COMPARATIVE ANALYSIS OF TWO AND THREE CELL RECTANGULAR AND TWO AND THREE CELL TRAPEZOIDAL PRESTRESSED BOX GIRDERS USING SAP 2000 SOFTWEAR

Shahrukh Mansoori[1], Sumit Singh Shekhawat[2]

[1]*Shahrukh Mansoori, Department of Civil Engineering, SD Bansal Collage, Indore, Madhya Pradesh, INDIA*
[2] *Sumit Singh Shekhawat[2], Department of Civil Engineering, SD Bansal Collage, Indore, Madhya Pradesh, INDIA*

---***---

Abstract A bridges are the backbone of our nation from where we divert the traffic easily and many types of bridges are constructed now a days, as traffic problems are increasing day by day ,to control the traffic we need to underpass and overpass the traffic and control the traffic in areas through bridges, and box girders are the elements which are used in various kinds of bridges, box girder type bridges are gaining popularity in bridge engineering fraternity because of its better stability, serviceability, economy, aesthetic appearance, structural efficiency and rigidity in torsion.

In this study, two different box girders bridge cross sections, rectangular and trapezoidal, are analyzed, designed and compared. The purpose of this study is to find out the efficient cross-section of box Girder Bridge. A comparative study is done on concrete two cell and three cell rectangular and two and three cells trapezoidal box girder using SAP2000 software. for three cell and two cell rectangular and trapezoidal girders the various parameters like torsion, bending moment , shear force, deflection, about different axis, and modal frequencies of entire girder span is studied.

It is observed from the study that two cell box girders are more effective than three cell girders as rectangular and trapezoidal. the shear force and moment of three cell rectangular and trapezoidal girders is more than two cell rectangular and trapezoidal girders and the two cell rectangular and trapezoidal box girders have less frequency and stiffness than three cell rectangular and trapezoidal box girders

Key Words: **rectangular box girders, trapezoidal box girders, stiffness, torsion, modal frequencies, shear force, Eigen value.**

1. INTRODUCTION

1.1 General Description of Box Girders

The bridge network expansion throughout the globe is mainly due to increase in population and traffic, and extensive growth of the metropolitan cities. The growth rate of traffic and population has led to many changes in development of various kinds of bridges, girders etc. The box girders are used in various types of bridges as suspension, cable stayed, beam, cantilever and truss type bridges. Every bridge use different construction techniques and material properties for different types of span and the application of bridges. By increasing the span the dead load also increases. To reduce the dead load, the ineffective materials, which is not utilized to its full capacity are removed from the cross-section. Therefore it leads to box girder or cellular type structure.

By joining two web plates with a common flange at both the top end and the bottom end of a bridge a box girder is formed. Box girder is a bridge in which a girder in shape of hollow box works as a main beam. Prestress can not only enhance the spanning capacity of bridges but also restrain the development of cracks and improve the durability of bridges

1.2 Girder Historical Development and Description

The first prestressed concrete bridges were most of I-sections and were build towards the end of the 1920's. After that the great breakthrough was achieved after 1945. The bridge over the river Maas "THE SCLAYN" which was built by magnel in 1948, was the first continuous prestressed concrete box –girder bridge with 2 spans of 62.70m.Within the following years the ratio of wages to the costs of girder cross-section evolved structurally from the hollow cell-deck bridge or T-beam bridges, so the area of compression zone extended throughout the entire length of the bridge according to the requirement at the central piers and because of the advantages transverse load-carrying characteristics.

The first girder box cross section possessed deck slabs that cantilevered out slightly from the box to the position using the prestressed concrete the length of cantilever could be increased and the number of members could reduce in the form of work cost that will caused the reduction in the number of cells. To reduce the construction loads to the minimum possible extent one longitudinal girder is sufficient for multiple traffic lanes.

1.2 Evolution of Box Girders

The evolution in box girder is due to the increase in the span and the width which increases the beams and bottom slabs to be tied to keep the geometry. The high torsional stresses occur due to eccentric load. The analysis of such sections are more complicated due to the combination of flexure, shear, torsion, distortion. But it is more efficient cross-section. The wide cross-section is used for larger spans. For the spans upon 150m it can be used depending upon the construction methods cantilever method of construction is preferred most.

