

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

Influence of Depth in Single Cell & Twin Cell Box Girder

V. Raja Srinivasa Reddy¹, P. Veerabhadra Rao²

P.G student, Dept. of Civil Engineering, GVP College of Engineering (A), Visakhapatnam, India¹

Professor, Dept. of Civil Engineering, GVP College of Engineering (A), Visakhapatnam, India²

ABSTRACT: Post tensioned Box girder bridges are one of the major developments in bridge engineering in the recent years. Segmental Box Girder construction offers maximum protection to the bridge environment, and facilitates maintenance of highway and railway traffic at the construction site. This paper deals with single cell and twin cell box girder of different spans with corresponding restricted depth. The Box girders of different spans with constant carriage way width are considered for analysis under IRC Class A and 70R wheel loading. Analysis results are compared to obtain efficient box girder sections of different spans for construction practice. Modeling and analysis is carried out using MIDAS Civil software.

KEYWORDS: Midas Civil, Single cell box girder, Twin cell box girder, Bending moment, Displacement, Depth.

I. INTRODUCTION

Segmental box girder bridges are easily adaptable to curved highway alignment and also provide aesthetic advantages. Now a days, precast segmental box girders play a vital role in metro railway as well as highways. Due to precast elements, the duration of construction will be reduced. Generally shuttering cost of precast box girder is huge when compared to regular precast I- girder. For a required carriageway width and when the depth of box girder is restricted, Standard dimension for different depths of box girder was made in order to suggest whether single cell or twin cell box girder is suitable for the proposed span of the bridge.

II. LITERATURE STUDY

Mayank Chourasia and Dr. Saleem Akhtar discussed the parametric study of four cell and single cell pre-stressed concrete box girder subjected to IRC class AA loading conditions to find the most economical cross-section. This paper concludes that the single cell pre-stressed concrete box girder is most suitable and economical cross-section for 2 lane Indian national highway bridges.

Vishal U. Misal et al. discussed the cost analysis and design of prestressed concrete girder. Analysis and design has been carried out in STAAD PRO under a IRC class 70 R loading. This paper concludes that losses is more in I girder as compared to Box girder and box girder is costlier than I girder.

III. DIMENSIONS OF BOX GIRDER

The following dimensions are considered for the design of box girder from the codal provisions

- The thickness of the web is taken as $d/36$ plus twice the clear cover to the reinforcement plus diameter of the duct hole where 'd' is the overall depth of the box girder measured from the top of the deck slab bottom of the soffit or 200 mm plus the diameter of duct holes, whichever is greater.
- The thickness of the bottom flange of box girder is taken as $1/20^{\text{th}}$ of the clear web spacing at the junction with bottom flange or 200 mm whichever is more.
- The minimum thickness of deck slab including that at cantilever tips is taken as 200mm

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

- For top or bottom flange having prestressing cables, the thickness of such flange is taken as 150 mm plus diameter of duct hole.
- Haunches of minimum size of 300 mm (horizontal) and 150 mm (vertical) shall be provided at the four extreme inner corners of the box section.
- The minimum clear height inside the box girders shall be 1.5 m to facilitate inspection.

All the dimensions are in mm. Overall carriageway width of Single cell and twin cell Box Girder = 12000 mm.

