International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 6, June-2018

Assessment of Structural Performance of Single V/S Multi Cell PSC Box Girder with and without Transverse Prestressing for 6 Lane Bridge

Manan S. Shah[1], Ankit M. Asher[2], Dr.M.M.Murudi[3]

[1]Civil Engineering Department, Sardar Patel College of Engineering, mananshah.professional@gmail.com
[2]Civil Engineering Department, Sardar Patel College of Engineering, ankitst.asher@gmail.com
[3]Civil Engineering Department, Sardar Patel College of Engineering, m_murudi@spce.ac.in

Abstract— ***Infrastructure plays vital role in any developing country's economic growth. Especially country like India where there is a huge demand of development of highway and railway bridges for the better connectivity. Prestressed Concrete Box girder i.e. PSC box girder is very common type of superstructure used in worldwide generally for the span ranging from 45m to 180m depending on construction method. Apart from that there are many long width deck bridges i.e. 6-lanes, 8-lanes etc. are coming up in India to control rapidly increasing traffic problem. In the present study, 6 different configurations are compared for the fixed six lane simply supported bridge i.e. 27.6 m deck Width Bridge having 50 m span. Out of 6 configurations, one configuration is taken with transverse prestressing of deck slab and in the rest of 5 configurations, one is single cell with and without internal strut, one is double cell with and without external strut and one is taken as triple cell. In all configurations results of transverse analysis and longitudinal analysis are compared and all calculations are as per IRC 112:2011 and IRC 6:2017.***

Keywords— Transverse prestressing, PSC box girder, Single V/S Multi cell, IRC 112:2011, IRC 6:2017,Internal strut, External strut

I. INTRODUCTION

The continuing expansion of highway network throughout the world is largely the result of great increase in traffic, population and extensive growth of metropolitan urban areas. As span increases, dead load is an important increasing factor. To reduce the dead load, unnecessary material, which is not utilized to its full capacity, is removed out of section, this results in the shape of box girder or cellular structures, depending upon whether the shear deformations can be neglected or not.so we can say that when tension flanges of longitudinal girders are connected together, the resulting structure is called a **box girder** bridge.

The box girder normally comprises either prestressed concrete, structural steel, or composite of steel and reinforced concrete. It typically rectangular or trapezoidal in cross section. Nowadays these box girders are used in flyovers, elevated metro bridges casted by segmental construction or integral one. The following diagram shows the evolution of box girder.

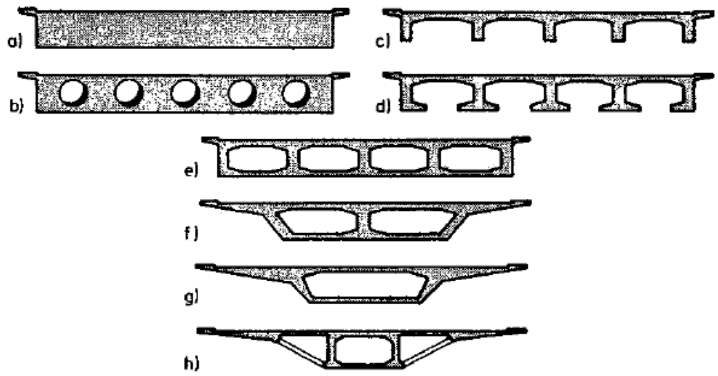


Figure 1 Evolution of box girder

The following table summarise the structural action involved in the design of box girder.

Structural action	Structural response
Longitudinal bending	• **Flexural stress in longitudinal direction** • **Shear stress**
St. Venant torsion	• **Torsional shear stress** • **Warping stress in longitudinal direction**
Transverse bending(Distortion)	• **Flexural stress in transverse direction** • **Normal stress in transverse direction** • **Warping stress in longitudinal direction** • **Shear stress**
Torsional warping	• **Warping Shear stress**
Distortional warping	• **Warping Shear stress**
Shear lag	• **Longitudinal stresses at the junction of web and top slab**

Table 1 Structural actions and response in the design of box girder

II. METHODOLOGY

The prestressed concrete box girder bridge is analysed in the present study using softwares. The software is **MIDAS (Civil)** for longitudinal analysis and **STAAD Pro.** For transverse analysis. The analysis and design of PSC box girder is based on IRC-112:2011 and load calculation is based on IRC-6:2017.The following diagram shows the typical methodology adopted in the present study.