As stated by the box girder are more advisable for longer spans and wider decks, box girders are to be suitable cross-section. They are aesthetic and svelter. Due to Economy and elegant further leads to the evolution of cantilevers in top flanges and inclined webs in external cells of the box girder. The dimension of cell could be controlled by prestressing.

1.4 Box Girder Bridge Deck

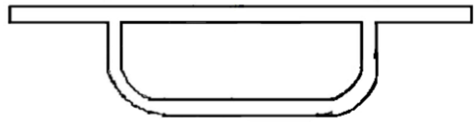
A box girder is a monolithic structure with two slabs, top and bottom slabs connected by two or more vertical stems called web that may be inclined or vertically placed as desired. This closed structure is efficient to deliver greater torsional stiffness and strength than typical open structure. A cellular hollow structure that which reduce the dead load of bridge deck and used for greater span and maintaining economy. An element of bridge in which the main beams comprises in box shaped structure and this type of bridge is called box girder bridge.

The following cross-sections of box girders shown below as:

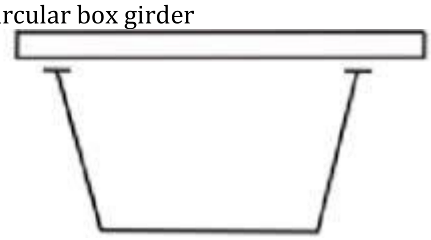
1) Rectangular box girder: -

.

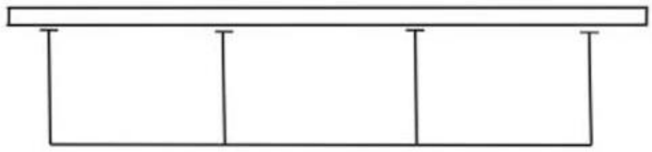
. 2) Trapezoidal box girder



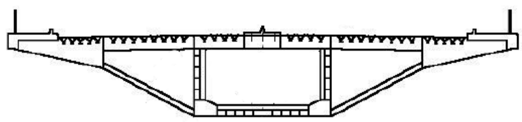
3) Circular box girder



4) Single cell box girde



5) Multi-cell box girder



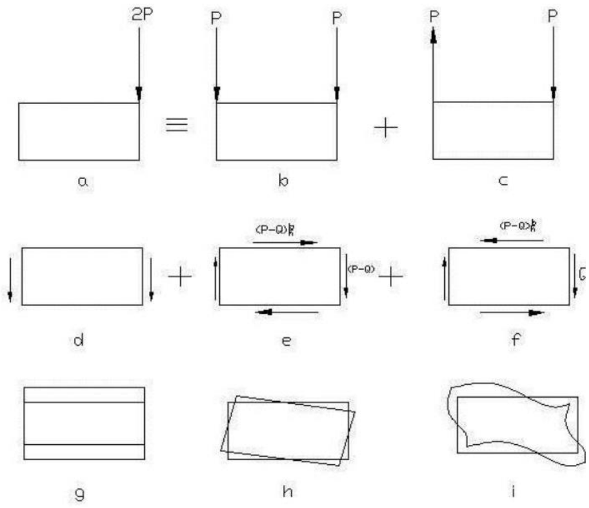
6) Single cell box girder with struts

1.5 Advantages of box girder bridge

- It is having Greater stiffness against torsion compared to normal girder bridge.
- The Overall depth of box girder bridge is less as compared to plate girder bridge.
- Box girders are more efficient in curved bridge, skewed bridge as compared to plate girders and many more bridge.
- The Large span to depth ratio can be obtained for box girder bridge.
- It is economical and cost effective than any other type.
- It has high structural efficiency than any other type of bridge

1.6 Disadvantages of box girder bridge

- The fabrication of Box girder are expensive .
- Box girders are not efficient as trusses of longer span.
- The Design part of box girder is complex.
- The transportation of box girder is difficult.
- It is difficult to cast in situ box girder due to inaccessibility to the bottom slab and need to extract internal shutter in casting box girder.



