

**DESIGN OF BARREL FOR BOX CULVERT- (Width 2.0 x 1.2m Depth)-TYPE1**

Width of Road, (Typical)	=	7.00	m
Width of Shoulder, (Typical)	=	1.50	m
Width of Culvert	L' =	10.00	m
Thickness of wearing coat	y =	0.08	m

**Check for culvet****Class AA - Tracked Vehicle**

Span =	2.00	m	
Weight of vehicle	=	700	kN
Tyre contact width perpendicular to span	a =	0.85	m
Tyre contact width along to span	b =	3.60	m
Clear distance between wheels	c =	1.20	m
Impact factor	I =	25	%
Weight of vehicle (For 1.3 m of loaded area)	=	252.78	kN
Load per wheel	=	126.39	kN
Clear Span of Culvert	=	2.00	m
Assumed thickness of slab	t =	0.30	m
Assumed effective thickness of slab	t <sub>eff</sub> =	0.25	m
Effective Span of Culvert	L =	2.25	m
Width of dispersion along the span	=	1.30	m
Width of dispersion perpendicular to the span	t <sub>p</sub> = a + 2(y + t <sub>eff</sub> ) =	1.51	m < 2.05 m (1.2+0.85)
Total dispersed load on slab (126.39 x 1.25)/(1.3 x 1.51)	=	80.49	kN/m

**Class AA - Wheeled Vehicle**

Span =	2.00	m	
Weight of vehicle	=	400	kN
Load per axle	=	200	kN
Clear distance between axle	c =	1.75	m
Clear distance between Wheels	c <sub>1</sub> =	0.70	m
Tyre contact width along to span	a =	0.15	m
Tyre contact width perpendicular to span	b =	0.30	m
Impact factor	I =	25	%
Clear Span of Culvert	=	2.00	m
Assumed effective thickness of slab	t <sub>eff</sub> =	0.25	m
Effective Span of Culvert	L =	2.25	m
Width of dispersion along the span	t <sub>p</sub> = a + 2(y + t <sub>eff</sub> ) =	0.81	m < 1.90 m
Width of dispersion perpendicular to the span	t <sub>p</sub> = b + 2(y + t <sub>eff</sub> ) =	0.96	m < 1.00 m
Effective dispersion width perpendicular to span	b <sub>e</sub> = k x [1-(x/l)]+b <sub>w</sub>		
Ratio of width to span of the culvert	(L'/L) =	4.45	
Factor, k (From Table A1)	=	3.00	
Distance of CG of load from near support	x =	0.25	m
Breadth of concentration area of load	b <sub>w</sub> = b + 2 * y =	0.46	m
Effective dispersion width perpendicular to span	b <sub>e</sub> = k x [1-(x/l)]+b <sub>w</sub> =	1.13	m
Width of dispersion perpendicular to the span (0.60+1.0+0.60 + b <sub>w</sub> )	=	3.33	m
Total dispersed load on slab (100 x 1.25) / (3.33)	=	37.54	kN/m

**Class A - Train of Vehicles**

Span =	2.00	m	
Weight of vehicle	=	114.00	kN
Load per axle	=	57.00	kN
Clear distance between axle	c <sub>1</sub> =	0.95	m
Clear distance between Wheels	c =	1.30	m
Tyre contact width along to span	a =	0.30	m