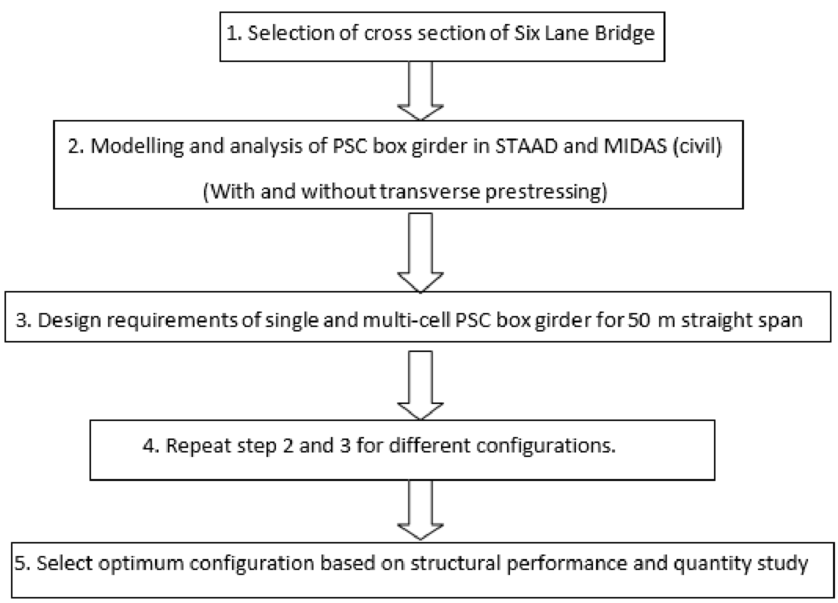


Figure 2 Flow Chart Showing the Methodology Adopted in the Present Study

Analysis of box girder contains two parts i.e. transverse analysis and longitudinal analysis. In the present study concept of **effective width** for the live load dispersion on deck width is used as given in Annexure B-3 of IRC 12:2011.Load combination for design is used as **1.35 DL+1.5 LL + 1.75 SIDL**.The following diagram explains the concept of effective width and all notations are as per formulas given in Annexure B-3 of IRC 12:2011.

