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EFFECT OF NUMBER OF CELLS IN PSC BOX GIRDER BRIDGE

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Abstract — *Prestressed concrete box girders have become increasingly popular as bridge superstructures because of its high torsional stiffness and strength. Most of the study is concentrated only on varying the span and depth of the box girder bridge. In the present study the effect of number of cells is considered. A simply supported single-span four-cell box girder bridge with span to depth ratio of 25 is considered. The analysis is carried out for two-cell, three-cell and four-cell rectangular box girder bridge. The modelling and analysis is done using SAP 2000 software. The responses such as bending moment, shear force and deflection are compared. Results shows that the two-cell box girder is efficient compared to three and four-cell box girder bridge.*

Keywords *- Box girder; PSC; Multi-cell; Bridge; SAP-2000; FEM;*

I. INTRODUCTION

Box girder bridges are very commonly used. A box girder bridge superstructure consists of a deck slab, two or more vertical or inclined webs and a bottom slab which results in a single or a multi-cell rectangular or trapezoidal cross-section. Recently box girders has got wide acceptance in flyover bridge system due to their better stability, serviceability, pleasing appearance and most importantly better structural efficient than T-beam or I-girder [1]. Moreover, it has got some other features such as high torsional rigidity, high bending stiffness, high transverse strength and economy due to hollow section. The box girder normally comprises of pre-stressed concrete, structural steel or steel reinforced concrete. The box girder section may take the form of single-cell or multi-cell with a common bottom flange. The box girder achieves its stability mainly because of shape and prestress tendons. Box girder bridges are mainly chosen for spanning ranging from 20 m to 40 m for reinforced concrete bridges and 40 m to 100 m for prestressed concrete bridges. For spans more than 100 m cable supported bridges are economical [18].

A. Objectives of the study

To study the effect of number of cells in box girder bridge by evaluating the bending moment , shear force and deflection. Also the variation of longitudinal and shear stresses are evaluated and compared for two, three and four-cell box girder bridges.

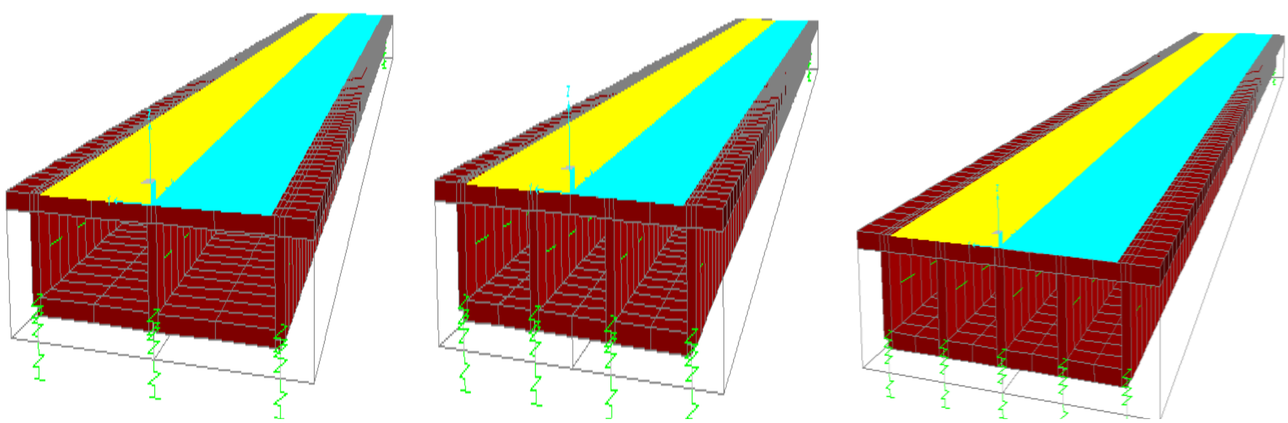
II. MODELLING AND ANALYSIS

To study the effect of number of cells on PSC box girder bridge, two-cell, three-cell and four-cell box girders are considered. The carriage width is kept constant for all the models as 7.5 m and the footpath considered is 1.25 m on both the sides. The boundary condition is simply supported, span of 50 m with l/d ratio of 25, depth of the box girder is 2 m. Figure 1, 2 and 3 shows the finite element model of two-cell, three-cell and four-cell rectangular box girder bridge modelled in SAP 2000 respectively.

