International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 11, November-2019

Analysis and Design of RCC Girder Bridge

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Abstract*— Currently Construction industries doing research to find better safe and economic I-girders bridges. Girders have been found wide acceptance construction of highways and bridges due to their structural stability, economic in construction and long duration. In this paper comparative analysis of single span RCC Girder Bridge under IRC loadings and PSC Girder Bridge under IRS loadings. This Analysis has been performed using Ansys Workbench 15.0 software, 2D Drawing performed using AutoCAD 19 and 3D Modeling performed using Solidworks 16.0 software. For this analysis we have used three different types of girder cross section.First is Case A, in this case girder cross section have no cavity which means regular filled cross section. Second is Case B, in this case girder cross section have cylindrical cavity. Third is Case C, in this case girder cross section have cubic cavity. Each case have six load type conditions. First is Class A type of Vehicular Load as per IRC:6-2014, second is Double Headed Diesel Loco, third is Double Headed Electric Loco (2 WAG9H), forth is Electric Loco [(B0-B0)+(B0-B0)], Fifth is With Double Head 25t LOCO and sixth is With Double Head 22.5t LOCO . In AutoCAD created 2D drawings and in Solidworks created 3D model using 2D drawing after that 3D model imported in Ansys Workbench 15.0 for applying load conditions according to bridges standard codes and then solved analysis. After solutions, it was observed that Case B is best model compared to another cases. Case B have less stress and less requirement volume of concrete mixture. So Design tools are very helpful to find out economic and better safe bridge parameters for constitutions.

KEYWORDS: AutoCAD, Solidworks, Ansys Workbench 15.0, Girder Bridge.

INTRODUCTION

Girder Bridges are widely adopted for short and medium spans. Deck and Girder usually act together to support the entire loads for highway and railway bridges to carry in Shear and Flexural bending. I-Girder Bridges are economical, simple to design and relatively straight forward to build. If the bridge contains any curves, the beams become subject to twisting forces, also known as torque, therefore they are best used to construct bridges that do not have any significant curves. In Pre-stressed Concrete (PSC) internal stresses of suitable magnitude are introduced so that the stresses resulting from external loads are counteracted to a desired degree. Analysis of PSC I-Girder Bridge is very complex because of its three dimensional behavior consisting of torsion, bending and shear. For Railway Bridges PSC I-Girders and for Highway Bridges RCC I-Girders with 4.8 m deck width and span of 19.76 m are adopted for this study. The codal provisions used for standard loads in case of bridges are according to IRC and IRS. Highway Bridges have to be designed to withstand the live loads specified by the Indian Roads Congress (IRC). The standard IRC loads specified in IRC: 6-2014 are grouped under four categories as Class AA, Class 70R, Class A and Class B. As per IRC: 6-2014, one lane of Class A type of loading is recommended with Impact factor for 4.4 m carriageway width in this study. The design guide lines of Railway Bridges in India shall be in accordance with the Indian Railway Standard (IRS) Code of Practice. The longitudinal loads for Broad Gauge standard loadings for all spans are 25t Loading-2008 and DFC loading (32.5t axle load) with a maximum axle load of 245.2 kN (25.0t) for the locomotives as per IRS. For this study, 25t Loading-2008 with five load combinations has been considered.

LITERATURE REVIEW

Simply supported RC T-beam Bridge by rational method and finite element method using STAAD Pro. This study concluded that Courbon’s Method gives the average result with respect Bending Moment values in the longitudinal girder has compared to Guyon Masssonet method whereas Guyon Masssonet method underestimates the Bending Moment values when compared with Courbon’s method.

The bridge deck by both grillage analogy as well as by finite element method. This study concluded that grillage analysis is easy to use and comprehend but analysis by finite element method gives more economical design when compared with the grillage analysis as finite element method gives lesser value in terms of bending moment compared with grillage model. Interior penalty function method can be used for solving resulting non-linear optimization problems.

Exterior penalty function method can be used for solving resulting non-linear optimization problems. It is possible to obtain the global minimum for the optimization problem by starting from different starting points with the interior penalty function method. The minimum cost design of R.C.C. I-beam girder is fully constrained design which is defined as the design bounded by at least as many constraints as there are the design variables in the problems. Actual percentage of the saving obtained for optimum design for R.C.C. I-beam girder depend upon the deck slab thickness, depth of girder, grade of steel and grade of concrete.