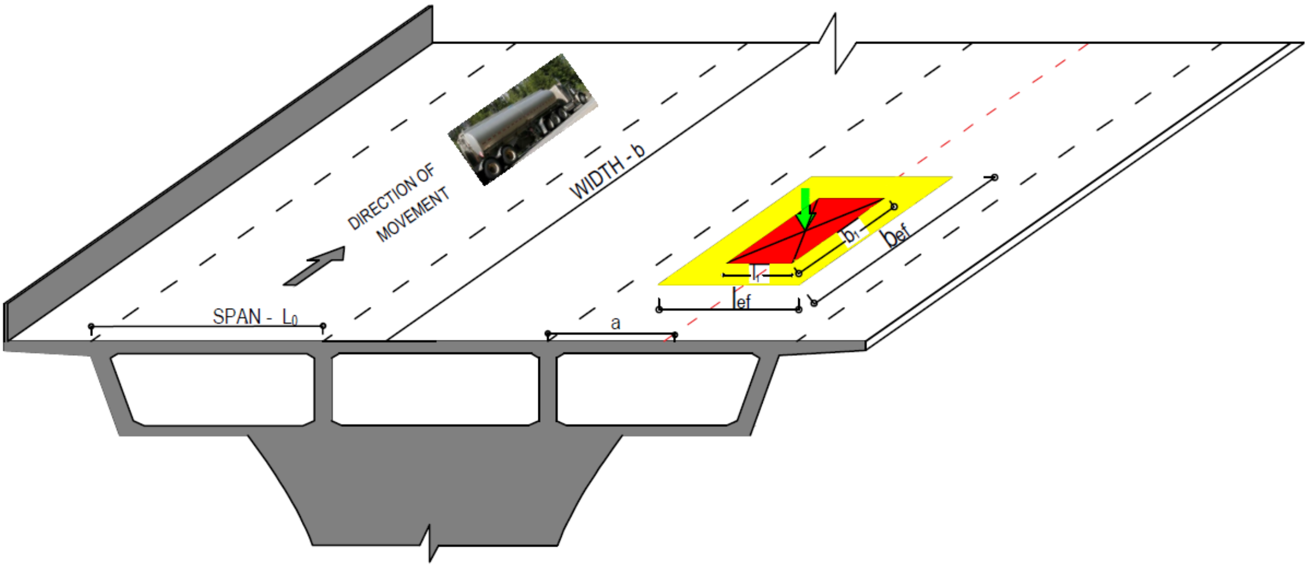


Figure 3 Concept of Effective Width for Wheel Load Dispersion

III. DESIGN HYPOTHESIS

Concrete Characteristics:	
Grade of concrete	M40
Modulus of elasticity of concrete	33 GPa
Reinforcing steel characteristics:	
Grade of reinforcing steel	Fe500
Modulus of elasticity of concrete	200 GPa
Clear cover to Reinforcement	40 mm
Prestressing steel characteristics: (For transverse prestressing case)	
Tendon sheathing	Corrugated HDPE
Stressing type	One End
Unit used for transverse prestressing	5S15 (5 strands of 15.2 mm dia.)
Area of 1 strand	181.46 mm^2
Area of cable	907.29 mm^2
Grade of strands-Ultimate stress of steel	1920 MPa
UTS-Ultimate Tensile Strength of 1 cable	1742 kN
Jacking force in 1 cable	1306.50 kN (Considering 75% of applied prestressing force)
Loss due to friction and anchorage has been calculated and long term losses are assumed as 10%	
Prestressing steel characteristics: (For longitudinal prestressing case)	
Tendon sheathing	Corrugated HDPE
Stressing type	Both End
Unit used for longitudinal prestressing	27K15 (27 strands of 15.2 mm dia.)
Area of 1 strand	181.46 mm^2
Area of cable	4899.38 mm^2
Grade of strands-Ultimate stress of steel	1860 MPa
UTS-Ultimate Tensile Strength of 1 cable	9112.84 kN
Jacking force in 1 cable	6834.63 kN (Considering 75% of applied prestressing force)
Total loss due to prestress	25 %

Table 2 Material Properties Used for Design

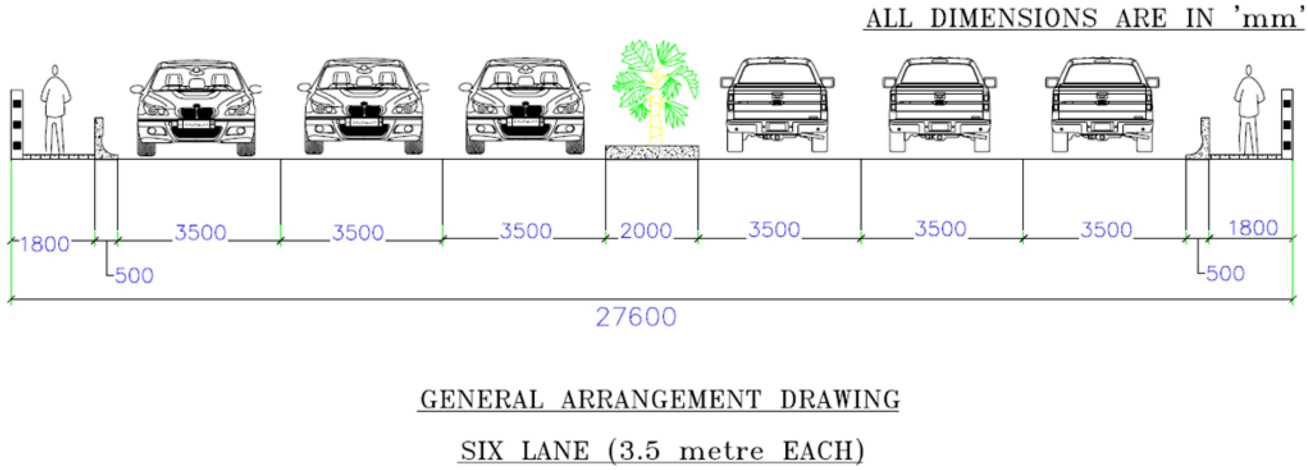


Figure 4 General Arrangement Drawing of Six Lane Bridge

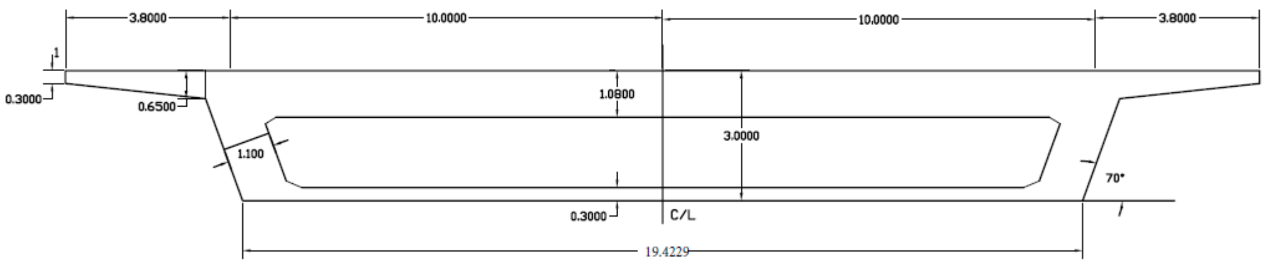
IV. PRELIMINARY DIMENSIONS

- Total depth of box is taken as 3 m considering span/depth ratio = 17
- For deck slab depth span/depth = 18 if deck is simply supported or continuous and span/depth = 8 if deck is cantilever.
- For total web thickness; approximately 8% of total deck width is taken (Reference-Section 2.3 of Precast Segmental Box Girder Bridge Manual by Post Tensioning Institute and Prestressed Concrete Institute).

