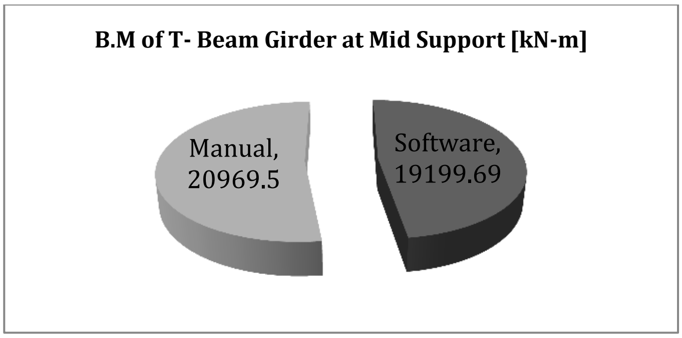

Figure 13: B.M of T- Beam Girder at Mid Support Section [kN-m]

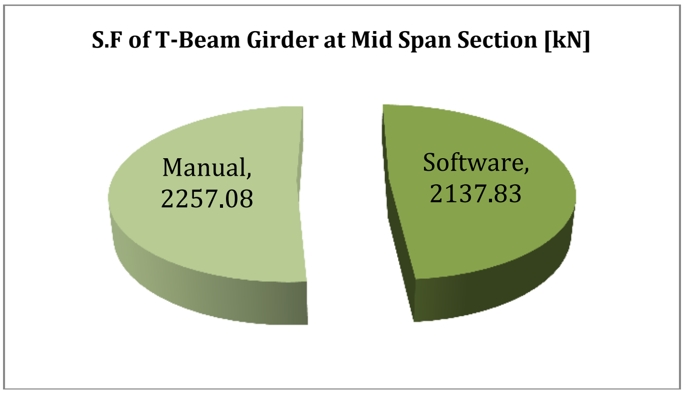

Figure 14: S.F of T-Beam Girder at Mid Span Section [kN]

By comparing the results obtained manually and analytically we can say that the results obtained from the software analysis are acceptable and can be adopted for further design. The critical results of vehicle is then selected and used for the design of substructure which is not described in this part of paper.

5. DESIGN USING EXCEL SHEETS

a. Design and quantity calculation of T- Beam girder

By using the excel sheet the results of 25, 30, 35 and 50m spans are obtained and the steel and concrete quantities are calculated. The input data of T-beam girder used for 50m span in excel sheet is shown below:

Table 1: Input for T-Beam girder

INPUT

Effective Span =	50m
Width of Road =	7.5m
Footpath =	1.25m
Thickness of Wearing Coat =	0.08m
f_{ck} for Deck Slab =	30 N/mm^2
f_{ck} for Prestressed Girders =	60 N/mm^2
f_y =	415 N/mm^2
Loss Ratio =	0.8
Spacing of Cross Girders =	5m
Width of Main Girder =	0.3m
Width of Cross Girder =	0.3m
R.C. Post =	0.15m x 0.15m
Density of Concrete =	24 kN/m^3
L.L on Footpath =	4 kN/m^3
Density of W.C =	22 kN/m^3
Depth of kerbs =	0.3m
Length of W.C in Cantilever =	1.25m
Free Space of Handrails From end of Cantilever Slab =	0.05m

The steel and concrete quantity for the 50m T-beam span is as shown below

Table 2: Sectional Properties of T-Beam girder

Span	50m
Carriage Way Width =	10m
Width of Web/Girder =	0.3m
Depth of Web =	2.8m
Thickness of Slab =	0.3m
Width of Bottom Flange =	0.5m
Depth of Bottom Flange =	0.4m
Width of Simply Supported Slab =	5m
Width of Cantilever Slab =	2.5m

Table 3: T-Beam Girder Quantity Calculation

	Slab				Stirrups
	Simply Supported		Cantilever		
	Main Bars	Dist Bars	Main Bars	Dist Bars	
Dia (mm)	16	12	16	12	8
Spacing (mm)	150	150	90	150	300
Length (m)	5	50	2.5	50	6.2
Steel (Kg)	2639	1511.1	4393.1	1511.1	1227.14