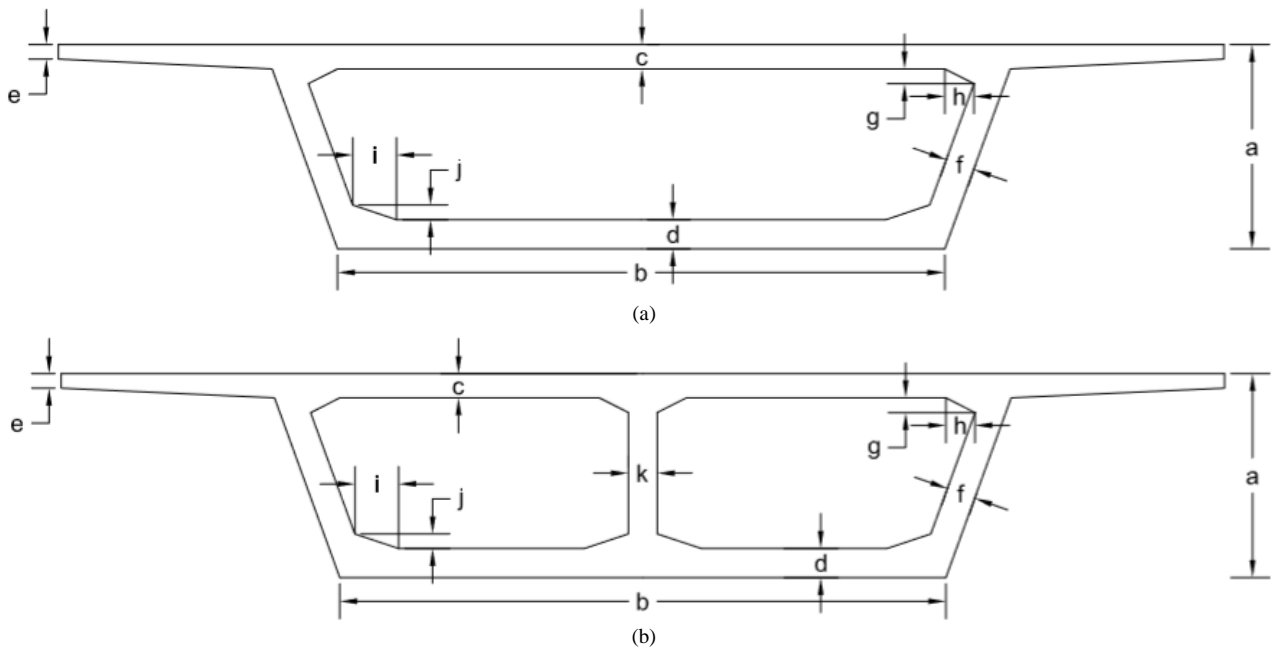


Fig. 1 Box Girder Sections (a) Single Cell (b) Twin Cell

Where

- a = Depth of the Box Girder
- b = Bottom width of Box Girder
- c = Depth of Top slab
- d = Depth of Soffit Slab
- e = Depth of Cantilever portion
- f = Thickness of the Web
- g = Horizontal Depth of Top Haunch
- h = Horizontal Width of Top Haunch
- i = Horizontal Width of Bottom Haunch
- j = Horizontal Depth of Bottom Haunch
- k = Intermediate Web thickness

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

Table.1 Dimensions of Box Girder

S.No	Type of girder	a	b	c	d	e	f	g	h	i	j	k
1	1-cell	1800	6460	225	300	150	300	150	300	450	150	-
2	2-cell	1800	6460	225	300	150	300	150	300	450	150	300
3	1-cell	2100	6260	225	300	150	300	150	300	450	150	-
4	2-cell	2100	6260	225	300	150	300	150	300	450	150	300
5	1-cell	2400	6060	275	300	150	325	150	300	450	150	-
6	2-cell	2400	6060	275	325	150	325	150	300	450	150	325
7	1-cell	2700	5840	275	325	150	325	150	300	450	150	-
8	2-cell	2700	5840	275	325	150	325	150	300	450	150	325
9	1-cell	3000	5640	300	325	150	325	150	300	450	150	-
10	2-cell	3000	5640	300	325	150	325	150	300	450	150	325

The above fig.1 and table.1 represents the dimensions of the single cell box girder and twin cell box girder.

IV. DESIGN PROCEDURE

Permissible stresses as per IRC: 112-2011 & IRC: 18-2000

- Grade of concrete = M45
- Characteristic compressive strength of concrete at 28 days = $f_{ck} = 45 \text{ N/mm}^2$
- $f_{cj} = 0.8 f_{ck}$ where f_{cj} = concrete strength at that time subject to maximum value of f_{ck}
- Allowable compressive stress at transfer = $f_{ci} = 0.45f_{cj} = 16.2 \text{ N/mm}^2$
- Allowable tensile stress at transfer = $0.1 f_{ci} = -1.62 \text{ N/mm}^2$
- Allowable compressive stress at service = $0.33 f_{ck} = 14.85 \text{ N/mm}^2$
- No tensile stresses shall be permitted at service
-ve = tensile; +ve = compressive.

Design loads

- Unit weight of concrete.
- Self weight of girder alone is considered as dead load.
- Self weight of crash barrier, wearing coats are considered as superimposed dead load.
- IRC – Class A and 70R wheel loading is considered for live load.