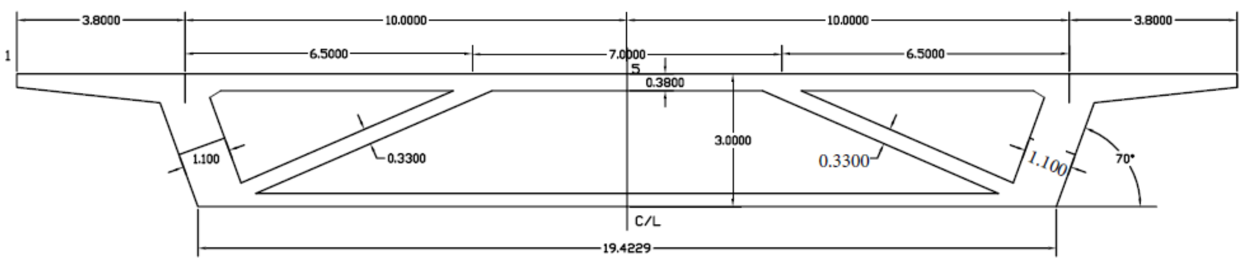
V. CONFIGURATIONS TAKEN FOR STUDY

All dimensions are in 'meter' in the following diagrams.

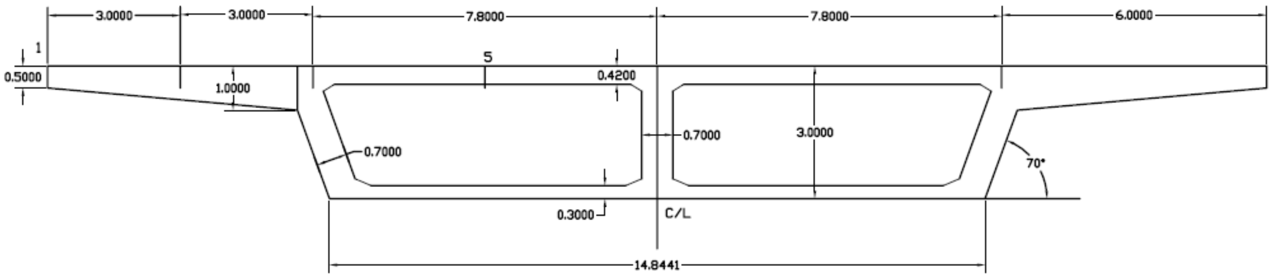
1.S_3.8 – Single cell with 3.8 m cantilever



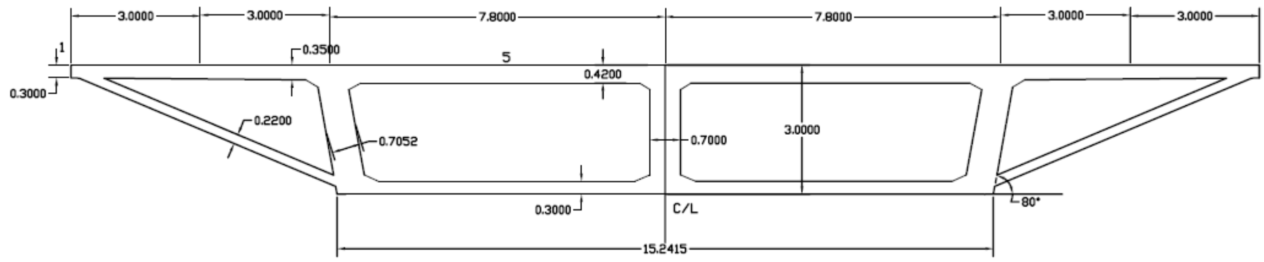
2.S_3.8_IS – Single cell with internal strut



