



*Ministry of Transport*



*Vietnam Expressway Corporation*



*Project Management Unit No. 85*



**THE WORLD BANK**

**IDA Credit No. / IDA tín dụng số : 4779-VN**

**Project ID No. / Mã dự án : P106235**

**Consulting Services for / Dịch vụ tư vấn**  
**Detailed Design for Danang - QuangNgai Expressway Development Project /**  
**Thiết kế kỹ thuật dự án Đường cao tốc Đà Nẵng-Quảng Ngãi**

**Detailed Engineering Design Report (Final)**

**Hồ sơ thiết kế kỹ thuật**

**Volume 4: Structural Calculation Report (PKG5)**

**Tập 4: Hồ sơ tính toán kết cấu (Gói thầu 5)**

**Volume 4.1: Box Culverts (PKG5)**

**Tập 4.1: Cống hộp (Gói thầu 5)**

**July 05, 2013**

**The Joint Venture of**



**NIPPON KOEI CO.,LTD.**



**NIPPON ENGINEERING CONSULTANTS CO.,LTD.**



**CHODAI CO.,LTD.**



**THAI ENGINEERING CONSULTANTS CO., LTD.**

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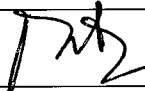
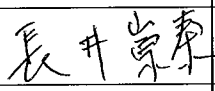
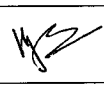
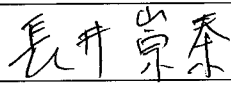
**Consulting Services  
for**

**Detailed Design for Danang - QuangNgai Expressway Development Project  
(Dịch vụ tư vấn Thiết kế kỹ thuật dự án Đường cao tốc Đà Nẵng – Quảng Ngãi)**

**Detailed Engineering Design Report (Final)  
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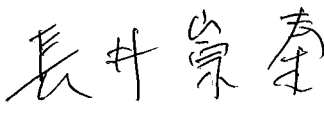
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**Volume 4.1: Box culverts (PKG5)  
Tập 4.1: Cống hộp (Gói thầu 5)**

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THE JOINT VENTURE OF NK-NE-CHODAI-TEC/LIÊN DANH TƯ VẤN

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For Ichizuru Ishimoto

***Da Nang, July 05, 2013/Đà Nẵng ngày 05 tháng 07 năm 2013***

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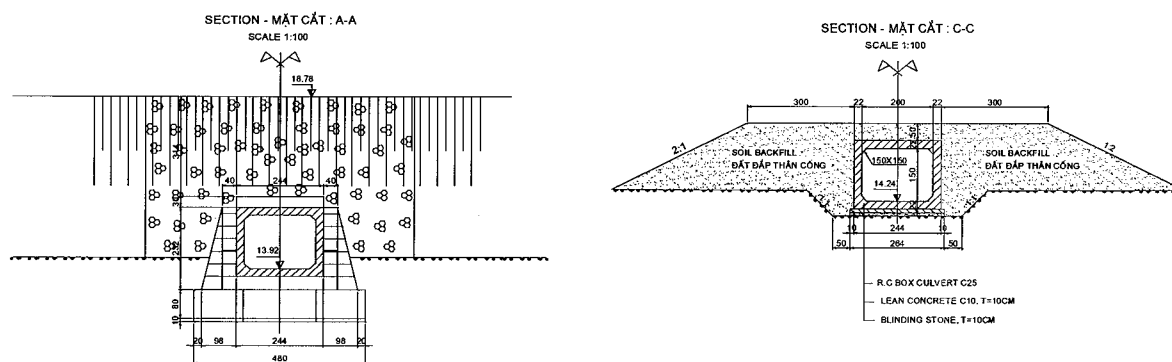


Figure 1.1: Typical plan of Cross drainage Box culverts

### 1.1.2.2 Underpass culverts

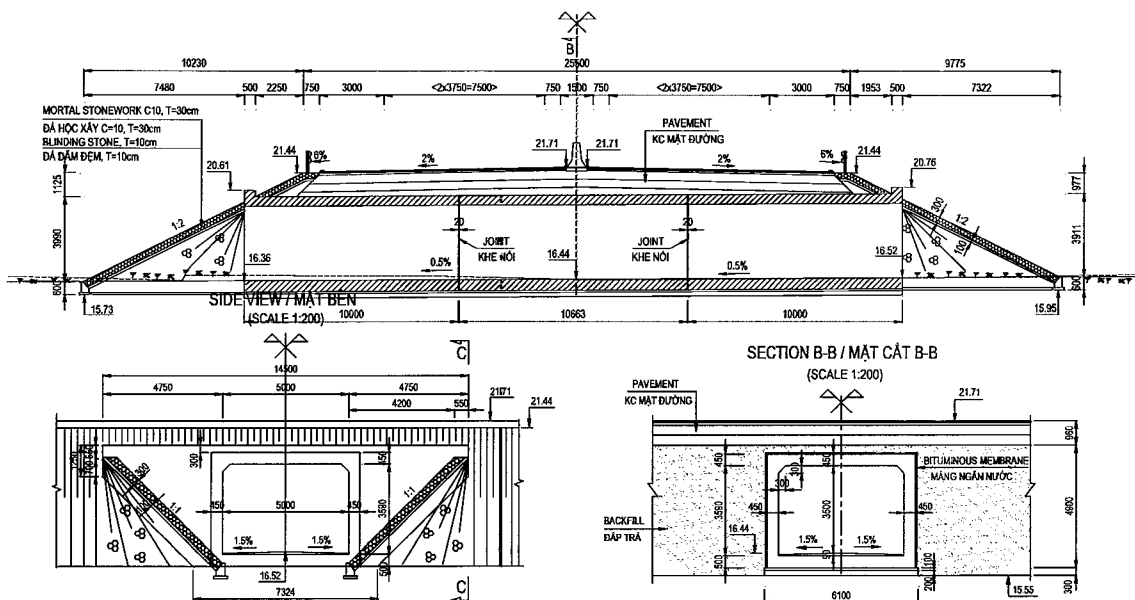


Figure 1.2: Typical plan of Underpass Box culverts

## 1.2 Summary of Design method

### 1.2.1 Typical design

- The typical design will be mentioned to box culvert on nominal section, box culvert placed on bearing layer enough strong compare with maximum factored stress at bottom of culvert.
- For box culvert on softsoil section will be considered individual.

### 1.2.2 Grouping

In Da Nang Quang Ngai Expressway development project have approximately 300 box culvert of two kind of: Cross drainage box culvert and Underpass culvert. The each culvert has difference of number of cell, the dimension, and covering height... The structural of culvert considered by design group depend below parameters and some special cases will be considered separately. The bearing capacity of soil at bottom of culvert will be considered in individual.

#### 1.2.2.1 Design group for Cross Drainage Box Culvert

The group are decided considering the following items:

- Cell Number of Box culvert.
- Dimension of Box culvert.
- Height of covering.

Table 1.3: Design group of Cross Drainage Box culverts

Group	Dimension			Group	Dimension		
	Width x Height W x H (m)	Covering (m)	Thickness (mm)		Width x Height W x H (m)	Covering (m)	Thickness (mm)
3	2.0 x 2.0	$0.6 > H$	250	9	2(2.0 x 2.0)	$0.6 > H$	250
		$0.6 \leq H < 4.5$	250			$0.6 \leq H < 4.5$	250
		$4.5 < H < 9.0$	300			$4.5 < H < 9.0$	300
4	2.5 x 2.5	$0.6 > H$	300	10	2(2.5 x 2.5)	$0.6 > H$	300
		$0.6 < H < 4.5$	300			$0.6 < H < 4.5$	300
		$4.5 < H < 9.0$	350			$4.5 < H < 9.0$	350
		$9.0 < H < 12.0$	400			$9.0 < H < 12.0$	400
6	3.0 x 3.0	$0.6 > H$	350	12	2(3.0 x 3.0)	$0.6 > H$	350
		$0.6 < H < 4.5$	350			$0.6 < H < 4.5$	350
		$4.5 < H < 9.0$	400			$4.5 < H < 9.0$	400
		$9.0 < H < 12.0$	450			$9.0 < H < 12.0$	450
		$H > 12.0$	450			$H > 12.0$	450

- $n$ : cell number of box culvert is 2 or more than.
- After the consideration of internal force in 2 cell box culvert and multiple cell box culvert are not so different, three cells culvert was design as two cell for safety.

#### 1.2.2.2 Design group for Underpass Culvert

The grouping was decided considering the following items:

- Cell number of underpass culvert.
- Dimension of Box culvert.
- Height of covering.
- Design live load of Cross road (Ex: 0.65HL93, 0.5 HL93...)

Table 1.4: Design group of Underpass Box culverts

Group	Dimension						Live load on cross road	
	Width (m)	Height (m)	Covering (m)	Member Thickness			Lane Number (lane)	Design Load
				Top slab (mm)	Bottom Slab (mm)	Web Slab (mm)		
1	3,0	3,0	$H < 0,6$	350	400	350	1	0.5 HL93
			$0.6 \leq H \leq 4.5$	350	400	350		
5	6.5	4.5	$H < 0,6$	550	600	585	1	0.65 HL93
			$0.6 \leq H \leq 4.5$	550	600	585		

The design live load applied to cross road is based on Memorandum of meeting between PMU85, F/S consultant and D/D consultant on August 27, 2012:

- The factor of axles weight on road of class V and below shall be applied the following coefficients in accordance with section 3.6.1.2.3 of 22 TCN 272-05.

+ Class V to Class B: 0.65.

+ Class C: 0.50.

### 1.2.3 Structural calculation and reinforced arrangement

- Typical structural will be calculated refer to above type of box culvert.
- For box culvert on softsoil section will be considered individual. If it didn't so much effect to internal force. The structural and reinforced arrangement would be applied to typical structural.

## 2 Design standard

- The box culvert structures shall be designed by the specified limit states in the Vietnamese Standards 22 TCN 272-05 – accordance to letter no DQEDD PMU 85-99-13 dated February 26<sup>th</sup> 2013.
- The reinforcing accordance to the standard TCVN1651 – 2008.

## 3 Design method

### 3.1 Limit states

The bridge structures shall be verified by the following limit states, and all of limit states shall be considered of equal importance:

- Strength limit state
- Service limit state

### 3.2 Load modifier factor $\eta$

Bridge Superstructure shall satisfy Eq.1 for each limit state, unless otherwise specified. For SERVICE and EXTREME EVENT limit states, resistance factors shall be taken as 1.0.

$$\sum \eta_i \gamma_i Q_i \leq \phi R_n = R_r \quad (\text{Eq.1})$$

$$\eta_D = 1.00 \text{ (for ductility).}$$

$$\eta_R = 1.00 \text{ (for redundancy).}$$

$$\eta_I = 1.00 \text{ (for operational Importance).}$$

### 3.3 Resistance Factor $\phi$

Resistance factor is shown bellow. For service and extreme event limit state, resistance factor  $\phi$  is 1.00.

Table3.1: Resistance Factor  $\phi$

Component	Flexure and Tension	Shear and Torsion	Compression with Spirals and Ties	Bearing and Compression in Strut and Tie models	For Anchorage Zones	
					Compression	Tension in Steel
Reinforced Concrete	0.90	0.90	0.75	0.70	0.80	1.00

\* For service and extreme event limit state,  $\phi=1.00$

\* Refer to Vietnamese “Specifications for Bridge Design 22TCN-272-05”

For compression members with flexure, the value of  $\phi$  may be increased linearly to the value for flexure as the factored axial load resistance,  $\phi P_n$ , decreases from  $0.10f'_c A_g$  to 0.

### 3.4 Load and Load Combinations:

#### 3.4.1 Load:

##### 3.4.1.1 Dead Load

Dead load of structural components and nonstructural attachments (DC) are calculated by use of the densities noted below:

Table3.2: The material density

No	Material	Density (kg/m <sup>3</sup> )	Unit Weight (kN/m <sup>3</sup> )
1	Plain Concrete	2400	23.5
2	Reinforced and Prestressed Concrete	2500	24.5
3	Asphalt Pavement	2250	22.0

\*The materials density based on 22TCN-272-05.

### 3.4.1.2 Live Load and Dynamic Load Allowance

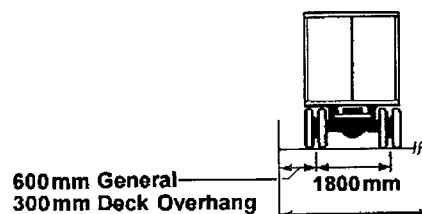
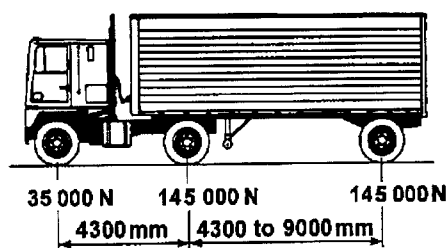
Live load and dynamic load allowance is based on Article 3.6.1 and 3.6.2 of 22TCN-272-05. The following requirements are adopted in the structural design of the culverts for drainage purposes:

- In case that the fill above the top of culvert is less than 0.60 m, the wheel load should be applied directly on the culvert (not a distributed load).
- In case that the fill above the top of culvert is more than 0.60 m, application of the wheel load on the culvert can be neglected.

#### ➤ Design Vehicular Live Load

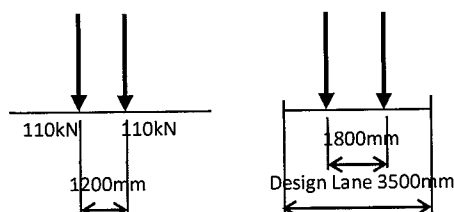
Vehicular live loading (HL-93) shall consist of a combination as followings:

- Design Truck
- Design Tandem
- Design Lane Load

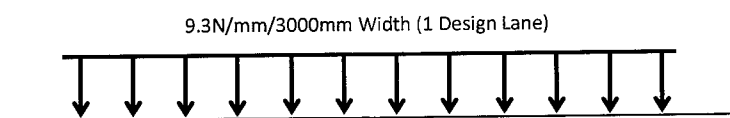


Note: For fatigue load, the distance between 145kN axles shall be constant of 9000mm

#### Design Truck



#### Design Tandem



#### Design Lane Load

The extreme force effect shall be taken the larger as followings:

- The effects of Design Tandem and Design Lane Load.
- The effects of Design Truck with variable axle spacing and Design Lane Load.

#### ➤ Dynamic Load Allowance: IM

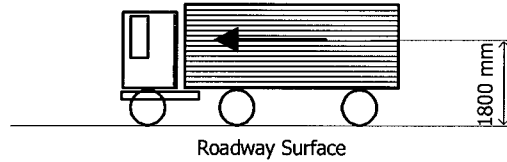
The dynamic load allowance for culverts in percent shall be taken as:

$$IM = 33(1 - 4.1 \times 10^{-4} D_E) \geq 0\%$$



### ➤ **Braking Force: BR**

The braking forces shall be taken as 25% of the axle weights of the design truck or tandem per lane placed in all design lanes which are carrying traffic headed in the same direction. Besides all design lanes shall be simultaneously loaded for bridges likely to become one-directional in the future.



These forces shall be assumed to act horizontally at a distance of 1800mm above the roadway surface in either longitudinal direction to cause extreme force effects. The multiple presence factors shall apply.

### 3.4.1.3 Water load and Stream pressure: WA

- Water pressure does not cause adverse effects to the structure so it will not be considered.

### 3.4.1.4 Earth pressure: EH

Earth pressure shall be assumed to be linearly proportional to the depth of earth and taken as.

$$P_h = K_a \cdot \gamma_s \cdot g \cdot Z \cdot 10^{-9} \quad (3.11.5.1-1)$$

In which:

$P_h$  : horizontal earth pressure at the depth of Z  
(N/mm<sup>2</sup>)

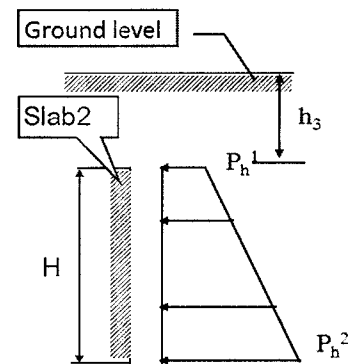
+ Lateral earth pressure applied on the plate as figure

$$P_h^1 = K_a \cdot \gamma_s \cdot g \cdot h_3 \cdot 10^{-9}$$

$$P_h^2 = K_a \cdot \gamma_s \cdot g \cdot (H + h_3) \cdot 10^{-9}$$

In which:

- $P_h$  : Horizontal earth pressure (N/mm)
- $K_a$  : active earth pressure coefficient
- $\gamma_s$  : Density of soil (kg/m<sup>3</sup>)
- $g$  : Gravitational acceleration (m/s<sup>2</sup>)
- $\varphi = 30^\circ$  : Angle of internal friction
- $h_3$  : filling height from top of box culvert (mm)
- $H$  : Total height of box culvert (mm)



### 3.4.1.5 Surcharge load: LS

Where a surcharge load is present, a constant horizontal earth pressure shall be added to the basic earth pressure. This constant earth pressure may be taken as

$$D_P = k \cdot \gamma_s \cdot g \cdot h_{eq} \cdot 10^{-9}$$

Where:

$D_P$  = constant horizontal earth pressure due to uniform surcharge load applied (Mpa)

$k$  = coefficient of earth pressure

$\gamma_s$  = density of soil (kg/m<sup>3</sup>)

$h_{eq}$  = height of soil equivalent to design truck (mm).

Wall height(mm)	heq (mm)
≤ 1500	1700
3000	1200
6000	760
≥ 9000	610

### 3.4.2 Load combination:

Table 3.3: Load combinations and Load factors

State	Mark	Str. I-A	Str. I-B	Str. I-C	Str. III-A	Str. III-B	Service I
Dead load of structural	DC	1.25	1.25	0.90	0.90	1.25	1.00
Dead load of wearing	DW	1.50	1.50	0.65	0.65	1.50	1.00
Vertical earth pressure	EV	1.30	1.30	0.90	0.90	1.30	1.00
Horizontal earth pressure	EH	1.50	0.90	1.50	1.50	1.50	1.00
Live load	LL	1.75	1.75	1.75	1.35	1.35	1.00
Live load surcharge	LS	1.75	1.75	1.75	1.35	1.35	1.00

Where :

DC- dead load of structural components and nonstructural attachments;

DW – Additional static load

LL - live load

IM - vehicular dynamic load allowance;

EV - Vertical earth pressure

EH - Horizontal earth pressure

### 3.5 Design principle for each Limit state

#### 3.5.1 Strength limit state

##### 3.5.1.1 Design flowchart for Strength limit state

Design flowchart for strength limit state is show below:

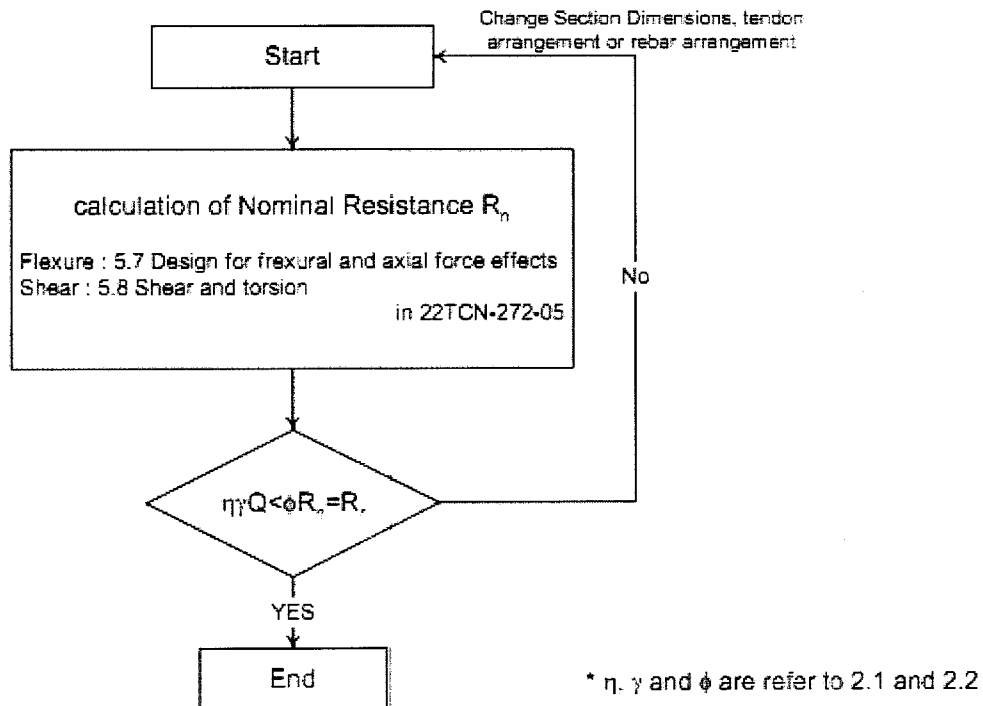


Figure 3.1: Design flowchart for Strength limit state

##### 3.5.1.2 Calculation formula for Flexural

The nominal flexural resistance:

$$M_n = A_{ps}f_{ps}\left(d_p - \frac{a}{2}\right) + A_s f_y \left(d_s - \frac{a}{2}\right) - A'_s f'_y \left(d_s - \frac{a}{2}\right) + 0.85f'_c(b - b_w)\beta_r h_r \left(\frac{a}{2} - \frac{h_r}{2}\right)$$

Where:

- $A_{ps}$  : area of prestressing steel (MM2)  
 $f_{ps}$  : average stress in prestressing steel at nominal bending resistance (MPa)  
 $d_p$  : distance from extreme compression fiber to the centroid of prestressing tendons (mm)  
 $A_s$  : area of nonprestressed tensile reinforcement (mm2)  
 $f_y$  : specified yield strength of reinforcing bar s (MPa)  
 $d_s$  : distance from extreme compression fiber to the centroid of nonprestressed tensile reinforcement (mm)  
 $A'_s$  : area of nonprestressed compression reinforcement (mm<sup>2</sup>)  
 $f'_y$  : specified yield strength of compression reinforcing bars (MPa)  
 $d'_s$  : distance from extreme compression fiber to the centroid of nonprestressed compression reinforcement (mm)  
 $f'_c$  : specified compressive strength of concrete at 28 days (MPa)  
 $b$  : width of the compression face of the member (mm)  
 $b_w$  : web width or diameter of a circular section (mm)  
 $\beta_1$  : stress block factor  
 $h_f$  : compression flange depth of an I or T member (mm)  
 $a$  :  $c.\beta_1$  ; depth of the equivalent stress block (mm)

### 3.5.1.3 Design flowchart for shear

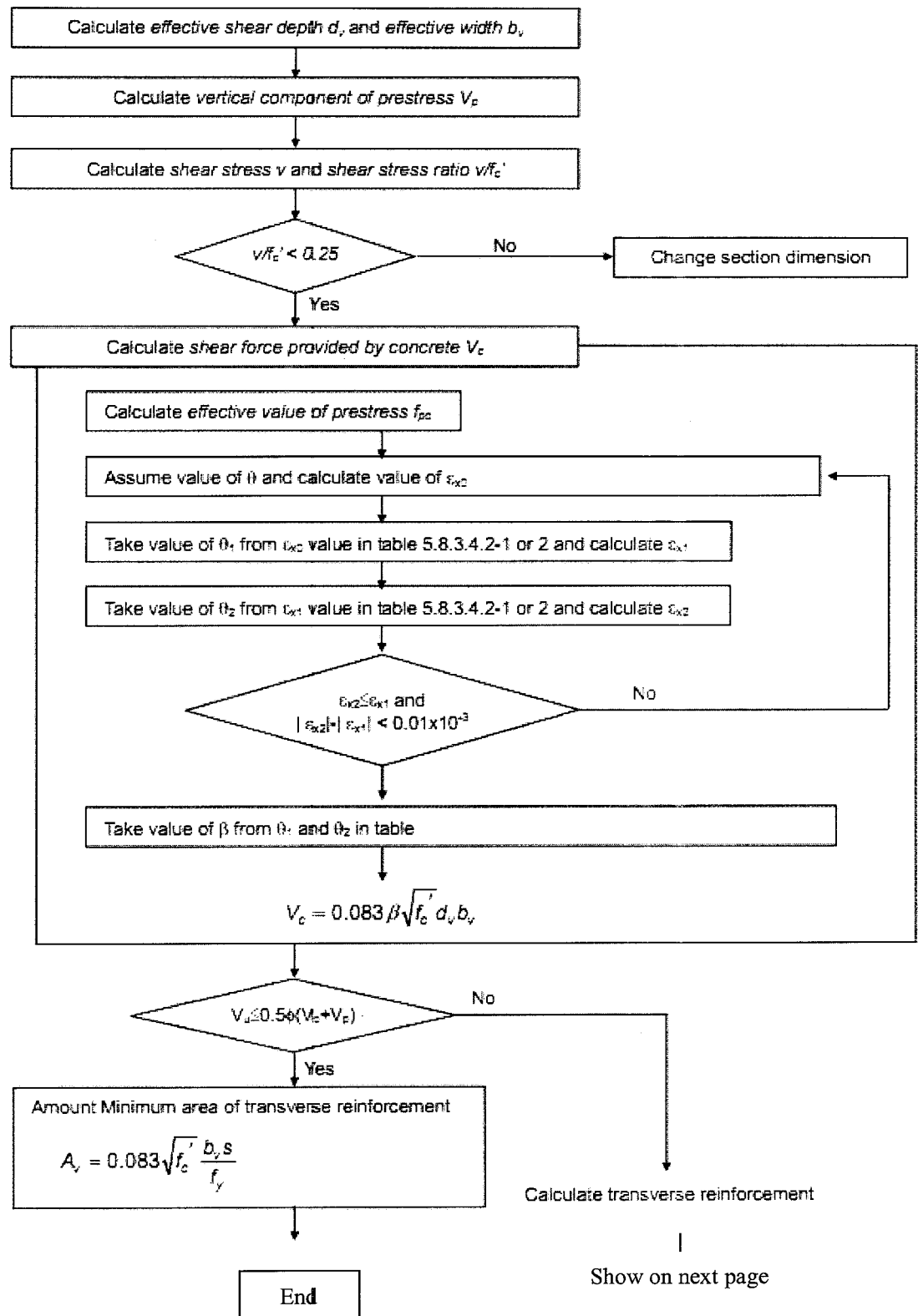


Figure 3.2: Design flowchart for shear (1/2)

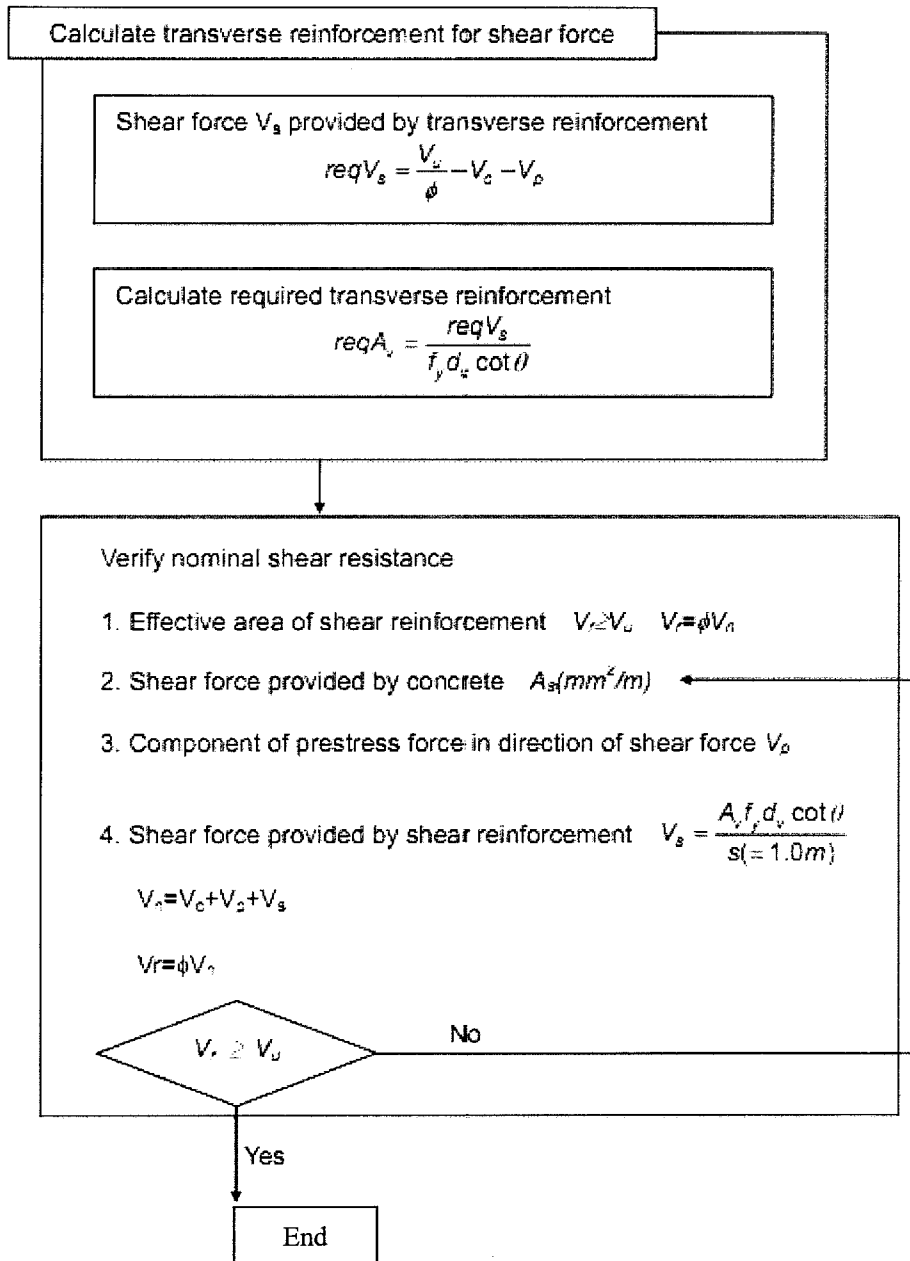


Figure 3.3: Design flowchart for shear (2/2)

### 3.5.2 Service limit state

#### 3.5.2.1 For RC component

##### a. Tensile stress limits for gross section

Table 4.5.2.1-1: Tensile stress limit for gross section

Condition	Limit tensile stress (Mpa)
Construction state	80% of $0.63 f'_{ci}{}^{0.5}$
Completion state	80% of $0.63 f'_c{}^{0.5}$

Where:

- +  $f_{ci}$ : is compression stress of concrete at time of calculation.
- +  $f_c$ : is compression stress of concrete at 28 days.

**b. Design follow chart at Service state**

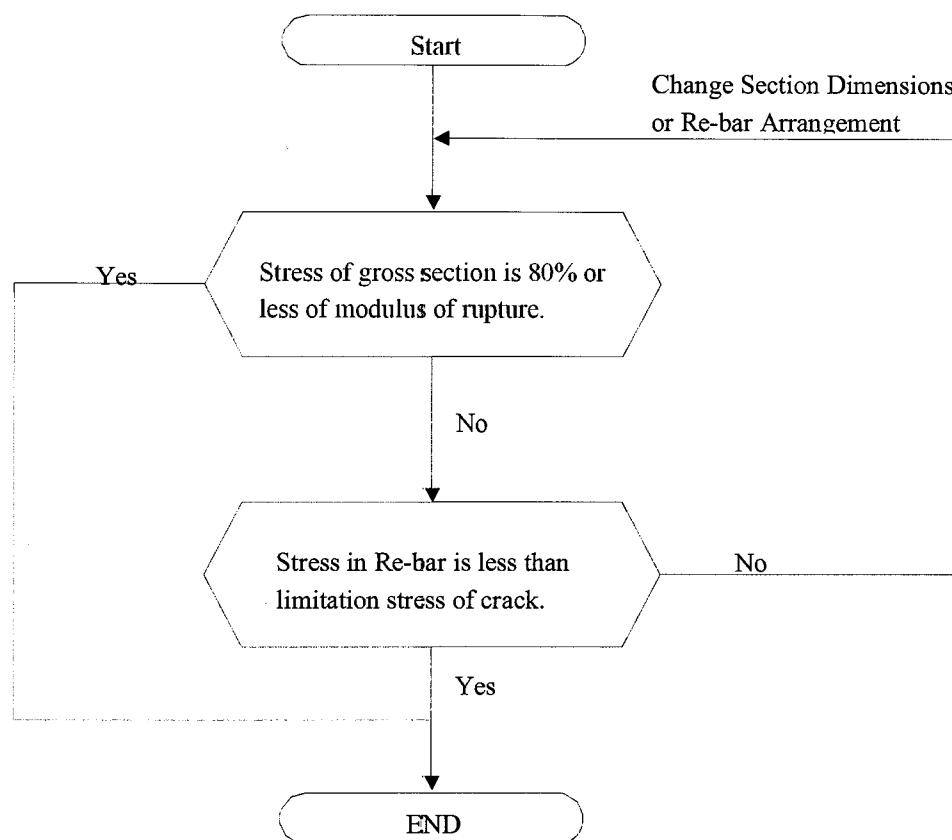


Figure 3.4: Design flowchart at Service state

**c. Crack control**

Components shall be so proportioned that the tensile stress in the mild steel reinforcement at the service limit state does not exceed  $f_{sa}$ , determined as 22TCN272-05 5.7.3.4-1:

$$f_s \leq \min( f_{sa} = \frac{Z}{(d_c A)^{1/3}} ; 0,6f_y)$$

Where:

$d_c$  = depth of concrete measured from extreme tension fiber to center of bar or wire located closest hereto; for calculation purposes, the thickness of clear cover used to compute  $d_c$  shall not be taken to be the greater than 50mm.

$A$  = Area of concrete having the same centroid as the principal tensile reinforcement and bounded by the surfaces of the cross section and a straight line parallel to the neutral axis, divided by the number of bars or wires ( $\text{mm}^2$ ); for calculation purposes, the thickness of clear concrete cover used to computed  $A$  shall not be taken to be greater than 50mm.

$Z$  = Crack width parameter (N/mm)

+  $Z = 17500(\text{N/mm})$  for buried structures.

## 4 Material Properties:

### 4.1 Concrete

Use of concrete grade of  $f'c=25\text{MPa}$  (Concrete Class :C25) is assumed for box culvert, wing wall in the design. Concrete strength,  $f'c$ , shall be based on the 28-day compressive strength of cylinder specimens.

Table 4.1 Concrete Properties

No	Item	Symbol	For Abutment, Pier, bored pile	Formula
1	Compressive Strength at 28 days	$f'c$	25 Mpa	
2	Modulus of Elasticity	$E_c$	26,875 MPa	$E_c=0.043\gamma_c^{1.5}(f'c)^{0.5}$
3	Modulus of Rupture	$f_r$	3.15MPa	$F_r=0.63(f'c)^{0.5}$
4	Coefficient of Thermal Expansion	$\alpha$	$10.8 \times 10^{-6}/\text{deg}$	
5	Poisson's Ratio	-	0.2	

\*The stress-strain curve was set up based on 22TCN-272-05.

### 4.2 Reinforcing Steel

- Reinforcement:
  - + The strength of reinforcement under the standard TCVN1651 - 2008
  - + Plain bar (CB300-T) :  $f_{sy} = 300 \text{ MPa}$ .
  - + Ribbed bar (CB400-V) :  $f_{sy} = 400 \text{ MPa}$
  - + Elastic modulus :  $E_s = 200000 \text{ MPa}$ .

## 5 Coefficient of subgrade reaction of bearing

The determine coefficient of subgrade reaction based on the "Principles of foundation engineering".