Calculation of prestressing force and final stresses

The basic equations of permissible stresses at top and bottom as per considered for arriving at the prestressing force are as follows

At transfer

$$\text{Stress at top} \quad \frac{P_i}{A} - \frac{eP_i}{z_t} + \frac{M_{D_i}}{z_t} \leq -0.1f_{ci} \quad \text{equation (1)}$$

$$\text{Stress at Bottom} \quad \frac{P_i}{A} + \frac{eP_i}{z_b} + \frac{M_{D_i}}{z_b} \leq f_{ci} \quad \text{equation (2)}$$

At service (Considering 20% loss of prestress)

$$\text{Stress at top} \quad \frac{0.8P_i}{A} - \frac{0.8eP_i}{z_b} + \frac{M_L}{z_b} \leq 0.33f_{ck} \quad \text{equation (3)}$$

$$\text{Stress at Bottom} \quad \frac{0.8P_i}{A} + \frac{0.8eP_i}{z_t} + \frac{M_L}{z_t} \leq 0 \quad \text{equation (4)}$$

On solving equation 1 & 4 P_{min} & e_{max} can be calculated.

On solving equation 2 & 3 P_{max} & e_{min} can be calculated.

Where e_{max} = Maximum eccentricity

e_{min} = Minimum eccentricity

P_{max} = Maximum Prestressing force

P_{min} = Minimum Prestressing force

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

Camber due to prestressing force

$$\text{Camber due to prestressing force} = -\frac{F l^3}{8 E I} \left[e_2 + \frac{l}{6} (e_1 - e_2) \right]$$

Where I = Moment inertia of section.

e_1 = Eccentricity at mid span with respect to center of gravity of concrete.

e_2 = Eccentricity at ends with respect to center of gravity of concrete.

Calculation of ultimate strength

For calculation of ultimate strength, the box girder is idealized as an equivalent I-girder

(i) Failure by yielding of steel

$$\text{Ultimate moment carrying capacity of the section} = M_{ult} = 0.9 d_b A_s f_p$$

Where A_s = Area of high tensile steel.

f_p = The ultimate tensile strength for steel without definite yield point or yield stress or stress at 4 percent elongation whichever is higher for steel with a definite yield point.

d_b = The depth of the beam from the maximum compression edge to the centre of gravity of the steel tendons.

(ii) Failure by crushing of concrete

$$M_{ult} = 0.176 b d_b^2 f_{ck} + \frac{2}{3} 0.8 (B_f - b) (d_b - t/2) t f_{ck}$$

Where b = width of box section.

B_f = width of flange.

T = thickness of flange.

V. MODELLING

Modelling is done in Midas Civil software. Different cross sections of single cell and twin cell box girder for spans of 30m, 35m, 42m, 55m, and 60m are considered for modelling. The angle of web is kept as 70° . Analysis is performed under IRC Class A wheeled vehicle and 70R wheeled vehicle.

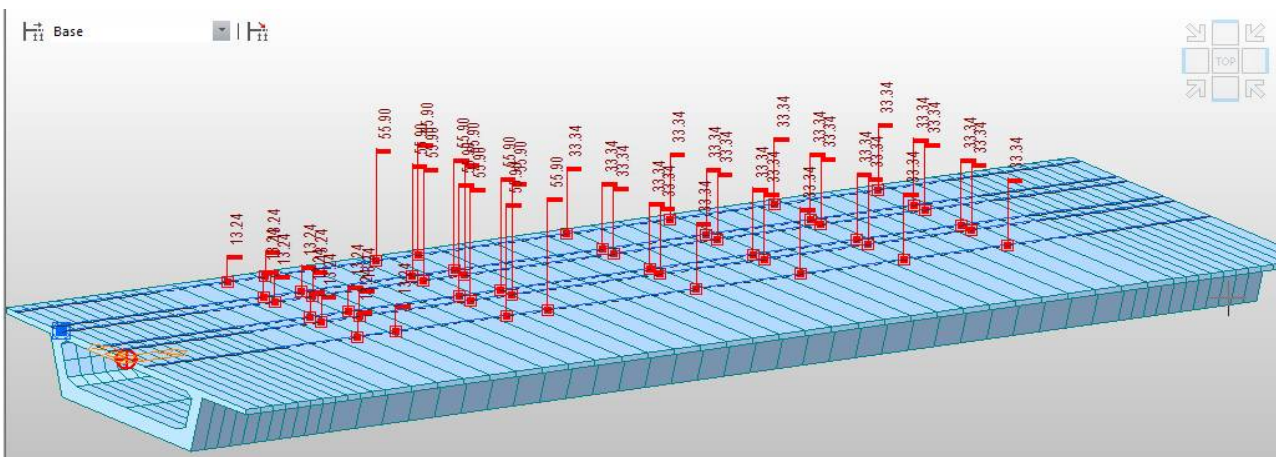


Fig.2 Longitudinal Position of 3 number of class A vehicles with maximum eccentricity with respect to central axis of box girder