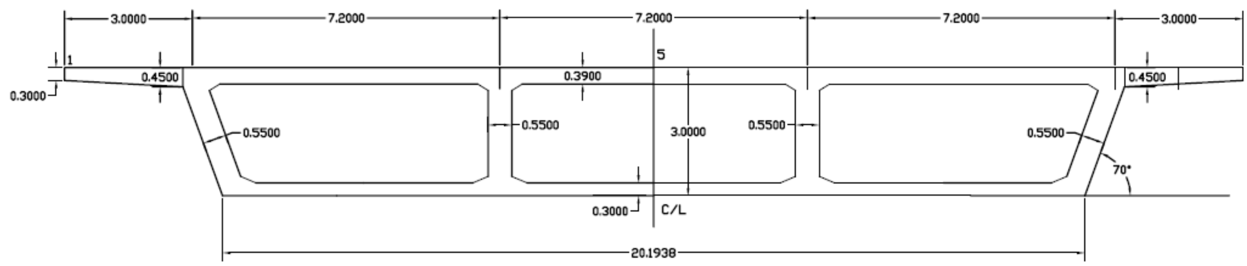
3.D_6 – Double cell with 6 m cantilever



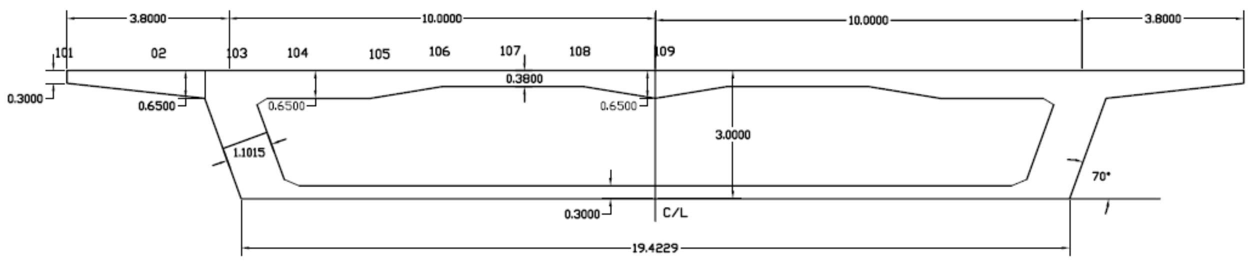
4.D_6_ES – Double cell with external strut



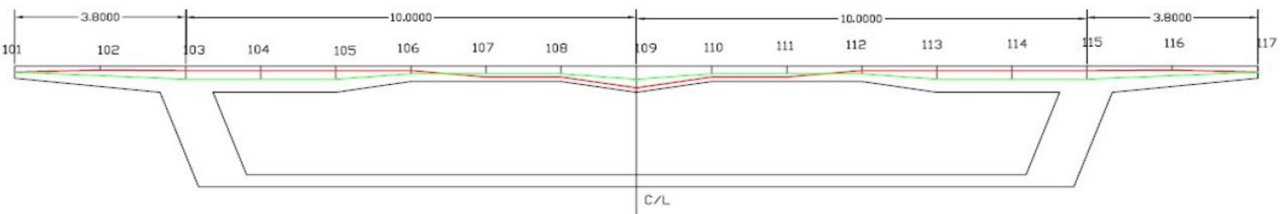
5.T_3 – Triple cell with 3 m cantilever



6.S_3.8_TP – Single cell with transverse prestressing of deck slab



Cable profile in deck slab in S_3.8_TP profile:

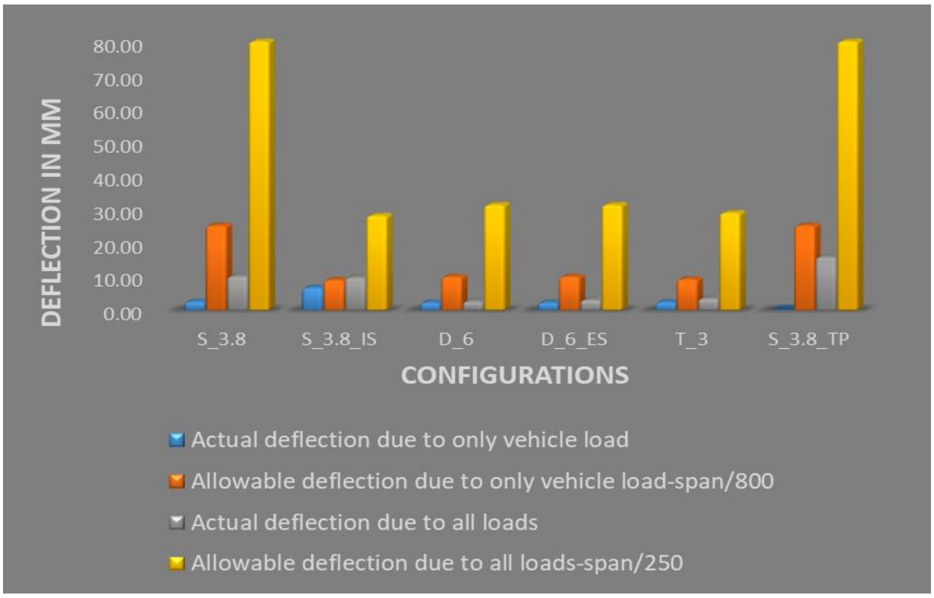


Note: In the above diagram Green line shows the center line of deck slab and Red line shows the cable profile of 5S15 type with 1920 MPa as UTS.