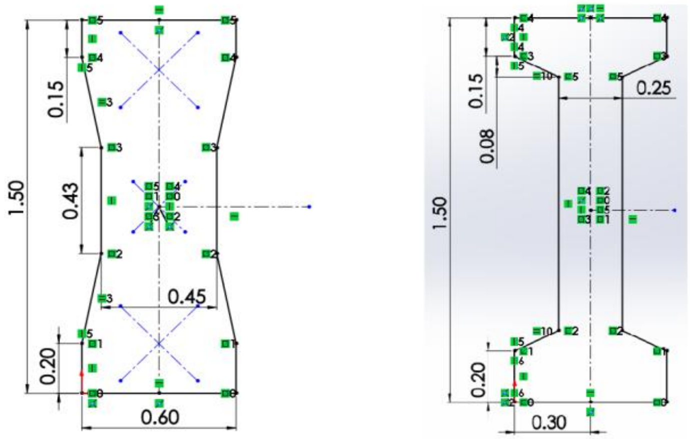
The optimum cost for a R.C.C. I-beam girder is achieved in M25 grade of concrete and fe415 grade of steel. The cost of R.C.C. I-beam girder unit increased rapidly with respect grade of concrete increases and grade of steel increases whereas cost of R.C.C. I-beam girder decreases as the span of bridge reduces, also the cost of girder decreases with the increase in the girder depth. Significant savings in cost over the normal design can be achieved by the optimization. However the actual percentage of the saving obtained for optimum design for R.C.C. I-beam girder depend upon the span of slab and grade of material. The cost of girder is directly proportional to grade of concrete.

DIMENSIONS AND LOADS OF BRIDGE

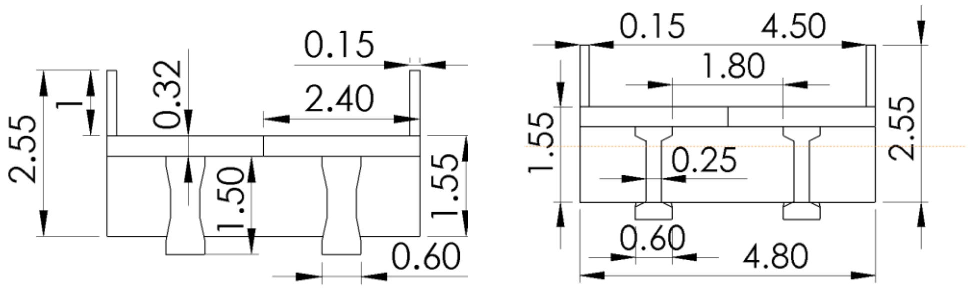
The following provisions are considered for the modelling and analysis of I-Girders as per codal provisions. The thickness of the web shall not be less than 200 mm plus diameter of duct hole. Where cables cross within the web, suitable increase in the thickness over the above value shall be made. The minimum thickness of deck slab including that at cantilever tips shall be 200 mm. In case of multi-beam arrangement, at least two cross girders, one at each support, shall be provided. The depth of the end cross girders shall be suitably adjusted to allow access for proper inspection of bearings and to facilitate positioning of jacks for future lifting up of the super structure. The thickness of cross girders shall not be less than the minimum web thickness of longitudinal girders. Haunches of 150 mm (H) x 150 mm (V) at top flange and 150 mm x 210 mm at bottom flange for PSC I-girder. For RCC I-girders haunches of 75 mm x 21 mm at top and 75 mm x 75 mm at bottom for End Section and haunches of 175 mm x 50 mm and 175 mm x 150 mm for running section. The following parameters are considered for Girder Bridges
Span of the bridge = 19.76 m
Effective span of the longitudinal girder (C/C of Girder) = 18.0 m
Overall Deck width = 4.80 m
19K13 strands are used for prestressing
Ultimate tensile stress of High tensile steel = 1860 N/mm2
Maximum allowable jacking stress is 85% of 0.2% proof stress = 1279 N/mm2
Nominal steel area of each strand = 128 mm2

The following are the sectional dimensions of girder, End cross section, Middle cross section and loadings for Highway Bridge.

Fig.1 shows the sectional dimensions of the RCC I-Girder at End section and at running section, End cross section and Middle cross section of the Highway Girder Bridge and Loading for Highway Bridge for single lane as per IRC: 6- 2014.The dimensions of the (a) End section and Middle section of Girder and (b) & (c) Cross sections of the bridge are in millimeters. In (d) spacing between the wheel loads are in meters and intensity of load in KN.

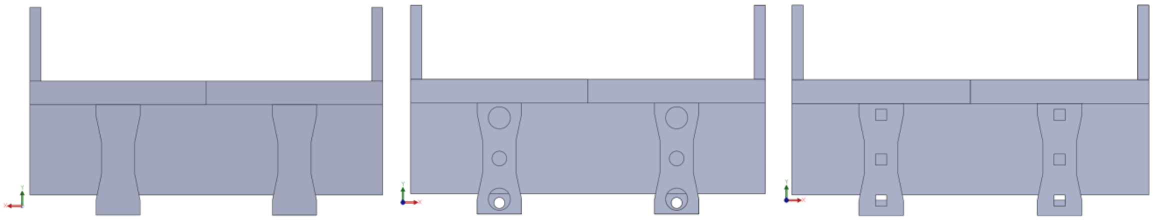


a.) End section b.) Running Section



c.) End Cross section d.) Middle Cross section

Fig. 1 Sectional Dimensions of Girders a.) End section b.) Running Section c.) End Cross section d.) Middle Cross section



a.) Case A b.) Case B c.) Case C

Fig. 2 3D Model of Girder Bridge a.) Case A, b.) Case B, c.) Case C.