If a foundation of width B, is subjected to a load per unit area of q, it will undergo a settlement  $\Delta$ .

The coefficient of subgrade modulus can be defined as:  $k = q / \Delta$

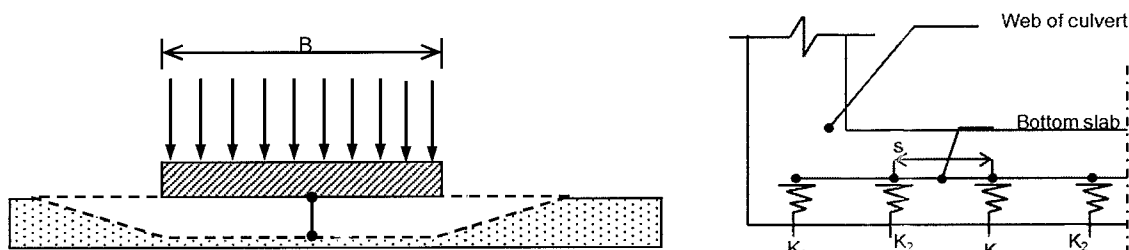


Figure 5.1: Model of coefficient of subgrade reaction

+ Square foundation:

For Foundation on sandy soils:

$$k_s = k_{0.3} ((B+0.3) / 2B)^2$$

For Foundation on Clays:

$$k_s = k_{0.3} (0.3 / B)$$

+ Rectangular foundation

$$k_r = k_s (1+0.5 B / L) / 1.5$$

Inwhich:

- $k_s$  : Coefficient of subgrade modulus of the square foundation BxB (m) (kN/m3).
- $k_r$  : Coefficient of subgrade modulus of the rectangular foundation LxB(m) (kN/m3).
- $k_{0.3}$  : Coefficient of subgrade modulus of foundation measuring 0.3x0.3(m) (kN/m3).

- B : The foundation width (m).
- L : Foundation length (m).

The value of  $k_{0.3}$  for Sand soil and Clays show on below table:

Sand soil					Clay		
	(Dry or moist)		Saturated				
Loose	8-25	MN/m <sup>3</sup>	10-15	MN/m <sup>3</sup>	Stiff	12-25	MN/m <sup>3</sup>
Medium	25-125	MN/m <sup>3</sup>	35-40	MN/m <sup>3</sup>	Very stiff	35-40	MN/m <sup>3</sup>
Dense	125-375	MN/m <sup>3</sup>	130-150	MN/m <sup>3</sup>	Hard	>50	MN/m <sup>3</sup>

#### + Coefficient of subgrade reaction

- L = Calculated length of culvert (m)
- B = Calculated width of culvert (m)
- $k_{0.3}$  = Coefficient of subgrade of foundation measuring 0.3x0.3(m)  $k_{0.3} = 25\text{MN/m}^3$

SN	Dimention	B (m)	L (m)	k <sub>03</sub> (MN/m³)	Sandy soil		Clay				
					k <sub>s</sub> (kN/m³)	k <sub>r</sub> (kN/m³)	k <sub>s</sub> (kN/m³)	k <sub>r</sub> (kN/m³)	s (m)	k <sub>1</sub> (kN/m³)	k <sub>2</sub> (kN/m³)
Cross drainage box culvert											
1	1x(2.0x2.0)	2,50	1,00	25,00	7840	7840	3000	4500	0,50	1960	3920
2	1x(2.5x2.5)	3,00	1,00	25,00	7563	7563	2500	4167	0,60	2269	4538
3	2x(2.0x2.0)	4,75	1,00	25,00	7064	7064	1579	3553	0,59	2097	4194
4	2x(2.5x2.5)	5,90	1,00	25,00	6902	6902	1271	3347	0,49	1697	3393
5	2x(3.0x3.0)	7,05	1,00	25,00	6793	6793	1064	3209	0,59	1996	3991
Underpass culvert											
1	3.0x3.0	3,70	1,00	25,00	7305	7305	2027	3851	0,46	1689	3378
2	6.5x4.5	7.6	1.00	25.00	6753	6753	987	1296	0.76	2566	5132

- In here Coefficient of subgrade of foundation  $k_{0.3}$  is 25 for medium sand and stiff clay.
- When the structure analysis, the coefficient of sand used to generate adverse effects for structural.
- Spring coefficient to input to software divided by s (m) follow below formular

$$K_1 = 0.5 \cdot k_r \cdot s \quad (\text{kN/m})$$

$$K_2 = k_r \cdot L \cdot s \quad (\text{kN/m})$$

## 6 Design result

### 6.1 Summary of Design results

Table 6.1: Summary of design results of drainage box culvert

SN	Station	Size (BxH) (m)	Angle (degree)	Covering (m)	Length (m)	Group	Covering group (m)	Bearing soil type
1	Km032+860.00	1-(2.5x2.5)	90	3.46	38.14	4	0.6-4.5	Nomal
2	Km036+894.00	2-(3.0x3.0)	90	2.92	35.98	12	0.6-4.5	Nomal
3	Km039+150.00	1-(2.0x2.0)	90	5.77	47.36	3	4.5-9.0	Nomal
4	Km041+107.26	1-(2.0x2.0)	90	7.70	69.09	3	4.5-9.0	Nomal
5	Km000+196.00	2-(2.0x2.0)	90	0.67	18.59	9	0.6-4.5	Nomal
6	Km041+460.00	1-(2.0x2.0)	90	4.68	43.82	2	4.5-9.0	Nomal
7	Km041+845.00	1-(2.0x2.0)	90	4.89	31.98	2	4.5-9.0	Nomal



Table 6.2: Summary of design results of Underpass culvert

SN	Underpass culverts			Dimension (m)				Design Group	Bearing soil type
	Station	Class	Live load Design	Width (m)	Height (m)	Length (m)	Covering (m)		
1	Km35+105.4	Rural C	0.5HL93	3.0	3.0	62.78	8.42	1	Nomal
2	Km37+628.2	Rural A	0.65HL93	6.5	4.5	25.88	0.50	5	Nomal
3	Km38+919.9	Rural A	0.65HL93	6.5	4.5	25.88	0.50	5	Nomal
4	Km40+468.4	Rural C	0.5HL93	3.0	3.0	42.03	1.26	1	Nomal

## 6.2 Bearing capacity

### 6.2.1 Soil parameters:

Some evaluations of geological conditions at box culvert location on PKG 5:

Most of the bearing layer at Box culvert location on PKG 5 are sand and sand with clay, SPT value from 6 to 23 blow/30cm.

Table 6.3: The soil properties at box culvert location of PKG 5

SN	Station	Dimension (m)				Covering	Bearing layer		
		Cell	Width	Height	Length (m)	(m)	Name	Soil type	SPT value
	Cross Drainage Box culverts								
1	Km032+860	1	2.5	2.5	38.14	3.46	3	SC	8
2	Km036+894	2	3.0	3.0	35.98	2.92	F		9
3	Km039+150	1	2.0	2.0	47.36	5.77	6	SC	9
4	Km041+107	1	2.0	2.0	69.09	7.70	2	SP	9
5	Km000+196	2	2.0	2.0	18.59	0.67	9	CL	27
6	Km041+460	1	2.0	2.0	43.82	4.68	11	SC-SM	31
7	Km041+845	1	2.0	2.0	31.98	4.89	8	SC	12
	Underpass Culvert								
1	Km035+105	1	3.0	3.0	62.78	8.42	8	SC	11
2	Km037+628	1	6.5	4.5	25.88	0.50	8	SC	17
3	Km038+920	1	6.5	4.5	25.88	0.50	9	SC	22
4	Km040+468	1	3.0	3.0	42.03	1.26	2	SP	16

In this table:

- SP : Poorly graded sand.
- SC : Sandy clay.
- CL : Low plasticity clay.
- SC-SM : Silty clayey sand.
- SW : Well graded sand.

### 6.2.2 Estimate bearing capacity formula

- Bearing resistance of soil will be estimated by theoretical method.
- Most of the bearing layer at Box culvert location on PKG 5 are sand and sand with clay.

The soil is loose and stiff, the soils are not enough strength to get undisturbed cores and don't have testing result for the unconfined compressive strength  $q_u$ . Therefore  $q_u$  value maybe estimated by SPT value.

- The bearing resistance of cohesionless soils:

$$Q_{ult1} = 0,5g\gamma B C_{w1} N_{\gamma m} 10^{-9} + g\gamma C_{w2} D_f N_{qm} 10^{-9}$$

In which

$D_f$	=	footing depth (mm)
$\gamma$	=	Density of soil (kg/m <sup>3</sup> )
$B$	=	Footing width (mm)
$C_{w1}, C_{w2}$	=	Coefficients as specified in table 1 as a function of $D_w$ (DIM)
$D_w$	=	Depth to water surface taken from the ground surface (mm)
$N_{gm}$	=	Modified bearing capacity factor (DIM)

Table 1: Coefficients  $C_{w1}$  and  $C_{w2}$  for various groundwater depths

$D_w$	$C_{w1}$	$C_{w2}$
0	0.50	0.50
$D_f$	0.50	1.00
$> 1.5B + D_f$	1.00	1.00

- The bearing capacity factors  $N_{\gamma m}$  and  $N_{qm}$  may be taken as:

$$N_{\gamma m} = N_{\gamma} s_{\gamma} c_{\gamma} i_{\gamma}$$

$$N_{qm} = N_q s_q c_q i_q d_q$$

In which

$N_{\gamma}$	=	Bearing capacity factor as specified in table 10.6.3.1.2c-2 for footings on relatively level ground (DIM)
$N_q$	=	Bearing capacity factor as specified in table 10.6.3.1.2c-2 for relatively level ground (DIM)
$s_q, s_{\gamma}$	=	Shape factors specified in tables 10.6.3.1.2c-3 & 4 respectively (DIM)
$c_q, c_{\gamma}$	=	Soil compressibility factors specified in table 10.6.3.1.2c-5 & 6 (DIM)
$i_q, i_{\gamma}$	=	Load inclination factors specified on table 10.6.3.1.2c-7 & 8 (DIM)
$d_q$	=	Depth factor specified in table 10.6.3.1.2c-9 (DIM)

The bearing resistance of saturated clays will be estimated by formula:

$$Q_{ult2} = c N_{cm} + g\gamma D_f N_{qm} 10^{-9}$$

In which:

The bearing capacity factors  $N_{cm}$  and  $N_{qm}$  may be taken as:

- For  $D_f/B \leq 2.5$ ,  $B/L \leq 1$  and  $H/V \leq 0.4$

$$N_{cm} = N_c [1 + 0,2D_f/B][1 + 0,2B/L][1 - 1,3H/V] \quad (10.6.3.1.2b-2)$$

- For  $D_f/B > 2.5$ , and  $H/V \leq 0.4$

$$N_{cm} = N_c [1 + 0,2B/L][1 - 1,3H/V] \quad (10.6.3.1.2b-3)$$

- $N_c$  = 5,0 for use in equation 2 on relatively level soil  
       = 7,5 for use in equation 2 on relatively level soil
- $N_{qm}$  = 1.0 for saturated clay and relatively level ground surface  
       = 0.0 for footing on sloping ground or adjacent to sloping ground
- $D_f$  = Footing depth (mm)
- $\gamma$  = Density of soil ( $\text{kg/m}^3$ )
- $c = S_u$  = undrained shear strength (Mpa)

In here the undrained shear strength of clay will be estimated from SPT value. Terzaghi and peck formula is used:

$$S_u = 0,5 q_u = 0,5.k.N.10^{-3} = 6.N.10^{-3}$$

+ The factor  $k = 12$

- $N$  = SPT value
- $S_u$  = undrained compression strength (Mpa)
- $q_u$  = drain compression strength (Mpa)

The result of bearing capacity of each culvert showed on Table 6.4.

### 6.2.3 Estimate maximum stress at bottom of culvert

Maximum stress at bottom of box culvert may be determined:

$$Q_{\max} = \Sigma V.(1+6*M/(V.B'))/(B'.L)$$

In which:

- $\Sigma V$  = Total vertical load applied to box culvert
- $M$  = The moment due to horizontal force of surcharge load.
- $B'$  = The effective width of box culvert  

$$B' = B - 2M/V$$
- $B$  = Width of box culvert
- $L$  = Length of culvert

The result of maximum stress of each culvert showed on Table 6.5.

TABLE 6.4: BEARING CAPACITY OF SOIL AT BOTTOM OF BOX CULVERT

SN	Station	Dimension (m)				1 Segment		Covering	L/B	H/V	SPT blow	s <sub>g</sub> (DIM)	C <sub>g</sub> (DIM)	i <sub>g</sub> (DIM)	s <sub>q</sub> (DIM)	c <sub>q</sub> (DIM)	i <sub>q</sub> (DIM)	N <sub>g</sub> (DIM)	N <sub>q</sub> (DIM)	N <sub>gm</sub> (DIM)	g (m/s <sup>2</sup> )	g (kg/m <sup>3</sup> )	Df (mm)	Cw1 (Dim)	Cw2 (Dim)	N <sub>c</sub>	N <sub>qm</sub>	c = S <sub>u</sub> (Mpa)	Q <sub>ult1</sub> (Mpa)	Q <sub>ult2</sub> (Mpa)		
		Cell	Width	Height	t	Width	Length (m)																								(m)	
Cross Drainage Box culverts																																
1	Km032+860.00	1	2.5	2.5	0.30	3.10	38.14	10.00	3.46	3.2	0.0	8	0.6	0.825	1	1.11	0.825	1	22	18	10.89	16.48	9.81	1800	500.0	0.5	0.50				0.222	
2	Km036+894.00	2	3.0	3.0	0.35	7.05	35.98	10.00	2.92	1.4	0.0	9	0.6	0.825	1	1.29	0.825	1	22	18	10.89	19.16	9.81	1800	450.0	0.5	0.50				0.415	
3	Km039+150.00	1	2.0	2.0	0.30	2.60	47.36	10.00	5.77	3.8	0.0	9	0.6	0.825	1	1.11	0.825	1	22	18	10.89	16.48	9.81	1800	650.0	0.5	0.50				0.220	
4	Km041+107.26	1	2.0	2.0	0.30	2.60	69.09	10.00	7.70	3.8	0.0	9	0.6	0.825	1	1.11	0.825	1	22	18	10.89	16.48	9.81	1800	650.0	0.5	0.50				0.220	
5	Km000+196.00	2	2.0	2.0	0.25	4.75	18.59	10.00	0.67	2.1	0.0	27	0.6	0.825	1	1.11	0.825	1	22	18	10.89	16.48	9.81	1800	550.0	0.5	0.50				0.308	
6	Km041+460.00	1	2.0	2.0	0.30	2.60	43.82	10.00	4.68	3.8	0.0	31	0.6	0.825	1	1.11	0.825	1	22	18	10.89	16.48	9.81	1800	550.0	0.5	0.50				0.205	
7	Km041+845.00	1	2.0	2.0	0.30	2.60	31.98	10.00	4.89	3.8	0.0	12	0.6	0.825	1	1.11	0.825	1	22	18	10.89	16.48	9.81	1800	550.0	0.5	0.50				0.205	
SN Underpass Culvert																																
1	Km035+105.44	1	3.0	3.0	0.35	3.70	62.78	10.00	8.42	2.7	0.023	11	0.6	0.825	1	1.11	0.825	1	22	18	10.89	16.48	9.81	1800	750.0	0.5	0.50				0.287	
2	Km037+628.21	1	6.5	4.5	0.55	7.60	25.88	10.00	0.50	1.3	0.059	17	0.6	0.825	0.73	1.29	0.825	0.81	22	18	7.95	15.52	9.81	1800	650.0	0.5	0.50				0.356	
3	Km038+919.86	1	6.5	4.5	0.55	7.60	25.88	10.00	0.50	1.3	0.036	22	0.6	0.825	1	1.29	0.825	1	22	18	10.89	19.16	9.81	1800	750.0	0.5	0.50				0.492	
4	Km040+468.40	1	3.0	3.0	0.35	3.70	42.03	10.00	1.26	2.7	0.035	16	0.6	0.825	1	1.11	0.825	1	22	18	10.89	16.48	9.81	1800	750.0	0.5	0.50				0.287	

Table 6.5: Maximum stress at bottom of culvert and compare with bearing capacity

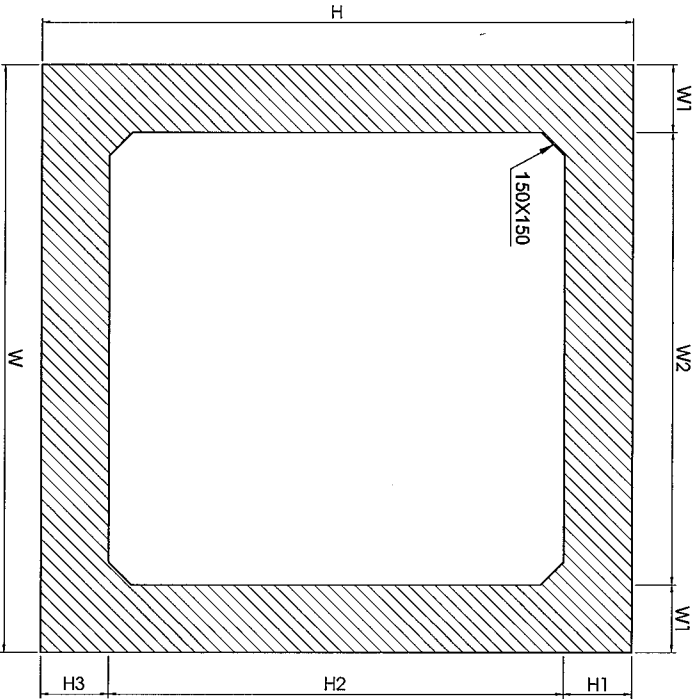
SN	Station	Dimension (m)				Covering $\gamma$ (Kg/m <sup>3</sup> )	DC	DW	EV	LL	$\Sigma V$ (Kn)	$\Sigma H$ (Kn)	$\Sigma M$ (Kn.m)	B' (m)	Qmax (Mpa)	Qult (Mpa)	Check $Q_{ult} \geq Q_{max}$	
		Cell	Width	Height	Thick													Length (m)
Gross Drainage Box culverts																		
1	Km032+860.00	1	2.5	2.5	0.30	38.14	3.46	1800	17525.3	378.9	6817.8	24721.9		2.50	0.259	0.222	NG	
2	Km036+894.00	2	3.0	3.0	0.35	35.98	2.92	1800	11.6	909.0	13345.7	14266.3		6.00	0.066	0.415	OK	
3	Km039+150.00	1	2.0	2.0	0.30	47.36	5.77	1800	8.7	303.1	10393.1	10704.9		2.00	0.113	0.220	OK	
4	Km041+107.26	1	2.0	2.0	0.30	69.09	7.70	1800	12.7	303.1	15314.8	15630.6		2.00	0.113	0.220	OK	
5	Km000+196.00	2	2.0	2.0	0.25	18.59	0.67	1800	2.8	606.0	1748.4	2357.2		4.00	0.032	0.308	OK	
6	Km041+460.00	1	2.0	2.0	0.30	43.82	4.68	1800	8.1	303.1	7933.6	8244.8		2.00	0.094	0.205	OK	
7	Km041+845.00	1	2.0	2.0	0.30	31.98	4.89	1800	5.9	303.1	8389.5	8698.5		2.00	0.136	0.205	OK	
Underpass Culvert																		
1	Km035+105.44	1	3.0	3.0	0.35	62.78	8.42	1800	11996.3	454.5	25973.5	43810.6	1007.8	2.93	0.255	0.287	OK	
2	Km037+628.21	1	6.5	4.5	0.55	25.88	0.50	1800	3717.2	984.7	2093.2	11434.3	678.0	6.23	0.080	0.356	OK	
3	Km038+919.86	1	6.5	4.5	0.55	25.88	0.50	1800	6348.0	984.7	2093.2	15150.2	549.8	6.34	0.100	0.492	OK	
4	Km040+468.40	1	3.0	3.0	0.35	42.03	1.26	1800	10310.0	454.5	2565.4	19229.2	674.7	2.90	0.175	0.287	OK	

- In which Qmax: is maximum stress at bottom of each box culvert

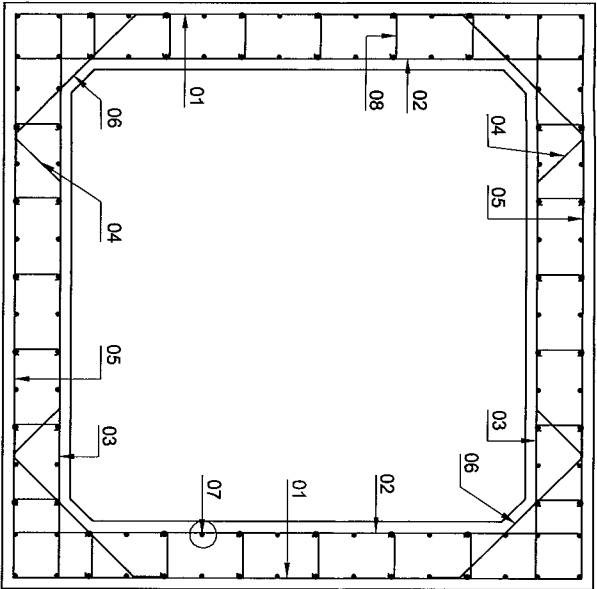
### **6.3. Summary of Reinforced arrangement**

DETAIL REINFORCEMENT OF BOX CULVERT  
CHI TIẾT CỐT THÉP CÔNG HỘP

GENERAL DIMENSION  
KÍCH THƯỚC CHUNG



ARRANGEMENT OF REINFORCEMENT  
BỐ TRÍ CỐT THÉP



NOTES:  
1. MATERIALS OF BOX CULVERT, MINGWALL, SHALL  
BE USED LIST BELOW:

CONCRETE	CLASS C25
REINFORCEMENT	CB-400-V

GHI CHÚ:

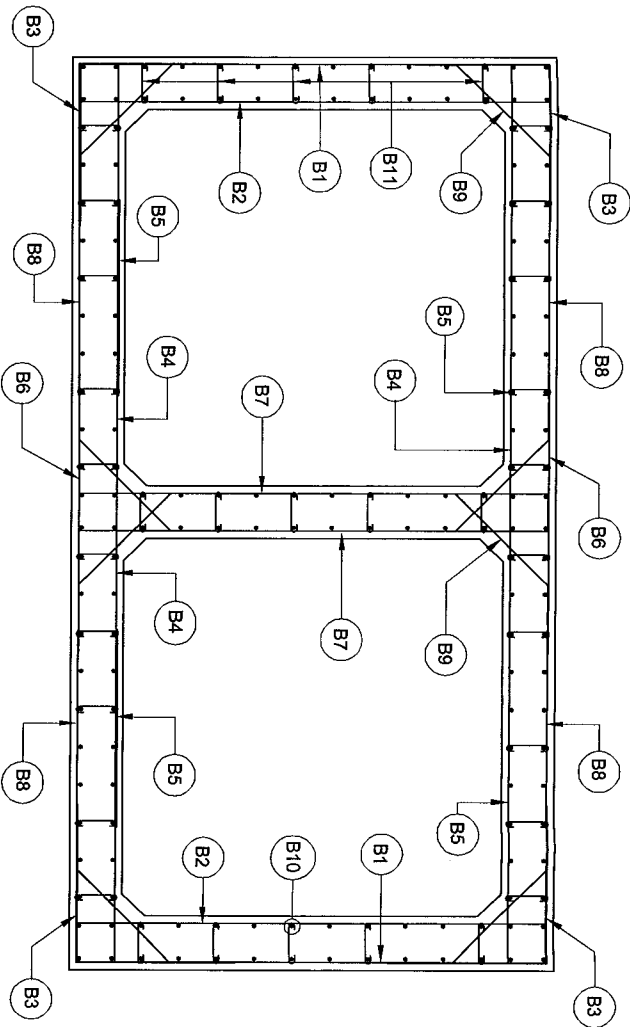
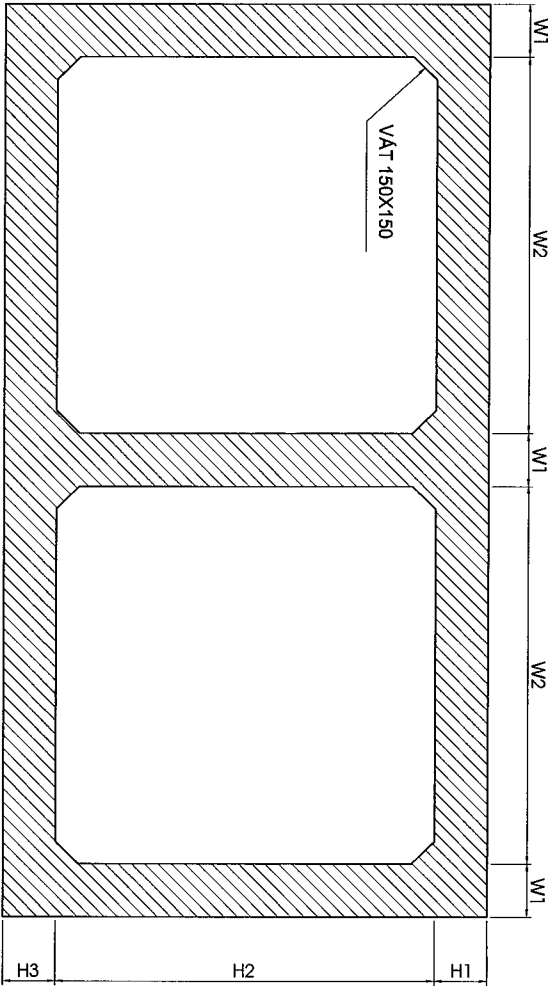
1. THÂN CÔNG, TƯỜNG CẢNH CÔNG  
ĐƯỢC THIẾT KẾ VỚI VẬT LIỆU NHƯ SAU:

BÊ TÔNG	MÁC C25
THÉP	CB-400-V

Group	Dimension										Reinforcement arrangement for Box Culvert with 1 span															
	W		H	Covering (m)	W <sub>1</sub> (mm)	H <sub>1</sub> (mm)	H <sub>2</sub> (mm)	Bar 01		Bar 02		Bar 03		Bar 04		Bar 05		Bar 06		Bar 07		Bar 08				
	(m)	(m)						D (mm)	@ (mm)	D (mm)	@ (mm)	D (mm)	@ (mm)	D (mm)	@ (mm)	D (mm)	@ (mm)	D (mm)	@ (mm)	D (mm)	@ (mm)					
				(m)	(mm)	(mm)	(mm)	D (mm)	@ (mm)	D (mm)	@ (mm)	D (mm)	@ (mm)	D (mm)	@ (mm)	D (mm)	@ (mm)	D (mm)	@ (mm)	D (mm)	@ (mm)	D (mm)	@ (mm)			
1	1.5	1.5	0.6 < H < 4.5	220	220	220	220	D 16	300	D 16	300	D 16	300	D 16	300	D 16	300	D 14	300	D 12	250	D 10	500			
			4.5 < H < 9.0	250	250	250	250	D 16	250	D 16	250	D 16	250	D 16	250	D 14	250	D 12	250	D 10	500					
			0.6 < H < 4.5	220	220	220	220	D 16	250	D 16	250	D 16	250	D 16	250	D 14	250	D 12	250	D 10	500					
2	2.0	1.5	4.5 < H ≤ 9.0	250	250	250	250	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 14	200	D 12	250	D 10	500			
			0.6 < H < 4.5	250	250	250	250	D 16	250	D 16	250	D 16	250	D 16	250	D 14	250	D 12	250	D 10	500					
			4.5 < H ≤ 9.0	300	300	300	300	D 16	200	D 16	200	D 16	200	D 16	200	D 14	200	D 12	250	D 10	500					
3	2.0	2.0	0.6 < H < 4.5	300	300	300	300	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 14	250	D 12	250	D 10	500			
			4.5 < H ≤ 9.0	350	350	350	350	D 16	200	D 16	200	D 16	200	D 16	200	D 14	200	D 12	250	D 10	500					
			9.0 < H ≤ 12.0	400	400	400	400	D 16	200	D 16	200	D 16	200	D 16	200	D 14	200	D 12	250	D 10	500					
4	2.5	2.5	0.6 < H < 4.5	300	300	300	300	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 14	250	D 12	250	D 10	500			
			4.5 < H ≤ 9.0	350	350	350	350	D 16	200	D 16	200	D 16	200	D 16	200	D 14	200	D 12	250	D 10	500					
			9.0 < H ≤ 12.0	400	400	400	400	D 16	200	D 16	200	D 16	200	D 16	200	D 14	200	D 12	250	D 10	500					
5	3.0	2.0	0.6 < H < 4.5	300	300	300	300	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 14	250	D 12	250	D 10	500			
			4.5 < H ≤ 9.0	350	350	350	350	D 16	200	D 16	200	D 16	200	D 16	200	D 14	200	D 12	250	D 10	500					
			0.6 < H < 4.5	350	350	350	350	D 16	250	D 16	250	D 16	250	D 16	250	D 14	250	D 12	250	D 10	500					
6	3.0	3.0	4.5 < H ≤ 9.0	400	400	400	400	D 18	250	D 18	250	D 18	250	D 18	250	D 18	250	D 16	250	D 14	250	D 10	500			
			9.0 < H ≤ 12.0	450	450	450	450	D 18	200	D 18	200	D 18	200	D 18	200	D 16	200	D 14	250	D 10	500					
			H > 12.0	450	450	450	450	D 18	200	D 18	200	D 20	200	D 20	200	D 18	200	D 14	250	D 10	500					

MINISTRY OF TRANSPORT VIETNAM				ENGINEERING DESIGN CONSULTANT				REMARKS:			
CLIENT		PROJECT MANAGEMENT CONSULTANT		The Joint Venture of Nippon Koei Co., Ltd. Nippon Engineering Consultants Co., Ltd. Chodai Co., Ltd. Thai Engineering Consultants Co., Ltd.							
VIETNAM EXPRESSWAY CORPORATION		PROJECT MANAGEMENT UNIT NO.85									
DA NANG-QUANG NGAI EXPRESSWAY DEVELOPMENT PROJECT								REINFORCEMENT DETAIL OF BOX CULVERT			
Package: 7								Station: KM52+000 -> KM65+000			
NAME		PREPARED BY		CHECKED BY		APPROVED BY		BỐ TRÍ CỐT THÉP CÔNG HỘP			
SIGNATURE		NGUYENXUAN DAT		MACHIRA C.		TAKI, ISHIKOTO		DRAWING NO.			
DATE		17/08		17/08		17/08		REV. NO.			
AS SHOWN								PKG7/DR-ML-BC			

DETAIL REINFORCEMENT OF BOX CULVERT  
CHI TIẾT CỐT THÉP CÔNG HỘP



NOTES:  
1. MATERIALS OF BOX CULVERT, WINGWALL,  
SHALL BE USED LIST BELOW:

CONCRETE	CLASS C25
REINFORCEMENT	CB-400-V

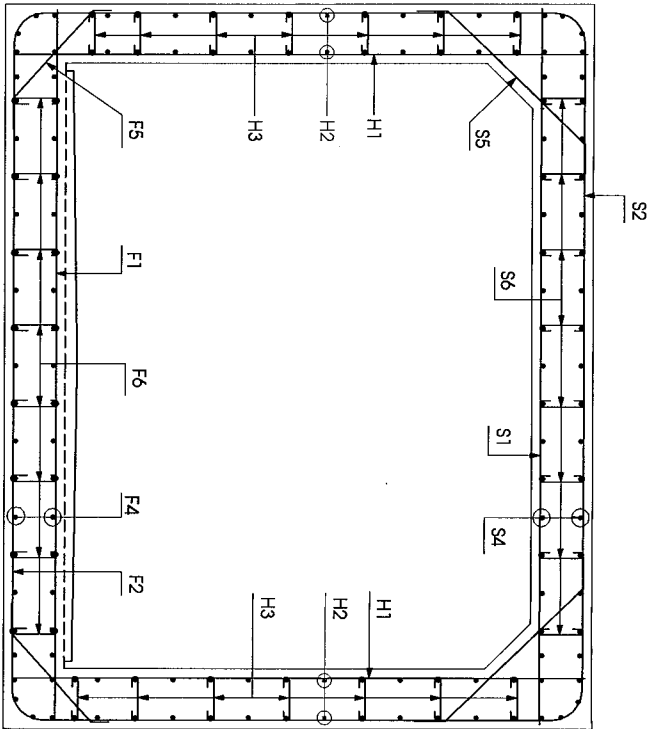
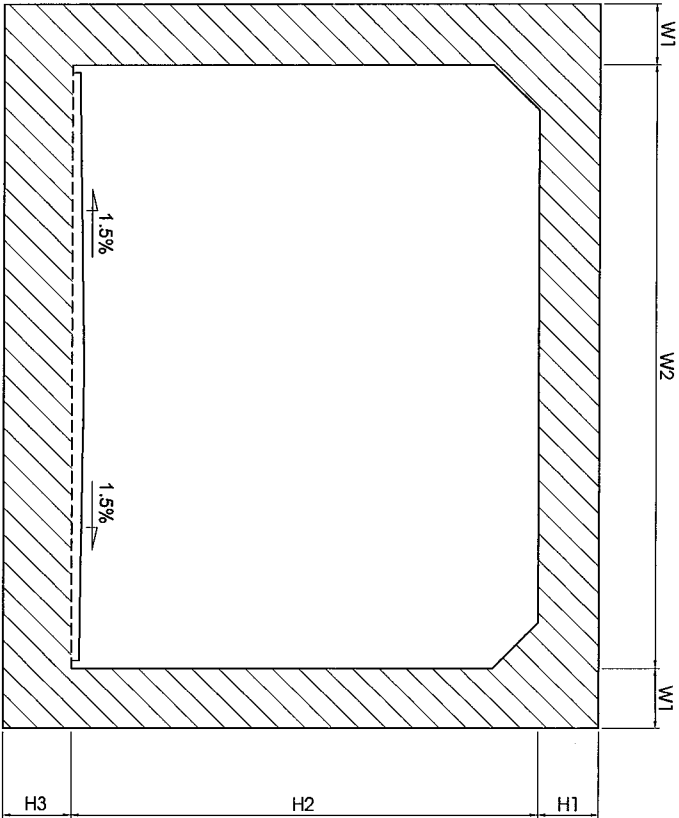
GHI CHÚ:  
1. THÂN CÔNG, TƯỜNG CẠNH CÔNG  
ĐƯỢC THIẾT KẾ VỚI VẬT LIỆU NHƯ SAU:

BÊ TÔNG	MÁC C25
THÉP	CB-400-V

Group	Dimension											Reinforcement arrangement for Box Culvert with 2 spans and more																					
	W		H	Covering (mm)	W <sub>1</sub> (mm)	H <sub>1</sub> (mm)	H <sub>3</sub> (mm)	Bar 01		Bar 02		Bar 03		Bar 04		Bar 05		Bar 06		Bar 07		Bar 08		Bar 09		Bar 10		Bar 11					
	(m)	(m)						D	@	D	@	D	@	D	@	D	@	D	@	D	@	D	@	D	@	D	@	D	@	D	@	D	@
7	1.5	1.5	0.6 < H < 4.5	220	220	220	D 16	300	D 16	300	D 16	300	D 16	300	D 16	300	D 16	300	D 16	150	D 14	300	D 14	300	D 14	300	D 12	250	D 10	500			
			4.5 < H ≤ 9.0	250	250	250	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 18	125	D 14	250	D 16	250	D 14	250	D 12	250	D 10	500			
			0.6 < H < 4.5	220	220	220	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 18	125	D 14	250	D 14	250	D 14	250	D 12	250	D 10	500			
8	2.0	1.5	4.5 < H ≤ 9.0	250	250	250	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 16	100	D 14	200	D 14	200	D 14	200	D 12	250	D 10	500			
			0.6 < H < 4.5	250	250	250	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 18	125	D 14	250	D 14	250	D 14	250	D 12	250	D 10	500			
			4.5 < H ≤ 9.0	300	300	300	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 18	100	D 14	200	D 14	200	D 14	200	D 12	250	D 10	500			
9	2.0	2.0	0.6 < H < 4.5	300	300	300	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 16	100	D 14	250	D 14	250	D 14	250	D 12	250	D 10	500			
			4.5 < H ≤ 9.0	350	350	350	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 18	125	D 14	250	D 14	250	D 14	250	D 12	250	D 10	500			
			0.6 < H < 4.5	300	300	300	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 18	125	D 14	250	D 14	250	D 14	250	D 12	250	D 10	500			
10	2.5	2.5	0.6 < H < 4.5	350	350	350	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 16	100	D 14	200	D 14	200	D 14	200	D 12	250	D 10	500			
			4.5 < H ≤ 9.0	400	400	400	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 18	100	D 14	200	D 14	200	D 14	200	D 12	250	D 10	500			
			9.0 < H ≤ 12.0	300	300	300	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 18	125	D 14	250	D 16	250	D 16	250	D 12	250	D 10	500			
11	3.0	2.0	0.6 < H < 4.5	350	350	350	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 16	100	D 14	200	D 14	200	D 14	200	D 12	250	D 10	500			
			4.5 < H ≤ 9.0	400	400	400	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 16	200	D 18	100	D 14	200	D 14	200	D 14	200	D 12	250	D 10	500			
			0.6 < H < 4.5	360	360	360	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 16	250	D 18	125	D 14	250	D 16	250	D 16	250	D 12	250	D 10	500			
12	3.0	3.0	4.5 < H ≤ 9.0	400	400	400	D 18	250	D 18	250	D 18	250	D 18	250	D 18	250	D 18	250	D 18	125	D 16	250	D 16	250	D 16	250	D 12	250	D 10	500			
			9.0 < H ≤ 12.0	450	450	450	D 18	200	D 18	200	D 18	200	D 18	200	D 18	200	D 18	200	D 18	100	D 16	200	D 16	200	D 16	200	D 12	250	D 10	500			
			H > 12.0	450	450	450	D 18	200	D 18	200	D 18	200	D 18	200	D 18	200	D 18	200	D 18	100	D 16	200	D 16	200	D 16	200	D 12	250	D 10	500			
14	4.0	4.0	0.6 < H < 4.5	400	400	400	D 18	200	D 18	200	D 18	200	D 18	200	D 18	200	D 18	200	D 18	100	D 16	200	D 16	200	D 16	200	D 12	250	D 10	500			



DETAIL REINFORCEMENT OF BOX CULVERT  
CHI TIẾT CỐT THÉP CÔNG HỘP



NOTES:  
1. MATERIALS OF BOX CULVERT, MINGWALL,  
SHALL BE USED LIST BELOW:

CONCRETE	CLASS C25
REINFORCEMENT	CB-400-V

GHI CHÚ:

1. THÀNH CÔNG, TƯỜNG CẠNH CÔNG  
ĐƯỢC THIẾT KẾ VỚI VẬT LIỆU NHƯ SAU:

BÊ TÔNG	MẠC C25
THÉP	CB-400-V

Group	Dimension					Reinforcement arrangement of Underpass Culvert																														
						Bar S1		Bar S2		Bar S3		Bar S4		Bar S5		Bar S6		Bar H1		Bar H2		Bar H3		Bar F1		Bar F2		Bar F3		Bar F4		Bar F5		Bar F6		
	WIDTH	HEIGHT	Covering	W <sub>1</sub>	H <sub>1</sub>	D	⌀	D	⌀	D	⌀	D	⌀	D	⌀	D	⌀	D	⌀	D	⌀	D	⌀	D	⌀	D	⌀	D	⌀	D	⌀	D	⌀	D	⌀	
	W(m)	H (m)	(m)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	
1	3.0	3.0	0.6 < H < 4.5	350	350	400	D 18	125	D 18	250	D 18	250	D 14	250	D 14	250	D 10	500	D 18	250	D 14	250	D 10	500	D 18	125	D 18	250	D 18	250	D 14	250	D 14	250	D 10	500
2	3.0	3.0	4.5 < H < 9.0	350	350	400	D 18	125	D 18	250	D 18	250	D 14	250	D 14	250	D 10	500	D 18	250	D 14	250	D 10	500	D 18	125	D 18	250	D 18	250	D 14	250	D 14	250	D 10	500
5	6.5	4.5	H < 0.6	550	550	600	D 22	125	D 22	250	D 22	250	D 14	250	D 16	250	D 10	500	D 22	250	D 14	250	D 10	500	D 25	125	D 22	250	D 22	250	D 14	250	D 16	250	D 10	500

MINISTRY OF TRANSPORT VIETNAM		ENGINEERING DESIGN CONSULTANT		REMARKS:	DA NANG-QUANG NGAI EXPRESSWAY DEVELOPMENT PROJECT Station: KM52+000 -:: KM65+000 Package: 7											
CLIENT	PROJECT MANAGEMENT CONSULTANT	The Joint Venture of Nippon Koei Co., Ltd. Nippon Engineering Consultants Co., Ltd. Chodal Co., Ltd. Thai Engineering Consultants Co., Ltd.			REINFORCEMENT DETAIL OF BOX CULVERT BỘ TRƯ CỐT THÉP CÔNG HỘP											
VIETNAM EXPRESSWAY CORPORATION	PROJECT MAANGEMENT UNIT NO.85				PREPARED BY		CHECKED BY		APPROVED BY		SCALE		AS SHOWN			
		NAME			NGUYEN XUANDAT		VACHIRA.C.		I. ISHIMOTO							
		SIGNATURE														
		DATE														

## **6.4. Calculation sheet for each type of Box culverts**

## Calculation sheet for each type of Drainage Box culverts

List of calculation sheet

SN	Group	Dimention (m)			Covering	Page
		Cell	Width	Height		
1	3	1 ( 2.00 x 2.00 )			$h < 0.6$	
2					$0.6 \leq h \leq 4.5$	
3					$4.5 < h \leq 9.0$	23
4	4	1 ( 2.50 x 2.50 )			$h < 0.6$	
5					$0.6 \leq h \leq 4.5$	32
6					$4.5 < h \leq 9.0$	
7					$9.0 < h \leq 12.0$	
8	9	2 ( 2.0 x 2.0 )			$h < 0.6$	
9					$0.6 \leq h \leq 4.5$	41
10					$4.5 < h \leq 9.0$	
11					$9.0 < h \leq 12.0$	
12	12	2 ( 3.00 x 3.00 )			$h < 0.6$	
13					$0.6 \leq h \leq 4.5$	50
14					$4.5 < h \leq 9.0$	
15					$9.0 < h \leq 12.0$	
16					$12.0 < h$	

## BOX CULVERT CALCULATION SHEET

### 1. General

- Group : 3
- Dimension : 1x(2,0x2,0) m
- Covering height :  $4,5 \leq H \leq 9,0$  m
- Live load : HL93
- Design standard: 22TCN-272-05
- Unit : KN and m, N and mm

### 2. Material property

#### 2.1. Concrete

- Compressive strength of cylindrical at 28 days:  $f'_c = 25$  MPa
- Concrete density  $\gamma_c = 24.5$  KN/m<sup>3</sup>
- Elastic modulus  $E_c = 0.043 \cdot \gamma_c^{1.5} \cdot \sqrt{f'_c} = 26875$  N/mm<sup>2</sup>
- Tensile strength of concrete:  $f_r = 0.63 \cdot \sqrt{f'_c} = 3.15$  N/mm<sup>2</sup>

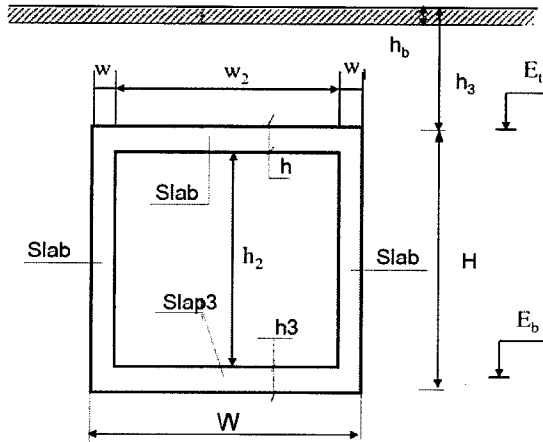
#### 2.2. Steel

- Elastic module of steel :  $E_s = 200000$  N/mm<sup>2</sup>
- Liquid limit:  $f_y = 400$  N/mm<sup>2</sup>

#### 2.2. Pavement and backfill

- Thickness of Asphalt pavement  $t = 0.16$  m
- Elastic module of ground soil  $E_o = 7840$  KN/m<sup>2</sup>
- Unit weight of soil  $\gamma_s = 17.66$  KN/m<sup>3</sup>
- Seftweight of Pavement  $\gamma_{as} = 22$  KN/m<sup>3</sup>
- Intenal friction angle of soil  $\phi'_r = 30$  deg
- Friction angle between soil and wall  $\delta = 0$  deg

### 3. Dimention of Box culvert



BOX CULVERT DIMENSION			
Item	Unit	Symbol	Value
Thickness of slab 1	m	$h_1$	0.300
Thickness of slab 2	m	$w_1$	0.300
Thickness of slab 3	m	$h_3$	0.300
Height of box culvert	m	$H$	2.600
Height of box culvert	m	$h_2$	2.000
Height of pavement structure	m	$h_b$	0.160
Height of backfilling on top of culvert	m	$h_3$	4,5 ~ 9,0
Span length	m	$w_2$	2.000
Culvert width	m	$W$	2.600

## 4. Loading

### 4.1. Deadload

- Deadload of box culvert (DC) will be automatic calculate by Midas program with selfweight of concrete is:  $\gamma_c = 24.5 \text{ (Mpa)}$
- Deadload of pavement (DW) will be automatic calculate by Midas program with selfweight of pavement is:  $\gamma_{as} = 22 \text{ (Mpa)}$

### 4.2. Live load

- Where the depth of fill is less than 600mm, the effect of fill on the distribution of live load shall be neglected.
- The uniformly distribution of wheel where covering depth  $\geq 600 \text{ mm}$  determined follow A 3.6.1.2.6.
- Impact load determined follow A 3.6.2.2.
- Where the depth of fill exceeds 600 mm, wheel loads may be considered to be uniformly distributed over rectangular area with sides equal to the dimension of the tire contact area as A 3.6.1.2.5, and increased by either 1.15 times the depth of the fill in select granular backfill, or the depth of the fill in all other cases.
- For single span culverts, the effects of live load may be neglected where the depth of fill is  $\geq 2400\text{mm}$  and exceeds the span length.
- For multiple span culverts, the effects of live load may be neglected where the depth of fill exceeds the distance between faces of end walls.
- Where such areas from several wheels overlap, the total load shall be uniformly distributed over the area.
- The dynamic load allowance for culverts shall be taken as:

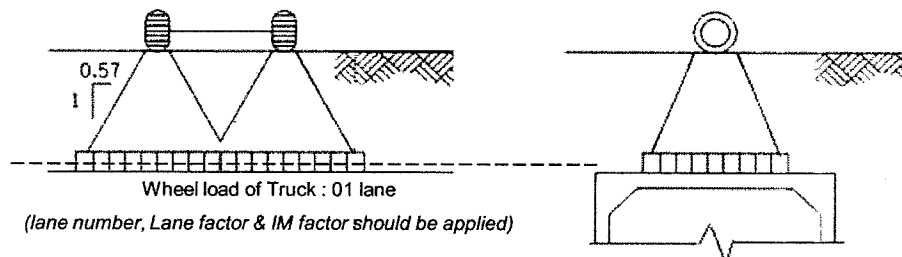
$$IM = 33 * (1.0 - 4.1 \times 10^{-4} \cdot De) \quad (3.6.2.2.1)$$

#### • Design truck:

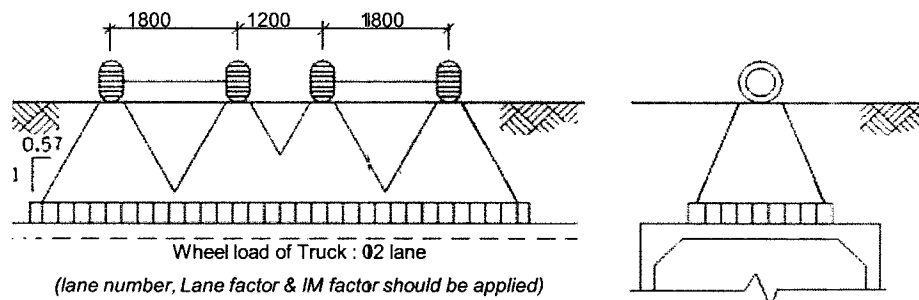
- Estimate for impact factor and distributed area of wheel

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
4.5	145	0.00	510	289	5685	5464
9	145	0.00	510	289	10860	10639

Distribution of wheel load for 1 lane



Distribution of wheel load for 2 lane



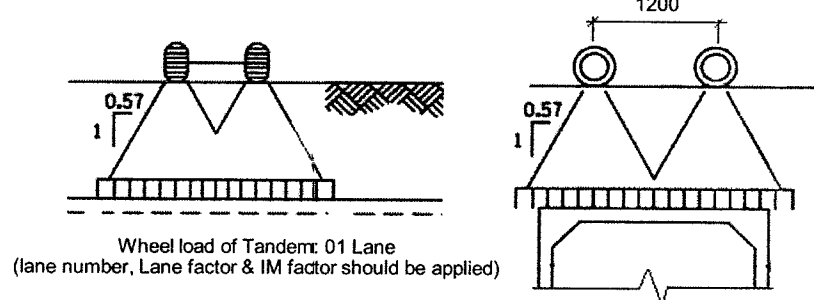
Distributed wheel load of truck

Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>truck -1 lane</sub> (Kn/m)	LL <sub>truck -2 lane</sub> (Kn/m)
4.5	145	5685	5464	3.97	3.97
9	145	10860	10639	1.56	1.56

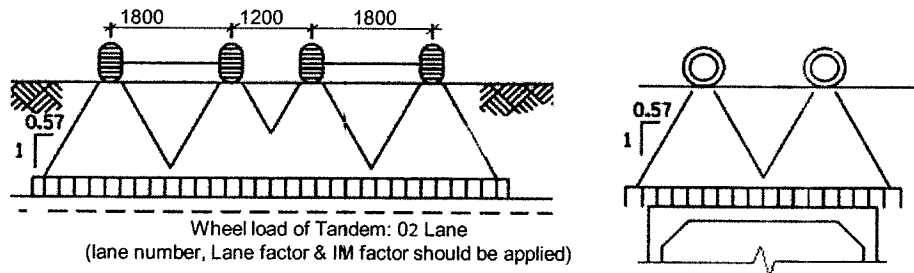
• **Tandem:**

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
4.5	110	0.00	510	219	5685	5394
9	110	0.00	510	219	10860	10569

Distribution of wheel load of Tandem for 1 lane



Distribution of wheel load of Tandem for 2 lane



Distributed wheel load of Tandem

Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>tandem -1 lane</sub> (Kn/m)	LL <sub>tandem -2 lane</sub> (Kn/m)
4.5	145	5685	5394	3.03	4.85
9	145	10860	10569	1.17	1.55

- Design live load applied to structure:  $\text{Max(LL)} = 4.85$  (Kn/m) with covering depth 4.5 m  
 $= 0.00$  (Kn/m) with covering depth 9 m

• **Lane load**

- Lane load distributed on 1 m  $= 3.10$  kN/m

**4.2.1. Surcharge load (LS)**

-Where a surcharge load is present, a constant horizontal earth pressure shall be added to the basic earth pressure.

This constant earth pressure may be taken as

$$D_p = k \cdot \gamma_s \cdot g \cdot h_{eq} (\times 10^{-3}) \quad (3.11.6.1-1)$$

Where:

- $D_p$  = constant horizontal earth pressure due to uniform surcharge load applied (Mpa)
- $k$  = coefficient of earth pressure
- $\gamma_s$  = density of soil (kg/m<sup>3</sup>)
- $h_{eq}$  = height of soil equivalent to design truck (mm).

The wall height: 4,5 ~ 9,0 m

Wall height(mm)	heq (mm)	Covering	Wall height (mm)	h <sub>eq</sub> (m)	D <sub>p</sub> (Kn/m <sup>2</sup> )
< 1500.	1700				
3000	1200	4.50 m	7100	705.00	4.15
6000	760	9.00 m	11600	610.00	3.59
> 9000.	610				

### 4.3. Earth Pressure (EV & EH):

#### 4.3.1. Vertical earth pressure (EV) (A12.11.2.2)

- The factor of vertical earth pressure

$$F_e = \text{MIN}(1+0.2 \cdot h_3/W, 1.15)$$

→ Vertical earth pressure on top slab of culvert

$$EV = F_e \cdot \gamma_s \cdot h$$

Covering ( $h_3$ )	$F_e$	$\gamma_s$ ( $\text{Kn/m}^3$ )	EV ( $\text{Kn/m}$ )
4.50 m	1.150	17.66	91.38
9.00 m	1.150	17.66	182.76

#### 4.3.2. Horizontal earth pressure (EH)

- Basic earth pressure shall be assumed to be linearly proportional to the depth of earth and taken as.

$$P_h = K_a \cdot \gamma_s \cdot g \cdot Z \cdot 10^{-9} \quad (3.11.5.1-1)$$

In which:

$P_h$  : horizontal earth pressure at the depth of Z (N/mm<sup>2</sup>)

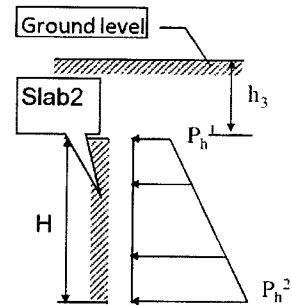
- + Lateral earth pressure applied on the plate as figure

$$P_h^1 = K_a \cdot \gamma_s \cdot g \cdot h_3 \cdot 10^{-9}$$

$$P_h^2 = K_a \cdot \gamma_s \cdot g \cdot (H+h_3) \cdot 10^{-9}$$

in which:

- $P_h$  : Horizontal earth pressure (N/mm)
- $K_a$  : active earth pressure coefficient  $K_a = 0.33$
- $\gamma_s$  : Density of soil (kg/m<sup>3</sup>)  $\gamma_s = 1800$
- $g$  : Gravitational acceleration (m/s<sup>2</sup>)  $g = 9.81$
- $\phi$  : Angle of internal friction  $\phi = 30 \text{ deg}$
- $h_3$  : filling height from top of box culvert (mm)
- $H$  : Total height of box culvert (mm)

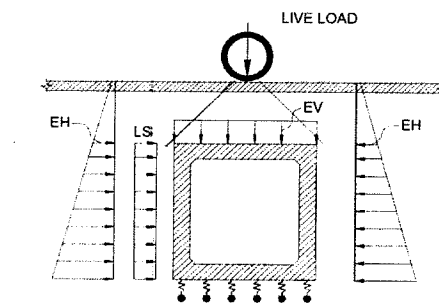


Covering	$K_a$	$\gamma_s$ ( $\text{Kg/m}^3$ )	$g$ ( $\text{m/s}^2$ )	$P_h^1$ ( $\text{Kn/m}^2$ )	$P_h^2$ ( $\text{Kn/m}^2$ )
4.50 m	0.33	1800	9.81	26.49	41.79
9.00 m	0.33	1800	9.81	52.97	68.28

### 5. Load combination

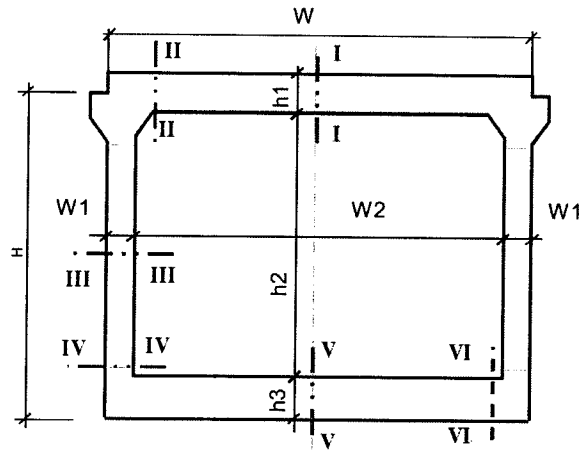
Load combination and load combination factor shall be taken as Table 3.4.1-1

State	Mark	Str. I-A	Str. I-B	Str. I-C	Str. III-A	Str. III-B	Service I
Dead load of structural	DC	1.25	1.25	0.90	0.90	1.25	1.00
Dead load of wearing	DW	1.50	1.50	0.65	0.65	1.50	1.00
Vertical earth pressure	EV	1.30	1.30	0.90	0.90	1.30	1.00
Horizontal earth pressure	EH	1.50	0.90	1.50	1.50	1.50	1.00
Live load	LL	1.75	1.75	1.75	1.35	1.35	1.00
Live load surcharge	LS	1.75	1.75	1.75	1.35	1.35	1.00



Model of structural of culvert by midas program

6. Design force applied to sections:



Design section

Table of Internal force with covering height  $h = 4.5 \text{ m}$

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	46.50	0.00	-60.00	36.80	0.00	-38.90
II - II	-34.00	150.60	-60.00	-25.90	110.60	-38.90
III - III	-17.20	0.00	-168.10	-14.90	0.00	-124.30
IV - IV	-42.00	65.90	-178.50	-32.90	26.45	-132.60
V - V	52.00	39.60	-75.90	40.80	29.30	-46.70
VI - VI	-35.00	165.20	-75.90	-26.90	122.50	-46.70

Table of Internal force with covering height  $h = 9 \text{ m}$

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	87.50	0.00	-105.60	70.60	0.00	-69.50
II - II	-62.30	281.70	-105.60	-48.60	207.00	-69.50
III - III	-32.80	0.00	-306.80	-27.60	0.00	-226.80
IV - IV	-73.70	107.60	-316.50	-56.50	71.70	-235.60
V - V	94.10	69.10	-115.50	72.60	51.20	-76.30
VI - VI	-60.50	294.60	-115.50	-45.00	218.30	-76.30

Table of Internal force applied to design section

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	87.50	0.00	105.60	70.60	0.00	69.50
II - II	62.30	281.70	105.60	48.60	207.00	69.50
III - III	32.80	0.00	306.80	27.60	0.00	226.80
IV - IV	73.70	107.60	316.50	56.50	71.70	235.60
V - V	94.10	69.10	115.50	72.60	51.20	76.30
VI - VI	60.50	294.60	115.50	45.00	218.30	76.30



# 7. Ultimate check, shear capacity check and crack control

Item		Section I-I (Bottom bar)	Section II-II (Top bar)	Section III-III (Inside bar)	Unit	
• Factored Plexural moment • Factored Shear force • Factored Nominal force • Hight of Section • Width of section • Section area • Moment of inertia of concrete section • Tension reinforcement • comp. reinforcement:	$M_u$	87.50	62.30	32.80	kN.m	
	$V_u$	-	281.70	-	kN	
	$N_u$	105.60	105.60	306.80	kN	
	$h$	300	300	300	mm	
	$b$	1000	1000	1000	mm	
	$A_c$	300000	300000	300000	mm <sup>2</sup>	
	$I_g$	2.3E+09	2.3E+09	2.3E+09	mm <sup>4</sup>	
	Distance from tension reinf. to extreme compression fiber	$d_c$	58	83	58	mm
	Reinf. Diameter	$\phi$	D16	D16	D16	mm
	Space	@	100	100	100	mm
	Number of bar	$n$	10	10	10	bar
	Total area of reinf.	$A_s$	2011	2011	2011	mm <sup>2</sup>
	Distance from compressive reinf. to extreme Tension fiber		83	83	83	mm
	Diameter		D16	D16	D16	mm
	Reinf. Space		200	200	200	mm
	Number of bar		5	5	5	bar
	Total area of reinf.	$A'_s$	1005	1005	1005	mm <sup>2</sup>
Check Flexural Moment						
• Resistance factor	$\Phi$	0.90	0.90	0.90		
• The corresponding effective	$d_e$	242	217	242	mm	
• Stress block factor	$\beta_1$	0.85	0.85	0.85		
• Depth of the equivalent stress block = $c \cdot \beta_1$	$a$	37.85	37.85	37.85	mm	
• Distance from extreme compression fiber to the neutr	$c$	44.53	44.53	44.53	mm	
• The nominal flexural resistance:	$M_n$	179	159	179	kN.m	
• Factored flexural resistance	$M_r = \Phi \cdot M_n$	161	143	161	kN.m	
• Check condition	$M_r > M_u$	O.K	O.K	O.K		
Mimimum Reinforcement						
• Cracking moment	$1.2M_{cr}$	56.70	56.70	56.70	Kn.m	
• Check	$M_r > \min(1.2M_{cr}, 1.33M_u)$	O.K	O.K	O.K		
Maximum Reinforcement						
• Obligation Condition	$c/d_e$	0.18	0.21	0.18		
• Check	$c/d_e < 0.42$	O.K	O.K	O.K		
Check shear resistance						
• Factored Shear force	$V_u$	-	281.70	-	kN	
• Resistance factor	$\Phi$	0.90	0.90	0.90		
• The effective shear deepth	$d_v$	242	217	242	mm	
• Effective width	$b_v$	1000	1000	1000	mm	
• Angle of inclination of diagonal compressive stress	$\theta$	45	39	45	degree	
• Angle of inclination of transverse reinf. To longitudir	$\alpha$	90	90	90	degree	
• Factor indicating ability of diagonally cracked concrete to transmit tension	$\beta$	2.00	2.00	2.00		
• Value	$0.1 \cdot f_c \cdot b_v \cdot d_v$	605	543	605	kN	
• Max spacing of transverse reinforcement	$s$	194	174	194	mm	
• Spacing of stirrup	$s$	500	200	500	mm	
• Diameter of transverse reinforcement	$\phi$	D 16	D 16	D 16		
• Number of transverse reinf. within distance $s$	$n$	5	2	5	bar	
• Assume	$\theta$	45.00	38.62	45.00	degree	
• Strain in tensile reinforcement	$\epsilon_s \cdot 1000$	1.03E+00	1.28E+00	7.19E-01		
If $\epsilon_s < 0$ , multiple with reduce factor	$\Phi_c$	-	-	-		
• Ratio of shear stress and $f_c$	$V/f_c$	0.00	0.06	0.00		
• $\beta$ final		2.00	2.05	2.00		
• $\theta$ final		45.00	38.66	45.00	degree	
• Total area of transverse reinf.	$A_v$	1005	402	1005	mm <sup>2</sup>	
• Diameter of stirrup	$\phi$	D 10	D 14	D 10	mm	
• Number of stirrup within distance $s$	$n$	2	5	2	bar	
• Total area of stirrup	$A_v$	157.08	769.69	157.08		
• The shear resistance of concrete:	$V_c$	200.86	180.11	200.86	kN	
• The shear resistance of stirrup	$V_s$	13.56	223.58	13.56	kN	
• Value	$0.25 \cdot f_c \cdot b_v \cdot d_v$	1512.50	1356.25	1512.50	kN	
• The nominal shear resistance:	$V_n$	214.42	403.69	214.42	kN	
• The factored shear resistance	$V_r$	192.98	363.32	192.98	kN	
• Check	$V_r > V_u$	O.K	O.K	O.K		
• Requiring transverse reinforcement	$V_u > 0.5 \cdot \Phi \cdot V_c$	Not required	Need	Not required		
• Check minimum transverse reinforcement	$A_v > 0.083 \cdot (f_c^{0.5}) \cdot b_v \cdot s / f_y$	not required	O.K	not required		

<b>Check crack</b>					
<b>Interior force combination</b>					
• Factored moment	$M_u$	7.06E+01	4.86E+01	4.86E+01	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f_c}$	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis:	$y_t = h - c$	255	255	255	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	8	6	6	MPa
• Check	$f_r >$	0.8 * $f_r$	0.8 * $f_r$	0.8 * $f_r$	
	check crack	check crack	check crack	check crack	
• Crack width parameter	$Z$	= 17500	= 17500	= 17500	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 8.00	= 8.00	= 8.00	
• The distance from extreme fiber to the neutral axis	$c$	= 105.77	= 101.17	= 105.77	mm
• Effective moment of inertia	$J$	6.93E+08	5.61E+08	6.93E+08	mm <sup>4</sup>
• Arm	$de - c$	= 136.23	= 115.83	= 136.23	mm
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (de - c) / J$	= 111.03	= 80.28	= 76.43	MPa
• Area of concrete having the same centroid as the principal tensile reinforcement divided by number of bars	$A$	= 10000	= 10000	= 10000	mm <sup>2</sup>
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 209.84	= 209.84	= 209.84	Mpa
• Check condition	$f_s < f_{sa}$	O.K	O.K	O.K	
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	

# 7. Ultimate check, shear capacity check and crack control

Item		Section IV-IV (outside bar)	Section V-V (Top bar)	Section VI-VI (Bottom bar)	Unit
• Factored Plexural moment	$M_u$	73.70	94.10	60.50	kN.m
• Factored Shear force	$V_u$	107.60	69.10	294.60	kN
• Factored Nominal force	$N_u$	316.50	115.50	115.50	kN
• Hight of Section	$h$	300	300	300	mm
• Width of section	$b$	1000	1000	1000	mm
• Section area	$A_c$	300000	300000	300000	mm <sup>2</sup>
• Moment of inertia of concrete section	$I_g$	2.3E+09	2.3E+09	2.3E+09	mm <sup>4</sup>
• Tension reinforcement	Distance from tension reinf. to extreme compression fiber	$d_c$	83	58	83
	Reinf. Diameter	$\varnothing$	D16	D16	mm
	Space	@	100	100	mm
	Number of bar	$n$	10	10	bar
	Total area of reinf.	$A_s$	2011	2011	mm <sup>2</sup>
• comp. reinforcement:	Distance from compressive reinf. to extreme Tension fiber	58	83	58	mm
	Diameter	D16	D16	D16	mm
	Reinf. Space	200	200	200	mm
	Number of bar	5	5	5	bar
	Total area of reinf.	$A'_s$	1005	1005	mm <sup>2</sup>
Check Flexural Moment					
• Resistance factor	$\Phi$	0.90	0.90	0.90	
• The corresponding effective	$d_e$	217	242	217	mm
• Stress block factor	$\beta_1$	0.85	0.85	0.85	
• Depth of the equivalent stress block = $c \cdot \beta_1$	$a$	37.85	37.85	37.85	mm
• Distance from extreme compression fiber to the neut	$c$	44.53	44.53	44.53	mm
• The nominal flexural resistance:	$M_n$	159	179	159	kN.m
• Factored flexural resistance	$M_r = \Phi \cdot M_n$	143	161	143	kN.m
• Check condition	$M_r > M_u$	O.K	O.K	O.K	
Mimimum Reinforcement					
• Cracking moment	$1.2M_{cr}$	56.70	56.70	56.70	Kn.m
• Check	$M_r > \min(1.2M_{cr}, 1.33M_u)$	O.K	O.K	O.K	
Maximum Reinforcement					
• Obligation Condition	$c/d_e$	0.21	0.18	0.21	
• Check	$c/d_e < 0.42$	O.K	O.K	O.K	
Check shear resistance					
• Factored Shear force	$V_u$	107.60	69.10	294.60	kN
• Resistance factor	$\Phi$	0.90	0.90	0.90	
• The effective shear deepth	$d_v$	217	242	217	mm
• Effective width	$b_v$	1000	1000	1000	mm
• Angle of inclination of diagonal compressive stress	$\theta$	40	38	39	degree
• Angle of inclination of transverse reinf. To longitudi	$\alpha$	90	90	90	degree
• Factor indicating ability of diagonally cracked concrete to transmit tension	$\beta$	2.01	2.00	2.04	
• Value	$0.1 \cdot f'_c \cdot b_v \cdot d_v$	543	605	543	kN
• Max spacing of transverse reinforcement	$s$	174	194	174	mm
• Spacing of stirrup	$s$	200	500	200	mm
• Diameter of transverse reinforcement	$\varnothing$	D 16	D 16	D 16	
• Number of transverse reinf. within distance $s$	$n$	2	5	2	bar
• Assume	$\theta$	39.90	38.20	38.65	degree
• Strain in tensile reinforcement	$\epsilon_x$	1.40E+00	1.22E+00	1.29E+00	
If $\epsilon_x < 0$ , multiple with reduce factor	$\Phi_c$	-	-	-	
• Ratio of shear stress and $f'_c$	$V/f'_c$	0.02	0.01	0.06	
• $\beta$ final		2.01	2.11	2.04	
• $\theta$ final		39.98	38.20	38.71	degree
• Total area of transverse reinf.	$A_v$	402	1005	402	mm <sup>2</sup>
• Diameter of stirrup	$\varnothing$	D 14	D 10	D 14	mm
• Number of stirrup within distance $s$	$n$	5	2	5	bar
• Total area of stirrup	$A_v$	769.69	157.08	769.69	
• The shear resistance of concrete:	$V_c$	180.74	200.86	183.78	kN
• The shear resistance of stirrup	$V_s$	206.46	20.93	223.00	kN
• Value	$0.25 \cdot f'_c \cdot b_v \cdot d_v$	1356.25	1512.50	1356.25	kN
• The nominal shear resistance:	$V_n$	387.20	221.79	406.78	kN
• The factored shear resistance	$V_r$	348.48	199.61	366.10	kN
• Check	$V_r > V_u$	O.K	O.K	O.K	
• Requiring transverse reinforcement	$V_u > 0.5 \cdot \Phi \cdot V_c$	Need	Not required	Need	
• Check minimum transverse reinforcement	$A_v > 0.083 \cdot (f'_c)^{0.5} \cdot b_v \cdot s / f_y$	O.K	not required	O.K	

<b>Check crack</b>					
<b>Interior force combination</b>					
• Factored moment	$M_u$	5.65E+01	7.26E+01	4.50E+01	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f'_c}$	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis	$y_t = h - c$	255	255	255	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	6	8	5	MPa
• Check	$f_r >$	0.8 $\cdot$ $f_r$	0.8 $\cdot$ $f_r$	0.8 $\cdot$ $f_r$	
		check crack	check crack	check crack	
• Crack width parameter	$Z$	= 17500	= 17500	= 17500	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 8.00	= 8.00	= 8.00	
• The distance from extreme fiber to the neutral axis	$c$	= 101.17	= 105.77	= 101.17	mm
• Effective moment of inertia	$J$	5.61E+08	6.93E+08	5.61E+08	mm <sup>4</sup>
• Arm	$de - c$	= 115.83	= 136.23	= 115.83	mm
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (de - c) / J$	= 93.33	= 114.18	= 74.33	MPa
• Area of concrete having the same centroid as the principal tensile reinforcement divided by number of bars	$A$	= 10000	= 10000	= 10000	mm <sup>2</sup>
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 209.84	= 209.84	= 209.84	Mpa
• Check condition	$f_s < f_{sa}$	O.K	O.K	O.K	
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	

## BOX CULVERT CALCULATION SHEET

### 1. General

- Group : 4
- Dimension : 1x(2,5x2,5) m
- Covering height :  $0.60 \leq H \leq 4.50\text{m}$
- Live load : HL93
- Design standard: 22TCN-272-05
- Unit : KN and m, N and mm

