iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 Issue: XI Month of publication: November 2018

DOI:

Design Aids of RCC Box Culvert by using Staad Pro

P. Chanakya[1], CH. Damodhar Naidu[2]
[1]M. Tech Student, Department of Civil Engineering, Gokul Group of Institutions, Bobbili, Vizianagaram-535558
[2]Assistant Professor, Department of Civil Engineering, Gokul Group of Institutions, Bobbili, Vizianagaram-535558

Abstract: Box culverts are very important part of a transportation network as they provide a cost-effective alternate to substantial bridges. A culvert is a structure that allows water to flow under a road ways, railways, or similar obstruction from one side to the other side. A culvert may be made from a pipe, reinforced concrete or other material. Culverts are commonly used both as cross drains for channel release and to pass water under a road at natural drainage and river crossings. A culvert may be a bridge like structure designed to allow vehicle or pedestrian traffic to cross over the watercourse while permitting suitable opening for the water. Culverts can be of different shapes such as arch, slab and box. These can be constructed with different material such as masonry (brick, stone etc.) or reinforced cement concrete. Since culvert pass through the earthen embankment, these are subjected to same traffic loads as the road carries and therefore, required to be designed for such loads. This Paper deals with box culverts made of RCC, without cushion. The size, invert level, layout etc. are decided by hydraulic considerations and site conditions. The scope of this Paper has been further restricted to the structural design of box. The structural design involves consideration of load cases (box empty, full, surcharge loads etc.) and factors like live load, effective width, braking force, dispersal of load through fill, impact factor, co-efficient of earth pressure etc. Relevant IRC Codes are required to be referred. The structural elements are required to be designed to withstand maximum bending moment and shear force. The Paper provides full discussions on the provisions in the Codes, considerations and justification of all the above aspects on design.
Keywords: Reinforced cement concrete box culvert, structural design, theoretical calculation, staad pro and comparison.

I. INTRODUCTION

An early mention of box culverts is contained in the 1900- 01 Geological Survey Report. The author reported that “after a number of attempts the contractor abandoned the construction of a box culvert at this point and substituted 30-inch pipe” (Reid 1902: 133).This statement illustrates that box culverts were known to contractors in Maryland during the first few years of the twentieth century. When the State Roads Commission issued the first Standard Plans for road way structures in 1912, they included designs for both “box culverts” and “box bridges.” The plans contained four designs for “steel-concrete” (reinforced concrete) culverts and one design for a “box bridge.” The culverts ranged from 18 inches x 18 inches to 6 feet x 8feet and specified plain concrete on the sides and bottom of the box and reinforced concrete on the top. The box bridge design was for spans from 10 feet to 16 feet and included reinforced concrete on all four sides of the box. These designs may have continued in use until the State Roads Commission issued revised box culvert designs in 1931. The size of the culvert designs in 1931 ranged from a 2-foot x 2-foot box to a 6-foot x 6-foot box. Designs were included for eight sizes of box culverts and each size culvert had a separate design for no-fill, 5-foot maximum fill and 10-foot maximum fill. The no-fill designs had a parapet rail with an incised rectangular design. A box can also be placed within the embankment where top slab is few meters below the road surface and such boxes are termed with cushion. The size of box and the invert level depend on the hydraulic requirements governed by hydraulic designs. The height of cushion is governed by the road profile at the location of the culvert. For a box culvert, the top slab is required to withstand dead loads, live loads from moving traffic, earth pressure on sidewalls, water pressure from inside, and pressure on the bottom slab besides self-weight of the slab.

Components of Box culvert:

The main parts of a box culvert are as below:

1) Leveling course
2) Bottom slab
3) Side walls
4) Top slab
5) Wing walls & aprons

II. LITERATURE REVIEW

M.G. Kalyanshetti and S.A. Gosavi (2014) The analysis is done by using stiffness matrix method and a computer program in C language is developed for the cost evaluation. Study is carried out related to variation in bending moment; subsequently cost comparison is made for different aspect ratios. The percentage reduction in cost of single cell, double cell and triple cell based on optimum thicknesses are presented. The optimum thicknesses presented over here are used to achieve the economical design of box culvert. Based on these optimum thicknesses optimum cost per meter width of single cell, double cell and triple cell is evaluated. The study reveals that the cost of box culvert reduces if the optimum thicknesses which are presented in this study are considered.

Sujata Shreedhar and R.Shreedhar (2013) presented the paper on Design coefficients for single and two cell box culverts. The box culvert has to be analyzed for moments, shear forces and thrusts developed due to the various loading conditions by any classical methods such as moment distribution method, slope deflection method etc. It becomes very tedious for the designer to arrive at design forces for various loading conditions. Hence a study is made to arrive at the coefficients for moments, shear forces and axial thrusts for different loading cases and for different ratios of length to height.

Lande Abhijeet Chandrakant, Patil Vidya Malgonda (2014) analysed the box culvert by finite element method. In the paper they presented about the structural elements are required to be designed to withstand maximum bending moment and shear force. So excel program is developed for analysis and it is compared with software results. So analysis of box culvert is carried out for it for various box conditions and structural design is suggested for critical cases. In skew box culvert various angles are considered and analysis of box culvert is carried out for various conditions

NehaKolate, Molly Mathew, Snehal Mali presented paper on analysis and design of RCC box culvert. This paper deals with study of some of the design parameters of box culverts like angle of dispersion or effective width of live load, effect of earth pressure and depth of cushion provided on top slab of box culverts. Depth of cushion, coefficient of earth pressure for lateral pressures on walls, width or angle of dispersion for live loads on box without cushion and with cushion for structural deformations are important items.

H. Chanson (2000) analysed the hydraulic design of culvert. The paper presents a new way to teach hydraulic design to civil and environmental engineering students in an undergraduate curriculum. The hydraulic design of a culvert is introduced as part of a complete design approach. The paper describes engineering design techniques in which individual originality and innovation is required.

III. ANALYSIS AND DESIGN OF RCC BOX CULVERT

Loads on Box culverts

The following are the various loads to be considered:

1) Dead load
2) Live load
3) Impact load
4) Longitudinal force/braking force
5) Soil pressure on the side walls
6) Surcharge due to live load
7) Water pressure from inside

Manual Design

The materials and member properties are considered as follows:

Clear span = 3 m

Clear height = 3 m

Concrete grade M25 = 25 Mpa

Steel grade Fe 415 = 415 Mpa

БSc (Concrete) = 8.33 Mpa

Bottom slab thickness = 0.42 m

БSt (Steel) = 200 Mpa

Side wall thickness = 0.42 m

Modular ratio = 10

Unit weight of concrete = 24 kN/m3

n (for depth of neutral axis) = 0.294

Unit weight of earth = 18 kN/m^3

(for effective depth) = 0.902

Unit weight of water = 10 kN/ m^3
k(for moment of resistance) = 1.105 Mpa
Co-efficient of earth pressure at rest = 0.5
All dimensions are in meter unless total cushion on top 0.0 m mentioned otherwise the thickness of wearing coat = 0.065 m