VI. RESULTS

Transverse analysis results:

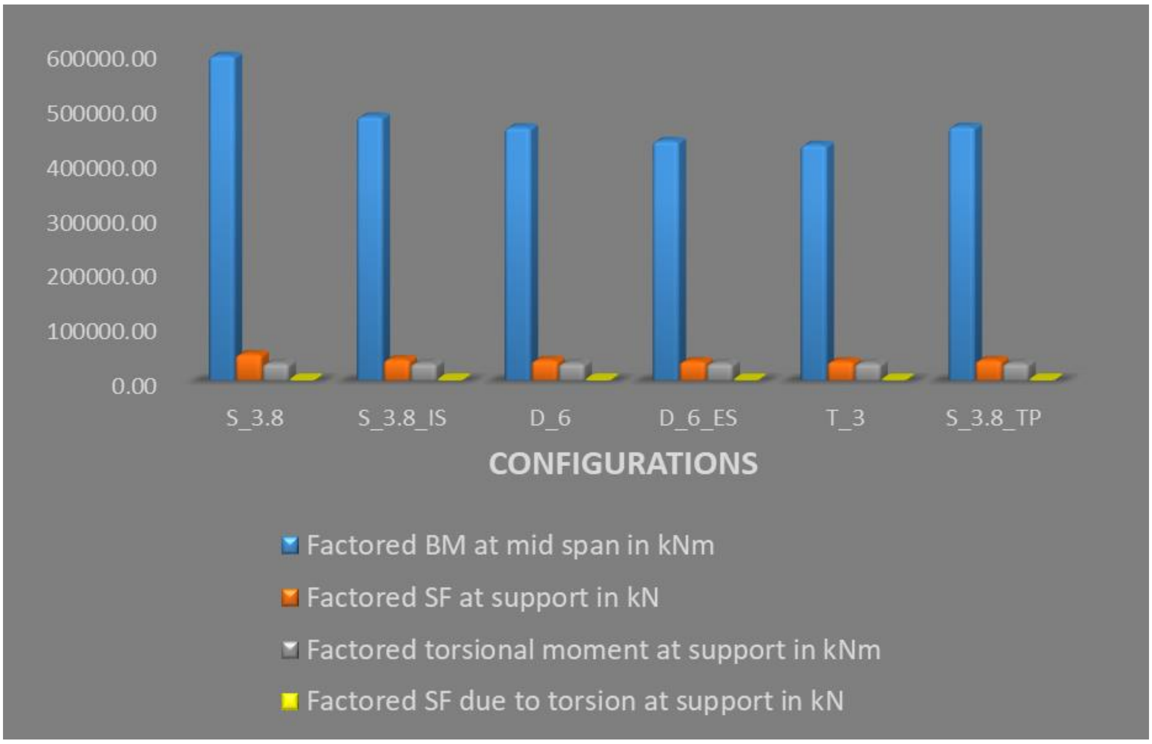
Graph 1 Comparison of Reinforcement Quantity due to Transverse Bending



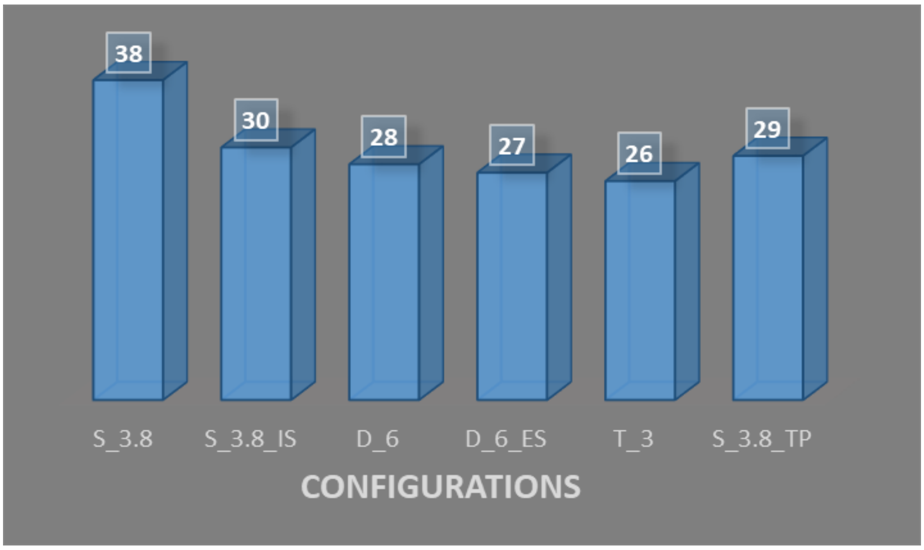
Graph 2 Comparison of Downward Deflection at Central Node