### 2. Material property

#### 2.1. Concrete

- Compressive strength of cylindrical at 28 days:  $f_c = 25$  MPa
- Concrete density:  $\gamma_c = 24.5$  KN/m<sup>3</sup>
- Elastic modulus:  $E_c = 0.043 \cdot \gamma_c^{1.5} \cdot \sqrt{f_c} = 26875$  N/mm<sup>2</sup>
- Tensile strength of concrete:  $f_r = 0.63 \cdot \sqrt{f_c} = 3.15$  N/mm<sup>2</sup>

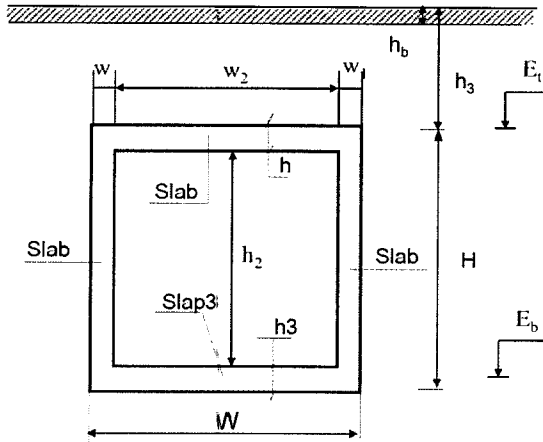
#### 2.2. Steel

- Elastic module of steel :  $E_s = 200000$  N/mm<sup>2</sup>
- Liquid limit:  $f_y = 400$  N/mm<sup>2</sup>

#### 2.2. Pavement and backfill

- Thickness of Asphalt pavement:  $t = 0.16$  m
- Elastic module of ground soil:  $E_o = 7563$  KN/m<sup>2</sup>
- Unit weight of soil:  $\gamma_s = 17.66$  KN/m<sup>3</sup>
- Seftweight of Pavement:  $\gamma_{as} = 22$  KN/m<sup>3</sup>
- Intenal friction angle of soil:  $\phi'_f = 30$  deg
- Friction angle between soil and wall:  $\delta = 0$  deg

### 3. Dimation of Box culvert



BOX CULVERT DIMENSION			
Item	Unit	Symbol	Value
Thickness of slab 1	m	$h_1$	0.300
Thickness of slab 2	m	$w_1$	0.300
Thickness of slab 3	m	$h_3$	0.300
Height of box culvert	m	$H$	3.100
Height of box culvert	m	$h_2$	2.500
Height of pavement structure	m	$h_b$	0.160
Height of backfilling on top of culvert	m	$h_3$	0.6 ~ 4.5
Span length	m	$w_2$	2.500
Culvert width	m	$W$	3.100

#### 4. Loading

##### 4.1. Deadload

- Deadload of box culvert (DC) will be automatic calculate by Midas program with selfweight of concrete is:  $\gamma_c = 24.5 \text{ (Mpa)}$
- Deadload of pavement (DW) will be automatic calculate by Midas program with selfweight of pavement is:  $\gamma_{as} = 22 \text{ (Mpa)}$

##### 4.2. Live load

- Where the depth of fill is less than 600mm, the effect of fill on the distribution of live load shall be neglected.
- The uniformly distribution of wheel where covering depth  $\geq 600 \text{ mm}$  determined follow A 3.6.1.2.6.
- Impact load determined follow A 3.6.2.2.
- Where the depth of fill exceeds 600 mm, wheel loads may be considered to be uniformly distributed over rectangular area with sides equal to the dimension of the tire contact area as A 3.6.1.2.5, and increased by either 1.15 times the depth of the fill in select granular backfill, or the depth of the fill in all other cases.
- For single span culverts, the effects of live load may be neglected where the depth of fill is  $\geq 2400\text{mm}$  and exceeds the span length.
- For multiple span culverts, the effects of live load may be neglected where the depth of fill exceeds the distance between faces of end walls.
- Where such areas from several wheels overlap, the total load shall be uniformly distributed over the area.
- The dynamic load allowance for culverts shall be taken as:

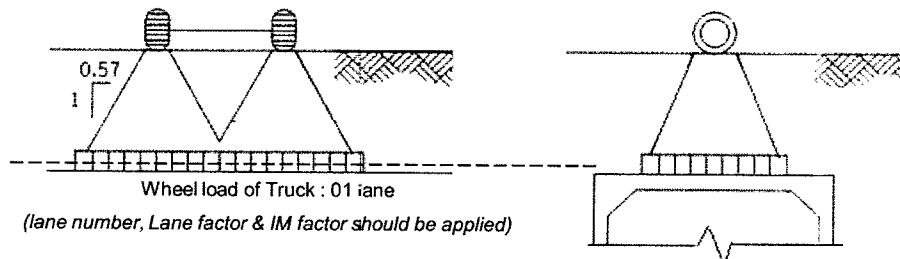
$$IM = 33 * (1.0 - 4.1 \times 10^{-4} \cdot De) \quad (3.6.2.2.1)$$

##### • Design truck:

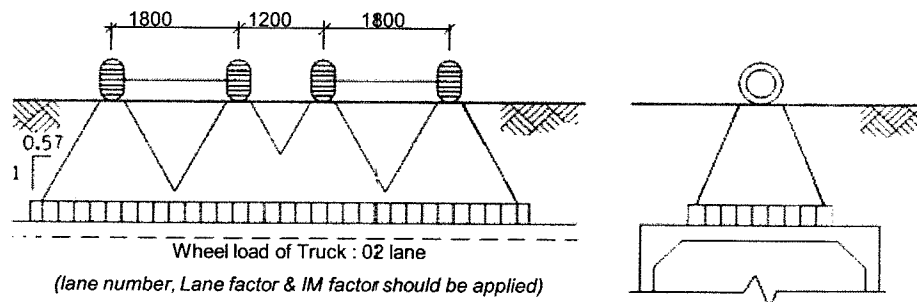
- Estimate for impact factor and distributed area of wheel

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
0.6	145	24.88	510	361	1200	1051
4.5	145	0.00	510	289	5685	5464

Distribution of wheel load for 1 lane



Distribution of wheel load for 2 lane



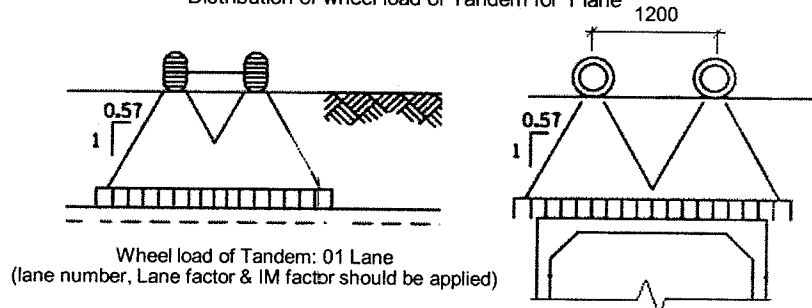
Distributed wheel load of truck

Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>truck - 1 lane</sub> (Kn/m)	LL <sub>truck - 2 lane</sub> (Kn/m)
0.6	145	1200	1051	57.47	57.47
4.5	145	5685	5464	4.09	4.09

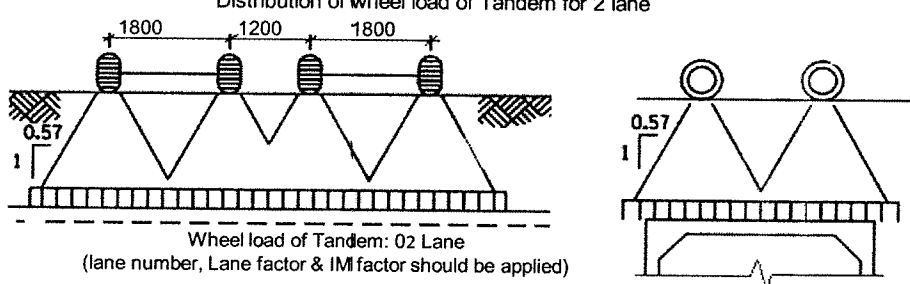
• **Tandem:**

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
0.6	110	24.88	510	274	1200	964
4.5	110	0.00	510	219	5685	5394

Distribution of wheel load of Tandem for 1 lane



Distribution of wheel load of Tandem for 2 lane



Distributed wheel load of Tandem

Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>tandem - 1 lane</sub> (Kn/m)	LL <sub>tandem - 2 lane</sub> (Kn/m)
0.6	145	1200	964	47.54	47.54
4.5	145	5685	5394	3.03	4.85

- Design live load applied to structure:  $\text{Max(LL)} = 57.47$  (Kn/m) with covering depth 0.6 m  
 $= 0.00$  (Kn/m) with covering depth 4.5 m

• **Lane load**

- Lane load distributed on 1 m  $= 3.10$  kN/m

**4.2.1. Surcharge load (LS)**

-Where a surcharge load is present, a constant horizontal earth pressure shall be added to the basic earth pressure.

This constant earth pressure may be taken as

$$D_p = k \cdot \gamma_s \cdot g \cdot h_{eq} (x 10^{-3}) \quad (3.11.6.1-1)$$

Where:

- $D_p$  = constant horizontal earth pressure due to uniform surcharge load applied (Mpa)
- $k$  = coefficient of earth pressure
- $\gamma_s$  = density of soil (kg/m<sup>3</sup>)
- $h_{eq}$  = height of soil equivalent to design truck (mm).

The wall height: 0.6 ~ 4.5 m

Wall height(mm)	heq (mm)	Covering	Wall height (mm)	h <sub>eq</sub> (m)	D <sub>p</sub> (Kn/m <sup>2</sup> )
< 1500.	1700	0.60 m	3700	1097.33	6.46
3000	1200	4.50 m	7600	680.00	4.00
6000	760				
> 9000.	610				

#### 4.3. Earth Pressure (EV & EH):

##### 4.3.1. Vertical earth pressure (EV) (A12.11.2.2)

- The factor of vertical earth pressure

$$F_e = \text{MIN}(1+0.2 \cdot h_3/W, 1.15)$$

→ Vertical earth pressure on top slab of culvert

$$EV = F_e \cdot \gamma_s \cdot h$$

Covering ( $h_3$ )	$F_e$	$\gamma_s$ (Kn/m <sup>3</sup> )	EV (Kn/m)
0.60 m	1.039	17.66	11.00
4.50 m	1.150	17.66	91.38

##### 4.3.2. Horizontal earth pressure (EH)

- Basic earth pressure shall be assumed to be linearly proportional to the depth of earth and taken as.

$$P_h = K_a \cdot \gamma_s \cdot g \cdot Z \cdot 10^{-9} \quad (3.11.5.1-1)$$

In which:

$P_h$  : horizontal earth pressure at the depth of Z (N/mm<sup>2</sup>)

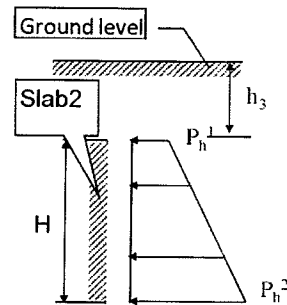
+ Lateral earth pressure applied on the plate as figure

$$P_h^1 = K_a \cdot \gamma_s \cdot g \cdot h_3 \cdot 10^{-9}$$

$$P_h^2 = K_a \cdot \gamma_s \cdot g \cdot (H+h_3) \cdot 10^{-9}$$

in which:

- $P_h$  : Horizontal earth pressure (N/mm)
- $K_a$  : active earth pressure coefficient  $K_a = 0.33$
- $\gamma_s$  : Density of soil (kg/m<sup>3</sup>)  $\gamma_s = 1800$
- $g$  : Gravitational acceleration (m/s<sup>2</sup>)  $g = 9.81$
- $\phi$  : Angle of internal friction  $\phi = 30 \text{ deg}$
- $h_3$  : filling height from top of box culvert (mm)
- $H$  : Total height of box culvert (mm)

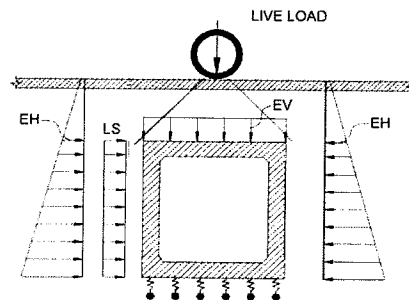


Covering	$K_a$	$\gamma_s$ (Kg/m <sup>3</sup> )	$g$ (m/s <sup>2</sup> )	$P_h^1$ (Kn/m <sup>2</sup> )	$P_h^2$ (Kn/m <sup>2</sup> )
0.60 m	0.33	1800.	9.81	3.53	21.78
4.50 m	0.33	1800.	9.81	26.49	44.73

#### 5. Load combination

Load combination and load combination factor shall be taken as Table 3.4.1-1

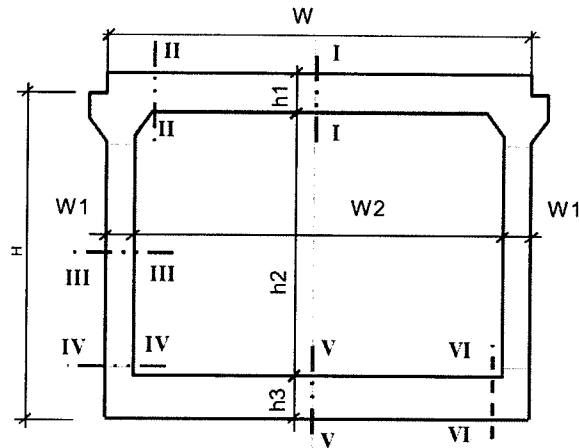
State	Mark	Str. I-A	Str. I-B	Str. I-C	Str. III-A	Str. III-B	Service I
Dead load of structural	DC	1.25	1.25	0.90	0.90	1.25	1.00
Dead load of wearing	DW	1.50	1.50	0.65	0.65	1.50	1.00
Vertical earth pressure	EV	1.30	1.30	0.90	0.90	1.30	1.00
Horizontal earth pressure	EH	1.50	0.90	1.50	1.50	1.50	1.00
Live load	LL	1.75	1.75	1.75	1.35	1.35	1.00
Live load surcharge	LS	1.75	1.75	1.75	1.35	1.35	1.00



Model of structural of culvert by midas program



6. Design force applied to sections:



Design section

Table of Internal force with covering height  $h = 0.6 \text{ m}$

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	76.60	55.20	-35.40	50.80	0.00	-21.00
II - II	-42.20	179.30	-35.40	-29.60	109.20	-21.00
III - III	-34.80	0.00	-202.30	-21.80	0.00	-130.90
IV - IV	-55.60	46.60	-213.80	-39.30	30.00	-138.90
V - V	76.20	41.50	-50.60	50.60	3.00	-32.40
VI - VI	-42.60	202.50	-50.60	-31.60	128.00	-32.40

Table of Internal force with covering height  $h = 4.5 \text{ m}$

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	75.20	0.00	-89.90	59.40	0.00	-53.60
II - II	-58.00	201.10	-89.90	-43.50	146.00	-53.60
III - III	-26.00	0.00	-225.60	-21.60	0.00	-164.60
IV - IV	-68.80	91.90	-236.50	-52.60	59.90	-173.80
V - V	73.90	41.50	-98.90	59.00	3.00	-64.20
VI - VI	-57.90	224.10	-98.90	-43.60	164.60	-64.20

Table of Internal force applied to design section

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	76.60	55.20	89.90	59.40	0.00	53.60
II - II	58.00	201.10	89.90	43.50	146.00	53.60
III - III	34.80	0.00	225.60	21.80	0.00	164.60
IV - IV	68.80	91.90	236.50	52.60	59.90	173.80
V - V	76.20	41.50	98.90	59.00	3.00	64.20
VI - VI	57.90	224.10	98.90	43.60	164.60	64.20

# 7. Ultimate check, shear capacity check and crack control

Item		Section I-I (Bottom bar)	Section II-II (Top bar)	Section III-III (Inside bar)	Unit	
• Factored Plexural moment • Factored Shear force • Factored Nominal force • Hight of Section • Width of section • Section area • Moment of inertia of concrete section • Tension reinforcement • comp. reinforcement:	$M_u$	76.60	58.00	34.80	kN.m	
	$V_u$	55.20	201.10	-	kN	
	$N_u$	89.90	89.90	225.60	kN	
	$h$	300	300	300	mm	
	$b$	1000	1000	1000	mm	
	$A_c$	300000	300000	300000	mm <sup>2</sup>	
	$I_g$	2.3E+09	2.3E+09	2.3E+09	mm <sup>4</sup>	
	Distance from tension reinf. to extreme compression fiber	$d_c$	58	83	58	mm
	Reinf. Diameter	$\phi$	D16	D16	D16	mm
	Space	@	125	125	125	mm
	Number of bar	$n$	8	8	8	bar
	Total area of reinf.	$A_s$	1608	1608	1608	mm <sup>2</sup>
	Distance from compressive reinf. to extreme Tension fiber		83	83	83	mm
	Diameter		D16	D16	D16	mm
	Reinf. Space		250	250	250	mm
	Number of bar		4	4	4	bar
	Total area of reinf.	$A'_s$	804	804	804	mm <sup>2</sup>
Check Flexural Moment						
• Resistance factor	$\Phi$	0.90	0.90	0.90		
• The corresponding effective	$d_e$	242	217	242	mm	
• Stress block factor	$\beta_1$	0.85	0.85	0.85		
• Depth of the equivalent stress block = $c \cdot \beta_1$	$a$	30.28	30.28	30.28	mm	
• Distance from extreme compression fiber to the neutr	$c$	35.62	35.62	35.62	mm	
• The nominal flexural resistance:	$M_n$	146	130	146	kN.m	
• Factored flexural resistance	$M_r = \Phi \cdot M_n$	131	117	131	kN.m	
• Check condition	$M_r > M_u$	O.K	O.K	O.K		
Mimimum Reinforcement						
• Cracking moment	$1.2M_{cr}$	56.70	56.70	56.70	Kn.m	
• Check	$M_r > \min(1.2M_{cr}, 1.33M_u)$	O.K	O.K	O.K		
Maximum Reinforcement						
• Obligation Condition	$c/d_e$	0.15	0.16	0.15		
• Check	$c/d_e < 0.42$	O.K	O.K	O.K		
Check shear resistance						
• Factored Shear force	$V_u$	55.20	201.10	-	kN	
• Resistance factor	$\Phi$	0.90	0.90	0.90		
• The effective shear deepth	$d_v$	242	217	242	mm	
• Effective width	$b_v$	1000	1000	1000	mm	
• Angle of inclination of diagonal compressive stress	$\theta$	45	39	45	degree	
• Angle of inclination of transverse reinf. To longitudir	$\alpha$	90	90	90	degree	
• Factor indicating ability of diagonally cracked concrete to transmit tension	$\beta$	2.00	2.00	2.00		
• Value	$0.1 \cdot f_c \cdot b_v \cdot d_v$	605	543	605	kN	
• Max spacing of transverse reinforcement	$s$	194	174	194	mm	
• Spacing of stirrup	$s$	500	300	500	mm	
• Diameter of transverse reinforcement	$\phi$	D 16	D 16	D 16		
• Number of transverse reinf. within distance s	$n$	4	2	4	bar	
• Assume	$\theta$	45.00	39.50	45.00	degree	
• Strain in tensile reinforcement	$\epsilon_s \cdot 1000$	1.21E+00	1.35E+00	7.98E-01		
If $\epsilon_s < 0$ , multiple with reduce factor	$\Phi_c$	-	-	-		
• Ratio of shear stress and $f_c$	$V/f_c$	0.01	0.04	0.00		
• $\beta$ final		2.00	2.03	2.00		
• $\theta$ final		45.00	39.50	45.00	degree	
• Total area of transverse reinf.	$A_v$	804	402	804	mm <sup>2</sup>	
• Diameter of stirrup	$\phi$	D 10	D 14	D 10	mm	
• Number of stirrup within distance s	$n$	2	3	2	bar	
• Total area of stirrup	$A_v$	157.08	461.81	157.08		
• The shear resistance of concrete:	$V_c$	200.86	180.11	200.86	kN	
• The shear resistance of stirrup	$V_s$	13.56	85.05	13.56	kN	
• Value	$0.25 \cdot f_c \cdot b_v \cdot d_v$	1512.50	1356.25	1512.50	kN	
• The nominal shear resistance:	$V_n$	214.42	265.16	214.42	kN	
• The factored shear resistance	$V_r$	192.98	238.65	192.98	kN	
• Check	$V_r > V_u$	O.K	O.K	O.K		
• Requiring transverse reinforcement	$V_u > 0.5 \cdot \Phi \cdot V_c$	Not required	Need	Not required		
• Check minimum transverse reinforcement	$A_v > 0.083 \cdot (f_c^{0.5}) \cdot b_v \cdot s / f_y$	not required	O.K	not required		

<b>Check crack</b>					
<b>Interior force combination</b>					
• Factored moment	$M_u$	5.94E+01	4.35E+01	4.35E+01	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f'_c}$	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis	$y_t = h - c$	264	264	264	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	7	5	5	MPa
• Check	$f_r >$	0.8*f <sub>r</sub>	0.8*f <sub>r</sub>	0.8*f <sub>r</sub>	
		check crack	check crack	check crack	
• Crack width parameter	$Z$	= 17500	= 17500	= 17500	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 8.00	= 8.00	= 8.00	
• The distance from extreme fiber to the neutral axis	$c$	= 92.83	= 88.70	= 92.83	mm
• Effective moment of inertia	$J$	5.53E+08	4.44E+08	5.53E+08	mm <sup>4</sup>
• Arm	$de - c$	= 149.17	= 128.30	= 149.17	mm
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (de - c) / J$	= 128.19	= 100.46	= 93.88	MPa
• Area of concrete having the same centroid as the principal tensile reinforcement divided by number of bars	$A$	= 12500	= 12500	= 12500	mm <sup>2</sup>
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 194.80	= 194.80	= 194.80	Mpa
• Check condition	$f_s < f_{sa}$	O.K	O.K	O.K	
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	

# 7. Ultimate check, shear capacity check and crack control

Item		Section IV-IV (outside bar)	Section V-V (Top bar)	Section VI-VI (Bottom bar)	Unit	
• Factored Plexural moment	M <sub>u</sub>	68.80	76.20	57.90	kN.m	
• Factored Shear force	V <sub>u</sub>	91.90	41.50	224.10	kN	
• Factored Nominal force	N <sub>u</sub>	236.50	98.90	98.90	kN	
• Hight of Section	h	300	300	300	mm	
• Width of section	b	1000	1000	1000	mm	
• Section area	A <sub>c</sub>	300000	300000	300000	mm <sup>2</sup>	
• Moment of inertia of concrete section	I <sub>g</sub>	2.3E+09	2.3E+09	2.3E+09	mm <sup>4</sup>	
• Tension reinforcement	Distance from tension reinf. to extreme compression fiber	d <sub>c</sub>	83	58	83	mm
	Reinf. Diameter	Ø	D16	D16	D16	mm
	Space	@	125	125	125	mm
	Number of bar	n	8	8	8	bar
• comp. reinforcement:	Total area of reinf.	A <sub>s</sub>	1608	1608	1608	mm <sup>2</sup>
	Distance from compressive reinf. to extreme Tension fiber		58	83	58	mm
	Diameter		D16	D16	D16	mm
	Reinf. Space		250	250	250	mm
	Number of bar		4	4	4	bar
	Total area of reinf.	A' <sub>s</sub>	804	804	804	mm <sup>2</sup>
Check Flexural Moment						
• Resistance factor	Φ	0.90	0.90	0.90		
• The corresponding effective	d <sub>e</sub>	217	242	217	mm	
• Stress block factor	β <sub>1</sub>	0.85	0.85	0.85		
• Depth of the equivalent stress block = c*β1	a	30.28	30.28	30.28	mm	
• Distance from extreme compression fiber to the neutri	c	35.62	35.62	35.62	mm	
• The nominal flexural resistance:	M <sub>n</sub>	130	146	130	kN.m	
• Factored flexural resistance	M <sub>r</sub> = Φ.M <sub>n</sub>	117	131	117	kN.m	
• Check condition	M <sub>r</sub> > M <sub>u</sub>	O.K	O.K	O.K		
Mimumum Reinforcement						
• Cracking moment	1.2M <sub>cr</sub>	56.70	56.70	56.70	Kn.m	
• Check	Mr> min(1.2M <sub>cr</sub> , 1.33Mu)	O.K	O.K	O.K		
Maximum Reinforcement						
• Obligation Condition	c/d <sub>e</sub>	0.16	0.15	0.16		
• Check	c/d <sub>e</sub> < 0.42	O.K	O.K	O.K		
Check shear resistance						
• Factored Shear force	V <sub>u</sub>	91.90	41.50	224.10	kN	
• Resistance factor	Φ	0.90	0.90	0.90		
• The effective shear depth	d <sub>v</sub>	217	242	217	mm	
• Effective width	b <sub>v</sub>	1000	1000	1000	mm	
• Angle of inclination of diagonal compressive stress	θ	41	38	40	degree	
• Angle of inclination of transverse reinf. To longitudinal axis	α	90	90	90	degree	
• Factor indicating ability of diagonally cracked concrete to transmit tension	β	1.94	2.00	2.01		
• Value	0.1*f <sub>c</sub> *b <sub>v</sub> *d <sub>v</sub>	543	605	543	kN	
• Max spacing of transverse reinforcement	s	174	194	174	mm	
• Spacing of stirrup	s	250	500	250	mm	
• Diameter of transverse reinforcement	Ø	D 16	D 16	D 16		
• Number of transverse reinf. within distance s	n	2	4	2	bar	
• Assume	θ	41.00	38.20	39.98	degree	
• Strain in tensile reinforcement	ε <sub>s</sub>	1.52E+00	1.21E+00	1.40E+00		
If ε <sub>s</sub> <0, multiple with reduce factor	Φ <sub>c</sub>	-	-	-		
• Ratio of shear stress and f <sub>c</sub>	V/f <sub>c</sub>	0.02	0.01	0.05		
• β final		1.94	2.11	2.01		
• θ final		41.07	38.14	39.99	degree	
• Total area of transverse reinf.	A <sub>v</sub>	402	804	402	mm <sup>2</sup>	
• Diameter of stirrup	Ø	D 14	D 10	D 14	mm	
• Number of stirrup within distance s	n	4	2	4	bar	
• Total area of stirrup	A <sub>v</sub>	615.75	157.08	615.75		
• The shear resistance of concrete:	V <sub>c</sub>	174.88	200.86	180.73	kN	
• The shear resistance of stirrup	V <sub>s</sub>	123.53	20.99	132.10	kN	
• Value	0.25*f <sub>c</sub> *b <sub>v</sub> *d <sub>v</sub>	1356.25	1512.50	1356.25	kN	
• The nominal shear resistance:	V <sub>n</sub>	298.42	221.85	312.83	kN	
• The factored shear resistance	V <sub>r</sub>	268.58	199.67	281.55	kN	
• Check	V <sub>r</sub> > V <sub>u</sub>	O.K	O.K	O.K		
•Requiring transverse reinforcement	V <sub>u</sub> > 0.5*Φ*V <sub>c</sub>	Need	Not required	Need		
•Check minimum transverse reinforcement	A <sub>v</sub> > 0.083*(f <sub>c</sub> <sup>0.5</sup> )*b <sub>v</sub> *s/f <sub>y</sub>	O.K	not required	O.K		

<b>Check crack</b>					
<b>Interior force combination</b>					
• Factored moment	$M_u$	5.26E+01	5.90E+01	4.36E+01	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f_c}$	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis	$y_t = h - c$	264	264	264	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	6	7	5	MPa
• Check	$f_r >$	0.8 $\cdot f_r$	0.8 $\cdot f_r$	0.8 $\cdot f_r$	
		check crack	check crack	check crack	
• Crack width parameter	$Z$	= 17500	= 17500	= 17500	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 8.00	= 8.00	= 8.00	
• The distance from extreme fiber to the neutral axis	$c$	= 88.70	= 92.83	= 88.70	mm
• Effective moment of inertia	$J$	4.44E+08	5.53E+08	4.44E+08	mm <sup>4</sup>
• Arm	$de - c$	= 128.30	= 149.17	= 128.30	mm
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (de - c) / J$	= 121.48	= 127.33	= 100.69	MPa
• Area of concrete having the same centroid as the principal tensile reinforcement divided by number of bars	$A$	= 12500	= 12500	= 12500	mm <sup>2</sup>
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 194.80	= 194.80	= 194.80	Mpa
• Check condition	$f_s < f_{sa}$	O.K	O.K	O.K	
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	

## BOX CULVERT CALCULATION SHEET

### 1. General

- Group : 9
- Dimension : 2x(2.0x2.0) m
- Covering height :  $0.6 \leq H \leq 4.5$  m
- Live load : HL93
- Design standard: 22TCN-272-05
- Unit : KN and m, N and mm

### 2. Material property

#### 2.1. Concrete

- Compressive strength of cylindrical at 28 days:  $f_c = 25$  MPa
- Concrete density  $\gamma_c = 24.5$  KN/m<sup>3</sup>
- Elastic modulus  $E_c = 0.043 \cdot \gamma_c^{1.5} \cdot \sqrt{f_c} = 26875$  N/mm<sup>2</sup>
- Tensile strength of concrete:  $f_t = 0.63 \cdot \sqrt{f_c} = 3.15$  N/mm<sup>2</sup>

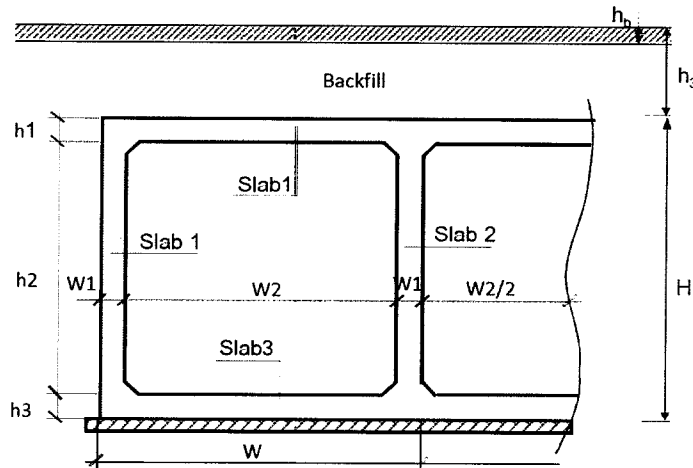
#### 2.2. Steel

- Elastic module of steel :  $E_s = 200000$  N/mm<sup>2</sup>
- Liquid limit:  $f_y = 400$  N/mm<sup>2</sup>

#### 2.2. Pavement and backfill

- Thickness of Asphalt pavement  $t = 0.16$  m
- Elastic module of ground soil  $E_o = 7064$  KN/m<sup>2</sup>
- Unit weight of soil  $\gamma_s = 17.66$  KN/m<sup>3</sup>
- Seftweight of Pavement  $\gamma_{as} = 22$  KN/m<sup>3</sup>
- Intenal friction angle of soil  $\phi'_f = 30$  deg
- Friction angle between soil and wall  $\delta = 0$  deg

### 3. Dimention of Box culvert



BOX CULVERT DIMENSION			
Item	Unit	Symbol	Value
Thickness of slab 1	m	$h_1$	0.250
Thickness of slab 2	m	$w_1$	0.250
Thickness of slab 3	m	$h_3$	0.250
Height of box culvert	m	$H$	2.500
Height of box culvert	m	$h_2$	2.000
Height of pavement structure	m	$h_b$	0.160
Height of backfilling on top of culvert	m	$h_3$	0.6 ~ 4.5
Span length	m	$w_2$	2.000
Culvert width	m	$W$	2.500

## 4. Loading

### 4.1. Deadload

- Deadload of box culvert (DC) will be automatic calculate by Midas program with selfweight of concrete is:  $\gamma_c = 24.5 \text{ (Mpa)}$
- Deadload of pavement (DW) will be automatic calculate by Midas program with selfweight of pavement is:  $\gamma_{as} = 22 \text{ (Mpa)}$

### 4.2. Live load

- Where the depth of fill is less than 600mm, the effect of fill on the distribution of live load shall be neglected.
- The uniformly distribution of wheel where covering depth  $\geq 600 \text{ mm}$  determined follow A 3.6.1.2.6.
- Impact load determined follow A 3.6.2.2.
- Where the depth of fill exceeds 600 mm, wheel loads may be considered to be uniformly distributed over rectangular area with sides equal to the dimension of the tire contact area as A 3.6.1.2.5, and increased by either 1.15 times the depth of the fill in select granular backfill, or the depth of the fill in all other cases.
- For single span culverts, the effects of live load may be neglected where the depth of fill is  $\geq 2400\text{mm}$  and exceeds the span length.
- For multiple span culverts, the effects of live load may be neglected where the depth of fill exceeds the distance between faces of end walls.
- Where such areas from several wheels overlap, the total load shall be uniformly distributed over the area.
- The dynamic load allowance for culverts shall be taken as:

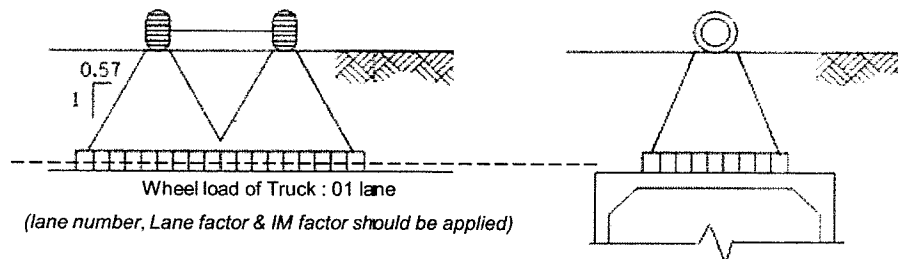
$$IM = 33 \cdot (1.0 - 4.1 \times 10^{-4} \cdot De) \quad (3.6.2.2.1)$$

#### • Design truck:

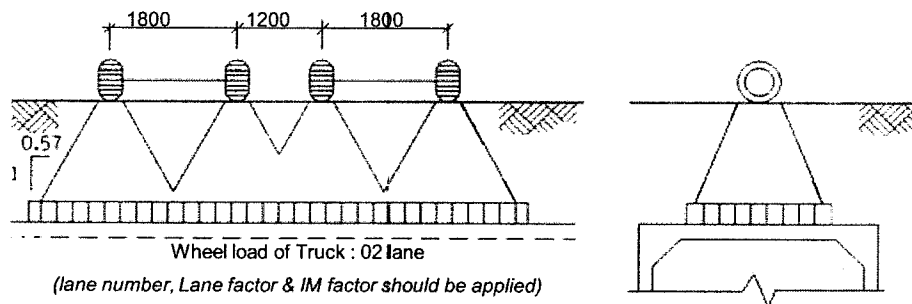
- Estimate for impact factor and distributed area of wheel

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
0.6	145	24.88	510	361	1200	1051
4.5	145	0.00	510	289	5685	5464

Distribution of wheel load for 1 lane



Distribution of wheel load for 2 lane



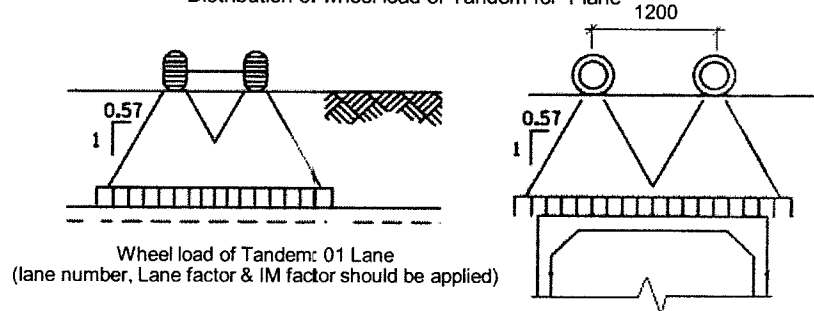
Distributed wheel load of truck

Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>truck -1 lane</sub> (Kn/m)	LL <sub>truck -2 lane</sub> (Kn/m)
0.6	145	1200	1051	57.47	57.47
4.5	145	5685	5464	4.09	4.09

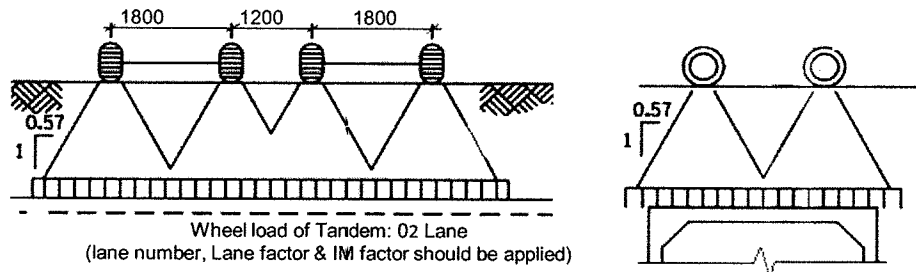
• **Tandem:**

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
0.6	110	24.88	510	274	1200	964
4.5	110	0.00	510	219	5685	5394

Distribution of wheel load of Tandem for 1 lane



Distribution of wheel load of Tandem for 2 lane



Distributed wheel load of Tandem

Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>tandem -1 lane</sub> (Kn/m)	LL <sub>tandem -2 lane</sub> (Kn/m)
0.6	145	1200	964	47.54	47.54
4.5	145	5685	5394	3.03	4.85

- Design live load applied to structure:  $\text{Max(LL)} = 57.47$  (Kn/m) with covering depth 0.6 m  
 $= 4.85$  (Kn/m) with covering depth 4.5 m

• **Lane load**

- Lane load distributed on 1 m  $= 3.10$  kN/m

**4.2.1. Surcharge load (LS)**

-Where a surcharge load is present, a constant horizontal earth pressure shall be added to the basic earth pressure.

