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Analysis of Box Culvert under Cushion Loading

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Abstract: Box culverts are the structures constructed below highways and railways to provide access to the natural drainage across them. The opening of the culvert is determined based on the waterway required to pass the design flood, whereas the thickness of the culvert section is designed based on the loads applied on the culvert. Culverts and bridges often serve the same purpose; however, they differ on the size of the structure. Box culverts are ideal for flows where hydraulic head is limited. For an equivalent waterway area to circular pipes, box culverts can be configured to have less impact on upstream water levels and downstream flow velocities than equivalent pipe structures. This report devotes to the box culverts constructed in reinforced concrete having different aspect ratios. The box culverts are analyzed for varying cushion and no cushion loading. The main emphasis is given to the behavior of the structure under the types of loading as per IRC codes and their combinations top produce worst effect of loading for safe structure. Comparison and conclusion are made on the basis of maximum bending moments shown for different loading cases.

Keywords: Aspect ratio, Bending Moments, IRC, Cushion, Earth pressure, Surcharge loading.

I. INTRODUCTION

Culverts are the structures constructed below highways and railways to provide access to the natural drainage across them. They are also constructed sometimes to provide the access to the animals across the road. The opening of the culvert is determined based on the waterway required to pass the design flood, whereas the thickness of the culvert section is designed based on the loads applied on the culvert. Culverts and bridges often serve the same purpose; however, they differ on the size of the structure.

Culverts are classified as rigid, semi rigid or flexible based on material type, how they carry load, and to what degree they rely on the soil surrounding them. The capacity of a culvert to carry imposed loads depends on many factors including the type and age of the material, the size and shape of the culvert, and the supporting materials surrounding the culvert. Its capacity gradually decreases mainly due to aging and degradation of the material after repeated loading of the culvert by heavy trucks. A box culvert can have more than single cell and can be placed such that the top slab is almost at road level and there is no cushion.

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. This report devotes to the box culverts constructed in reinforced concrete having different aspect ratios.

The box culverts are analyzed for varying cushion and no cushion loading. The main emphasis is given to the behavior of the structure under the types of loading as per IRC codes and their combinations top produce worst effect of loading for safe structure. Comparison and conclusion are made on the basis of maximum bending moments shown for different loading cases.

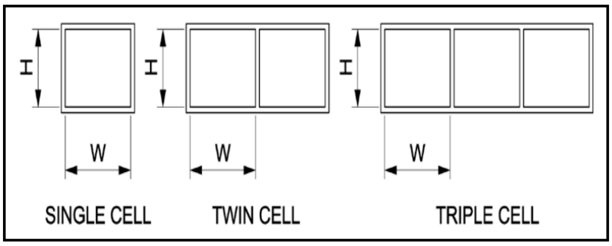

Fig. 1: Single, twin and triple cell box culverts.

II. OBJECTIVE OF STUDY

1. To study the behavior of box culvert with cushion and without cushion load for different aspect ratios.
2. To study the effect of different load combinations which will produces worst effect for safe structural design.

III. REVIEW OF LITERATURE

Shreedhar [1] studied on design coefficients for single and two cell box culverts that the design coefficients developed for bending moment, shear and normal thrust at critical sections for various loading cases enables the designer to arrive at design forces thus reducing design time and effort. The study showed that the maximum positive moment develop at the center of top and bottom slab for the condition that the sides of the culvert not carrying the live load and the culvert is running full of water and the maximum negative moments develop at the support sections of the bottom slab for the condition that the culvert is empty and the top slab carries the dead load and live load. Navarro [2] analyzed a large structure of reinforced concrete of box shape and totally embedded in soil. The dynamic pressures acting on walls, roof and floor, due to body and surface wave are considered in the analysis. He made some recommendations about the choice of seismic forces to be considered for analysis of underground rectangular structures and more attention should be given when massive buildings are the buried structures under consideration. Kalyanshetti [3] had done on the study of analysis of box culvert and cost optimization for different aspect ratios. They concluded that for different cells and different heights the optimized thickness of box culverts is to be obtained by the different formulas which will a cost effective design of the box.

Lee [4] performed analysis of rectangular single, double and triple box structures to define damage states and corresponding damage indices (DIs) under seismic loading. The tunnel structure modeled by nonlinear frame elements attached to a series of normal and shear springs to simulate the soil tunnel interaction. Conclusion was made that the box tunnels do not immediately collapse even when plastic hinges form at all outer corners of the structure, primarily due to the support from the surrounding soil. However, double and triple box tunnels may collapse due to flexural failure when inner column collapses. Kattimani [5] has analyzed the box culvert by considering different Parameters. The study deals with the design parameters of box culverts like angle of dispersion of live load, effect of co-efficient of earth pressure and depth of cushion provided on top slab of box culverts. Gil [6] studied simplified method for the analysis of square cross section buried structures subjected to seismic motion. Finite element analyses were performed to assess the fundamental modes of vibration of the soil layer with and without tunnel to arrive at resulting model. Finally concluded that, once free field displacements are obtained then many different structures can be easily analyzed using simplified method. Malkhare [7] has analyzed box culvert by considering soil structure interaction and the results obtained are compare without considering soil structure interaction. The comparative study of bending moments was presented.

