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Comparative Study of Wide Deck Box Girder Bridge Superstructures

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***Abstract:** Box Girder superstructures are most popular type amongst all other type bridge superstructures and are extensively used. Nowadays to provide better riding quality and in order to reduce number of substructures and foundations for more clear space underneath, long span continuous or integral type bridge superstructures are preferred. For longer span bridges to reduce dead load and to utilize material to its capacity cellular sections are the most efficient sections in this regard. Box girder is one of the cellular sections.*

In metropolitan cities one of the restrictions is the availability of land to widen the existing roads. Present trend is to use wide deck bridge superstructure to utilize surface level and elevated level space more efficiently. Bridge aesthetics are also important as bridges are located in metro cities, tourist's places. In wide deck bridges, ribbed cantilever slab or cantilever with supporting struts are used to impart transverse stiffness while further reducing dead load of the superstructure deck.

Three different types of box girder superstructures are studied to inspect their behaviour in longitudinal and in transverse direction.

Analysis of three different types of box girder superstructures has been carried out using software CSI SAP2000 and analysis results are presented and compared. In this parametric study various parameters of mechanical behaviour such as deflection, shear lag, effects, bending stresses in transverse direction are compared.

Keywords: Box girder, Cellular sections, mechanical behaviour, shear lag, Bridge aesthetics,

I. INTRODUCTION

Rapid industrialization in India requires a well-organized road transportation infrastructure, which has led to construction and improvement of road network with bridges and flyovers. Recently, massive investments have been made to improve highway infrastructure. Large number of flyovers are being constructed in various major cities as they help in easing traffic congestion and reducing the travel time of road users. Construction of large number of flyovers gained momentum in India. The length of the flyovers also varies from few hundred metres to several kilometres. One of the barriers in the fast progress of road infrastructure is land acquisition. In cities road width is restricted to widen the road across traffic direction to accommodate additional number of traffic lanes. Therefore, the answer is to use wide deck bridge superstructures with a cantilever pier, to avoid land acquisition and project cost.

In the Past, flyovers were constructed by covering space underneath for landscaping or for shops. Therefore, the superstructures are supported on portal piers or divided deck superstructures with separate substructure and foundations, covering a maximum space underneath and the at grade road was kept outside of the flyover width. Present trend is to provide only a single pier into the road median below to support the 4 to 6 lane wide deck, so as to accommodate elevated corridor and surface level road within the available width for development of road network.

Civil structural and construction industry is growing rapidly, selecting most suitable structural arrangement is very essential and should result in quick construction & it should be cost effective. Wide deck box girder superstructures are rapidly gaining popularity over conventional multicell box girders due to the various types of requirements like Bridge aesthetics, construction & erection, site suitability, design requirements. Comparative studies of the basic structural behaviour are required to understand fulfill the industry requirement. Also, to mitigate industrial demand and to arrive at cost effective solution this study is necessary before adopting or proposing a structural scheme.

II. OVERVIEW OF THE GIRDER CROSS SECTIONS

Various structural forms are available and can be developed depending upon specific requirement and based on available construction techniques.

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Various bridge superstructure types are as follows:
1) Solid Slab
2) Voided slab
3) RCC or Prestressed I Girders with Deck slab
4) Conventional Box Girders single cell or multi cell
5) Ribbed box girder
6) Strutted box girder

Nowadays long span multilane bridges, elevated corridors are being constructed in the road median keeping under side traffic functional and requires vertical clearance for movement of traffic below. In order to full fill the requirements box girder sections are used which requires smaller size pier caps. Conventional box girders are mostly used to serve the purpose and recently strutted box girders and ribbed box girders are becoming popular.

A. Conventional single or Multi cell box girder

Conventional cellular box girders span in transverse direction, and transfers load over deck slab to webs through flexure. Deck slab and soffit slabs longitudinally carries compressive and tensile stresses and in transverse direction flexural stresses. Webs carry shear forces in longitudinal direction and flexural stresses in transverse direction.

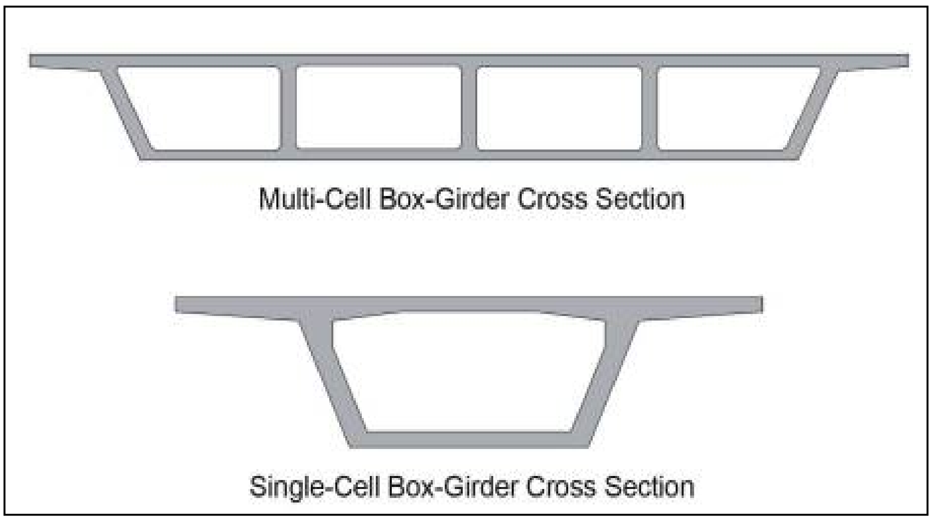

Fig. 1 Single or Multi cell box girder

B. Box girder with Transverse Ribs

Rib provided under the cantilever imparts stiffness in transverse direction and changes the spanning direction of cantilever slab, it also changes one-way transverse spanning of deck slab to two-way action if provided between webs. It increases the transverse stiffness of the girder cross section.

