COMPARATIVE STUDY OF RECTANGULAR AND TRAPEZOIDAL BOX GIRDER FOR IRC LOADINGS

Dr. P. P. Tapkire[1], Ms. Prajakta G. Pathak[2], Mr. A. S. Chandanshive[3]

[1] H.O.D. Civil Dept., N.B. Navale Sinhgad College of Engineering, Solapur, Maharashtra, India-413255
[2]Master Of Technology Student in Civil Dept., N.B. Navale Sinhgad College of Engineering, Solapur, Maharashtra, India-413255
[3]Lecturer in Solapur Education Society's Polytechnic Solapur, Maharashtra-413002

---***---

Abstract - *Box girder bridges have emerged as a prominent choice in contemporary infrastructure projects due to their superior structural properties and versatility in construction. This paper explores the advantages and applications of box girders, highlighting their ability to resist torsion, accommodate heavier loads, and provide enhanced structural stiffness and strength compared to traditional I-beams. Economy and aesthetics play a significant role in the evolution of box girder designs, with features such as cantilevers and inclined webs enhancing both efficiency and visual appeal. Despite the complexity of analysis involving factors like flexure, shear, torsion, and distortion, box girder bridges remain a preferred choice for spans of up to 150 meters, demonstrating their effectiveness in meeting the demands of modern infrastructure development.*

Key Words: IRC loadings, Box girder bridges, Rectangular box girder, Trapezoidal box girder, Torsional resistance.

1.INTRODUCTION

A box or tubular girder is a girder that forms an enclosed tube with multiple walls, as opposed to an I- or H-beam. Originally constructed of riveted wrought iron, they are now made of rolled or welded steel, aluminum extrusions or prestressed concrete. Compared to an I-beam, the advantage of a box girder is that it better resists torsion. Having multiple vertical webs, it can also carry more load than an I-beam of equal height (although it will use more material than a taller I-beam of equivalent capacity) Box girder bridges are commonly used for highway flyovers and for modern elevated structures of light rail transport. Although the box girder bridge is normally a form of beam bridge, box girders may also be used on cable-stayed and other bridges. A box girder is formed when two web plates are joined by a common flange at both the top and bottom. The closed cell which is formed has a much greater torsional stiffness and strength than an open section and it is this feature which is the usual reason for choosing a box girder configuration. The box girder consists of concrete, steel or a combination of both. Most modern elevated structures are built on the basis of the box girder bridge. Any eccentric load will cause high torsional stresses which will be counter acted by the box section. The analysis of such sections are more complicated due combination of flexure, shear, torsion, distortion. It is used for larger spans with wide cross-section. It can be used for spans up to 150m depending upon the construction methods.

1.1 AIM & OBJECTIVE

This paper aims to find a suitable cross section for different span to depth ratio with various IRC Loading.

- Analysis and design of various sections of box girder for various IRC Loading.
- Different span to depth ratio for trapezoidal and rectangular section must be analyses and design.
- Comparative charts are proposed to prepare for different span to depth ratio and for different cross section.
- Finding effect of span to depth ratio on deformation of Trapezoidal and rectangular cross section girder

1. LITERATURE REVIEW

B. Paval [1] This was a Study of a pre-stressed concrete box girder bridge and to describe the linear, non-linear and time history analysis of this concrete spread box girder superstructure when subjected to different loads simulating the effect of traffic. The prestressed concrete box girder bridge superstructure analysed in the base case consists of two concrete box girders with simple span. The superstructure is loaded by IRC loads and the loads are incremented until the bridge superstructure system fails.

Pragya Soni, Dr. P.S. Bokare [2] In this Paper The use of box-girders was proven to be a very efficient structural solution for highway bridges and flyovers due to its high tensional rigidity, serviceability, economy, aesthetics, and the ability to efficiently distribute the eccentric vehicular live load among the webs of the box-girder. For the multilane bridges, multi-spine/cell box-girders are most adopted in order to limit the local deformations in the top slab of box. It was found that researchers have used finite element method for the analysis of box girder bridge. However, not many studies are available for the design of box Girder Bridge. Hence, this study emphasized on the design and analysis of box girder structure. The literature also indicates that the various researchers have used ANSYS, MIDAS and Staad-Pro for the analysis of Prestressed Concrete Structures using FEM.