This constant earth pressure may be taken as

$$D_p = k \cdot \gamma_s \cdot g \cdot h_{eq} (x10^{-4}) \quad (3.11.6.1-1)$$

Where:

- $D_p$  = constant horizontal earth pressure due to uniform surcharge load applied (Mpa)
- $k$  = coefficient of earth pressure
- $\gamma_s$  = density of soil (kg/m<sup>3</sup>)
- $h_{eq}$  = height of soil equivalent to design truck (mm).

The wall height: 0.6 ~ 4.5 m

Wall height(mm)	heq (mm)	Covering	Wall height (mm)	$h_{eq}$ (m)	$D_p$ (Kn/m <sup>2</sup> )
< 1500.	1700	0.60 m 4.50 m	3100 7000	1185.33 710.00	6.98 4.18
3000	1200				
6000	760				
> 9000.	610				



#### 4.3. Earth Pressure (EV & EH):

##### 4.3.1. Vertical earth pressure (EV) (A12.11.2.2)

- The factor of vertical earth pressure

$$F_e = \text{MIN}(1+0.2 \cdot h_3/W, 1.15)$$

→ Vertical earth pressure on top slab of culvert

$$EV = F_e \cdot \gamma_s \cdot h$$

Covering ( $h_3$ )	$F_e$	$\gamma_s$ (Kn/m <sup>3</sup> )	EV (Kn/m)
0.60 m	1.048	17.66	11.10
4.50 m	1.150	17.66	91.38

##### 4.3.2. Horizontal earth pressure (EH)

- Basic earth pressure shall be assumed to be linearly proportional to the depth of earth and taken as.

$$P_h = K_a \cdot \gamma_s \cdot g \cdot Z \cdot 10^{-9} \quad (3.11.5.1-1)$$

In which:

$P_h$  : horizontal earth pressure at the depth of Z (N/mm<sup>2</sup>)

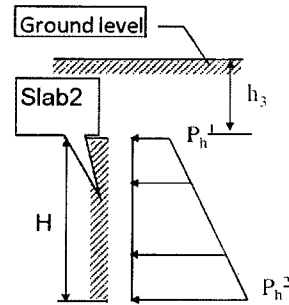
- + Lateral earth pressure applied on the plate as figure

$$P_h^1 = K_a \cdot \gamma_s \cdot g \cdot h_3 \cdot 10^{-9}$$

$$P_h^2 = K_a \cdot \gamma_s \cdot g \cdot (H+h_3) \cdot 10^{-9}$$

in which:

- $P_h$  : Horizontal earth pressure (N/mm)
- $K_a$  : active earth pressure coefficient  $K_a = 0.33$
- $\gamma_s$  : Density of soil (kg/m<sup>3</sup>)  $\gamma_s = 1800$
- $g$  : Gravitational acceleration (m/s<sup>2</sup>)  $g = 9.81$
- $\varphi$  : Angle of internal friction  $\varphi = 30 \text{ deg}$
- $h_3$  : filling height from top of box culvert (mm)
- $H$  : Total height of box culvert (mm)

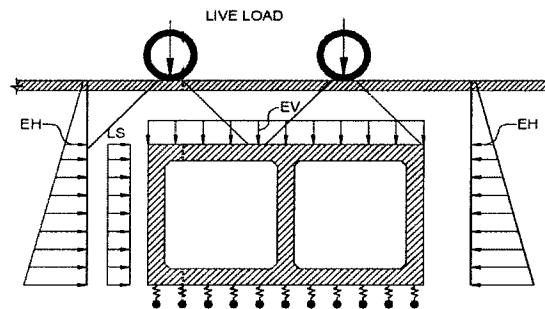


Covering	$K_a$	$\gamma_s$ (Kg/m <sup>3</sup> )	$g$ (m/s <sup>2</sup> )	$P_h^1$ (Kn/m <sup>2</sup> )	$P_h^2$ (Kn/m <sup>2</sup> )
0.60 m	0.33	1800.	9.81	3.53	18.25
4.50 m	0.33	1800.	9.81	26.49	41.20

#### 5. Load combination

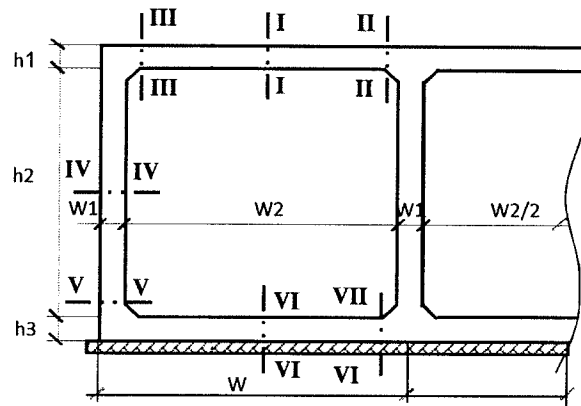
Load combination and load combination factor shall be taken as Table 3.4.1-1

State	Mark	Str. I-A	Str. I-B	Str. I-C	Str. III-A	Str. III-B	Service I
Dead load of structural	DC	1.25	1.25	0.90	0.90	1.25	1.00
Dead load of wearing	DW	1.50	1.50	0.65	0.65	1.50	1.00
Vertical earth pressure	EV	1.30	1.30	0.90	0.90	1.30	1.00
Horizontal earth pressure	EH	1.50	0.90	1.50	1.50	1.50	1.00
Live load	LL	1.75	1.75	1.75	1.35	1.35	1.00
Live load surcharge	LS	1.75	1.75	1.75	1.35	1.35	1.00



Model of structural of culvert by midas program

6. Design force applied to sections:



Design section

Table of Internal force with covering height  $h = 0.6 \text{ m}$

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	37.30	15.80	-65.90	25.60	10.30	-47.20
II - II	-69.80	152.60	-65.90	48.60	93.30	-47.20
III - III	-35.40	132.50	-65.90	-28.90	79.70	-47.20
IV - IV	3.20	0.00	-149.40	1.60	0.00	-89.90
V - V	-36.80	68.90	-156.90	-28.75	43.80	-95.90
VI - VI	37.80	47.40	-78.10	23.50	29.80	-61.00
VII - VII	-55.90	159.15	-78.10	-35.60	99.18	-61.00

Table of Internal force with covering height  $h = 4.5 \text{ m}$

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	24.40	13.50	-71.90	18.30	9.60	-47.20
II - II	-61.90	143.10	-71.90	-44.70	105.80	-47.20
III - III	-20.50	103.20	-71.90	-13.30	74.80	-47.20
IV - IV	15.40	0.00	-124.80	15.40	0.00	-89.90
V - V	-29.40	84.00	-133.80	-27.50	56.20	-95.90
VI - VI	25.50	33.70	-91.30	18.80	23.10	-61.00
VII - VII	-63.80	156.30	-91.30	-48.60	123.60	-61.00

Table of Internal force applied to design section

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	37.30	15.80	71.90	25.60	10.30	47.20
II - II	69.80	152.60	71.90	48.60	105.80	47.20
III - III	35.40	132.50	71.90	28.90	79.70	47.20
IV - IV	15.40	0.00	149.40	15.40	0.00	89.90
V - V	36.80	84.00	156.90	28.75	56.20	95.90
VI - VI	37.80	47.40	91.30	23.50	29.80	61.00
VII - VII	63.80	159.15	91.30	48.60	123.60	61.00

# 7. Ultimate check, shear capacity check and crack control

Item		Section I-I (Bottom bar)	Section II-II (Top bar)	Section III-III (Inside bar)	Section IV-IV	Unit
• Factored Flexural moment	$M_u$	37.30	69.80	35.40	15.40	kN.m
• Factored Shear force	$V_u$	15.80	152.60	132.50	-	kN
• Factored Nominal force	$N_u$	71.90	71.90	71.90	149.40	kN
• Height of Section	$h$	250	250	250	250	mm
• Width of section	$b$	1000	1000	1000	1000	mm
• Section area	$A_c$	250000	250000	250000	250000	mm <sup>2</sup>
• Moment of inertia of concrete section	$I_g$	1.3E+09	1.3E+09	1.3E+09	1.3E+09	mm <sup>4</sup>
• Tension reinforcement	Distance from tension reinf. to extreme compression fiber	$d_c$	58	84	58	mm
	Reinf. Diameter	$\varnothing$	D16	D18	D16	mm
	Space	@	125	125	125	mm
	Number of bar	$n$	8	8	8	bar
	Total area of reinf.	$A_s$	1608	2036	1608	mm <sup>2</sup>
• comp. reinforcement:	Distance from compressive reinf. to extreme		83	83	83	mm
	Tension fiber					
	Diameter		D16	D16	D16	mm
	Reinf. Space		250	250	250	mm
	Number of bar		4	4	4	bar
	Total area of reinf.	$A'_s$	804	804	804	mm <sup>2</sup>
<b>Check Flexural Moment</b>						
• Resistance factor	$\Phi$	0.90	0.90	0.90	0.90	
• The corresponding effective	$d_e$	192	166	192	192	mm
• Stress block factor	$\beta_1$	0.85	0.85	0.85	0.85	
• Depth of the equivalent stress block = $c \cdot \beta_1$	$a$	30.28	38.32	30.28	30.28	mm
• Distance from extreme compression fiber to the neutr	$c$	35.62	45.08	35.62	35.62	mm
• The nominal flexural resistance:	$M_n$	114	120	114	114	kN.m
• Factored flexural resistance	$M_r = \Phi M_n$	102	108	102	102	kN.m
• Check condition	$M_r > M_u$	O.K	O.K	O.K	O.K	
<b>Minimum Reinforcement</b>						
• Cracking moment	$M_{cr} = 1.2 M_{cr}$	39.38	39.38	39.38	39.38	Kn.m
• Check	$M_r > \min(1.2 M_{cr}, 1.33 M_u)$	O.K	O.K	O.K	O.K	
<b>Maximum Reinforcement</b>						
• Obligation Condition	$c/d_e$	0.19	0.27	0.19	0.19	
• Check	$c/d_e < 0.42$	O.K	O.K	O.K	O.K	
<b>Check shear resistance</b>						
• Factored Shear force	$V_u$	15.80	152.60	132.50	-	kN
• Resistance factor	$\Phi$	0.90	0.90	0.90	0.90	
• The effective shear depth	$d_v$	192	180	192	192	mm
• Effective width	$b_v$	1000	1000	1000	1000	mm
• Angle of inclination of diagonal compressive stress	$\theta$	45	39	36	45	degree
• Angle of inclination of transverse reinf. To longitudinal	$\alpha$	90	90	90	90	degree
• Factor indicating ability of diagonally cracked concrete to transmit tension	$\beta$	2.00	2.00	2.25	2.00	
• Value	$0.1 \cdot f'_c \cdot b_v \cdot d_v$	480	450	480	480	kN
• Max spacing of transverse reinforcement	$s$	154	144	154	154	mm
• Spacing of stirrup	$s$	500	250	250	500	mm
• Diameter of transverse reinforcement	$\varnothing$	D 16	D 18	D 16	D 16	
• Number of transverse reinf. within distance s	$n$	4	2	2	4	bar
• Assume	$\theta$	45.00	38.65	35.66	45.00	degree
• Strain in tensile reinforcement	$\epsilon_s \cdot 1000$	7.40E-01	1.28E+00	9.72E-01	4.82E-01	
If $\epsilon_s < 0$ , multiple with reduce factor	$\Phi_c$	-	-	-	-	
• Ratio of shear stress and $f'_c$	$V/f'_c$	0.00	0.04	0.03	0.00	
• $\beta$ final		2.00	2.08	2.25	2.00	
• $\theta$ final		45.00	38.75	35.66	45.00	degree
• Total area of transverse reinf.	$A_v$	804	509	402	804	mm <sup>2</sup>
• Diameter of stirrup	$\varnothing$	D 10	D 14	D 14	D 10	mm
• Number of stirrup within distance s	$n$	2	4	4	2	bar
• Total area of stirrup	$A_v$	157.08	615.75	615.75	157.08	
• The shear resistance of concrete:	$V_c$	159.36	149.40	178.94	159.36	kN
• The shear resistance of stirrup	$V_s$	10.76	118.07	150.90	10.76	kN
• Value	$0.25 \cdot f'_c \cdot b_v \cdot d_v$	1200.00	1125.00	1200.00	1200.00	kN
• The nominal shear resistance:	$V_n$	170.12	267.47	329.84	170.12	kN
• The factored shear resistance	$V_r$	153.11	240.72	296.86	153.11	kN
• Check	$V_r > V_u$	O.K	O.K	O.K	O.K	
• Requiring transverse reinforcement	$V_u > 0.5 \cdot \Phi \cdot V_c$	Not required	Need	Need	Not required	
• Check minimum transverse reinforcement	$A_v > 0.083 \cdot (f'_c)^{0.5} \cdot b_v \cdot s / f_y$	not required	O.K	O.K	not required	

Check crack						
<b>Interior force combination</b>						
• Factored moment	$M_u$	2.56E+01	4.86E+01	2.89E+01	1.54E+01	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f'_c}$	3.15	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis:	$y_t = h - c$	214	205	214	214	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	4	8	5	3	MPa
• Check	$f_r >$	0.8*f <sub>r</sub>	0.8*f <sub>r</sub>	0.8*f <sub>r</sub>	0.8*f <sub>r</sub>	
	check crack	check crack	check crack	check crack	check crack	
• Crack width parameter	$Z$	= 17500	= 17500	= 17500	= 17500	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 8.00	= 8.00	= 8.00	= 8.00	
• The distance from extreme fiber to the neutral axis	$c$	= 84.33	= 91.60	= 84.33	= 84.33	mm
• Effective moment of inertia	$J$	3.49E+08	3.46E+08	3.49E+08	3.49E+08	mm <sup>4</sup>
• Arm	$d - c$	= 107.67	= 74.40	= 107.67	= 107.67	mm
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (d - c) / J$	= 63.17	= 83.52	= 71.31	= 38.00	MPa
• Area of concrete having the same centroid as the principal tensile reinforcement divided by number of bars	$A$	= 12500	= 12500	= 12500	= 12500	mm <sup>2</sup>
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 194.80	= 193.69	= 194.80	= 194.80	Mpa
• Check condition	$f_s < f_{sa}$	O.K	O.K	O.K	O.K	
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	O.K	

# 7. Ultimate check, shear capacity check and crack control

Item		Section V-V (outside bar)	Section VI-VI (Top bar)	Section VII-VII (Bottom bar)	Unit
• Factored Plexural moment	$M_u$	36.80	37.80	63.80	kN.m
• Factored Shear force	$V_u$	84.00	47.40	159.15	kN
• Factored Nominal force	$N_u$	156.90	91.30	91.30	kN
• Hight of Section	$h$	250	250	250	mm
• Width of section	$b$	1000	1000	1000	mm
• Section area	$A_c$	250000	250000	250000	mm <sup>2</sup>
• Moment of inertia of concrete section	$I_g$	1.3E+09	1.3E+09	1.3E+09	mm <sup>4</sup>
• Tension reinforcement Distance from tension reinf. to extreme compression fiber	$d_c$	83	83	83	mm
Reinf. Diameter	$\varnothing$	D16	D16	D16	mm
Space	@	125	125	125	mm
Number of bar	$n$	9	9	9	bar
Total area of reinf.	$A_s$	1810	1810	1810	mm <sup>2</sup>
• comp. reinforcement: Distance from compressive reinf. to extreme Tension fiber		58	58	58	mm
Diameter		D16	D16	D16	mm
Reinf. Space		250	250	250	mm
Number of bar		5	5	5	bar
Total area of reinf.	$A'_s$	1005	1005	1005	mm <sup>2</sup>
<b>Check Flexural Moment</b>					
• Resistance factor	$\Phi$	0.90	0.90	0.90	
• The corresponding effective	$d_e$	167	167	167	mm
• Stress block factor	$\beta_1$	0.85	0.85	0.85	
• Depth of the equivalent stress block = $c \cdot \beta_1$	$a$	34.06	34.06	34.06	mm
• Distance from extreme compression fiber to the neut	$c$	40.07	40.07	40.07	mm
• The nominal flexural resistance:	$M_n$	109	109	109	kN.m
• Factored flexural resistance	$M_r = \Phi \cdot M_n$	98	98	98	kN.m
• Check condition	$M_r > M_u$	O.K	O.K	O.K	
<b>Minimum Reinforcement</b>					
• Cracking moment	$1.2M_{cr}$	39.38	39.38	39.38	Kn.m
• Check	$M_r > \min(1.2M_{cr}, 1.33M_u)$	O.K	O.K	O.K	
<b>Maximum Reinforcement</b>					
• Obligation Condition	$c/d_e$	0.24	0.24	0.24	
• Check	$c/d_e < 0.42$	O.K	O.K	O.K	
<b>Check shear resistance</b>					
• Factored Shear force	$V_u$	84.00	47.40	159.15	kN
• Resistance factor	$\Phi$	0.90	0.90	0.90	
• The effective shear deepth	$d_v$	180	180	180	mm
• Effective width	$b_v$	1000	1000	1000	mm
• Angle of inclination of diagonal compressive stress	$\theta$	35	34	40	degree
• Angle of inclination of transverse reinf. To longitudi	$\alpha$	90	90	90	degree
• Factor indicating ability of diagonally cracked concrete to transmit tension	$\beta$	2.26	2.00	2.02	
• Value	$0.1 \cdot f'_c \cdot b_v \cdot d_v$	450	450	450	kN
• Max spacing of transverse reinforcement	$s$	144	144	144	mm
• Spacing of stirrup	$s$	250	500	250	mm
• Diameter of transverse reinforcement	$\varnothing$	D 16	D 16	D 16	
• Number of transverse reinf. within distance s	$n$	2	4	2	bar
• Assume	$\theta$	35.36	33.66	39.72	degree
• Strain in tensile reinforcement	$\epsilon_s$	9.45E-01	8.05E-01	1.37E+00	
If $\epsilon_s < 0$ , multiple with reduce factor	$\Phi_c$	-	-	-	
• Ratio of shear stress and $f'_c$	$V/f'_c$	0.02	0.01	0.04	
• $\beta$ final		2.26	2.34	2.02	
• $\theta$ final		35.34	33.66	39.70	degree
• Total area of transverse reinf.	$A_v$	402	804	402	mm <sup>2</sup>
• Diameter of stirrup	$\varnothing$	D 14	D 10	D 14	mm
• Number of stirrup within distance s	$n$	4	2	4	bar
• Total area of stirrup	$A_v$	615.75	157.08	615.75	
• The shear resistance of concrete:	$V_c$	168.87	149.40	151.10	kN
• The shear resistance of stirrup	$V_s$	144.10	20.24	111.49	kN
• Value	$0.25 \cdot f'_c \cdot b_v \cdot d_v$	1125.00	1125.00	1125.00	kN
• The nominal shear resistance:	$V_n$	312.97	169.64	262.59	kN
• The factored shear resistance	$V_r$	281.68	152.67	236.33	kN
• Check	$V_r > V_u$	O.K	O.K	O.K	
• Requiring transverse reinforcement	$V_u > 0.5 \cdot \Phi \cdot V_c$	Need	Not required	Need	
• Check minimum transverse reinforcement	$A_v > 0.083 \cdot (f'_c)^{0.5} \cdot b_v \cdot s / f_y$	O.K	not required	O.K	

<b>Check crack</b>					
<b>Interior force combination</b>					
• Factored moment	$M_u$	2.88E+01	2.35E+01	4.86E+01	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f_c}$	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis	$y_t = h - c$	210	210	210	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	5	4	8	MPa
• Check	$f_r >$	0.8*f <sub>r</sub>	0.8*f <sub>r</sub>	0.8*f <sub>r</sub>	
		check crack	check crack	check crack	
• Crack width parameter	$Z$	= 17500	= 17500	= 17500	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 8.00	= 8.00	= 8.00	
• The distance from extreme fiber to the neutral axis	$c$	= 85.50	= 85.50	= 85.50	mm
• Effective moment of inertia	$J$	3.05E+08	3.05E+08	3.05E+08	mm <sup>4</sup>
• Arm	$de - c$	= 81.50	= 81.50	= 81.50	mm
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (de - c) / J$	= 61.56	= 50.32	= 104.06	MPa
• Area of concrete having the same centroid as the principal tensile reinforcement divided by number of bars	$A$	= 11111	= 11111	= 11111	mm <sup>2</sup>
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 202.60	= 202.60	= 202.60	Mpa
• Check condition	$f_s < f_{sa}$	O.K	O.K	O.K	
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	

## BOX CULVERT CALCULATION SHEET

### 1. General

- Group : 12
- Dimension : 2x(3,0x3.0) m
- Covering height :  $0.6 \leq H \leq 4.5\text{m}$
- Live load : HL93
- Design standard: 22TCN-272-05
- Unit : KN and m, N and mm

### 2. Material property

#### 2.1. Concrete

- Compressive strength of cylindrical at 28 days:  $f'_c = 25$  MPa
- Concrete density:  $\gamma_c = 24.5$  KN/m<sup>3</sup>
- Elastic modulus:  $E_c = 0.043 \cdot \gamma_c^{1.5} \cdot \sqrt{f'_c} = 26875$  N/mm<sup>2</sup>
- Tensile strength of concrete:  $f_r = 0.63 \cdot \sqrt{f'_c} = 3.15$  N/mm<sup>2</sup>

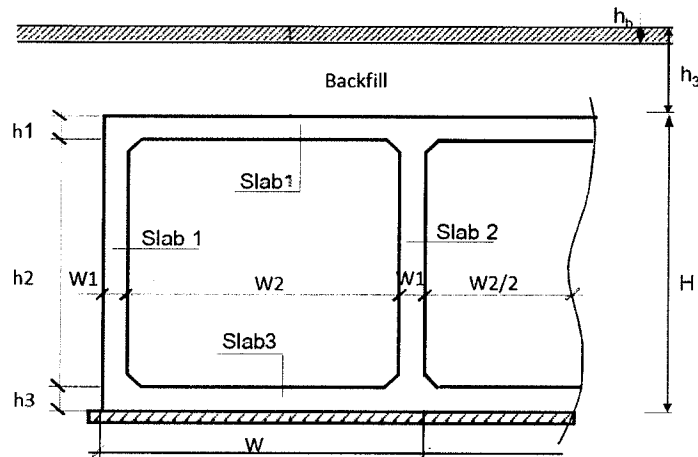
#### 2.2. Steel

- Elastic module of steel :  $E_s = 200000$  N/mm<sup>2</sup>
- Liquid limit:  $f_y = 400$  N/mm<sup>2</sup>

#### 2.2. Pavement and backfill

- Thickness of Asphalt pavement:  $t = 0.16$  m
- Elastic module of ground soil:  $E_o = 6793$  KN/m<sup>2</sup>
- Unit weight of soil:  $\gamma_s = 17.66$  KN/m<sup>3</sup>
- Seftweight of Pavement:  $\gamma_{as} = 22$  KN/m<sup>3</sup>
- Internal friction angle of soil:  $\phi'_f = 30$  deg
- Friction angle between soil and wall:  $\delta = 0$  deg

### 3. Dimention of Box culvert



BOX CULVERT DIMENSION			
Item	Unit	Symbol	Value
Thickness of slab 1	m	$h_1$	0.350
Thickness of slab 2	m	$w_1$	0.350
Thickness of slab 3	m	$h_3$	0.350
Height of box culvert	m	H	3.700
Height of box culvert	m	$h_2$	3.000
Height of pavement structure	m	$h_b$	0.160
Height of backfilling on top of culvert	m	$h_3$	0.6 ~ 4.5
Span length	m	$w_2$	3.000
Culvert width	m	W	3.700

## 4. Loading

### 4.1. Deadload

- Deadload of box culvert (DC) will be automatic calculate by Midas program with selfweight of concrete is:  $\gamma_c = 24.5 \text{ (Mpa)}$
- Deadload of pavement (DW) will be automatic calculate by Midas program with selfweight of pavement is:  $\gamma_{as} = 22 \text{ (Mpa)}$

### 4.2. Live load

- Where the depth of fill is less than 600mm, the effect of fill on the distribution of live load shall be neglected.
- The uniformly distribution of wheel where covering depth  $\geq 600 \text{ mm}$  determined follow A 3.6.1.2.6.
- Impact load determined follow A 3.6.2.2.
- Where the depth of fill exceeds 600 mm, wheel loads may be considered to be uniformly distributed over rectangular area with sides equal to the dimension of the tire contact area as A 3.6.1.2.5, and increased by either 1.15 times the depth of the fill in select granular backfill, or the depth of the fill in all other cases.
- For single span culverts, the effects of live load may be neglected where the depth of fill is  $\geq 2400\text{mm}$  and exceeds the span length.
- For multiple span culverts, the effects of live load may be neglected where the depth of fill exceeds the distance between faces of end walls.
- Where such areas from several wheels overlap, the total load shall be uniformly distributed over the area.
- The dynamic load allowance for culverts shall be taken as:

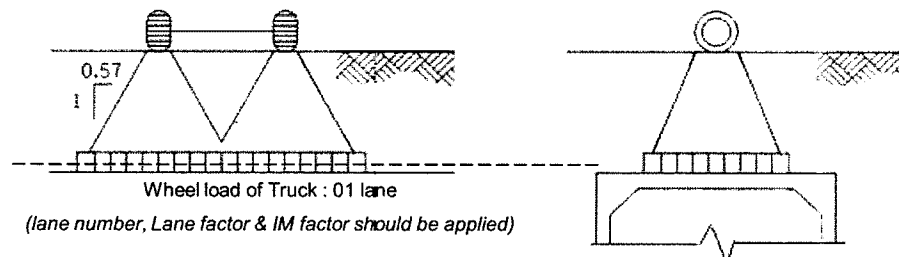
$$IM = 33 * (1.0 - 4.1 \times 10^{-4} \cdot De) \quad (3.6.2.2.1)$$

#### • Design truck:

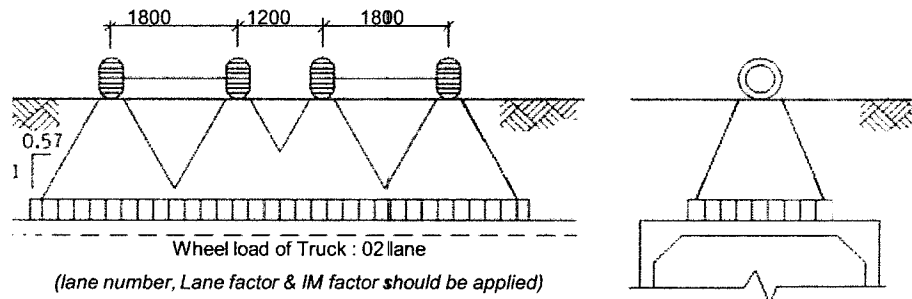
- Estimate for impact factor and distributed area of wheel

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
0.6	145	24.88	510	361	1200	1051
4.5	145	0.00	510	289	5685	5464

Distribution of wheel load for 1 lane



Distribution of wheel load for 2 lane



Distributed wheel load of truck

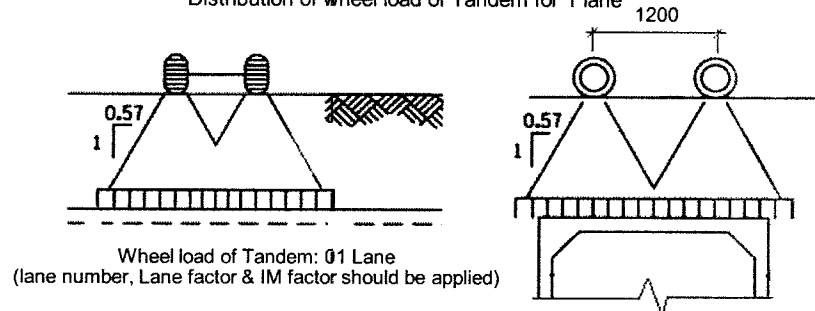
Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>truck -1 lane</sub> (Kn/m)	LL <sub>truck -2 lane</sub> (Kn/m)
0.6	145	1200	1051	57.47	57.47
4.5	145	5685	5464	4.09	4.09



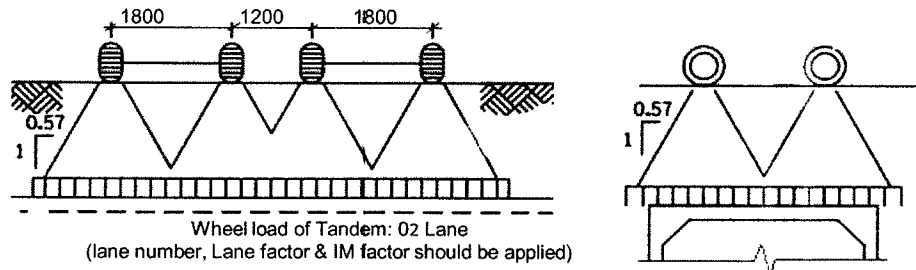
• **Tandem:**

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
0.6	110	24.88	510	274	1200	964
4.5	110	0.00	510	219	5685	5394

Distribution of wheel load of Tandem for 1 lane



Distribution of wheel load of Tandem for 2 lane



Distributed wheel load of Tandem

Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>tandem - 1 lane</sub> (Kn/m)	LL <sub>tandem - 2 lane</sub> (Kn/m)
0.6	145	1200	964	47.54	47.54
4.5	145	5685	5394	3.03	4.85

- Design live load applied to structure:  $\text{Max(LL)} = 57.47$  (Kn/m) with covering depth 0.6 m  
 $= 4.85$  (Kn/m) with covering depth 4.5 m

• **Lane load**

- Lane load distributed on 1 m  $= 3.10$  kN/m

**4.2.1. Surcharge load (LS)**

-Where a surcharge load is present, a constant horizontal earth pressure shall be added to the basic earth pressure.

This constant earth pressure may be taken as

$$D_p = k \cdot \gamma_s \cdot g \cdot h_{eq} (x10^{-3}) \quad (3.11.6.1-1)$$

Where:

- $D_p$  = constant horizontal earth pressure due to uniform surcharge load applied (Mpa)
- $k$  = coefficient of earth pressure
- $\gamma_s$  = density of soil (kg/m<sup>3</sup>)
- $h_{eq}$  = height of soil equivalent to design truck (mm).