Generated FEA (Finite Element Analysis) Model using Ansys Workbench 15.0 for analysis. In Meshing the whole body/part is divided into small elements and nodes. FEA is useful for problems with complicated geometries and loadings where analytical solutions cannot be obtained.

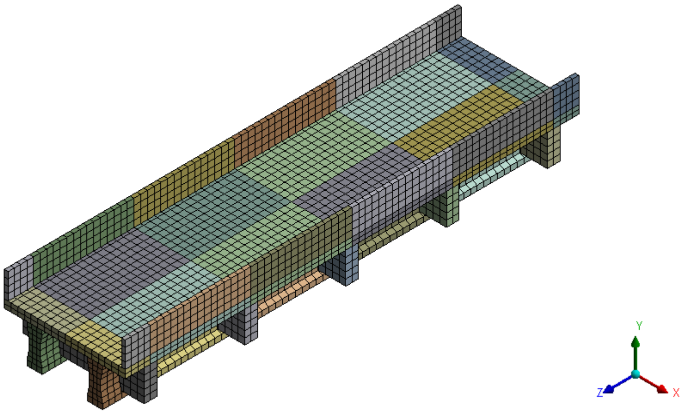


Fig. 3 Meshing Model of Girder

In this analysis following Loads are Considered :-
Load Type 1
Class A type of Vehicular Load as per IRC:6-2014

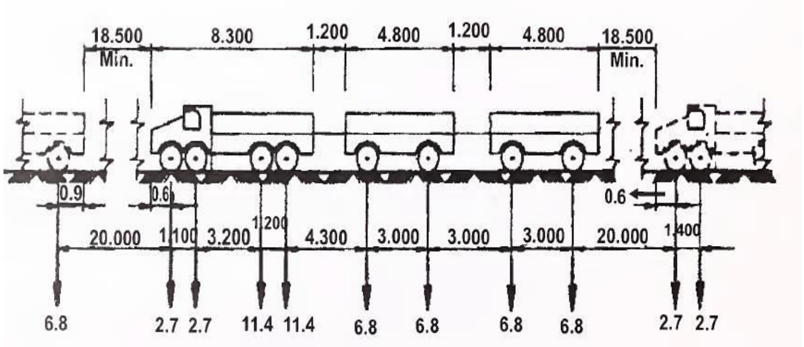


Fig. 4 Loading conditions for Vehicular load.

Load Type 2 : Double Headed Diesel Loco

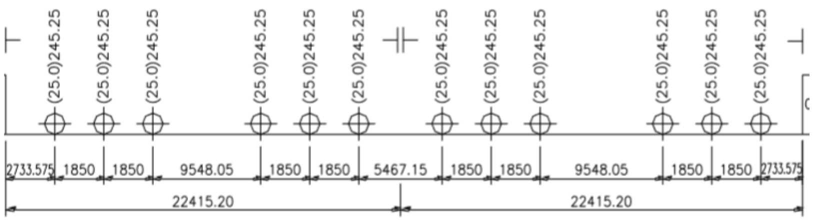


Fig. 5 Loading Conditions for : Double Headed Diesel Loco

Load Type 3 : Double Headed Electric Loco (2 WAG9H)

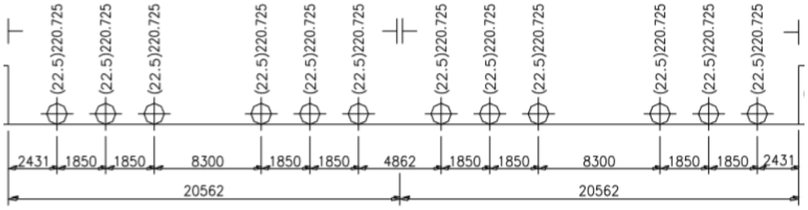


Fig. 6 Loading Conditions for Double Headed Electric Loco

Load Type 4 : Electric Loco [(B0-B0)+(B0-B0)]

