Parametric Study on Behavior Of Box-Girder Bridges Using Finite Element Method

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Abstract

Box girders, have gained wide acceptance in freeway and bridge systems due to their structural efficiency, better stability, serviceability, economy of construction and pleasing aesthetics. Analysis and design of box-girder bridges are very complex because of its three-dimensional behavior consisting of torsion, distortion and bending in longitudinal and transverse directions. The longitudinal bending stress distribution in wide flange girder is distributed non-uniformity throughout the width. It remains maximum at the edge and reduces towards the center and usually cannot be obtained accurately from elementary beam theory. To study of box-girder bridge namely rectangular and trapezoidal cross-section has been carried out in the present work. Commercially available SAP 2000 software is used for the finite element analysis of these box-girders. The box girder are analyzed for load combination of Dead Load (Self weight) and Live load of IRC 70R loading for zero eccentricity (centrally placed) for simply supported span and continuous span. The study has been carried out for Bending moment and Longitudinal bending stress in top and bottom flange along the span for these cross-sections.

Key Words: *box-girder, complex structural systems, ductility characteristics.,*

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1. GENERAL

Nowadays, single or multi cell reinforced and prestressed concrete box girder bridge have been widely used economic and aesthetic solutions for overcrossing, undercrossing, separation structure and viaducts found in today's modern highway systems. The main advantage of these types of bridges lies in the high torsional rigidity available because of the closed box section and convenience in varying the depth along the span. High torsional stiffness gives stability and load distribution characteristics and also makes this form particularly suited for Grade Separation, where the alignment of bridges are normally curved in plan. Also the hallow section may be used to accommodate services such as water mains, telephones, electric, cables, sewage pipes etc. and the section has an added advantage of being light.

1.1 Procedure for Modeling

In the current study, SAP2000/Bridge software is utilized to create 3D models and carry out all the analysis. Design allows for quick and easy design and retrofitting of steel and concrete bridges. The parametric modeler allows the user to build simple or complex bridge models and to make changes efficiently while maintaining total control over the design process. Lanes and vehicles can be defined quickly and include width effects. Simple and practical Gantt charts are available to simulate modeling of construction sequences and scheduling. The SAP2000/Bridge module runs within the SAP2000 Plus or Advanced versions of SAP2000. It includes an easy to follow Wizard that outlines the steps necessary to create a bridge model

1.2 Assumptions made in the analysis

i. The flange (top and bottom) and web are monolithic in nature.
ii. All materials are elastic and homogeneous.
iii. The vehicle load considered for analysis purpose is Class 70 R loading. This is the highest loading in IRC loading.
iv. It is also presumed that the thickness of slab is not varied.
v. Unless otherwise specified, the finite element method is adopted to analyze bridge behavior.

1.3 Dead loads

For the purpose of dead load calculation self weight is considered. Self weight is calculated from the cross sectional properties of girder.

1.4 Vehicle loading details

All vehicles used in the study are Class 70 R wheeled vehicle with seven axles, specified in the IRC. The distance between the interior face of the barrier to the outer most line of wheels of the first vehicle was varied from 150 mm to 1200 mm. In the standard load configuration, the vehicle was spaced 1200 mm apart. The live load placement configurations are shown in fig. 1.

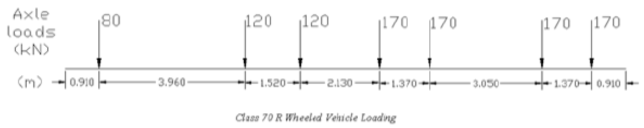

Fig. 1: IRC class Wheeled Vehicle loading in longitudinal direction

The vehicle has seven axles. The distance between the each axle and load carried by each wheel is shown in figure below. The front and rear clearance for the vehicle is 90310 mm and the vehicle width is 2.72 m.

2. BOX GIRDER DETAILS

In the present work two different cross-sections namely Rectangular and Trapezoidal section of the Single-cell Box-Girder Bridges are analyzed. The details of the cross-sections are given in Fig. 2a , 2b and Table 1.