The wall height: 0.6 ~ 4.5 m

Wall height(mm)	heq (mm)	Covering	Wall height (mm)	$h_{eq}$ (m)	$D_p$ (Kn/m <sup>2</sup> )
< 1500.	1700	0.60 m 4.50 m	4300 8200	1009.33 650.00	5.94 3.83
3000	1200				
6000	760				
> 9000.	610				

#### 4.3. Earth Pressure (EV & EH):

##### 4.3.1. Vertical earth pressure (EV) (A12.11.2.2)

- The factor of vertical earth pressure

$$F_e = \text{MIN}(1+0.2 \cdot h_3/W, 1.15)$$

→ Vertical earth pressure on top slab of culvert

$$EV = F_e \cdot \gamma_s \cdot h$$

Covering ( $h_3$ )	$F_e$	$\gamma_s$ (Kn/m <sup>3</sup> )	EV (Kn/m)
0.60 m	1.032	17.66	10.94
4.50 m	1.150	17.66	91.38

##### 4.3.2. Horizontal earth pressure (EH)

- Basic earth pressure shall be assumed to be linearly proportional to the depth of earth and taken as.

$$P_h = K_a \cdot \gamma_s \cdot g \cdot Z \cdot 10^{-9} \quad (3.11.5.1-1)$$

In which:

$P_h$  : horizontal earth pressure at the depth of Z (N/mm<sup>2</sup>)

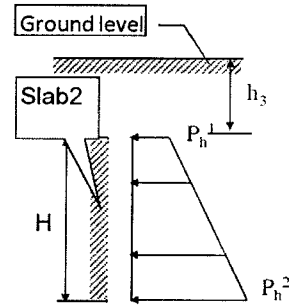
- + Lateral earth pressure applied on the plate as figure

$$P_h^1 = K_a \cdot \gamma_s \cdot g \cdot h_3 \cdot 10^{-9}$$

$$P_h^2 = K_a \cdot \gamma_s \cdot g \cdot (H+h_3) \cdot 10^{-9}$$

in which:

- $P_h$  : Horizontal earth pressure (N/mm)
- $K_a$  : active earth pressure coefficient  $K_a = 0.33$
- $\gamma_s$  : Density of soil (kg/m<sup>3</sup>)  $\gamma_s = 1800$
- $g$  : Gravitational acceleration (m/s<sup>2</sup>)  $g = 9.81$
- $\varphi$  : Angle of internal friction  $\varphi = 30 \text{ deg}$
- $h_3$  : filling height from top of box culvert (mm)
- $H$  : Total height of box culvert (mm)

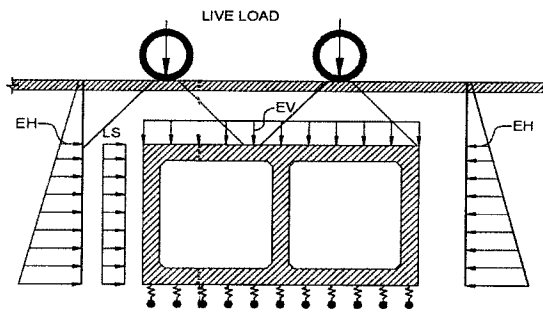


Covering	$K_a$	$\gamma_s$ (Kg/m <sup>3</sup> )	$g$ (m/s <sup>2</sup> )	$P_h^1$ (Kn/m <sup>2</sup> )	$P_h^2$ (Kn/m <sup>2</sup> )
0.60 m	0.33	1800	9.81	3.53	25.31
4.50 m	0.33	1800	9.81	26.49	48.27

#### 5. Load combination

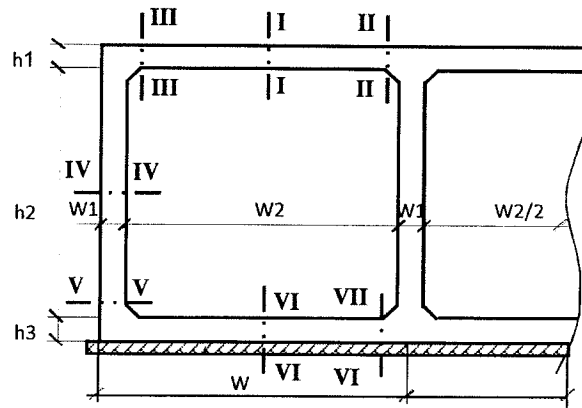
Load combination and load combination factor shall be taken as Table 3.4.1-1

State	Mark	Str. II-A	Str. I-B	Str. I-C	Str. III-A	Str. III-B	Service I
Dead load of structural	DC	1.25	1.25	0.90	0.90	1.25	1.00
Dead load of wearing	DW	1.50	1.50	0.65	0.65	1.50	1.00
Vertical earth pressure	EV	1.30	1.30	0.90	0.90	1.30	1.00
Horizontal earth pressure	EH	1.50	0.90	1.50	1.50	1.50	1.00
Live load	LL	1.75	1.75	1.75	1.35	1.35	1.00
Live load surcharge	LS	1.75	1.75	1.75	1.35	1.35	1.00



Model of structural of culvert by midas program

6. Design force applied to sections:



Design section

Table of Internal force with covering height  $h = 0.6 \text{ m}$

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	94.10	56.20	-44.90	58.80	27.30	-25.10
II - II	-155.00	253.60	-44.90	-68.80	189.20	-25.10
III - III	-53.00	200.90	-44.90	-24.90	110.60	-25.10
IV - IV	-38.00	0.00	-239.00	-16.80	0.00	-132.20
V - V	-71.50	55.10	-247.00	-44.80	41.60	-145.30
VI - VI	91.90	31.90	-62.50	66.30	15.60	-44.20
VII - VII	-138.40	268.90	-62.50	-55.30	131.60	-44.20

Table of Internal force with covering height  $h = 4.5 \text{ m}$

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	81.50	39.30	-78.70	59.90	31.60	-64.10
II - II	-159.70	268.90	-78.70	-115.90	201.30	-64.10
III - III	-69.50	192.20	-78.70	-45.50	151.80	-64.10
IV - IV	-19.50	0.00	-222.30	-14.60	0.00	-182.40
V - V	-90.60	100.70	-238.60	-63.90	78.30	-189.80
VI - VI	89.80	24.70	-107.80	65.90	20.00	-83.60
VII - VII	-153.60	266.00	-107.80	-102.50	182.00	-83.60

Table of Internal force applied to design section

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	94.10	56.20	78.70	59.90	31.60	64.10
II - II	159.70	268.90	78.70	115.90	201.30	64.10
III - III	69.50	200.90	78.70	45.50	151.80	64.10
IV - IV	38.00	0.00	239.00	16.80	0.00	182.40
V - V	90.60	100.70	247.00	63.90	78.30	189.80
VI - VI	91.90	31.90	107.80	66.30	20.00	83.60
VII - VII	153.60	268.90	107.80	102.50	182.00	83.60

# 7. Ultimate check, shear capacity check and crack control

Item		Section I-I (Bottom bar)	Section II-II (Top bar)	Section III-III (Inside bar)	Section IV-IV	Unit
• Factored Flexural moment	$M_u$	94.10	159.70	69.50	38.00	kN.m
• Factored Shear force	$V_u$	56.20	268.90	200.90	-	kN
• Factored Nominal force	$N_u$	78.70	78.70	78.70	239.00	kN
• Height of Section	$h$	350	350	350	350	mm
• Width of section	$b$	1000	1000	1000	1000	mm
• Section area	$A_c$	350000	350000	350000	350000	mm <sup>2</sup>
• Moment of inertia of concrete section	$I_g$	3.6E+09	3.6E+09	3.6E+09	3.6E+09	mm <sup>4</sup>
• Tension reinforcement	Distance from tension reinf. to extreme compression fiber	$d_c$	58	85	58	mm
	Reinf. Diameter	⊙	D16	D20	D16	mm
	Space	@	125	125	125	mm
	Number of bar	$n$	8	8	8	bar
	Total area of reinf.	$A_s$	1608	2513	1608	mm <sup>2</sup>
• comp. reinforcement:	Distance from compressive reinf. to extreme		83	83	83	mm
	Tension fiber					
	Diameter		D16	D16	D16	mm
	Reinf. Space		250	250	250	mm
	Number of bar		4	4	4	bar
	Total area of reinf.	$A'_s$	804	804	804	mm <sup>2</sup>
<b>Check Flexural Moment</b>						
• Resistance factor	$\Phi$	0.90	0.90	0.90	0.90	
• The corresponding effective	$d_e$	292	265	292	292	mm
• Stress block factor	$\beta_1$	0.85	0.85	0.85	0.85	
• Depth of the equivalent stress block = $c \cdot \beta_1$	$a$	30.28	47.31	30.28	30.28	mm
• Distance from extreme compression fiber to the neutr	$c$	35.62	55.66	35.62	35.62	mm
• The nominal flexural resistance:	$M_n$	178	243	178	178	kN.m
• Factored flexural resistance	$M_r = \Phi \cdot M_n$	160	218	160	160	kN.m
• Check condition	$M_r > M_u$	O.K	O.K	O.K	O.K	
<b>Minimum Reinforcement</b>						
• Cracking moment	$1.2M_{cr}$	77.18	77.18	77.18	77.18	Kn.m
• Check	$M_r > \min(1.2M_{cr}, 1.33M_u)$	O.K	O.K	O.K	O.K	
<b>Maximum Reinforcement</b>						
• Obligation Condition	$c/d_e$	0.12	0.21	0.12	0.12	
• Check	$c/d_e < 0.42$	O.K	O.K	O.K	O.K	
<b>Check shear resistance</b>						
• Factored Shear force	$V_u$	56.20	268.90	200.90	-	kN
• Resistance factor	$\Phi$	0.90	0.90	0.90	0.90	
• The effective shear depth	$d_v$	292	265	292	292	mm
• Effective width	$b_v$	1000	1000	1000	1000	mm
• Angle of inclination of diagonal compressive stress	$\theta$	45	41	39	45	degree
• Angle of inclination of transverse reinf. To longitudinal	$\alpha$	90	90	90	90	degree
• Factor indicating ability of diagonally cracked concrete to transmit tension	$\beta$	2.00	2.00	2.08	2.00	
• Value	$0.1 \cdot f'_c \cdot b_v \cdot d_v$	730	663	730	730	kN
• Max spacing of transverse reinforcement	$s$	234	212	234	234	mm
• Spacing of stirrup	$s$	500	250	250	500	mm
• Diameter of transverse reinforcement	⊙	D 16	D 20	D 16	D 16	
• Number of transverse reinf. within distance s	$n$	4	2	2	4	bar
• Assume	$\theta$	45.00	41.76	37.14	45.00	degree
• Strain in tensile reinforcement	$\epsilon_s \cdot 1000$	1.21E+00	1.58E+00	1.27E+00	7.76E-01	
If $\epsilon_s < 0$ , multiple with reduce factor	$\Phi_c$	-	-	-	-	
• Ratio of shear stress and $f'_c$	$V_u/f'_c$	0.01	0.05	0.03	0.00	
• $\beta$ final		2.00	1.91	2.08	2.00	
• $\theta$ final		45.00	41.31	38.74	45.00	degree
• Total area of transverse reinf.	$A_v$	804	628	402	804	mm <sup>2</sup>
• Diameter of stirrup	⊙	D 10	D 14	D 14	D 10	mm
• Number of stirrup within distance s	$n$	2	4	4	2	bar
• Total area of stirrup	$A_v$	157.08	615.75	615.75	157.08	
• The shear resistance of concrete:	$V_c$	242.36	219.95	251.61	242.36	kN
• The shear resistance of stirrup	$V_s$	16.36	148.63	191.61	16.36	kN
• Value	$0.25 \cdot f'_c \cdot b_v \cdot d_v$	1825.00	1656.25	1825.00	1825.00	kN
• The nominal shear resistance:	$V_n$	258.72	368.58	443.21	258.72	kN
• The factored shear resistance	$V_r$	232.85	331.72	398.89	232.85	kN
• Check	$V_r > V_u$	O.K	O.K	O.K	O.K	
• Requiring transverse reinforcement	$V_u > 0.5 \cdot \Phi \cdot V_c$	Not required	Need	Need	Not required	
• Check minimum transverse reinforcement	$A_v > 0.083 \cdot (f'_c)^{0.5} \cdot b_v \cdot s / f_y$	not required	O.K	O.K	not required	

Check crack						
<b>Interior force combination</b>						
• Factored moment	$M_u$	5.99E+01	1.16E+02	4.55E+01	1.68E+01	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f_c}$	3.15	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis:	$y_t = h - c$	314	294	314	314	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	5	10	4	1	MPa
• Check	$f_r >$	0.8*f <sub>r</sub>	0.8*f <sub>r</sub>	0.8*f <sub>r</sub>	0.8*f <sub>r</sub>	
	check crack	check crack	check crack	check crack	No check	
• Crack width parameter	$Z$	= 17500	= 17500	= 17500	= 17500	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 8.00	= 8.00	= 8.00	= 8.00	
• The distance from extreme fiber to the neutral axis	$c$	= 100.51	= 125.28	= 100.51	= 100.51	mm
• Effective moment of inertia	$J$	8.10E+08	1.05E+09	8.10E+08	8.10E+08	mm <sup>4</sup>
• Arm	$d - c$	= 191.49	= 139.72	= 191.49	= 191.49	mm
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (d - c) / J$	= 113.25	= 123.63	= 86.02	= 31.76	MPa
• Area of concrete having the same centroid as the principal tensile reinforcement divided by number of bars	$A$	= 12500	= 12500	= 12500	= 12500	mm <sup>2</sup>
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 194.80	= 192.61	= 194.80	= 194.80	Mpa
• Check condition	$f_s < f_{sa}$	O.K	O.K	O.K	O.K	
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	O.K	

# 7. Ultimate check, shear capacity check and crack control

Item		Section V-V (outside bar)	Section VI-VI (Top bar)	Section VII-VII (Bottom bar)	Unit	
• Factored Plexural moment	M <sub>u</sub>	90.60	91.90	153.60	kN.m	
• Factored Shear force	V <sub>u</sub>	100.70	31.90	268.90	kN	
• Factored Nominal force	N <sub>u</sub>	247.00	107.80	107.80	kN	
• Hight of Section	h	350	350	350	mm	
• Width of section	b	1000	1000	1000	mm	
• Section area	A <sub>c</sub>	350000	350000	350000	mm <sup>2</sup>	
• Moment of inertia of concrete section	I <sub>g</sub>	3.6E+09	3.6E+09	3.6E+09	mm <sup>4</sup>	
• Tension reinforcement Distance from tension reinf. to extreme compression fiber	d <sub>c</sub>	83	83	85	mm	
	Reinf. Diameter	Ø	D16	D20	mm	
	Space	@	125	125	mm	
	Number of bar	n	8	8	bar	
	Total area of reinf.	A <sub>s</sub>	1608	1608	2513	mm <sup>2</sup>
• comp. reinforcement:	Distance from compressive reinf. to extreme Tension fiber	58	58	58	mm	
	Diameter	D16	D16	D16	mm	
	Reinf. Space	250	250	250	mm	
	Number of bar	4	4	4	bar	
	Total area of reinf.	A' <sub>s</sub>	804	804	804	mm <sup>2</sup>
Check Flexural Moment						
• Resistance factor	Φ	0.90	0.90	0.90		
• The corresponding effective	d <sub>e</sub>	267	267	265	mm	
• Stress block factor	β <sub>1</sub>	0.85	0.85	0.85		
• Depth of the equivalent stress block = c*β <sub>1</sub>	a	30.28	30.28	47.31	mm	
• Distance from extreme compression fiber to the neut	c	35.62	35.62	55.66	mm	
• The nominal flexural resistance:	M <sub>n</sub>	162	162	243	kN.m	
• Factored flexural resistance	M <sub>r</sub> = Φ·M <sub>n</sub>	146	146	218	kN.m	
• Check condition	M <sub>r</sub> > M <sub>u</sub>	O.K	O.K	O.K		
Mimimum Reinforcement						
• Cracking moment	1.2M <sub>cr</sub>	77.18	77.18	77.18	Kn.m	
• Check	Mr> min(1.2M <sub>cr</sub> , 1.33Mu)	O.K	O.K	O.K		
Maximum Reinforcement						
• Obligation Condition	c/d <sub>e</sub>	0.13	0.13	0.21		
• Check	c/d <sub>e</sub> < 0.42	O.K	O.K	O.K		
Check shear resistance						
• Factored Shear force	V <sub>u</sub>	100.70	31.90	268.90	kN	
• Resistance factor	Φ	0.90	0.90	0.90		
• The effective shear deepth	d <sub>v</sub>	267	267	265	mm	
• Effective width	b <sub>v</sub>	1000	1000	1000	mm	
• Angle of inclination of diagonal compressive stress	θ	42	39	41	degree	
• Angle of inclination of transverse reinf. To longitudi	α	90	90	90	degree	
• Factor indicating ability of diagonally cracked concrete to transmit tension	β	1.89	2.00	1.92		
• Value	0.1*f <sub>c</sub> ·b <sub>v</sub> ·d <sub>v</sub>	668	668	663	kN	
• Max spacing of transverse reinforcement	s	214	214	212	mm	
• Spacing of stirrup	s	250	500	250	mm	
• Diameter of transverse reinforcement	Ø	D 16	D 16	D 20		
• Number of transverse reinf. within distance s	n	2	4	2	bar	
• Assume	θ	39.71	39.23	40.91	degree	
• Strain in tensile reinforcement	ε <sub>s</sub>	1.63E+00	1.30E+00	1.57E+00		
If ex<0, multiple with reduce factor	Φ <sub>c</sub>	-	-	-		
• Ratio of shear stress and f'c	V/f'c	0.02	0.01	0.05		
• β final		1.89	2.06	1.92		
• θ final		41.51	38.98	41.28	degree	
• Total area of transverse reinf.	A <sub>v</sub>	402	804	628	mm <sup>2</sup>	
• Diameter of stirrup	Ø	D 14	D 10	D 14	mm	
• Number of stirrup within distance s	n	4	2	4	bar	
• Total area of stirrup	A <sub>v</sub>	615.75	157.08	615.75		
• The shear resistance of concrete:	V <sub>c</sub>	209.59	221.61	210.96	kN	
• The shear resistance of stirrup	V <sub>s</sub>	147.86	22.03	148.92	kN	
• Value	0.25*f <sub>c</sub> ·b <sub>v</sub> ·d <sub>v</sub>	1668.75	1668.75	1656.25	kN	
• The nominal shear resistance:	V <sub>n</sub>	357.45	243.64	359.88	kN	
• The factored shear resistance	V <sub>r</sub>	321.70	219.28	323.89	kN	
• Check	V <sub>r</sub> > V <sub>u</sub>	O.K	O.K	O.K		
•Requiring transverse reinforcement	V <sub>u</sub> > 0.5·Φ·V <sub>c</sub>	Need	Not required	Need		
•Check minimum transverse reinforcement	A <sub>v</sub> > 0.083·(f' <sub>c</sub> <sup>0.5</sup> )·b <sub>v</sub> ·s/f <sub>y</sub>	O.K	not required	O.K		

<b>Check crack</b>					
<b>Interior force combination</b>					
• Factored moment	$M_u$	6.39E+01	6.63E+01	1.03E+02	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f_c}$	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis	$y_t = h - c$	314	314	294	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	6	6	8	MPa
• Check	$f_r >$	0.8*f <sub>r</sub>	0.8*f <sub>r</sub>	0.8*f <sub>r</sub>	
		check crack	check crack	check crack	
• Crack width parameter	$Z$	= 17500	= 17500	= 17500	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 8.00	= 8.00	= 8.00	
• The distance from extreme fiber to the neutral axis	$c$	= 96.76	= 96.76	= 125.28	mm
• Effective moment of inertia	$J$	6.75E+08	6.75E+08	1.05E+09	mm <sup>4</sup>
• Arm	$de - c$	= 170.24	= 170.24	= 139.72	mm
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (de - c) / J$	= 128.95	= 133.80	= 109.34	MPa
• Area of concrete having the same centroid as the principal tensile reinforcement divided by number of bars	$A$	= 12500	= 12500	= 12500	mm <sup>2</sup>
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 194.80	= 194.80	= 192.61	Mpa
• Check condition	$f_s < f_{sa}$	O.K	O.K	O.K	
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	

## **Calculation sheet for each type of Underpass culverts**

List of calculation sheet

SN	Group	Dimention	Covering	Page
		Width x height		
1	1	3.0 x 3.0	$0.6 \leq h \leq 4.5$	59
2			$4.5 < h \leq 9.0$	68
3	5	6.5 x 4.5	$h < 0.6$	77



## UNDERPASS CULVERT CALCULATION SHEET

### 1. General

- Group : 1
- Dimension : 3.0x3.0 m
- Covering height :  $0.60 \leq H \leq 4.50\text{m}$
- Live load on thruway: HL93
- Live load on cross road: 0.5 HL93
- Design standard: 22TCN-272-05

### 2. Material property

#### 2.1. Concrete

- Compressive strength of cylindrical at 28 days  $f'_c = 25$  MPa
- Concrete density  $\gamma_c = 24.5$  KN/m<sup>3</sup>
- Elastic modulus  $E_c = 0.043 \cdot \gamma_c^{1.5} \cdot \sqrt{f'_c} = 26875$  N/mm<sup>2</sup>
- Tensile strength of concrete:  $f_r = 0.63 \cdot \sqrt{f'_c} = 3.15$  N/mm<sup>2</sup>

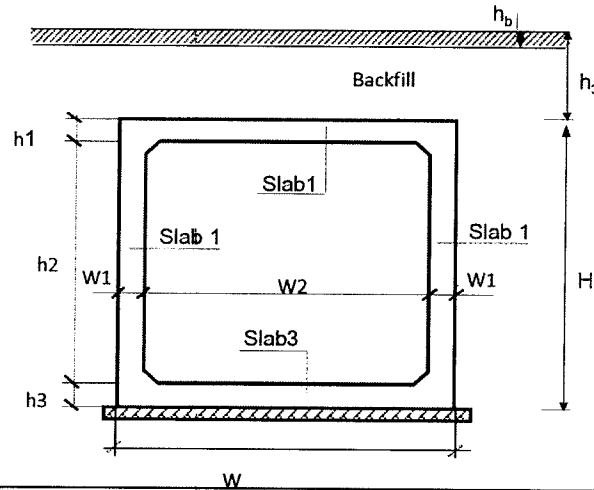
#### 2.2. Steel

- Elastic module of steel :  $E_s = 200000$  N/mm<sup>2</sup>
- Liquid limit:  $f_y = 400$  N/mm<sup>2</sup>

#### 2.2. Pavement and backfill

- Thickness of Asphalt pavement  $t = 0.16$  m
- Elastic module of ground soil  $E_o = 7305$  KN/m<sup>2</sup>
- Unit weight of soil  $\gamma_s = 17.66$  KN/m<sup>3</sup>
- Seftweight of Pavement  $\gamma_{as} = 22$  KN/m<sup>3</sup>
- Intenal friction angle of soil  $\phi'_t = 30$  deg
- Friction angle between soil and wall  $\delta = 0$  deg

### 3. Dimention of Box culvert



BOX CULVERT DIMENSION			
Item	Unit	Symbol	Value
Thickness of slab 1	m	$h_1$	0.350
Thickness of slab 2	m	$w_1$	0.350
Thickness of slab 3	m	$h_3$	0.400
Height of box culvert	m	H	3.750
Height of box culvert	m	$h_2$	3.000
Height of pavement structure	m	$h_b$	0.160
Height of backfilling on top of culvert	m	$h_3$	0.6 ~ 4.5
Span length	m	$w_2$	3.000
Culvert width	m	W	3.700

## 4. Loading

### 4.1. Deadload

- Deadload of box culvert (DC) will be automatic calculate by Midas program with selfweight of concrete is:  $\gamma_c = 24.5 \text{ (Mpa)}$
- Deadload of pavement (DW) will be automatic calculate by Midas program with selfweight of pavement is:  $\gamma_{as} = 22 \text{ (Mpa)}$

### 4.2. Live load

- Where the depth of fill is less than 600mm, the effect of fill on the distribution of live load shall be neglected.
- The uniformly distribution of wheel where covering depth  $\geq 600 \text{ mm}$  determined follow A 3.6.1.2.6.
- Impact load determined follow A 3.6.2.2.
- Where the depth of fill exceeds 600 mm, wheel loads may be considered to be uniformly distributed over rectangular area with sides equal to the dimension of the tire contact area as A 3.6.1.2.5, and increased by either 1.15 times the depth of the fill in select granular backfill, or the depth of the fill in all other cases.
- For single span culverts, the effects of live load may be neglected where the depth of fill is  $\geq 2400\text{mm}$  and exceeds the span length.
- For multiple span culverts, the effects of live load may be neglected where the depth of fill exceeds the distance between faces of end walls.
- Where such areas from several wheels overlap, the total load shall be uniformly distributed over the area.
- The dynamic load allowance for culverts shall be taken as:

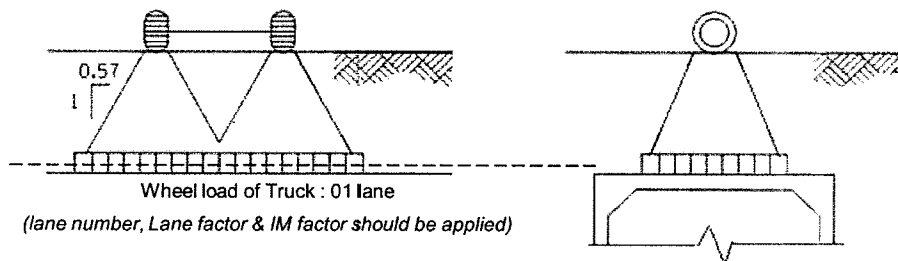
$$IM = 33 * (1.0 - 4.1 \times 10^{-4} \cdot De) \quad (3.6.2.2.1)$$

#### • Design truck:

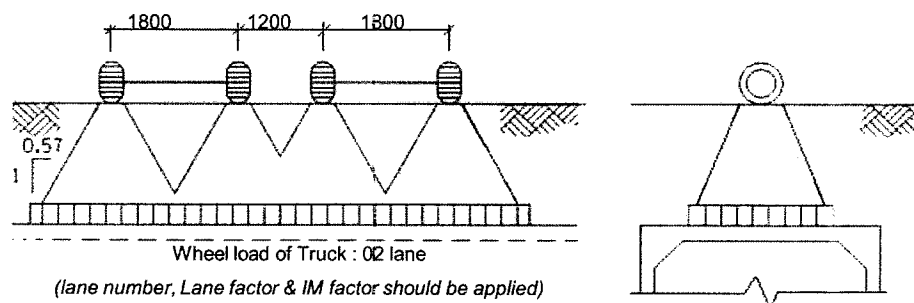
- Estimate for impact factor and distributed area of wheel

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
0.6	145	24.88	510	361	1200	1051
4.5	145	0.00	510	289	5685	5464

Distribution of wheel load for 1 lane



Distribution of wheel load for 2 lane



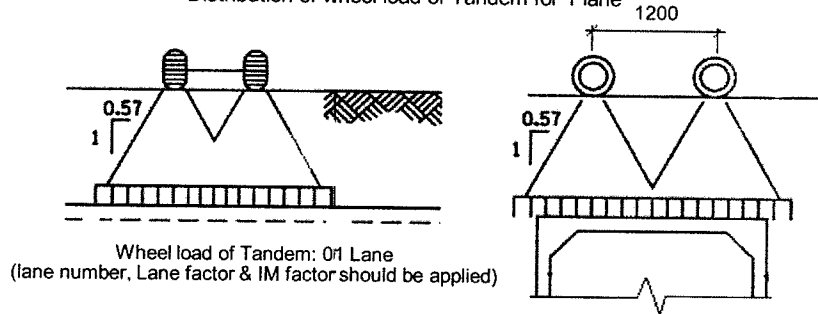
Distributed wheel load of truck

Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>truck -1 lane</sub> (Kn/m)	LL <sub>truck -2 lane</sub> (Kn/m)
0.6	145	1200	1051	57.47	57.47
4.5	145	5685	5464	4.09	4.09

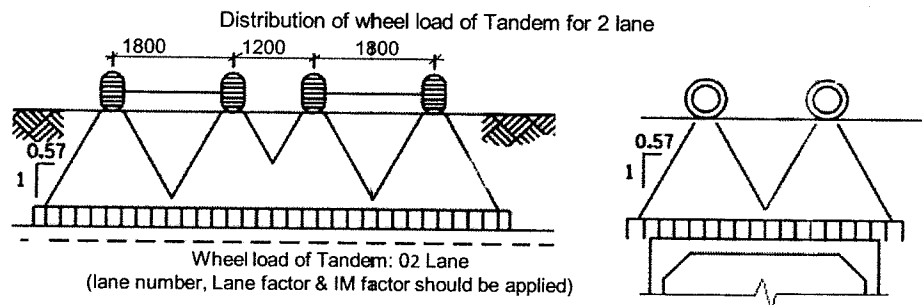
• **Tandem:**

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
0.6	110	24.88	510	274	1200	964
4.5	110	0.00	510	219	5685	5394

Distribution of wheel load of Tandem for 1 lane



Distribution of wheel load of Tandem for 2 lane



Distributed wheel load of Tandem

Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>tandem -1 lane</sub> (Kn/m)	LL <sub>tandem -2 lane</sub> (Kn/m)
0.6	145	1200	964	47.54	47.54
4.5	145	5685	5394	3.03	4.85

- Design live load applied to structure:  $\text{Max(LL)} = 57.47$  (Kn/m) with covering depth 0.6 m  
 $= 0.00$  (Kn/m) with covering depth 4.5 m

• **Lane load**

- Lane load distributed on 1 m  $= 3.10$  kN/m

**4.3. Live load on cross road (for bottom slab)**

Design live load:

Number of lane:

Bottom slab span:

- The width of the equivalent strip of a deck shall be taken

Dynamic load allowance:

- Point load from wheel load of design truck
- Point load from wheel load of design tandem
- Load from design lane load

0.65HL93

n	=	1 lane
S	=	3350 mm
E	=	2058 mm (Table 4.6.2.1.3-1)
IM	=	25 % (3.6.2.1)
	=	34.36 kN
	=	32.92 kN
	=	3.10 kN/m

**4.2.1. Surcharge load (LS)**

-Where a surcharge load is present, a constant horizontal earth pressure shall be added to the basic earth pressure.

This constant earth pressure may be taken as

$$D_p = k \cdot \gamma_s \cdot g \cdot h_{eq} (\times 10^{-4}) \quad (3.11.6.1-1)$$

Where:

$D_p$	=	constant horizontal earth pressure due to uniform surcharge load applied (Mpa)
$k$	=	coefficient of earth pressure
$\gamma_s$	=	density of soil (kg/m <sup>3</sup> )
$h_{eq}$	=	height of soil equivalent to design truck (mm).

Wall height(mm)	heq (mm)	Covering	Wall height (mm)	heq (m)	Dp (Kn/m <sup>2</sup> )
< 1500.	1700				
3000	1200	0.60 m	4350	1002.00	5.90
6000	760	4.50 m	8250	647.50	3.81
> 9000.	610				

#### 4.3. Earth Pressure (EV & EH):

##### 4.3.1. Vertical earth pressure (EV) (A12.11.2.2)

- The factor of vertical earth pressure  $F_e = \text{MIN}(1+0.2 \cdot h_3/W, 1.15)$
- Vertical earth pressure on top slab of culvert  $EV = F_e \cdot \gamma_s \cdot h$

Covering ( $h_3$ )	$F_e$	$\gamma_s$ (Kn/m <sup>3</sup> )	EV (Kn/m)
0.60 m	1.032	17.66	10.94
4.50 m	1.150	17.66	91.38

##### 4.3.2. Horizontal earth pressure (EH)

- Basic earth pressure shall be assumed to be linearly proportional to the depth of earth and taken as.

$$P_h = K_a \cdot \gamma_s \cdot g \cdot Z \cdot 10^{-9} \quad (3.11.5.1-1)$$

In which:

$P_h$  : horizontal earth pressure at the depth of Z (N/mm<sup>2</sup>)

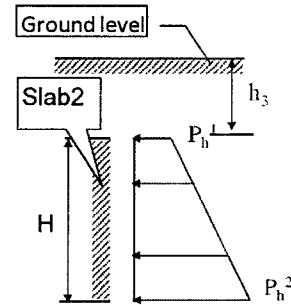
- + Lateral earth pressure applied on the plate as figure

$$P_h^1 = K_a \cdot \gamma_s \cdot g \cdot h_3 \cdot 10^{-9}$$

$$P_h^2 = K_a \cdot \gamma_s \cdot g \cdot (H + h_3) \cdot 10^{-9}$$

in which:

- $P_h$  : Horizontal earth pressure (N/mm)
- $K_a$  : active earth pressure coefficient  $K_a = 0.33$
- $\gamma_s$  : Density of soil (kg/m<sup>3</sup>)  $\gamma_s = 1800$
- $g$  : Gravitational acceleration (m/s<sup>2</sup>)  $g = 9.81$
- $\varphi$  : Angle of internal friction  $\varphi = 30 \text{ deg}$
- $h_3$  : filling height from top of box culvert (mm)
- $H$  : Total height of box culvert (mm)

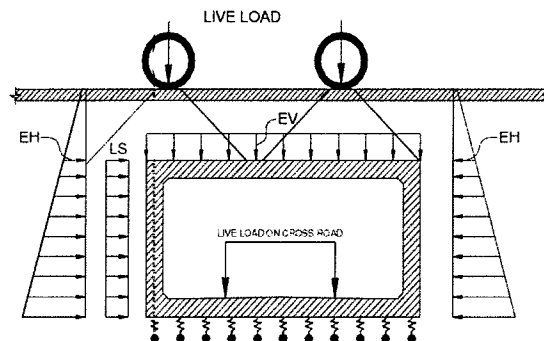


Covering	$K_a$	$\gamma_s$ (Kg/m <sup>3</sup> )	$g$ (m/s <sup>2</sup> )	$P_h^1$ (Kn/m <sup>2</sup> )	$P_h^2$ (Kn/m <sup>2</sup> )
0.60 m	0.33	1800.	9.81	3.53	25.60
4.50 m	0.33	1800.	9.81	26.49	48.56

#### 5. Load combination

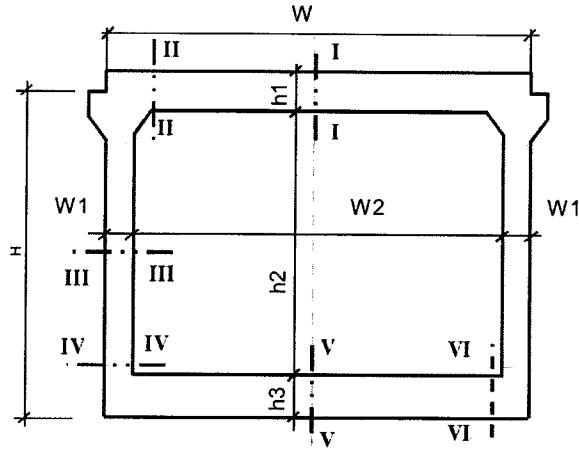
Load combination and load combination factor shall be taken as Table 3.4.1-1

State	Mark	Str. I-A	Str. I-B	Str. I-C	Str. III-A	Str. III-B	Service I
Dead load of structural	DC	1.25	1.25	0.90	0.90	1.25	1.00
Dead load of wearing	DW	1.50	1.50	0.65	0.65	1.50	1.00
Vertical earth pressure	EV	1.30	1.30	0.90	0.90	1.30	1.00
Horizontal earth pressure	EH	1.50	0.90	1.50	1.50	1.50	1.00
Live load	LL	1.75	1.75	1.75	1.35	1.35	1.00
Live load surcharge	LS	1.75	1.75	1.75	1.35	1.35	1.00



Model of structural of culvert by midas program

6. Design force applied to sections:



Design section

Table of Internal force with covering height  $h=0.6m$

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	101.60	72.30	-36.50	61.30	40.63	-25.60
II - II	-56.80	231.60	-36.50	-35.21	142.53	-25.60
III - III	-42.60	28.53	-260.30	-27.56	16.25	-165.20
IV - IV	-63.50	56.32	-273.50	-41.65	40.15	-182.30
V - V	125.60	85.62	-60.50	80.12	49.52	-39.65
VI - VI	-52.60	260.60	-60.50	-31.56	165.35	-39.65

Table of Internal force with covering height  $h=4.5m$

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	132.10	0.00	-87.50	89.50	0.00	-27.80
II - II	-63.40	241.50	-87.50	-58.60	176.50	-27.80
III - III	-65.60	0.00	-276.50	-35.60	0.00	-200.60
IV - IV	-100.50	50.00	-296.30	-78.90	69.80	-213.60
V - V	154.80	105.60	-112.40	97.60	36.10	-74.30
VI - VI	-76.50	348.00	-112.40	-64.50	240.00	-74.30

Table of Internal force applied to design section

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	132.10	72.30	87.50	89.50	40.63	27.80
II - II	63.40	241.50	87.50	58.60	176.50	27.80
III - III	65.60	28.53	276.50	35.60	16.25	200.60
IV - IV	100.50	56.32	296.30	78.90	69.80	213.60
V - V	154.80	105.60	112.40	97.60	49.52	74.30
VI - VI	76.50	348.00	112.40	64.50	240.00	74.30