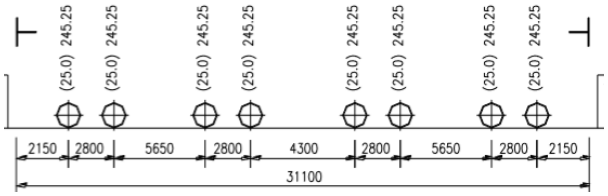


Fig. 7 Loading Conditions for Electric Loco

Load Type 5 : With Double Head 25t LOCO

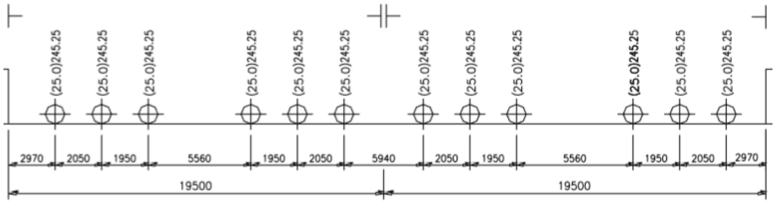


Fig. 8 Loading Conditions With Double Head 25t LOCO

Load Type 6 : With Double Head 22.5t LOCO

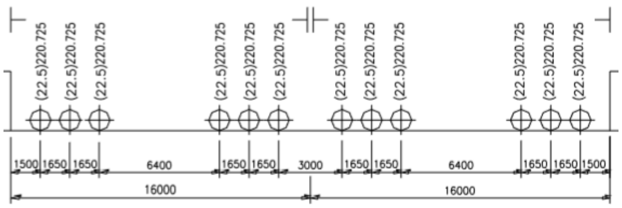


Fig. 9 Loading Conditions With With Double Head 22.5t LOCO

METHODOLOGY

The analysis starts by collecting authentic and authorized data such as dimensions of bridges and loads for bridges according to bridges standard codes by articles IRC: 21- 2000. The Flowchart for whole analysis is shown below in Fig. 10. After data collection a 2D model of girders were drawn using AutoCAD 2016 Software. The 2D drawing was then Imported to solidworks and a 3D model was created. This 3D model was then imported to ANSYS Workbench 15.0 in which the analysis of girder bridge was done under different loading conditions and the results were obtained for Von mises stress and Total deformation of Girders were evaluated. In this analysis we will consider three different cases for Girders: In Case A a uniform cross section of girder is taken and further the load is applied. Further in case B a Girder with hole of circular cross section is taken and loads were applied and the results were evaluated. In case C Girder with hole of Cubical cross section is taken and loads were applied and then the results were analyzed. In each case six different types of Load conditions were applied to look for the best girder under applied loading conditions by comparing the results with each other.

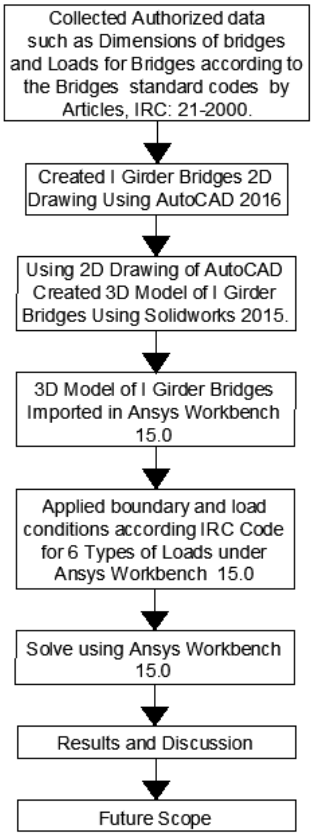


Fig. 10 Flowchart for Analysis.

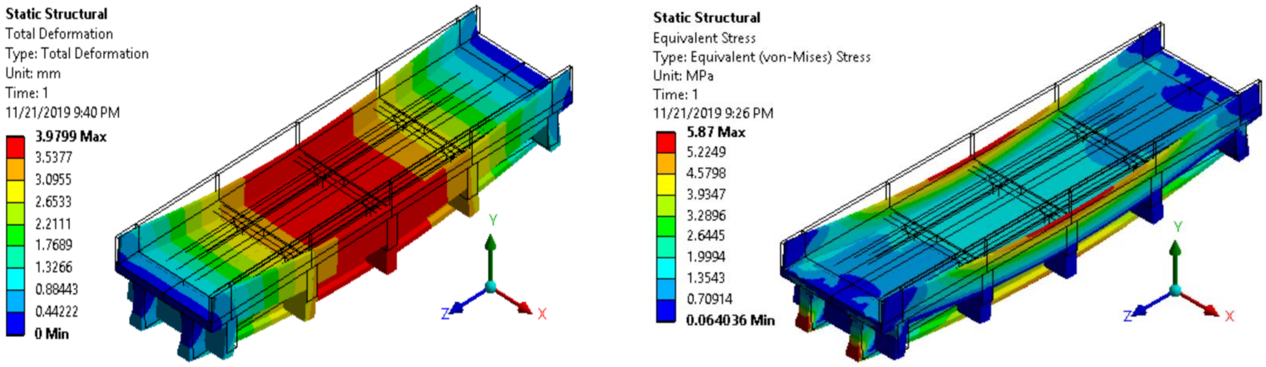
RESULTS AND DISSCUSION

The Analysis starts with 2D Drawing which was drawn in AutoCAD Software. The 2D drawing was then extracted in SOLIDWORKS to create a 3D model. After completion of 3D model the model was extracted to ANSYS Workbench 15.0 for stress analysis and to see the total deformation. Three cases were analyzed in which six different load combinations were applied to each case. In the first case the girder taken was of uniform cross section without any cavity to which six different load types were applied and further the results were analyzed. In second case circular holes of uniform cross section were drilled into each girders and then five different loads combinations were applied and results were analyzed. In third case holes of cubic cross sections were drilled out from each girders and the results were analyzed.