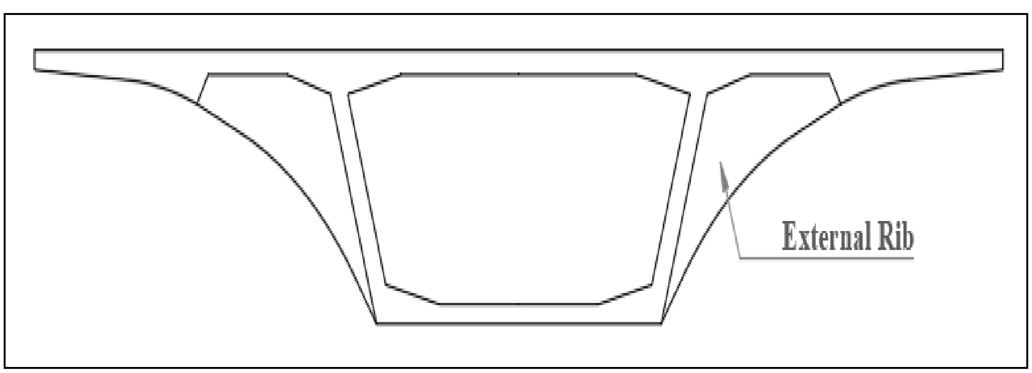

Fig. 2 Box girder with Transverse Ribs

C. *Box girder with struts.* In this type cantilever subject to two-way action and deck slab and soffit slab span in transverse direction. Struts carry load from deck slab and transfer to the webs, struts are prominently axial members and carry minor bending moments. Strut causes truss like action and carries axial compression in strut and axial tension in deck slab.

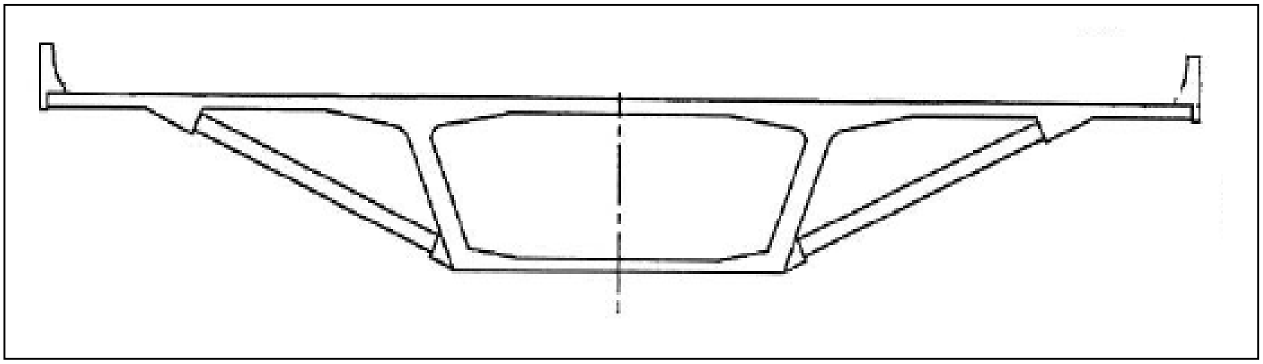

Fig. 3 Box girder with Transverse Ribs

III. METHODOLOGY

For the purpose of comparative study three types of box girder cross sections have been chosen, deck width, depth of superstructure and span of superstructures are kept identical so as to compare results without having variation in geometrical properties except mechanical cross-sectional properties. All the three box girder decks are considered to be cast in one go and none of the deck is subjected to staged construction.

1) Conventional two cell box girder,
2) Single cell box girder with transverse ribs and
3) Single cell box girder with strut.

In order to understand the behaviour, these three different types of box girder superstructures have been modelled and analysed in Csi Sap 2000 software. Shell elements have been used to model girder cross section and frame elements to model struts. All the three spans assumed simply supported over bearings. Bearings are modelled as supports in SAP200.

To check the efficiency of the deck section in longitudinal direction, Span deflection and shear lag effects have been studied. For this purpose, a uniform surface pressure is applied over the deck slabs, keeping pressure intensity same in all the three box girder models. Also, to study the behaviour of box girder in transverse direction, transverse directional stresses are studied for critical locations across the width. Critical locations under consideration are root of the cantilever, mid of deck slab between webs, deck section over transverse rib and strut.

A. *Deck Cross section*

Following deck cross sectional features are assumed as follows.

Deck width = 18m	Span length = 36m	Girder depth = 2.8m
Crash barrier width = 0.4m	C/S Area = 0.4 sq. m	Wearing coarse thickness = 0.065m

B. *Material and Density*

Grade of concrete = M50
Density of Concrete = 25 kN/m3
Density of Wearing Coarse = 22 kN/m3

C. *Load calculation*

1) Dead load – Self-weight is applied as Dead Load with self-weight multiplication factor as -1.
2) Super imposed dead load – As a part of bridge deck components load of crash barriers and wearing coarse is applied at their respective location over deck slab.

Load of Crash Barrier = 25 x 0.4 = 10 kN/m2
Load of wearing coarse= 22 x 0.065 = 1.43 kN/m2

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3) Live load – Vehicular live load is applied at strategic locations over deck slab so as to cause most critical effects in the box girder elements. For vehicular live load application provisions given in IRC 6:2017 have been referred.

Maximum axel Loads of Class A vehicle and Class 70R wheeled vehicle are considered over deck slab with impact factor.