Table 1: Material Properties

Material Properties	Values
Grade of concrete	M60
Weight/unit volume	25 kN/m^2
Young's modulus (E)	38729833 kN/m^2
Poisson's ratio (υ)	0.2
Shear Modulus (G)	16137430 kN/m^2
Coefficient of thermal expansion (A)	9.900E-06
Specific compressive strength of concrete (fc')	60 N/mm^2

The loading considered are dead load and live load as per IRC : 6-2000. The analysis is done and the results are presented at 5 m interval of the box girder bridge. For dead load analysis the density of concrete is taken as 25 kN/m^3 and the grade of concrete considered is M-60. For live load analysis two lanes of IRC Class-A wheeled loading is taken. Mid-span deflection, bending moment and shear forces are presented. Also the longitudinal stresses at top and bottom and shear stresses are compared for different models. The material properties considered are shown in table 1.



(a) (b) (c)

Figure 1: Finite Element model of (a) two-cell (b) three-cell and (c) four-cell rectangular box girder created in SAP 2000

III. RESULTS AND DISCUSSION

A. Deflection: The maximum deflection of various number of cells for dead load, live load and combined load case (DL+LL+Prestress) is presented in table 2.

Table 2: Maximum deflection for different cells of box girder bridge in mm

Load Case	Two	Three	Four
Dead load	88	91	97
Live load	33	32	31
DL+LL+Prestress	36	38	40

Figure 4, 5 and 6 shows the deflection of different cells for dead load, live load and combined load case respectively. In two-cell box girder bridge the number of girders are reduced and due to which the dead load is reduced. Hence the deflection is less in case of two-cell box girder bridge compared to three and four-cell box girder bridge. Therefore the deflection is reduced in two-cell box girder by 3% and 10% compared to three and four-cell box girder bridge respectively. For live load case there is no much variation. The camber due to prestress is decreased on increasing the number of cells. Due to which for combined load case the deflection of three-cell and four-cell box girder is increased by 5% and 11% compared to two-cell box girder bridge.