CASE A

Load Type 1 (Class A type of Vehicular Load as per IRC)

First images shows Total Deformation when first load type was applied. Red Color shows max. deformation i.e. 3.9799mm as shown in Fig. 11 b.) and blue color shows min deformation. Dark black line shows bridge condition without load and colored area shows bridge after load. Second image shows Von Mises Stress when first load type was applied. Red Color shows max. Max Von Mises stress and blue colour min Von Mises stress. Dark black line shows bridge condition without load and colored area shows bridge after load.

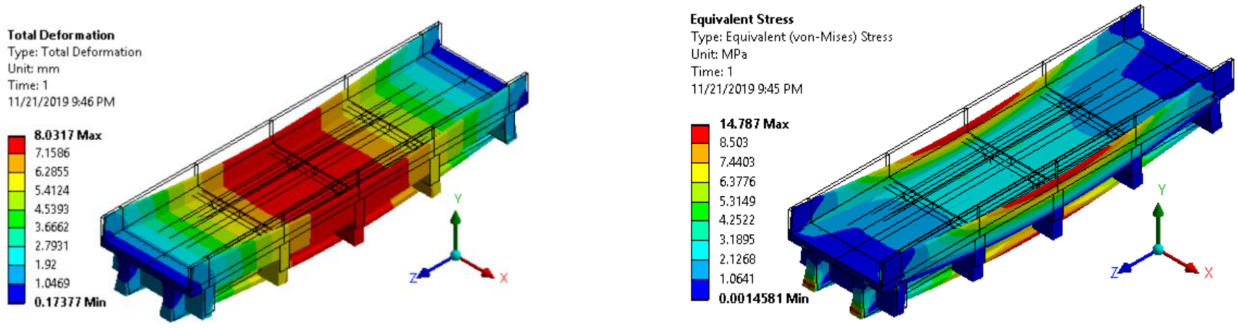


a.) Total Deformation b.) Von Mises Stress.

Fig. 11 Results of Load type 1st a.) Von Mises Stress and b.) Total Deformation.

Load Type 2 (Class A type of Vehicular Load as per IRC)

First images shows Total Deformation when first load type was applied. Red Colour shows max. deformation and blue colour min deformation. Dark black line shows bridge condition without load and colored area shows bridge after load. Second image shows Von Mises Stress when first load type was applied. Red Colour shows max. Max Von Mises stress and blue colour min Von Mises stress. Dark black line shows bridge condition without load and colored area shows bridge after load.

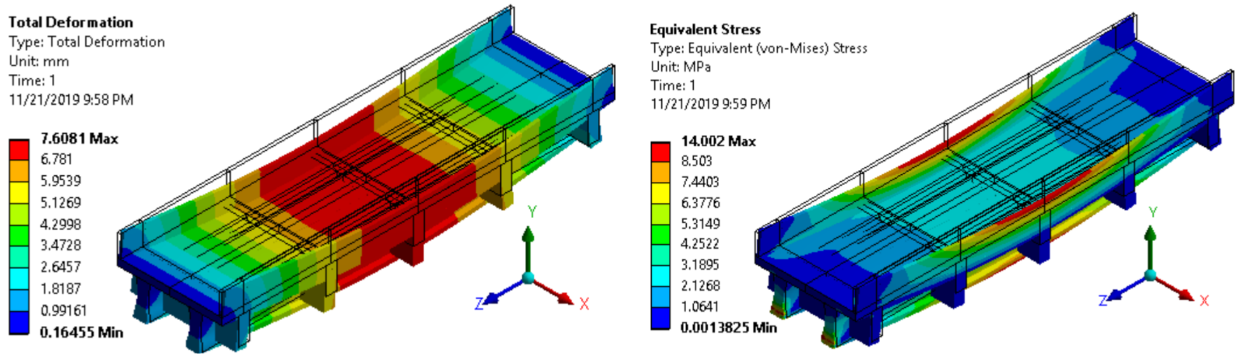


a.) Total Deformation b.) Von Mises Stress

Fig. 12 Results of Load type 2nd a.) Total Deformation. and b.) Von Mises Stress

Load Type 3 (Class A type of Vehicular Load as per IRC)

First images shows Total Deformation when first load type was applied. Red Colour shows max. deformation and blue color min deformation. Dark black line shows bridge condition without load and colored area shows bridge after load. Second image shows Von Mises Stress when first load type was applied. Red Color shows max. Max Von Mises stress and blue colour min Von Mises stress. Dark black line shows bridge condition without load and colored area shows bridge after load.