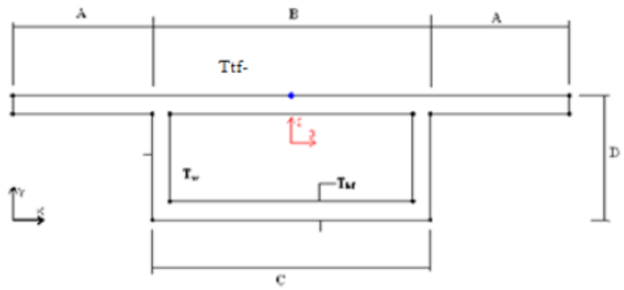

Fig.2a: Single-cell Rectangular cross-section of Box Girder Bridge

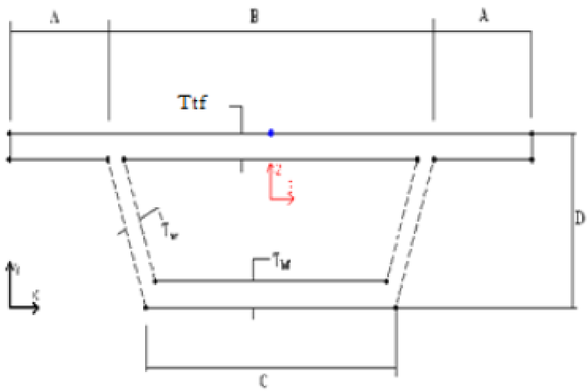

Fig.2b: Single-cell Trapezoidal cross-section of Box Girder Bridge

Ttf, Tbf and Tw are 0.3 m and same for all cross-sections. All dimensions are in meter.

Table- 1: Geometries of bridges used in parametric study

Depth	Rectangular			Trapezoidal		
D	A	B	C	A	B	C
2.0	2.4	4.8	4.8	1.8	6.0	4.6
2.4	2.4	4.8	4.8	1.8	6.0	4.7
2.8	2.4	4.8	4.8	1.7	6.2	4.6

The analysis of the bridge was done taking into consideration same width of the bridge deck with same area of cross-section and a span of 20.0 m and 40.0 m for all types of cross sections. A constant thickness of 0.3 m was assumed throughout the bridge cross section with varying depth parameter. Linear analysis was performed for dead load (Self Weight) and I.R.C live load Class 70R loading for both the cross-sections of the bridge. The loads are placed in accordance with IRC: 6-2000. The results and graphs are obtained by using SAP-2000 software.