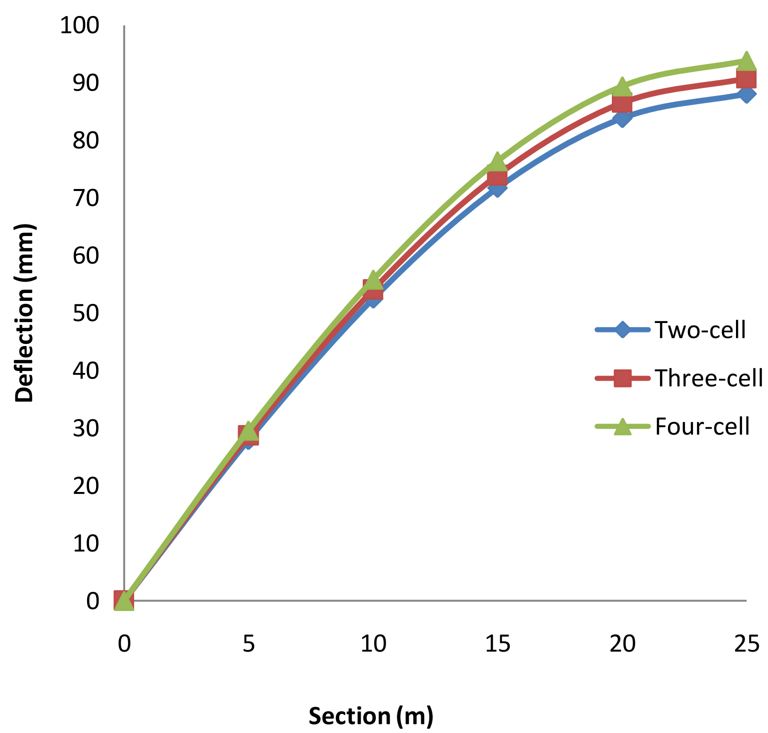


Figure 4: Dead load deflection for various cells

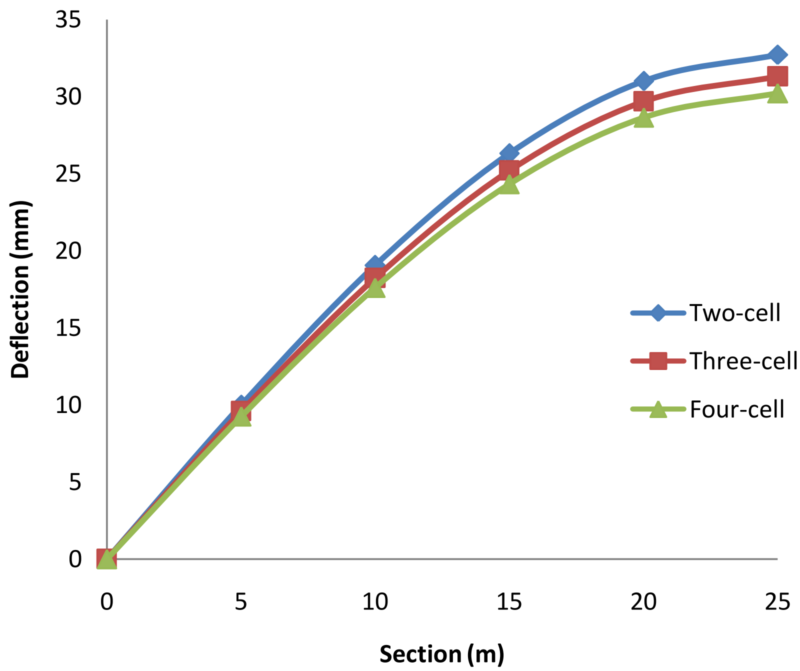


Figure 5: Live load deflection for various cells

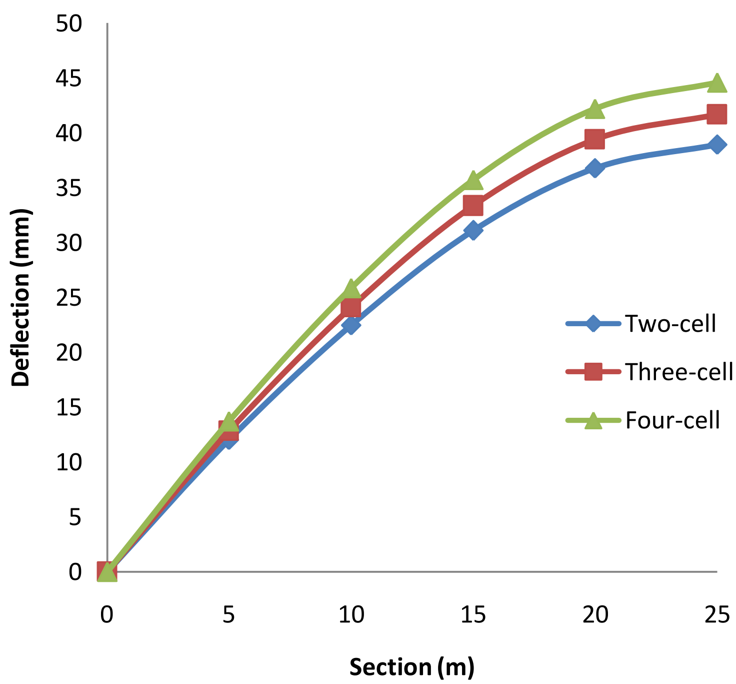


Figure 6: Deflection for combined load case.

B. Bending Moment: Bending moment of two-cell, three-cell and four-cell box girders for dead load, live load and combined load case are shown in table 3.