Graph 3 Comparison of Downward Deflection at Cantilever End

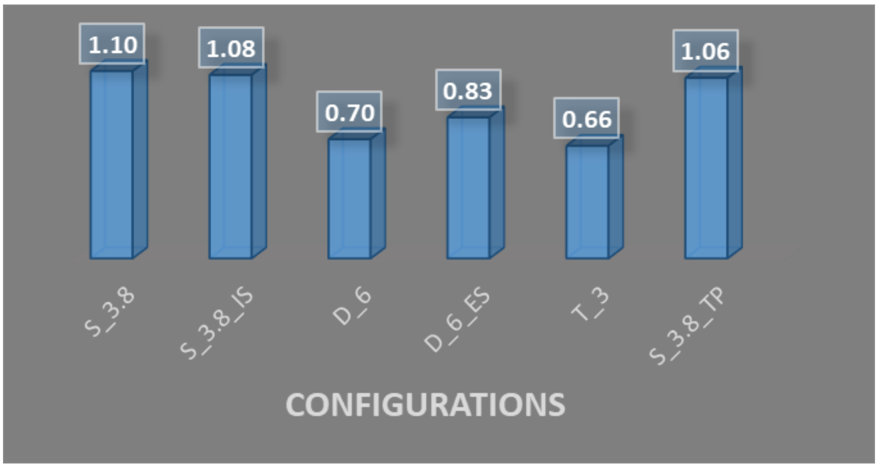
Longitudinal analysis results:



Graph 4 Comparison of Design Forces

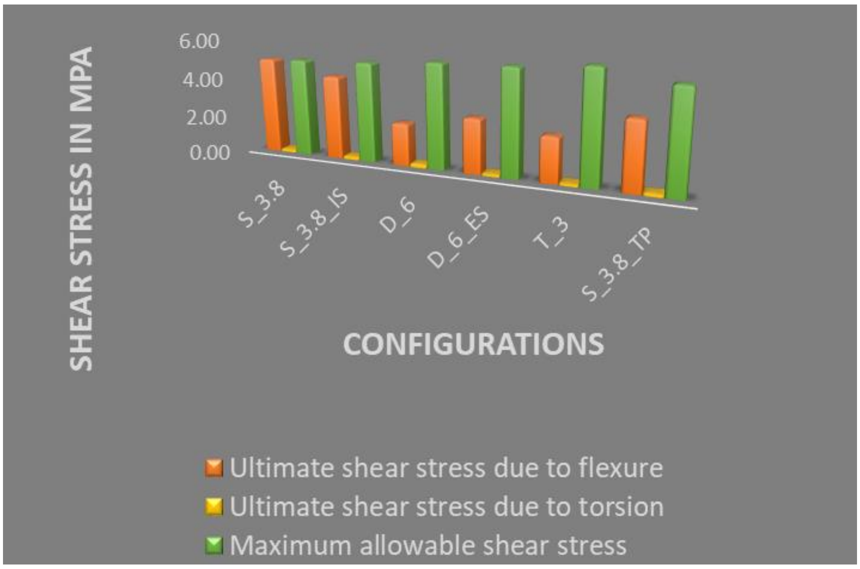


Graph 5 Comparison of No. of Cables Required at Mid span to Design Class-1 Section