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

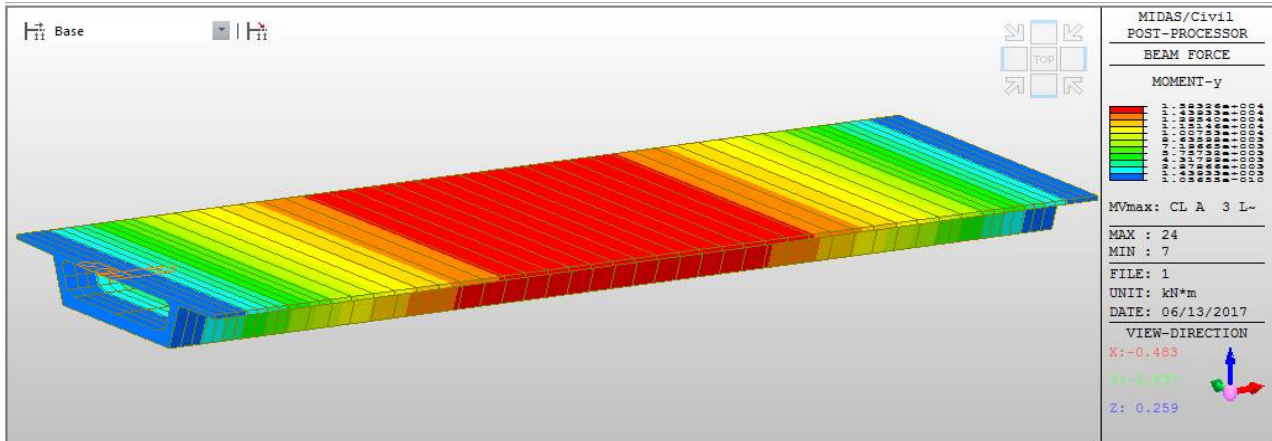


Fig.3 Maximum bending moment location of single cell box girder in render view

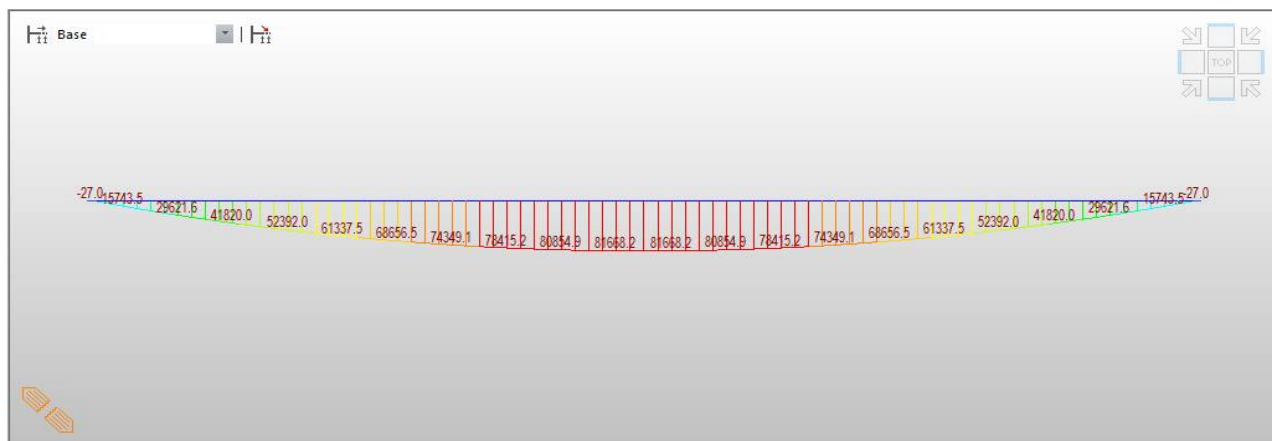


Fig.4 Beam diagram for single cell box girder

The following table denotes the bending moment due to self weight, superimposed dead load, vehicular live load, Minimum prestressing force, Maximum prestressing force and number of tendons required for single cell and twin cell box girder.