	Supplementary Reinforcement In Webs	Cross Girders [Supplementary Reinforcement]
Dia (mm)	16	16
Spacing (mm)	90	90

Length (m)	50	50
Steel (Kg)	7585.18	22755.55

Total = 41622.20 Kg

	Simply Supported		Cantilever
Concrete (m^3)	75		75
	Main Girder		Cross Girders
	Webs	Bottom Flange	
Concrete (m^3)	126	30	43.2

Total = 349.2 m^3

b. Design and quantity calculation of Box girder

By using the excel sheet the results of 25, 30, 35 and 50m spans are obtained and the steel and concrete quantities are calculated. The input data of Box girder used for 50m span in excel sheet is shown below:

Table 4: Input for Box Girder

INPUT

Effective Span, L=	50m
Cross Section =	Two Celled Box Girder
Cell Dimensions =	2.5m x 2.5m
Road Width=	7.5m
Foot Path + Kerbs =	1.25m on either side
Depth of Kerbs =	0.3m
R.C Posts =	0.15m x 0.15m
Wearing Coat =	0.08m
Thickness of Web =	0.3m
Thickness of Top Slab =	0.3m
Thickness of Bottom Slab =	0.3m
Concrete Grade, f_{ck} =	60 N/mm^2
Loss Ratio =	0.8
Grade of Steel =	415 N/mm^2
Type of Structure =	Class I
Density of Concrete =	24 kN/m^3
Density of Wearing Coat =	22 kN/m^3
Length of W.C in Cantilever Slab =	1.25m
Free Space of Handrails From end of Cantilever Slab =	0.05m
Live Load on Foot path =	4 kN/m^2

The steel and concrete quantity for the 50m T-beam span is as shown below

Table 5: Sectional Properties of Box Girder

Span =	50m
Carriage Way Width =	10m
Width of Web/Girder =	0.3m
Depth of Web =	1.4m
Thickness of Top Slab =	0.3m
Thickness of Bottom Slab =	0.3m
Width of Flange =	2.5m
Width of Simply Supported Slab =	5m
Width of Cantilever Slab =	2.5m

Table 6: Box Girder Quantity Calculation

	Slab				Stirrups
	Simply Supported		Cantilever		
	Main Bars	Dist Bars	Main Bars	Dist Bars	
Dia (mm)	16	12	16	12	12
Spacing (mm)	130	160	90	150	100
Length (m)	5	50	2.5	50	3.4
Steel Quantity (Kg)	3042	1422.2	4393.1	1511.1	4533.33

	Supplementary Reinforcement In Webs	Cross Girders [Supplementary Reinforcement]
Dia (mm)	12	-
Spacing	200	-

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 07 | July -2017 www.irjet.net p-ISSN: 2395-0072

(mm)		
Length (m)	50	-
Steel Quantity (Kg)	933.33	-

Total = 15835.06 Kg

	Simply Supported		Cantilever
Concrete (m^3)	Top & Bottom		75
	154.5		
	Main Girder		Cross Girders
	Webs	Bottom Flange	
Concrete (m^3)	63	-	-

Total = 292.5 m^3

6. COST COMPARISON

The steel and concrete quantity of al different spans mentioned above are calculated and by considering the present cost of steel per kg and concrete per cubic meter the cost comparison is carried out and the quantity and cost are tabulated as shown below:

Cost of Steel/kg = Rs.45
Cost of Concrete/cumec = Rs.5000

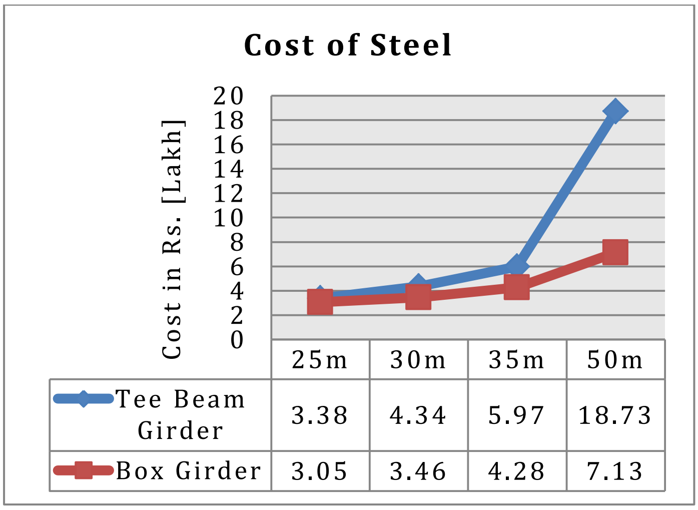

Figure 15: Cost of Steel

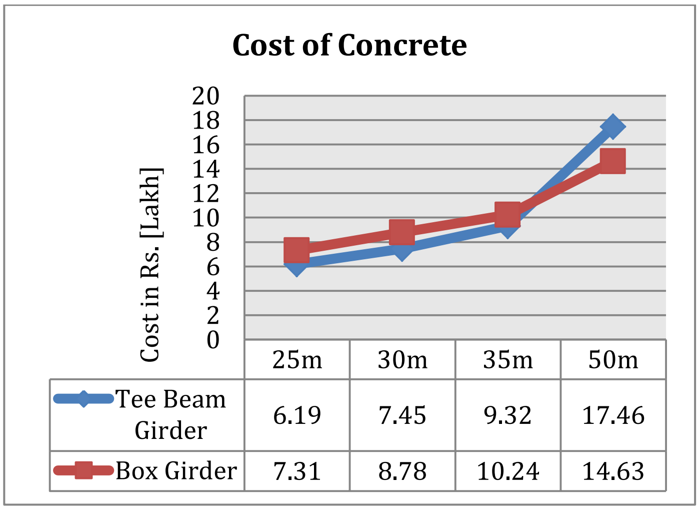

Figure 16: Cost of Concrete

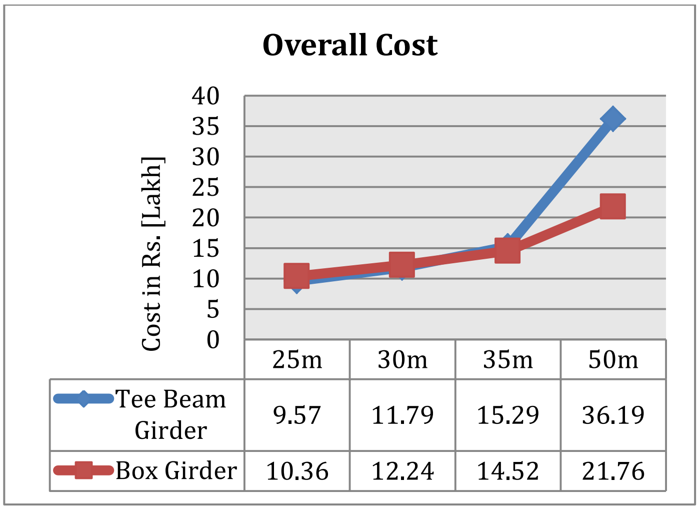

Figure 17: Overall Cost

7. RESULTS DISCUSSION

As per the above cost comparison it can be seen that the cost of 25, 30 and 35m spans are less for T-beam girder whereas for 50m span Box girder is economical. So we can provide T-beam girder if the span is less than 30m. For higher spans Box girder is suitable.

Further, if the span is more than 100m or 200m than the box girder with more than two cells can be adopted in order to decrease the overall depth.

7.1 Analytical Results

The analytical results obtained from the CSI bridge software are discussed below:

a. Shear Force and Bending Moment Diagrams

The Shear Forces and Bending Moments of 50m span of both T-beam and box girder are shown below: the results are of vehicle type AA tracked is noted and these values are validated with the manual calculated results for the same class of vehicle.