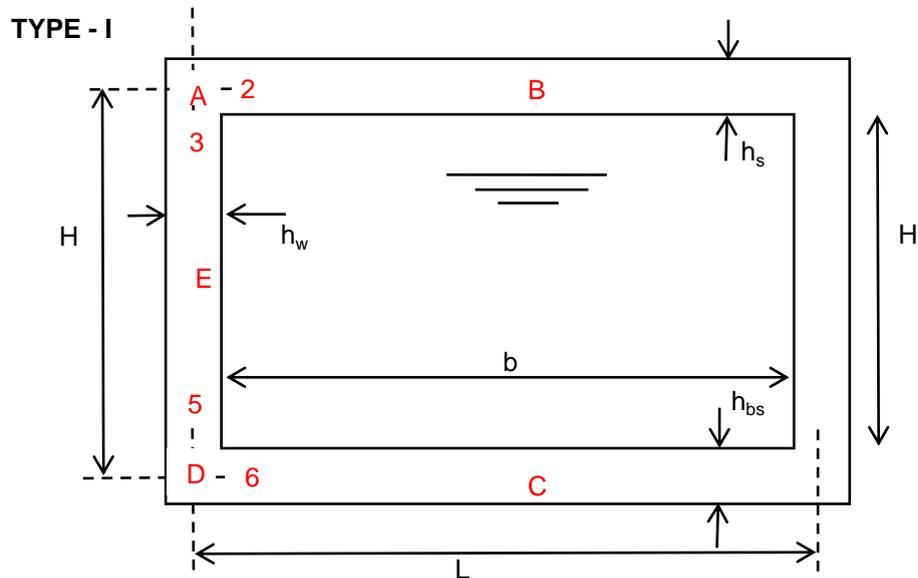
Tyre contact width perpendicular to span	$b =$	<b>0.50</b>	m	
Impact factor, $(4.50 / 6 + L)$	$I =$	0.55		
Clear Span of Culvert	$=$	2.00	m	
Assumed effective thickness of slab	$t_{eff} =$	<b>0.30</b>	m	
Effective Span of Culvert	$L =$	2.30	m	
Width of dispersion along the span	$t_p = a + 2(y + t_{eff}) =$	1.06	m	< 1.25 m
Width of dispersion perpendicular to the span	$t_p = b + 2(y + t_{eff}) =$	1.26	m	< 1.80 m
Total dispersed load on slab $(57 \times 1.55) / (1.26)$	$=$	70.12	kN/m	

Weight of Top slab $(2.4 \times 0.25 \times 25)$	$w_1 =$	15.00	kN
Weight of Walls $(2 \times 0.2 \times 1.2 \times 25)$	$w_2 =$	12	kN
Weight of Base slab $(2.4 \times 0.25 \times 25)$	$w_3 =$	15.00	kN
Weight of Soil $(2 \times 1.45 \times 0.9 \times 18)$	$w_4 =$	46.98	kN
Projection of base slab on either side	$=$	<b>900</b>	mm

**Check for Bearing Pressure:**

Safe bearing capacity assumed	$=$	<b>50</b>	kN/m <sup>2</sup>
Gross bearing capacity	$=$	80.6	kN/m <sup>2</sup>
Weight of Culvert including soil wt	$W =$	88.98	kN
Wheel load on roof $(80.49 \times 2.2)$	$=$	177.078	kN
Total weight on Structure	$=$	266.06	kN
Area of base slab	$=$	4.20	m
Bearing Pressure on Soil	$=$	63.35	kN/m <sup>2</sup> < 80.6 kN/m <sup>2</sup> <b>SAFE</b>

For Coefficients of Moment & Shear refer Table - 6.8, from Essentials of Bridge engineering - D.Johnson Victor



**TYPE - I**

Load	BM	SF
Load 1	Coeff x WL	Coeff x W
Load 2	Coeff x $wL^2$	Coeff x $wL$
Load 3	Coeff x WL	Coeff x W
Load 4	Coeff x $pH^2$	Coeff x $pH$
Load 5	Coeff x $pH^2$	Coeff x $pH$
Load 6	Coeff x $pH^2$	Coeff x $pH$

$\gamma_w$	$\gamma_{sat}$	$H_1$	b	$h_s$	$h_{bs}$	$h_w$	$k_a$	$\gamma_{sub}$	H	L	L / H
kN/m <sup>3</sup>	kN/m <sup>3</sup>	m	mm	mm	mm	mm		kN/m <sup>3</sup>	m	m	
<b>9.81</b>	<b>18.00</b>	<b>1.200</b>	<b>2000</b>	<b>250</b>	<b>250</b>	<b>200</b>	<b>0.33</b>	8.19	1.450	2.20	1.52