Table.2 Bending Moments due to SW, SIDL, VLL, P_{max} and P_{min}

S. No	Depth of box girder(m)	No. of cells	Clear Span (m)	B.M due to SW (kN-m)	B.M due to SIDL (kN-m)	B.M due to VLL (kN-m)	Total B.M (kN-m)	P _{min} (kN)	P _{max} (kN)	No. of tendons required
1.	1.8	1	30	12750	2250	9344	24344	17189	73065	10
2.	1.8	2	30	16140	2250	9344	27734	18568	81819	12
3.	2.1	1	35	21100	3060	11152	35312	18794	77520	11
4.	2.1	2	35	22765	3060	11152	36977	20164	83826	12
5.	2.4	1	42	33406	4408	14544	52358	22590	83676	14
6.	2.4	2	42	36470	4408	14544	55422	24464	91465	14
7.	2.7	1	55	58460	7560	20298	86318	31632	76194	18
8.	2.7	2	55	64600	7560	20298	92458	34648	84185	20
9.	3.0	1	60	74000	9000	22560	105560	33335	81438	19
10.	3.0	2	60	81700	9000	22560	113260	36725	90812	21

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

Where

B.M = Bending moment.

SW = Self weight.

SIDL = Superimposed dead load.

VLL = Vehicular live load.

P_{min} = Minimum prestressing force required.

P_{max} = Maximum prestressing force required.

- 19K15 and 12K15 strands are used for prestressing
- Ultimate tensile stress in High tensile steel = 1860 N/mm²
- Maximum allowable jacking stress is 85% of 0.2% proof stress = 1422.9 N/mm²
- Adoptable cable configuration = 15.2mm-7ply
- Nominal steel area of each strand = 140 mm²

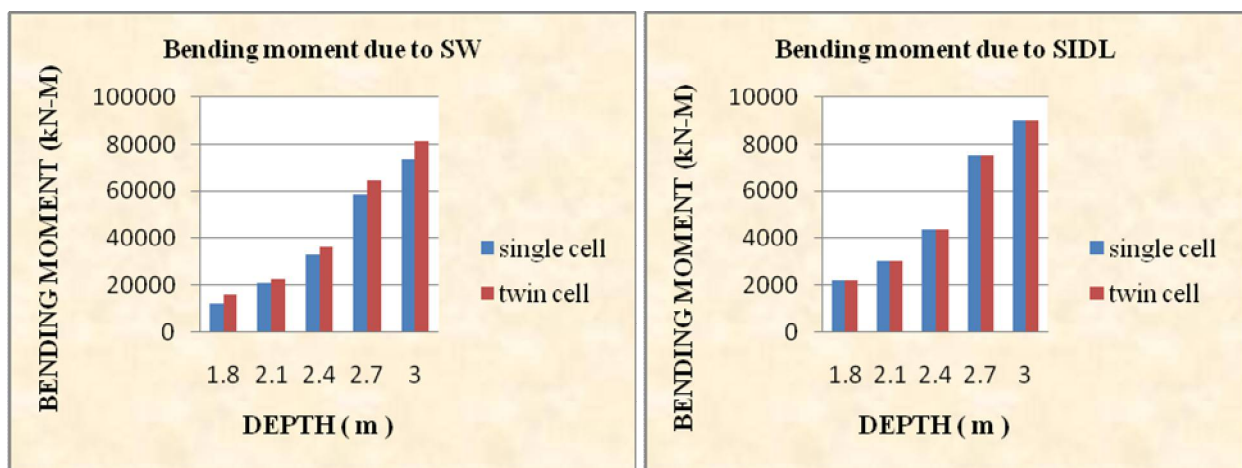


Fig. 5 Bending Moments of Single Cell and Twin Cell Box Girders due to (a) SW (b) SIDL