Table 1. Moment distribution for total load for top and bottom slabs

Joint	A		B		C		D	
Member	AB	AD	BA	BC	CB	CD	DC	DE
D.F	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
F.E.M	-105.320	22.530	105.320	-22.530	28.53	-47.63	47.63	-28.53
DIST	41.39	41.39	-41.39	-41.39	9.55	9.55	-9.55	-9.55
C.O	-20.69	-4.78	20.693	4.776	-20.693	-4.776	4.776	20.693
DIST	12.73	12.73	-12.73	-12.73	12.73	12.73	-12.73	-12.73
C.O	-6.37	-6.37	6.367	6.367	-6.367	-6.37	6.37	6.367
DIST	6.37	6.37	-6.37	-6.37	6.37	6.37	-6.37	-6.37
C.O	-3.18	-3.18	3.184	3.18	-3.184	-3.18	3.184	3.184
DIST	3.18	3.18	-3.18	-3.18	3.18	3.18	-3.18	-3.18
C.O	-1.59	-1.592	1.592	1.592	-1.592	-1.59	1.592	1.59
DIST	1.59	-1.59	-1.59	-1.59	1.59	1.59	-1.59	-1.59
FINAL	-71.89	71.89	71.89	-71.89	30.12	-30.12	30.12	-30.12

Table 2. Distributed Moments at Supports

Load	Distributed Moments at Supports				
	Case	M_{AB}	M_{DC}	M_{AD}	M_{DA}
		M_{DA}	M_{CD}	M_{BC}	M_{CB}
Dead Load	(1)	-10.72	23.74	10.72	(-)23.74
	(2)	-6.96	19.15	6.969	(-)19.15
	(3)	-6.96	19.15	6.96	(-)19.15
Live Load	(1)	-61.17	6.38	61.17	(-)6.38
	(2)	-61.17	6.38	67.17	(-)6.38
	(3)	-55.91	1.12	55.91	(-)1.12
Total Load	(1)	-71.89	30.12	71.89	(-)30.12
	(2)	-68.13	25.53	68.13	(-)25.53
	(3)	-62.87	20.27	62.87	(-)20.27
Maximum	All cases	-71.89	30.12	71.89	(-)30.12

Table 3. Design of section for the members

Member	MAB	MDC	Mid span		
			AB	DC	AD
Moments in KN.m	120.79	79.02	95.09	51.18	31.57
Area of steel in mm^2	1849.6	1299.8	1456	841.8	483.4

Table 4. Design moments at the supports

Load	case	Maximum distributed moments at supports			
		M_{AB}	M_{DC}	M_{AD}	M_{DA}
Total load	Maximum of all cases	71.89	30.12	71.89	30.12
Braking force	Disturbed Moments at moments	48.90	48.90	48.90	48.90
Design Moments	Supports Moments including braking	120.79	79.02	120.79	79.02

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue XI, Nov 2018- Available at www.ijraset.com

A. Computer Aided Analysis Of Box Culvert

The maximum bending and hence the overall economics of the Box Culvert depends upon the spacing of the longitudinal girders to arrive at a optimum spacing manual analysis of different Box Culvert with different longitudinal girder spacing is a not only time taking task but also a method that invites human errors with advert of computers many such problems have been solved easily by adopting relevant software. The Box Culvert with the same data was redesigned in STAAD Pro and the results are compared.

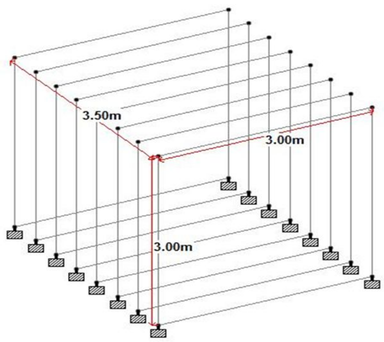


Figure 1. Similar panels in Box Culvert.

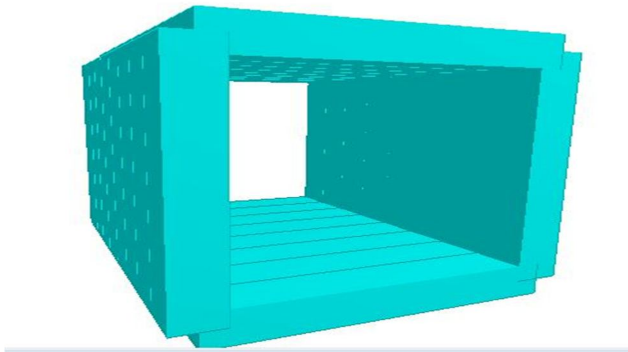


Figure 2. 3D Rendered view of Box Culvert.