Table 3: Maximum bending moment for different cells of box girder bridge in kNm

Load Case	Two	Three	Four
Dead load	54098	58070	62040
Live load	21866	21858	21851
DL+LL+Prestress	24894	26996	29087

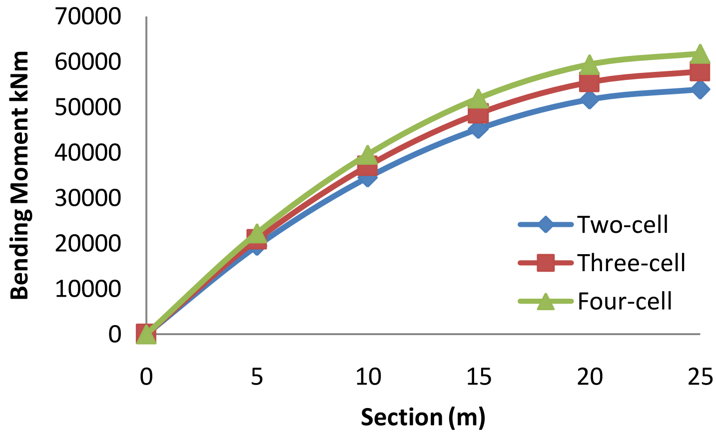


Figure 7: Dead load bending moment for various cells

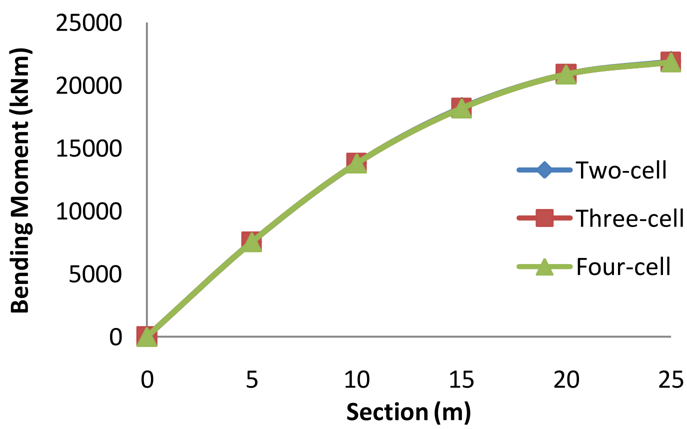


Figure 8: Live load bending moment for various cells

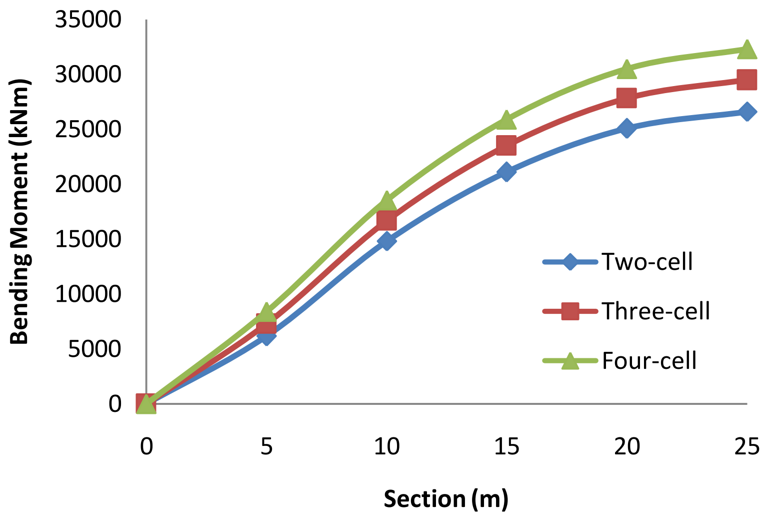


Figure 9: Combined load bending moment for different cells of box girder bridge.

Variation of bending moment for different cells is shown in figure 7, 8 and 9 for dead load, live load and combined load case. Due to increase in the number of girders the self weight of the bridge is increased. Therefore the dead load bending moment of three-cell and four-cell box girders increased by 7% and 15% compared to two-cell box girder. Whereas for live load case, there is no variation in entire bridge bending moment on increasing the number of cells but the bending moment of interior girder changes. For combined load case the bending moment is increased by 9% and 17% in three-cell and four-cell box girder compared to two-cell box girder bridge.