Torsional warping ` Distortion

Torsional wraping and distortion

1.7 Box Girders analyzing methods

There are some methods for the analysis of box girder bridges are as follows:

1. Simple line analysis or beam analysis of Box Girder
2. Grillage analysis of Box Girder
3. Beams on elastic foundation analysis of Box Girder
4. Space frame analysis of Box Girder
5. Finite element analysis of Box Girder

1 Methodology and Modeling

Box Girder Bridges analysis

- finite element method is more accurate method for analyzing box girder bridge of different shapes and cells. The project is performed to compare the two cell and three cell rectangular and two cell and three cell trapezoidal box cell girder. In this project 35 m span of girder bridge will be taken for static and dynamic analysis of girder. In dynamic analysis of girder the dead load, live (vehicle) load, prestressed load and earthquake load will be considered in design . box girders of different shapes and cells will be analyzed using the model designed in SAAP 2000 software and the results for the deformation, moment, shear and stresses, Deflection, for different models will be computed and results are shown by plotting graphs of different models.

Loads Calculation of Bridge Design as Per IRC 6:2016 Section II

The loads that are to be considered on the superstructure of a box girder bridge as per IRC 6:2000 are listed below: -

A. Permanent Loads:
   - Dead loads
   - Superimposed dead loads

B. Temporary Loads
   - Vehicle loads
   - Earthquakes loads
   - Wind forces
   - Channel forces
   - Centrifugal forces
   - Impact forces
   - Construction loads

C. Deformation Loads
   - Creep
   - Shrinkage
   - Settlement
   - Uplift forces
   - Thermal forces

D. Group Loading Combinations

All these loads are present in bridge construction, for present study of multi-cell box girders, the scope is limited to dead load, live load , prestressed load and earthquake load only.

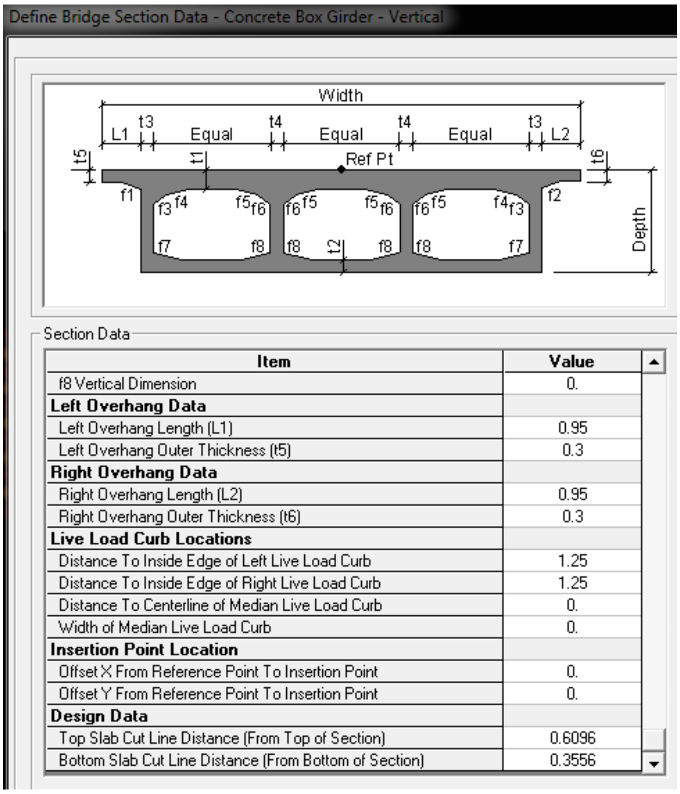
2 Design Parameters

- A box girder for 2 lane national highway bridge of total 12 m wide deck and further data given below as per IRC 6 table 6:
- Type of support: - simply supported.
- length: - 40 m
- Carriageway width: - 8m
- Foot path width: - 1.5 m
- load type: - (IRC 6 & IRC 18:2000) code of bridge.
- Concrete grade: M40 for both the cell types.

Design Specifications of Models:

Let the dimensions of girder section are as given below:

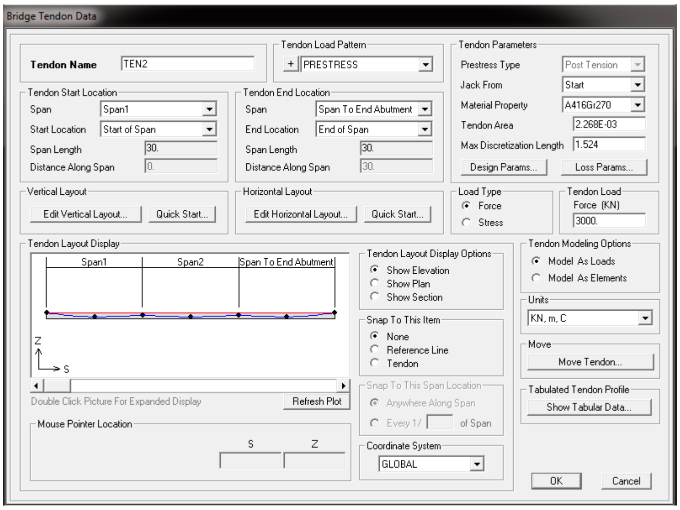
- Depth of web =1.725 m dw
- Thickness of web = 0.3 m tw
- Width of top flange = 12 m w
- t Thickness of top flange =0.325m tt
- Width of bottom flange = 8.15m wb
- Thickness of bottom flange =0.325 m tb


Define Bridge Section Data - Concrete Box Girder - Vertical

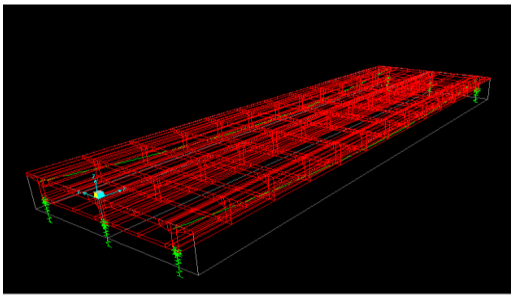
Section Data

Item	Value
f8 Vertical Dimension	0.
Left Overhang Data	
Left Overhang Length (L1)	0.95
Left Overhang Outer Thickness (t5)	0.3
Right Overhang Data	
Right Overhang Length (L2)	0.95
Right Overhang Outer Thickness (t6)	0.3
Live Load Curb Locations	
Distance To Inside Edge of Left Live Load Curb	1.25
Distance To Inside Edge of Right Live Load Curb	1.25
Distance To Centerline of Median Live Load Curb	0.
Width of Median Live Load Curb	0.
Insertion Point Location	
Offset X From Reference Point To Insertion Point	0.
Offset Y From Reference Point To Insertion Point	0.
Design Data	
Top Slab Cut Line Distance (From Top of Section)	0.6096
Bottom Slab Cut Line Distance (From Bottom of Section)	0.3556

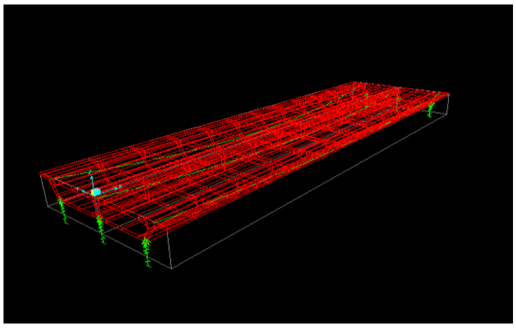
Bridge section data of Girder Bridge



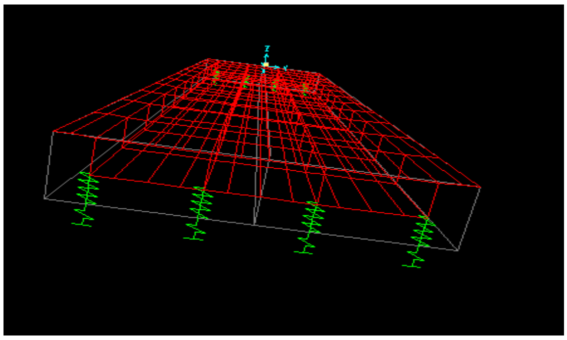
Bridge Tendon data



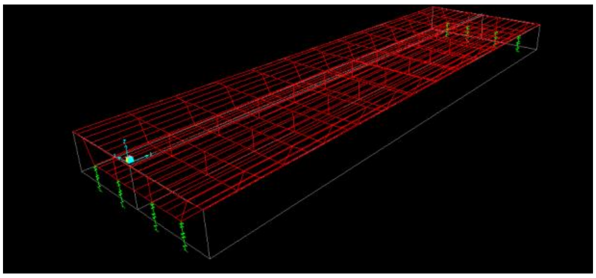
3 D View of 2 cell rectangular box girder