T-Beam Results

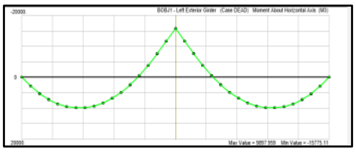

Figure 24: Dead Load B.M Diagram Showing the Values at Mid Span & Mid Support-Section

Dead load B.M at mid span section: 9897.959 kN-m
Dead load B.M at mid support section: -15775.11 kN-m

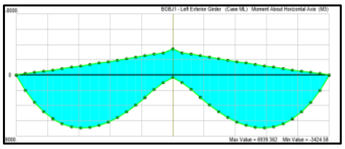

Figure 25: Live Load B.M Diagram Showing the Values at Mid Span & Mid Support-Section

Live load B.M at mid span section: 6939.362 kN-m
Live load B.M at mid support section: -3424.58 kN-m

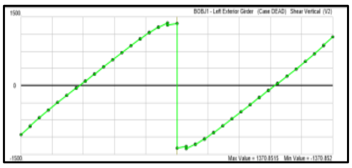

Figure 26: Dead Load S.F Diagram Showing the Values at Mid Support-Section

Dead load S.F at mid support section: 1370.8515 kN

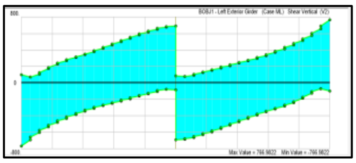

Figure 27: Live Load S.F Diagram Showing the Values at Mid Support-Section

Live load S.F at mid support section: 766.9822 kN

Box Girder Results

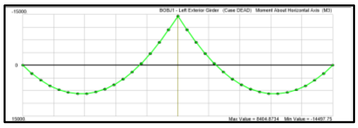

Figure 28: Dead Load B.M Diagram Showing the Values at Mid Span & Mid Support-Section

Dead load B.M at mid span section: 8404.8734 kN-m
Dead load B.M at mid support section: -14497.75 kN-m

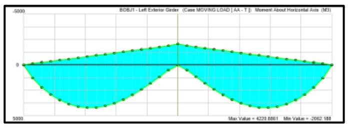

Figure 29: Live Load B.M Diagram Showing the Values at Mid Span & Mid Support-Section

Live load B.M at mid span section: 4220.8861 kN-m
Live load B.M at mid support section: -2062.188 kN-m

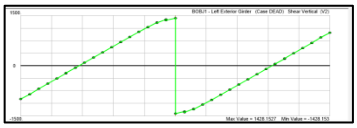

Figure 30: Dead Load S.F Diagram Showing the Values at Mid Support-Section

Dead load S.F at mid support section: 1428.1527 kN

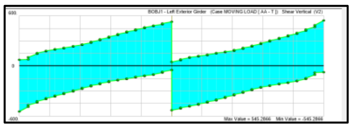

Figure 31: Live Load S.F Diagram Showing the Values at Mid Support-Section

Live load S.F at mid support section: 545.2866 kN

b. Dead Load and Live Load Reactions

The reactions of dead load and live load of different IRC vehicles are considered and the maximum value is taken into consideration.

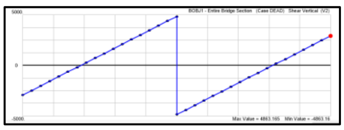

Figure 32: Dead Load Reactions for Box Girder

The Dead Load reaction on box girder: 4863.165 kN

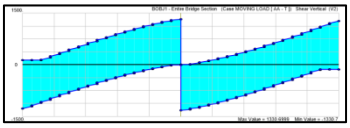

Figure 33: Live Load Reaction of IRC Class AA Tracked Vehicle

The Live Load reaction of IRS class AA tracked vehicle on box girder: 1330.6999Kn