C. Shear Force:

Table 4: Maximum shear force for different cells of box girder bridge in kN

Load Case	Two	Three	Four
Dead load	4334	4654	4974
Live load	1632	1632	1632
DL+LL+Prestress	2307	2477	2648

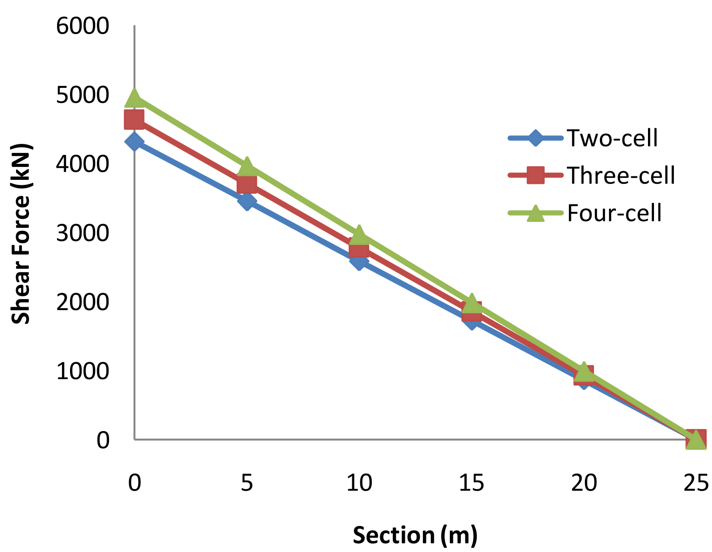


Figure 10: Dead load shear force for various cells

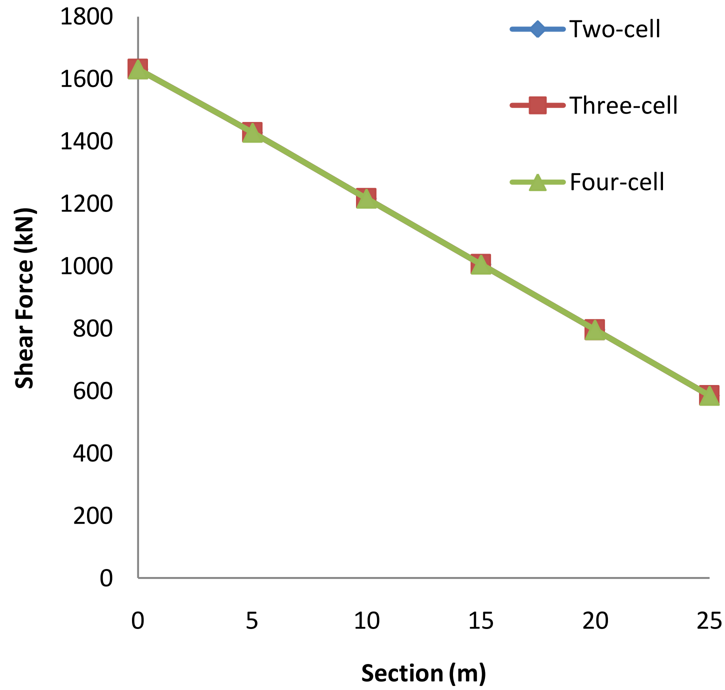


Figure 11: Live load shear force for various cells

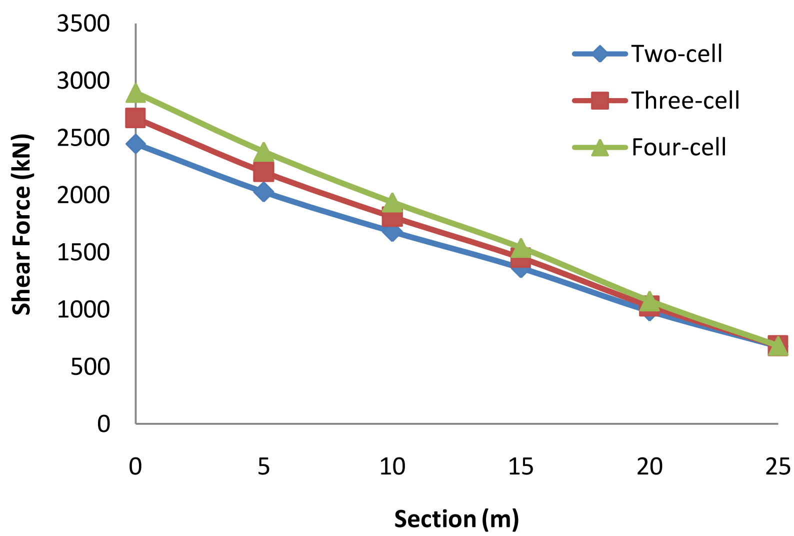


Figure 12: Combined load case shear force

Figure 10, 11 and 12 shows the shear force variation of different number of cells for dead load, live load and combined load case. The shear force is maximum at support, which was increased by 8% and 15% for three-cell and four-cell box girder compared to two-cell box girder bridge. In live load case there is no variation in the shear force for different number of cells. For combined load case from the figure 4.25, it is observed that the shear force has increased in four-cell and three-cell box girder bridge by 15% and 8% compared to two-cell box girder bridge.