Mr. Praveen Naik, Dr. R. Shreedhar [3] In the Thesis two most common types of girders that are used in practice are beam and Box Girders was analysed. Though box girder design is more complicated, it has wide acceptance due to their structural efficiency, aesthetic appearance, better stability, and serviceability. Over years simple RCC box girders used for short spans resulted in long span pre-stressed concrete bridges. The use of pre-stressing enables concrete bridge beams to span long distances. Box girders are constructed in single cell, double cell or multicell. Generally, bridge with a skew angle less than 20° is designed as normal bridge. If it is more than 20° there is change in the behaviour of the skew bridge. The objective of present study is to compare normal and skew bridge of box girder type, with parameter such as bending moments, shear forces & torsional moments for two span deck slabs by considering IRC class AA tracked loading. A simply supported two span, two lane PSC slab bridge deck is considered in the present study. The different bridge spans considered are 50m, 60m and 70 m and skew angle is varied from 0° to 60° at 15°interval. The analysis has been carried out using SAP 2000 software.

Palden Humagai, Pavan Kumar Peddineni [4] In this Study they had worked on segmental pre-cast bridge structure member that was manufactured in several short units which during erection are joined together, end to end, and post- tensioned to form the completed superstructure. Cantilever concrete T-Beam girder bridges composed of precast reinforced and pre-stressed concrete beams with a T- cross section and a cast-in place top slab are frequently used for medium spans due to their competitiveness. The service behaviour of such bridges is very much influenced by their segmental construction, due to time-dependent materials behaviour that makes it difficult.

Vivek P. Joshi Ronak S. Gujjari [5] This paper was presented a literature review related to curved span PSC Box girder. The curvilinear nature of box girder bridges with their complex deformation patterns and stress fields have led designers adopt conservative methods for analysis & design. Recent literature on curved girder bridges to understand the complex behaviour. In the present study an attempt has been made to study the Significance of PSC Box Girders & Type, Curvature effect of span, live load effect, wrapping stress in curved Box girder, Shear Lag & Torsion effect due to curvature. Comparative study of analysis & design of PSC T-girder with PSC Box girder using software Staad - pro, ANSYS, MIDAS and CSI Bridge. Normal & Skew Box Girder with different geometrical combinations has been included.

Punil Kumar M P, Shilpa B. S. [6] This Paper was represented on Analysing the PSC Box girder bridge, statically and dynamically. Here with and without application of dynamic loads, the performance of bridge is studied. The study of bridge with bearing between girder and top of pier are included. By applying moving load, vehicle (or) truck load, pre-stress and axial forces, the effects of bridge model are carefully studied. Determining the actual seismic demand of bridge depends on the behaviour of these models and the importance of bearing between girder and top of pier is taken into consideration. Box girder bridges can have a considerable effect on the behaviour of the bridge especially in the short to medium range of span such as 30m, 40m and 50m. In our project we study the behaviour of box girder bridges with respect to support reaction shear force, bending moment, torsion and axial force under standard IRC Class AA loading and the box girder bridges models analysed by finite element method.

A. Jayasri, V. Senthil Kumar [7] The author worked on study of Bridges range from timber deck on stringers that are supported at each end to very complex designs. Span lengths can vary from 6m (20 feet) to hundreds of meters(feet). The obstacle to be crossed may be a river, a road, railway, or a valley. Structural engineering work consists of designing new structures and repairing or rehabilitating existing ones. The bridge is a structure providing a passage over an obstacle may be for a road, a railway and pipeline. This study is aimed to understand the behaviour of Girder Bridge with two lanes of different span. ANSYS software is used as a tool for the analysis of performance including total deformation, bending moment, shear stress under static and dynamic load.

Selvan V and Gopinath R.S [8] Author had worked on the continued enlargement of route network throughout the globe is basically the results of nice increasing traffic, population, and intensive growth of metropolitan urban areas. This growth has caused several changes within the use and development of assorted varieties of bridges. As Span will increase, dead load is an important increasing factor. To reduce the load, unnecessary material, which is not utilized to its full capacity, is removed out of section, this ends up in the form of box beam or cellular structures, depending upon whether the shear deformations may be neglected or not. "When tension flanges of longitudinal girders area unit connected along, the resulting structure is called a box girder bridge." In this work, a trial was created to comparative study the various shapes of PSC box beam Multi Cell Bridge exploitation CSI Bridge (V-2017). Loading of IRC Class-A is applied and analysis is completed exploitation IRC 112 (2011).

