Design Coefficients for Three Cell Box Culvert

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Abstract

Multiple cell reinforced box culverts are ideal bridge structure if the discharge in a drain crossing the road is large and if the bearing capacity of the soil is low as the single box culvert becomes uneconomical because of the higher thickness of the slab and walls. In such cases, more than one box can be constructed side-by-side monolithically.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

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Index terms — Design coefficients, three cell, culvert, moment, axial thrust, shear.

1 I.

2 General

CC box culverts comprising of top slab, base slab and stem are cast monolithically to carry live load, embankment load, water pressure and lateral earth pressure in a better way. They may be either single cell or multiple cells. The top of the box may be at road level or it may at a depth below the road level if the road is in embankment. The required height and number of boxes depends on hydraulic and other requirements at the site such as road level, nalla bed level, scour depth etc. The barrel of the box culvert should be of sufficient length to accommodate the carriageway and the kerbs.

3 II.

4 Loads

The loads considered for the analysis of box culverts are Dead load, Live load, Soil pressure on side walls, Surcharge due to live load, and Water pressure from inside.

5 a) Uniform Distributed Load

The weight of embankment, deck slab and the track load are considered to be uniformly distributed loads on the top slab with the uniform soil reaction on the bottom slab. For live load distribution, the width of dispersion perpendicular to the span is computed first.

Width of dispersion parallel to the span is also calculated. Then the maximum magnitude of load is divided by width of dispersion parallel to span and width of dispersion perpendicular to the span to get the load intensity on the top slab.

6 b) Weight of Side Walls

The self weight of two side walls acting as concentrated loads are assumed to produce uniform soil reaction on the bottom slab.

7 c) Water Pressure Inside Culvert

The pressure distribution on side walls is assumed to be triangular with a maximum pressure intensity of p=wh at the base, where w is the density of water and h is the depth of flow.

8 d) Earth Pressure on Vertical Side Walls

The earth pressure on the vertical side walls of the box culvert is computed according to the Coloumb's theory. The earth pressure intensity on the side walls is given by H, where Ka is coefficient of active earth pressure, is the density of soil and H is he vertical height of box. e) Uniform Lateral Load on Side Walls Uniform lateral pressure on vertical side walls is considered due to the sum of effect of embankment loading and live load surcharge. Also the uniform lateral pressure on vertical side walls is considered due to embankment loading alone.

9 III.

10 Design Moments, Shears and Thrusts

The box culvert is analysed for moments, shear forces and axial thrusts developed at the critical sections due to the various loading conditions by moment distribution method. The critical sections considered are at the centre of top slab, bottom slab and vertical slab and at the corners of top slab, bottom slab and vertical wall. The moments, shear forces and axial thrusts at the critical sections for different loading cases are computed for different ratios of L/H = 1.0, L/H IV.

11 Design

12 Sign Conventions

The following sign conventions are used in the analysis for moment, shear and thrust:

Positive moment indicates tension on inside face.

Positive shear indicates that the summation of force at the left of the section acts outwards when viewed from within.

Positive thrust indicates compression on the section.

VI.

13 Results and Discussions

The results for the box culvert analysed for moments, shears, and thrusts at the critical sections for various loading conditions are presented in tables (table no.s 1 to 5) and graphs (figure no.s 2 to 11). The variation of bending moment, shear forces and thrusts for various ratios of box culvert can be observed from the graphs plotted for various loading cases. This enables to arrive at the design forces resulting from the combination of the various cases yielding maximum moments and forces at the support and midspan sections. The various loading cases are as given below:

14 Discussions on Three Cell Box Culvert

The maximum positive moment develop at the centre of top slab when the culvert is running full and uniform lateral pressure due to superimposed dead load only as shown in figure **??**. As the span increases, there is significant contribution to positive bending moment due to dead load and live load only as the contribution due to earth pressure becomes less significant.

It is seen from figure **??** that the maximum negative moment develop at the corner of top slab when the culvert is empty and the top slab carries the dead load and live load. The weight of side walls decreases the net negative moment as the moment due to side walls is positive. As the span increases, there is significant contribution to negative bending moment due to dead load and live load only as the contribution due to earth pressure becomes less significant.

The maximum positive moment develop at the centre of bottom slab when the culvert is running full and uniform lateral pressure due to superimposed dead load and live load (referring fig. **??**). As the span increases, there is significant contribution to positive bending moment due to dead load and live load only as the contribution due to earth pressure becomes less significant. The weight of side walls also has the significant effect on net positive bending moment. The maximum negative moment develop at the corner of bottom slab when the culvert is empty and the top slab carries the dead load and live load as shown in figure **??**. There is significant contribution to maximum negative moment due to weight of side walls. As the span increases, there is contribution to negative bending moment due to dead load and live load only as the contribution due to earth pressure becomes less significant.

From figure **??** , it can be seen that the maximum negative moment develop at the centre of vertical wall when the culvert is running full and when uniform lateral pressure due to superimposed dead load acts only. As the span increases, there is significant contribution to negative bending moment due to dead load and live load only as the contribution due to water pressure becomes less significant.

The maximum positive shear force occurs at section A2 in the top slab and at section F8 in the bottom slab due to the superimposed dead load and live load case only as seen from figures 7 and 9. As seen in figures 8 and 10, the maximum negative shear occurs at section D6 in the bottom slab and at section H13 in the top slab. There is significant contribution to shear force values due to weight of side walls at section D6 and F8. The maximum positive normal thrust occurs at mid height of vertical wall due to superimposed dead and live load and due to weight of side walls as seen in figures 11.

15 VIII.

16 Conclusions

The present study makes an effort to evaluate the design coefficients for bending moment, shear force and normal thrust for three celled box culvert subject to various loading cases. An attempt is made to provide the information of the effects for different ratios of L/H = 1.0, L/H = 1.25, L/H = 1.5, L/H = 1.75 and L/H = 2.0 three celled box culverts. The results of the study lead to the following conclusions: a) 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.

b) The critical sections considered are the centre of span of top and bottom slabs and the support sections and at the centre of the vertical walls since the maximum design forces develop at these sections due to various combinations of loading patterns.

c) The study shows that the maximum design forces develop for the following loading conditions:

i. When the top slab supports the dead load and live load and the culvert is empty. ii. When the top slab supports the dead load and live loads and the culvert is running full. iii. When the sides of the culvert do not carry the live load and the culvert is running full. d) The study shows that the maximum positive moment develop at the centre 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. e) 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. f) The maximum negative moment develop at the centre of vertical wall when the culvert is running full and when uniform lateral pressure due to superimposed dead load acts only. g) The maximum shear forces develop at the corners of top and bottom slab when the culvert is running full and the top slab carries the dead and live load, h) The study shows that there is significant contribution to positive normal thrust at centre of vertical wall (section E4) due to superimposed dead load & live load and weight of side walls. i) The study shows that the multi celled box culverts are more economical for larger spans compared to single cell box culvert as the maximum bending moment and shear force values decreases considerably, thus requiring thinner sections.

IX. [1] [2]

[2] Design Coefficients for Three Cell Box Culvert

Figure 1:

1

L	L:H	Section	Coefficients for	1	2	Loading Case 3	4	5

Figure 2: Table 1 :

2

L:H	Section	Coefficients for	1	2	Loading Case 3	4	5
	B1	M N	+0.061 0	+0.006 -0.106	+0.005 -0.129	-0.005 +0.129	-0.005 +0.395
		M	-0.035	+0.016	+0.014	-0.014	-0.014
	A2	N	0	-0.106	-0.129	+0.129	+0.395
1.25:1		V M	+0.437 -0.035	-0.019 +0.016	-0.018 +0.014	+0.018 -0.014	+0.018 -0.014
	A3	N	+0.437	-0.325	-0.018	+0.018	+0.018
		V	0	-0.019	0.129	-0.129	-0.395
	E4	M	-0.035	-0.026	-0.025	+0.025	+0.064

Figure 3: Table 2 :

3

L:H	Section	Coefficients for	1	2	3	4	5
			+0.059	+0.006 -	Loading Case	-0.003	-0.003
1.5:1	B1	for	0 -0.038	0.133 +0.016	3 +0.003	+0.108 -	+0.329 -
	A2	M N	0 +0.441	-0.133 -	-0.108 +0.009	0.009 +0.108	0.009 +0.329
	A3	M N	-0.038	0.020 +0.016	-0.108 -0.012	+0.012	+0.012
	E4	V M	+0.441	-0.318 -	+0.009 -0.012	-0.009	-0.009
	D5	N V	0 -0.038	0.020 -0.029	0.108 -0.018	+0.012 -	+0.012 -
		M N	+0.441	+0.182 -	-0.012 +0.011	0.108 +0.018	0.329 +0.045
		M N	-0.038	0.073 +0.682	-0.015 -0.225	+0.012 -	+0.012 -
		V	+0.441 0	+0.133		0.011 +0.015	0.011 +0.015
						+0.225	+0.336
		M	-0.038	-0.073	+0.011	-0.011	-0.011
	D6	N	0	+0.133	-0.225	+0.225	+0.336
		V	-0.441	-0.682	+0.015	-0.015	-0.015
	C7	M N	+0.059 0	+0.082	+0.004 -0.225	+0.004	+0.004
				+0.133		+0.225	+0.336
		M	-0.097	-0.143	-0.004	+0.004	+0.004
	F8	N	0	+0.133	-0.225	+0.225	+0.336
		V	+0.559	+0.822	+0.015	-0.015	-0.015

Figure 4: Table 3 :

4

L L:H	Section	Coefficients for	1	2	Loading Case 3	4	5
	B1	M N	+0.057 0	+0.006 -0.162	+0.002 -0.093	-0.002 +0.093	-0.002 +0.283
		M	-0.042	+0.015	+0.006	-0.006	-0.006
	A2	N	0	-0.162	-0.093	+0.093	+0.283
		V	+0.445	-0.019	-0.008	+0.008	+0.008
		M	-0.042	+0.015	+0.006	-0.006	-0.006
	A3	N	+0.445	-0.313	-0.008	+0.008	+0.008
		V	0	-0.019	0.093	-0.093	-0.283
	E4	M N	-0.042 +0.445	-0.031 +0.187	-0.014 -0.008	+0.014 +0.008	+0.034 +0.008
		M	-0.042	-0.078	+0.008	-0.008	-0.008
	D5	N	+0.445	+0.687	-0.010	+0.010	+0.010
		V	0	+0.162	-0.193	+0.193	+0.288
		M	-0.042	-0.078	+0.008	-0.008	-0.008
	D6	N	0	+0.162	-0.193	+0.193	+0.288
		V	-0.445	-0.687	+0.010	-0.010	-0.010
1.75	C7	M N M	+0.057 0 - 0.097	+0.080 +0.162 -0.142	+0.003 -0.193 - 0.002	+0.003 +0.193 +0.002	+0.003 +0.288 +0.002
	F8	N	0	+0.162	-0.193	+0.193	+0.288
		V	+0.555	+0.816	+0.010	-0.010	-0.010
		M	-0.088	-0.130	-0.001	+0.001	+0.001
	F9	N	0	+0.162	-0.193	+0.193	+0.288
		V	-0.500	0	0	0	0
		M	-0.009	-0.012	-0.002	+0.002	+0.002
	F10	N	+1.055	+0.816	+0.010	-0.010	-0.010
		V	0	-0.019	-0.001	+0.001	0
	G11	M N	-0.009 +1.055	-0.006 +0.316	-0.002 +0.010	+0.002 -0.010	+0.002 -0.010
		M	-0.009	-0.001	-0.001	+0.001	+0.001
	H12	N	+1.055	-0.184	+0.008	-0.008	-0.008
		V	0	-0.019	-0.001	+0.001	+0.001
	H13	M N	-0.097 0	-0.004 -0.162	-0.002 -0.093	+0.002 +0.093	+0.002 +0.283

Figure 5: Table 4 :

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