3D View of 2 cell trapezoidal box girder



3 D View of 3 cell rectangular box girder



3 D View of 3 cell trapezoidal box girder

3. RESULT AND DISCUSSION

The percentage variations of different accelerations static and dynamic and shear and moment and frequency between different cell girders as well as different shape of girders is observed from the graphs above and mentioned below as :

1.The percentage variation Ux between 2 cell and 3 cell rectangular girder observed as 0.05%

2. The percentage variation Ux between 2 cell and 3 cell trapezoidal girder observed as 0.05%

3. The percentage variation Ux between 2 cell rectangular and 2 cell trapezoidal girder observed as 0.02%

4. The percentage variation Ux between 3 cell rectangular and 3 cell trapezoidal girder observed as 0.0002%

5.The percentage variation Uy between 2 cell and 3 cell rectangular girder observed as 0.3 %

6. The percentage variation Uy between 2 cell and 3 cell trapezoidal girder observed as 0.25 %

7. The percentage variation Uy between 2 cell rectangular and 2 cell trapezoidal girder observed as 0.01%

8. The percentage variation Uy between 3 cell rectangular and 3 cell trapezoidal girder observed as 0.03 %

9.The percentage variation Uz between 2 cell and 3 cell rectangular girder observed as 0.02%

10. The percentage variation Uz between 2 cell and 3 cell trapezoidal girder observed as 0.02%

11. The percentage variation Uz between 2 cell rectangular and 2 cell trapezoidal girder observed as 0.0002%

12. The percentage variation Uz between 3 cell rectangular and 3 cell trapezoidal girder observed as 0.0002%

13. The percentage variation dynamic Ux between 2 cell and 3 cell rectangular girder observed as 0.21%

14. The percentage variation dynamic Ux between 2 cell and 3 cell trapezoidal girder observed as 0.37%

15. The percentage variation dynamic Ux between 2 cell rectangular and 2 cell trapezoidal girder observed as 0.75 %

16. The percentage variation dynamic Ux between 3 cell rectangular and 3 cell trapezoidal girder observed as 0.01

17. The percentage variation dynamic Uy between 2 cell and 3 cell rectangular girder observed as 3.56

18. The percentage variation dynamic Uy between 2 cell and 3 cell trapezoidal girder observed as 4.33

19. The percentage variation dynamic Uy between 2 cell rectangular and 2 cell trapezoidal girder observed as 2.45

20. The percentage variation dynamic Uybetween 3 cell rectangular and 3 cell trapezoidal girder observed as 0.35

21.The percentage variation dynamic Uz between 2 cell and 3 cell rectangular girder observed as 0.40

22. The percentage variation dynamic Uz between 2 cell and 3 cell trapezoidal girder observed as 0.60

23. The percentage variation dynamic Uz between 2 cell rectangular and 2 cell trapezoidal girder observed as 0.05

24. The percentage variation dynamic Uz between 3 cell rectangular and 3 cell trapezoidal girder observed as 0.12

25.The percentage variation V2 between 2 cell and 3 cell rectangular girder observed as 72.40

26. The percentage variation V2 between 2 cell and 3 cell trapezoidal girder observed as 90.45

27. The percentage variation V2 between 2 cell rectangular and 2 cell trapezoidal girder observed as 75.71

28. The percentage variation V2 between 3 cell rectangular and 3 cell trapezoidal girder observed as 92.65

29.The percentage variation V3 between 2 cell and 3 cell rectangular girder observed as 7.02

30. The percentage variation V3between 2 cell and 3 cell trapezoidal girder observed as 7.05

31. The percentage variation V3 between 2 cell rectangular and 2 cell trapezoidal girder observed as 80.92

32. The percentage variation V3 between 3 cell rectangular and 3 cell trapezoidal girder observed as 75.70

33.The percentage variation M2 between 2 cell and 3 cell rectangular girder observed as 7.85

34. The percentage variation M2 between 2 cell and 3 cell trapezoidal girder observed as 30.45

35. The percentage variation M2 between 2 cell rectangular and 2 cell trapezoidal girder observed as 80

36 The percentage variation M2 between 3 cell rectangular and 3 cell trapezoidal girder observed as 85.45

37.The percentage variation M3 between 2 cell and 3 cell rectangular girder observed as 70.35