IV. METHODOLOGY

A. Effective width in the run of culvert

It is required to understand the concept behind effective width. Basically, it is the width of slab perpendicular to the span which is affected by the load placed on the top of slab. It shall be related to the area of slab expected to deform under load. It can be well imagined that this area of slab which may get affected will depend on how the slab is supported whether in one direction or both directions and secondly on the condition of support that is whether free or continuous or partially or fully fixed. The IRC:21-20006 Clause 305.16 gives an equation for obtaining effective width for simply supported and continuous slab for different ratio of overall width verses span for these two kinds of supports.

$$b_{ef} = \alpha_e (1 - \frac{a}{lo}) + b_1$$

b_{ef} = effective width of slab on which load acts.

L_0 = effective span.

a = distance of the centre of gravity of the concentrated load from the nearer support.

B_1 = breadth of concentration area of the load.

α = constant having the following values depending upon ratio $\frac{b}{lo}$.

Where however, if there is large cushion the live load gets dispersed on a very large area through the fill and the load per unit area becomes less and does not remain significant for the design of box, particularly in comparison to the dead load due to such large cushion. In case of dead load or uniform surcharge load the effective width has no role to play and such loads are to be taken over the entire area for the design.

B. Braking force / Longitudinal force

These forces result from vehicles braking or accelerating while travelling on a bridge. At a vehicle brakes, load of the vehicle is transferred from its wheels to the bridge deck. The IRC specifies a longitudinal force of 20% of the appropriate lane load. The effect of braking force on superstructure is inconsequential: substructure elements however are affected more significantly. Question however arises up to what cushion height no braking force need be taken. This height generally is taken to be 3m. Thus no braking force for cushion height of 3 m and more and full braking force for no cushion, for intermediate heights of cushion the braking force can be interpolated. IRC: 6-2000 Clause 211.7 mentions that no effect to be taken at 3 m below bed block in case of bridge pear/abutment. Some researcher says that the effect should be considered on the same area as considered for live load effective width and some of says that the dispersal area is to be calculated separately and the effect is considered on that particular area only. However in this study the effect of braking force is considered on the same area as live load is considered.

C. Impact of live load

In order to account for the dynamic effects of the sudden loadings of a vehicle on to a bridge structures, an impact factor is to used as a multiplier for loads on certain structural elements. From basic dynamics we know that a load that moves across a member introduces larger stresses than those caused by a standstill load. However the basis of impact factor predicted by IRC is not fully known. It has been felt by researchers that the impact factor to a large extent depends on weight of the vehicle, its velocity, as well as surface characteristics of the road. It is pertinent to note that live load increases on account of the consideration of impact effect. IRC specifications for impact factor are computed as mentioned below:

For class AA loading and class 70R loading,

a) For spans less than 9m:

1. for tracked vehicles: 25% for spans up to 5m linear reducing to 10% for spans of 9m.
2. for wheeled vehicles: 25%

Appropriate impact factors as mentioned below need to be considered for substructures as well:

- At the bottom of the bed block: 0.5
- For the top 3m of the substructure: 0.5 – 0.0
- For the portion of the substructure > 3m below the block: 0.0

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D. Coefficient of earth pressure

Earth always exerts a pressure maximum as passive and minimum as active, or in between which is known as pressure at rest. In case of box culverts the structure is constructed before the backfill earth is placed in position and the situation is like that the structure is not in position to yield on the other sides, so the earth pressure reaches a state of rest. In such cases the coefficient of earth pressure will be more then the active condition. The co-efficient of earth pressure in case of box is taken to be 0.333 for a soil having $\phi = 30^0$ or may take value 0.5 for normal soil having $\phi = 30^0$. In this study the earth pressure coefficient 0.5 is used considering the rest condition.

V. RESULTS AND OBSERVATIONS

For the analysis IRC Class 70R tracked loading is considered on the box culvert to produce worst effect for a safe structure. The loading contains live load of Class 70R tracked vehicle, dead load of top and bottom slab as well as side walls. Impact of live load and braking force is considered only for box without cushion load as per IRC 6:2000. Also the soil pressure is considered to be acting on side walls from outside and water pressure from inside. The loadings are find out by manual calculation and modeled in SAP2000. The effect of the loading is observed for three different cases as specified by Ramamurtham S. as given below.