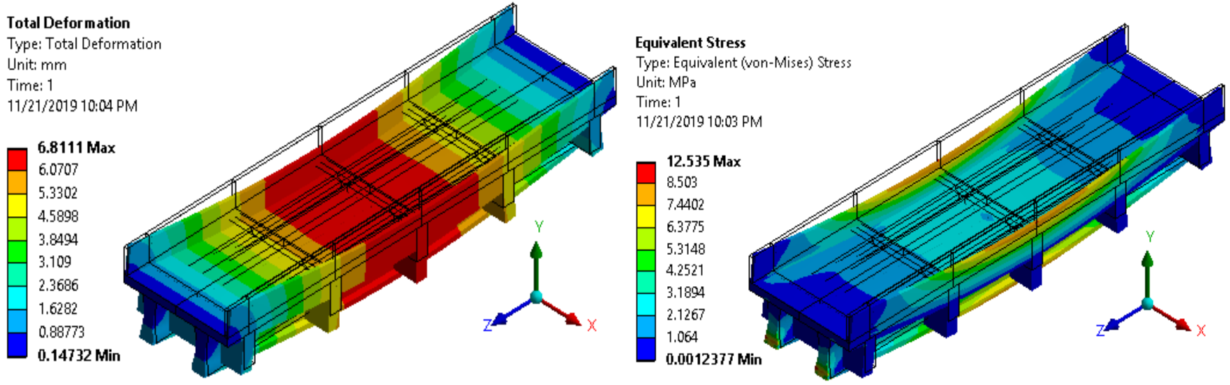


a.) Total Deformation b.) Von Mises Stress

Fig. 13 Results of Load type 3rd a.) Total Deformation. and b.) Von Mises Stress

The red colour in the image shows maximum deformation while blue colour shows the least deformation.

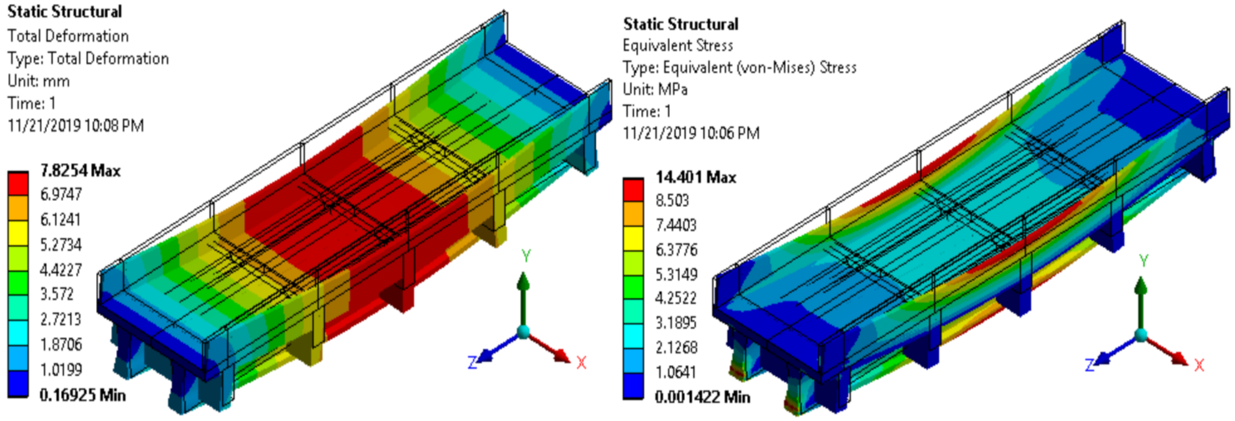
Load Type 4 (Class A type of Vehicular Load as per IRC)
First images shows Total Deformation when first load type was applied. Red Colour shows max. deformation and blue colour min deformation. Dark black line shows bridge condition without load and colored area shows bridge after load. Second image shows Von Mises Stress when first load type was applied. Red Colour shows max. Max Von Mises stress and blue colour min Von Mises stress. Dark black line shows bridge condition without load and colored area shows bridge after load.



a.) Total Deformation b.) Von Mises Stress

Fig. 14 Results of Load type 4th a.) Total Deformation and b.) Von Mises Stress.