38. The percentage variation M3 between 2 cell and 3 cell trapezoidal girder observed as 90

39. The percentage variation M3 between 2 cell rectangular and 2 cell trapezoidal girder observed as 75.95

40. The percentage variation M3 between 3 cell rectangular and 3 cell trapezoidal girder observed as 90.65

41.The percentage variation frequency between 2 cell and 3 cell rectangular girder observed as 20.45

42. The percentage variation frequency between 2 cell and 3 cell trapezoidal girder observed as 15.25

43. The percentage variation frequency between 2 cell rectangular and 2 cell trapezoidal girder observed as 0.28

44. The percentage variation frequency between 3 cell rectangular and 3 cell trapezoidal girder observed as 4.65

45.The percentage variation circular frequency between 2 cell and 3 cell rectangular girder observed as 15.40

46. The percentage variation circular frequency between 2 cell and 3 cell trapezoidal girder observed as 15.68

47. The percentage variation circular frequency between 2 cell rectangular and 2 cell trapezoidal girder observed as 0.65

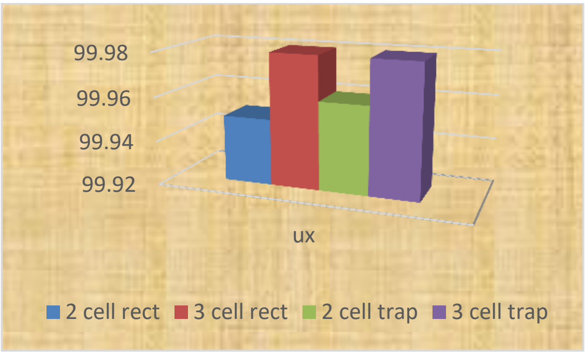
48. The percentage variation circular frequency between 3 cell rectangular and 3 cell trapezoidal girder observed as 2.05

49.The percentage variation eigen value between 2 cell and 3 cell rectangular girder observed as 0.75

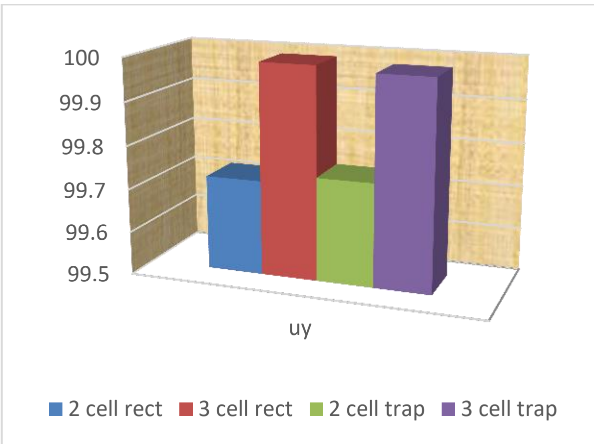
50. The percentage variation eigen value between 2 cell and 3 cell trapezoidal girder observed as 35

51. The percentage variation eigen value between 2 cell rectangular and 2 cell trapezoidal girder observed as 0.69

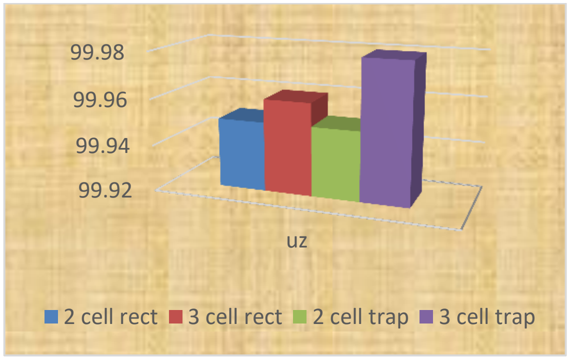
52. The percentage variation eigen value between 3 cell rectangular and 3 cell trapezoidal girder observed as 40.73



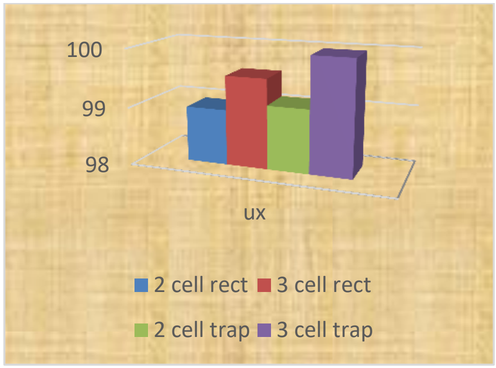
Static acceleration (Ux) variation between 2 and 3 cell rectangular and trapezoidal girder