Case 1: Box empty, live load surcharge on top slab of box and superimposed surcharge load on earth fill.

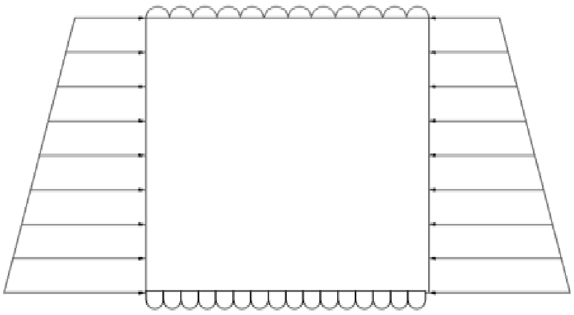


Fig. 2: Loading case 1

Case 2: Box inside full with water, live load surcharge on top slab and superimposed surcharge load on earth fill.

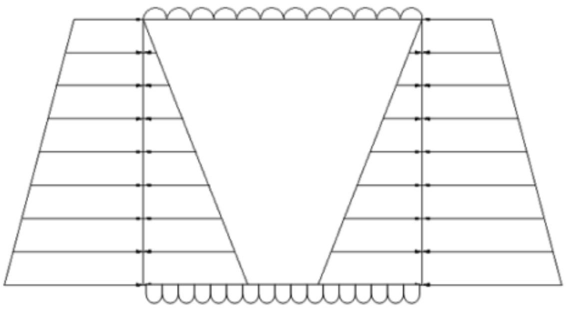


Fig. 3: Loading case 2

Case 3: Box inside full with water, live load surcharge on top slab and no superimposed surcharge on earth fill.

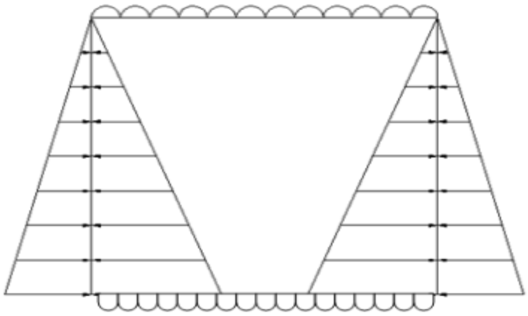


Fig. 4: Loading case 3

For the above three loading cases, variation of the max. bending moment is obsereved. The values of the max. bending moments are as shown in table 1 and 2. The values are higher for the case when there is cushion loadings on the culverts. The variation of the same is shown by graphs below.

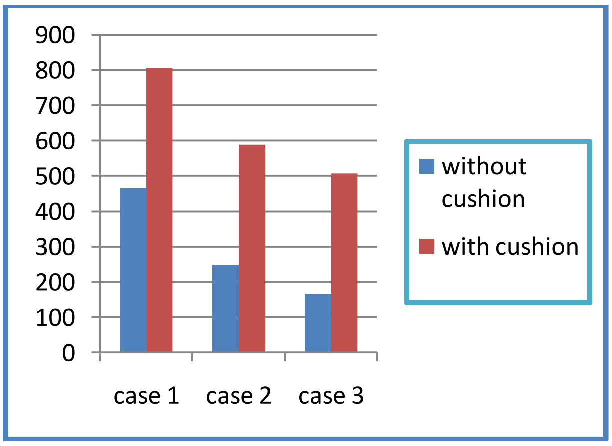
Table 1: Maximum BM in structure without cushion loading.

Aspect Ratio	**Maximum Bending Moment in Structure for Loading Cases in kN.m**		
	Case 1	**Case 2**	**Case 3**
1	465.22	248.74	166.91
1.5	156.28	89.78	85.68
2	76.30	76.30	76.30
3	67.16	67.16	67.16

Table 2: Maximum BM in structure with cushion loading

Aspect Ratio	**Maximum Bending Moment in Structure for Loading Cases in kN.m**		
	Case 1	**Case 2**	**Case 3**
1	805.80	589.35	507.60
1.5	313.92	247.24	209.58
2	167.55	167.55	167.55
3	152.23	152.23	152.23

Following graphs shows the variation of maximum bending moments under cushion and without cushion loadings.