J.S. Kalyan Rama [9] In this research work author had worked on "tension flanges of longitudinal girders which are connected results structure as a box girder bridge." An encompassing review of literature has been made regarding construction and a summary of general specifications with reference to IRC:18 have been discussed in chapter 3. Box girders can be universally applied from the point of view of load carrying, to their indifference as to whether the bending moments are positive or negative and to their torsional stiffness; from the point of view of economy. Analysis principles for torsion and distortion effects are applied to the section selected, and found satisfactory. Correspondingly, the problem has been analysed and designed for flexure and shear by giving due considerations for torsional and distortional effects as a precautionary measure.

Alyaa Shatti Mohan Alhamaidah [10] In this study, a three dimensional straight and horizontally curved pre-stressed box section had been analysed with shell elements using the finite element analysis program ANSYS to examine structural behaviour and load carrying capacity. The box girder under static gravity, pre-stressed and gravity + pre-stressed loading has been analysed. The model which has been investigated in this report is taken from a published paper and expanded to study the effects of curvature under different loads applied (UDLs). The report concludes that the FEA using shell elements can predict the behaviour of box girders with adequate accuracy through the comparisons made between stress results from analytical hand calculations and published work, both for the straight and curved box girder bridges. Further theoretical and analytical investigations have been carried out to study the effects of parameters such as horizontal curvature, pre-stressing, and traffic patterning. For this purpose, a new model was created, modelled with an accurate pre-stress representation, and analysed as a three- dimensional model using the ANSYS.

Sandeep Kumar Ahirwar (2014) [11] the author had presented the various methods to understand the behaviour of Box Girder Bridges. Analysis of this paper indicates need to understand behaviour of box girder bridges with the help of various analytical methods to understand the behavioural aspect.

K, Chethan V R, Ashwini B TPG Student [12] The authors have worked on analysis of box girder bridges under IRC loading. Their discussion was on the Analysis of Box girder bridges under IRC loading of two different types Single1cell and Multi cell with IRC standard codes followed superstructures subjected to load of heavy vehicles using CSi Bridge software 2015 version to know its structural behavior and to decide which standard code is better when comparing the results in determining the economical section in all aspects for the assumed problem Statement. Also, to know about the modeling pattern using CSi bridge and to know the structural behaviour1considering the bridge object responses and horizontal moments of both single cell and multi cell box girders under IRC loading condition.

Rao Jang Sher1a, Muhammad Irfan-ul-Hassan1b, Muhammad Tal. Ghafoor1c, Atif [13] the authors had discussed analysis and design of box and T beam girder has been performed using SAP2000 in order to find out the most suitable type of bridge superstructure. The main objective of this study is to compare the structural behavior; optimization of materials used in each component and cost comparison of box and T beam Girder Bridge. Previous research in this regard is based upon working stress method but this research follows limit state design. Detailed comparison shows that box girder is more suitable as compared to T beam girder even for shorter span in terms of structural stability and cost efficiency.

Gokul Mohandas V. Dr. P. Eswaramoorthi [14] Analysis of Prestressed concrete girder for bridge. The authors had Analysed BOX girder for un-factored Gravity loads and moving vehicular loads as per IRC: 6-2014 and as per IRC: 18-2000. The work discusses about the modeling and analysis pattern of prestressed concrete bridges for different tendon profiles in MIDAS CIVIL software. The curved profile gives reduction in stress level and deflection compared to straight tendon profile.

