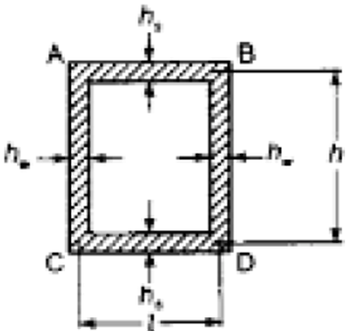
Rectangular Culvert

Bending moments (per unit length of culvert)
Ma: Mb Mc: Md

Pressures and uniform loads are per unit area of walls or slab
Loads F and G are total loads per unit length of culvert
h and l measured between centres of walls or slabs



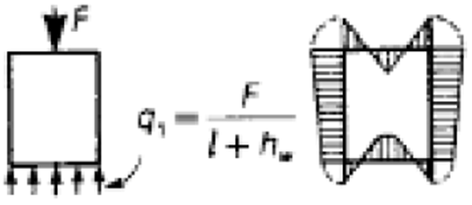
Horizontal span of culvert	$l := 3\ \text{m}$
Vertical height of culvert	$h := 1.5\ \text{m}$
Horz slab thickness	$h_s := 400\ \text{mm}$
Vert wall thickness	$h_w := 400\ \text{mm}$

$$k := \frac{h}{l} \cdot \left(\frac{h_s}{h_w}\right)^3 = 0.5$$

$K_1 := k + 1 = 1.5$ $K_3 := k + 3 = 3.5$ $K_5 := 2 \cdot k + 3 = 4$ $K_7 := 2 \cdot k + 7 = 8$

$K_2 := k + 2 = 2.5$ $K_4 := 4 \cdot k + 9 = 11$ $K_6 := k + 6 = 6.5$ $K_8 := 3 \cdot k + 8 = 9.5$

Concentrated load on Roof



$F := 1\ \text{kN}$

$$M_A := -\frac{F \cdot l \cdot K_4}{24 \cdot K_1 \cdot K_3} = -0.2619\ \text{kN m}$$

$$M_C := \frac{K_6}{K_4} \cdot M_A = -0.1548\ \text{kN m}$$

Mikhelson matches above

$$-\frac{F \cdot l}{24} \cdot \frac{4 \cdot k + 9}{k^2 + 4 \cdot k + 3} = -0.2619\ \text{kN m}$$

Mikhelson does not match above

$$-\frac{F \cdot l}{24} \cdot \frac{4 \cdot k + 6}{k^2 + 4 \cdot k + 3} = -0.1905\ \text{kN m}$$

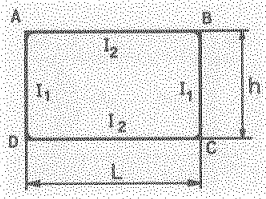
Correction to Mikhelson matches above

$$-\frac{F \cdot l}{24} \cdot \frac{k + 6}{k^2 + 4 \cdot k + 3} = -0.1548\ \text{kN m}$$

PIPES AND TUNNELS

RECTANGULAR CROSS–SECTION

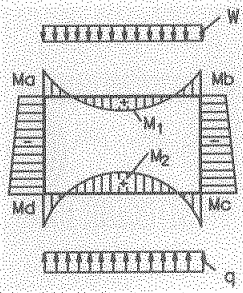
12.1



$$k = \frac{I_2 h}{I_1 L}$$

+M = tension on inside of section

1



For $q \neq w$

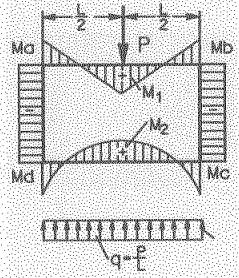
$$M_a = M_b = -\frac{L^2}{12}\cdot\frac{w(2k+3)-qk}{k^2+4k+3}$$

$$M_c = M_d = -\frac{L^2}{12}\cdot\frac{q(2k+3)-wk}{k^2+4k+3}$$

For $q = w$

$$M_a = M_b = M_c = M_d = -\frac{wL^2}{12}\cdot\frac{k+3}{K^2+4k+3}$$

2



$$M_a = M_b = -\frac{PL}{24}\cdot\frac{4k+9}{k^2+4k+3}$$

$$M_c = M_d = -\frac{PL}{24}\cdot\frac{4k+6}{k^2+4k+3}$$

For $k = 1$

$$M_a = M_b = -\frac{13}{192}PL$$

$$M_c = M_d = -\frac{7}{192}PL$$

Rectangular culverts

2.87

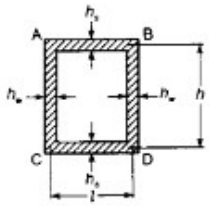
Bending moments (per unit length of culvert)

$M_A = M_B \qquad M_C = M_D$

Pressures and uniform loads are per unit area of walls or slab.