Graph 1: Variation of Max. BM for aspect ratio=1

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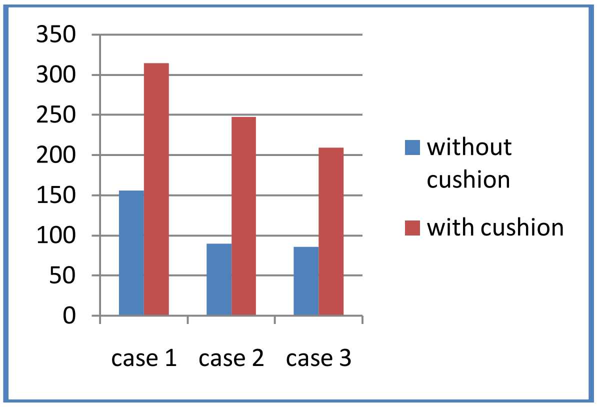
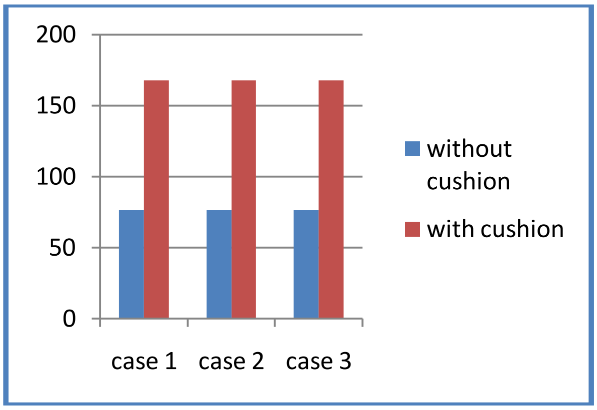
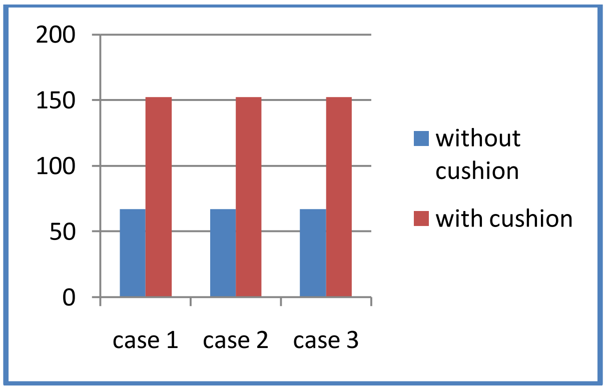


Graph 2: Variation of Max. BM for aspect ratio=1.5



Graph 3: Variation of Max. BM for aspect ratio=2



Graph 4: Variation of Max. BM for aspect ratio=3

VI. CONCLUSIONS

Following are the conclusions made on the basis of observations and results as shown above:

1. The load combination with empty box is found to be the critical combination for all values of aspect ratios under consideration.
2. Bending moments for aspect ratio 1 and 1.5 are found to be varying for all load combinations, with and without cushion.
3. Bending moments for aspect ratio 2 and 3 are found to be constant for all load combinations, with and without cushion.
4. The effect of soil pressure and water pressure is considerable for aspect ratio 1 and 1.5 and negligible for aspect ratio 2 and 3.

REFERENCES

[1] S. Shreedhar and R. Shreedhar, "Design coefficients for single and two cell box culvert", International Journal Of Civil And Structural Engineering Volume 3 No. 3, pp. 475-494, March 2013.
[2] C. Navarro, "Seismic analysis of underground structures",Earthquake Engineering, Tenth World Conference, pp. 1939-1944, 1192.
[3] M.G. Kalyanshetti and S.A. Gosavi, "Analysis of box culvert - cost optimization for different aspect ratios of cell", International Journal of Research in Engineering and Technology, Vol. 03, Issue 04, pp. 508-514, April 2014.
[4] Tae-Hyung Lee, Duhee Park, Duy Duan Nguyen, Jeong-Seon Park,"Damage analysis of cut-and-cover tunnel structures Under seismic loading",Springer, Oct 2015.
[5] Komal S.Kattimani and R.Shreedhar, "Parametric Studies of box culverts", International Journal of Research in Engineering and Science, Vol. 1, Issue 1, PP.58-65, 2013.
[6] L. M. Gil et al.,"Simplified method for the analysis of square cross section buried structures", Soil Dynamics And Earthquake Engineering, Vol 21, pp. 735-740, May 2001.
[7] Kalyanshetti M.G and Malkhare S.V, "Analysis of box culvert by considering soil structure interaction", Paripex- Indian journal of research, Vol. 1, Issue 4, PP.71-74, 2012.
[8] B.N.Sinha and R. P.sharma, Analysis of Box culvert by Stiffness Method, journal of Indian Road Congress, Paper No. 555, PP. 189-219, 2009.
[9] T. R. Jagdeesh and M.A. Jayaram, "Design of bridge structures", PHI Delhi, second edition, pp. 134-149, 2014.
[10] IRC 6, Standard specification and code of practice for road bridges section II Loads and stresses, The Indian Road Congress, 2014.
[11] IRC:5,"Standard Specifications and Code of Practice for Road Bridges", Section I,1998.
[12] IRC:21, "Standard Specifications and Code ofPractice for Road Bridges", Section III,2000.