Class A: Two axels of 11.4 MT each 1.2m apart having wheel spacing 1.8m

Class 70R: Two axels of 17 MT each 1.37m apart having wheel spacing 1.93m

4) Uniform surface pressure of 10kN/m2 is applied over deck slab for shear lag effect and deflection comparison.

Load parameter is kept constant to check structural behaviour and direct comparison of the results.

D. Girder Cross sections

Detailed dimensions of girder cross sections are as follows:

1) Two cell box Girder

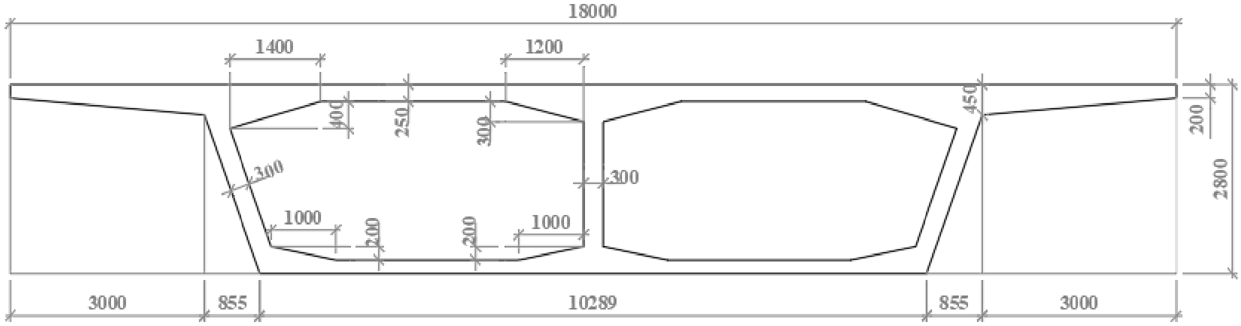

Fig. 4 1) Two cell box Girder

2) Single cell box girder with transverse ribs

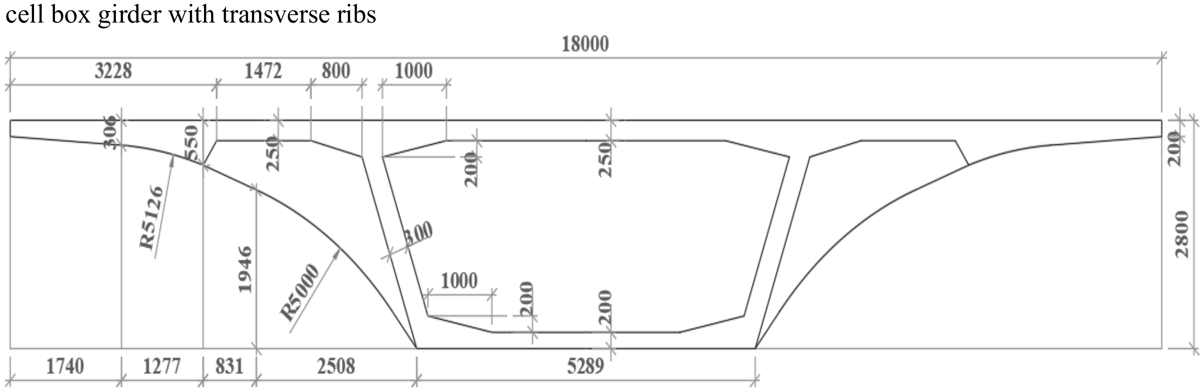

Fig. 5 Box girder with Transverse Ribs

3) Single cell box girder with struts

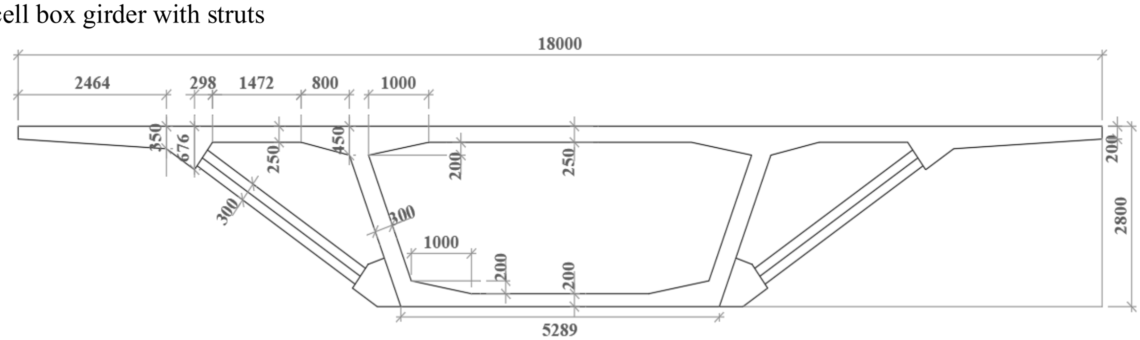

Fig. 6 Single cell box girder with struts

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E. Analysis Model

Isometric Views of the Analytical Model from CSI SAP2000 are presented below:

1) Two cell box Girder

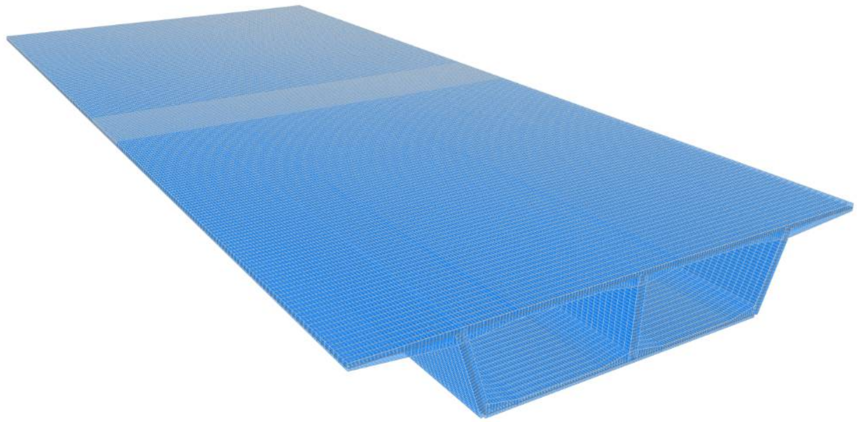

Fig. 7 Two cell box Girder

2) Single cell box girder with transverse ribs

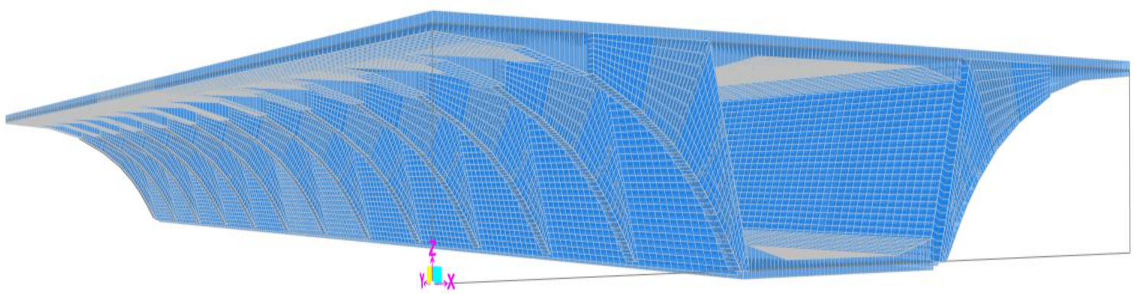

Fig. 8 Single cell box girder with transverse ribs

3) Single cell box girder with struts

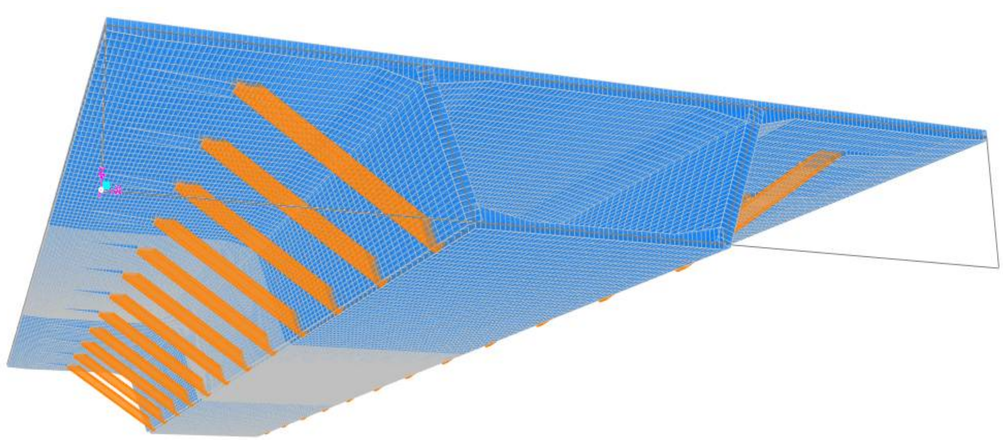

Fig. 9 Single cell box girder with struts

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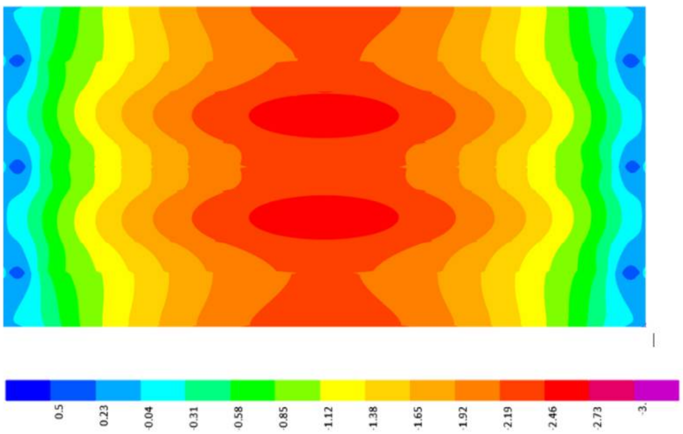
IV. RESULTS AND DISCUSSION

Results from the analysis have been presented to investigate specific structural behavioural effects and performance of structure.

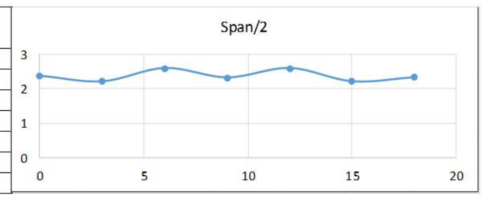
A. Shear Lag Effects

Normal stresses plots of deck slab shell elements along the longitudinal directions in all the three models have been studid and graphical output of the stress variation across the deck slab with stress values is also presented.
Stress contours presented below are for uniform pressure load of 10kN/m2.