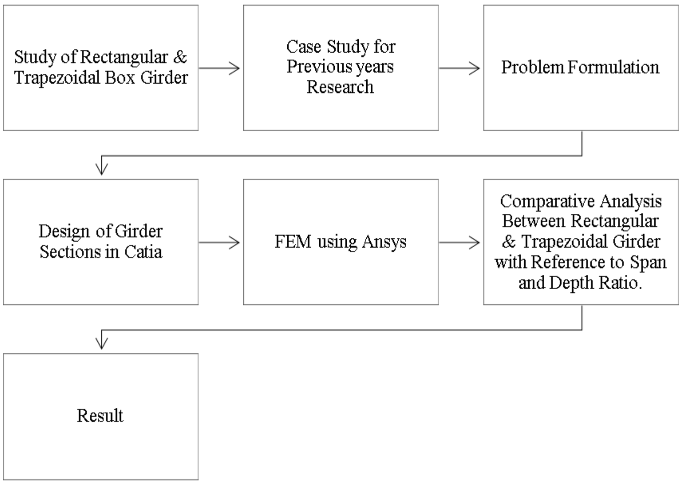
K. Hemalatha, Chippymol James, L. Natrayan, V. [15] the author decided main objective of this paper is to check whether both the T and box girder bridges have adopted for the assumed data with different Span conditions. The present study, a two-lane simply supported RCC Tee beam girder and prestressed concrete box girder bridge analyzed and designed for dead load and IRC moving loads, where the considered moving load is of the tracked vehicle of class A-A loading. Courbon's method adopted for analysis and designing

3. PROBLEM FORMULATION

3.1 General

Structural engineering is closely connected in analysis of civil engineering structures, often analysis can be performed independently with accurate result. A comparative analysis is performed to get best cross section of bridge girder. In previous chapter we have seen about the theoretical formulation of box girder and loading conditions and flow and methodology is discussed in current chapter.

3.2 Flow of Research Work:



3.3 Methodology

The concrete slab is bonded to the bridge deck. A CAM layer is used to join the concrete slab and precast base track. The transverse movement of the precast concrete slab is restricted by the lateral stopper. The concrete slab and the base slab are separated between adjacent girders at the girder end. As a result, the continuous rail fastener system is the only thing keeping the neighbouring girders in place. The deck of the bridge is supported on the Butment and pier using a fixed bearing modelled as a spring element, whose stiffness has been mentioned in Table 3.1. Also, the rail fastener system is modeled as a non-linear spring element with a discrete spacing of 0.6 m.

At every point, two fasteners were attached to the left and right sides of the bottom face of the rail to provide stability and restrict the transverse movement of the rails. The length of the spring element is taken as the thickness equal to that of a rail pad, which is generally 0.085 m. Tables 3.3 and 3.4 show the relationships between the different parts of the model and the size of their mesh. The selection of a reasonable size for various components based on mesh convergence is required for reliable outcomes. The optimum finer mesh was adopted.

3.3.1 Problem statement

Type of Bridge Superstructure	**Rectangular Box Girder Bridge**	**Trapezoidal Box Girder Bridge**
Cross section	Box Girder	Multi celled box girder
Carriageway Width	7.5 m	
Kerbs	600 mm on each side	
Foot Paths	1.25 m wide on each side	
Thickness of wearing coat	80 mm	
Lane of bridge	Two lane	
Longitudinal Girders	4 main girders at 2.5 m interval	
Spacing of cross Girders	5 m	
Cell dimensions		2 m wide by 1.8 m deep
TH. of Top bottom Slab	250 mm & 300mm	300 mm
Overhang Th.	180 mm	180 mm
Thickness of Web	200 mm	300 mm
Span	30, 40, 50, 60m	
Grade of Concrete	M40	
Material	Prestressed Concrete	
Loss Ratio	0.8	
Type of tendons	High tensile strands of 15.2 mm dia. Confirming to IRC: 6006-2000.	
Anchorages Type	27K-15 Freyssinet type anchorages.	
Type of Supplementary r/f	Fe-415 HYSD bars	
Loading Considered	Dead load, wind & Prestress, Class 70R-Wheeled vehicle, and Seismic Forces	
Design of bridge Deck	Class-1 type Design of structure conforming to the codes IRC:6-2014,IRC:21- 2000, IS:1893-1987,IS: 875 (Part-III) – 1987	