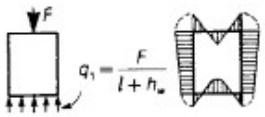
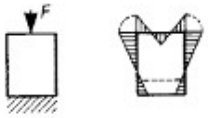
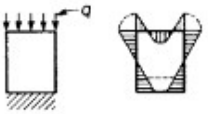
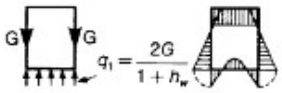
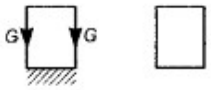
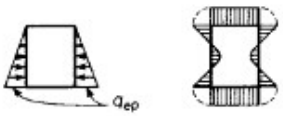
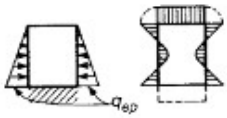
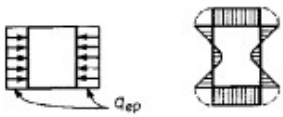
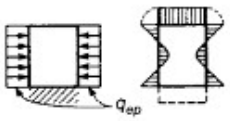
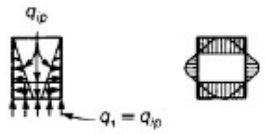
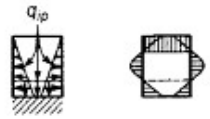
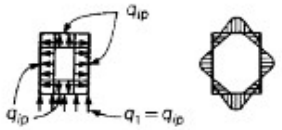
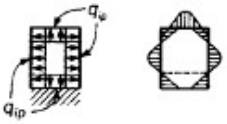
Loads F and G are total loads per unit length of culvert. h and l are measured between centres of walls or slabs.

q_1 = pressure transferred to soil.



$$k = \frac{h}{l}\left(\frac{h_s}{h_w}\right)^3$$

$K_1 = k + 1$
$K_2 = k + 2$
$K_3 = k + 3$
$K_4 = 4k + 9$
$K_5 = 2k + 3$
$K_6 = k + 6$
$K_7 = 2k + 7$
$K_8 = 3k + 8$

Loading	Condition of supporting ground (limiting cases)			
	Highly compressible		Non-compressible	
Concentrated load on roof		$M_A = -\frac{FlK_4}{24K_1K_3}$ $M_C = \frac{K_6}{K_4}M_A$		$M_A = -\frac{Fl}{4K_2}$ $M_C = -\frac{M_A}{2}$
Uniform load on roof		$\left.\begin{matrix}M_A\\M_C\end{matrix}\right\} = -\frac{ql^2}{12K_1}$		$M_A = -\frac{ql^2}{6K_2}$ $M_C = -\frac{M_A}{2}$
Weight of walls		$M_A = +\frac{q_1l^2k}{12K_1K_3}$ $M_C = -\frac{K_5}{k}M_A$		$M_A = M_C = 0$
Earth pressure on walls		$M_A = -\frac{q_{ep}h^2kK_7}{60K_1K_3}$ $M_C = \frac{K_8}{K_7}M_A$		$M_A = -\frac{q_{ep}h^2k}{30K_2}$ $M_C = \frac{K_8}{2k}M_A$
Earth (surcharge) pressure on walls		$\left.\begin{matrix}M_A\\M_C\end{matrix}\right\} = -\frac{q_{ep}h^2k}{12K_1}$		$M_A = -\frac{q_{ep}h^2k}{12K_2}$ $M_C = \frac{K_3}{k}M_A$
Hydrostatic (internal) pressure		$M_A = +\frac{q_{ip}h^2kK_7}{60K_1K_3}$ $M_C = \frac{K_8}{K_7}M_A$		$M_A = +\frac{q_{ip}h^2k}{30K_2}$ $M_C = \frac{K_8}{2k}M_A$
Excess hydrostatic (internal) pressure		$M_A = +\frac{q_{ip}(h^2kK_3 + l^2K_5)}{12K_1K_3}$ $M_C = +\frac{q_{ip}k(h^2K_3 - l^2)}{12K_1K_3}$		$M_A = +\frac{q_{ip}(h^2k + 2l^2)}{12K_2}$ $M_C = +\frac{q_{ip}(h^2K_3 - l^2)}{12K_2}$