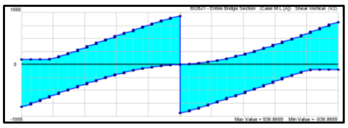

Figure 34: Live Load Reaction of IRC Class A Vehicle

The Live Load reaction of IRS class A vehicle on box girder: 936.8669kN

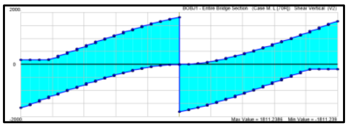

Figure 35: Live Load Reaction of IRC 70R Vehicle

The Live Load reaction of IRS class 70R vehicle on box girder: 1811.2386kN

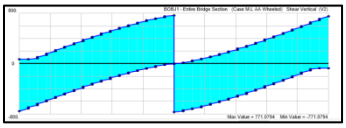

Figure 36: Live Load Reaction of IRC Class AA Wheeled Vehicle

The Live Load reaction of IRS class AA Wheeled vehicle on box girder: 771.1kN

From the above figures, it is clear that the reaction from IRC Class 70R vehicle is maximum i.e., 1811.2386 kN and it can be adopted for the design of sub-structures.

8. CONCLUSION

In view of achieving the aim and objectives of this project the detailed design of two types of deck sections is carried out in excel sheets and the comparative statement is given as per the results obtained. It gives us idea about the methodology used and the suitable section to be adopted.

i. By validating the analytical data with the manual, it can be concluded that the software (CSI Bridge) results can be considered for the design of substructure as the results obtained is showing good agreement.
ii. By extracting the results it is seen that for the spans greater than 30m, box girder is economical overall and is suitable type of section.
iii. For lower spans the T-beam girder can be adopted which is easy to install and maintain.
iv. By having self-developed excel user feels easy to design the sections for different spans in less time.
v. Number of cells in the box girder can be increased to decrease the overall depth of the girder for higher spans.

REFERENCES

[1]. Dr R N Khare, Rajesh Tamrakar, (2015), "Case Study On Flyover Bridge Resting On Hard Strata Materials At Raipur Naka, Durg (India)", Global Journal Of Multidisciplinary Studies Volume 4, Issue 8.
[2]. R. Shreedhar, (2012), "Analysis of T-beam Bridge Using Finite Element Method", International Journal of Engineering and Innovative Technology Volume 2, Issue 3.
[3]. Amit Saxena, Dr. Savita Maru,(2013), "Comparative Study of the Analysis and Design of T-Beam Girder and Box Girder Superstructure", International Journal of Research in Engineering & Advanced Technology, Volume 1, Issue 2.
[4]. Vishal U. Misal, N. G. Gore, P. J. Salunke, (2014), "Analysis and Design of Prestressed Concrete Girder", International Journal of Inventive Engineering and Sciences, Volume 2, Issue 2.
[5]. Rajamoori Arun Kumar, B. Vamsi Krishna, (2014), "Design of Pre-Stressed Concrete T-Beams", International Journal of Scientific Engineering and Research, Volume 2 Issue 8.
[6]. Mahantesh. S. Kamatagi, Prof. M. Manjunath, (2015), "Comparative Study of design of longitudinal girder of T- Beam Bridge Using IRC 21-2000 & IRC 112-2011", International Research Journal of Engineering and Technology, Volume 02 Issue 06.
[7]. K. Venkateswara Rao, Dr. M. Kameswara Rao, (2015), "Comparative Design of RCC and Prestressed Concrete Flyover along with RCC Abutments", International Journal for Scientific Research & Development| Vol. 3, Issue 06.
[8]. IRC 6-2010, "Standard Specifications and Code of Practice for Road Bridges", Section II, loads and stresses, The Indian Roads Congress, New Delhi, India, 2010.
[9]. IRC: 21-2000, "Standard Specifications and Code of Practice for Road Bridges, Section III, Cement Concrete (Plain and Reinforced)", The Indian Roads Congress, New Delhi, India, 2000.

[10]. D Johnson Victor (2007), "Essential of Bridge Engineering" 6th edition.
[11]. V. K. Raina (2007) "Concrete bridge practise analysis, Design and Economics", 2nd edition.
[12]. Krishnaraju. N, "Design of Bridges", fourth edition, Oxford and IBH publishing CO.PVT.LTD, New Delhi.