3.3.2 Bridge Details

Bridge Details		
Sr No	**Description**	
1	Span of Bridge	30,40,50,60
2	Width of Bridge	8.6 m
3	Lanes	2 Lanes
4	Number of Main Girders	3 No's
5	Total depth	2.495 m
6	Slab thickness (average)	0.26m
7	Type of Loading	IRC class A Train
8	Loads	DL+LL+IL+EQ
9	Strength of Concrete (fck) (M40)	30000 KN/m^2
10	Modulus of Elasticity $E=5000\sqrt{fck}$ $E=5000\sqrt{30} = 30000\ N/mm^2$	27386128 KN/m^2
11	Poisson's Ratio of Concrete	0.18
12	Type of Analysis	Linear & Nonlinear
13	PRESTRESS TENDON	Freyssinet 12/7
14	Prestressing Force	1400 KN

Table 4.1 Bridge Details

4. RESULTS

4.1 General

For multilane bridges box girders are the most adopted structural form. The parameters are varying which influences structural performance of box girders, the extensive research survey indicates various parameters as mentioned in the previous chapter. Considering various parameters flow of study also discussed in the previous chapter. Considering these various parameters two cross section of box girder i.e., Trapezoidal box girder and rectangular box girder is finalized for study. The combination of span to depth ratio and IRC loadings for different spans are analysed using the Finite Element Method and the cases and results obtained are discussed in the subsequence section.

5.2 Cases Considered for study

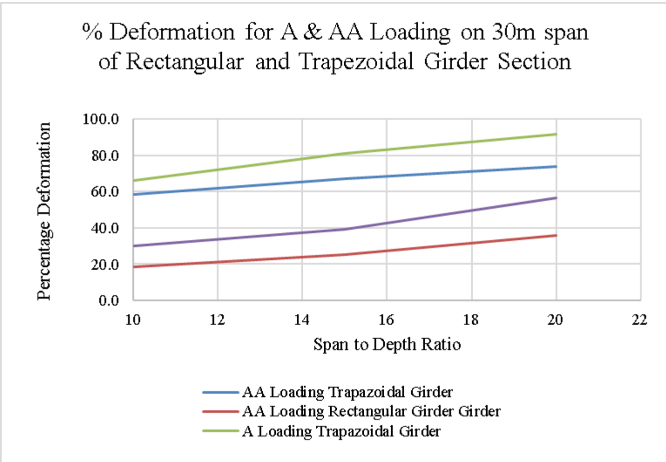
From the literature review various parameters influencing box girder performance are identified and combine effect of these parameter is selected as a task, with this objective rectangular and trapezoidal cross section of box girder for span 30m, 40m, 50m & 60m for loading class AA & class A variation of actual deflection in comparison with permissible value are plotted and observation are noted in previous section also variation in shear stresses is studied and observation are worked out. Based on observations mentioned in previous subsection conclusions are drawn which are mentioned in subsequent chapters. The cases obtained from combination of above parameters are studied, and for comparison following terms are defined.

- Various Span and varying depth of girder.
- Study of maximum shear stress for Class A and Class AA loading.
- Study of Deflection for Class A & Class AA loading.

4.3 Effect of span to depth ratio on deformation for rectangular and trapezoidal box girder

As discussed in previous section various cases are studied for considering wearing span and Debt the cross section are analysed using finite element package maximum deformation are worked for each section. The variations of deformation are plotted for considering class a loading and class AA loading for different spans. Variations are plotted considering 2D parameters. The ratio of actual deformation to permissible formation is calculated and various S/D are considered to differentiate changes that occur.

4.3.1. Variation of deformation for class A and class AA loading for 30m span



G1- <u>Percentage Deformation for A & AA Loading on 30m span of Rectangular and Trapezoidal Girder Section</u>

<u>Observations:</u>

From the above graph following points are noted.

As span to depth ratio increases deformation also increases

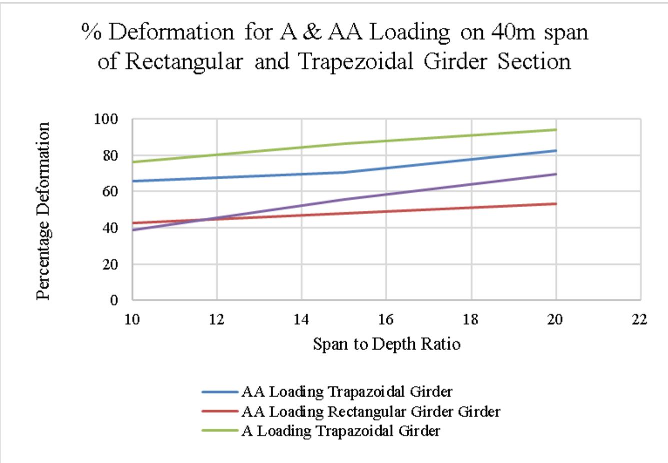
The deformation ratio for class AA loading is on higher side as compared to class A loading for considering C/S.