1) Two cell box Girder



Dist (m)	Stress (Mpa)
0	2.37
3	2.21
6	2.59
9	2.32
12	2.59
15	2.21
18	2.33



Dist (m)	Stress (Mpa)
0	1.7
3	1.62
6	1.99
9	1.72
12	1.99
15	1.62
18	1.7

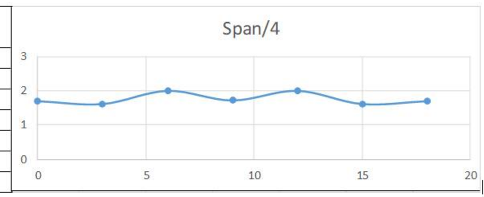
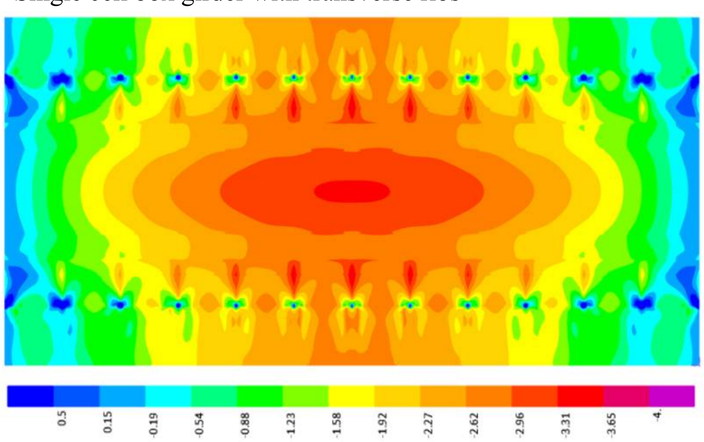


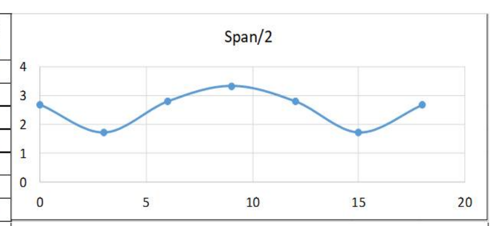
Fig. 10 Two cell box Girder

Stress plot shows higher normal stresses near to the webs and drop in stresses near to the free edge. From the above stress plot and graphs, it can be seen that drop in stress near cantilever edges is negligible as compare with pick values. Complete deck width in this section can be assumed to be effective. To check the variation of stresses across the deck minimum to maximum stress ratio is calculated which is coming around 0.85 & 0.81 for the sections at span/2 and span/4 respectively.

2) Single cell box girder with transverse ribs



Dist (m)	Stress (Mpa)
0	2.67
3	1.7
6	2.79
9	3.33
12	2.79
15	1.7
18	2.67



Dist (m)	Stress (Mpa)
0	1.7
3	1.8
6	2.1
9	2.68
12	2.1
15	1.8
18	1.7

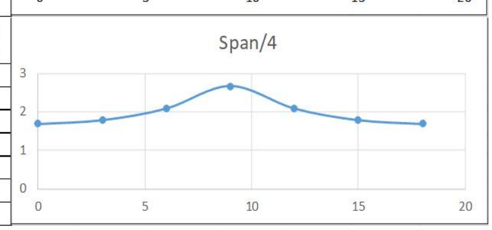


Fig. 11 Single cell box girder with transverse ribs

Stress plot shows the higher normal stresses between webs and lower values along free edge of the cantilever. Negative shear lag effect is also seen between webs. From the above stress plot and graphs, it can be seen that drop in stress near cantilever edges is considerable as compared with pick values. Complete deck width in this section cannot be assumed to be effective. Negative shear lag effect is also seen between webs at mid span. Minimum to maximum stress ratio = 0.51 & 0.63 for the sections at span/2 and span/4 respectively.

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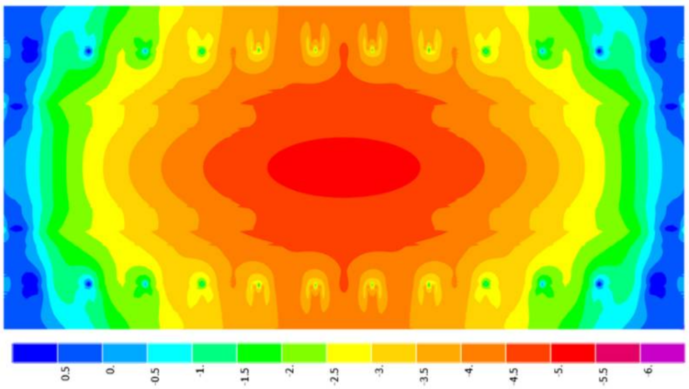
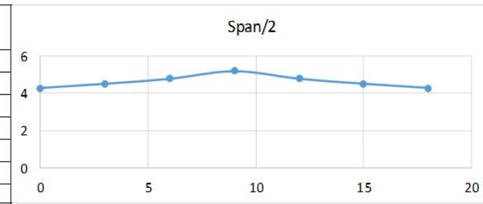
3) Single cell box girder with struts



Dist (m)	Stress (Mpa)
0	4.28
3	4.51
6	4.78
9	5.2
12	4.78
15	4.51
18	4.28



Dist (m)	Stress (Mpa)
0	2.87
3	3.35
6	3.7
9	4.1
12	3.7
15	3.36
18	2.87

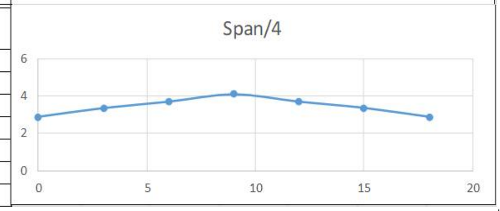


Fig 12 Single cell box girder with strut

From the above stress plot and graphs, it can be seen that drop in stress near cantilever edges is considerable as compared with pick values. Complete deck width in this section cannot be assumed to be effective. Negative shear lag effect is also seen especially between webs. Minimum to maximum stress ratio = 0.82 & 0.7 for the sections at span/2 and span/4 respectively.