**Wheel Load on roof**

Wheel Load on Slab  $W =$  **80.49** kN/m

Section	B1	A2	A3	E4	D5	D6	C7
Moment Ceff	0.170	-0.079	-0.079	-0.062	-0.045	-0.045	0.079
Shear Ceff	0.000	0.500	0.000	0.000	0.000	-0.500	0.000
Moment, kNm	30.03	-14.06	-14.06	-11.04	-8.02	-8.02	13.93
Shear Force, kN	0.00	40.25	0.00	0.00	0.00	-40.25	0.00

**Uniform Load on roof**

Live load	=	5.00	kN/m <sup>2</sup>
Self weight of slab	=	6.25	kN/m <sup>2</sup>
Total Load q on slab	=	11.25	kN/m <sup>2</sup>

Section	B1	A2	A3	E4	D5	D6	C7
Moment Ceff	0.075	-0.050	-0.050	-0.050	-0.050	-0.050	0.075
Shear Ceff	0.000	0.500	0.000	0.000	0.000	-0.500	0.000
Moment, kNm	4.07	-2.74	-2.74	-2.74	-2.74	-2.74	4.07
Shear Force, kN	0.00	12.38	0.00	0.00	0.00	-12.38	0.00

**Weight of Walls**

Weight of wall (1.7 x 0.2 x 25) G = 8.50 kN

Section	B1	A2	A3	E4	D5	D6	C7
Moment Ceff	0.018	0.018	0.018	-0.050	-0.122	-0.118	0.132
Shear Ceff	0.000	0.000	0.000	0.000	0.000	-1.000	0.000
Moment, kNm	0.33	0.33	0.33	-0.94	-2.28	-2.22	2.46
Shear Force, kN	0.00	0.00	0.00	0.00	0.00	-8.50	0.00

**Hydrostatic Internal pressure on walls**

Water pressure In Walls,  $\gamma_w \times H_1$  p = 11.78 kN/m

Section	B1	A2	A3	E4	D5	D6	C7
Moment Ceff	0.015	0.015	0.015	-0.047	0.018	0.018	0.018
Shear Ceff	0.000	0.000	0.167	0.000	-0.344	0.011	0.000
Moment, kNm	0.37	0.37	0.37	-1.17	0.44	0.44	0.44
Shear Force, kN	0.00	0.00	2.85	0.00	-5.88	0.20	0.00

**Earth pressure on walls**

Height of Earthfill to be considered h = 1.45 m  
 Earth pressure due to soil  $K_a \times \gamma \times h$  = 8.61 kN/m  
 Total Earth Pressure,  $q_{ep}$  (p) = 8.61 kN/m

Section	B1	A2	A3	E4	D5	D6	C7
Moment Ceff	-0.015	-0.015	-0.015	0.050	-0.018	-0.018	-0.018
Shear Ceff	0.000	0.000	-0.167	0.000	0.344	-0.011	0.000
Moment, kNm	-0.269	-0.269	-0.269	0.907	-0.323	-0.32	-0.32
Shear Force, kN	0.000	0.000	-2.086	0.000	4.30	-0.14	0.00

**Surcharge pressure on walls**

Height of Earthfill to be considered for surcharge h = 1.45 m  
 Earth pressure due to surcharge  $\gamma_w \times h$  = 14.2245 kN/m  
 Total Surcharge Pressure,  $q_s$  (p) = 14.2245 kN/m

Section	B1	A2	A3	E4	D5	D6	C7
Moment Ceff	-0.033	-0.343	-0.033	0.092	-0.033	-0.033	-0.033
Shear Ceff	0.000	0.000	-0.500	0.000	0.500	0.000	0.000
Moment, kNm	-0.978	-10.259	-0.978	2.761	-0.978	-0.98	-0.98
Shear Force, kN	0.000	0.000	-10.313	0.000	10.313	0.00	0.00

**Design Parameters:**

$f_{ck}$	$E_s$	$E_c$	$\sigma_{cbc}$	$f_y$
N/mm <sup>2</sup>				
35	210000	29580	12	500

**Design of Top Slab:**

At section B - Critical Case - Culvert Full  
 At section A2 - Critical Case - Culvert Empty