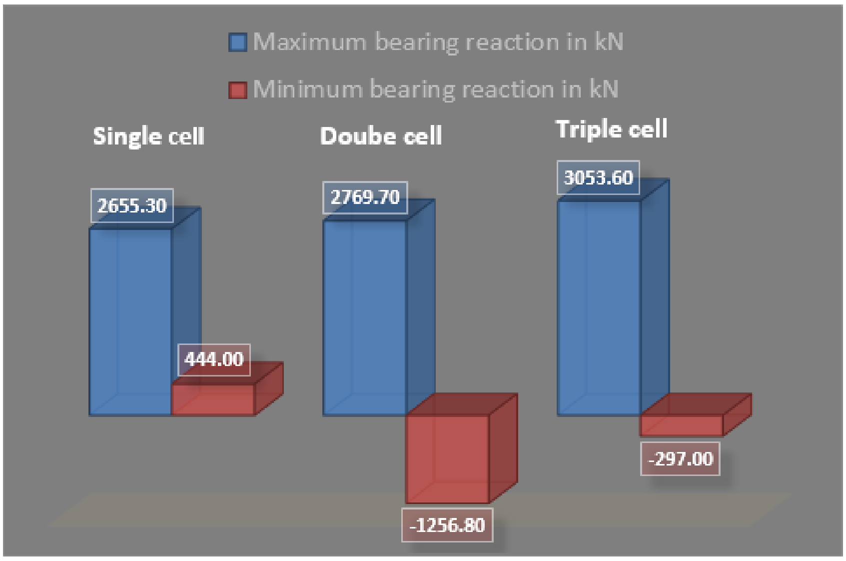


Graph 6 Comparison of Interaction Check for Shear and Torsion

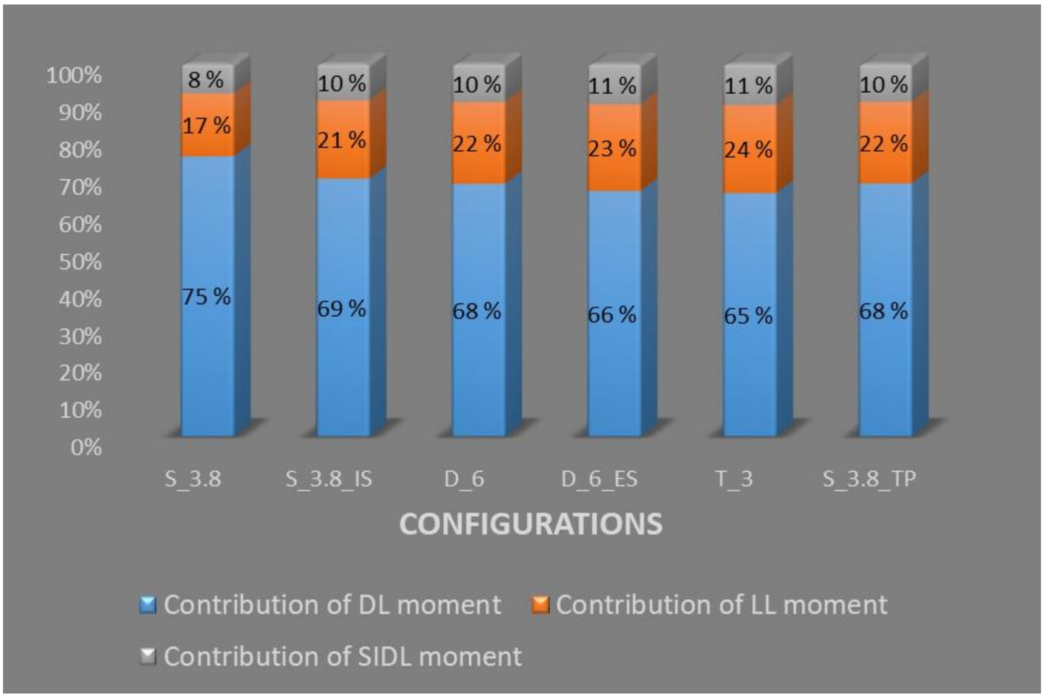
Graph 7 Comparison of Required Shear RF



Graph 8 Comparison of Shear Stress at Support



Graph 9 Comparison of Bearing Reactions in Single, Double and Triple cell



Graph 10 Comparison of Individual Contribution of Total Moment

VII. CONCLUSION

- By looking at the results it is observed that the T_3 is the best suitable configuration amongst all other configurations as its structural performance is reasonably superior and looks economical amongst all.
- By performing transverse analysis using effective width concept given in IRC 112:2011,it is noticed that same concept cannot be used in configurations with Internal Struts and External struts as they are not continuous members in the longitudinal direction.
- To know true dispersion of load in transverse direction, 3D Finite Analysis should be performed in configurations having internal or external strut.
- S_3.8 is not advisable configuration for this 6-lane cross section. Instead of using Single cell one should use single cell with internal strut.
- D_6 is the worst configuration amongst all. To minimize deflection at cantilever end, external strut should be provided.
- In the case where strut is provided, detailing and construction must be taken care properly as true behaviour of compression member should be achieved.
- One can use steel strut as a substitute of concrete strut.
- There is no guidelines available in IRC: 112-2011 for design of steel for the transverse tension in strut case.
- L/D = 18 for simply supported/continuous slab and L/D = 8 for cantilever slab holds good for RCC slab design in box girder as it satisfies deflection criteria.
- By doing transverse prestressing in deck slab, the ratio of L/D for simply supported/continuous slab can be go in the range of 35 to 40.
- Friction loss analysis plays vital role in the case of transverse prestressing case as geometry changes at each and every point based on moment envelope. (I.e. for provided cable profile).
- Potential cracking due to transverse prestressing should be taken care while construction.

- Deck slab should be locally thick to get better advantage of transverse prestressing.
- Special Vehicle load and its combinations are critical in longitudinal analysis. One should not ignore it as given in latest Amendments of IRC-006.
- Self-weight can be more minimized if transverse prestressing would have been done in T_3 configuration.
- It is advisable not to give more than 3 m clear cantilever in the configuration where external strut is not provided.

REFERENCES

[1] IRC: 112-2011 Code of Practice for Concrete Road Bridges.

[2] IRC: 6-2017 Standard Specifications and Code of Practice for Concrete Road Bridges Section: II Loads and Stresses

[3] Explanatory Handbook to IRC: 112-2011 published by Indian Road Congress

[4] Bridge Superstructure by N.Rajagopalan

[5] Design of Bridges by Krishna Raju

[6] Prestressed Concrete by N.Rajagopalan

[7] Post-Tensioned Box Girder Design Manual published by Federal Highway Administration, U.S Department of Transportation in June 2016

[8] Prestressing Manual by the Freyssinet Prestressed Concrete Co. Ltd.

[9] Precast Segmental Box Girder Bridge Manual by Post Tensioning Institute and Prestressed Concrete Institute

[10] Concrete Box Girder Bridges by J.Schlaich

[11] Bridge Deck Behaviour by E.C.Hambly