# 7. Ultimate check, shear capacity check and crack control

Item		Section I-I (Bottom bar)	Section II-II (Top bar)	Section III-III (Inside bar)	Unit	
• Factored Plexural moment • Factored Shear force • Factored nominal force • Hight of Section • Width of section • Section area • Moment of inertia of concrete section • Tension reinforcement • comp. reinforcement:	$M_u$	132.10	63.40	65.60	kN.m	
	$V_u$	72.30	241.50	28.53	kN	
	$N_u$	36.50	36.50	260.30	kN	
	$h$	350	350	350	mm	
	$b$	1000	1000	1000	mm	
	$A_c$	350000	350000	350000	mm <sup>2</sup>	
	$I_g$	3.6E+09	3.6E+09	3.6E+09	mm <sup>4</sup>	
	Distance from tension reinf. to extreme compression fiber	$d_c$	59	84	59	mm
	Reinf. Diameter	$\phi$	D18	D18	D18	mm
	Space	@	125	125	250	mm
	Number of bar	$n$	8	8	4	bar
	Total area of reinf.	$A_s$	2036	2036	1018	mm <sup>2</sup>
	Distance from compressive reinf. to extreme Tension fiber		84	84	84	mm
	Diameter		D18	D18	D18	mm
	Reinf. Space		250	125	250	mm
	Number of bar		4	8	4	bar
Total area of reinf.	$A'_s$	1018	2036	1018	mm <sup>2</sup>	
Check Flexural Moment						
• Resistance factor	$\Phi$	0.90	0.90	0.90		
• The corresponding effective	$d_e$	291	266	291	mm	
• Stress block factor	$\beta_1$	0.85	0.85	0.85		
• Depth of the equivalent stress block = $c \cdot \beta_1$	$a$	38.32	38.32	19.16	mm	
• Distance from extreme compression fiber to the neutr	$c$	45.08	45.08	22.54	mm	
• The nominal flexural resistance:	$M_n$	221	201	115	kN.m	
• Factored flexural resistance	$M_r = \Phi \cdot M_n$	199	181	103	kN.m	
• Check condition	$M_r > M_u$	O.K	O.K	O.K		
Minimum Reinforcement						
• Cracking moment	$1.2M_{cr}$	77.18	77.18	77.18	Kn.m	
• Check	$M_r > \min(1.2M_{cr}, 1.33M_u)$	O.K	O.K	O.K		
Maximum Reinforcement						
• Obligation Condition	$c/d_e$	0.15	0.17	0.08		
• Check	$c/d_e < 0.42$	O.K	O.K	O.K		
Check shear resistance						
• Factored Shear force	$V_u$	72.30	241.50	28.53	kN	
• Resistance factor	$\Phi$	0.90	0.90	0.90		
• The effective shear depth	$d_v$	291	266	291	mm	
• Effective width	$b_v$	1000	1000	1000	mm	
• Angle of inclination of diagonal compressive stress	$\theta$	45	36	45	degree	
• Angle of inclination of transverse reinf. To longitudir	$\alpha$	90	90	90	degree	
• Factor indicating ability of diagonally cracked concrete to transmit tension	$\beta$	2.00	2.00	2.00		
• Value	$0.1 \cdot f_c \cdot b_v \cdot d_v$	728	665	728	kN	
• Max spacing of transverse reinforcement	$s$	233	213	233	mm	
• Spacing of stirrup	$s$	500	250	500	mm	
• Diameter of transverse reinforcement	$\phi$	D 18	D 18	D 18		
• Number of transverse reinf. within distance $s$	$n$	4	2	2	bar	
• Assume	$\theta$	45.00	36.32	45.00	degree	
• Strain in tensile reinforcement	$\epsilon_s \cdot 1000$	1.25E+00	1.03E+00	1.82E+00		
If $\epsilon_s < 0$ , multiple with reduce factor	$\Phi_c$	-	-	-		
• Ratio of shear stress and $f_c$	$V/f_c$	0.01	0.04	0.00		
• $\beta$ final		2.00	2.21	2.00		
• $\theta$ final		45.00	36.34	45.00	degree	
• Total area of transverse reinf.	$A_v$	1018	509	509	mm <sup>2</sup>	
• Diameter of stirrup	$\phi$	D 10	D 14	D 10	mm	
• Number of stirrup within distance $s$	$n$	2	4	2	bar	
• Total area of stirrup	$A_v$	157.08	615.75	157.08		
• The shear resistance of concrete:	$V_c$	241.53	220.78	241.53	kN	
• The shear resistance of stirrup	$V_s$	16.31	201.09	16.31	kN	
• Value	$0.25 \cdot f_c \cdot b_v \cdot d_v$	1818.75	1662.50	1818.75	kN	
• The nominal shear resistance:	$V_n$	257.84	421.87	257.84	kN	
• The factored shear resistance	$V_r$	232.05	379.68	232.05	kN	
• Check	$V_r > V_u$	O.K	O.K	O.K		
• Requiring transverse reinforcement	$V_u > 0.5 \cdot \Phi \cdot V_c$	Not required	Need	Not required		
• Check minimum transverse reinforcement	$A_v > 0.083 \cdot (f_c^{0.5}) \cdot b_v \cdot s / f_y$	not required	O.K	not required		

<b>Check crack</b>					
<b>Interior force combination</b>					
• Factored moment	$M_u$	8.95E+01	5.86E+01	3.56E+01	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f_c}$	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis	$y_t = h - c$	305	305	327	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	8	5	3	MPa
• Check	$f_r >$	$0.8 \cdot f_r$	$0.8 \cdot f_r$	$0.8 \cdot f_r$	
• Crack width parameter	$Z$	check crack	check crack	check crack	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 17500	= 17500	= 17500	
• The distance from extreme fiber to the neutral axis	$c$	= 8.00	= 8.00	= 8.00	
• Effective moment of inertia	$J$	= 115.00	= 110.78	= 77.47	mm
• Arm	$de - c$	= 1.01E+09	= 8.46E+08	= 5.26E+08	mm <sup>4</sup>
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (de - c) / J$	= 176.00	= 155.22	= 213.53	mm
• Area of concrete having the same centroid as the principal	$A$	= 124.60	= 86.06	= 115.56	MPa
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 12500	= 12500	= 25000	mm <sup>2</sup>
• Check condition	$f_s < f_{sa}$	= 193.69	= 193.69	= 153.74	Mpa
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	
• Check condition		O.K	O.K	O.K	

# 7. Ultimate check, shear capacity check and crack control

Item		Section IV-IV (outside bar)	Section V-V (Top bar)	Section VI-VI (Bottom bar)	Unit	
• Factored Plexural moment	M <sub>u</sub>	100.50	154.80	76.50	kN.m	
• Factored Shear force	V <sub>u</sub>	56.32	105.60	348.00	kN	
• Factored Shear force	N <sub>u</sub>	296.30	112.40	112.40	kN	
• Hight of Section	h	350	400	400	mm	
• Width of section	b	1000	1000	1000	mm	
• Section area	A <sub>c</sub>	350000	400000	400000	mm <sup>2</sup>	
• Moment of inertia of concrete section	I <sub>g</sub>	3.6E+09	5.3E+09	5.3E+09	mm <sup>4</sup>	
• Tension reinforcement	Distance from tension reinf. to extreme compression fiber	d <sub>c</sub>	84	59	84	mm
	Reinf. Diameter	Ø	D18	D18	D18	mm
	Space	@	125	125	125	mm
	Number of bar	n	8	8	8	bar
	Total area of reinf.	A <sub>s</sub>	2036	2036	2036	mm <sup>2</sup>
• comp. reinforcement:	Distance from compressive reinf. to extreme Tension fiber		59	84	59	mm
	Diameter		D18	D18	D18	mm
	Reinf. Space		250	250	125	mm
	Number of bar		4	4	8	bar
	Total area of reinf.	A' <sub>s</sub>	1018	1018	2036	mm <sup>2</sup>
Check Flexural Moment						
• Resistance factor	Φ	0.90	0.90	0.90		
• The corresponding effective	d <sub>o</sub>	266	341	316	mm	
• Stress block factor	β <sub>1</sub>	0.85	0.85	0.85		
• Depth of the equivalent stress block = c*β <sub>1</sub>	a	38.32	38.32	38.32	mm	
• Distance from extreme compression fiber to the neut	c	45.08	45.08	45.08	mm	
• The nominal flexural resistance:	M <sub>n</sub>	201	262	242	kN.m	
• Factored flexural resistance	M <sub>r</sub> = Φ.M <sub>n</sub>	181	236	218	kN.m	
• Check condition	M <sub>r</sub> > M <sub>u</sub>	O.K	O.K	O.K		
Minimum Reinforcement						
• Cracking moment	1.2M <sub>cr</sub>	77.18	100.80	100.80	Kn.m	
• Check	M <sub>r</sub> > min(1.2M <sub>cr</sub> , 1.33M <sub>u</sub> )	O.K	O.K	O.K		
Maximum Reinforcement						
• Obligation Condition	c/d <sub>o</sub>	0.17	0.13	0.14		
• Check	c/d <sub>o</sub> < 0.42	O.K	O.K	O.K		
Check shear resistance						
• Factored Shear force	V <sub>u</sub>	56.32	105.60	348.00	kN	
• Resistance factor	Φ	0.90	0.90	0.90		
• The effective shear depth	d <sub>v</sub>	266	341	316	mm	
• Effective width	b <sub>v</sub>	1000	1000	1000	mm	
• Angle of inclination of diagonal compressive stress	θ	40	40	39	degree	
• Angle of inclination of transverse reinf. To longitudi	α	90	90	90	degree	
• Factor indicating ability of diagonally cracked concrete to transmit tension	β	2.02	2.00	2.08		
• Value	0.1*f' <sub>c</sub> *b <sub>v</sub> *d <sub>v</sub>	665	853	790	kN	
• Max spacing of transverse reinforcement	s	213	273	253	mm	
• Spacing of stirrup	s	250	500	250	mm	
• Diameter of transverse reinforcement	Ø	D 18	D 18	D 18		
• Number of transverse reinf. within distance s	n	2	4	2	bar	
• Assume	θ	39.71	40.10	38.64	degree	
• Strain in tensile reinforcement	ε <sub>x</sub>	1.38	1.41	1.27		
If ex<0, multiple with reduce factor	Φ <sub>c</sub>	-	-	-		
• Ratio of shear stress and f' <sub>c</sub>	V/f' <sub>c</sub>	0.01	0.01	0.05		
• β final		2.02	2.00	2.08		
• θ final		39.75	40.07	38.67	degree	
• Total area of transverse reinf.	A <sub>v</sub>	509	1018	509	mm <sup>2</sup>	
• Diameter of stirrup	Ø	D 14	D 10	D 14	mm	
• Number of stirrup within distance s	n	4	2	4	bar	
• Total area of stirrup	A <sub>v</sub>	615.75	157.08	615.75		
• The shear resistance of concrete:	V <sub>c</sub>	222.98	283.03	272.82	kN	
• The shear resistance of stirrup	V <sub>s</sub>	164.26	26.34	208.26	kN	
• Value	0.25*f' <sub>c</sub> *b <sub>v</sub> *d <sub>v</sub>	1662.50	2131.25	1975.00	kN	
• The nominal shear resistance:	V <sub>n</sub>	387.24	309.37	481.07	kN	
• The factored shear resistance	V <sub>r</sub>	348.52	278.43	432.97	kN	
• Check	V <sub>r</sub> > V <sub>u</sub>	O.K	O.K	O.K		
•Requiring transverse reinforcement	V <sub>u</sub> > 0.5•Φ•V <sub>c</sub>	Not required	Not required	Need		
•Check minimum transverse reinforcement	A <sub>v</sub> > 0.083•(f' <sub>c</sub> <sup>0.5</sup> )•b <sub>v</sub> •s/f <sub>y</sub>	not required	not required	O.K		



<b>Check crack</b>					
<b>Interior force combination</b>					
• Factored moment	$M_u$	7.89E+01	9.76E+01	6.45E+01	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f_c}$	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis	$y_t = h - c$	305	355	355	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	7	6	4	MPa
• Check	$f_r >$	0.8 $\cdot f_r$	0.8 $\cdot f_r$	0.8 $\cdot f_r$	
		check crack	check crack	check crack	
• Crack width parameter	$Z$	= 17500	= 17500	= 17500	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 8.00	= 8.00	= 8.00	
• The distance from extreme fiber to the neutral axis	$c$	= 110.78	= 122.93	= 119.04	mm
• Effective moment of inertia	$J$	8.46E+08	1.39E+09	1.19E+09	mm <sup>4</sup>
• Arm	$de - c$	= 155.22	= 218.07	= 196.96	mm
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (de - c) / J$	= 115.87	= 122.17	= 85.11	MPa
• Area of concrete having the same centroid as the principal	$A$	= 12500	= 12500	= 12500	mm <sup>2</sup>
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 193.69	= 193.69	= 193.69	Mpa
• Check condition	$f_s < f_{sa}$	O.K	O.K	O.K	
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	

## UNDERPASS CULVERT CALCULATION SHEET

### 1. General

- Group : 1
- Dimension : 3.0x3.0 m
- Covering height :  $4.5 \leq H \leq 9.0\text{m}$
- Live load on thruway: HL93
- Live load on cross road: 0.5 HL93
- Design standard: 22TCN-272-05

### 2. Material property

#### 2.1. Concrete

- Compressive strength of cylindrical at 28 days  $f_c = 25$  MPa
- Concrete density  $\gamma_c = 24.5$  KN/m<sup>3</sup>
- Elastic modulus  $E_c = 0.043 \cdot \gamma_c^{1.5} \cdot \sqrt{f_c} = 26875$  N/mm<sup>2</sup>
- Tensile strength of concrete:  $f_t = 0.63 \cdot \sqrt{f_c} = 3.15$  N/mm<sup>2</sup>

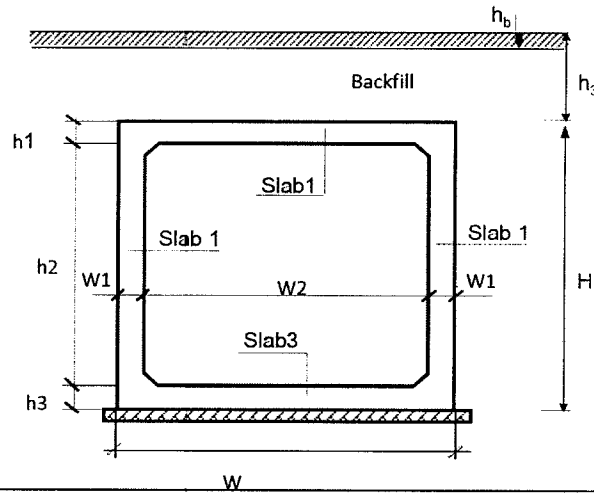
#### 2.2. Steel

- Elastic module of steel :  $E_s = 200000$  N/mm<sup>2</sup>
- Liquid limit:  $f_y = 400$  N/mm<sup>2</sup>

#### 2.2. Pavement and backfill

- Thickness of Asphalt pavement  $t = 0.16$  m
- Elastic module of ground soil  $E_o = 7305$  KN/m<sup>2</sup>
- Unit weight of soil  $\gamma_s = 17.66$  KN/m<sup>3</sup>
- Seftweight of Pavement  $\gamma_{as} = 22$  KN/m<sup>3</sup>
- Intenal friction angle of soil  $\phi'_f = 30$  deg
- Friction angle between soil and wall  $\delta = 0$  deg

### 3. Dimention of Box culvert



BOX CULVERT DIMENSION			
Item	Unit	Symbol	Value
Thickness of slab 1	m	$h_1$	0.350
Thickness of slab 2	m	$w_1$	0.350
Thickness of slab 3	m	$h_3$	0.400
Height of box culvert	m	$H$	3.750
Height of box culvert	m	$h_2$	3.000
Height of pavement structure	m	$h_b$	0.160
Height of backfilling on top of culvert	m	$h_3$	4.5~9.0
Span length	m	$w_2$	3.000
Culvert width	m	$W$	3.700

## 4. Loading

### 4.1. Deadload

- Deadload of box culvert (DC) will be automatic calculate by Midas program with selfweight of concrete is:  $\gamma_c = 24.5 \text{ (Mpa)}$
- Deadload of pavement (DW) will be automatic calculate by Midas program with selfweight of pavement is:  $\gamma_{as} = 22 \text{ (Mpa)}$

### 4.2. Live load

- Where the depth of fill is less than 600mm, the effect of fill on the distribution of live load shall be neglected.
- The uniformly distribution of wheel where covering depth  $\geq 600 \text{ mm}$  determined follow A 3.6.1.2.6.
- Impact load determined follow A 3.6.2.2.
- Where the depth of fill exceeds 600 mm, wheel loads may be considered to be uniformly distributed over rectangular area with sides equal to the dimension of the tire contact area as A 3.6.1.2.5, and increased by either 1.15 times the depth of the fill in select granular backfill, or the depth of the fill in all other cases.
- For single span culverts, the effects of live load may be neglected where the depth of fill is  $\geq 2400\text{mm}$  and exceeds the span length.
- For multiple span culverts, the effects of live load may be neglected where the depth of fill exceeds the distance between faces of end walls.
- Where such areas from several wheels overlap, the total load shall be uniformly distributed over the area.
- The dynamic load allowance for culverts shall be taken as:

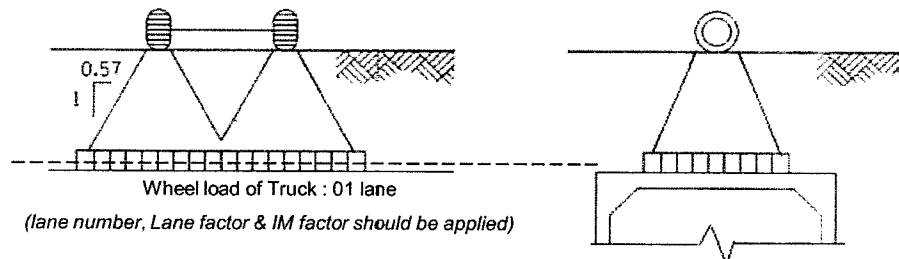
$$IM = 33 * (1.0 - 4.1 \times 10^{-4} \cdot De) \quad (3.6.2.2.1)$$

#### • Design truck:

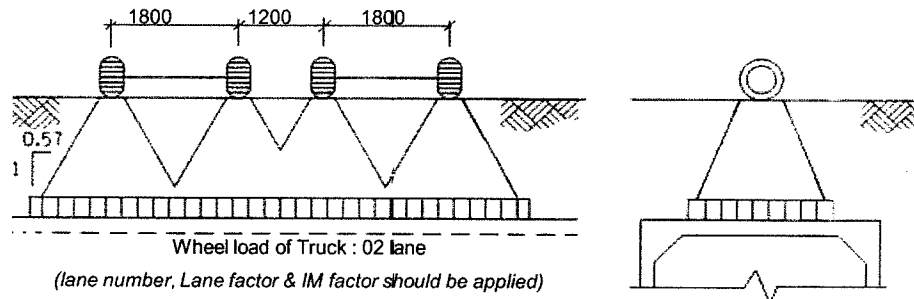
- Estimate for impact factor and distributed area of wheel

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
4.5	145	0.00	510	289	5685	5464
9	145	0.00	510	289	10860	10639

Distribution of wheel load for 1 lane



Distribution of wheel load for 2 lane



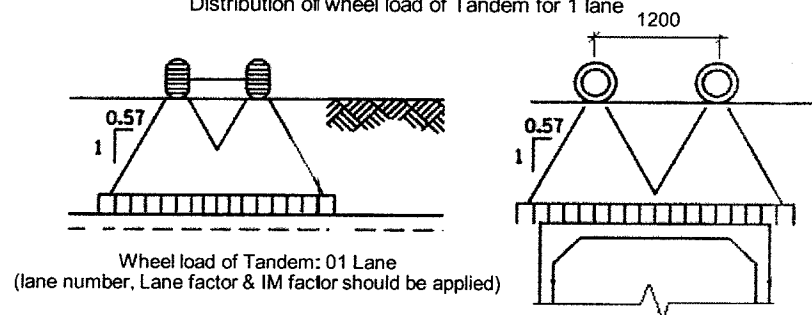
Distributed wheel load of truck

Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>truck -1 lane</sub> (Kn/m)	LL <sub>truck -2 lane</sub> (Kn/m)
4.5	145	5685	5464	3.97	3.97
9	145	10860	10639	4.09	4.09

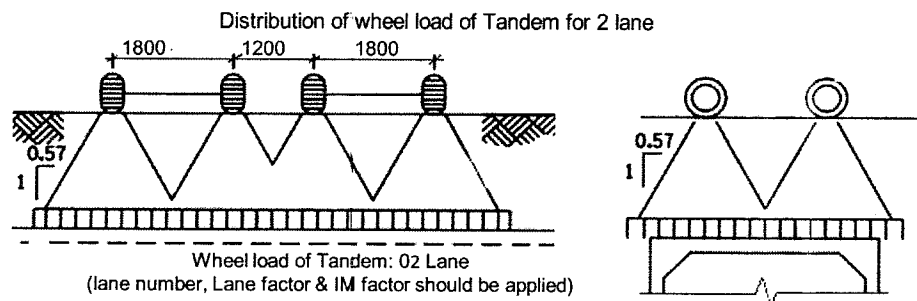
• **Tandem:**

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
4.5	110	0.00	510	219	5685	5394
9	110	0.00	510	219	10860	10569

Distribution of wheel load of Tandem for 1 lane



Distribution of wheel load of Tandem for 2 lane



Distributed wheel load of Tandem

Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>tandem -1 lane</sub> (Kn/m)	LL <sub>tandem -2 lane</sub> (Kn/m)
0.6	145	5685	5394	50.40	50.40
4.5	145	10860	10569	3.03	4.85

- Design live load applied to structure: Max(LL) = 50.40 (Kn/m) with covering depth 0.6 m  
= 0.00 (Kn/m) with covering depth 4.5 m

• **Lane load**

- Lane load distributed on 1 m = 3.10 kN/m

**4.3. Live load on cross road (for bottom slab)**

Design live load:

Number of lane:

Bottom slab span:

- The width of the equivalent strip of a deck shall be taken

Dynamic load allowance:

→ Point load from wheel load of design truck

→ Point load from wheel load of design tandem

→ Load from design lane load

0.65HL93

n	=	1 lane
S	=	3350 mm
E	=	2058 mm (Table 4.6.2.1.3-1)
IM	=	25 % (3.6.2.1)
	=	34.36 kN
	=	32.92 kN
	=	3.10 kN/m

**4.2.1. Surcharge load (LS)**

-Where a surcharge load is present, a constant horizontal earth pressure shall be added to the basic earth pressure.

This constant earth pressure may be taken as

$$D_p = k \cdot \gamma_s \cdot g \cdot h_{eq} (\times 10^{-1}) \quad (3.11.6.1-1)$$

Where:

$D_p$  = constant horizontal earth pressure due to uniform surcharge load applied (Mpa)

$k$  = coefficient of earth pressure

$\gamma_s$  = density of soil (kg/m<sup>3</sup>)

$h_{eq}$  = height of soil equivalent to design truck (mm).

Wall height(mm)	heq (mm)	Covering	Wall height (mm)	heq (m)	Dp (Kn/m <sup>2</sup> )
< 1500.	1700				
3000	1200	0.60 m	4350	1002.00	5.90
6000	760	4.50 m	8250	647.50	3.81
> 9000.	610				

#### 4.3. Earth Pressure (EV & EH):

##### 4.3.1. Vertical earth pressure (EV) (A12.11.2.2)

- The factor of vertical earth pressure  $F_e = \text{MIN}(1+0.2 \cdot h_3/W, 1.15)$
- Vertical earth pressure on top slab of culvert  $EV = F_e \cdot \gamma_s \cdot h$

Covering ( $h_3$ )	$F_e$	$\gamma_s$ ( $\text{Kn/m}^3$ )	EV ( $\text{Kn/m}$ )
0.60 m	1.032	17.66	10.94
4.50 m	1.150	17.66	91.38

##### 4.3.2. Horizontal earth pressure (EH)

- Basic earth pressure shall be assumed to be linearly proportional to the depth of earth and taken as.

$$P_h = K_a \cdot \gamma_s \cdot g \cdot Z \cdot 10^{-9} \quad (3.11.5.1-1)$$

In which:

$P_h$  : horizontal earth pressure at the depth of Z ( $\text{N/mm}^2$ )

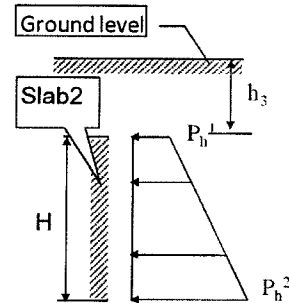
- + Lateral earth pressure applied on the plate as figure

$$P_h^1 = K_a \cdot \gamma_s \cdot g \cdot h_3 \cdot 10^{-9}$$

$$P_h^2 = K_a \cdot \gamma_s \cdot g \cdot (H + h_3) \cdot 10^{-9}$$

in which:

- $P_h$  : Horizontal earth pressure ( $\text{N/mm}^2$ )
- $K_a$  : active earth pressure coefficient  $K_a = 0.33$
- $\gamma_s$  : Density of soil ( $\text{kg/m}^3$ )  $\gamma_s = 1800$
- $g$  : Gravitational acceleration ( $\text{m/s}^2$ )  $g = 9.81$
- $\phi$  : Angle of internal friction  $\phi = 30 \text{ deg}$
- $h_3$  : filling height from top of box culvert (mm)
- $H$  : Total height of box culvert (mm)

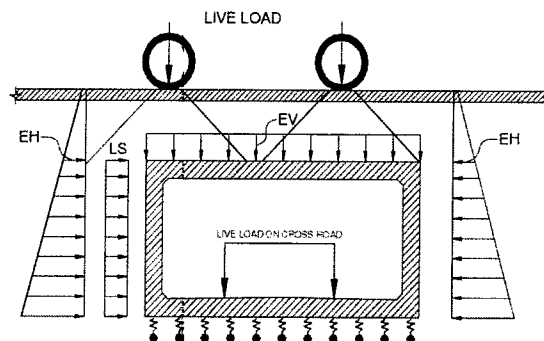


Covering	$K_a$	$\gamma_s$ ( $\text{Kg/m}^3$ )	$g$ ( $\text{m/s}^2$ )	$P_h^1$ ( $\text{Kn/m}^2$ )	$P_h^2$ ( $\text{Kn/m}^2$ )
0.60 m	0.33	1800.	9.81	3.53	25.60
4.50 m	0.33	1800.	9.81	26.49	48.56

#### 5. Load combination

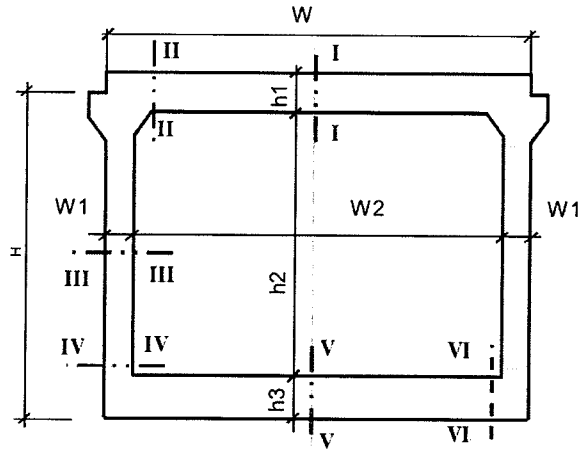
Load combination and load combination factor shall be taken as Table 3.4.1-1

State	Mark	Str. I-A	Str. I-B	Str. I-C	Str. III-A	Str. III-B	Service I
Dead load of structural	DC	1.25	1.25	0.90	0.90	1.25	1.00
Dead load of wearing	DW	1.50	1.50	0.65	0.65	1.50	1.00
Vertical earth pressure	EV	1.30	1.30	0.90	0.90	1.30	1.00
Horizontal earth pressure	EH	1.50	0.90	1.50	1.50	1.50	1.00
Live load	LL	1.75	1.75	1.75	1.35	1.35	1.00
Live load surcharge	LS	1.75	1.75	1.75	1.35	1.35	1.00



Model of structural of culvert by midas program

6. Design force applied to sections:



Design section

Table of Internal force with covering height  $h=4.5\text{m}$

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	110.10	0.00	-98.80	82.60	0.00	-63.00
II - II	-83.20	243.30	-98.80	-57.80	176.90	-63.00
III - III	-38.30	0.00	-274.60	-30.00	0.00	-201.00
IV - IV	-107.90	116.80	-291.00	-77.70	76.90	-214.00
V - V	122.80	44.60	-124.80	93.00	33.10	-82.10
VI - VI	-92.50	276.10	-124.80	-65.70	203.30	-82.10

Table of Internal force with covering height  $h=9.0\text{m}$

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	194.50	0.00	-166.20	136.50	0.00	108.10
II - II	-146.20	342.60	-166.20	-103.10	322.00	108.10
III - III	73.50	0.00	-460.00	-57.80	0.00	-354.10
IV - IV	-180.60	179.80	-472.30	-130.30	118.80	-367.10
V - V	201.30	74.60	-191.80	145.20	55.10	-126.50
VI - VI	-152.60	393.60	-191.80	-108.50	347.10	-126.50

Table of Internal force applied to design section

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	194.50	0.00	166.20	136.50	0.00	108.10
II - II	146.20	342.60	166.20	103.10	322.00	108.10
III - III	73.50	0.00	460.00	57.80	0.00	354.10
IV - IV	180.60	179.80	472.30	130.30	118.80	367.10
V - V	201.30	74.60	191.80	145.20	55.10	126.50
VI - VI	152.60	393.60	191.80	108.50	347.10	126.50

# 7. Ultimate check, shear capacity check and crack control

Item		Section I-I (Bottom bar)	Section II-II (Top bar)	Section III-III (Inside bar)	Unit	
• Factored Plexural moment	$M_u$	194.50	146.20	73.50	kN.m	
• Factored Shear force	$V_u$	-	342.60	-	kN	
• Factored nominal force	$N_u$	98.80	98.80	274.60	kN	
• Hight of Section	$h$	350	350	350	mm	
• Width of section	$b$	1000	1000	1000	mm	
• Section area	$A_c$	350000	350000	350000	mm <sup>2</sup>	
• Moment of inertia of concrete section	$I_g$	3.6E+09	3.6E+09	3.6E+09	mm <sup>4</sup>	
• Tension reinforcement	Distance from tension reinf. to extreme compression fiber	$d_c$	59	84	59	mm
	Reinf. Diameter	$\phi$	D18	D18	D18	mm
	Space	@	125	125	250	mm
	Number of bar	$n$	8	8	4	bar
	Total area of reinf.	$A_s$	2036	2036	1018	mm <sup>2</sup>
• comp. reinforcement:	Distance from compressive reinf. to extreme Tension fiber		84	84	84	mm
	Diameter		D18	D18	D18	mm
	Reinf. Space		250	125	250	mm
	Number of bar		4	8	4	bar
	Total area of reinf.	$A'_s$	1018	2036	1018	mm <sup>2</sup>
<b>Check Flexural Moment</b>						
• Resistance factor	$\Phi$	0.90	0.90	0.90		
• The corresponding effective	$d_e$	291	266	291	mm	
• Stress block factor	$\beta_1$	0.85	0.85	0.85		
• Depth of the equivalent stress block = $c*\beta_1$	$a$	38.32	38.32	19.16	mm	
• Distance from extreme compression fiber to the neutr	$c$	45.08	45.08	22.54	mm	
• The nominal flexural resistance:	$M_n$	221	201	115	kN.m	
• Factored flexural resistance	$M_r = \Phi \cdot M_n$	199	181	103	kN.m	
• Check condition	$M_r > M_u$	O.K	O.K	O.K		
<b>Mimimum Reinforcement</b>						
• Cracking moment	$M_{cr}$	77.18	77.18	77.18	Kn.m	
• Check	$M_r > \min(1.2M_{cr}, 1.33M_u)$	O.K	O.K	O.K		
<b>Maximum Reinforcement</b>						
• Obligation Condition	$c/d_e$	0.15	0.17	0.08		
• Check	$c/d_e < 0.42$	O.K	O.K	O.K		
<b>Check shear resistance</b>						
• Factored Shear force	$V_u$	-	342.60	-	kN	
• Resistance factor	$\Phi$	0.90	0.90	0.90		
• The effective shear deepth	$d_v$	291	266	291	mm	
• Effective width	$b_v$	1000	1000	1000	mm	
• Angle of inclination of diagonal compressive stress	$\theta$	45	43	45	degree	
• Angle of inclination of transverse reinf. To longitudir	$\alpha$	90	90	90	degree	
• Factor indicating ability of diagonally cracked concrete to transmit tension	$\beta$	2.00	2.00	2.00		
• Value	$0.1*f_c \cdot b_v \cdot d_v$	728	665	728	kN	
• Max spacing of transverse reinforcement	$s$	233	213	233	mm	
• Spacing of stirrup	$s$	500	250	500	mm	
• Diameter of transverse reinforcement	$\phi$	D 18	D 18	D 18		
• Number of transverse reinf. within distance s	$n$	4	2	2	bar	
• Assume	$\theta$	45.00	36.32	45.00	degree	
• Strain in tensile reinforcement	$\epsilon_s \cdot 1000$	1.76E+00	2.04E+00	1.92E+00		
If $\epsilon_s < 0$ , multiple with reduce factor	$\Phi_c$	-	-	-		
• Ratio of shear stress and $f_c$	$V/f_c$	0.00	0.06	0.00		
• $\beta$ final		2.00	1.68	2.00		
• $\theta$ final		45.00	42.88	45.00	degree	
• Total area of transverse reinf.	$A_v$	1018	509	509	mm <sup>2</sup>	
• Diameter of stirrup	$\phi$	D 10	D 14	D 10	mm	
• Number of stirrup within distance s	$n$	2	4	2	bar	
• Total area of stirrup	$A_v$	157.08	615.75	157.08		
• The shear resistance of concrete:	$V_c$	241.53	220.78	241.53	kN	
• The shear resistance of stirrup	$V_s$	16.31	134.83	16.31	kN	
• Value	$0.25*f_c \cdot b_v \cdot d_v$	1818.75	1662.50	1818.75	kN	
• The nominal shear resistance:	$V_n$	257.84	355.61	257.84	kN	
• The factored shear resistance	$V_r$	232.05	320.05	232.05	kN	
• Check	$V_r > V_u$	O.K	NOT O.K	O.K		
• Requiring transverse reinforcement	$V_u > 0.5 \cdot \Phi \cdot V_c$	Not required	Need	Not required		
• Check minimum transverse reinforcement	$A_v > 0.083 \cdot (f_c^{0.5}) \cdot b_v \cdot s / f_y$	not required	O.K	not required		

<b>Check crack</b>					
<b>Interior force combination</b>					
• Factored moment	$M_u$	1.37E+02	1.03E+02	5.78E+01	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f_c}$	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis	$y_t = h - c$	305	305	327	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	12	9	5	MPa
• Check	$f_r >$	0.8 $\cdot f_r$	0.8 $\cdot f_r$	0.8 $\cdot f_r$	
		check crack	check crack	check crack	
• Crack width parameter	$Z$	= 17500	= 17500	= 17500	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 8.00	= 8.00	= 8.00	
• The distance from extreme fiber to the neutral axis	$c$	= 115.00	= 110.78	= 77.47	mm
• Effective moment of inertia	$J$	1.01E+09	8.46E+08	5.26E+08	mm <sup>4</sup>
• Arm	$de - c$	= 176.00	= 155.22	= 213.53	mm
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (de - c) / J$	= 190.03	= 151.41	= 187.63	MPa
• Area of concrete having the same centroid as the principal	$A$	= 12500	= 12500	= 25000	mm <sup>2</sup>
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 193.69	= 193.69	= 153.74	Mpa
• Check condition	$f_s < f_{sa}$	O.K	O.K	NOT O.K	
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	