3. PROCEDURE FOR THE ANALYSIS

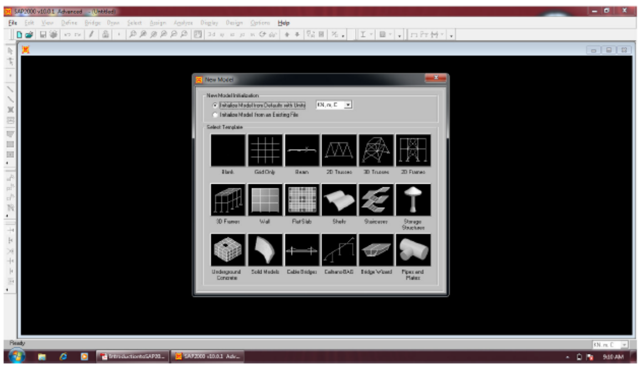

Fig. 3: New Model form

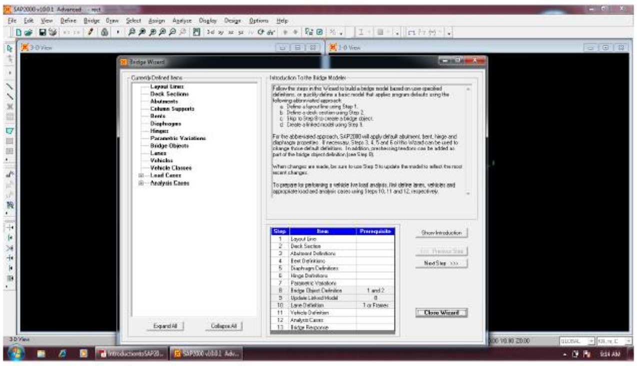

Fig. 4: SAP2000/Bridge Wizard

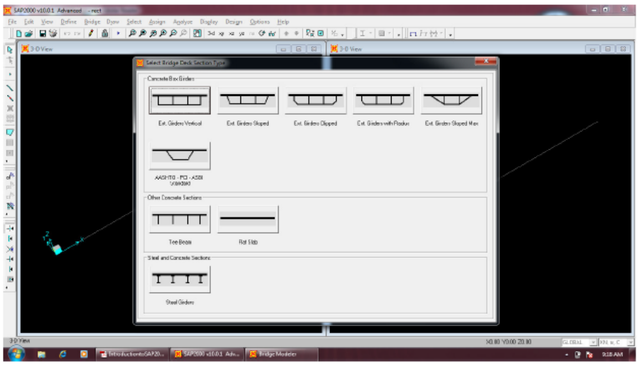

Fig. 5: Bridge deck section

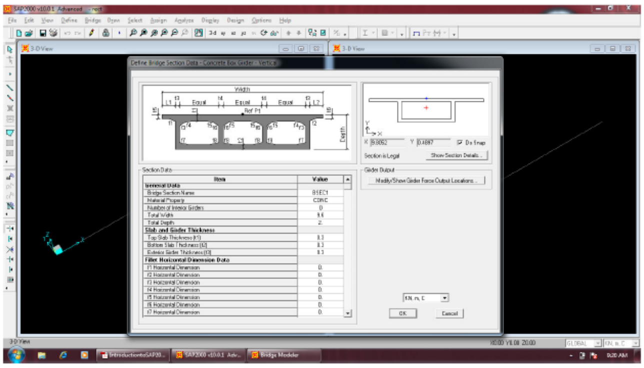

Fig. 6: Specify deck section properties

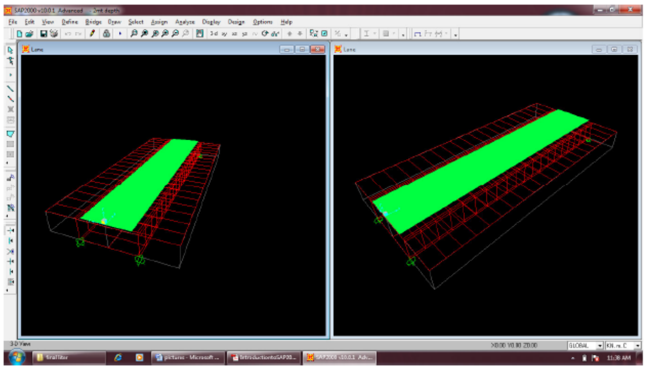

Fig. 7: 3D view of bridge model and lanes

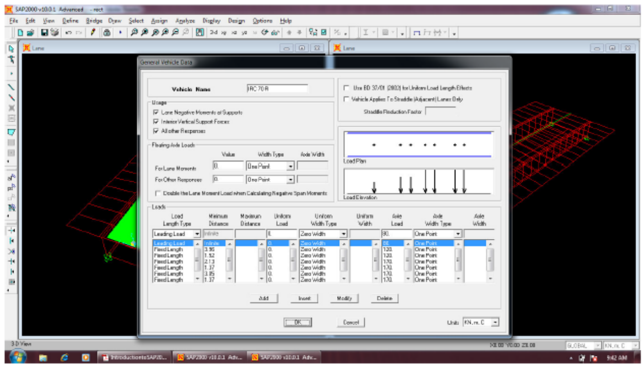

Fig. 8: IRC 70 R Vehicle Data form

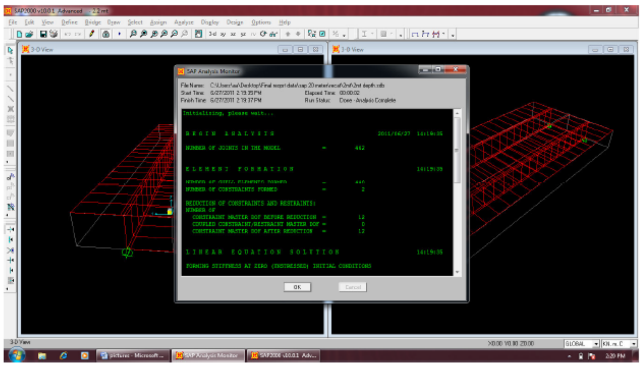

Fig. 9: Showing the analysis

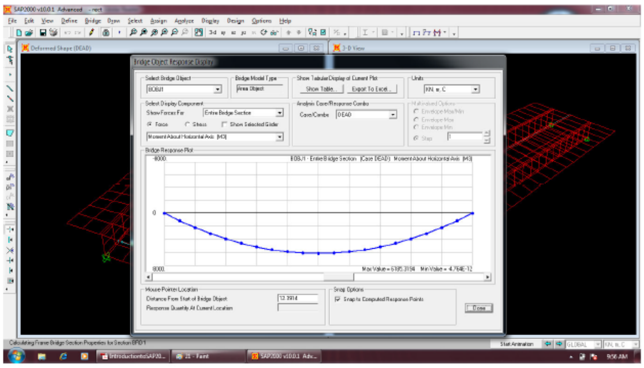

Fig. 10: Graphical Results

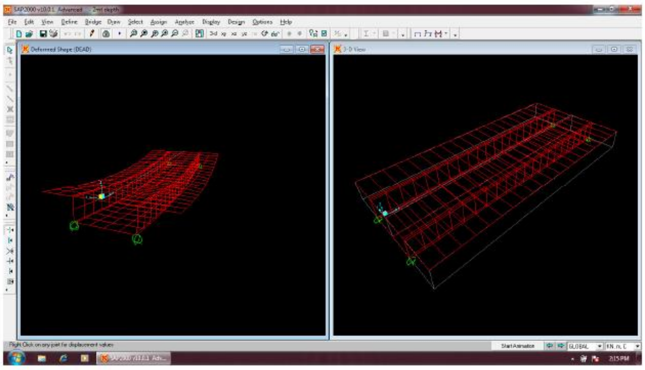

Fig. 11: Bridge Object Response Display

4. RESULTS

4.1 Span 20 m (simply supported span)

Table- 2: Maximum Bending Moment for Single-Cell Rectangular Box-Girder Bridge

Depth (m)	Rectangular box-girder (KN-m)	Increase Percentage in Bending Moment
2.0	6185.31	---
2.4	6468.07	4.57
2.8	6750.83	9.14

Table- 3: Maximum Longitudinal Bending Stress in Top Flange along the span for Single-Cell Rectangular Box-Girder Bridge

Depth (m)	Rectangular box-girder (KN/m²)	Decrease Percentage in stress
2.0	1572.46	---
2.4	1276.01	18.85
2.8	1082.53	31.15

Table- 4: Maximum Longitudinal Bending Stress in Bottom Flange along the span for Single-Cell Rectangular Box-Girder Bridge

Depth (m)	Rectangular box-girder (KN/m²)	Decrease Percentage in stress
2.0	2550.46	---
2.4	2052.72	19.51
2.8	1721.83	32.48

Table- 5: Maximum Bending Moment for Single-Cell Trapezoidal Box-Girder Bridge

Depth (m)	Trapezoidal box-girder (KN-m)	Increase Percentage in Bending Moment
2.0	6397.38	---
2.4	6680.14	4.41
2.8	6962.90	8.83

Table- 6: Maximum Longitudinal Bending Stress in Top Flange along the span for Single-Cell Trapezoidal Box-Girder Bridge

Depth (m)	Trapezoidal box-girder (KN/m²)	Decrease Percentage in stress
2.0	1592.54	---
2.4	1292.17	18.86
2.8	1095.65	31.20

Table- 7: Maximum Longitudinal Bending Stress in Bottom Flange along the span for Single-Cell Trapezoidal Box-Girder Bridge

Depth (m)	Trapezoidal box-girder (KN/m²)	Decrease Percentage in stress
2.0	2376.88	---
2.4	1919.03	19.26
2.8	1614.19	32.08

4.2 Span 40 m (continuous span)

Table- 8: Maximum Bending Moment for Single-Cell Rectangular Box-Girder Bridge

Depth (m)	Rectangular box-girder (KN-m)		Increase Percentage in BM	
	+ ve BM	- ve BM	+ ve BM	- ve BM
2.0	5698.38	3658.55	---	---
2.4	5835.65	3875.09	2.40	5.91
2.8	5933.73	4107.31	4.13	12.26

Table- 9: Maximum Longitudinal Bending Stress in Top Flange along the span for Single-Cell Rectangular Box-Girder Bridge

Depth (m)	Rectangular box-girder (KN/m²)		Decrease Percentage in stress	
	+ ve BM	- ve BM	+ ve BM	- ve BM
2.0	1448.67	930.09	---	---
2.4	1151.25	764.47	20.53	17.80
2.8	951.50	658.63	34.31	29.18

Table- 10: Maximum Longitudinal Bending Stress in Bottom Flange along the span for Single-Cell Rectangular Box-Girder Bridge

Depth (m)	Rectangular box-girder (KN/m²)		Decrease Percentage in stress	
	+ ve BM	- ve BM	+ ve BM	- ve BM
2.0	2349.67	1508.56	---	---
2.4	1852.01	1229.80	21.17	18.47
2.8	1513.42	1047.58	35.59	30.55

Table- 11: Maximum Bending Moment for Single-Cell Trapezoidal Box-Girder Bridge

Depth (m)	Trapezoidal box-girder (KN-m)		Increase Percentage in BM	
	+ ve BM	- ve BM	+ ve BM	- ve BM
2.0	5556.18	3511.84	---	---
2.4	5939.89	4036.98	6.90	14.95
2.8	6023.56	4274.96	8.41	21.72

Table- 12: Maximum Longitudinal Bending Stress in Top Flange along the span for Single-Cell Trapezoidal Box-Girder Bridge

Depth (m)	Trapezoidal box-girder (KN/m²)		Decrease Percentage in stress	
	+ ve BM	- ve BM	+ ve BM	- ve BM
2.0	1443.96	912.67	---	---
2.4	1148.98	780.89	20.42	14.43
2.8	947.84	672.69	34.35	26.29

Table- 13: Maximum Longitudinal Bending Stress in Bottom Flange along the span for Single-Cell Trapezoidal Box-Girder Bridge

Depth (m)	Trapezoidal box-girder (KN/m²)		Decrease Percentage in stress	
	+ ve BM	- ve BM	+ ve BM	- ve BM
2.0	2528.88	1598.40	---	---
2.4	1706.38	1159.72	32.52	27.44
2.8	1396.42	991.05	44.81	37.99

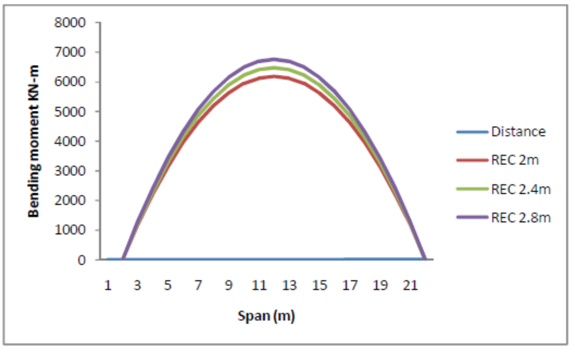

Fig. 12: Variation of Maximum Bending Moment for Single-Cell Rectangular Box-Girder Bridge

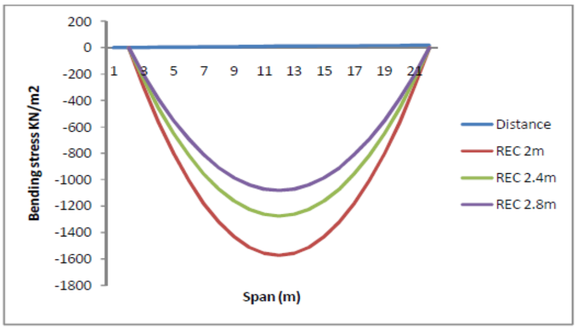

Fig. 13: Variation of Maximum Longitudinal Bending Stress in Top Flange along the span for Single-Cell Rectangular Box-Girder Bridge

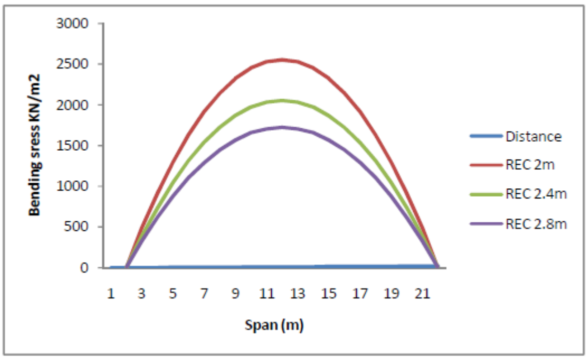

Fig. 14: Variation of Maximum Longitudinal Bending Stress in Bottom Flange along the span for Single-Cell Rectangular Box-Girder Bridge

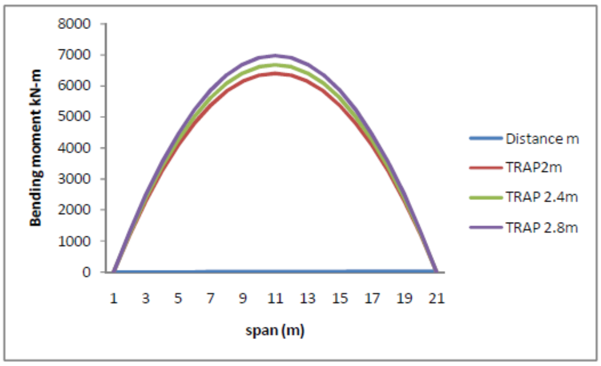

Fig. 15: Variation of Maximum Bending Moment for Single-Cell Trapezoidal Box- Girder Bridge

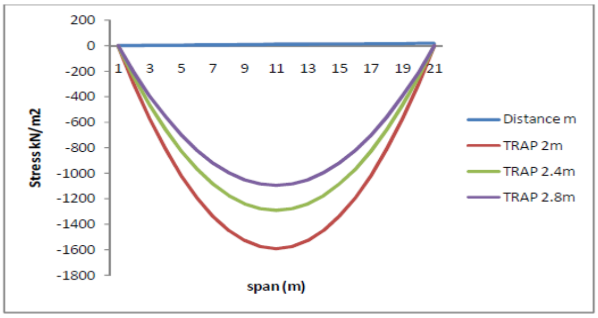

Fig. 16: Variation of Maximum Longitudinal Bending Stress in Top Flange along the span for Single-Cell Trapezoidal Box-Girder Bridge

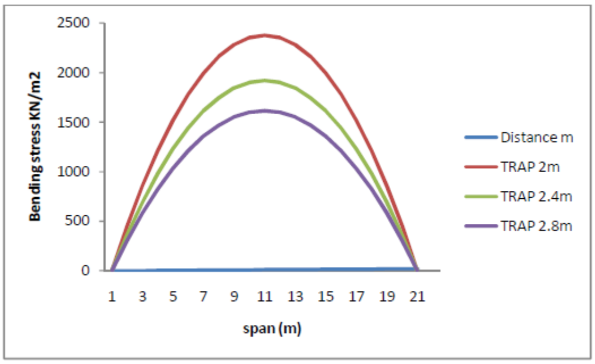

Fig. 17: Variation of Maximum Longitudinal Bending Stress in Bottom Flange along the span for Single-Cell Trapezoidal Box-Girder Bridge

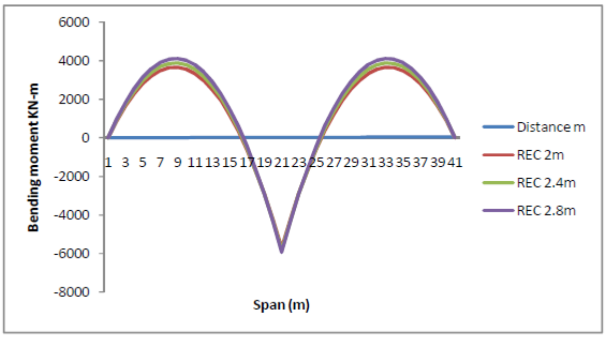

Fig. 18: Variation of Maximum Bending Moment for Single-Cell Rectangular Box-Girder Bridge

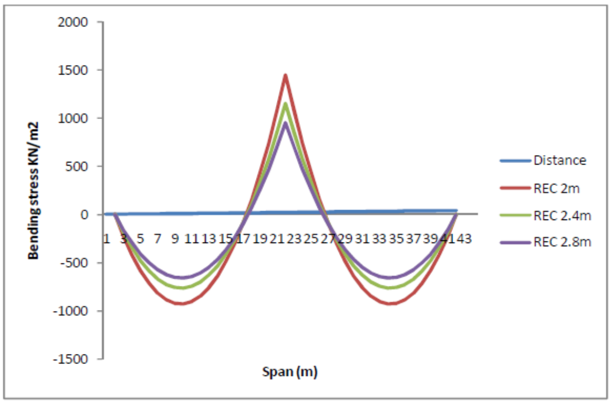

Fig. 19: Variation of Maximum Longitudinal Bending Stress in Top Flange along the span for Single-Cell Rectangular Box-Girder Bridge

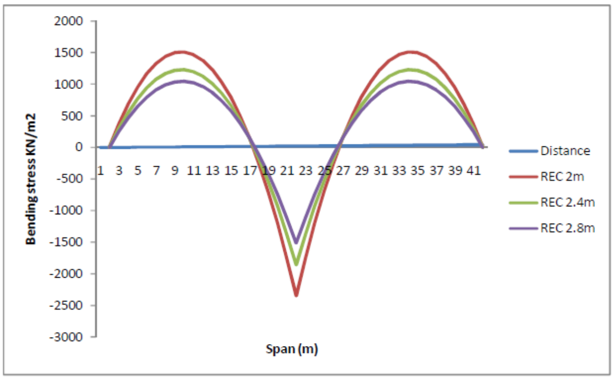

Fig. 20: Variation of Maximum Longitudinal Bending Stress in Bottom Flange alongthe span for Single-Cell Rectangular Box-Girder Bridge

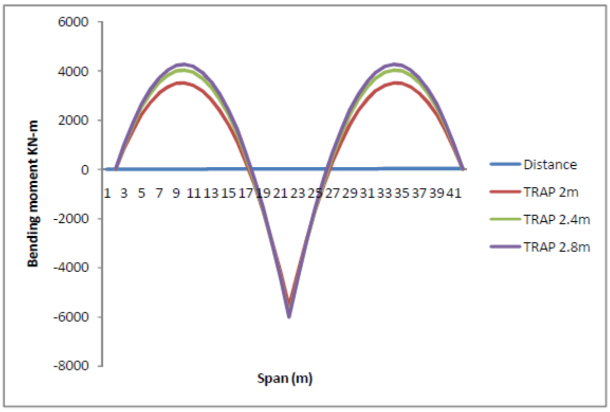

Fig. 21: Variation of Maximum Bending Moment for Single-Cell Trapezoidal Box- Girder Bridge

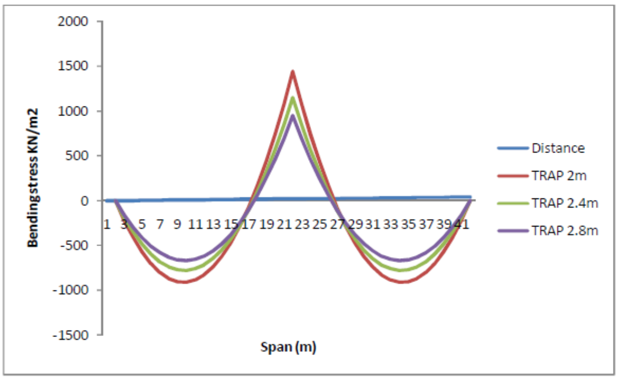

Fig. 22: Variation of Maximum Longitudinal Bending Stress in Top Flange along the span for Single-Cell Trapezoidal Box-Girder Bridge

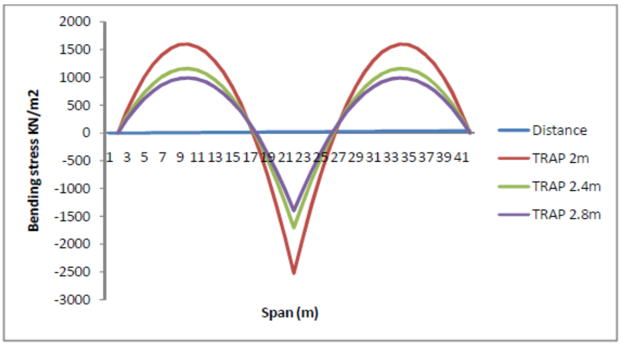

Fig. 23: Variation of Maximum Longitudinal Bending Stress in Bottom Flange along the span for Single-Cell Trapezoidal Box-Girder Bridge

5. CONCLUSION

An extensive parametric study was conducted on behavior of box-girder bridges analyzed using finite element model. Based on this study the following conclusions were made:

i. As the depth of box-girder Increases the Bending moment also increases.

ii. As the depth of box-girder Increase the longitudinal bending stress in top flange and bottom flange along the span decreases.

iii. Among rectangular and trapezoidal cross section box girders for all depths, the bending moment is highest in trapezoidal girder under the load combination of dead load and live load (centrally) and least in rectangular girder. Therefore it can be concluded that the rectangular section is the stiffest section among these two sections.

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