At section B - Load 1 + Load 2 + Load 3 + Load 4 + Load 5  
 At section A2 - Load 1 + Load 2 + Load 3 + Load 5 + Load 6

Net moment at B at bottom, +ve = 34.53 kNm  
 Net moment at A2 at top, -ve = -26.99 kNm

**Check for required slab thickness:**

Maximum moment along both the directions = 34.53 kNm  
 $M_u/fckbd^2 = 0.133$   
 Required effective thickness,  $d_{req}$  (sqrt( $M/QxB$ )) = 105 mm

**Bottom Reinforcement:**

M	$M_u$	$D = h_s$	b	$d_{req}$	$d_{pro}$	$M_u/bd^2$	$A_{st,req}$	$A_{st,pro}$	$p_t$	$\phi$	Spacing
kNm/m	kNm/m	mm	mm	mm	mm		mm <sup>2</sup>	mm <sup>2</sup>	%	mm	mm
34.53	51.795	250	1000	105	194	1.38	645	754	0.39	12	150

Hence safe in shear

**Top Reinforcement:**

M	$M_u$	$D = h_s$	b	$d_{req}$	$d_{pro}$	$M_u/bd^2$	$A_{st,req}$	$A_{st,pro}$	$p_t$	$\phi$	Spacing
kNm/m	kNm/m	mm	mm	mm	mm		mm <sup>2</sup>	mm <sup>2</sup>	%	mm	mm
26.99	40.485	250	1000	93	194	1.08	499	754	0.39	12	150

Hence safe in shear

**Check for Shear on Top Slab**

Ast provided @ Top -Y 12 @ 150 mm

Pt provided at top

Factored Shear force at A2

Nominal Shear stress

Permissible Shear stress

$$= 0.39\%$$

$$= 78.93 \text{ kN}$$

$$T_v = 0.41 \text{ N/mm}^2$$

$$T_c = 0.44 \text{ N/mm}^2$$

**Distribution Reinforcement:**

$$T_v < T_c \text{ Hence safe in shear}$$

$P_{t,req}$	$P_{t,pro}$	$\phi$	s
%	%	mm	mm
0.06	0.27	10	150

**Design of Wall: Earthface Reinforcement**

At section A3 - Critical Case - Culvert Empty  
 At section E - Critical Case - Culvert Full  
 At section D5 - Critical Case - Culvert Empty

At section A3 - Load 1 + Load 2 + Load 3 + Load 5 + Load 6  
 At section E - Load 1 + Load 2 + Load 3 + Load 4 + Load 5  
 At section D5 - Load 1 + Load 2 + Load 3 + Load 5 + Load 6

Net moment at A3 at earthface, -ve = -17.71 kNm  
 Net moment at E at earthface, -ve = -14.98 kNm  
 Net moment at D5 at earthface, -ve = -14.34 kNm

**Inner face Reinforcement**

At section A3 - Critical Case - Nil  
 At section E - Critical Case - Culvert Empty without wheel load  
 At section D5 - Critical Case - Nil

At section A3 - -  
 At section E - Load 2 + Load 3 + Load 5 + Load 6  
 At section D5 - -

Net moment at A3 at innerface, +ve = 0.00 kNm  
 Net moment at E at innerface, +ve = -0.01 kNm  
 Net moment at D5 at innerface, +ve = 0.00 kNm

Net moment for earthface reinforcement, -ve = 17.71 kNm  
 Net moment for Inner face reinforcement, +ve = 0.01 kNm

**Check for required wall thickness:**

Maximum moment along both the directions = 17.71 kNm  
 $M_u / f_c k b d^2 = 0.133$   
 Required effective thickness,  $d_{req}$  (sqrt(M/QxB))  $d_{req} = 76$  mm

**Earthface Reinforcement**

M	M <sub>u</sub>	D = h <sub>w</sub>	b	d <sub>req</sub>	d <sub>pro</sub>	M <sub>u</sub> / b d <sup>2</sup>	A <sub>st,req</sub>	A <sub>st,pro</sub>	p <sub>t</sub>	φ	Spacing
kNm/m	kNm/m	mm	mm	mm	mm		mm <sup>2</sup>	mm <sup>2</sup>	%	mm	mm
17.71	26.565	200	1000	76	144	1.28	444	754	0.52	12	150