# 7. Ultimate check, shear capacity check and crack control

Item		Section IV-IV (outside bar)	Section V-V (Top bar)	Section VI-VI (Bottom bar)	Unit	
• Factored Plexural moment	$M_u$	180.60	201.30	152.60	kN.m	
• Factored Shear force	$V_u$	179.80	74.60	393.60	kN	
• Factored Shear force	$N_u$	472.30	191.80	191.80	kN	
• Hight of Section	$h$	350	400	400	mm	
• Width of section	$b$	1000	1000	1000	mm	
• Section area	$A_c$	350000	400000	400000	mm <sup>2</sup>	
• Moment of inertia of concrete section	$I_g$	3.6E+09	5.3E+09	5.3E+09	mm <sup>4</sup>	
• Tension reinforcement	Distance from tension reinf. to extreme compression fiber	$d_c$	84	59	84	mm
	Reinf. Diameter	$\varnothing$	D18	D18	D18	mm
	Space	@	125	125	125	mm
	Number of bar	$n$	8	8	8	bar
	Total area of reinf.	$A_s$	2036	2036	2036	mm <sup>2</sup>
• comp. reinforcement:	Distance from compressive reinf. to extreme Tension fiber		59	84	59	mm
	Diameter		D18	D18	D18	mm
	Reinf. Space		250	250	125	mm
	Number of bar		4	4	8	bar
	Total area of reinf.	$A'_s$	1018	1018	2036	mm <sup>2</sup>
Check Flexural Moment						
• Resistance factor	$\Phi$	0.90	0.90	0.90		
• The corresponding effective	$d_o$	266	341	316	mm	
• Stress block factor	$\beta_1$	0.85	0.85	0.85		
• Depth of the equivalent stress block = $c \cdot \beta_1$	$a$	38.32	38.32	38.32	mm	
• Distance from extreme compression fiber to the neut	$c$	45.08	45.08	45.08	mm	
• The nominal flexural resistance:	$M_n$	201	262	242	kN.m	
• Factored flexural resistance	$M_r = \Phi \cdot M_n$	181	236	218	kN.m	
• Check condition	$M_r > M_u$	O.K	O.K	O.K		
Minimum Reinforcement						
• Cracking moment	$1.2M_{cr}$	77.18	100.80	100.80	Kn.m	
• Check	$M_r > \min(1.2M_{cr}, 1.33M_u)$	O.K	O.K	O.K		
Maximum Reinforcement						
• Obligation Condition	$c/d_o$	0.17	0.13	0.14		
• Check	$c/d_o < 0.42$	O.K	O.K	O.K		
Check shear resistance						
• Factored Shear force	$V_u$	179.80	74.60	393.60	kN	
• Resistance factor	$\Phi$	0.90	0.90	0.90		
• The effective shear deepth	$d_v$	266	341	316	mm	
• Effective width	$b_v$	1000	1000	1000	mm	
• Angle of inclination of diagonal compressive stress	$\theta$	45	42	43	degree	
• Angle of inclination of transverse reinf. To longitudi	$\alpha$	90	90	90	degree	
• Factor indicating ability of diagonally cracked concrete to transmit tension	$\beta$	1.48	2.00	1.69		
• Value	$0.1 \cdot f'_c \cdot b_v \cdot d_v$	665	853	790	kN	
• Max spacing of transverse reinforcement	$s$	213	273	253	mm	
• Spacing of stirrup	$s$	250	500	125	mm	
• Diameter of transverse reinforcement	$\varnothing$	D 18	D 18	D 18		
• Number of transverse reinf. within distance $s$	$n$	2	4	1	bar	
• Assume	$\theta$	39.71	40.10	38.64	degree	
• Strain in tensile reinforcement	$\epsilon_x$	2.51	1.79	2.03		
If $\epsilon_x < 0$ , multiple with reduce factor	$\Phi_c$	-	-	-		
• Ratio of shear stress and $f'_c$	$V/f'_c$	0.03	0.01	0.06		
• $\beta$ final		1.48	1.81	1.69		
• $\theta$ final		45.05	42.18	42.89	degree	
• Total area of transverse reinf.	$A_v$	509	1018	254	mm <sup>2</sup>	
• Diameter of stirrup	$\varnothing$	D 14	D 10	D 14	mm	
• Number of stirrup within distance $s$	$n$	4	2	8	bar	
• Total area of stirrup	$A_v$	615.75	157.08	1231.50		
• The shear resistance of concrete:	$V_c$	163.80	283.03	221.98	kN	
• The shear resistance of stirrup	$V_s$	116.42	23.08	640.45	kN	
• Value	$0.25 \cdot f'_c \cdot b_v \cdot d_v$	1662.50	2131.25	1975.00	kN	
• The nominal shear resistance:	$V_n$	280.22	306.11	862.43	kN	
• The factored shear resistance	$V_r$	252.20	275.50	776.19	kN	
• Check	$V_r > V_u$	O.K	O.K	O.K		
• Requiring transverse reinforcement	$V_u > 0.5 \cdot \Phi \cdot V_c$	Need	Not required	Need		
• Check minimum transverse reinforcement	$A_v > 0.083 \cdot (f'_c)^{0.5} \cdot b_v \cdot s / f_y$	O.K	not required	O.K		

<b>Check crack</b>					
<b>Interior force combination</b>					
• Factored moment	$M_u$	1.30E+02	1.45E+02	1.09E+02	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f'_c}$	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis	$y_t = h - c$	305	355	355	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	11	10	7	MPa
• Check	$f_r >$	$0.8 \cdot f_r$	$0.8 \cdot f_r$	$0.8 \cdot f_r$	
	check crack	check crack	check crack	check crack	
• Crack width parameter	$Z$	= 17500	= 17500	= 17500	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 8.00	= 8.00	= 8.00	
• The distance from extreme fiber to the neutral axis	$c$	= 110.78	= 122.93	= 119.04	mm
• Effective moment of inertia	$J$	8.46E+08	1.39E+09	1.19E+09	mm <sup>4</sup>
• Arm	$de - c$	= 155.22	= 218.07	= 196.96	mm
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (de - c) / J$	= 191.35	= 181.76	= 143.18	MPa
• Area of concrete having the same centroid as the principal	$A$	= 12500	= 12500	= 12500	mm <sup>2</sup>
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 193.69	= 193.69	= 193.69	Mpa
• Check condition	$f_s < f_{sa}$	O.K	O.K	O.K	
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	

## UNDERPASS CULVERT CALCULATION SHEET

### 1. General

- Group : 5
- Dimension : 6.5x4.5 m
- Covering height :  $H \leq 0.6\text{m}$
- Live load on thruway: HL93
- Live load on cross road: 0.65 HL93
- Lane number on cross road: 2 lane
- Design standard: 22TCN-272-05

### 2. Material property

#### 2.1. Concrete

- Compressive strength of cylindrical at 28 da:  $f'_c = 25$  MPa
- Concrete density  $\gamma_c = 24.5$  KN/m<sup>3</sup>
- Elastic modulus  $E_c = 0.043 \cdot \gamma_c^{1.5} \cdot \sqrt{f'_c} = 26875$  N/mm<sup>2</sup>
- Tensile strength of concrete:  $f_r = 0.63 \cdot \sqrt{f'_c} = 3.15$  N/mm<sup>2</sup>

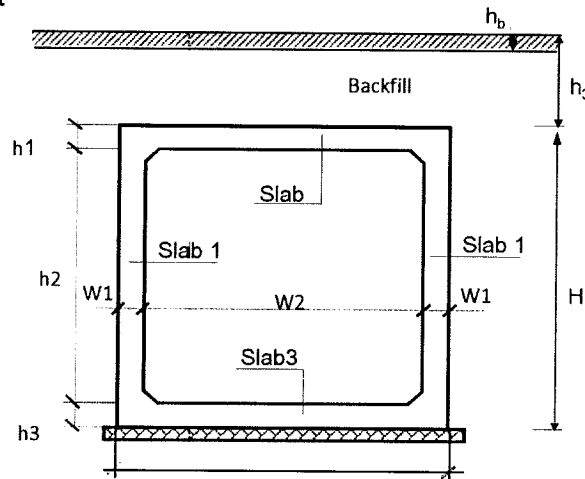
#### 2.2. Steel

- Elastic module of steel :  $E_s = 200000$  N/mm<sup>2</sup>
- Liquid limit:  $f_y = 400$  N/mm<sup>2</sup>

#### 2.2. Pavement and backfill

- Thickness of Asphalt pavement  $t = 0.16$  m
- Elastic module of ground soil  $E_o = 6902$  KN/m<sup>2</sup>
- Unit weight of soil  $\gamma_s = 17.66$  KN/m<sup>3</sup>
- Seftweight of Pavement  $\gamma_{as} = 22$  KN/m<sup>3</sup>
- Intenal friction angle of soil  $\phi'_f = 30$  deg
- Friction angle between soil and wall  $\delta = 0$  deg

### 3. Dimention of Box culvert



BOX CULVERT DIMENSION			
Item	Unit	Symbol	Value
Thickness of slab 1	m	$h_1$	0.550
Thickness of slab 2	m	$w_1$	0.550
Thickness of slab 3	m	$h_3$	0.600
Height of box culvert	m	$H$	5.650
Height of box culvert	m	$h_2$	4.500
Height of pavement structure	m	$h_b$	0.160
Height of backfilling on top of culvert	m	$h_3$	0~0.6
Span length	m	$w_2$	6.500
Culvert width	m	$W$	7.600

## 4. Loading

### 4.1. Deadload

- Deadload of box culvert (DC) will be automatic calculate by Midas program with selfweight of concrete is:  $\gamma_c = 24.5 \text{ (Mpa)}$
- Deadload of pavement (DW) will be automatic calculate by Midas program with selfweight of pavement is:  $\gamma_{as} = 22 \text{ (Mpa)}$

### 4.2. Live load

- Where the depth of fill is less than 600mm, the effect of fill on the distribution of live load shall be neglected.
- The uniformly distribution of wheel where covering depth  $\geq 600 \text{ mm}$  determined follow A 3.6.1.2.6.
- Impact load determined follow A 3.6.2.2.
- Where the depth of fill exceeds 600 mm, wheel loads may be considered to be uniformly distributed over rectangular area with sides equal to the dimension of the tire contact area as A 3.6.1.2.5, and increased by either 1.15 times the depth of the fill in select granular backfill, or the depth of the fill in all other cases.
- For single span culverts, the effects of live load may be neglected where the depth of fill is  $\geq 2400\text{mm}$  and exceeds the span length.
- For multiple span culverts, the effects of live load may be neglected where the depth of fill exceeds the distance between faces of end walls.
- Where such areas from several wheels overlap, the total load shall be uniformly distributed over the area.
- The dynamic load allowance for culverts shall be taken as:

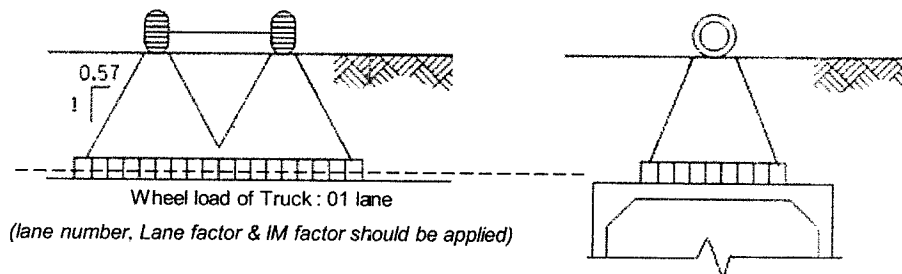
$$IM = 33 * (1.0 - 4.1 \times 10^{-4} \cdot De) \quad (3.6.2.2.1)$$

#### • Design truck:

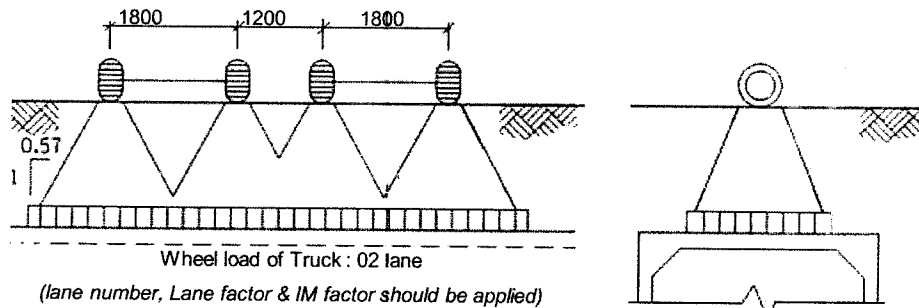
- Estimate for impact factor and distributed area of wheel

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
0	145	33.00	510	385	510	385
0.6	145	24.88	510	361	1200	1051

Distribution of wheel load for 1 lane



Distribution of wheel load for 2 lane



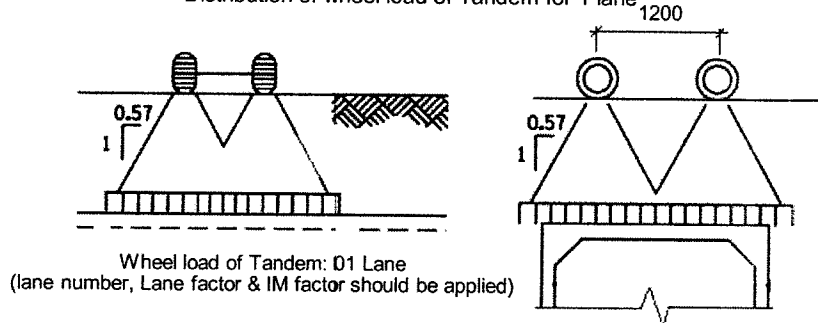
Distributed wheel load of truck

Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>truck -1 lane</sub> (Kn/m)	LL <sub>truck -2 lane</sub> (Kn/m)
0	145	510	385	369.49	369.49
0.6	145	1200	1051	4.09	4.09

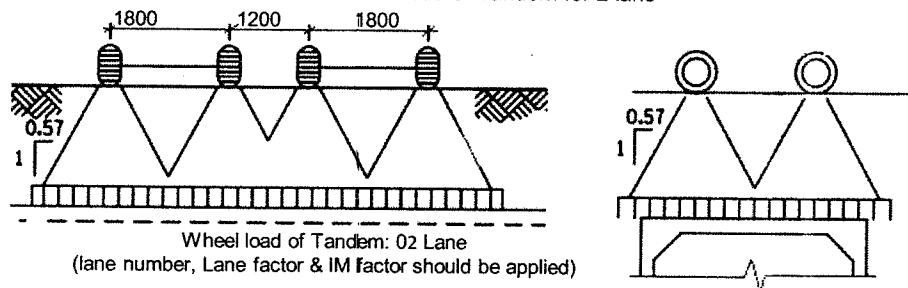
• **Tandem:**

Covering (m)	Wheel load (Kn)	IM (%)	B (mm)	L (mm)	Be (mm)	Le (mm)
0	110	33.00	510	292	510	292
0.6	110	24.88	510	274	1200	964

Distribution of wheel load of Tandem for 1 lane



Distribution of wheel load of Tandem for 2 lane



Distributed wheel load of Tandem

Covering (m)	Wheel load (Kn)	Be (mm)	Le (mm)	LL <sub>tandem -1 lane</sub> (Kn/m)	LL <sub>tandem -2 lane</sub> (Kn/m)
0.6	145	510	292	46.68	46.68
4.5	145	1200	964	3.01	4.81

- Design live load applied to structure:  $\text{Max(LL)} = 369.49$  (Kn/m) with covering depth 0.6 m  
 $= 4.81$  (Kn/m) with covering depth 4.5 m

• **Lane load**

- Lane load distributed on 1 m  $= 3.10$  kN/m

**4.3. Live load on cross road (for bottom slab)**

Design live load:

Number of lane:

Bottom slab span:

- The width of the equivalent strip of a deck shall be taken

Dynamic load allowance:

Lane factor

→ Point load from wheel load of design truck

→ Point load from wheel load of design tandem

→ Load from design lane load

Number of lane:

Dynamic load allowance:

Lane factor

→ Point load from wheel load of design truck

→ Point load from wheel load of design tandem

→ Load from design lane load

	0.65HL93	
n	=	1 lane
S	=	7050 mm
E	=	2983 mm (Table 4.6.2.1.3-1)
IM	=	25 % (3.6.2.1)
	=	1.2
	=	23.70 kN
	=	25.64 kN
	=	3.10 kN/m
n	=	2 lane
IM	=	25 % (3.6.2.1)
	=	1.0
	=	19.75 kN
	=	21.37 kN
	=	3.10 kN/m

#### 4.2.1. Surcharge load (LS)

-Where a surcharge load is present, a constant horizontal earth pressure shall be added to the basic earth pressure.

This constant earth pressure may be taken as

$$D_p = k \cdot \gamma_s \cdot g \cdot h_{eq} \times 10^{-9} \quad (3.11.6.1-1)$$

Where:

$D_p$  = constant horizontal earth pressure due to uniform surcharge load applied (Mpa)  
 $k$  = coefficient of earth pressure  
 $\gamma_s$  = density of soil (kg/m<sup>3</sup>)  
 $h_{eq}$  = height of soil equivalent to design truck (mm).

Wall height(mm)	heq (mm)	Covering	Wall height (mm)	h <sub>eq</sub> (m)	D <sub>p</sub> (Kn/m <sup>2</sup> )
< 1500.	1700				
3000	1200	0.60 m	6250	747.50	4.40
6000	760	4.50 m	10150	610.00	3.59
> 9000.	610				

#### 4.3. Earth Pressure (EV & EH):

##### 4.3.1. Vertical earth pressure (EV) (A12.11.2.2)

- The factor of vertical earth pressure

$$F_e = \text{MIN}(1+0.2 \cdot h_3/W, 1.15)$$

→ Vertical earth pressure on top slab of culvert

$$EV = F_e \cdot \gamma_s \cdot h$$

Covering (h <sub>3</sub> )	F <sub>e</sub>	γ <sub>s</sub> (Kn/m <sup>3</sup> )	EV (Kn/m)
0.60 m	1.016	17.66	10.76
4.50 m	1.118	17.66	88.87

##### 4.3.2. Horizontal earth pressure (EH)

- Basic earth pressure shall be assumed to be linearly proportional to the depth of earth and taken as.

$$P_h = K_a \cdot \gamma_s \cdot g \cdot Z \cdot 10^{-9} \quad (3.11.5.1-1)$$

In which:

$P_h$  : horizontal earth pressure at the depth of Z (N/mm<sup>2</sup>)

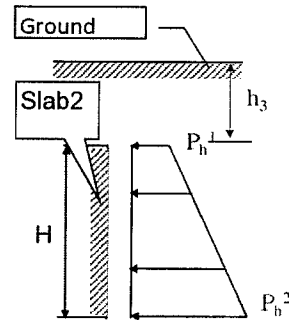
- + Lateral earth pressure applied on the plate as figure

$$P_h^1 = K_a \cdot \gamma_s \cdot g \cdot h_3 \cdot 10^{-9}$$

$$P_h^2 = K_a \cdot \gamma_s \cdot g \cdot (H+h_3) \cdot 10^{-9}$$

in which:

- $P_h$  : Horizontal earth pressure (N/mm)
- $K_a$  : active earth pressure coefficient  $K_a = 0.33$
- $\gamma_s$  : Density of soil (kg/m<sup>3</sup>)  $\gamma_s = 1800$
- $g$  : Gravitational acceleration (m/s<sup>2</sup>)  $g = 9.81$
- $\phi$  : Angle of internal friction  $\phi = 30 \text{ deg}$
- $h_3$  : filling height from top of box culvert (mm)
- $H$  : Total height of box culvert (mm)

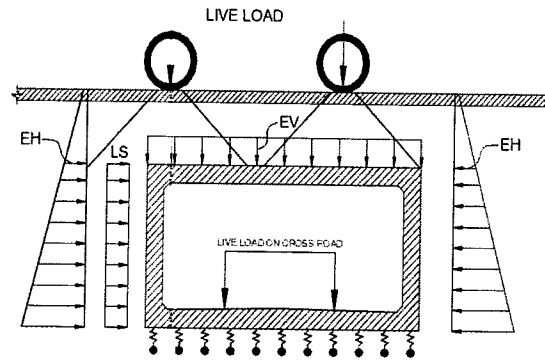


Covering	k <sub>a</sub>	γ <sub>s</sub> (Kg/m <sup>3</sup> )	g (m/s <sup>2</sup> )	P <sub>h</sub> <sup>1</sup> (Kn/m <sup>2</sup> )	P <sub>h</sub> <sup>2</sup> (Kn/m <sup>2</sup> )
0.60 m	0.33	1800.	9.81	3.53	36.79
4.50 m	0.33	1800.	9.81	26.49	59.74

#### 5. Load combination

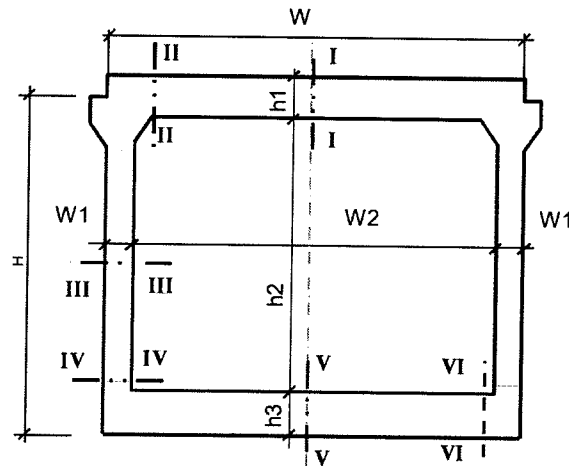
Load combination and load combination factor shall be taken as Table 3.4.1-1

State	Mark	Str. I-A	Str. I-B	Str. I-C	Str. III-A	Str. III-B	Service I
Dead load of structural	DC	1.25	1.25	0.90	0.90	1.25	1.00
Dead load of wearing	DW	1.50	1.50	0.65	0.65	1.50	1.00
Vertical earth pressure	EV	1.30	1.30	0.90	0.90	1.30	1.00
Horizontal earth pressure	EH	1.50	0.90	1.50	1.50	1.50	1.00
Live load	LL	1.75	1.75	1.75	1.35	1.35	1.00
Live load surcharge	LS	1.75	1.75	1.75	1.35	1.35	1.00



Model of structural of culvert by midas program

#### 6. Design force applied to sections:



Design section

Table of Internal force with covering height  $h=0.6\text{m}$

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	477.70	64.30	-80.30	297.50	39.90	-48.50
II - II	-315.20	464.60	-80.30	-194.50	288.50	-48.50
III - III	-296.80	24.60	-527.60	-185.90	24.40	-350.70
IV - IV	-390.60	114.60	-566.20	-254.10	76.70	-366.10
V - V	593.90	67.90	-123.90	368.00	40.70	-82.80
VI - VI	-333.70	598.10	-123.90	-216.50	349.70	-82.80

Table of Internal force applied to design section

Section	Strength State (envelope)			Service State		
	M (KN.m)	Q (KN)	N (KN)	M (KN.m)	Q (KN)	N (KN)
I - I	477.70	64.30	80.30	297.50	39.90	48.50
II - II	315.20	464.60	80.30	194.50	288.50	48.50
III - III	296.80	24.60	527.60	185.90	24.40	350.70
IV - IV	390.60	114.60	566.20	254.10	76.70	366.10
V - V	593.90	67.90	123.90	368.00	40.70	82.80
VI - VI	333.70	598.10	123.90	216.50	349.70	82.80

7. Ultimate check, shear capacity check and crack control

Item		Section I-I (Bottom bar)	Section II-II (Top bar)	Section III-III (Inside bar)	Unit	
• Factored Plexural moment	$M_u$	477.70	315.20	296.80	kN.m	
• Factored Shear force	$V_u$	64.30	464.60	24.60	kN	
• Factored nominal force	$N_u$	80.30	80.30	527.60	kN	
• Hight of Section	$h$	550	550	550	mm	
• Width of section	$b$	1000	1000	1000	mm	
• Section area	$A_c$	550000	550000	550000	mm <sup>2</sup>	
• Moment of inertia of concrete section	$I_g$	1.4E+10	1.4E+10	1.4E+10	mm <sup>4</sup>	
• Tension reinforcement	Distance from tension reinf. to extreme compression fiber	$d_c$	64	86	64	mm
	Reinf. Diameter	$\phi$	D22	D22	D22	mm
	Space	@	125	125	125	mm
	Number of bar	$n$	8	8	8	bar
	Total area of reinf.	$A_s$	3041	3041	3041	mm <sup>2</sup>
• comp. reinforcement:	Distance from compressive reinf. to extreme Tension fiber		86	86	85	mm
	Diameter		D22	D22	D20	mm
	Reinf. Space		250	125	125	mm
	Number of bar		4	8	8	bar
	Total area of reinf.	$A'_s$	1521	3041	2513	mm <sup>2</sup>
<b>Check Flexural Moment</b>						
• Resistance factor	$\phi$	0.90	0.90	0.90		
• The corresponding effective	$d_e$	486	464	486	mm	
• Stress block factor	$\beta_1$	0.85	0.85	0.85		
• Depth of the equivalent stress block = $c \cdot \beta_1$	$a$	57.24	57.24	57.24	mm	
• Distance from extreme compression fiber to the neutr	$c$	67.35	67.35	67.35	mm	
• The nominal flexural resistance:	$M_n$	556	530	556	kN.m	
• Factored flexural resistance	$M_r = \phi \cdot M_n$	501	477	501	kN.m	
• Check condition	$M_r > M_u$	O.K	O.K	O.K		
<b>Minimum Reinforcement</b>						
• Cracking moment	$1.2M_{cr}$	190.58	190.58	190.58	Kn.m	
• Check	$M_r > \min(1.2M_{cr}, 1.33M_u)$	O.K	O.K	O.K		
<b>Maximum Reinforcement</b>						
• Obligation Condition	$c/d_e$	0.14	0.15	0.14		
• Check	$c/d_e < 0.42$	O.K	O.K	O.K		
<b>Check shear resistance</b>						
• Factored Shear force	$V_u$	64.30	464.60	24.60	kN	
• Resistance factor	$\phi$	0.90	0.90	0.90		
• The effective shear deepeth	$d_v$	486	464	486	mm	
• Effective width	$b_v$	1000	1000	1000	mm	
• Angle of inclination of diagonal compressive stress	$\theta$	45	41	45	degree	
• Angle of inclination of transverse reinf. To longitudinal	$\alpha$	90	90	90	degree	
• Factor indicating ability of diagonally cracked concrete to transmit tension	$\beta$	2.00	2.00	2.00		
• Value	$0.1 \cdot f_c \cdot b_v \cdot d_v$	1215	1160	1215	kN	
• Max spacing of transverse reinforcement	$s$	389	371	389	mm	
• Spacing of stirrup	$s$	500	250	500	mm	
• Diameter of transverse reinforcement	$\phi$	D 22	D 22	D 22		
• Number of transverse reinf. within distance s	$n$	4	2	4	bar	
• Assume	$\theta$	45.00	41.52	45.00	degree	
• Strain in tensile reinforcement	$\epsilon_s \cdot 1000$	1.73E+00	1.61E+00	1.46E+00		
If $\epsilon_s < 0$ , multiple with reduce factor	$\phi_c$	-	-	-		
• Ratio of shear stress and $f_c$	$V/f_c$	0.01	0.04	0.00		
• $\beta$ final		2.00	1.90	2.00		
• $\theta$ final		45.00	41.46	45.00	degree	
• Total area of transverse reinf.	$A_v$	1521	760	1521	mm <sup>2</sup>	
• Diameter of stirrup	$\phi$	D 10	D 16	D 10	mm	
• Number of stirrup within distance s	$n$	2	4	2	bar	
• Total area of stirrup	$A_v$	157.08	804.25	157.08		
• The shear resistance of concrete:	$V_c$	403.38	385.12	403.38	kN	
• The shear resistance of stirrup	$V_s$	27.23	336.71	27.23	kN	
• Value	$0.25 \cdot f_c \cdot b_v \cdot d_v$	3037.50	2900.00	3037.50	kN	
• The nominal shear resistance:	$V_n$	430.61	721.83	430.61	kN	
• The factored shear resistance	$V_r$	387.55	649.64	387.55	kN	
• Check	$V_r > V_u$	O.K	O.K	O.K		
• Requiring transverse reinforcement	$V_u > 0.5 \cdot \phi \cdot V_c$	Not required	Need	Not required		
• Check minimum transverse reinforcement	$A_v > 0.083 \cdot (f_c^{0.5}) \cdot b_v \cdot s / f_y$	not required	O.K	not required		



Check crack					
<b>Interior force combination</b>					
• Factored moment	$M_u$	2.98E+02	1.95E+02	1.86E+02	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f_c}$	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis:	$y_t = h - c$	483	483	483	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	10	7	6	MPa
• Check	$f_r >$	$0.8 \cdot f_r$	$0.8 \cdot f_r$	$0.8 \cdot f_r$	
	check crack	check crack	check crack	check crack	
• Crack width parameter	$Z$	= 17500	= 17500	= 17500	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 8.00	= 8.00	= 8.00	
• The distance from extreme fiber to the neutral axis	$c$	= 180.02	= 176.54	= 180.02	mm
• Effective moment of inertia	$J$	4.22E+09	3.84E+09	4.22E+09	mm <sup>4</sup>
• Arm	$de - c$	= 305.98	= 287.46	= 305.98	mm
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (de - c) / J$	= 172.47	= 116.35	= 107.77	MPa
• Area of concrete having the same centroid as the principal	$A$	= 12500	= 12500	= 12500	mm <sup>2</sup>
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 191.55	= 191.55	= 191.55	Mpa
• Check condition	$f_s < f_{sa}$	O.K	O.K	O.K	
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	

7. Ultimate check, shear capacity check and crack control

Item		Section IV-IV (outside bar)	Section V-V (Top bar)	Section VI-VI (Bottom bar)	Unit	
• Factored Plexural moment	$M_u$	390.60	593.90	333.70	kN.m	
• Factored Shear force	$V_u$	114.60	67.90	598.10	kN	
• Factored Shear force	$N_u$	566.20	123.90	123.90	kN	
• Hight of Section	$h$	550	600	600	mm	
• Width of section	$b$	1000	1000	1000	mm	
• Section area	$A_c$	550000	600000	600000	mm <sup>2</sup>	
• Moment of inertia of concrete section	$I_g$	1.4E+10	1.8E+10	1.8E+10	mm <sup>4</sup>	
• Tension reinforcement	Distance from tension reinf. to extreme compression fiber	$d_c$	86	63	86	mm
	Reinf. Diameter	$\varnothing$	D22	D25	D22	mm
	Space	@	125	125	125	mm
	Number of bar	$n$	8	8	8	bar
	Total area of reinf.	$A_s$	3041	3927	3041	mm <sup>2</sup>
• comp. reinforcement:	Distance from compressive reinf. to extreme		61	88	61	mm
	Tension fiber					
	Diameter		D22	D25	D22	mm
	Reinf. Space		250	250	125	mm
	Number of bar		4	4	8	bar
	Total area of reinf.	$A'_s$	1521	1963	3041	mm <sup>2</sup>
<b>Check Flexural Moment</b>						
• Resistance factor	$\Phi$	0.90	0.90	0.90		
• The corresponding effective	$d_e$	464	538	514	mm	
• Stress block factor	$\beta_1$	0.85	0.85	0.85		
• Depth of the equivalent stress block = $c \cdot \beta_1$	$a$	57.24	73.92	57.24	mm	
• Distance from extreme compression fiber to the neut	$c$	67.35	86.96	67.35	mm	
• The nominal flexural resistance:	$M_n$	530	786	590	kN.m	
• Factored flexural resistance	$M_r = \Phi \cdot M_n$	477	708	531	kN.m	
• Check condition	$M_r > M_u$	O.K	O.K	O.K		
<b>Mimumum Reinforcement</b>						
• Cracking moment	$1.2M_{cr}$	190.58	226.80	226.80	Kn.m	
• Check	$M_r > \min(1.2M_{cr}, 1.33M_u)$	O.K	O.K	O.K		
<b>Maximum Reinforcement</b>						
• Obligation Condition	$c/d_e$	0.15	0.16	0.13		
• Check	$c/d_e < 0.42$	O.K	O.K	O.K		
<b>Check shear resistance</b>						
• Factored Shear force	$V_u$	114.60	67.90	598.10	kN	
• Resistance factor	$\Phi$	0.90	0.90	0.90		
• The effective shear deepth	$d_v$	464	538	514	mm	
• Effective width	$b_v$	1000	1000	1000	mm	
• Angle of inclination of diagonal compressive stress	$\theta$	43	41	42	degree	
• Angle of inclination of transverse reinf. To longitudi	$\alpha$	90	90	90	degree	
• Factor indicating ability of diagonally cracked concrete to transmit tension	$\beta$	1.74	2.00	1.85		
• Value	$0.1 \cdot f'_c \cdot b_v \cdot d_v$	1160	1344	1285	kN	
• Max spacing of transverse reinforcement	$s$	371	430	411	mm	
• Spacing of stirrup	$s$	250	500	250	mm	
• Diameter of transverse reinforcement	$\varnothing$	D 22	D 25	D 22		
• Number of transverse reinf. within distance s	$n$	2	4	2	bar	
• Assume	$\theta$	43.56	42.31	42.52	degree	
• Strain in tensile reinforcement	$\epsilon_s$	1.95	1.53	1.71		
If $\epsilon_s < 0$ , multiple with reduce factor	$\Phi_c$	-	-	-		
• Ratio of shear stress and $f'_c$	$V/f'_c$	0.01	0.01	0.05		
• $\beta$ final		1.74	1.93	1.85		
• $\theta$ final		42.79	41.13	41.75	degree	
• Total area of transverse reinf.	$A_v$	760	1963	760	mm <sup>2</sup>	
• Diameter of stirrup	$\varnothing$	D 16	D 10	D 16	mm	
• Number of stirrup within distance s	$n$	4	2	4	bar	
• Total area of stirrup	$A_v$	804.25	157.08	804.25		
• The shear resistance of concrete:	$V_c$	335.76	446.13	394.94	kN	
• The shear resistance of stirrup	$V_s$	309.01	38.88	366.06	kN	
• Value	$0.25 \cdot f'_c \cdot b_v \cdot d_v$	2900.00	3359.38	3212.50	kN	
• The nominal shear resistance:	$V_n$	644.77	485.00	761.00	kN	
• The factored shear resistance	$V_r$	580.29	436.50	684.90	kN	
• Check	$V_r > V_u$	O.K	O.K	O.K		
• Requiring transverse reinforcement	$V_u > 0.5 \cdot \Phi \cdot V_c$	Not required	Not required	Need		
• Check minimum transverse reinforcement	$A_v > 0.083 \cdot (f'_c)^{0.5} \cdot b_v \cdot s / f_y$	not required	not required	O.K		

<b>Check crack</b>					
<b>Interior force combination</b>					
• Factored moment	$M_u$	2.54E+02	3.68E+02	2.17E+02	kN.m
• Modulus of rupture of concrete	$f_r = 0.63 \cdot \sqrt{f'_c}$	3.15	3.15	3.15	MPa
• Distance from extreme tension fiber to the neutral axis	$y_t = h - c$	483	513	533	mm
• Stress of concrete at tension fiber	$f_r = M_s \cdot y_t / I_g$	9	10	6	MPa
• Check	$f_r >$	$0.8 \cdot f_r$	$0.8 \cdot f_r$	$0.8 \cdot f_r$	
		check crack	check crack	check crack	
• Crack width parameter	$Z$	= 17500	= 17500	= 17500	N/mm
• Ratio of reinf. Modulus with concrete modulus	$n = E_s / E_c$	= 8.00	= 8.00	= 8.00	
• The distance from extreme fiber to the neutral axis	$c$	= 176.54	= 217.85	= 184.33	mm
• Effective moment of inertia	$J$	3.84E+09	6.66E+09	4.73E+09	mm <sup>4</sup>
• Arm	$de - c$	= 287.46	= 319.65	= 329.67	mm
• Tension stress in reinforcement	$f_s = n \cdot M_s \cdot (de - c) / J$	= 152.00	= 141.37	= 120.67	MPa
• Area of concrete having the same centroid as the principal	$A$	= 12500	= 12500	= 12500	mm <sup>2</sup>
• Tension stress in reinforcement with service state	$f_{sa} = Z / (d_c \cdot A)^{1/3}$	= 191.55	= 190.01	= 191.55	Mpa
• Check condition	$f_s < f_{sa}$	O.K	O.K	O.K	
• Check condition	$f_s < 0.6 \cdot f_y$	O.K	O.K	O.K	