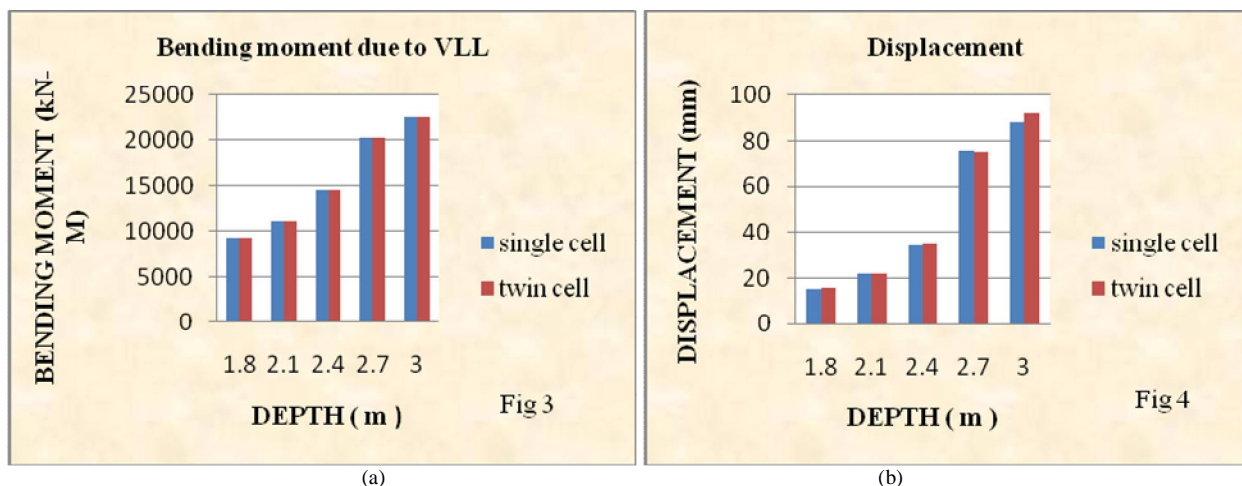


Fig. 6 Single Cell and Twin Cell Box Girders (a) Bending Moments due to VLL (b) Displacement

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

The above graphs represents the bending moment due to self weight (SW), superimposed dead load (SIDL), vehicular live load (VLL) and displacement with respect to depth for single cell and twin cell box girder.

VI. RESULTS AND DISCUSSIONS

- The self weight of box girder governs the type of girder i.e. single cell or twin cell box girder.
- The bending moment due to super imposed dead load and vehicular live load are same for both single cell and twin cell box girder.
- For spans less than 50m where depth is restricted, more number of tendons is needed to be provided and to accommodate these tendons, twin cell box girder is more significant over single cell box girder.
- For spans greater than 50m and where depth is restricted, self weight of twin cell box girder is more compared to single cell box girder as the consumption of concrete and tendons are more.

VII. CONCLUSIONS

- For spans less than 50m where depth is restricted, twin cell box girder is preferred over single cell box girder.
- For spans greater than 50m and where depth is restricted, single cell box girder is preferred over twin cell box girder over single cell box girder.

REFERENCES

- [1] Mayank Chourasia, Dr. Saleem Akhtar, "Design and Analysis of Prestressed Concrete Box Girder by Finite Element Method (4 Cells & 1 Cell)", International Journal of Civil and Structural Engineering Research(IJCSE), Vol. 3, Issue 1, pp: (413-421), Month: April 2015 - September 2015 Vishal U. Misal, N. G. Gore, P. J. Salunke, "Analysis and Design of Prestressed Concrete Girder", International Journal of Inventive Engineering and Sciences (IJIES), Volume-2, Issue-2, January 2014.
- [2] Vishal U. Misal, N. G. Gore, P. J. Salunke, "Analysis and Design of Prestressed Concrete Girder", International Journal of Inventive Engineering and Sciences (IJIES), Volume-2, Issue-2, January 2014.
- [3] K. Venkateswara Rao, G.RamaKrishna, Dr. M. Kameswara Rao, "A Comparative Design of RCC and Prestressed Concrete Flyover along with RCC Abutments", IJSRD - International Journal for Scientific Research & Development| Vol. 3, Issue 06, 2015.
- [4] IRC: 6-2014 Standard Specifications for Code of Practice for Road Bridges.
- [5] IRC:112-2011 Code of practice for concrete road bridges
- [6] IRC: 18-2000 DESIGN Criteria for Pre-stressed Concrete Road Bridges (Post-Tensioned Concrete).
- [7] IRC: 21-2000 Standard Specifications and Code of Practice for Road Bridges.
- [8] Grillage analogy in bridge deck analysis by C.S. Surana and R. Agarwal, Narosa Publishing House, ISBN: 978-81-7319-153-4, 1998.
- [9] Walter Podolny, Jean M. Muller, "Construction and design of prestressed concrete segmental bridges", John wiley & sons, 1982.
- [10] Prestressing manual, The freyssinet prestressed concrete co. ltd.
- [11] Prestressed concrete by S.K. Mallick and A.P. Gupta
- [12] Concrete box girder bridges by J.Schlaich and H.Scheer