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Analytical and Parametric Study of Double Box Girder

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Abstract*—* *Bridge construction today has achieved a worldwide level of importance. Due to efficient dissemination of congested traffic, economic considerations, and aesthetic box girder bridges have become increasingly popular nowadays in modern highway systems, including urban interchanges. Box girder bridges are commonly used for highway flyovers and for modern elevated structures of light rail transport. A box girder bridge is a bridge in which the main beams comprise girders in the shape of a hollow box. The box is typically rectangular or trapezoidal in cross-section. Use of box girder is gaining popularity in bridge engineering fraternity because of its better stability, serviceability, economy, aesthetic appearance and structural efficiency. The present study focus on the study of double cell box girder bridges curved in plan of rectangular, trapezoidal and circular cross-section.*

The present study also focuses parametric study like varying span to depth ratio, radius of curvature and varying span length. Response of box girder analyzed using IRC class A loading and also using response spectrum analysis, Analysis will carried out in finite element Software ANSYS 16. The longitudinal deflection, stress, moment reaction and fundamental frequency will obtained.

Keywords*—* *Double Box Girder, IRC Class A, Response Spectrum*.

I. INTRODUCTION

Now a days, bridge construction achieved a worldwide level of importance, due to efficient dissemination of congested traffic, economic considerations, and aesthetic appearance. Box girder bridges become increasingly popular in modern highway systems, including urban interchanges. Box girder bridges are commonly used for highway flyovers and for modern elevated structures of light rail transport.

A box girder bridge is a bridge in which the main beams comprise girders in the shape of a hollow box. The box is typically rectangular or trapezoidal in cross-section. Use of box girder is gaining popularity in bridge engineering fraternity because of its better stability, serviceability, economy, aesthetic appearance and structural efficiency.

A box or tubular girder is a girder that forms an enclosed tube with multiple walls, rather than an I or H-beam. Originally constructed of riveted wrought iron, they are now found in rolled or welded steel, aluminum extrusions or concrete. Compared to an I-beam, the advantage of a box girder is that it resists torsion. Having multiple vertical webs, it can also carry more load than an I-beam of equal height (although it will use more material than a taller I-beam of equivalent capacity). Although normally the box girder bridge is a form of beam bridge, box girders may also be used on cable-stayed bridges and other forms.

Box girders can be classified in so many ways according to their method of construction, uses, and shapes. Box girders can be constructed as single cell, double cell or multicell. It may be monolithically constructed with the deck, called closed box girder or the deck can be separately constructed afterwards called open box girder. Box girders may be rectangular, trapezoidal and circular in shapes.

II. CROSS SECTION SPECIFICATION AND MATERIAL PROPERTY

Double Cell Concrete Box-Girder with two traffic lanes The cross-sectional properties for the box girder like span length, width of bridge, depth of bridge, thickness of top flange, width of top flange, width of bottom flange etc.

Top slab thickness (Tapered) = at the centre 300 mm & at corner 200 mm
Bottom Slab thickness = 200 mm
External wall thickness = 300 mm
Span = 30m
Total width = 10m Road (Including 1.25m of foot path both side)
Width of Carriage way = 7.5m
Wearing coat = 80mm

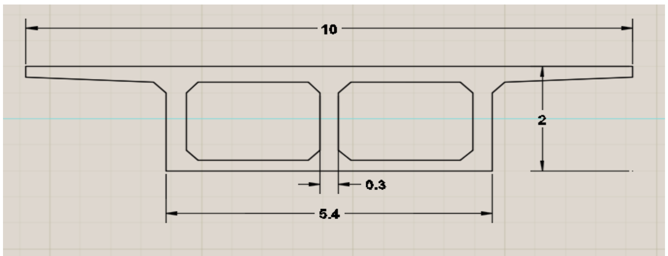

Fig. 1. Cross-sectional details of rectangular box girder (all dimensions are in meter).

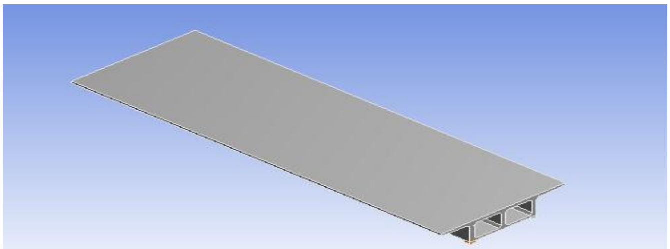
Fig. 2. Perspective view of rectangular straight box girder.