B. Deflection Check

Performance of the superstructure systems have been checked, for this purpose uniform pressure of 10kN/m2 is applied over the deck. Deflection of superstructure mainly depend upon the moment of inertia of the girder cross section. System having higher moment of inertia deflects less. Moment of inertia and deflection are inversely proportional.
Deflection values at centre of span below the webs are tabulated below.

Sr. No	**Type of superstructure**	Deflection (mm)
1	Two cell box Girder	10.88 ↓
2	Single cell box girder with transverse ribs	16.96 ↓
3	Single cell box girder with struts	27.10 ↓

From the above results it is observed that the deflection of the two-cell box girder is very less as compere to other type of superstructures.

1) Deflection of Single cell box girder with transverse rib is 1.55 times more than two cell box girder.
2) Deflection of Single cell box girder with strut is 2.55 times more than two cell box girder.
3) Deflection of Single cell box girder with strut is 1.59 times more than Single cell box girder with transverse rib.

From deflection point of view two box giders are observed most efficient sections.

C. Transverse Analysis

Transverse analysis of deck slab has been studied to investigate the crtical sections across deck slab under applied loads which needs special attention. Normal stresses plots of deck slab shell elements across the traffic direction in all the three models have been studid and graphical output of the stress pattern across the deck slab with stress values is also presented for Dead Load, Superimposed Dead Load (Crash Barrier and Wearing Course) and for envelope of Live Load. Class A and Class 70R vehicles are applied individually and in combination. Stress plots for half of the sections are ploted for live load envelope considering symmetry. For deck slab design generally live load cases are the governing loads that controls the deck slab design. Critical sections across deck slab are identified in this study.

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Transverse normal stress distribution across deck width is shown in the graphs

1) Two cell box Girder

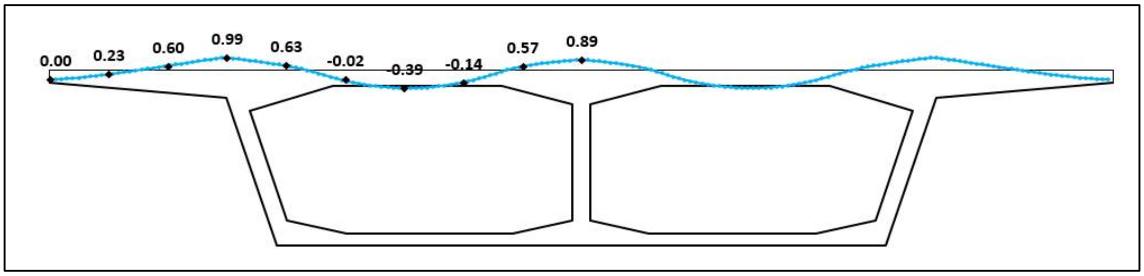

Fig 13 Two cell box Girder (DL+ SIDL CB + SIDL WC)

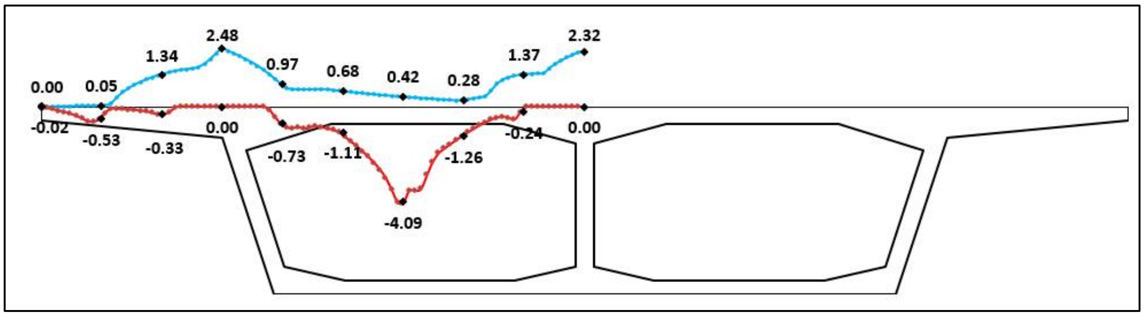

Fig 14 Two cell box Girder (Live Load envelope)

2) Single cell box girder with transverse ribs

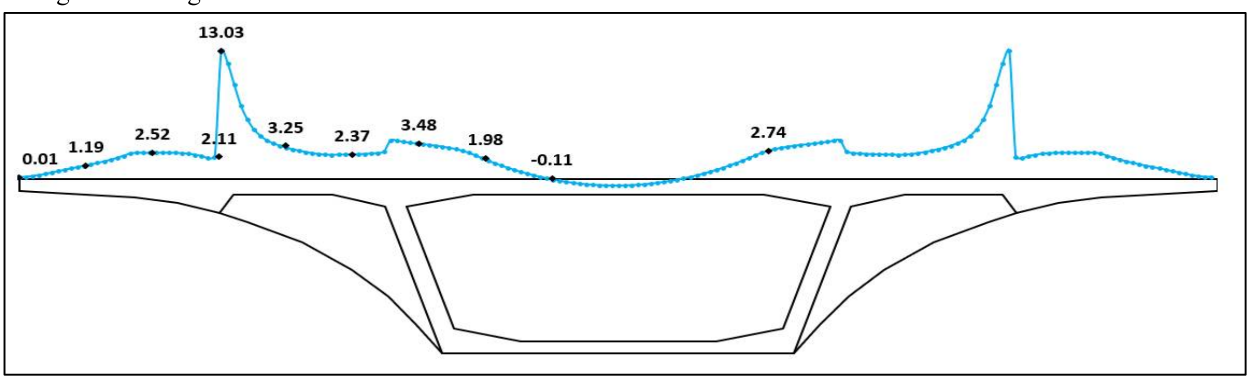

Fig 15 Single cell box girder with transverse ribs (DL+ SIDL CB + SIDL WC)