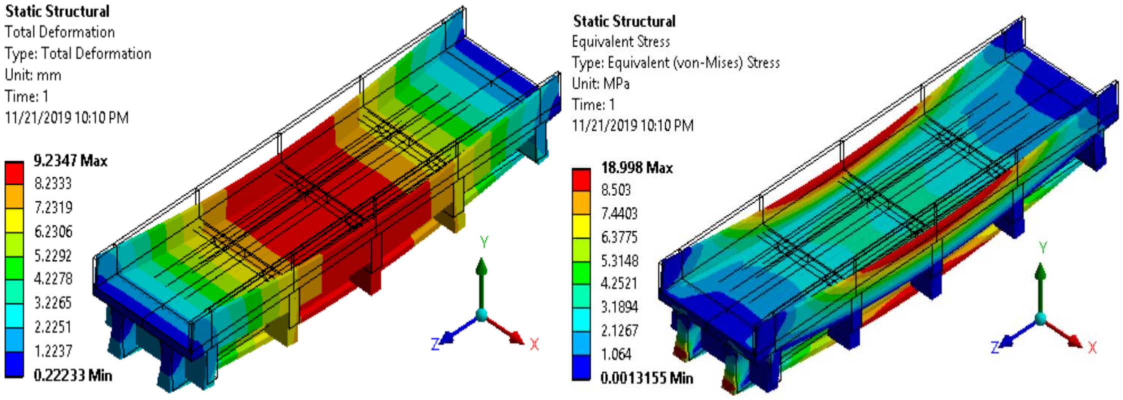
Load Type 5 (Class A type of Vehicular Load as per IRC)
First images shows Total Deformation when first load type was applied. Red Colour shows max. deformation and blue colour min deformation. Dark black line shows bridge condition without load and colored area shows bridge after load. Second image shows Von Mises Stress when first load type was applied. Red Colour shows max. Max Von Mises stress and blue colour min Von Mises stress. Dark black line shows bridge condition without load and colored area shows bridge after load.



a.) Total Deformation b.) Von Mises Stress

Fig. 15 Results of Load type 5th a.) Total Deformation and b.) Von Mises Stress.

Load Type 6 (Class A type of Vehicular Load as per IRC)
First images shows Total Deformation when first load type was applied. Red Colour shows max. deformation and blue colour min deformation. Dark black line shows bridge condition without load and colored area shows bridge after load. Second image shows Von Mises Stress when first load type was applied. Red Colour shows max. Max Von Mises stress and blue colour min Von Mises stress. Dark black line shows bridge condition without load and colored area shows bridge after load.



a.) Total Deformation b.) Von Mises Stress

Fig. 16 Results of Load type 6th a.) Total Deformation and b.) Von Mises Stress.

Analysis for Case B and Case C is also done accordingly as mentioned above and the results obtained from them are plotted graphically as shown below in Fig. 17, 18 and 19 for Case A Case B and Case C respectively.

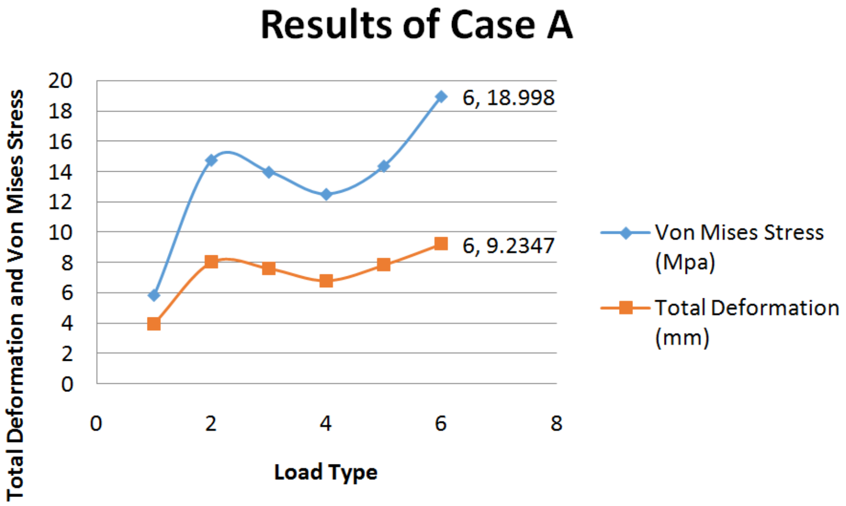


Fig. 17 Graphical plot of Total Deformation and Von mises stress for Case A.

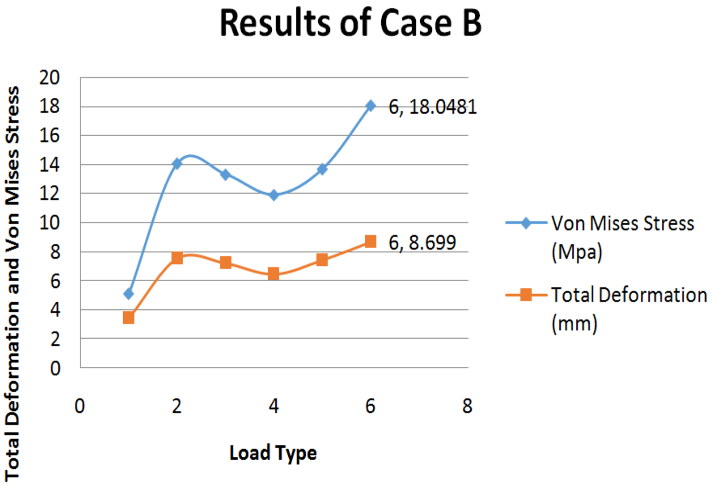


Fig. 18 Graphical plot of Total Deformation and Von mises stress for Case B.