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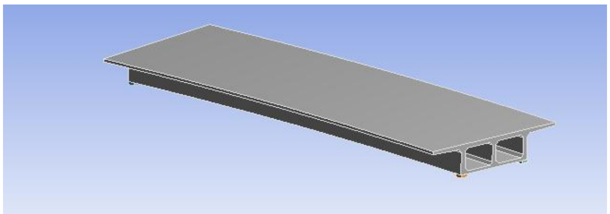

Fig .3. Perspective view of rectangular curved box girder.

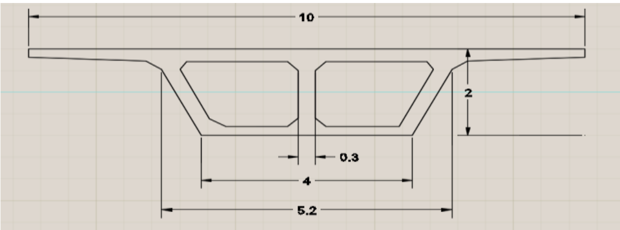

Fig .4. Cross-sectional details of trapezoidal box girder (all dimensions are in meter).

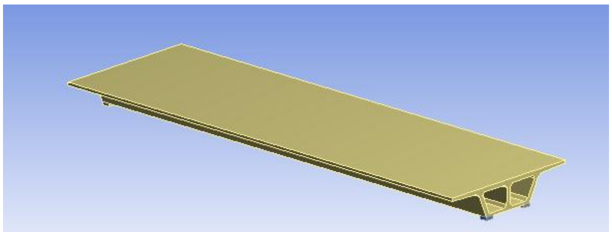

Fig. 5. Perspective view of trapezoidal straight box girder.

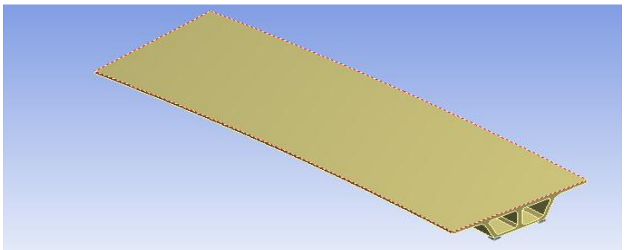

Fig. 6. Perspective view of trapezoidal curved box girder.

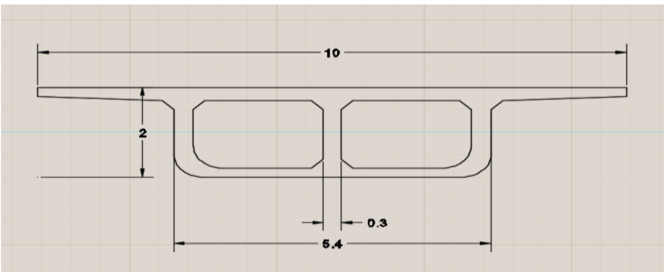

Fig. 7. Cross-sectional details circular straight box girder (all dimensions are in meter).

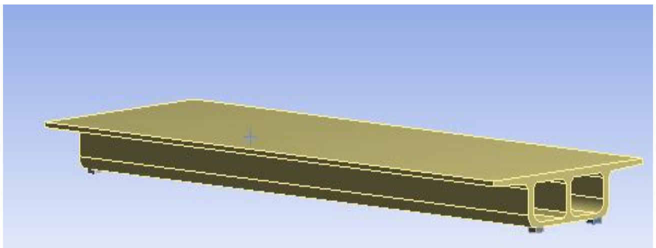

Fig. 8. Perspective view of circular straight box girder.

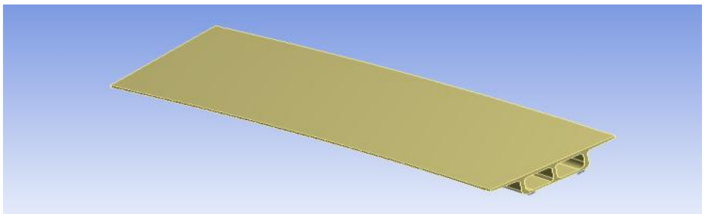

Fig. 9. Perspective view of circular curved box girder.

TABLE I. Material property.

Material Properties	Values
Young's modulus (E)	3.8730×10^7 kN/m^2
Poisson's ratio (υ)	0.15
weight /unit volume	25kN/m^3

III. Boundary Condition

The boundary condition is provided as fixed support on endplate.

IV. Analysis Conducted for Present Study

Static analysis and Response spectrum analysis conducted. For static analysis all the models are subjected to self-weight and moving load of IRC class A.