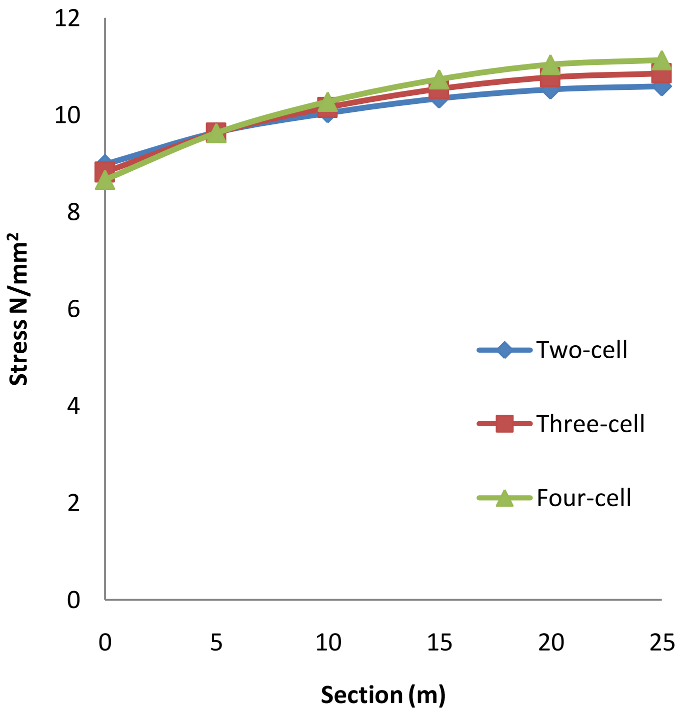


Figure 13: Longitudinal stresses at top of the box girder along the span

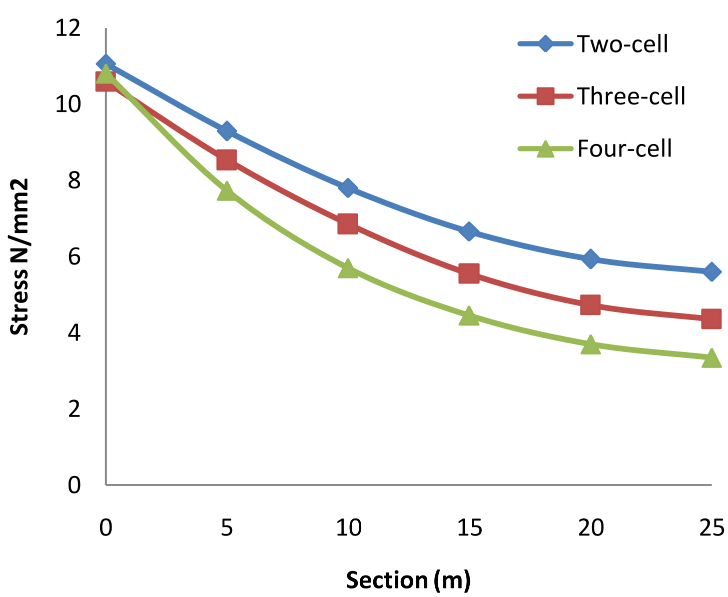


Figure 14: Longitudinal stresses at bottom of the box girder along the span

Figure 13 and 14 shows the variation of longitudinal stresses at top and bottom of the box girder bridge along the span at an interval of 5 m. The variation of longitudinal