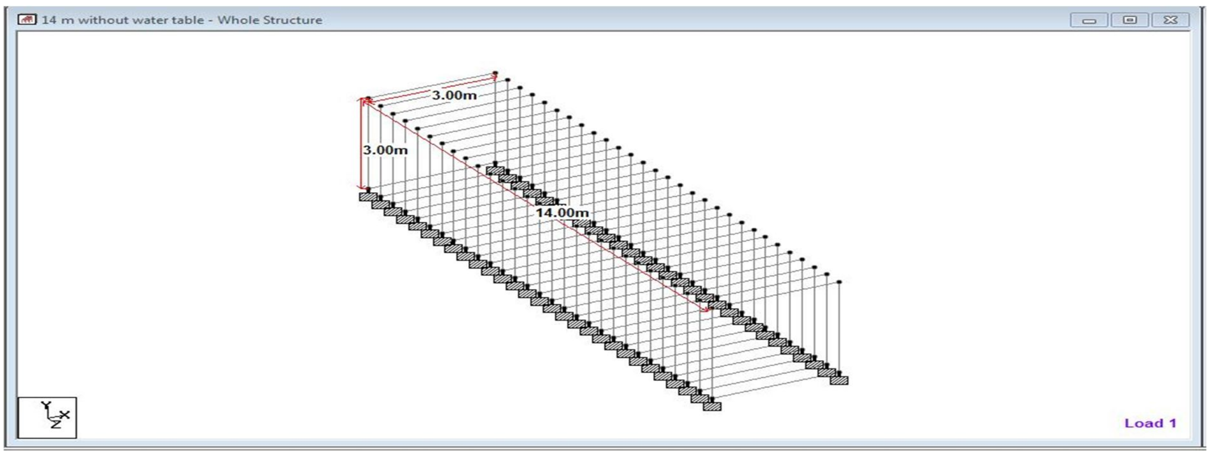


Figure 3. Skeleton structure of the Box Culvert for 14 m

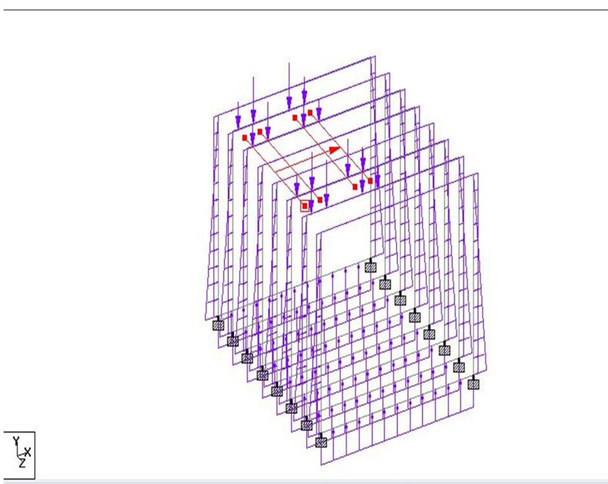


Figure 4. Dead load and moving load On the Box Culvert

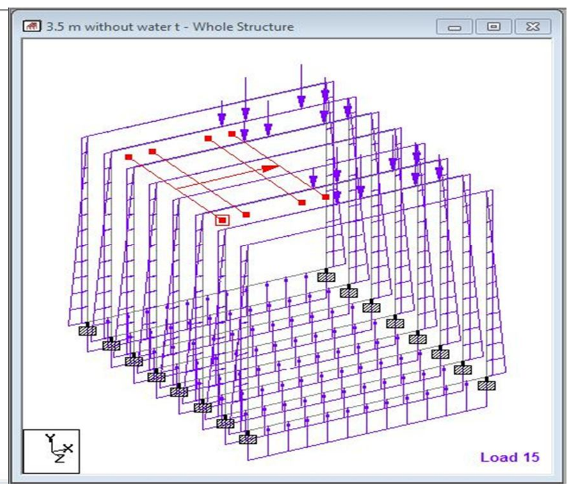


Figure 5. Load generation for vehicle and self-weight on Box Culvert

IV. RESULTS AND DISCUSSION

Validation of STAAD Pro results with results from manual calculation.
3.5 m width box culvert is considered for validation subjected to IRC class 70R loading.

Table 5. STAAD PRO results for IRC 70R loading for 3.5 m width and 3 m length box culvert

S. No.	Description	Bending Moment(KN-m), Manual results	Bending Moment(KN-m), STAAD results	Percentage Difference
1	AB	71.89	77.621	7
2	BC	71.89	77.621	7
3	CD	30.12	35.78	8
4	DA	30.12	35.78	8

Table 6. STAAD PRO results for IRC 70R loading for 3.5 m width and 3 m length box culvert for box is empty, earth pressure with live load surcharge on both sides fills.

S. No.	Span(m)	Maximum Deflection(mm)	Maximum Bending Moment(KN-m)	Maximum Shear Force(KN)
1	3.5	0.684	77.621	166.716
2	7	1.331	174.309	365.606
3	10.5	0.668	77.621	166.716
4	14	1.293	175.056	359.137

Table 7. STAAD PRO results for IRC 70R loading for 3.5 m width and 3 m length box culvert for box is full, live load surcharge on both sides fills.

S. No.	Span(m)	Maximum Deflection(mm)	Maximum Bending Moment(KN-m)	Maximum Shear Force(KN)
1	3.5	0.716	79.335	166.716
2	7	1.319	176.452	361.997
3	10.5	0.714	73.096	166.716
4	14	1.316	176.784	359.137

Table 8. STAAD PRO results for IRC class AA Tracked loading for 3.5 m width and 3 m length box culvert

S. No.	Span (m)	Maximum Deflection(mm)	Maximum Bending Moment(KN-m)	Maximum Shear Force(KN)
1	3.5	0.933	104.955	220.811
2	7	1.459	191.964	400.492
3	10.5	0.757	85.557	182.421
4	14	1.425	192.710	394.024

Table 9. STAAD PRO results for IRC class AA wheeled loading for 3.5 m width and 3 m length box culvert

S. No.	Span(m)	Maximum Deflection(mm)	Maximum Bending Moment(KN-m)	Maximum Shear Force(KN)
1	3.5	0.801	66.841	183.342
2	7	1.420	151.941	359.930
3	10.5	0.648	54.372	151.765
4	14	1.368	152.688	353.461

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue XI, Nov 2018- Available at www.ijraset.com

Table 10. STAAD PRO results for IRC class AA Tracked loading for 3.5 m width and 3 m length box culvert for cross girder.

S. No.	SPAN(m)	Maximum Deflection(mm)	Maximum Bending Moment(KN-m)	Maximum Shear Force(KN)
1	3.5	0.757	30.650	202.858
2	7	0.714	28.898	28.50
3	10.5	0.745	30.806	204.030
4	14	0.712	29.664	278.073

Table 11. STAAD PRO results for IRC class AA wheeled loading for 3.5 m width and 3 m length box culvert for cross girder

S. No.	Span(m)	Maximum Deflection(mm)	Maximum Bending Moment(KN-m)	Maximum Shear Force(KN)
1	3.5	0.562	15.375	65.142
2	7	0.695	28.506	98.579
3	10.5	0.549	16.826	64.167
4	14	0.619	28.80	99.135

Table 12.STAAD PRO results for IRC class AA Tracked loading for 3.5 m width and 3 m length box culvert for plate and beam.

S. No.	Span(m)	Maximum Deflection(mm)	Maximum Bending Moment(KN-m)	Maximum Shear Force(KN)
1	3.5	1.038	159.536	391.491
2	7	1.101	230.262	552.576
3	10.5	0.942	166.350	392.810
4	14	1.103	230.568	552.501

Table 13.STAAD PRO results for IRC class AA wheeled loading for 3.5 m width and 3 m length box culvert for plate and beam

S. No.	Span(m)	Maximum Deflection(mm)	Maximum Bending Moment(KN-m)	Maximum Shear Force(KN)
1	3.5	0.842	140.503	337.808
2	7	1.017	224.187	523.175
3	10.5	0.750	145.561	340.115
4	14	1.019	224.409	523.472

Interaction curve and bar diagrams subjected to IRC class 70R and Class AA loading:
Interaction curves and bar diagram are developed based on result shown in table 5 to 13 and presented in fig below

Figure 6 Graphical representations of results for Max. Deflection, span length subjected to IRC Class 70R loading for box is empty, earth pressure with live load surcharge on both side fills.