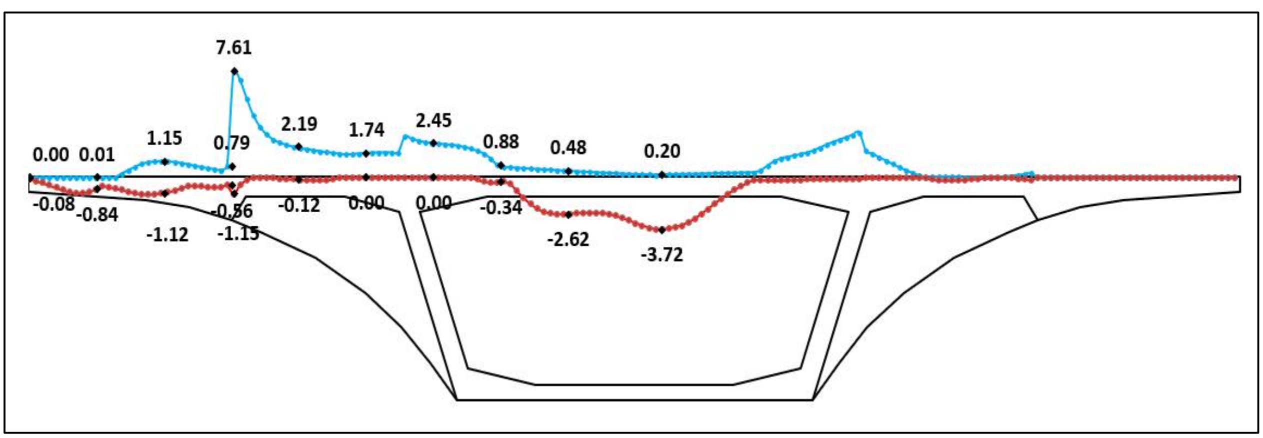

Fig 16 Single cell box girder with transverse ribs (Live Load envelope)

3) Single cell box girder with strut

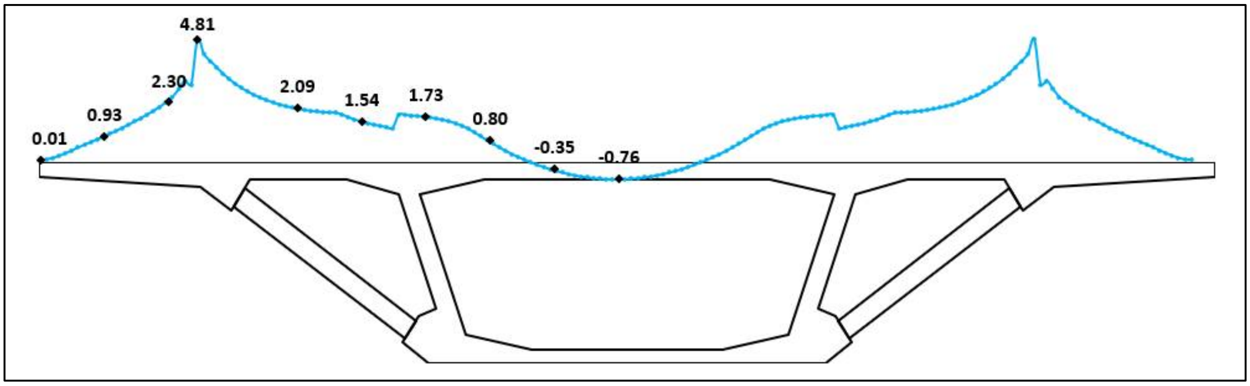

Fig 17 Single cell box girder with struts (DL+ SIDL CB + SIDL WC)

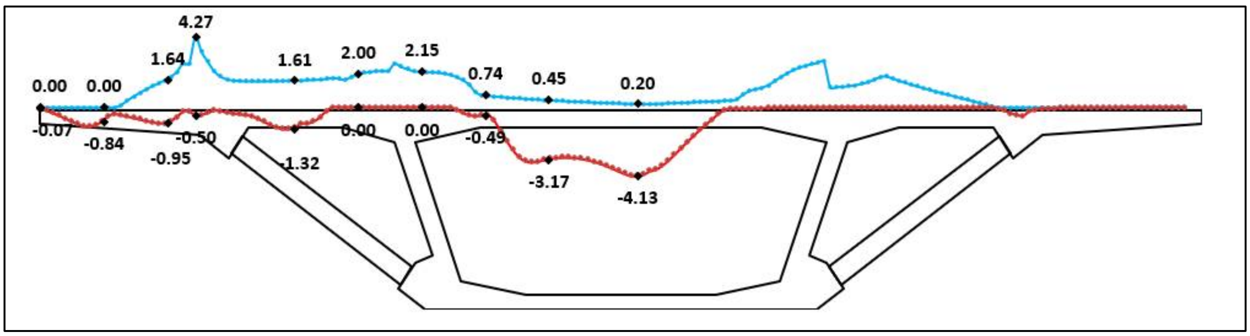

Fig 18 Single cell box girder with struts (Live Load envelope)

From the transverse analysis and above graphical representation of stress in deck in transverse direction it can be seen that structural behaviour in all the three cases is different. Critical locations of absolute maximum stressses for two cell box girder and single cell box girder with transverse ribs are different whereas stress pattern looks simillar for single cell ribbed box girder and strutted box girder.