In order to perform the seismic analysis and design of a structure to be built at a particular location, the actual time history record is required. However, it is not possible to have such records at each and every location. Further, the seismic analysis of structures cannot be carried out simply based on the peak value of the ground acceleration as the response of the structure depend upon the frequency content of ground motion and its own dynamic properties. To overcome the above difficulties, earthquake response spectrum is the most popular tool in the seismic analysis of structures.

In this thesis Savannah River Site Disaggregated Seismic Spectra is used to study behavior of box girder .The strongest earthquake ever to strike the east coast of the United States hit Savannah on a Tuesday night 125 years ago: August 31, 1886. The three epicenters of this major destructive quake, now estimated to have been about a 7.3 magnitude, were located just outside of Charleston, one hundred miles north. But on the night of August 31, people in Savannah thought they must be experiencing The Great Savannah Earthquake.

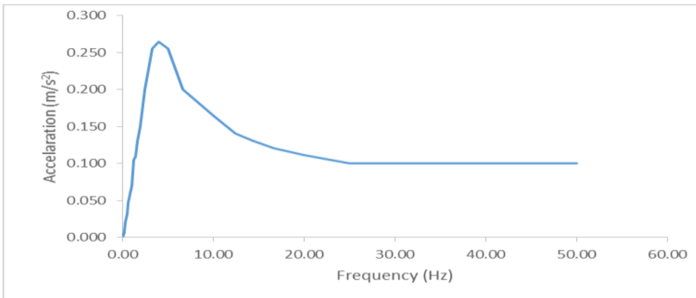

Fig. 10. Savannah River site disaggregated seismic spectra.

V. Results and Discussion

The results of modal analysis static analysis and response spectrum analysis of double box girder have been discussed. The analysis was conducted to obtain best shape box girder and also conduct parametric study like span to depth and radius of curvature. The analysis was done for obtaining maximum deflection, maximum stress, moment reaction and fundamental frequency.

A. Maximum Deflection

The rectangular, trapezoidal and circular double box girder is analyzed under IRC class A loading and response spectrum analysis. After the analysis the deflection results obtained is listed in table II

TABLE II. Deflection in straight and curved box girder.

	Deflection (mm)		
	Rectangular	**Trapezoidal**	**Circular**
Straight box girder	8.35	8.20	8.58
Curved box girder	7.52	7.51	7.56

TABLE III. Deflection straight and curved box girder (Response spectrum analysis).

	Deflection (mm)		
	Rectangular	**Trapezoidal**	**Circular**
Straight box girder	0.132	0.128	0.136
Curved box girder	0.112	0.109	0.113

From above table II and table III it is clear that deflection was minimum in trapezoidal box girder and also from graph it is clear that the deflection was maximum in middle of span and minimum in support. And also deflection is less in curved box girder than straight box girder. So parametric study conducted for trapezoidal shape only.

Span to depth ratio adopted for study starting from 15 to 19 and span length kept constant.

TABLE IV Deflection for varying span to depth ratio.

L/D ratio	Deflection (mm)	
	Static analysis	**Response spectrum analysis**
15	8.26	0.130
16	9.31	0.150
17	10.65	0.181
18	12	0.213
19	13.43	0.249

For static and response spectrum analysis also deflection value increases with increase in span to depth ratio. For varying span to depth ratio, deflection value is minimum for span to depth ratio (L/d) 15 .So for designing box girder span to depth ratio L/d ratio minimum is best.

The next parametric study concentrated on radius of curvature. With variation in radius of curve in plan from 750m, 500m, 250m and 100m and 75m.

TABLE V. Deflection for varying radius of curvature.

Radius of curvature	Deflection (mm)	
	Static analysis	**Response spectrum analysis**
750 m	7.5	0.109
500m	8.56	0.135
250m	8.59	0.147
100m	8.65	0.160
75m	9.2	0.223

From table V for static and response spectrum analysis also deflection decreases with increase in radius of curvature.

The trapezoidal double box girder is analyzed for different span length under IRC class A loading. Span length adopted for thesis is 30m, 35m and 40m.

TABLE VI. Deflection for varying span length.

Span length	Deflection (mm)	
	Static analysis	**Response spectrum analysis**
30 m	8.26	0.13
35m	10.34	0.19
40m	12.82	0.29

From table VI for static and response spectrum analysis also deflection increases with increase in span length.

B. Maximum Stress

For the same static load of IRC Class A, the stress resultant is observed for the straight and curved box girder. The stress results also checked for response spectrum analysis.

TABLE VII. Maximum Stress in straight and curved box girder.