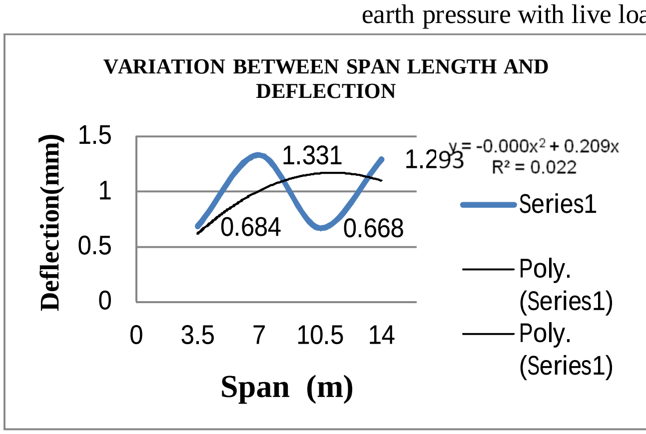


Fig 6.a: Max. Deflection vs. Span (scatter chart)

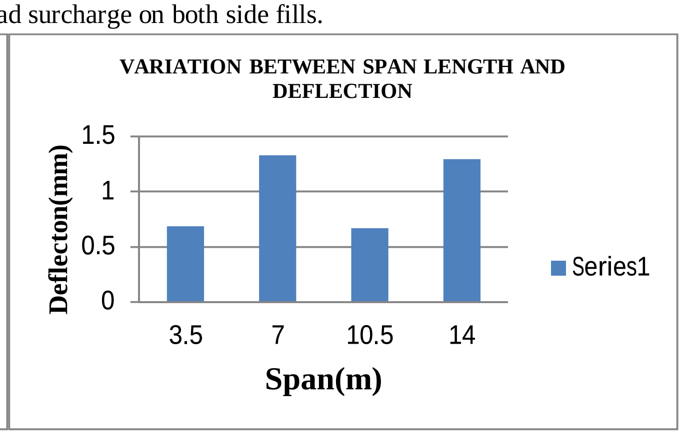
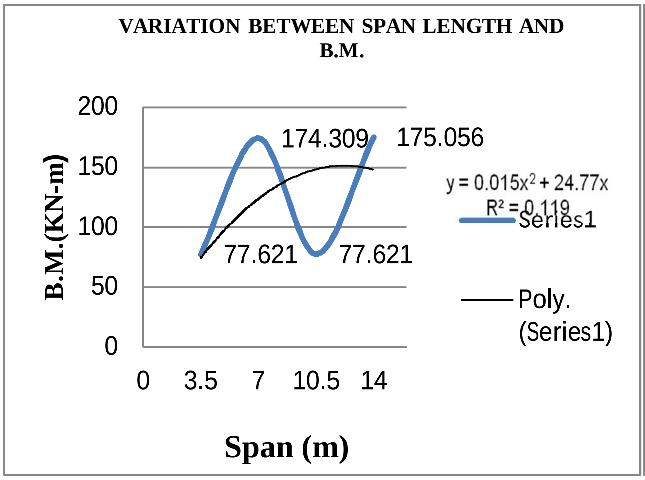


Fig 6.b: Max. Deflection vs. Span (Bar chart)

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue XI, Nov 2018- Available at www.ijraset.com

Figure 7 Graphical representations of results for Max. B.M., span length subjected to IRC Class 70R loading for box is empty, earth pressure with live load surcharge on both sides fills.



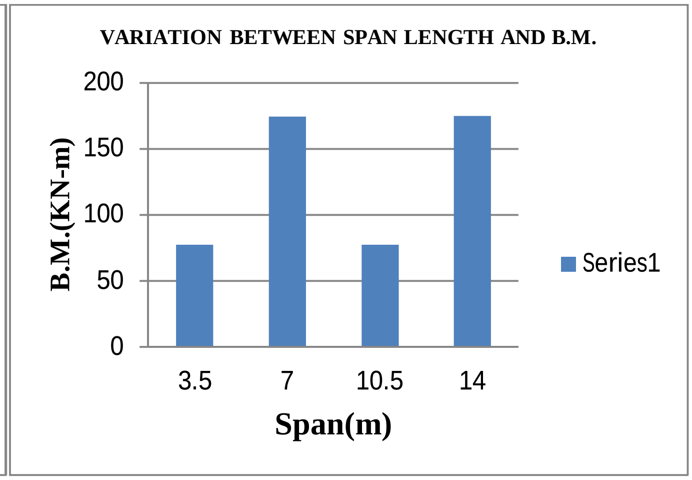
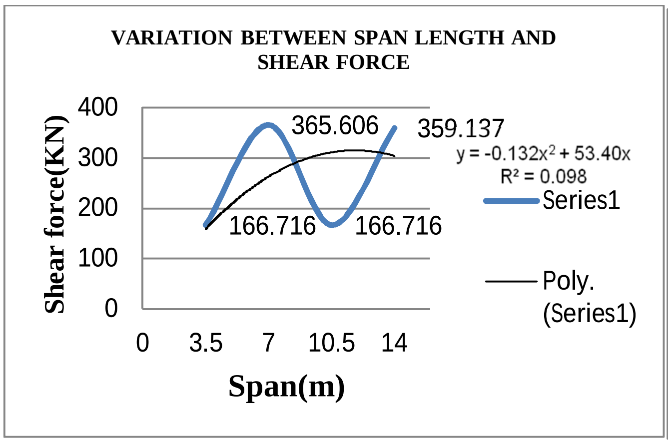


Fig 7.a: Max. B.M. vs. Span (scatter chart)

Fig 7.b: Max. B.M. vs. Span (Bar chart)

Figure 8 Graphical representations of results for Max. S.F., span length subjected to IRC Class 70R loading for box is empty, earth pressure with live load surcharge on both side fills.



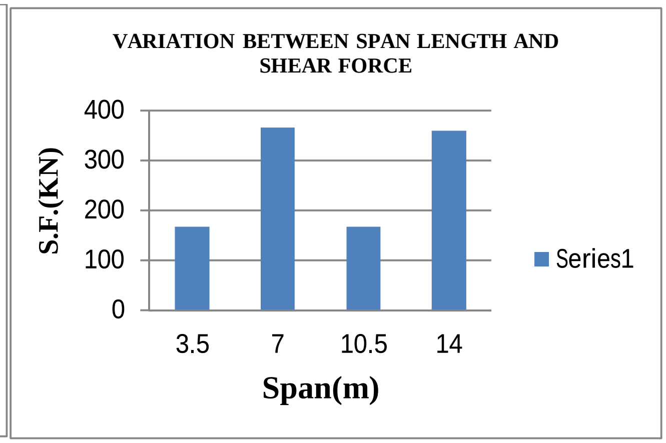
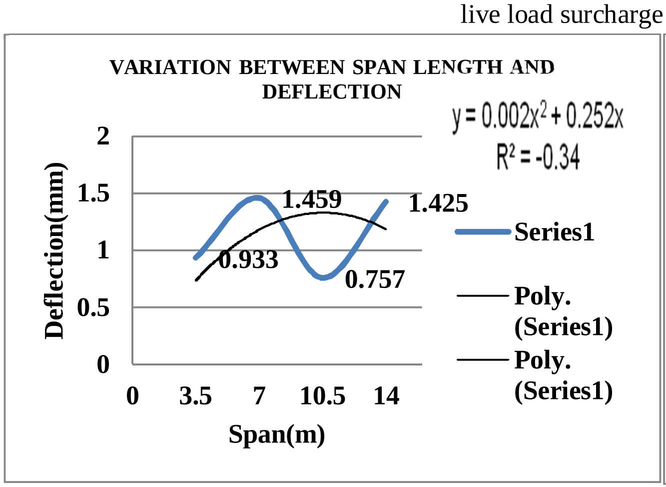


Fig 8.a: Max. S.F. vs. Span (scatter chart)

Fig 8.b: Max. S.F. vs. Span (Bar chart)

Figure 9 Graphical representations of results for Max. Deflection, span length subjected to IRC Class 70R loading for box is full, live load surcharge on both side fills.