Static acceleration (Uy) variation between 2 and 3 cell rectangular and trapezoidal girder



Static acceleration (Uz) variation between 2 and 3 cell rectangular and trapezoidal girder



Dynamic horizontal acceleration (Ux) variation between 2 and 3 cell rectangular and trapezoidal girder

4. CONCLUSIONS

In the above project the different models of two cell and three cell rectangular as well as trapezoidal girder of 40 m span for different loads and load condition is performed and different variations in terms of static and dynamic acceleration , shear force ,frequencies and moments were observed from the graphs above and disscussions above the following conclusions are drawn.

1.The two cell trapezoidal girders and rectangular girders have more frequencies,circular frequencies and eigen value than three cell rectangular and trapezoidal girders from this we observe that as the cell of girders increases the frequencies of girder bridge decreases and eigen values of girder decreases therefore two cell girders are more efferctive than three cell girders rectangular and trapezoidal.

2.The shear force and moment of three cell rectangular and trapezoidal girders is more than two cell rectangular trapezoidal and rectangular girders from this we observe that as moment is more in three cell girder the reinforcement provided should be more therefore it not effective to construct a three cell girder and two cell rectangular and trapezoidal girder is more effective than three cell rectangular and trapezoidal girder.

5. REFERENCES

1. Paul J. Barr, Marc O. Eberhard, and John F. Stanton (2001):- "Live-Load Distribution Factors In Prestressed Concrete Girder Bridges".

2. Khaled M. Sennah, J. B. (2002). Literature Review in Analysis of Box-Girder Bridges. Journal of Bridge Engineering, 134-143

3. P.K. Gupta, K. K. (2010). Parametric Study On Behaviour of Box-Girder. Asian Journal of Civil Engineering (Building and Housing), 135-148.

4. Vikash Khatri, Pramod Kumar Singh and P.R.Maiti (2012) :- "Comparative study of prestressed steel – concrete composite bridge of different span length and girder spacing".
5. Amit Saxena, Dr. Savita Maru (2013):- "Comparative Study of the Analysis and Design of T-Beam Girder and Box Girder Superstructure".

6. Vishal U. Misal, N. G. Gore, P. J. Salunke (2014) :- "Analysis and Design of Prestressed Concrete Girder".

7. Ajith Kumar R., Dr. J. K. Dattatreya (2015) :- "Study on the Structural Behaviour and Design of a Typical Single Cell Post Tensioned Concrete Box Girder Bridge".

8. B.Paval (2015):- "Analysis of Multi-Cell Prestressed Concrete Box-Girder Bridge".

9. Chetan T Naik , Dr.M M Achar , K Lakshmi(2015) :- "Analysis and Design of Multi Cell Post-Tensioned PSC Box Girder".

10. Jefeena Sali, Kashif Quamar Inqualabi, Reji P Mohan (2015) :- "Parametric Study of Behavior of Box Girder Bridges Under Different Radius of Curvature".

11. Mayank Chourasia, Dr. Saleem Akhtar (2015) :- "Design and Analysis of Prestressed Concrete Box Girder by Finite Element Method (4 Cells & 1 Cell)".

12. Payoshni Mali, Shilpa Kewate, Savita Lokare (2015) :- "Comparison of Rectangular and Trapezoidal sections of Post Tensioned Box Girder".

13. Pranathi Reddy, Karuna S. (2015): - "Comparative Study on Normal and Skew Bridge of Psc Box Girder".

14. Karthika Santhosh, Prof. P Asha Varma (2016):- "Parametric Study on Behaviour of Box Girder Bridges with Different Shape Based On Torsion".

15. Phani Kumar.Ch, S.V.V.K.Babu (2016):- "Analysis and Design of Prestressed Box Girder Bridge by IRC: 112-2011“

16. Punil Kumar M P, Shilpa B S(2016) :- “Dynamic analysis of box girder bridges”.

17. Pampana Geetha Ramesh, Dr. P. V. Surya Prakash (2018): - “Comparative Study on Concrete rectangular and Trapezoidal Box Girder (Single & Double Cells) Bridges Using Finite Element Method”.