Rectangular C/S shows lower deformation compared to trapezoidal C/S for all span to depth ratio considered in section.

Almost 20% deformation ratio increases for span to depth ratio of rectangular C/S from 10 to 20. There are slightly higher values after 15 span to depth ratio in both type of loading.

For trapezoidal C/S linear variation is observed for AA loading and deformations slightly increases after 15 span to depth ratio

4.3.2 Variation of deformation for class A and class AA loading for 40m span.



G2- <u>Percentage Deformation for A & AA Loading on 40m span of Rectangular and Trapezoidal Girder Section</u>

<u>Observations:</u>

From the above graphs following points are noted.

1. As spent to depth ratio increases deformation also increases

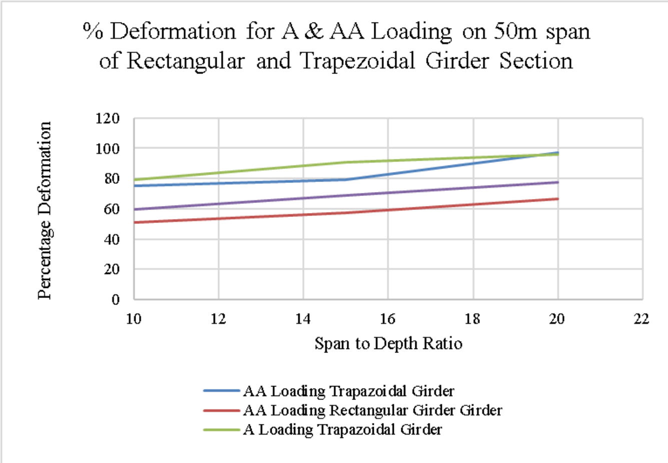
2. The deformation ratio for class AA loading is on lower side as compared to class A loading for considering C/S

3. Rectangular C/S shows lower deformation compared to trapezoidal C/S for all span to depth ratio considered in section

4. Deformation percentage of rectangular girder in A loading is almost increased by 10% as compared with AA loading, also 10% lower than A loading of trapezoidal girder.

5. It seems that almost 20% difference of deformation percentage in trapezoidal girder section and rectangular girder section

4.3.3 Variation of deformation for class A and class AA loading for 50m span.



G3- <u>Percentage Deformation for A & AA Loading on 50m span of Rectangular and Trapezoidal Girder Section</u>.

<u>Observations:</u>

From the above graph following points are noted.

1. As spent to depth ratio increases deformation also increases

2. The formation ratio for class AA loading is on the lower side as compared to class A loading for considering C/S, especially rectangular girder C/S.

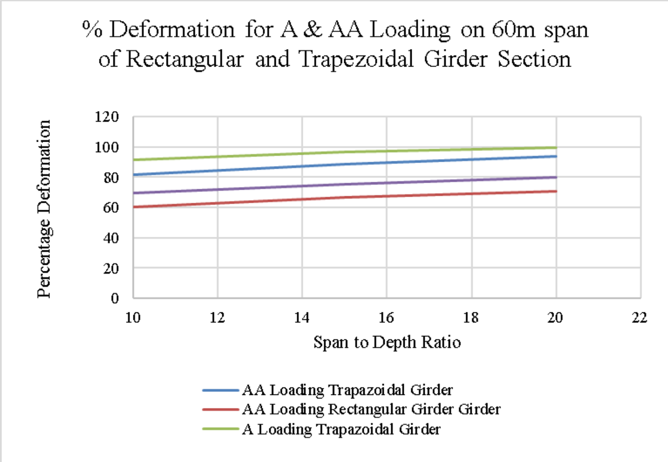
3. Rectangular C/S shows lower deformation compared to trapezoidal C/S for all span to depth ratio considered in section

4. In the trapezoidal section for lower span to depth ratio difference of % has been recorded in A loading and AA loading. For mid snap to depth ratio around % of difference has been recorded.