- Critical locations for two cell box girder are 1)Top surface at the root of the cantilever and 2) bottom surface at mid section between the webs. Live load effects are much pronounced as compare with combination of Dead load and Sumperimposed Dead Load. It can be observed that the Live Load effects are governing.
- Critical location for single cell box girder with transverse rib are 1) top surface of the deck slab cantilever at the junction of rib 2) top of deck slab over the webs and 3) bottom surface at middle of deck slab between webs. In this case also live load effects are govering compared with combination of Dead load and Sumperimposed Dead Load.
- Critical location for single cell box girder with strut are 1)Top surface of deck slab at the junction of strut with deck slab cantilever 2) over the webs and 3) bottom surface at middle of deck slab between webs.In this case effects of live and dead load are observed and are equivalent at the junction of strut with deck slab and live load is found governing for the portion of deck slab between webs.

V. CONCLUSIONS

After the analysis of box girders, it is concluded that:

1) Shear lag effects in single cell box girder with transverse rib and single cell box girder with strut are more compared with two cell box girders. Shear lag effects in single cell box girder with transverse rib at span /2 and at span /4 are 34% & 18% more respectively as compared with two cell box girder. Shear lag effects in single cell box girder with strut at span /2 and at span /4 are 3% & 11% more respectively as compared with two cell box girder.

2) Vertical deflection of single cell box girder in longitudinal direction with strut is found maximum. Deflection of Single cell box girder with transverse rib is 1.55 times more than two cell box girder. Deflection of Single cell box girder with strut is 2.55 times more than two cell box girder. Deflection of Single cell box girder with strut is 1.59 times more than Single cell box girder with transverse rib.

3) From the transverse analysis it is observed that the for two cell box girder stresses in the transverse direction are well distributed and sudden picks in stress diagram has occurred in single cell box girder with transverse rib and with strut. Maximum stress at the top surface in single cell box girder with transverse rib is 13.16 times than the two-cell box girder under Dead load & Super Imposed Dead Load combination. Maximum stress at the top surface in single cell box girder with transverse rib is 4.85 times than the two-cell box girder under Dead load & Super Imposed Dead Load combination.
4) Maximum stress at the top surface in single cell box girder with transverse rib is 3.07 times and at the bottom surface 0.9 times than the two-cell box girder for Live Load envelope.
5) Maximum stress at the top surface in single cell box girder with strut is 1.72 times than the two-cell box girder and at the bottom surface almost similar stresses observed for Live Load envelope.

From the above point it can be concluded that two cell box girder is structurally behaving optimally and results shows the structurally favorable behaviour compared with single cell box girder with transverse ribs and single cell box girder with strut.

REFERENCES

[1] Kenneth W. Shushkewich, "The Strutted Box Widening Method for Prestressed Concrete Segmental Bridges", PCI Journal, V.48, No. 2, November-December 2003, pp.64-81
[2] Ramakko, O. E. (1984). "The Twelve Mile Creek bridges—Design and construction." Can. J. Civil Eng., 11(4), 771–781.
[3] Koji Osada, Taketo Kanamoto, Kimito Saito, Takahiro Arai, "Progressive Erection Applied to Box Girder with Strutted Wing Slab"
[4] Man Zhou, Jiandong Zhang, Dingyi Yang, Mostafa Fahmi Hassanein and Lin An (2017): - "Transverse Analysis of a Prestressed Concrete Wide Box Girder with Stiffened Ribs". American Society of Civil Engineers, Journal of Bridge Engineering Vol. 22, Issue 8 (August 2017)
[5] Park, Jong-Hwa, Jang, In-Ho, Park, Chan-Soo, Lee, Han-Woo (2009): - "Development of new PSC box grater bridge with concrete filled FRP struts". International Commemorative Symposium for the Incheon Bridge, Korea, 23 Sep. 2009
[6] Misal Vishal U, Gore N. G. and Salunke P. J., Analysis and design of Prestressed Concrete Girder, International Journal of Incentive Engineering and sciences, 2014, Volume 2(2).
[7] Mayank Chourasia, Dr. Saleem Akhtar (2015) :- "Design and Analysis of Prestressed Concrete Box Girder by Finite Element Method (4 Cells & 1 Cell)". International Journal of Civil and Structural Engineering Research, Vol. 3, Issue 1, pp: (413-421), Month: April 2015 - September 2015.R. E. Sorace, V. S. Reinhardt, and S. A. Vaughn, "High-speed digital-to-RF converter," U.S. Patent 5 668 842, Sept. 16, 1997.
[8] Amit Saxena, Dr. Savita Maru (2013):- "Comparative Study of the Analysis and Design of T-Beam Girder and Box Girder Superstructure". IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 1, and Issue 2, April-May 2013
[9] Sanket Patel, Umang Parekh (2016): - "Comparative Study of PSC. Tee Girder and PSC. Box Girder". IJSTE - International Journal of Science Technology & Engineering | Volume 2 | Issue 11 | May 2016.
[10] Dr. R B Khadiranaikar1, Tiger Venkateshwar2 (2016):- "Effect of Number of Cells in Psc Box Girder Bridge". International Journal of Advance Engineering and Research Development Volume 3, Issue 6, June -2016.
[11] Zahraa Sermed Zuhdiy and Ali Laftah Abbas (2020): - "Comparative Study of Structural Behaviour of Reinforced Concrete Box Girder with Different Numbers of Cells". IOP Conference Series: Materials Science and Engineering, Volume 1076, 2nd International Scientific Conference of Engineering Sciences (ISCES 2020) 16th-17th December 2020, Diyala, Iraq.
[12] Bhargav Y. Mone & P. S. Mote (2022) "Comparative Study of Wide Deck Bridge Superstructure Systems and Their Suitability: A Review Paper" International Journal of Scientific Research and Engineering Development– Volume 5 Issue 1, Jan-Feb 2022.
[13] IRC:6-2017, "Standard Specifications and Code of Practice for Road Bridges, Section II Loads and Load Combinations (Seventh Revision)."