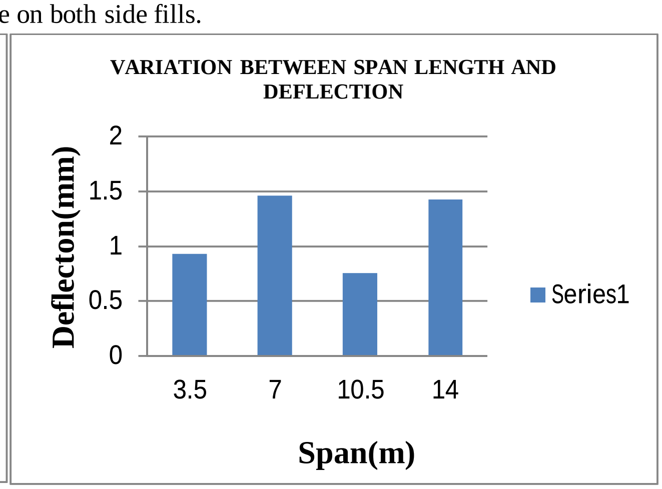


Fig 9.a: Max. Deflection vs. Span (scatter chart)

Fig 9.b: Max. Deflection vs. Span (Bar chart)

Figure 10 Graphical representations of results for Max. B.M., span length subjected to IRC Class 70R loading for box is full, live load surcharge on both sides fills.

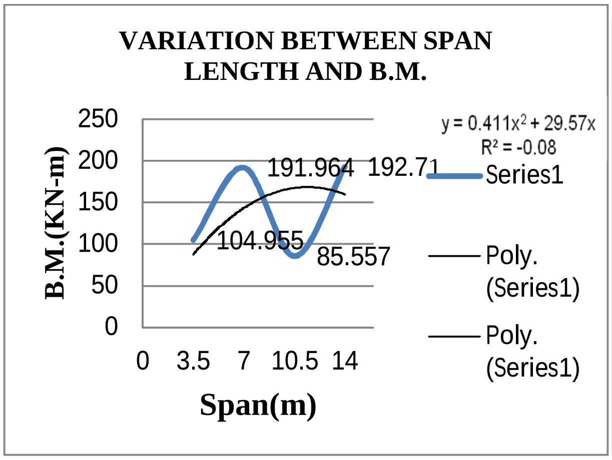


Fig 10.a: Max. B.M. v span (scatter chart)

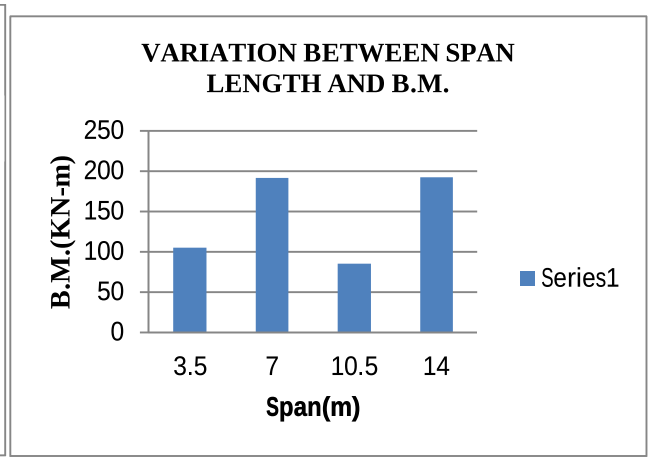


Fig 10.b: Max. B.M. vs. Span (Bar chart)

Figure 11 Graphical representations of results for Max. S.F., span length subjected to IRC Class 70R loading for box is full, live load surcharge on both sides fills.

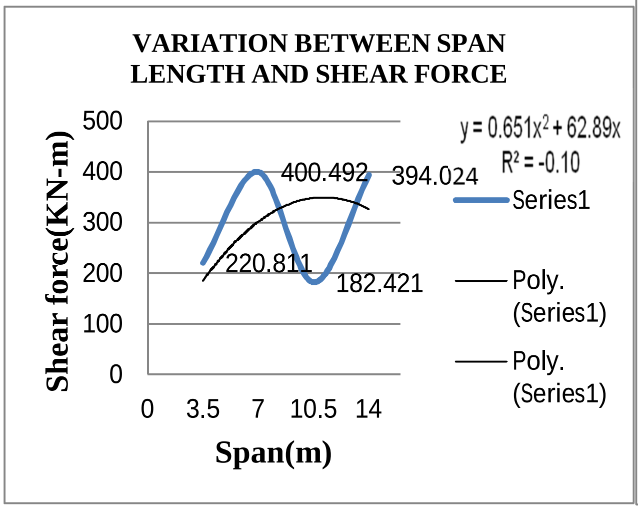


Fig 11.a: Max. S.F. vs. Span (scatter chart)

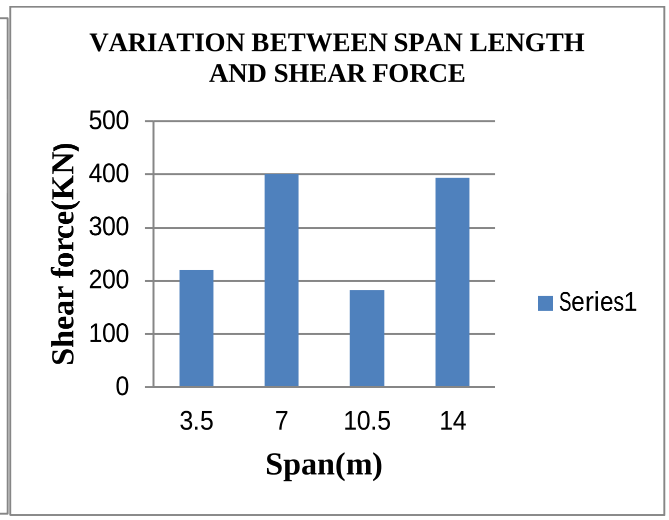


Fig 11.b: Max. S.F. vs. Span (Bar chart)

Figure 12 Graphical representations of results for Max. Deflection, span length subjected to IRC Class AA Tracked loading.