5. As we go for higher span to depth ratio the deformation percentages between trapezoidal section A loading and AA loading recorded almost the same.

6. For rectangular C/S the difference variation of deformation is observed almost the same for AA loading and A loading for all span to depth ratio.

4.3.4 Variation of deformation for class A and class AA loading for 60m span



G4- Percentage Deformation for A & AA Loading on 60m span of Rectangular and Trapezoidal Girder Section

Observations:

From the above graph following points are noted.

As spent to depth ratio increases deformation also increases

The formation ratio for class AA loading is on lower side as compared to class A loading for considering C/S

Rectangular C/S shows lower deformation compared to trapezoidal C/S for all span to depth ratio considered in section

For this span the trapezoidal section reaches its deformation limit for A class loading specified by IRC in higher span to depth ratio

5. CONCLUSIONS

Effect of span to depth ratio on deformation for rectangular and trapezoidal box girder

1. From the variation of different loading it is concluded that deformation due to loading A is on a higher side that of loading AA.

2. As the span to depth ratio increases the deformation percentage also increases.

3. For span to depth ratio 10 for all spans the deformation percentage values are ranging from 40% to 80% for both the cross sections, except 30m span which shows deformation percentage values ranging from 20% to 70% for all classes of loadings.

4. For 40m, the percentage deformation in the rectangular girder is likely the same for the 10 and 15 span to depth ratio for class A and class AA loading. And then the deformation ratio in the loading rectangular cross section increased.

5. For 50m span, the percentage deformation in triazolide girder is likely the same for 10 and 20 span to depth ratio for class A and class AA loading. And then the deformation ratio in A loading for the same increased.

6. For a 60m span, the percentage deformation increases gradually for both the class loading.

7. From the discussion of results, it is concluded that the percentage deformation in the rectangular cross section is approximately 20% less than that of the trapezoidal cross section for all types of loading as well as all types of span to depth ratio.

REFERENCES

[1] Hassan A. Saab (1990), "Non-linear finite element analysis of steel frames in fire conditions", University of Sheffield.

[2] Elsayed Mashaly, Mohamed El-Heweity *, Hamdy Abou-Elfath, Mohamed Osman (2010), "Finite element analysis of beam-to-column joints in steel frames under cyclic loading", Alexandria Engineering Journal.

[3] R.A. Hawileh, A. Rahman, H. Tabatabai (2009), "Nonlinear finite element analysis and modeling of a precast hybrid", University of Wisconsin-Milwaukee, Applied Mathematical Modelling 34 (2010) 2562–2583.

[4] M. R. Mohamadi-Shoore, H. Ghafari, M. Amankhani (2013), "Finite Element Modeling of RHS Splice Beam Bolted Connections", Indian Journal of Science and Technology.

[5] Mr. Vishawadeep Shivaji Ghodajkar, Dr. R.M. Sawant (2018), "FEM Analysis of Steel Beam Column Joint by using Cantilever Weight and Acceleration", Journal of Ceramics and Concrete Sciences Volume 3 Issue 3.

[6] Kuldeep Kaushik, Avadesh K. Sharma, Rishi Kumar (2013), "A Review on Finite Element Analysis of Beam to Column Endplate Bolted Connection.", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 8, Issue 1 (Jul. - Aug. 2013), PP 97-103.

[7] Mr. Chintamani N. Khadake, Dr. Prashant M.Pawar (2020), "Finite element analysis of beam column joint in reinforced concrete structure." International Research

Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 07 Issue: 07 | July 2020.

[8] Kathirvel Murugan K R V, Satheshkumar K. (2016), "ANALYTICAL & EXPERIMENTAL STUDY ON STRUCTURAL STEEL CONNECTIONS USING COMPONENT BASED FINITE ELEMENT MODEL", International Journal of Engineering Science Invention Research & Development; Vol. II Issue XI May 2016.

[9] Balamuralikrishnan R., Saravanan J. (2019), "Finite element analysis of Beam – Column joints reinforced with GFRP reinforcements.", Civil Engineering Journal Vol. 5, No. 12, December, 2019.