top stresses is very less. The longitudinal bottom stresses at mid span shows that the box girder with two-cell is in more compression compared to three and four-cell box girder bridge.

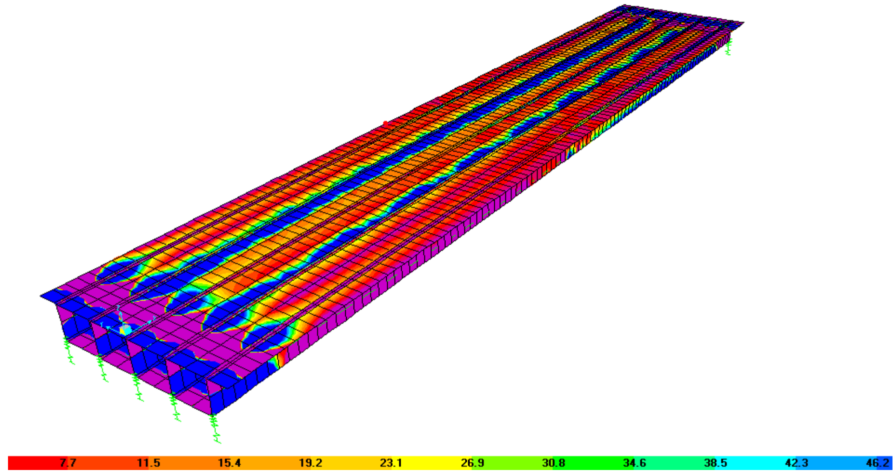


Figure 15: Variation of shear stress in four-cell box girder bridge.

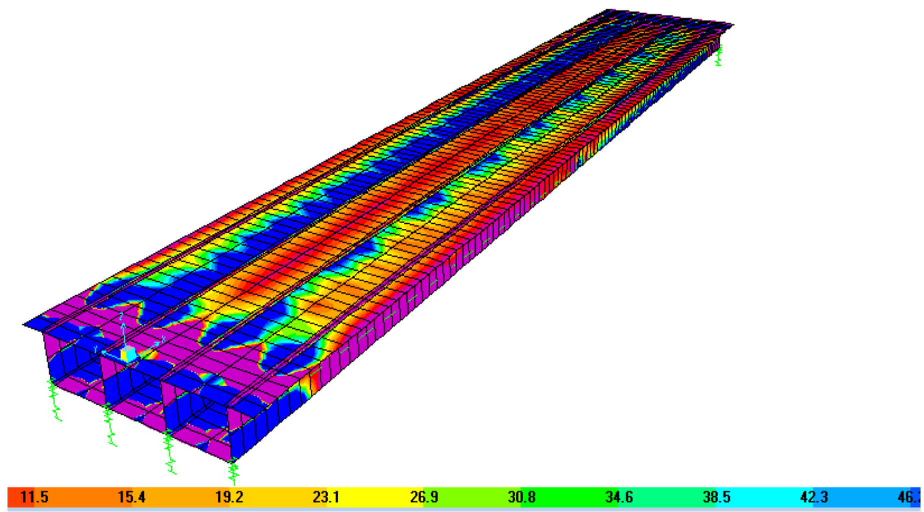


Figure 16: Variation of shear stress in three-cell box girder bridge.