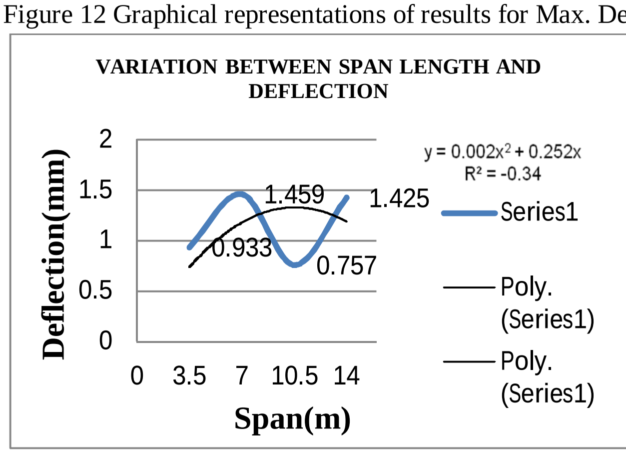


Fig 12.a: Max. Deflection vs. Span (scatter chart)

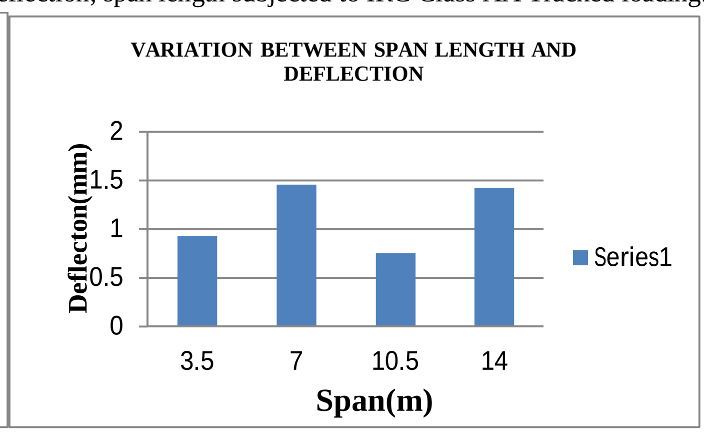


Fig 12.b: Max. Deflection vs. Span (Bar chart)

Figure 13 Graphical representations of results for Max. B.M., span length subjected to IRC Class AA Tracked loading.

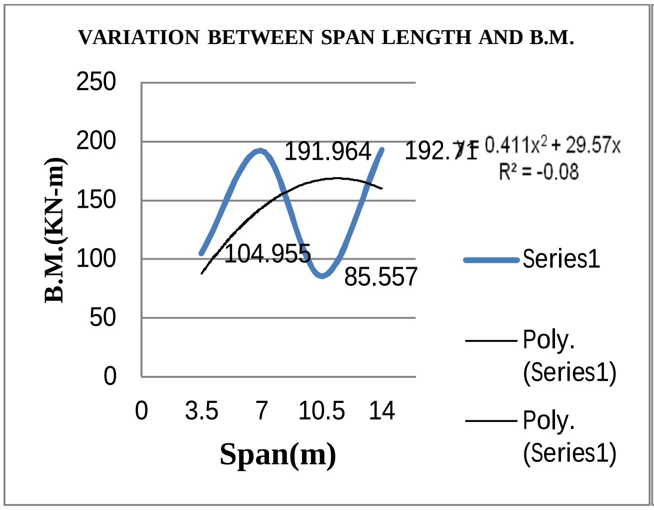


Fig 13.a: Max. B.M. vs. Span (scatter chart)

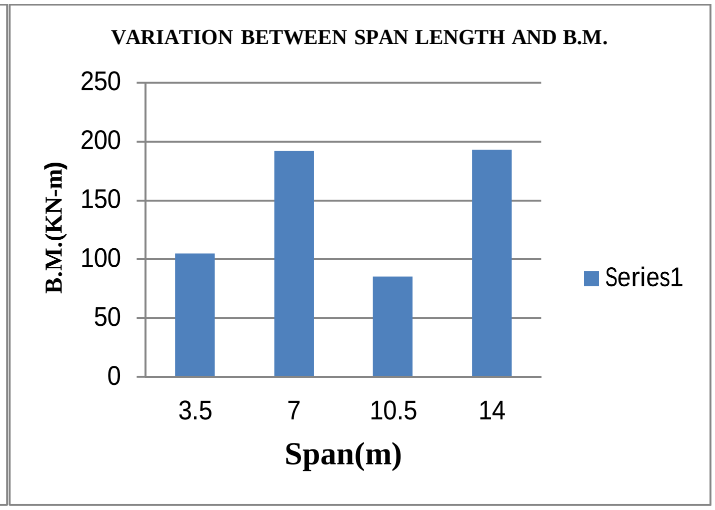


Fig 13.b: Max. B.M. vs. Span (Bar chart)

Figure 14 Graphical representations of results for Max. S.F, span length subjected to IRC Class AA Tracked loading

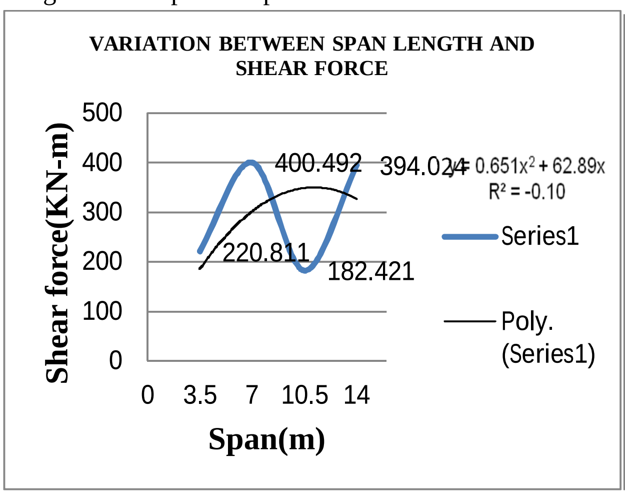


Fig 14.a: Max. S.F. vs. Span (scatter chart)

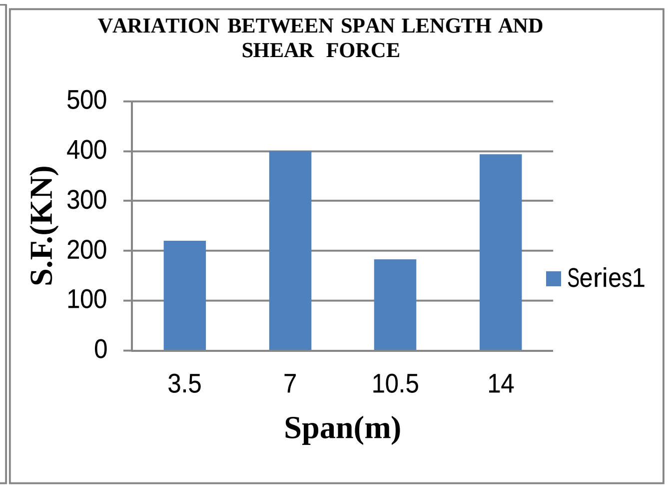


Fig 14.b: Max. S.F. vs. Span (Bar chart)

Figure 15 Graphical representations of results for Max. Deflection, span length subjected to IRC Class AA wheeled loading.