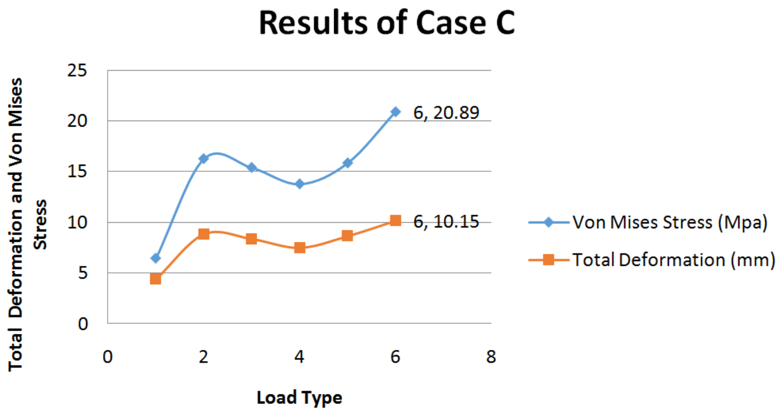
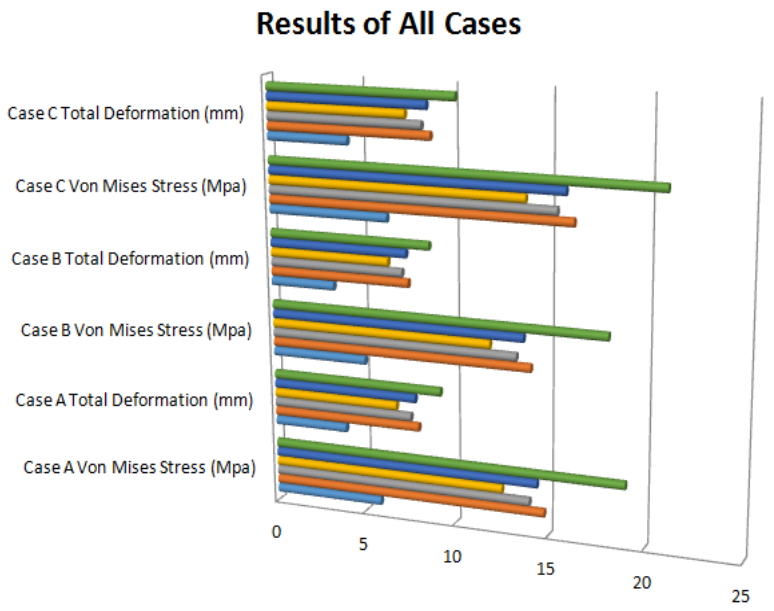


Fig. 19 Graphical plot of Total Deformation and Von mises stress for Case C.

CONCLUSION

The analysis for each Cases A, B and C are performed seperately and analysed one by one. It is seen that stress generation for class B type is less as well as concrete requirement is also low as shown in Figure 20. where each results are analysed and compared with each other. Hence we conclude that this analysis proves that class B type girder is best to be used for bridge construction.



	Case A Von Mises Stress (Mpa)	Case A Total Deformation (mm)	Case B Von Mises Stress (Mpa)	Case B Total Deformation (mm)	Case C Von Mises Stress (Mpa)	Case C Total Deformation (mm)
🟩 Load Combination V	18.998	9.2347	18.0481	8.699	20.89	10.15
🟦 Load Combination IV	14.401	7.8524	13.68	7.45	15.84	8.63
🟨 Load Combination III	12.535	6.811	11.9	6.47	13.78	7.49
⬜ Load Combination II	14.002	7.6081	13.302	7.22	15.4	8.36
🟧 Load Combination I	14.787	8.0317	14.061	7.5632	16.26	8.83
🟦 Class A type	5.87	3.98	5.12	3.45	6.45	4.37

Fig. 20 Graphical plot of Total Deformation and Von mises stress and comparison of each class of girders Class A, B and C.

So, we can finally conclude that the stresses generated in Class B analysis is less and the volume of concrete required is also lesser as compared to others hence class B is economically proven to be the best girder to be used in the construction of Bridges.

FUTURE SCOPE

For this study future scope are following as-
1- Change sizes of top flange and bottom flange and compare.
2- Compare with different type of Concrete mixture grades.

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