Hence safe in shear

**Inner face Reinforcement**

M	M <sub>u</sub>	D = h <sub>w</sub>	b	d <sub>req</sub>	d <sub>pro</sub>	M <sub>u</sub> / b d <sup>2</sup>	A <sub>st,req</sub>	A <sub>st,pro</sub>	p <sub>t</sub>	φ	Spacing
kNm/m	kNm/m	mm	mm	mm	mm		mm <sup>2</sup>	mm <sup>2</sup>	%	mm	mm
0.01	0.015	200	1000	2	144	0.00	1	754	0.52	12	150

Hence safe in shear

**Check for Shear on walls**

A<sub>st</sub> provided @ walls -Y 12 @ 150 mm  
 P<sub>t</sub> provided at wall = 0.52 %  
 Factored Shear force at D5 = 21.92 kN  
 Nominal Shear stress  $T_v = 0.15$  N/mm<sup>2</sup>  
 Permissible Shear stress  $T_c = 0.51$  N/mm<sup>2</sup>

**Distribution Reinforcement:**

$T_v < T_c$  Hence safe in shear

P <sub>t,req</sub>	P <sub>t,pro</sub>	φ	s
%	%	mm	mm
0.06	0.36	10	150

**Design of Bottom Slab:**

At section D6 - Critical Case - Culvert Empty

At section C7 - Critical Case - Culvert Full

At section D6 - Load 1 + Load 2 + Load 3 + Load 5 + Load 6

At section C7 - Load 1 + Load 2 + Load 3 + Load 4 + Load 5

Net moment at D6 at bottom, -ve =  $\boxed{-14.28}$  kNm

Net moment at C7 at top, +ve =  $\boxed{20.58}$  kNm

**Check for required slab thickness:**

Maximum moment along both the directions =  $\boxed{20.58}$  kNm

$M_u / f_{ck} b d^2 = \boxed{0.133}$

Required effective thickness,  $d_{req}$  (sqrt(M/QxB))  $d_{req} = \boxed{68}$  mm

**Bottom Reinforcement:**

M	M <sub>u</sub>	D = h <sub>bs</sub>	b	d <sub>req</sub>	d <sub>pro</sub>	M <sub>u</sub> / b d <sup>2</sup>	A <sub>st,req</sub>	A <sub>st,pro</sub>	p <sub>t</sub>	φ	Spacing
kNm/m	kNm/m	mm	mm	mm	mm		mm <sup>2</sup>	mm <sup>2</sup>	%	mm	mm
14.28	21.42	250	1000	68	194	0.57	259	754	0.39	12	150

Hence safe in shear

**Top Reinforcement:**

M	M <sub>u</sub>	D = h <sub>bs</sub>	b	d <sub>req</sub>	d <sub>pro</sub>	M <sub>u</sub> / b d <sup>2</sup>	A <sub>st,req</sub>	A <sub>st,pro</sub>	p <sub>t</sub>	φ	Spacing
kNm/m	kNm/m	mm	mm	mm	mm		mm <sup>2</sup>	mm <sup>2</sup>	%	mm	mm
20.58	30.87	250	1000	81	194	0.82	377	754	0.39	12	150

Hence safe in shear

**Check for Shear on Bottom Slab**

A<sub>st</sub> provided @ Bottom -Y 12 @ 150 mm

P<sub>t</sub> provided at bottom =  $\boxed{0.39}$  %

Factored Shear force at D6 =  $\boxed{91.90}$  kN

Nominal Shear stress  $T_v = \boxed{0.47}$  N/mm<sup>2</sup>

Permissible Shear stress  $T_c = \boxed{0.49}$  N/mm<sup>2</sup>

**Distribution Reinforcement:**

$T_v < T_c$  Hence safe in shear

P <sub>t,req</sub>	P <sub>t,pro</sub>	Φ	s
%	%	mm	mm
0.06	0.27	10	150