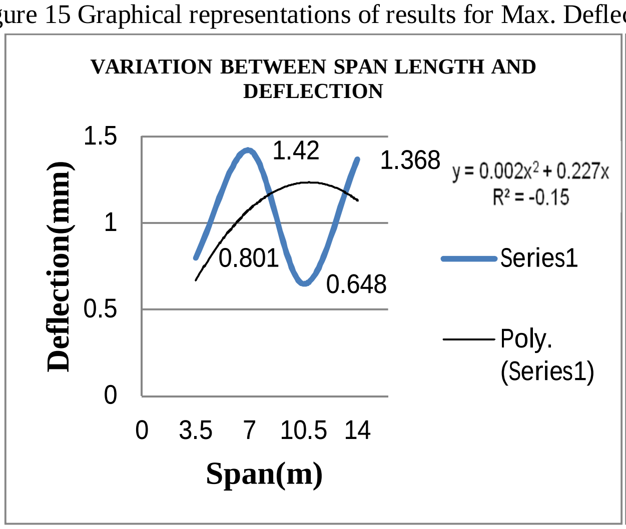


Fig 15.a: Max. Deflection vs. Span (scatter chart)

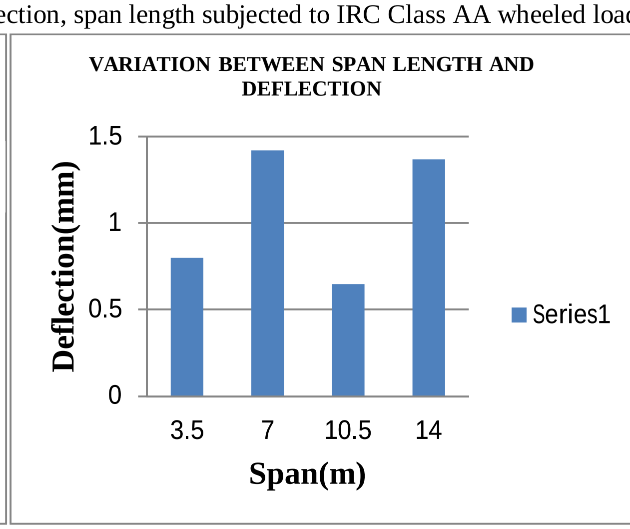
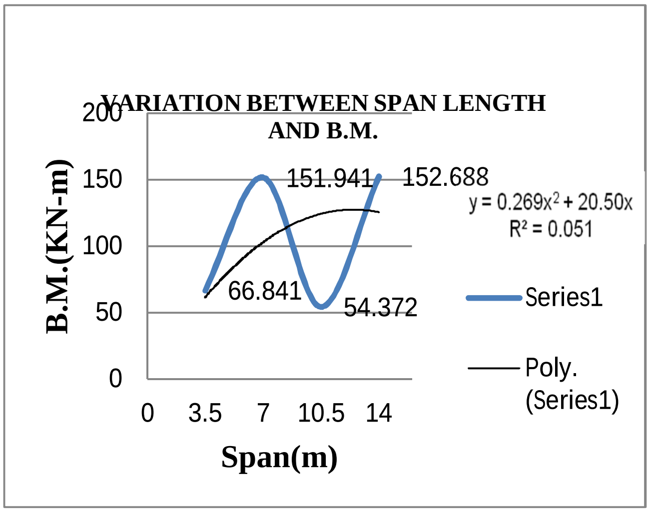


Fig 15.b: Max. Deflection vs. Span (Bar chart)

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue XI, Nov 2018- Available at www.ijraset.com

Figure 16 Graphical representations of results for Max. B.M., span length subjected to IRC Class AA wheeled loading.



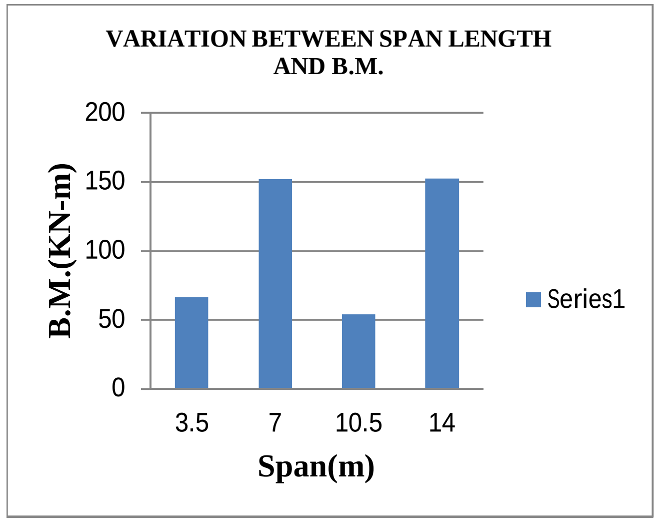


Figure 17 Graphical representations of results for Max. S.F, span length subjected to IRC Class AA wheeled loading.

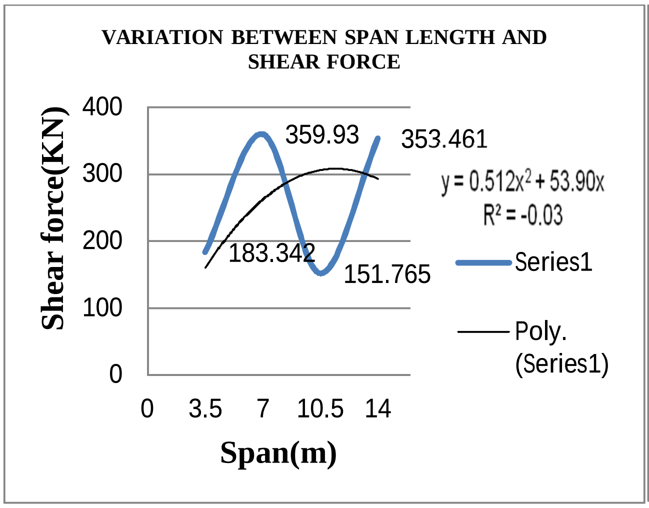


Fig 7.13.a: Max. S.F. vs. Span (scatter chart)

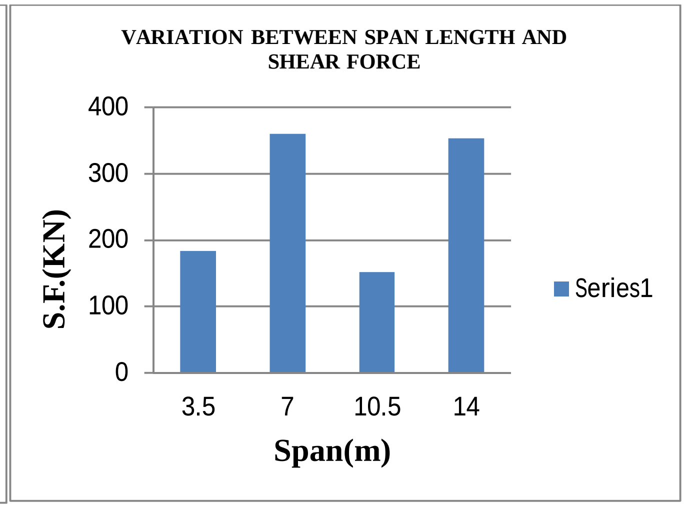


Fig 7.13.b: Max. S.F. vs. Span (Bar chart)