	Maximum Stress (kN/m^2)		
	Rectangular	**Trapezoidal**	**Circular**
Straight box girder	355	353	389
Circular box girder	381	311	684

TABLE VIII. Maximum stress in straight and curved box girder (Response spectrum analysis).

	Maximum Stress (kN/m^2)		
	Rectangular	**Trapezoidal**	**Circular**
Straight box girder	254	227	255
Circular box girder	399	113	498

From above table VIII it is clear that stress distribution is minimum in trapezoidal shape for straight and curved box girder for static and response spectrum analysis.

TABLE IX. Maximum stress for varying L/D ratio.

L/D ratio	Maximum Stress (kN/m^2)	
	Static analysis	**Response spectrum analysis**
15	376	256
16	414	281
17	452	322
18	492	361
19	510	390

From table IX for static and response spectrum analysis also stress value increases with increase in span to depth ratio. For varying span to depth ratio, stress value is minimum for span to depth ratio (L/d) 15 .So for designing box girder span to depth ratio L/d ratio minimum is best

TABLE X. Maximum Stress for varying radius of curvature.

Radius of curvature	Maximum Stress (kN/m^2)	
	Static analysis	**Response spectrum analysis**
750 m	311	113
500m	333	280
250m	344	319
100m	392	354
75m	522	397

From above table X it is concluded that for response spectrum analysis stress value decrease with increase in radius of curvature.

TABLE XI. Maximum stress for varying span length.

Span length	Maximum Stress (kN/m^2)	
	Static analysis	Response spectrum analysis
30 m	376	254
35m	404	335
40m	440	428

From table XI for static and response spectrum analysis also stress increases with increase in span length.

C. Moment Reaction

TABLE XII. Moment reaction in straight and curved box girder.

	Moment reaction (kN-m)		
	Rectangular	Trapezoidal	Circular
Straight box girder	1055	1038	1082
Curved box girder	1053	931	1076

From above table XII it is clear that moment reaction was minimum in trapezoidal shape for straight and curved box girder.

TABLE XIII. Moment reaction for varying span to depth ratio.

Span to depth ratio	L/d =15	L/d =16	L/d =17	L/d =18	L/d =19
Moment reaction(kNm)	1038	1533	1760	1785	1907

From above table XIII it is clear that moment reaction is minimum for span to depth ratio 15.

TABLE XIV. Moment reaction for varying radius of curvature.

Radius of curvature	750m	500m	250m	100m	75m
Moment reaction(kNm)	1038	1041	1043	1278	1435

From above table XIV it is clear that moment reaction was decreasing as increasing radius of curvature.

TABLE XV. Moment reaction for varying span length.

Span length	30m	35m	40m
Moment reaction(kNm)	1038	1345	1543

From above table XV it is clear that moment reaction is increasing with increase in span length.

D. Modal Analysis

The modal analysis or free vibration analysis of straight and curved box girder conducted. Modal analysis was done to find out the natural frequency of the model.

TABLE XVI. Frequency of straight and curved box girder.

	Frequency (Hz)		
	Rectangular	Trapezoidal	Circular
Straight box girder	30.79	30.32	31.11
Curved box girder	30.06	29.92	30.32

From table XVI As the span length and the material property is same for all the models so, the mass for all models are same; therefore there is no great change in natural frequency.

TABLE XVII. Frequency of varying span to depth ratio.

Span to depth ratio	L/d =15	L/d =16	L/d =17	L/d =18	L/d =19
Frequency (Hz)	30.32	30.58	31.34	31.63	31.89

TABLE XVIII. Frequency of varying radius of curvature ratio.

Radius of curvature	750m	500m	250m	100m	75m
Frequency (Hz)	30.32	30.61	31.54	31.76	31.86

TABLE XIX. Frequency of varying span to depth ratio.

Span to depth ratio	30m	35m	40m
Frequency (Hz)	30.32	30.98	31.34

VI. CONCLUSIONS

Results are obtained for static and response spectrum analysis. From the results obtained for deflection, maximum stress, moment ratio and frequency and the performance of each type is compared.

1. For static analysis deflection, moment reaction and stress is less in trapezoidal shape.
2. For response spectrum analysis also deflection, moment reaction and stress is less for trapezoidal shape. So for designing box girder trapezoidal shape is best.
3. From study conducted for span to depth ratio, best span to depth ratio obtained as L/d 15.
4. From study conducted for varying radius of curvature, as radius of curvature increases deflection, moment reaction and stress decreases.
5. From study conducted for varying span length, as span length increases deflection, moment reaction and stress increases.

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