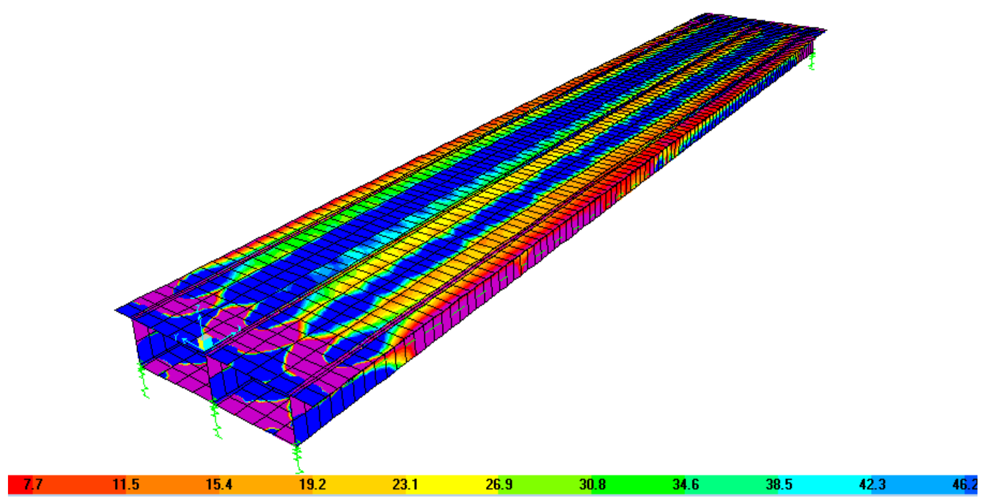


Figure 17: Variation of shear stress in two-cell box girder bridge.

Figure 15, 16 and 17 shows the variation of shear stresses in four-cell, three-cell and two-cell box girder bridge models modelled in SAP 2000. The shear stresses are maximum at the support for two-cell box girder bridge. Figure 18 shows the variation of shear stresses for various cells of box girder bridge. From the figure it is observed that the shear stresses in two-cell box girder bridge increased by 9% and 7% compared to four and three-cell box girder bridge.

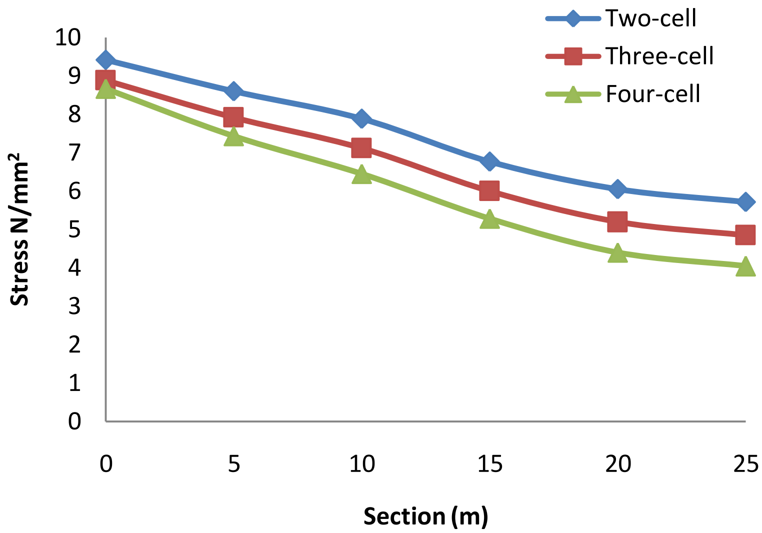


Figure 18: Variation of shear stress in various cells of box girder bridge.

IV. CONCLUSIONS

1. On increasing the number of cells the self weight of the box girder bridge increases due to which the deflection is increased by 11% and 5% in four and three-cell box girder compared to two-cell box girder for combined load case.
2. For live load case on increasing the number of cells of box girder bridge there is no variation in deflection, shear force and bending moments.
3. The bending moment is increased by 17% and 9% in four-cell and three-cell box girder compared to two-cell box girder. Two-cell box girder is more efficient compared to three and four-cell box girder bridge.
4. Shear stress at support in four-cell and three-cell box girder is increased by 15% and 8% compared to two-cell box girder bridge.
5. The longitudinal stresses at bottom for two-cell box girder are increased by 67% and 28% compared to four-cell and three-cell box girder bridge. This shows that the two-cell box girder bridge is in more compression.

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