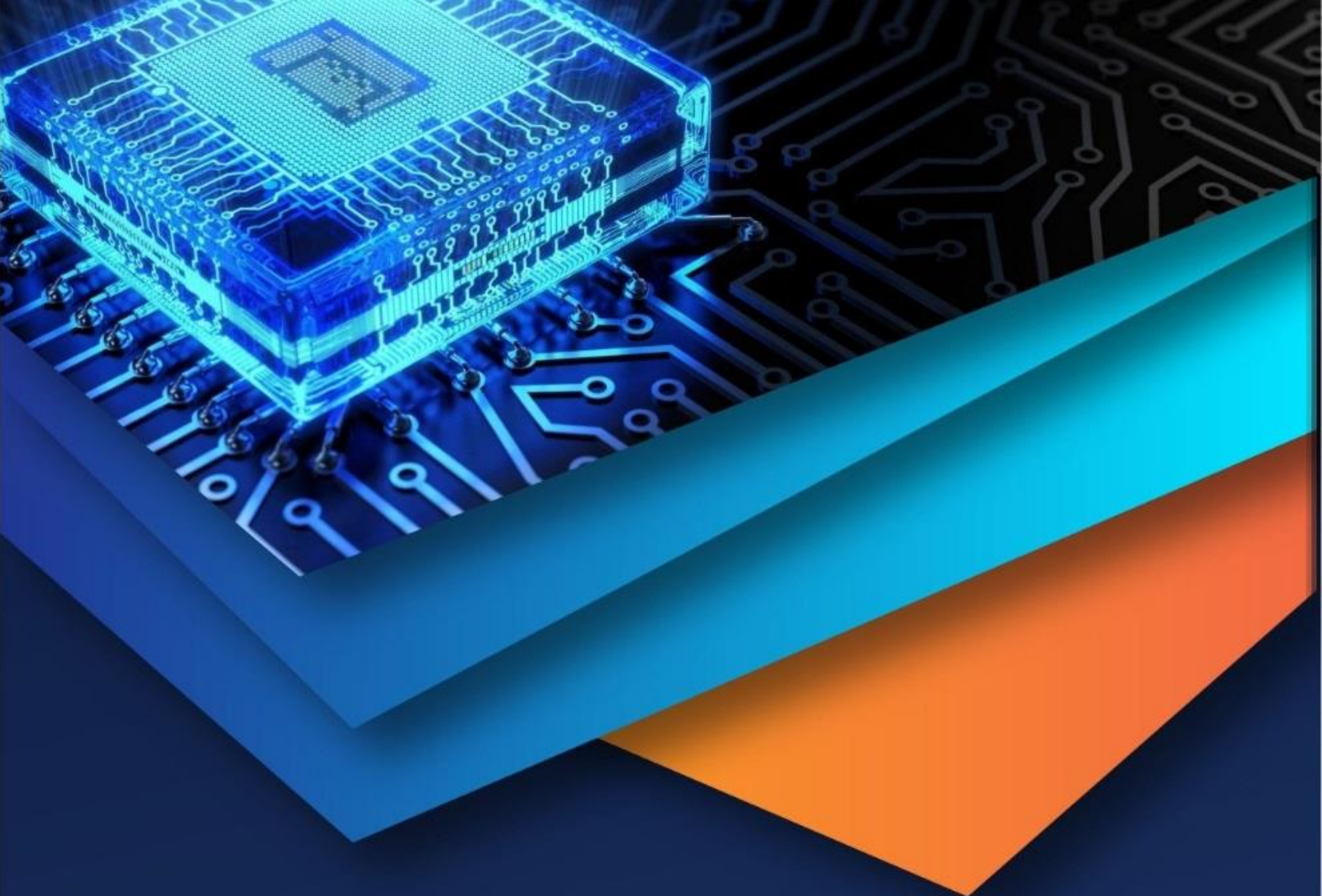
V. CONCLUSION

Design of a Reinforced Box culvert requires determination of Bending Moment and Shear Force in longitudinal panels for corresponding IRC load position. This is a tedious process and involves lot of time. This project developed mathematical models for their parameters. While B.M in each panel is marginally over estimated by the model the shear forces are marginally over estimated. Both the positive and negative errors for all the parameters were less than 10% which can be taken care by adopting suitable factor of safety while designing structures based on these charts. Small variation in co-efficient of earth pressure has little influence on the design of box particularly without cushion. For culverts without cushion taking effective width corresponding to α for continuous slab shall not be correct. It is likely to provide design moments and shear on lower side hence not safe. 9. For box without cushion braking force is required to be considered particularly for smaller span culverts. Further for distribution of braking force effects the same effective width as applicable for vertical application of live load shall be considered. If braking force is not considered or distributed over the whole length of box (not restricted within the effective width) shall be unsafe. It can be concluded from the study that the interaction curves can be used for analysis of a box culvert of spans ranging from 3.5 m to 14 m subjected to IRC Class AA tracked and wheeled loading.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue XI, Nov 2018- Available at www.ijraset.com

REFERENCES

[1] Krishna Raju N, Design of bridges, Oxford and IBH Publishing Co. PVT. Ltd, New Delhi, Fourth edition, ISBN 978- 81-204-1741-0.
[2] Komal S. Kattimani & R. Shreedhar., "Parametric studies of Box Culverts", International Journal of Research in Engineering & Science, May 2013
[3] David Z. Yankelevsky., "Loads on Rigid Box Buried In Nonlinear Mdium", Journal of Transportation Engineering, Vol. 115, No. 5, September, 1989. @ asce, ISSN 0733-947X/89/0005- 0461. Paper No. 23870.
[4] Kyungsik Kim & Chai H. Yoo., "Design Loading on Deeply Buried Box Culverts" Journal of Geotechnical and Geo environmental Engineering, Vol. 131, No.1, January 1, 2005, @ASCE, ISSN 1090-0241/2005/1-20-27.
[5] IRC 5:1998, Standard specifications and code of practice for road bridges Section1, General Feature of Design (Seventh Revision) 1998, Indian Roads Congress, Jamnagar House, Shahjahan Road, New Delhi- 110011.
[6] IRC: 21-2000 Standard specifications and code of practice for road bridges Section III, Cement Concrete (Plain and reinforced), The Indian Road Congress 2000.
[7] IRC: SP: 13-2004 Guidelines for the design of small Bridges and Culverts, The Indian Road Congress.
[8] IRC: 6-2000 Standard specifications and code of practice for road bridges Section II, Loads and stresses, The Indian Road Congress, 2000
[9] Reinforced cement concrete by B.C. Punmia



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY