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Analysis of Box Culvert for Non-Overburden Case

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Abstract: *Box culverts are the monolithic structure made to pass across a roadway, railway lines etc. Embankments are used to balance the flood water on both sides. Box takes various types of loads generated by water, traffic, cushion, soil etc. This work deals with complete design of box culvert manually and study the design parameters such as effect of earth pressure, depth of cushion at the top slab of culvert, factor such as braking force, Impact load, Live load, Dispersal of load through tracked or wheeled vehicle, effective width etc. In this work, study of culvert with and without cushion analyzed for different classes of IRC loadings and conclusions made on the basis of bending moments and shear forces with and without cushioning cases. This paper provides full discussion of provisions provided by Indian Standards, their justifications and considerations are taken into the account for design purpose.*

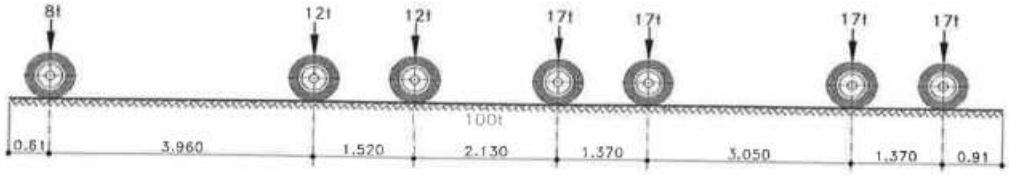
Key Word: *BOX CULVERT, IRC-115, BRIDGE ENGINEERING, IRC-06, STAAD PRO*

I. INTRODUCTION

Box culverts are low rise bridge or structure which is used to discharge water in the proper channel in crossing of railway, flyover, roads etc. and is used where the bearing capacity of soil is low. Culverts are always economical than bridge where the discharge in the opening is 18 m2 it depends on the number of cells which is generally used where roadway crosses the high embankment. Box culverts are generally cast in situ in India, but in other countries the box culverts are preferred due to low cost and economically with having fast workmanship. The box is just name given for its shape, can be found in various types of shapes and also it can be act as minor bridge when the number of cells increases and span greater than 6m in length. Its height depends on span. It can control all water coming from irrigation, surface water, river and canals they control all the storm water and flood water during rainy season.

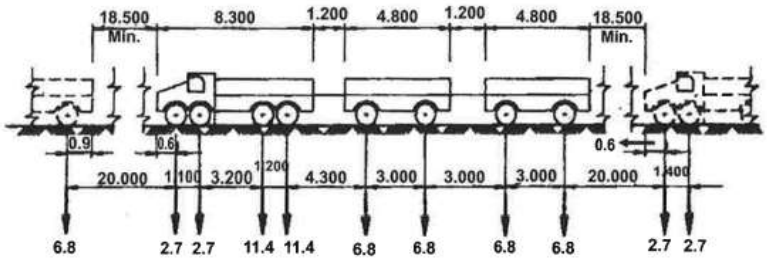
II. VEHICLES CONSIDERED

2.1) IRC-CLASS-70 R: - It is a loading which used by the municipality which includes industrial areas along with major highways, bridges culverts etc. For military heavy loads vehicles, the bridge, culverts designed for Class-A and also for Class-B. It should be checked for Class-A loading because there will be heavy stresses created under Class-A loadings. As per IRC 6, the value for Class 70 R provided is 350 KN for tracked vehicle.



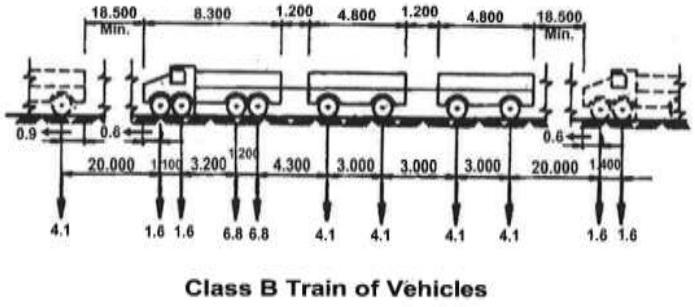
CLASS 70R (WHEELED) - LONGITUDINAL POSITION

2.2) IRC-CLASS-A: - This loading is preferred on each and every roads on which permanent structures are made such as bridges, culverts etc. As per IRC 6, the value for Class A provided is 114 KN for wheeled vehicle.



Class A Train of Vehicles

2.3) IRC-CLASS-B: - This loading is preferred on each and every road on which temporary structures are made and for bridges the different materials are used respect to situations. As per IRC 6, the value for Class B provided is 68 KN for wheeled vehicle.



Class B Train of Vehicles

III. COMBINATION OF LIVE LOAD:-

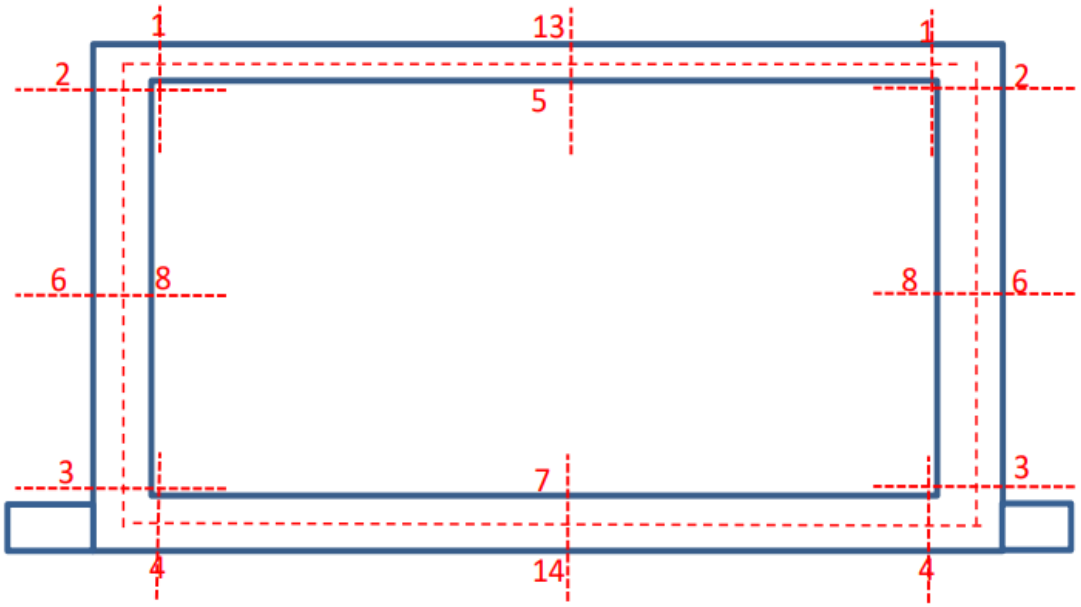
Table-01

Sr. No.	Carriageway Width	Number of lanes for design purposes	Load combination
1	9.6m and above but less than 16.6m	3	One lane of class 70R for every two lanes with one lane of class A on the remaining lane or 3 lanes of class A

IV. METHODOLOGY & PROBLEM SOLVING STATEMENT

1. Fixing of dimensions based on hydraulic report.
2. Calculation of dead load and superimposed dead load
3. Calculation of live load from vehicles as per lane consideration for various cases which will act on Top slab
4. Calculation of Braking Force(As per Cl.No.211.2-IRC-6-2016)
5. Calculation of Earth pressure:- At Rest and Sliding condition.
6. Calculation of loads acting on Bottom slab.
7. Calculation of modulus of subgrade reaction for Allowable safe bearing capacity of 15T/M3.
8. Calculation of ULS, SLS & QPC Moments at section 1,2,3,4,5,6,7,8,13 & 14 by using Staad pro software.
9. Calculation of shear force at sections 1,2,3 & 4 sections.
10. RCC design of Box culvert by ultimate limit state method (IRC-112-2011).
11. Verification of Structural Strength under imposed Ultimate Shear(Ved).
12. Checking stresses under Serviceability Limit State
13. Calculation of Stresses for Quasi Permanent Combination.
14. Checking Crack Width under Serviceability Limit State.

V. BOX CULVERT DISTRIBUTED INTO SECTIONS-



VI. DESIGN OF TOP SLAB

6.1) Calculation of Dead load and super impsosed dead load

Dead Load-

Table-02

Self weight of slab Weight of Top slab-	0.250x2.5x1=0.625T/m
Weight of 4 Haunch portion	0.011x2.5=0.113T/m

Superimposed Dead load-

Table-03

Dead load of one crash barrier	0.285x1.1x2.5=0.785T/m
Dead load due to two crash barrier	1.570T/m
Dead load due to road crust	0.610x 2.2x1.00=1.342T/m
Per unit weight of Two Crash Barrier	0.122
Dead load due to wearing coat	1x0.065x2.2=0.143T/m

6.2). Braking Force (As per Cl.No.211.2-IRC-6-2016)

No. of lanes can be accommodate = 3
Case 1
3 Class A Vehicle
Load from 2 Class A Vehicle = 45.60 T
Load from Class A Vehicle = 22.80 T
Case 1 Class A-3 Lanes
Horizontal load due braking = 20% of first Two lanes + 5%of Excess lane
= 9.12 + 1.14
= 10.26 T
= 1.47 T/m
Case 2
Check 1 One Class A Vehicle + Class 70R (WHEELED)
Load from 1 Class A Vehicle = 22.80 T
Load from Class 70 R (WHEELED) = 34.0 T 17+17
2 Lane of Class A +1 Lane of Class 70R (W)
Horizontal load due braking = 20% of class A + 5% of 70R (W)
= 4.56 + 1.7
= 6.26 T
= 0.89 T/m
Check 2
One Class A Vehicle+ One Class 70RW (BOGIE)
Load from 1Class A Vehicle = 22.80 T
Load from Class 70RW (BOGIE) = 40.0 T
2 Lane of Class A +1 Lane of Class 70R (W)
Horizontal load due braking = 20% of Class A
= 4.56 = 4.56 T
= 0.65 T/m
MAX BRAKING FORCE = 1.47 T/m along width
Breaking force on Exterior Wall = 0.733 T/m
Moment due Breaking Force = 0.971 T-m/m

VII. LOAD COMBINATIONS FOR VERIFICATION 0F ULIMATE LIMIT STATE (ULS)

Load Cases Considered:

1. Dead Load (DL) 2. Wearing Coat (WC) 3. Active Earth Pressure (AEP) 4. Surcharge on One Side (SOS) 5. Surcharge on Both Side (SBS) 6. Breaking Force (BP) 7. Tempertaure Uniform Rise (TUR) 8. Temperature Uniform Fall (TUF) 9. Temperature Gradient Rise (TGR) 10. Temperature Gradient Fall (TGF) 11. Earth Pressure at Rest (EP)

Load cases considered for Non-overburden case

ULS1: 1.35DL + 1.75WC + 1.5AEP + 1.2 SOS + 1.2BP + 0.9TUR + 0.9TGR
ULS2: 1.35DL + 1.75WC + 1.5AEP + 1.2 SOS + 1.5BP + 0.9TUF + 0.9TGF
ULS3: : 1.35DL + 1.75WC + 1.5AEP + 1.2 SOS + 1.15BP + 1.5TUR + 1.5TGR

ULS4: 1.35DL + 1.75WC + 1.5AEP + 1.2SOS + 1.15BP + 1.5TUF + 1.5TGF
ULS5: : 1.35DL + 1.75WC + 1.5AEP + 1.2 SBS + 1.5BP + 0.9TUR + 0.9TGR
ULS6: :1.35DL + 1.75WC + 1.5AEP + 1.2 SBS + 1.5BP + 0.9 TUF + 0.9TGF
ULS7: 1.35DL + 1.75WC + 1.5AEP + 1.2 SBS + 1.2BP + 1.5TUR + 1.5TGR
ULS8: : 1.35DL + 1.75WC + 1.5AEP + 1.2 SBS + 1.15BP + 1.5TUF + 10TGF
ULS9: : 1.35DL + 1.75WC + 1.5TUR + 1.5TGR
ULS10: .35DL + 1.75WC + 1.2TUF + 1.5TGR

VIII. RESULT

Table-04

FOR SECTION 1

Combinations	Factored moments		Total
	Other load	Live load	
ULS1	48	15	63
ULS2	30	15	45
ULS3	51	12	62
ULS4	29	12	41
ULS5	42	15	57
ULS6	25	15	40
ULS7	45	12	57
ULS8	20	12	32
ULS9	26	0	26
ULS10	0	0	0
Governing moments			63KN.m

FOR SECTION 2

Combinations	Factored moments		Total
	Other load	Live load	
ULS1	27	20	47
ULS2	26	20	46
ULS3	33	15	48
ULS4	26	15	41
ULS5	18	20	38
ULS6	19	20	39
ULS7	25	15	40
ULS8	19	15	34
ULS9	18	0	18
ULS10	11	0	11
Governing moments			48KN.m

FOR SECTION 3

Combinations	Factored moments		Total
	Other load	Live load	
ULS1	29	3	32
ULS2	30	3	33
ULS3	26	3	29
ULS4	27	3	29
ULS5	19	3	22
ULS6	20	3	23
ULS7	16	3	19
ULS8	17	3	19
ULS9	5	0	5
ULS10	6	0	6
Governing moments			33KN.m

FOR SECTION 4

Combinations	Factored moments		Total
	Other load	Live load	
ULS1	33	3	
ULS2	33	3	
ULS3	31	3	
ULS4	30	3	
ULS5	23	3	
ULS6	23	3	
ULS7	23	3	
ULS8	20	3	
ULS9	8	0	
ULS10	7	0	
Governing moments			36KN. m

FOR SECTION 5

Combinations	Factored moments		Total
	Other load	Live load	
ULS1	0	41	41
ULS2	0	41	41
ULS3	0	32	32
ULS4	10	32	42
ULS5	0	41	41
ULS6	0	41	41
ULS7	0	32	32
ULS8	0	32	32
ULS9	0	0	0
ULS10	0	0	0
Governing moments			42KN.m

FOR SECTION 13

Combinations	Factored moments		Total
	Other load	Live load	
ULS1	12	2	14
ULS2	0	2	2
ULS3	24	2	26
ULS4	0	2	2
ULS5	23	2	25
ULS6	0	2	2
ULS7	26	2	28
ULS8	0	2	2
ULS9	20	0	20
ULS10	0	0	0
Governing moments			26KN.m

FOR SECTION 7

Combinations	Factored moments		Total
	Other load	Live load	
ULS1	0	6	6
ULS2	0	6	6
ULS3	0	5	5
ULS4	0	5	5
ULS5	0	6	6
ULS6	0	6	6
ULS7	3	5	8
ULS8	2	5	7
ULS9	2	0	2
ULS10	1	0	1
Governing moments			8KN.m

FOR SECTION 14

Combinations	Factored moments		Total
	Other load	Live load	
ULS1	6	0	6
ULS2	7	0	7
ULS3	9	0	9
ULS4	6	0	6
ULS5	2	0	2
ULS6	2	0	2
ULS7	1	0	1
ULS8	1	0	1
ULS9	0	0	0
ULS10	0	0	0
Governing moments			9KN.m

FOR SECTION 6

Combinations	Factored moments		Total
	Other load	Live load	
ULS1	0	9	9
ULS2	0	9	9
ULS3	0	7	7
ULS4	0	7	7
ULS5	0	9	9
ULS6	0	9	9
ULS7	0	7	7
ULS8	0	7	7
ULS9	0	0	0
ULS10	0	0	0
Governing moments			9KN.m

FOR SECTION 8

Combinations	Factored moments		Total
	Other load	Live load	
ULS1	15	0	15
ULS2	6	0	6
ULS3	19	0	19
ULS4	5	0	5
ULS5	15	0	15
ULS6	6	0	6
ULS7	20	0	20
ULS8	5	0	5
ULS9	17	0	17
ULS10	2	0	2
Governing moments			9KN.m

CONCLUSION

After analayis of Box culvert for ULS in Staad pro software following moments were calculated, Maximum moment was found at section 5 since it was at center of bottom of top slab. Section 1 & 3 also shown maximum moments in staad model for other load, In live load modeling maximum moment was found at sction 5.

IX. LOAD COMBINATIONS FOR VERIFICATION 0F SERVICEABILITY LIMIT STATE (SLS)

Load Cases Considered:

1.Dead Load (DL) 2. Wearing Coat (WC) 3. Active Earth Pressure (AEP) 4. Surcharge on One Side (SOS) 5. Surcharge on Both Side (SBS) 6. Breaking Force (BP) 7. Tempertaure Uniform Rise (TUR) 8. Temperature Uniform Fall (TUF) 9. Temperature Gradient Rise (TGR) 10. Temperature Gradient Fall (TGF) 11. Earth Pressure at Rest (EP)

Load Combinations Considered:

SLS1: DL + 1.2WC + AEP + 0.8SOS + BP + 0.6 TUR + 0.6TGR
SLS2: DL + 1.2WC + AEP + 0.8SOS + BP + 0.6TUF + 0.6TGF
SLS3: DL + 1.2WC + AEP + 0.8SOS + 0.75BP + TUR + TGF
SLS4: DL + 1.2WC + AEP + 0.8SOS + 0.75BP + TUF + TGF
SLS5: DL + 1.2WC + AEP + 0.8SBS + BP + 0.6TUR + 0.6TGR
SLS6: DL + 1.2 WC + AEP + 0.8SBS + BP + 0.6TUF + 0.6TGF
SLS7: DL + 1.2WC + AEP + 0.8SBS + 0.75BP + TUR + TGR
SLS8: DL + 1.2WC + AEP + 0.8SBS + 0.75BP + TUF + TGF
SLS9: DL + 1.2WC + TUR + TGR SLS10: DL + 1.2WC + TUF + TGF

X. RESULT

Table-06

FOR SECTION 1

Combinations	Factored moments		Total
	Other load	Live load	
SLS1	32	10	42
SLS2	20	10	30
SLS3	34	8	41
SLS4	19	8	27
SLS5	29	10	39
SLS6	17	10	27
SLS7	30	8	38
SLS8	10	8	18
SLS9	18	0	18
SLS10	0	0	0
Governing moments			42KN.m

FOR SECTION 2

Combinations	Factored moments		Total
	Other load	Live load	
SLS1	7	13	20
SLS2	18	13	31
SLS3	0	10	10
SLS4	18	10	28
SLS5	2	13	15
SLS6	13	13	26
SLS7	0	10	10
SLS8	13	10	23
SLS9	0	0	0
SLS10	7	0	7
Governing moments			31KN.m

FOR SECTION 3

Combinations	Factored moments		Total
	Other load	Live load	
SLS1	20	2	22
SLS2	20	2	22
SLS3	18	2	20
SLS4	18	2	20
SLS5	12	2	14
SLS6	12	2	14
SLS7	11	2	13
SLS8	12	2	14
SLS9	3	0	3
SLS10	4	0	4
Governing moments			22KN.m

FOR SECTION 4

Combinations	Factored moments		Total
	Other load	Live load	
SLS1	22	2	
SLS2	22	2	
SLS3	20	2	
SLS4	20	2	
SLS5	15	2	
SLS6	15	2	
SLS7	14	2	
SLS8	13	2	
SLS9	5	0	
SLS10	5	0	
Governing moments			24KN.m

FOR SECTION 5

Combinations	Factored moments		Total
	Other load	Live load	
SLS1	0	27	27
SLS2	5	27	32
SLS3	0	21	21
SLS4	7	21	28
SLS5	0	27	27
SLS6	3	27	30
SLS7	0	21	21
SLS8	6	21	28
SLS9	0	0	0
SLS10	8	0	8
Governing moments			32KN.m

FOR SECTION 13

Combinations	Factored moments		Total
	Other load	Live load	
SLS1	8	1	9
SLS2	0	1	1
SLS3	17	1	18
SLS4	0	1	1
SLS5	12	1	13
SLS6	0	1	1
SLS7	17	1	18
SLS8	0	1	1
SLS9	13	0	13
SLS10	0	0	0
Governing moments			18KN.m

FOR SECTION 7

Combinations	Factored moments		Total
	Other load	Live load	
SLS1	2	4	6
SLS2	2	4	6
SLS3	4	3	7
SLS4	4	3	7
SLS5	4	4	8
SLS6	2	4	6

FOR SECTION 14

Combinations	Factored moments		Total
	Other load	Live load	
SLS1	3	0	3
SLS2	3	0	3
SLS3	4	0	4
SLS4	4	0	4
SLS5	4	0	4
SLS6	4	0	4

SLS7	1	3	4
SLS8	1	3	4
SLS9	1	0	1
SLS10	1	0	1
Governing moments			8KN.m

SLS7	4	0	4
SLS8	3	0	3
SLS9	1	0	1
SLS10	1	0	1
Governing moments			4KN.m

FOR SECTION 6

Combinations	Factored moments		Total
	Other load	Live load	
SLS1	0	6	6
SLS2	6	6	12
SLS3	0	5	5
SLS4	0	5	5
SLS5	0	6	6
SLS6	0	6	6
SLS7	0	5	5
SLS8	0	5	5
SLS9	0	0	0
SLS10	0	0	0
Governing moments			12KN.m

FOR SECTION 8

Combinations	Factored moments		Total
	Other load	Live load	
SLS1	10	0	10
SLS2	7	0	7
SLS3	18	0	18
SLS4	5	0	5
SLS5	11	0	11
SLS6	4	0	4
SLS7	15	0	15
SLS8	3	0	3
SLS9	12	0	12
SLS10	1	0	1
Governing moments			18KN.m

CONCLUSION

After analayis of Box culvert for SLS in Staad pro software following moments were calculated, Maximum moment was found at section 1 since it was at center of bottom of top slab. Section 3 & 4 also shown maximum moments in staad model for other load, In live load modeling maximum moment was found at sction 5.

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