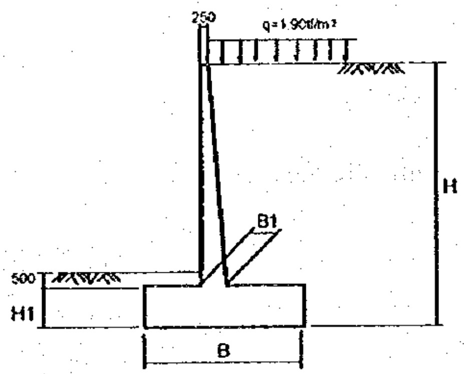
5.1.3 Retaining Wall

(1) Inverted T-Type Wall

(a) General conditions

1) Structural dimensions



Spread foundation type

(Unit:m)

Type	H=9.00m	H=8.00m	H=7.00m	H=6.00m	H=5.00m
H1	1.100	1.000	0.900	0.700	0.500
B	5.500	5.000	4.500	4.000	3.500
B1	0.900	0.800	0.700	0.600	0.500

Pile foundation type

(per 15 m long)

Type	H=9.00m	H=8.00m	H=7.00m	H=6.00m	
H1	1.100	1.000	0.900	0.700	
B	5.500	5.000	4.500	4.000	
B1	0.900	0.800	0.700	0.600	
Pile arrangement	4×10	4×9	3×8	2×9	
Pile numbers	40 Nos.	36 Nos.	24 Nos.	18 Nos.	

Pile arrangement expresses (transverse direction)×(longitudinal direction).

2) Unit weight

Reinforced concrete	: Wc	=	2.5 tf/m^3
Soil on the front part of footing	: Wa	=	1.8 tf/m^3
Backfillingsoil	: γ s	=	1.9 tf/m^3

3) Coefficient of earth pressure

For the calculation of the retaining wall structures, Coulomb's earth pressure theory was adopted.

Vertical earth pressure	: Kv	= 1.0
Horizontal earth pressure	: Ka	= 0.333

4) Live load

Live load as a surcharge	: q	= 1.90 tf/m^2

5) Material strength and allowable stresses

a) Concrete

Specified design strength			σ ck = 240.0 kgf/cm^2
Allowable flexural stress	General use		σ ca = 80.0 kgf/cm^2
	at corner	with haunch	σ ca = 80.0 kgf/cm^2
		without haunch	σ ca = 80.0 kgf/cm^2
Allowable shear stress			τ a = 3.90 kgf/cm^2
Allowable bond stress	General use		τ oa = 16.0 kgf/cm^2
	at corner		τ oa = 28.0 kgf/cm^2
Young's Modulus			Ec = 2.5×10^6 kgf/cm^2

b) Reinforcing steel

Allowable tensile strength	σ sa = 1600.0 kgf/cm^2

c) Ratio of Young's Modulus (Es/Ec) n = 15

6) Cover of reinforcing steel

Location		Cover (cm)
Wall	Outside	7.0
	Inside	7.0
Bottom Slab	Upper side	7.0
	Lower side	10.0 (15.0)

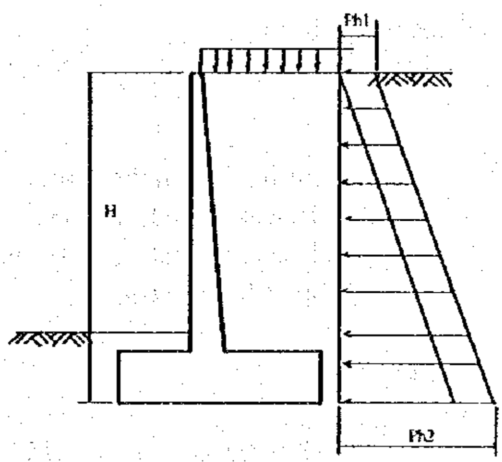
* For the pile foundation type, the value in the bracket will be applied.

(b) Calculation of load

1) Calculation of earth pressure

$$Phi = K_A \times (q + Z_0 \cdot \gamma)$$

K_A	: Coefficient of Coulomb's active earth pressure	=	0.333	
q	: Surcharge live load	=	1.90	tf/m^2
γ	: Unit weight of soil	=	1.90	tf/m^3
Z_0	: Depth at calculating point		(m)	



	Ph1 (tf/m^2)	Ph2 (tf/m^2)
H=9.00m	0.63	6.33
H=8.00m	0.63	5.70
H=7.00m	0.63	5.06
H=6.00m	0.63	4.43
H=5.00m	0.63	3.80

(c) Stability Calculation

1) Spread Foundation

a) Calculation Condition

Allowable Ground Reaction	Qa = 40	tf/m^2
Adhesion between the bottom of slab and the ground	C = 0	tf/m^2
Coefficient of friction between the bottom of slab and the ground	$\tan \phi b$ = 0.6	

b) Summary of external force applying at the center of footing

Forces shown in the table below show the value per meter in longitudinal direction.

	H=9.00m	H=8.00m	H=7.00m	H=6.00m	H=5.00m
Vertical (tf)	91.17	75.93	59.51	46.90	35.76
Horizontal (tf)	31.32	25.33	19.93	15.19	11.07
Moment (tfm)	63.91	47.73	30.89	20.82	13.27

c) Stability calculation

Stability against over-turning

Safety condition : $e = \frac{M}{V} \leq \frac{B}{6}$

where:

e : Eccentricity from the center of footing (m)
V : Applied external force in vertical (tf)
M : Applied external bending moment (tfm)
B : Width of footing (m)

Stability against sliding

Shear resistance at the bottom of footing : $Hu = C \cdot B + V \cdot \tan \phi_b = V \cdot 0.6$

The safety factor against sliding: $Fs = \frac{Hu}{H} \rangle 1.5$

where:

Fs : Safety factor against sliding
Hu : Shear resistance (tf)
H : Applied external force in horizontal (tf)

Ground reaction

In this detailed design of retaining wall, the distribution of ground reaction has trapezoid shape.

$$\frac{Q_{max}}{Q_{min}} = \frac{V}{L \times B} = \pm \frac{6 \times M}{L \times B^2} \leq Qa = 40.0 \quad (tf/m^2)$$

where:

Qmax : Calculated maximum ground reaction (tf/m^2)
Qmin : Calculated minimum ground reaction (tf/m^2)
Qa : Allowable ground reaction (tf/m^2)
L : Length of footing (m)
B : Width of footing (m)

2) Pile foundation

a) Calculation conditions

Pile condition

Kind of pile : Cast-in-place concrete pile

Pile diameter : ϕ 600 mm

Pile length : 7.50 m

Allowable bearing capacity per pile	Ra =	76.0	tf
Allowable pull-out capacity per pile	Pa =	0	tf
Coefficient of horizontal ground reaction	Kh =	2.58	kgf/cm^3
Spring constant of pile in longitudinal direction	Kv =	221.9	tf/cm
Allowable displacement at pile head	δ a =	15.0	mm

b) Summary of external force Applied at the Center of Footing

Forces in the below table show the value per meter in longitudinal direction.

	H=9.00m	H=8.00m	H=7.00m	H=6.00m
Vertical (tf)	1381.14	1253.29	852.74	635.94
Horizontal (tf)	469.80	379.95	298.95	227.85
Moment (tfm)	840.01	498.81	509.09	361.85

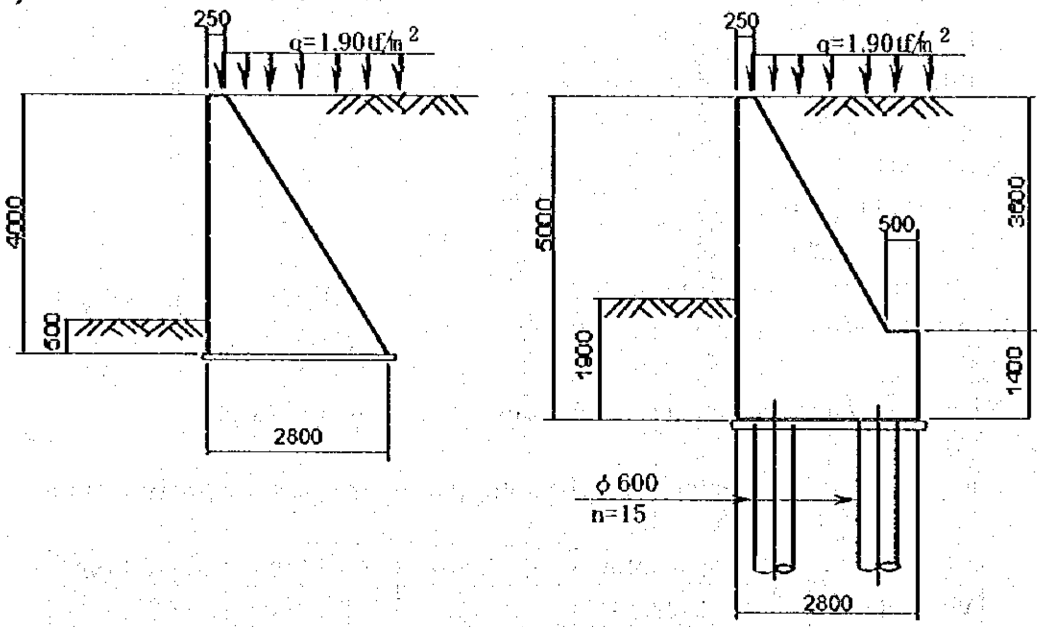
c) Stability calculation

The method of the stability calculation on pile foundation of retaining wall is the same as that of bridge substructure in Clause 5.1.2.

(2) Gravity Wall

(a) General conditions

1) Structural dimensions



2) Unit weight

Reinforced concrete	: Wc	=	2.5	tf/m^3
Soil on the front part of footing	: Wa	=	1.8	tf/m^3
Backfillingsoil	: γ s	=	1.9	tf/m^3

3) Coefficient of earth pressure

For the calculation of the retaining wall structures, Coulomb's earth pressure theory was adopted.

Vertical earth pressure	: Kv	=	1.0
Horizontal earth pressure	: Ka	=	0.595

4) Live Load

Live load as a surcharge	: q	=	1.90	tf/m^2

5) Material strength and allowable stresses

a) Concrete

Specified design strength			σ ck = 240.0 kgf/cm²
Allowable flexural stress	General use		σ ca = 80.0 kgf/cm²
	at corner	with haunch	σ ca = 80.0 kgf/cm²
		without haunch	σ ca = 80.0 kgf/cm²
Allowable shear stress			τ a = 3.90 kgf/cm²
Allowable bond stress	General use		τ oa = 16.0 kgf/cm²
	at corner		τ oa = 28.0 kgf/cm²
Young's Modulus			Ec = 2.5×10^6 kgf/cm²

b) Reinforcing steel

Allowable tensile strength	σ sa = 1600.0 kgf/cm²

c) Ratio of Young's Modulus (Es/Ec) n = 15

6) Cover of reinforcing steel

Location		Cover (cm)
Wall	Outside	7.0
	Inside	7.0
Bottom Slab	Upper side	7.0
	Lower side	10.0 (15.0)

* For the pile foundation type, the value in the bracket shall be applied.

(b) Summary of external force applied at the center of bottom

Forces in the below table show the value per meter in longitudinal direction.

	Spread Foundation	Pile Foundation
Vertical (tf)	25.68	36.15
Horizontal (tf)	8.70	13.22
Moment (tfm)	11.95	22.40

(c) Stability calculation

The stability calculation of gravity wall is carried out by the same method as that of bridge substructure and inverted T-type wall. (Refer to Clause 5.1.2 and 5.1.3 (1))

Pile condition of the gravity wall

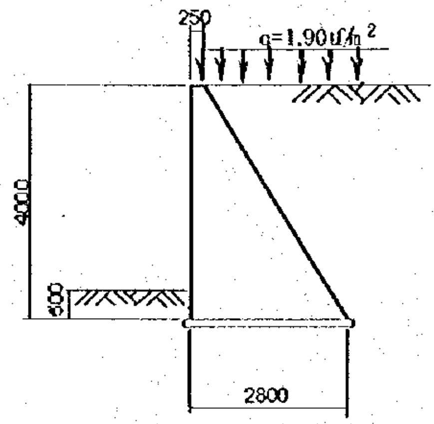
Type of pile	: Cast-in-place concrete pile		
Pile diameter	: ϕ 600 mm		
Pile length	: 7.50 m		
Allowable bearing capacity per pile		Ra =	76.0 tf
Allowable pull-out capacity per pile		Pa =	0 tf
Coefficient of horizontal ground reaction		Kh =	2.58 kgf/cm^3
Spring constant of pile in longitudinal direction		Kv =	221.9 tf/cm
Allowable displacement at pile head		δ a =	15.0 mm

(3) Design Summary of Retaining Walls

Results of design calculation for retaining walls are summarized in Tables 5.20 to 5.22.

Table 5.20 DESIGN SUMMARY OF GRAVITY RETAINING WALL

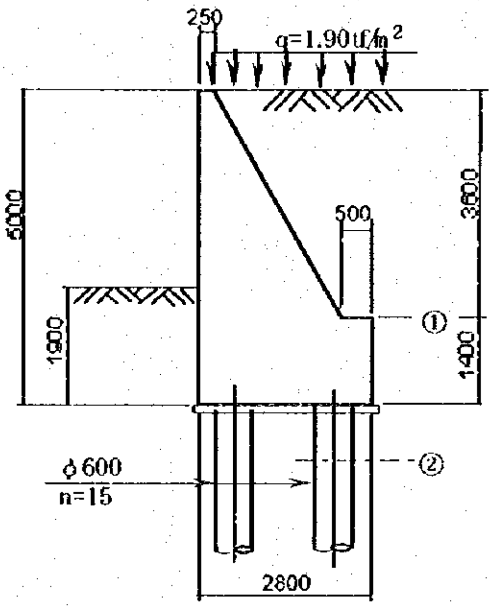
A.Spread Foundation



Stability Calculation

Case	H=4.0m	
	Result	Allowable
Eccentricity (cm)	0.460	0.467
Safety factor agianst Sliding	1.77	1.50
Maximum ground reaction (tf/m²)	18.30	30.00

B.Pile Founation



Stability Calculation

Case	H=4.0m	
	Result	Allowable
Bearing capacity (tf/pile)	66.20	76.00
Pull-out capacity (tf/pile)	1.80	0.00
Displacement at Pile head (mm)	0.60	15.00

Member Stresses

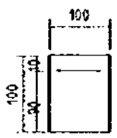
Section No.				①	②
Section					
Force		M	tfm/m	7.72	10.92
Force		N	tf/m	19.75	1.75
Force		S	tf/m	7.61	-
Reinforcing		Required	cm²		
Reinforcing		Minimum	cm²		
Reinforcing		Design	cm²	-	38.71
Reinforcing		Dia.	mm	-	D32
Reinforcing		Interval	mm	-	10 nos.
Reinforcing		Cover	mm	-	150
Stress	Designed	σ c	kgf/cm²	2.2	76.4
Stress	Designed	σ s	kgf/cm²	-	1128.0
Stress	Designed	τ o	kgf/cm²	0.33	-
Stress	Allowable	σ ca	kgf/cm²	80	80
Stress	Allowable	σ sa	kgf/cm²	-	1600
Stress	Allowable	τ oa	kgf/cm²	3.0	-

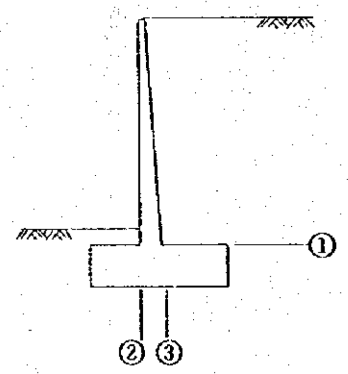
Table 5.21 DESIGN SUMMARY OF INVERTED T TYPE RETAINING WALL (Spread Foundation)

Result of Stability Caluculation

Case	H=9.00m		H=8.00m		H=7.00m		H=6.00m		H=5.00m	
	Result	Allowable	Result	Allowable	Result	Allowable	Result	Allowable	Result	Allowable
Eccentricity(cm)	0.70	0.92	0.63	0.83	0.52	0.75	0.44	0.67	0.37	0.58
Safety Factor against Sliding	1.75	1.50	1.80	1.50	1.79	1.50	1.85	1.50	1.62	1.50
Maximum Ground Reaction (tf/m2)	29.30	40.00	26.60	40.00	22.40	40.00	19.50	40.00	16.70	40.00

Member Stresses

General Diagram — Calculation Points



Member			H=9.00m			H=8.00m			H=7.00m			H=6.00m			H=5.00m					
Section No.			①	②	③	①	②	③	①	②	③	①	②	③	①	②	③			
Section																				
Force	M	tfm/m	57.54	15.74	56.01	40.67	9.91	42.28	27.41	8.08	27.89	18.29	4.53	19.44	11.42	2.19	12.79			
	N	tf/m	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
	S	tf/m	21.85	25.18	24.49	17.43	19.08	19.56	13.48	15.52	15.14	10.36	10.93	10.89	7.61	7.09	7.21			
Reinforcing Bar	Required	cm²																		
	Minimum	cm²																		
	Design	cm²	51.39	15.89	15.89	40.54	15.89	40.54	30.97	15.89	40.54	40.54	15.89	22.92	22.92	15.89	22.92			
	Dia.	mm	D29	D16	D16	D25	D16	D25	D22	D16	D22	D22	D16	D19	D19	D16	D19			
	Interval	mm	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125			
	Cover	mm	70	100	100	70	100	100	70	100	100	70	100	100	70	100	100			
Stress Designed	σ c	kgf/cm²	51.1	17.2	42.4	49.2	12.8	38.0	46.4	12.6	33.5	41.1	11.2	41.7	41.0	10.4	53.4			
	σ s	kgf/cm²	1515.0	1060.0	1532.0	1539.0	744.0	1291.0	1567.0	685.0	1245.0	1255.0	518.0	1563.0	1301.0	382.0	1571.0			
	τ o	kgf/cm²	2.63	2.52	2.45	2.39	2.12	2.17	2.14	1.94	1.89	1.95	1.82	1.81	1.77	1.77	1.81			
Stress Allowable	σ ca	kgf/cm²	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80			
	σ sa	kgf/cm²	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600			
	τ oa	kgf/cm²	3.9	7.8	7.8	3.9	7.8	7.8	3.9	7.8	7.8	3.9	7.8	7.8	3.9	7.8	7.8			

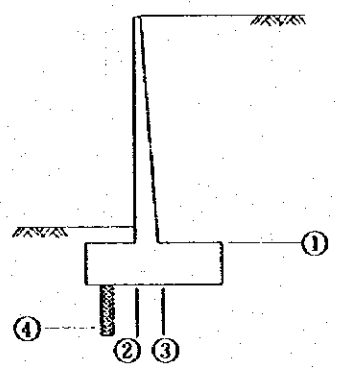
Table 5.22 DESIGN SUMMARY OF INVERTED T TYPE RETAINING WALL (Pile Foundation)

Result of Stability Caluculation

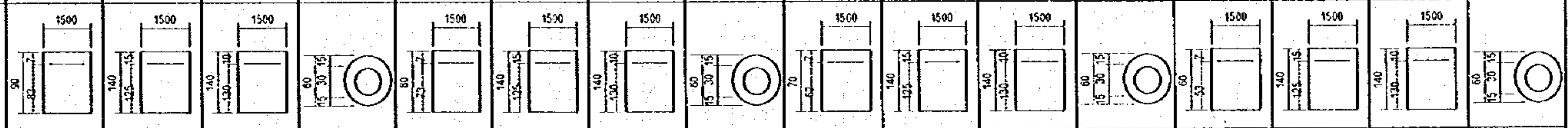
Case	H=9.00m		H=8.00m		H=7.00m		H=6.00m	
	Result	Allowable	Result	Allowable	Result	Allowable	Result	Allowable
Bearing Capacity (tf/pile)	57.40	76.00	51.60	76.00	62.60	76.00	57.40	76.00
Pull-out Capacity (tf/pile)	6.20	0.00	12.00	0.00	1.90	0.00	6.40	0.00
Displacement at Pile Head (mm)	3.63	15.00	3.18	15.00	4.31	15.00	4.45	15.00

Member Stresses

General Diagram — Calculation Points



Section



		Member	H=9.00m				H=8.00m			
		Section No.	①	②	③	④	①	②	③	④
Force	M	tfm/m	775.41	442.41	1020.32	11.60	518.52	343.56	797.37	10.80
Force	N	tf/m	-	-	-	6.20	-	-	-	12.00
Force	S	tf/m	306.08	475.06	611.52	-	235.69	365.24	501.64	-
Reinforcing Bar	Required	cm²								
Reinforcing Bar	Minimum	cm²								
Reinforcing Bar	Design	cm²	770.88	238.32	608.04	79.42	608.04	238.32	464.52	79.42
Reinforcing Bar	Dia.	mm	D22	D16	D25	D32	D25	D16	D22	D32
Reinforcing Bar	Interval	mm	125	125	125	10 nos.	125	125	125	10 nos.
Reinforcing Bar	Cover	mm	70	150	100	150	70	150	100	150
Stress – Designed	σ c	kgf/cm²	45.9	22.6	33.6	80.0	41.9	17.6	29.2	74.8
Stress – Designed	σ s	kgf/cm²	1361.0	1578.0	1415.0	1134.0	1309.0	1226.0	1432.0	964.0
Stress – Designed	τ 0	kgf/cm²	2.46	2.53	3.14	-	2.15	1.95	2.57	-
Stress – Allowable	σ ca	kgf/cm²	80	80	80	80	80	80	80	80
Stress – Allowable	σ sa	kgf/cm²	1600	1600	1600	1600	1600	1600	1600	1600
Stress – Allowable	τ 0a	kgf/cm²	3.9	7.8	7.8		3.9	7.8	7.8	

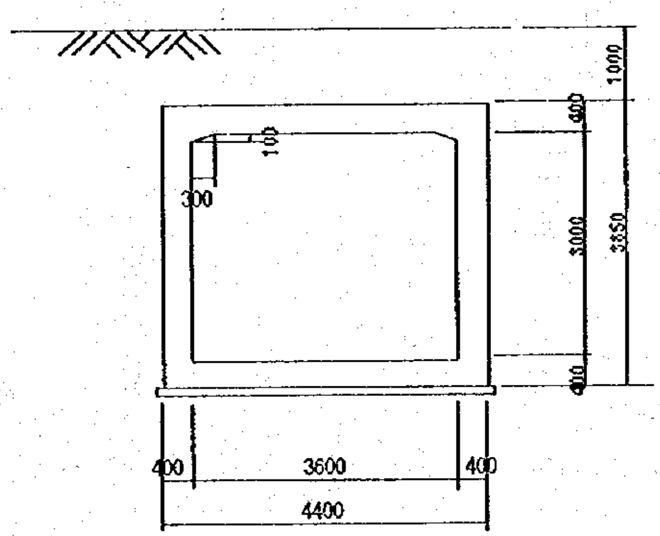
		Member	H=7.00m				H=6.00m			
		Section No.	①	②	③	④	①	②	③	④
Force	M	tfm/m	324.91	167.37	324.91	10.30	185.84	82.22	318.6	10.50
Force	N	tf/m	-	-	-	1.90	-	-	-	6.40
Force	S	tf/m	174.06	434.94	262.53	-	121.20	463.90	336.15	-
Reinforcing Bar	Required	cm²								
Reinforcing Bar	Minimum	cm²								
Reinforcing Bar	Design	cm²	464.52	238.32	238.32	79.42	343.8	238.32	238.32	79.42
Reinforcing Bar	Dia.	mm	D22	D16	D16	D32	D13	D16	D16	D32
Reinforcing Bar	Interval	mm	125	125	125	10nos.	125	125	125	10 nos.
Reinforcing Bar	Cover	mm	70	150	100	150	70	150	100	150
Stress – Designed	σ c	kgf/cm²	36.7	8.6	15.6	72.0	31.6	4.2	15.3	73.1
Stress – Designed	σ s	kgf/cm²	1238.0	597.0	1113.0	1060.0	1133.0	243.0	1092.0	1015.0
Stress – Designed	τ 0	kgf/cm²	1.84	2.32	1.35	-	1.52	2.47	1.72	-
Stress – Allowable	σ ca	kgf/cm²	80	80	80	80	80	80	80	80
Stress – Allowable	σ sa	kgf/cm²	1600	1600	1600	1600	1600	1600	1600	1600
Stress – Allowable	τ 0a	kgf/cm²	3.9	7.8	7.8		3.9	7.8	7.8	

5.1.4 Pedestrian Underpasses

(1) Main Body (Single-box tunnel)

(a) General conditions

1) Structural dimensions



2) Unit weight

Reinforced concrete	: Wc	=	2.5	tf/m³
Asphalt pavement	: Wa	=	2.3	tf/m³
Soil	: γ s	=	1.9	tf/m³

3) Coefficient of earth pressure

Vertical earth pressure	: Kv	=	1.0
Horizontal earth pressure	: Kh (K_0)	=	0.5

4) Live load

- Special Truck Type A
- AASHTO HS20-44 increased 100%

5) Material strength and allowable stresses

a) Concrete

Specified design strength			σ ck = 240.0 kgf/cm^2
Allowable flexural stress	General use		σ ca = 80.0 kgf/cm^2
	at corner	with haunch	σ ca = 80.0 kgf/cm^2
		without haunch	σ ca = 80.0 kgf/cm^2
Allowable Shear Stress			τ a = 3.90 kgf/cm^2
Allowable bond stress	General use		τ oa = 16.0 kgf/cm^2
	at corner		τ oa = 28.0 kgf/cm^2
Young's Modulus			Ec = 2.5×10^6 kgf/cm^2

b) Reinforcing steel

Allowable tensile strength	σ sa = 1600.0 kgf/cm^2

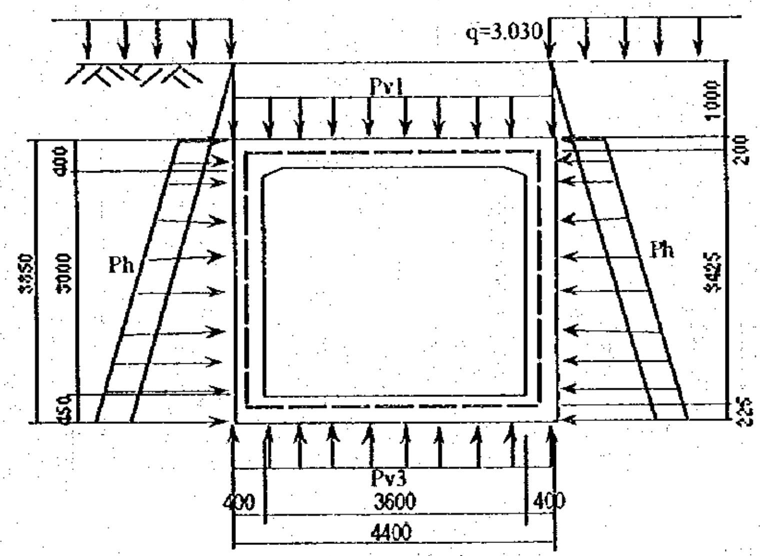
c) Ratio of Young's Modulus (Es/Ec) n = 15

6) Cover of reinforcing steel

Location		Cover(cm)	Location		Cover(cm)
Upper slab	Upper side	7.0	Right wall	Outside	7.0
	Lower side	7.0		Inside	7.0
Left wall	Outside	7.0	Lower slab	Upper side	7.0
	Inside	7.0		Lower side	10.0
Middle wall		7.0	Re-bar for haunch		7.0

(b) Calculation of Load

a) Case-1: Dead Load + Live Load + Horizontal earth pressure by surcharge + Earth pressure



a)-1 Self weight of box tunnel

Upper slab	W1	0.400×4.400×2.5	=	4.400	tf/m
	W2	0.300×0.150×2.5	=	0.113	tf/m
		Σ W	=	4.513	tf/m
		4.513/4.000	=	1.128	tf/m^2
Side wall	W3	0.400×2.5	=	1.000	tf/m^2
Lower slab	W4	0.450×4.400×2.5	=	4.950	tf/m
		4.950/4.000	=	1.238	tf/m^2

a)-2 Surcharge Load

Soil	Pv1	1.000×1.90	=	1.900	tf/m^2
Live load	q		=	3.030	tf/m^2

a)-3 Horizontal earth pressure by surcharge live load and earth pressure

$Phi = K_0 \times (qd + Z_0 \cdot \gamma)$

Where :

K_0	:	Coefficient of earth pressure at rest	=	0.5	
qd	:	Surcharge by live load	=	3.03	tf/m^2
γ	:	Unit weight of soil	=	1.90	tf/m^3
Z_0	:	Depth at calculation point (m)			

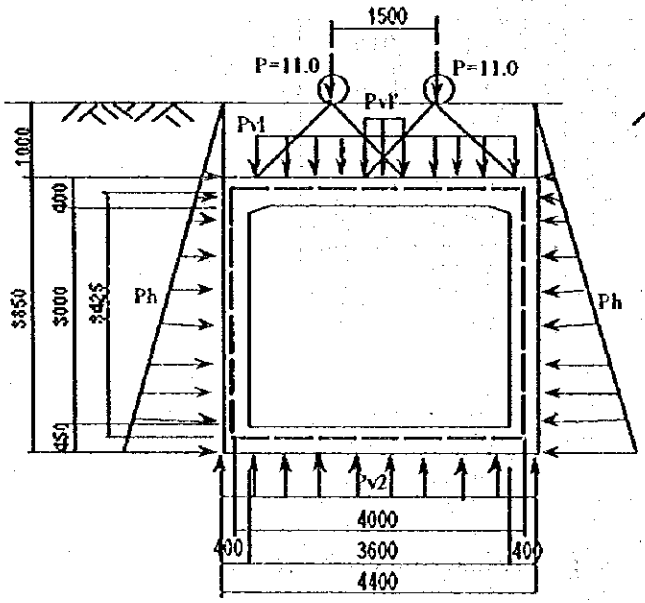
Location of calculation points are defined below:

Symbol	Designation	Z0 (m)	Phi (tf/m³)
Ph1	Top of upper slab	1.000	2.465
Ph2	Framing axle of upper slab	1.200	2.655
Ph3	Framing axle of lower slab	4.625	6.909
Ph4	Bottom of lower slab	4.850	6.123

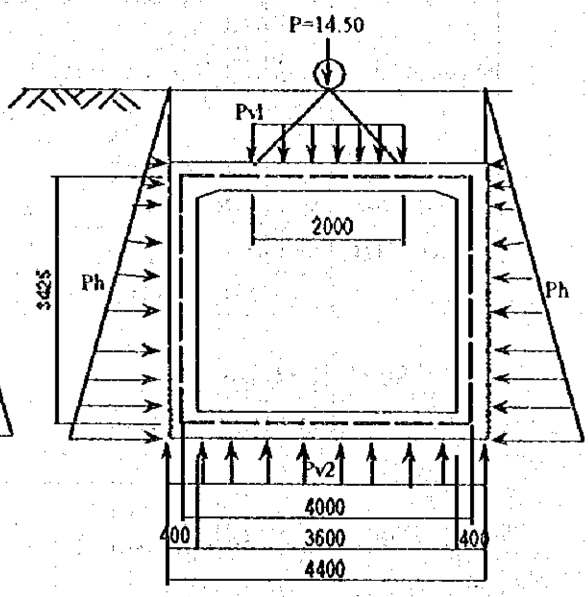
a)-4 Ground reaction applied to lower slab

Surcharge soil	4.400×1.000×1.9	=	8.360	tf/m
Self weight of upper slab	4.400×0.400×2.5	=	4.400	tf/m
Self weight of haunch	0.300×0.150×2.5	=	0.113	tf/m
Self weight of side wall	0.400×3.000×2.5×2	=	6.000	tf/m
Self weight of lower slab	canceled			
Total	0.300×0.150×2.5	=	18.873	tf/m
Pv2 = Σ V/B	18.873/4.000	=	4.718	tf/m²

b) Case 2 : (Wheel load + Earth pressure)



Special Truck Type A



HS20-44 increased 100%

b)-1 Load intensity by wheel load

General formula to calculate the load intensity by wheel load is shown below:

$$P_{l+i} = \frac{2 \cdot P \cdot (1+i)}{W} \qquad Pvl = \frac{P_{l+i}}{2h}$$

Where,

P_{l+i} : Live load per metre in longitudinal direction (tf/m)
P : Wheel load (tf)
i : Impact coefficient = 0.1 (of 0.610m < h ≦ 1.000m)
h : Depth from ground surface to top of upper slab = 1.000m
W : Occupying width of truck (m)

※Special Truck Type A				
Pl+i =	(2*11*(1+0.1))／3.000	=	8.067	tf/m
Pvl =	8.067／(2*1.000)	=	4.033	tf/m^2
※HS20-44 increased 100%				
Pl+i =	(2*11*(1+0.1))／3.000	=	8.067	tf/m
Pvl =	8.067／(2*1.000)	=	4.033	tf/m^2

b)-2 Earth pressure

$Phi = K_0 \times (qd + Z_0 \cdot \gamma)$

Where :

K_0	:	Coefficient of earth pressure at rest	=	0.5	
qd	:	Surcharge by live load	=	3.03	tf/m^2
γ	:	Unit weight of soil	=	1.90	tf/m^3
Z_0	:	Depth at calculation point (m)			

Location of calculation points are defined as below:

Symbol	Designation	Z_0(m)	Phi (tf/m^3)
Ph1	Top of upper slab	1.000	0.950
Ph2	Framing axle of upper slab	1.200	1.140
Ph3	Framing axle of lower slab	4.625	4.394
Ph4	Bottom of lower slab	4.850	4.608

b)-3 Ground reaction applied to lower slab

※For the special truck type A loading

Surcharge live load	4.033×(3.500+0.500)	=	16.132	tf/m
Surcharge soil	4.400×1.000×1.9	=	8.360	tf/m
Self weight of upper slab	4.400×0.400×2.5	=	4.400	tf/m
Self weight of haunch	0.300×0.150×2.5	=	0.113	tf/m
Self weight of side wall	0.400×3.000×2.5×2	=	6.000	tf/m
Self weight of lower slab	canceled			
Total	0.300×0.150×2.5	=	35.005	tf/m
Pv2 = Σ V/B	35.005/4.000	=	8.752	tf/m²

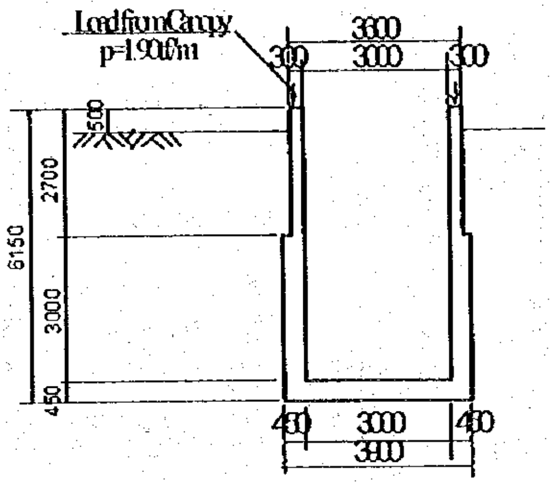
※For the HS20-44 increased 100% (AASHTO) loading

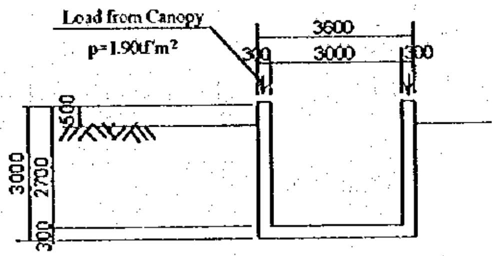
Surcharge live load	5.229×2.000	=	16.132	tf/m
Surcharge soil	4.400×1.000×1.9	=	8.360	tf/m
Self weight of upper slab	4.400×0.400×2.5	=	4.400	tf/m
Self weight of haunch	0.300×0.150×2.5	=	0.113	tf/m
Self weight of side wall	0.400×3.000×2.5×2	=	6.000	tf/m
Self weight of lower slab	canceled			
Total	0.300×0.150×2.5	=	29.331	tf/m
Pv2 = Σ V/B	29.331/4.000	=	7.333	tf/m²

(2) Approach Staircase (Side Wall)

(a) General conditions

1) Structural dimensions





(b) Unit weight

Reinforced concrete	: Wc	=	2.5	tf/m^3
Soil on the front part of footing	: Wa	=	1.8	tf/m^3
Backfillingsoil	: γ s	=	1.9	tf/m^3

(c) Coefficient of earth pressure

For the calculation of the retaining wall structures, Coulomb's earth pressure theory was adopted.

Vertical earth pressure	: Kv	=	1.0
Horizontal earth pressure	: Ka	=	0.333

(d) Live load

Live load as a surcharge : q = 1.90 tf/m^2

(e) Material strength and allowable stresses

1) Concrete

Specified design strength			σ ck = 240.0 kgf/cm^2
Allowable flexural stress	General use		σ ca = 80.0 kgf/cm^2
	at corner	with haunch	σ ca = 80.0 kgf/cm^2
		without haunch	σ ca = 80.0 kgf/cm^2
Allowable shear stress			τ a = 3.90 kgf/cm^2
Allowable bond stress	General use		τ oa = 16.0 kgf/cm^2
	at corner		τ oa = 28.0 kgf/cm^2
Young's Modulus			Ec = 2.5×10^6 kgf/cm^2

2) Reinforcing steel

Allowable tensile strength	σ sa = 1600.0 kgf/cm^2

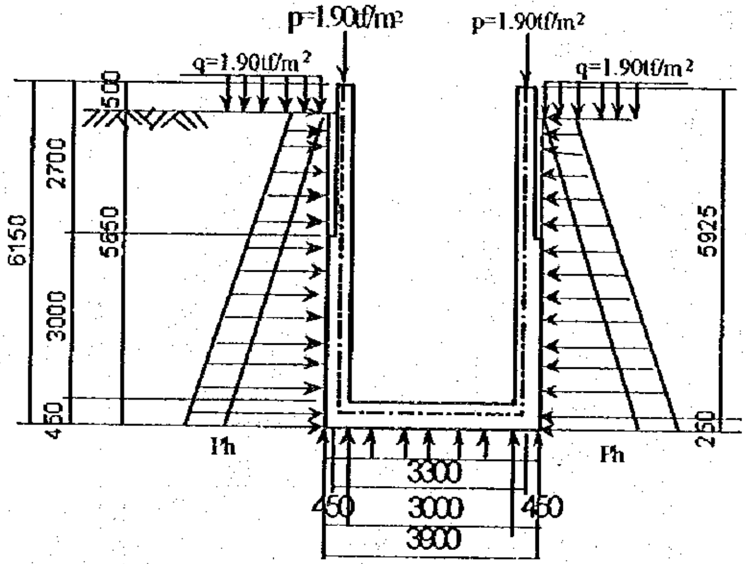
3) Ratio of Young's Modulus (Es/Ec) n = 15

(f) Cover of reinforcing steel

Location		Cover (cm)
Wall	Outside	7.0
	Inside	7.0
Bottom Slab	Upper side	7.0
	Lower side	10.0

(2) Calculation of Load

a) Type A



a)-1 Self weight

Side wall	W1	0.300 × 2.5	=	0.750	tf/m²
	W2	0.450 × 2.5	=	1.125	tf/m²
Lower slab	W4	0.450 × 3.900 × 2.5	=	4.388	tf/m
		4.388/3.300	=	1.330	tf/m²

a)-2 Horizontal earth pressure by surcharge live load and earth pressure

$Phi = K_A \times (qd + Z_0 \cdot \gamma)$

Where :

K_A	:	Coefficient of Coulomb's active earth pressure	=	0.309	
qd	:	Surcharge by live load	=	1.900	tf/m²
γ	:	Unit weight of soil	=	1.90	tf/m³
Z_0	:	Depth at calculation point (m)			

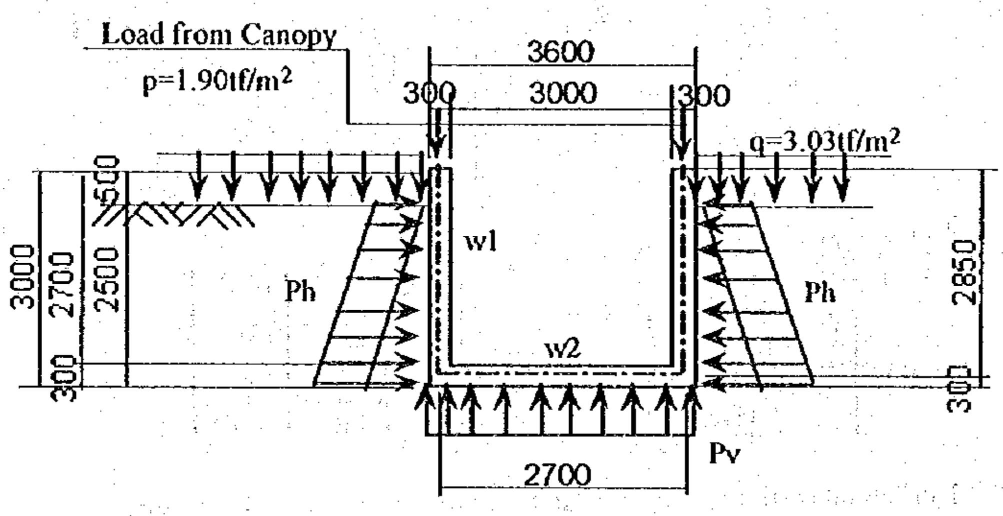
Location of calculation points are defined as below:

Symbol	Designation	Z0 (m)	Phi (tf/m³)
Ph1	Ground surface	0.000	0.587
Ph2	Framing axle of lower slab	5.425	3.772
Ph3	Bottom of lower slab	5.650	3.904

a)-3 Ground reaction applied to lower slab

Surcharge soil	4.400×1.000×1.9	=	8.360	tf/m
Self weight of upper slab	4.400×0.400×2.5	=	4.400	tf/m
Self weight of haunch	0.300×0.150×2.5	=	0.113	tf/m
Self weight of side wall	0.400×3.000×2.5×2	=	6.000	tf/m
Self weight of lower slab	canceled			
Total	0.300×0.150×2.5	=	18.873	tf/m
PvA = Σ V／B	18.873/4.000	=	4.718	tf/m^2

b) Type B



b)-1 Self weight

Side wall	W1	0.300×2.5	=	0.750	tf/m^2
Lower slab	W2	0.300×3.600×2.5	=	2.700	tf/m
		2.700/3.300	=	0.818	tf/m^2

b)-2 Horizontal earth pressure by surcharge live load and earth pressure

$Phi = K_A \times (qd + Z_0 \cdot \gamma)$

Where :

K_A	:	Coefficient of Coulomb's active earth pressure	=	0.309	
qd	:	Surcharge by live load	=	1.900	tf/m^2
γ	:	Unit weight of soil	=	1.90	tf/m^3
Z_0	:	Depth at calculation point (m)			

Location of calculation points are defined as below:

Symbol	Designation	Z0 (m)	Phi (tf/m^3)
Ph1	Ground surface	0.000	0.587
Ph2	Framing axle of lower slab	2.350	1.967
Ph3	Bottom of lower slab	2.500	2.055

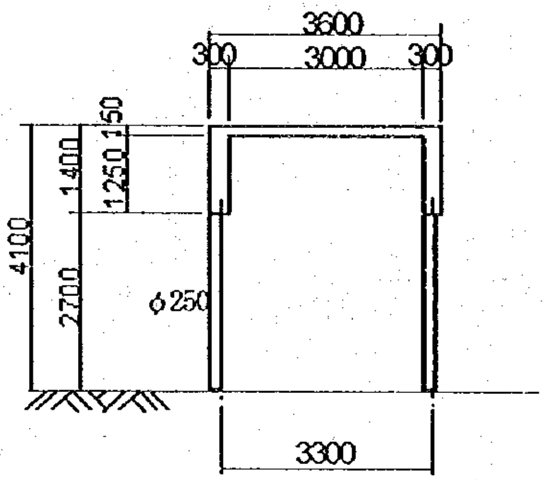
b)-3 Ground reaction applied to lower slab

Load from canopy	1.90×2	=	3.800	tf/m
Self weight of side wall	0.300×2.700×2.5×2	=	4.050	tf/m
Self weight of lower slab	0.300×3.600×2.5	=	2.700	tf/m
Total			10.550	tf/m
$PvB = \Sigma V / B$	10.550/3.300	=	3.197	tf/m^2

(3) Canopy

(a) General conditions

1) Structural dimensions



2) Unit weight

Reinforced concrete : Wc = 2.5 tf/m³

3) Wind load

Circular or oval shape : 150 kgf/m²
Square shape : 300 kgf/m²

4) Material strength and allowable stresses
a) Concrete

Specified design strength			σ ck = 240.0 kgf/cm²
Allowable flexural stress	General use		σ ca = 80.0 kgf/cm²
	at corner	with haunch	σ ca = 80.0 kgf/cm²
		without haunch	σ ca = 80.0 kgf/cm²
Allowable shear stress			τ a = 3.90 kgf/cm²
Allowable bond stress	General use		τ oa = 16.0 kgf/cm²
	at corner		τ oa = 28.0 kgf/cm²
Young's Modulus			Ec = 2.5×10⁶ kgf/cm²

b) Reinforcing steel

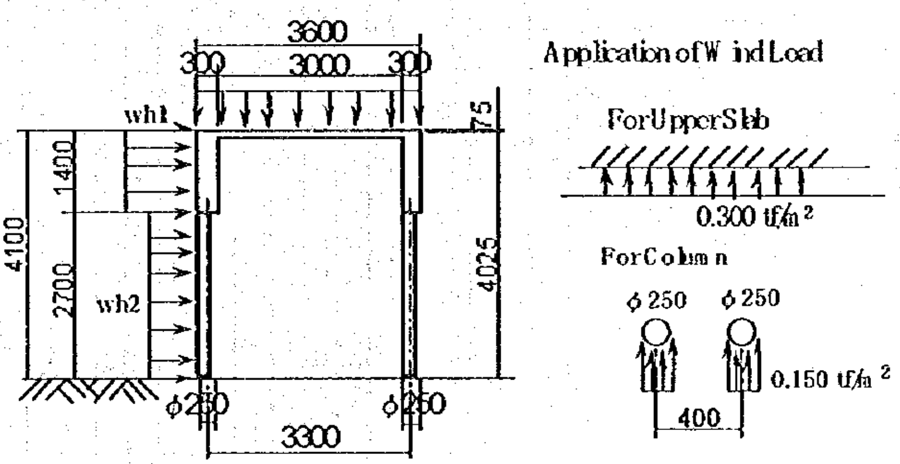
Allowable tensile strength	σ sa = 1800.0 kgf/cm²

c) Ratio of Young's Modulus (Es/Ec) n = 15

6) Cover of reinforcing steel

Location	Cover(cm)
Upper slab	7.0
Column	7.0

(b) Calculation of load



b)-1 Self weight of box tunnel

Upper slab	W1	0.150 × 3.600 × 2.5 × 4.200/2	=	2.385	tf
	W2	0.300 × 1.250 × 2.5 × 4.200/2	=	3.938	tf
		Σ W	=	6.773	tf
		6.773/3.300/2	=	1.026	tf/m
Column	W3	1/4 × π × 0.250² × 2.5	=	0.123	tf/m

a)-2 Wind load

Circular	wh1	0.300 × 4.200/2 × 1/2	=	0.315	tf/m
Square	wh2	0.150 × 0.250	=	0.038	tf/m

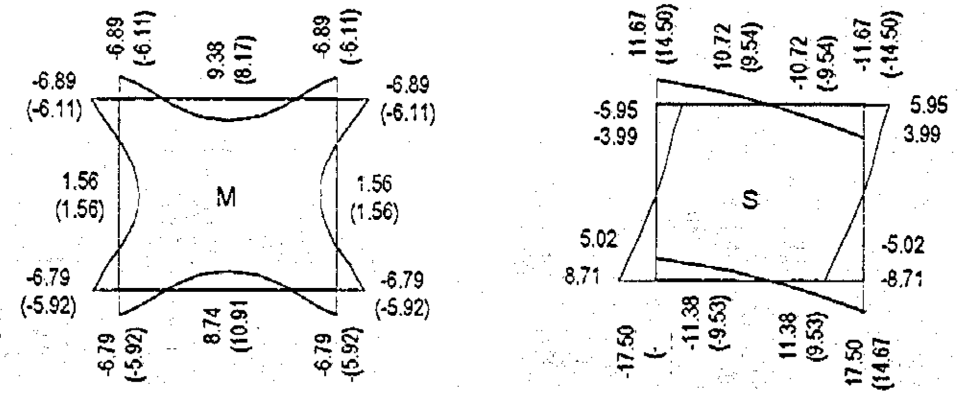
(4) Design Summary of Pedestrian Underpass

Summaries of design calculation for a pedestrian underpass with box tunnel, approach wall and canopy are shown in Tables 5.23 to 5.25.

Table 5.23 DESIGN SUMMARY OF PEDESTRIAN UNDERPASS (Box Tunnel)

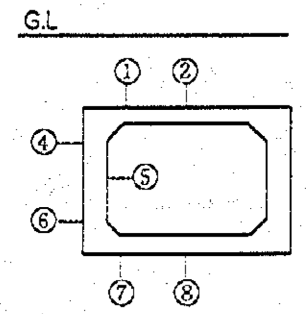
General Diagram

Sectional Force Diagram



The values in bracket shows result by applying AASHTO increased 100%

Calculating Section



Member			Top Slab			Side Wall			Bottom Slab		
Section No.			①	②		④	⑤	⑥	⑦	⑧	
Section											
Force	M	tfm/m	6.89	9.83		6.89	1.56	6.79	6.79	10.71	
	N	tf/m	3.84	3.84		14.50	7.95	17.50	5.63	5.63	
	S	tf/m	10.72			5.02		5.02	11.38		
Reinforcing Bar	Required	cm²									
	Minimum	cm²									
	Design	cm²	15.89	22.92		15.89	15.89	15.89	15.89	22.92	
	Dia.	mm	D16	D19		D16	D16	D16	D16	D19	
	Interval	mm	125	125		125	125	125	125	125	
	Cover	mm	70	70		70	70	70	70	70	
Stress Designed	σ c	kgf/cm²	45.4	54.5		46.1	45.5	45.5	40.4	49.6	
	σ s	kgf/cm²	1345.1	1328.7		1020.9	915.0	915.0	1166.9	1270.9	
	τ 0	kgf/cm²	3.25			1.52		1.52	3.25		
Stress Allowable	σ ca	kgf/cm²	80	80		80	80	80	80	80	
	σ sa	kgf/cm²	1600	1600		1600	1600	1600	1600	1600	
	τ 0a	kgf/cm²	3.9	3.9		3.9	3.9	3.9	3.9	3.9	

Arrangement of Reinforcing Bars

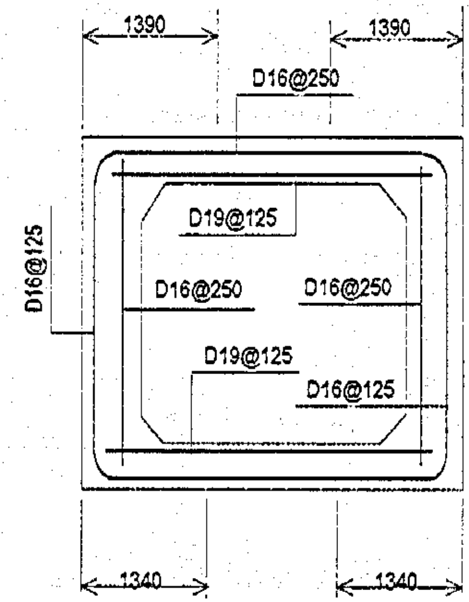
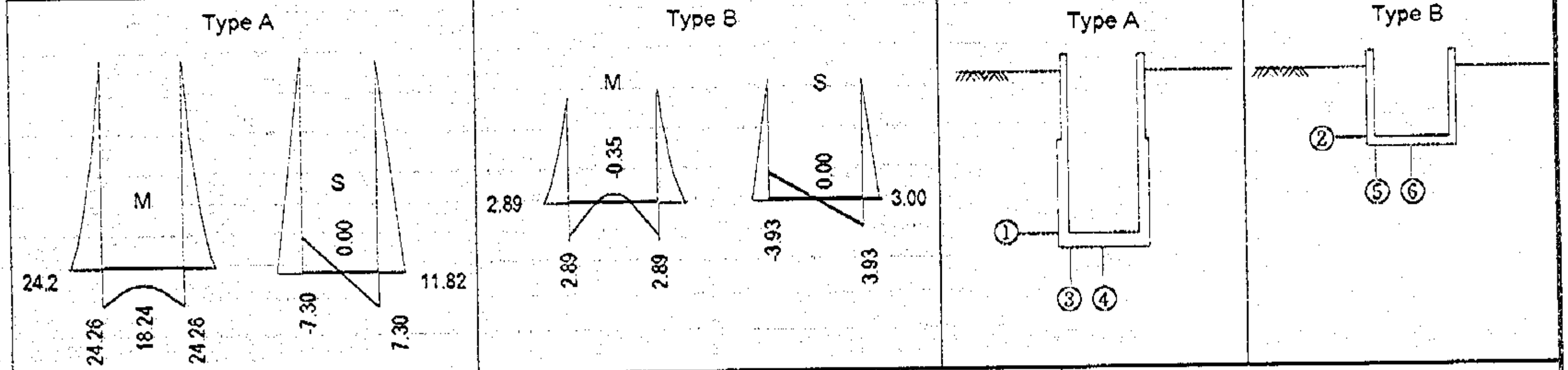


Table 5.24 DESIGN SUMMARY OF PEDESTRIAN UNDERPASS (Approah Wall)

General Diagram

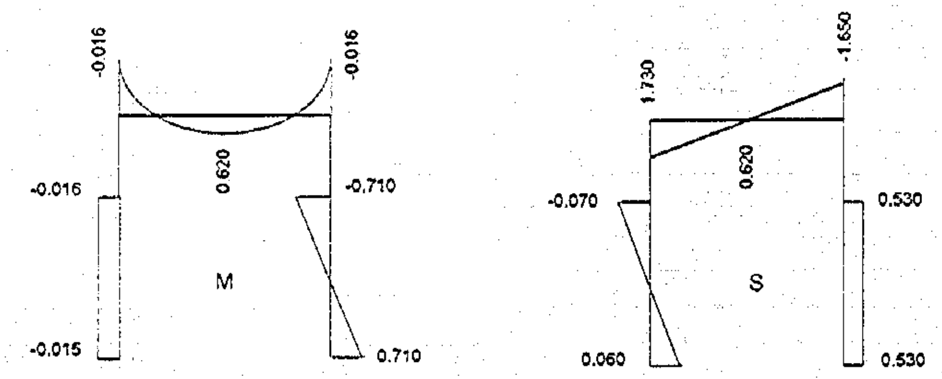


		Member	Side Wall			Bottom Slab (Type A)			Bottom Slab (Type B)		
		Section No.	①	②		③	④		⑤	⑥	
		Section	100 / 45 / 38 / 7	100 / 30 / 23 / 7		100 / 45 / 35 / 10	100 / 45 / 38 / 7		100 / 30 / 20 / 10	100 / 30 / 23 / 7	
Force	M	tfm/m	21.70	2.46		23.22	-		2.33	0.35	
	N	tf/m	7.30	3.93		11.24	-		3.00	3.00	
	S	tf/m	10.99	2.71		6.64	-		3.57	-	
Reinforcing Bar	Required	cm²									
	Minimum	cm²									
	Design	cm²	63.54	7.94		63.54	-		7.94	7.94	
	Dia.	mm	D32	D16		D32	-		D16	D16	
	Interval	mm	125	250		125	-		250	250	
	Cover	mm	70	70		100	-		100	70	
Stress	Designed σ c	kgf/cm²	73.7	37.1		72.5	-		0.3	4.3	
	Designed σ s	kgf/cm²	1028.1	1204.9		1007.8	-		-3.7	33.8	
	Designed τ o	kgf/cm²	2.89	1.18		1.66	-		0.12	-	
	Allowable σ ca	kgf/cm²	80	80		80	80		80	80	
	Allowable σ sa	kgf/cm²	1600	1600		1600	1600		1600	1600	
	Allowable τ oa	kgf/cm²	3.9	3.9					3.9	-	

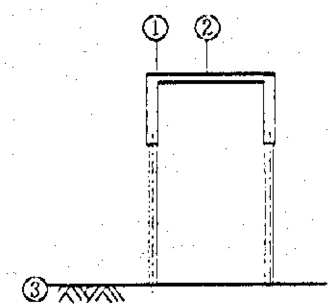
Table 5.25 DESIGN SUMMARY OF PEDESTRIAN UNDERPASS (Canopy)

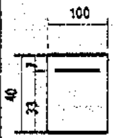
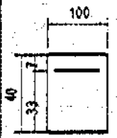
General Diagram

Sectional Force Diagram



Calculating Section



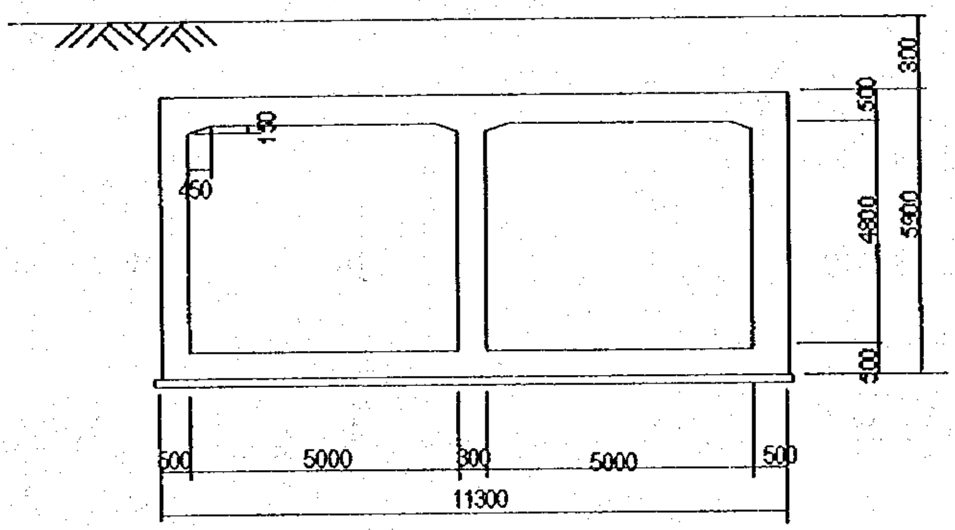
Member			Canopy			Column
Section No.			①	②		③
Section						
Force	M	tfm/m	0.58	0.62		0.70
	N	tf/m	0.27	0.27		2.80
	S	tf/m	1.58	-		0.53
Reinforcing Bar	Required	cm²				
	Minimum	cm²				
	Design	cm²	5.07	5.07		5.07
	Dia.	mm	D13	D13		D13
	Interval	mm	250	250		118
	Cover	mm	75	75		50
Stress (Designed)	σ c	kgf/cm²	64.2	68.7		89.4
	σ s	kgf/cm²	1679.1	1798.2		1722.1
	τ o	kgf/cm²	0.3	-		1.1
Stress (Allowable)	σ ca	kgf/cm²	80	80		100
	σ sa	kgf/cm²	1800	1800		2250
	τ oa	kgf/cm²	3.9	-		4.9

5.1.5 Box Culvert at Aqr

(1) Main Body (Double-box tunnel)

(a) General conditions

1) Structural dimensions



2) Unit weight

Reinforced concrete	: Wc	=	2.5	tf/m^3
Asphalt pavement	: Wa	=	2.3	tf/m^3
Soil	: γ s	=	1.9	tf/m^3

3) Coefficient of earth pressure

Vertival earth pressure	: Kv	=	1.0
Horizontal earth pressure	: Kh (K_0)	=	0.5

4) Live load

- Special Truck Type A
- AASHTO HS20-44 increased 100%

5) Material strength and allowable stresses

a) Concrete

Specified design strength			σ_{ck} = 240.0 kgf/cm^2
Allowable flexural stress	General use		σ_{ca} = 80.0 kgf/cm^2
	at corner	with haunch	σ_{ca} = 80.0 kgf/cm^2
		without haunch	σ_{ca} = 80.0 kgf/cm^2
Allowable Shear Stress			τ_a = 3.90 kgf/cm^2
Allowable bond stress	General use		τ_{oa} = 16.0 kgf/cm^2
	at corner		τ_{oa} = 28.0 kgf/cm^2
Young's Modulus			Ec = 2.5×10^6 kgf/cm^2

b) Reinforcing steel

Allowable tensile strength	σ_{sa} = 1600.0 kgf/cm^2

c) Ratio of Young's Modulus (Es/Ec) n = 15

6) Cover of reinforcing steel

Location		Cover(cm)	Location		Cover(cm)
Upper slab	Upper side	7.0	Right wall	Outside	7.0
	Lower side	7.0		Inside	7.0
Left wall	Outside	7.0	Lower slab	Upper side	7.0
	Inside	7.0		Lower side	10.0
Middle wall		7.0	Re-bar for haunch		7.0

(b) Calculation of Load

a) Case-1: Dead Load + Live Load + Horizontal earth pressure by surcharge + Earth pressure

a)-1 Self weight of box tunnel

Upper slab	W1	0.500×11.300×2.5	=	14.125	tf/m
			Σ W =	14.125	tf/m
		14.125/10.800	=	1.308	tf/m^2
Side wall	W2	0.500×2.5	=	1.250	tf/m^2
	W3	0.300×2.5	=	0.750	tf/m^2

a)-2 Surcharge Load

Soil	Pv1	0.300×1.90	=	0.570	tf/m^2
Live load	q		=	3.030	tf/m^2

a)-3 Horizontal earth pressure by surcharge live load and earth pressure

$Phi = K_0 \times (qd + Z_0 \cdot \gamma)$

Where :

K_0	:	Coefficient of earth pressure at rest	=	0.5	
qd	:	Surcharge by live load	=	3.03	tf/m^2
γ	:	Unit weight of soil	=	1.90	tf/m^3
Z_0	:	Depth at calculation point (m)			

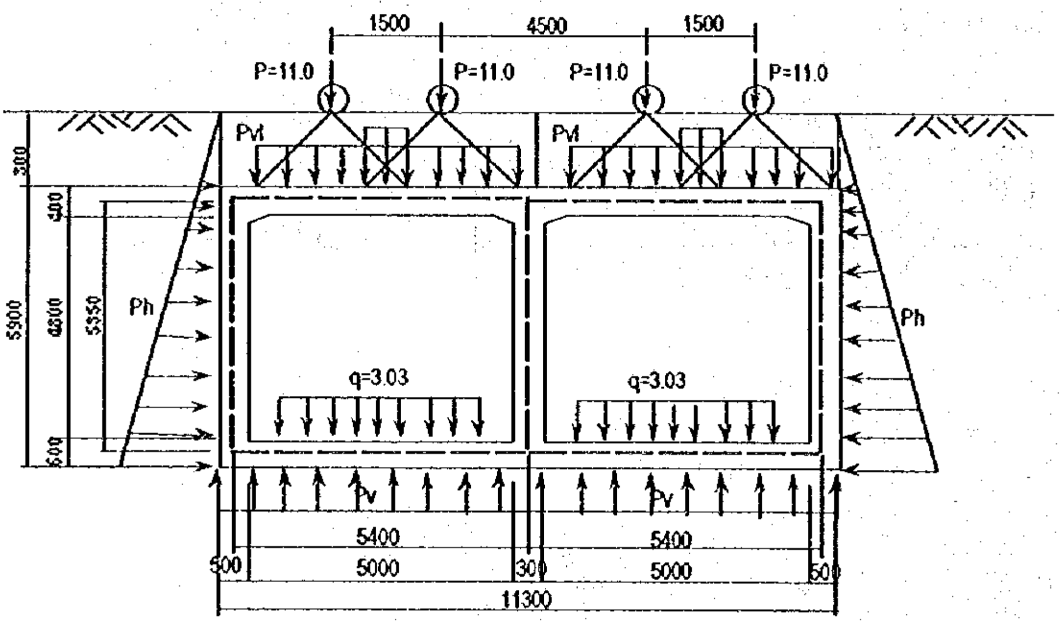
Location of calculation points are defined below:

Symbol	Designation	Z0 (m)	Phi (tf/m^3)
Ph1	Top of upper slab	0.300	1.800
Ph2	Framing axle of upper slab	0.550	2.038
Ph3	Framing axle of lower slab	5.900	7.120
Ph4	Bottom of lower slab	6.200	7.405

a)-4 Ground reaction applied to lower slab

Surcharge soil	11.300×0.300×1.9	=	6.441	tf/m
Self weight of upper slab	11.300×0.500×2.5	=	14.125	tf/m
Self weight of side wall	0.500×4.800×2.5×2	=	12.000	tf/m
Self weight of diaphragm	0.300×4.800×2.5	=	3.600	tf/m
Inner live load	3.030×4.000×2	=	24.240	tf/m
Total			60.406	tf/m
Pv2 = Σ V/B	60.406/10.800	=	5.593	tf/m^2

b) Case 2 : (Wheel load + Earth pressure)



b)-1 Load intensity by wheel load

General formula to calculate the load intensity by wheel load is shown below:

$$P_{l+i} = \frac{2 \cdot P \cdot (1+i)}{W} \qquad Pvl = \frac{P_{l+i}}{2h}$$

Where,

P_{l+i} : Live load per metre in longitudinal direction (tf/m)

P : Wheel load (tf)

i : Impact coefficient = 0.3 (of 0.000m $<$ h $\leqq$ 0.305m)

h : Depth from ground surface to top of upper slab = 0.300m

W : Occupying width of truck (m)

※Special Truck Type A				
Pl+i =	(2*11*(1+0.3))/3.000	=	9.533	tf/m

b)-2 Earth pressure

$Phi = K_0 \times (qd + Z_0 \cdot \gamma)$

Whrere :

K_0	:	Coefficient of earth pressure at rest	=	0.5	
γ	:	Unit weight of soil	=	1.90	tf/m³
Z_0	:	Depth at calculation point (m)			

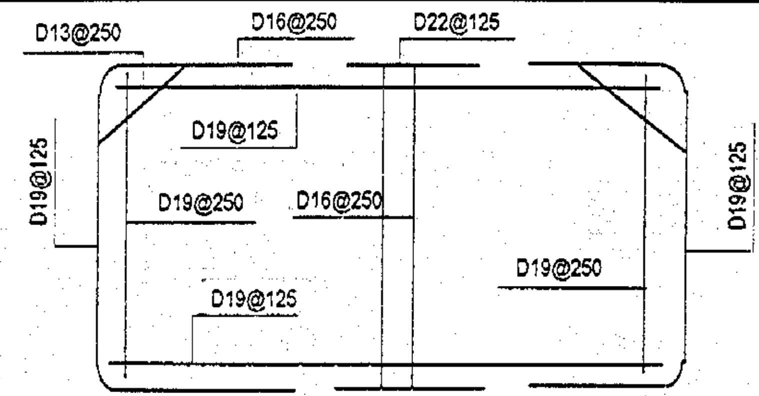
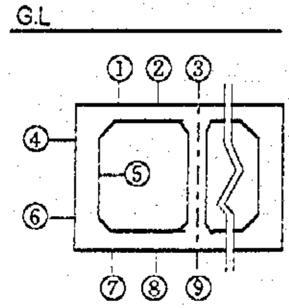
Location of calculation points are defined as below:

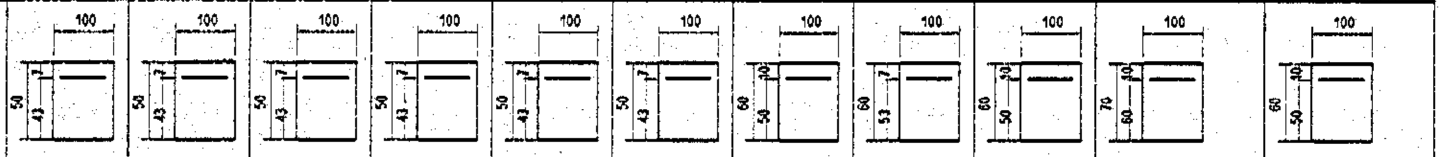
Symbol	Designation	Z_0 (m)	Phi (tf/m³)
Ph1	Top of upper slab	0.300	0.285
Ph2	Framing axle of upper slab	0.550	0.523
Ph3	Framing axle of lower slab	5.900	5.605
Ph4	Bottom of lower slab	6.200	5.890

b)-3 Ground reaction applied to lower slab

Surcharge live load	9.533×4	=	38.132	tf/m
Surcharge soil	11.300×0.300×1.9	=	6.441	tf/m
Self weight of upper slab	11.300×0.500×2.5	=	14.125	tf/m
Self weight of side wall	0.500×4.800×2.5×2	=	12.000	tf/m
Self weight of diaphragm	0.300×4.800×2.5	=	3.600	tf/m
Total		=	74.298	tf/m
Pv2 = Σ V/B	74.928/10.800	=	6.879	tf/m²

Table 5.26 DESIGN SUMMARY OF BOX CULVERT AT AQR

General Diagram	Bar Arrangement	Calculating Section
		

Member				Top Slab			Side Wall			Bottom Slab			Wing	
Section No.				①	②	③	④	⑤	⑥	⑦	⑧	⑨	Left	Right
Section														
Force	M		tfm/m	11.29	11.17	18.43	11.29	6.75	11.76	11.76	12.34	20.84	34.17	20.52
	N		tf/m	6.36	6.27	6.27	14.76	9.26	12.30	-	-	-	-	-
	S		tf/m	13.01	-	12.68	6.99	-	7.47	8.46	-	13.61	14.47	10.44
Reinforcing Bar	Required		cm²											
	Minimum		cm²											
	Design		cm²	22.92	22.92	30.97	22.92	11.46	22.92	22.92	22.92	30.97	51.39	30.97
	Dia.		mm	D19	D19	D22	D19	D19	D19	D19	D19	D22	D29	D22
	Interval		mm	125	125	125	125	250	125	125	125	125	125	125
	Cover		mm	70	70	70	70	70	70	100	70	100	100	100
Stress	Designed	σ c	kgf/cm²	42.8	42.3	62.7	43.6	32.8	45.2	34.0	32.4	54.2	55.4	53.4
		σ s	kgf/cm²	1154.6	1142.9	1484.4	987.9	1095.5	1089.1	1143.6	1129.2	1522.5	1276.0	1499.4
		τ o	kgf/cm²	3.1	-	3.0	1.7	-	1.8	1.7	-	2.6	2.4	2.1
	Allowable	σ ca	kgf/cm²	80	80	80	80	80	80	80	80	80	80	80
		σ sa	kgf/cm²	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
		τ oa	kgf/cm²	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.6	3.6

5.2 Calculation Analysis for Highway

5.2.1 Alignment

The proposed road at one grade separation consists of highways, crossroads, rampways,a roundabout and service roads. Above all, the alignments of highways and a roundabout are so important that these alignments are described in this chapter.

(1) Control Point

a) R/A-2 A'Naseem Garden

- Horizontal Alignment
  - Utilization of the existing elliptical roundabout
  - Securing 10m distance at both sides from the center of monument
  - Avoiding the neighboring mosque on Muscat side of inland service road

-Vertical Alignment
  - Keeping 5.7m vertical clearance at the carriageway of roundabout

b) R/A-3 Barka

- Horizontal Alignment
  - Securing fountain at the center of roundabout
  - Avoiding the neighboring filling station on Muscat side of inland service road
  - Utilization of the service roads improvement plan

- Vertical Alignment
  - Keeping 5.7m vertical clearance at the carriageway of roundabout
  - Keeping the elevation of Irish bridge on Muscat side

c) R/A-5 Al Muladdah

- Horizontal Alignment
  - Utilization of the elliptical roundabout under construction
  - Avoiding the neighboring mosque and residences on Aqr side of inland service road
  - Maintenance of the existing narrow median from the point of land acquisition

- Vertical Alignment
  - Keeping 5.7m vertical clearance at the carriageway of roundabout

d) R/A-8 Al Khaburah

- Horizontal Alignment
  - Avoiding the neighboring office buildings and iron workshops on Aqr side of inland service road
  - Avoiding the adjacent shops at the seaside corner, and GTO control station at the inland corner of roundabout
  - Utilization of the service roads improvement plan

- Vertical Alignment
  - Keeping 5.7m vertical clearance at the carriageway of roundabout

e) R/A-10 Saham

- Horizontal Alignment
  - Avoiding the neighboring ministry office building, shops and garages on Muscat side of inland road
  - Leaving intact the adjacent area to roundabout due to the existence of a great number of buildings such as filling station, mosque and shops
  - Utilization of the service roads improvement plan

- Vertical Alignment
  - Keeping 5.7m vertical clearance at the carriageway of roundabout

f) R/A-12 Sohar

- Horizontal Alignment
  - Securing the new monument and the sizes of the elliptical roundabout under constrction
  - Securing 20m distance at both sides from the center of the monument
  - Avoiding the neighboring mosque on Muscat side of inland service road
  - Leaving intact the Muscat side coastal service road due to the existance of a number of government buildings along the coastal side of this road

- Vertical Alignment
  - Keeping 5.7m vertical clearance at the carriageway of roundabout

g) R/A-14 Falaj Al Qabail

- Horizontal Alignment
  - Avoiding the neighboring cemetry and fillingstation on Muscat side of inland service road
  - Leaving intact the adjacent area to coastal service road due to the existence of a great number of buildings such as mosque, bank, shop and house
  - The median width similar to that of the existing ones at the broadest section is maintained because it is difficult to set the new alignment for grade separation considering the existing alignment with small radius and spiral curves at both sides

- Vertical Alignment
  - Keeping 5.7m vertical clearance at the carriageway of roundabout
  - Securing a vertical length of sag at Aqr side considering the existing descending grade

h) R/A-18 Aqr, Highway

- Horizontal Alignment
  - Keeping the right-of-way(65m) set up newly
  - Passing the open area between the residential area and the garage area
  - Avoiding the neighboring houses of the above open area

- Vertical Alignment
  - Rasing the elevation at the crossing point with service road in order to install a crossing box culvert
  - Descending the elevations at the crossing points with rampway in order to install low piers

i) R/A-18 Aqr, Rampway

- Horizontal Alignment
  - Securing the adequate intersection angle between highway and rampway in oder to provide a bridge with 30m span for the rampway

- Vertical Alignment

- Keeping 5.7m vertical clearance at the carriageway of highway
- Ending the vertical curve before the Aqr roundabout

(2) Result of Alignment Calculation

The brief result of alignment calculation for each grade separation at eight roundabouts are shown in Tables 5.27 to 5.29.

Table 5.27(a) Horizontal Alignment of Highway

No of R/A	Line		Aqr Side		R/A		Muscat Side	
R/A-2	A		Straight	R= 8,000m	R=-8,000m	R= 3,000m	R= 6,000m	
	B		Straight	R= 8,000m	R=-8,000m	R= 3,000m	R=5,987.2m	
R/A-3	A		Straight	R=-10,000m	Straight	R=10,000m	R=-10,000m	Straight
	B		Straight	R=-5,000m	Straight	R=10,000m	R=-12,000m	Straight
R/A-5	A		R=-800m	R=450m	Straight	R=22,000m	R=-22,000m	Straight
	B		R=-815m	R=550m	Straight	R=-22,000m	R=22,000m	Straight
R/A-8	A			R= 5,900m	Straight			
	B			R= 5,912m	Straight			
R/A-10	A				R=-5,000m			
	B				R=-5,012m			
R/A-12	A	R=-900m	A=400m	Straight	R=1,400m	Straight		
	B	R=-915.4m	A=450m	Straight	R=1,600m	Straight		
R/A-14	A			A=945m	R=-1,186m	A=745m	Straight	
	B			A=950m	R=-1,200m	A=750m	Straight	
R/A-18	A		Straight	A=400m	R=-800m	A=400m	Straight	
	B		Straight	A=400m	R=-785m	A=400m	Straight	

Notes: A line and B line indicate a seaside and inland highway respectively.
A indicates parameter of transition at curve.

Table 5.27(b) Horizontal Alignment of Rampway

No of R/A	Line	Muscat(Dubai) side	Bridge	Aqr Side	
R/A-18	A : Muscat-Aqr	R= -900m	R= 900m	R=-1,000m	R=2,400m
	B : Dubai Aqr	R=1,500m	R=-900m	R=2,000m	

Table 5.28 Horizontal Alignment of Roundabout

No of R/A	Shape	Dimension (m)		Remark
R/A-2	Ellipse	R1=35.5	R2=100.5	Existing
R/A-3	Circle	R=50		
R/A-5	Ellipse	R1=28.39	R2=125.35	Existing
R/A-8	Circle	R=50		
R/A-10	Circle	R=50		
R/A-12	Ellipse	R1=50	R2=125	Modified to Large Ellipse
R/A-14	Circle	R=50		
R/A-18	Ellipse	R1=42	R2=152	Existing(Out of designed area)

Table 5.29(a) Vertical Alignment of Highway

No of R/A	Line	Element		Aqr Side — R/A — Muscat Side
R/A-2	A	Grade		i=-0.190% i=3.000% i=-3.000% i=-0.070%
		Vertical Curve	Crest	R=10,000m
			Sag	R=6,600m R=8,900m
	B	Grade		i=-0.190% i=3.000% i=-3.000% i=-0.070% i=-0.050%
		Vertical Curve	Crest	R=10,000m R=504,800m
			Sag	R=6,600m R=8,900m
R/A-3	A	Grade		i=0.000% i=3.000% i=-3.000% i=0.000% i=-0.400%
		Vertical Curve	Crest	R=10,000m R=50,000m
			Sag	R=7,000m R=8,300m
	B	Grade		i=0.000% i=3.000% i=-3.000% i=0.000% i=-0.850% i=0.450% i=0.000%
		Vertical Curve	Crest	R=10,000m R=21,200m R=62,200m
			Sag	R=7,000m R=7,700m R=7,700m
R/A-5	A	Grade		i=0.015% i=3.000% i=-3.000% i=0.040%
		Vertical Curve	Crest	R=10,000m
			Sag	R=7,700m R=7,200m
	B	Grade		i=0.015% i=3.000% i=-3.000% i=0.130%
		Vertical Curve	Crest	R=10,000m
			Sag	R=7,700m R=7,300m
R/A-8	A	Grade		i=0.000% i= 0.100% i=3.000% i=-3.000% i= 0.000% i=-0.100%
		Vertical Curve	Crest	R=10,000m R=100,000m
			Sag	R=100,000m R=7,900m R=6,000m
	B	Grade		i=0.035% i=3.000% i=-3.000% i=-0.100% i=-0.020%
		Vertical Curve	Crest	R=10,000m
			Sag	R=7,100m R=6,200m R=200,000m
R/A-10	A	Grade		i= 0.100% i= 0.000% i=3.000% i=-3.000% i=-0.120%
		Vertical Curve	Crest	R=200,000m R=10,000m
			Sag	R=7,100m R=7,100m
	B	Grade		i= 0.200% i= 0.050% i=3.000% i=-3.000% i=-0.150% i=-0.100%
		Vertical Curve	Crest	R=66,700m R=10,000m R=6,300m
			Sag	R=6,800m R=6,300m R=400,000m

Table 5.29(b) Vertical Alignment of Highway

No of R/A	Line	Element		Aqr Side / R/A / Muscat Side
R/A-12	A	Grade		i=0.020% i=-0.250% i=3.000% i=-3.000% i=0.080%
		Vertical Curve	Crest	R=74,100m R=10,000m
			Sag	R=6,800m R=6,500m
	B	Grade		i=0.000% i=-0.400% i=3.000% i=-3.000% i=0.250% i=0.500%
		Vertical Curve	Crest	R=50,000m R=10,000m
			Sag	R=7,100m R=7,700m R=10,000m
R/A-14	A	Grade		i=0.160% i=-0.030% i=2.500% i=-3.000% i=-0.150%
		Vertical Curve	Crest	R=52,600m R=10,900m
			Sag	R=8,300m R=13,300m
	B	Grade		i= 0.100% i=-0.100% i=2.500% i=-3.000% i=-0.400% i=-0.120%
		Vertical Curve	Crest	R=50,000m R=10,900m R=35,700m
			Sag	R=7,100m R=11,900m
R/A-18	A	Grade		i=-0.950% i=-2.000% i=3.000% i= 0.000%
		Vertical Curve	Crest	R=10,000m
			Sag	R=4,700m R=4,000m
	B	Grade		i= 0.860% i= 0.100% i=-2.000% i=3.000% i= 0.000%
		Vertical Curve	Crest	R=114,300m R=10,000m
			Sag	R=4,700m R=4,000m

Table 5.29(c) Vertical Alignment of Rampway

No of R/A	Line	Element		Muscat(Dubai) Side / Aqr Side
R/A-18	A	Grade		i= 0.000% i=5.000% i=-5.000% i= 0.000%
		Vertical Curve	Crest	R=3,300m
			Sag	R=2,400m R=2,400m
	B	Grade		i=-0.100% i= 4.000% i=-5.000% i=-0.730%
		Vertical Curve	Crest	R=3,000m
			Sag	R=3,200m R=2,300m

5.2.2 Pavement

The pavement designs of eight roundabouts were carried out in accordance with the design standards mentioned in Chapter 4.4.

(1) Design CBR

a) CBR value at embankment section

The CBR value of embankment materials from borrow pits was derived from the results of soil tests shown below:

Borrow Pit Location	CBR Value (%)
A' Tareef / Al Muladdah	65.1
Wudan A'Sahil	62.0
Al Hijari	59.0
Wadi Salah	100.0
Ohi	46.1

Note: * CBR value of 100 is ignored because of the extreme value.

The design CBR of embankment is calculated by the following formula.

Design CBR value = Average CBR value of individual locations
- (Max.CBR - Min.CBR)/C

Where, C: Standard deviation value

Therefore, the design CBR = 58.1-(65.1-46.1)/2.24 = 49.6%

b) CBR value at Cutting Section

The cutting at existing roads is determined to maintain the designed pavement thickness. The CBR value is assumed more than 25%, considering the following fact:

- The existing highway was constructed with the embankment materials from the borrow pits in the same region as mentioned in the above table.

c) Determination of Design CBR

Considering the complex construction process, it is not desirable to change the thickness of the pavement frequently in a short road section. Hence, the design same CBR value is adopted in spite of embankment or cutting.

The determined value is 25% which is the lowest limit without the subbase.

(2) Equivalent Single Axle Load (ESAL)

a) Traffic volume

The traffic volume for pavement design is obtained as shown in Table 5.30 and 5.31 from the analysis of traffic survey, when the middle of a 20-year design life will be the year 2010. Additionally, the traffic composition by vehicle type at eight roundabouts is shown in Table 5.32 as the result of traffic survey.

b) Accumulated Equivalent Single Axle Load (ESAL)

The accumulated ESAL for 20 years at each roundabout is derived from the axle load equivalent factor of each vehicle type and the above traffic volume as shown in Table 5.33.

(3) Structural Number (SN)

The required structural number for each accumulative ESAL classified into the following table is shown below, in accordance with the chart in Chapter 4.4.2.

ESAL(x 1000)	Required SN
15,000	3.80
9,000	3.50
5,000	3.15
2,000	2.71
1,000	2.41

On the other hand, the types of pavement structure and each calculated structural number are shown in Figure 5.13.
From the above results, the relation between the pavement structure and the classified ESAL is shown as bellow:

Pavement Structure	ESAL (x Thousand)
Type A	9,000 ~ 15,000
Type B	5,000 ~ 9,000
Type C	2,000 ~ 5,000
Type D	1,000 ~ 2,000
Type E	0 ~ 1,000

(4) Determination of Pavement Structure

The pavement structure of each road section at eight roundabouts is determined as shown in Table 5.33 and Figure 5.13.

Table 5.30 Forecasted Daily Traffic Volume for 2010

No. of R/A	Name of R/A	Highway			Roundabout	Rampway				Crossroad	
		Aqr	Muscat	flyover		A-1	B-1	A-2	B-2	Inland	Coast
R/A-2	A'Naseem Garden	59,450	61,280	56,000	3,340	1,950	1,500	2,620	2,660	6,600	5,570
R/A-3	Barka	44,900	58,000	32,000	20,330	6,000	6,900	13,000	13,600	21,000	21,860
R/A-5	Al Muladdah	31,700	44,600	25,000	9,800	3,000	3,700	9,800	9,800	25,000	-
R/A-8	Al Khaburah	32,250	30,850	25,000	11,600	5,600	4,300	5,600	3,600	18,800	13,980
R/A-10	Saham	29,680	32,060	21,500	18,860	3,960	4,220	5,160	5,400	28,760	29,500
R/A-12	Sohar	29,700	27,400	14,700	23,290	7,540	7,460	6,500	6,200	27,100	39,800
R/A-14	Falaj Al Qabail	24,700	28,770	18,000	6,690	3,350	3,350	5,350	5,420	11,500	6,650
R/A-18	Aqr	13,200	19,030	11,000	5,050	1,100	1,100	4,020	4,010	13,200	1,800

Notes : (1) Rampway is classified as follows:

A-1 : merge lane towards Aqr . (for R/A-18, it denotes the merge lane towards Dubai.)
A-2 : diverge lane from Muscat side . (for R/A-18,it denotes the diverge lane from Muscat side.)
B-1 : diverge lane from Aqr side. (for R/A-18,it denotes the diverge lane from Dubai side)
B-2 : merge lane towards Muscat. (for R/A-18,it denotes the merge lane towards Muscat.)

(2) For R/A-18,Aqr and flyover are to be replaced by Dubai and At-grade respectively.

Table 5.31 Forecasted Single-lane Daily Traffic Volume for 2010

No. of R/A	Name of R/A	Highway			Roundabout	Rampway				Crossroad	
		Aqr	Muscat	flyover		A-1	B-1	A-2	B-2	Inland	Coast
R/A-2	A'Naseem Garden	14,863	15,320	14,000	1,670	1,950	1,500	2,620	2,660	3,300	2,785
R/A-3	Barka	11,225	14,500	8,000	10,165	6,000	6,900	6,500	6,800	5,250	5,465
R/A-5	Al Muladdah	7,925	11,150	6,250	4,900	3,000	3,700	9,800	9,800	6,250	-
R/A-8	Al Khaburah	8,063	7,713	6,250	5,800	5,600	4,300	5,600	3,600	4,700	6,990
R/A-10	Saham	7,420	8,015	5,375	9,430	3,960	4,220	5,160	5,400	7,190	7,375
R/A-12	Sohar	7,425	6,850	3,675	11,645	7,540	7,460	6,500	6,200	6,775	9,950
R/A-14	Falaj Al Qabail	6,175	7,193	4,500	3,345	3,350	3,350	5,350	5,420	5,750	3,325
R/A-18	Aqr	3,300	4,758	2,750	2,525	1,100	1,100	4,020	4,010	10,000	1,800

Table 5.32 Accumulative Equivalent Single Axle Load (ESAL)

No. of R/A	Name of R/A	Type of Vehicle	Comp. %	Axle Load Equivalent factor	HIGHWAY						ROUNDABOUT		Rampway								Crossroad			
					Aqr (at-grade sect.)		Muscat (at-grade sect.)		Retaining wall sect.				A-1		B-1		A-2		B-2		Inland		Coast	
					Volume	ESAL	Volume	ESAL	Volume	ESAL	Volume	ESAL	Volume	ESAL	Volume	ESAL	Volume	ESAL	Volume	ESAL	Volume	ESAL	Volume	ESAL
R/A-2	A'Naseem Garde	Passenger car/tax	78.8	0.0003	11,712	26	12,072	27	11,032	25	1,316	3	1,537	4	1,182	3	2,065	5	2,096	5	2,600	6	2,195	5
		Pickups	17.9	0.0170	2,660	331	2,742	341	2,506	311	299	38	349	44	269	34	469	59	476	60	590	74	498	62
		Medium Trucks	1.2	0.7030	178	916	184	945	168	863	20	103	23	119	18	93	31	160	32	165	40	204	33	170
		Heavy Trucks	1.9	1.5000	282	3088	291	3187	266	2913	32	351	37	406	29	313	50	548	51	559	63	687	53	581
		Buses	0.2	0.6460	30	142	31	147	28	133	3	15	4	19	3	15	5	24	5	24	7	34	6	29
		Total	100		14,863	4,503	15,320	4647	14,000	4,245	1,670	510	1,950	592	1,500	458	2,620	796	2,660	813	3,300	1,005	2,785	847
R/A-3	Barka	Passenger car/tax	71.4	0.0003	8,015	18	10,353	23	5,712	13	7,258	16	4,284	10	4,927	11	4,641	11	4,855	11	3,749	9	3,902	9
		Pickups	24.9	0.0170	2,795	347	3,610	449	1,992	248	2,531	315	1,494	186	1,718	214	1,618	201	1,693	211	1,307	163	1,361	169
		Medium Trucks	1.5	0.7030	168	863	217	1114	120	616	152	781	90	462	103	529	98	503	102	524	79	406	82	421
		Heavy Trucks	2.1	1.5000	236	2585	305	3340	168	1840	213	2333	126	1380	145	1588	136	1490	143	1566	110	1205	115	1260
		Buses	0.1	0.6460	11	52	15	71	8	38	10	48	6	29	7	34	7	34	7	34	5	24	5	24
		Total	100		11,225	3,865	14,500	4997	8,000	2,755	10,165	3,493	6,000	2,067	6,900	2,376	6,500	2,239	6,800	2,346	5,250	1,807	5,465	1,883
R/A-5	Al Muladdah	Passenger car/tax	70.6	0.0003	5,595	13	7,872	18	4,413	10	3,459	8	2,118	5	2,612	6	6,919	16	6,919	16	4,413	10	0	0
		Pickups	24.4	0.0170	1,934	241	2,720	338	1,525	190	1,196	149	732	91	903	113	2,391	297	2,391	297	1,525	190	0	0
		Medium Trucks	1.7	0.7030	135	693	190	976	106	544	83	426	51	262	63	324	167	858	166	852	106	544	0	0
		Heavy Trucks	2.2	1.5000	174	1906	245	2683	137	1501	108	1183	66	723	81	887	215	2355	216	2366	137	1501	0	0
		Buses	1.1	0.6460	87	411	123	581	69	326	54	255	33	156	41	194	108	510	108	510	69	326	0	0
		Total	100		7,925	3,264	11,150	4596	6,250	2,571	4,900	2,021	3,000	1,237	3,700	1,524	9,800	4,036	9,800	4,041	6,250	2,571	0	0
R/A-8	Al Khaburah	Passenger car/tax	63.1	0.0003	5,087	12	4,867	11	3,944	9	3,660	9	3,534	8	2,713	6	3,534	8	2,272	5	2,966	7	4,411	10
		Pickups	32.6	0.0170	2,629	327	2,515	313	2,038	253	1,891	235	1,826	227	1,402	174	1,826	227	1,174	146	1,532	191	2,279	283
		Medium Trucks	1.4	0.7030	113	580	108	555	88	450	81	417	78	401	60	308	78	401	50	257	66	339	98	503
		Heavy Trucks	2.7	1.5000	218	2388	208	2278	169	1849	157	1715	151	1654	116	1271	151	1654	97	1063	127	1391	189	2070
		Buses	0.2	0.6460	16	76	15	71	13	59	12	57	11	52	9	43	11	52	7	34	9	43	14	67
		Total	100		8,063	3,383	7,713	3228	6,250	2,620	5,800	2,433	5,600	2,342	4,300	1,802	5,600	2,342	3,600	1,505	4,700	1,971	6,990	2,933
R/A-10	Saham	Passenger car/tax	53.3	0.0003	3,955	9	4,272	10	2,865	7	5,026	12	2,111	5	2,249	5	2,750	7	2,878	7	3,832	9	3,931	9
		Pickups	35.6	0.0170	2,642	328	2,853	355	1,914	238	3,357	417	1,410	175	1,502	187	1,837	228	1,922	239	2,560	318	2,626	326
		Medium Trucks	7.0	0.7030	519	2664	561	2879	376	1930	660	3388	277	1422	295	1514	361	1854	378	1940	503	2582	516	2649
		Heavy Trucks	4.0	1.5000	297	3253	321	3515	215	2355	377	4131	158	1731	169	1851	206	2256	216	2366	288	3154	295	3231
		Buses	0.1	0.6460	7	34	8	38	5	24	9	43	4	19	4	19	5	24	5	24	7	34	7	34
		Total	100		7,420	6,288	8,015	6797	5,375	4,554	9,430	7,991	3,960	3,352	4,220	3,576	5,160	4,369	5,400	4,576	7,190	6,097	7,375	6,249
R/A-12	Sohar	Passenger car/tax	55.4	0.0003	4,113	10	3,795	9	2,036	5	6,451	15	4,177	10	4,133	10	3,601	8	3,435	8	3,753	9	5,512	13
		Pickups	30.1	0.0170	2,235	278	2,062	256	1,106	138	3,505	435	2,270	282	2,246	279	1,957	243	1,866	232	2,039	254	2,995	372
		Medium Trucks	6.8	0.7030	505	2592	466	2392	250	1283	792	4065	513	2632	507	2604	442	2269	422	2164	461	2366	677	3475
		Heavy Trucks	3.8	1.5000	282	3088	260	2847	140	1533	443	4851	287	3138	283	3099	247	2705	236	2580	257	2815	378	4140
		Buses	3.9	0.6460	290	1368	267	1260	143	675	454	2141	294	1387	291	1373	254	1196	242	1141	264	1245	388	1830
		Total	100		7,425	7,336	6,850	6764	3,675	3,634	11,645	11,507	7,540	7,449	7,460	7,365	6,500	6,421	6,200	6,125	6,775	6,689	9,950	9,830
R/A-14	Falaj Al Qabail	Passenger car/tax	57.8	0.0003	3,569	8	4,157	10	2,601	6	1,933	5	1,936	5	1,936	5	3,092	7	3,133	7	3,324	8	1,922	5
		Pickups	33.3	0.0170	2,056	256	2,395	298	1,499	186	1,114	139	1,116	139	1,116	139	1,782	222	1,805	225	1,915	238	1,107	138
		Medium Trucks	5.0	0.7030	309	1586	360	1846	225	1155	167	859	168	863	168	863	268	1376	271	1391	288	1478	166	854
		Heavy Trucks	3.2	1.5000	198	2169	230	2521	144	1577	107	1172	107	1172	107	1172	171	1873	173	1895	184	2015	106	1166
		Buses	0.7	0.6460	43	203	50	238	32	149	23	111	23	109	23	109	37	175	38	180	40	189	23	110
		Total	100		6,175	4,222	7,193	4913	4,500	3,073	3,345	2,286	3,350	2,288	3,350	2,288	5,350	3,653	5,420	3,698	5,750	3,928	3,325	2,273
R/A-18	Aqr	Passenger car/tax	62.5	0.0003	2,063	5	2,973	7	1,719	4	1,578	4	688	2	688	2	2,513	6	2,506	6	6,250	14	1,125	3
		Pickups	33.0	0.0170	1,089	136	1,570	195	908	113	833	104	363	46	363	46	1,327	165	1,323	165	3,300	410	594	74
		Medium Trucks	1.1	0.7030	36	185	52	269	30	156	28	144	12	62	12	62	44	226	44	226	110	565	20	103
		Heavy Trucks	3.4	1.5000	112	1227	162	1772	94	1024	86	942	37	406	37	406	137	1501	136	1490	340	3723	61	668
		Buses	0.0	0.6460	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	100		3,300	1,553	4,758	2243	2,750	1,297	2,525	1,194	1,100	516	1,100	516	4,020	1,898	4,010	1,887	10,000	4,712	1,800	848

Note: The design ESAL is in thousands

Table 5.33 CLASSIFICATION OF PAVEMENT STRUCTURE

Design ESAL Unit: Thousands

No. of R/A	Name of R/A	Pavement	Highway			Roundabout	Rampway				Crossroad	
			At-grade		Retaining Wall Section							
			Aqr	Muscat			A-1	B-1	A-2	B-2	Inland	Coast
R/A-2	A'Naseem Gard	Design ESAL	4,503	4,647	4,245	510	592	458	796	813	1,005	847
		Pavement type	C	C	C	-	E	E	E	E	D *	E *
R/A-3	Barka	Design ESAL	3,865	4,997	2,755	3,493	2,067	2,376	2,239	2,346	1,807	1,883
		Pavement type	C	C	C	C	C	C	C	C	D	D
R/A-5	Al Muladdah	Design ESAL	3,264	4,596	2,571	2,021	1,237	1,524	4,036	4,041	2,571	0
		Pavement type	C	C	C	-	D	D	C	C	C *	- *
R/A-8	Al Khaburah	Design ESAL	3,383	3,228	2,620	2,433	2,342	1,802	2,342	1,505	1,971	2,933
		Pavement type	C	C	C	C	C	D	C	D	D	C
R/A-10	Saham	Design ESAL	6,288	6,797	4,554	7,991	3,352	3,576	4,369	4,576	6,097	6,249
		Pavement type	B	B	C	B	C	C	C	C	B	B
R/A-12	Sohar	Design ESAL	7,336	6,764	3,634	11,507	7,449	7,365	6,421	6,125	6,689	9,830
		Pavement type	B	B	C	A	B	B	B	B	B	A
R/A-14	Falaj Al Qabail	Design ESAL	4,222	4,913	3,073	2,286	2,288	2,288	3,653	3,698	3,928	2,273
		Pavement type	C	C	C	C	C	C	C	C	C	C
R/A-18	Aqr	Design ESAL	1,553	2,243	1,297	1,194	516	516	1,898	1,887	4,712	848
		Pavement type	D	C	D	-	E	E	D	D	C *	E *

*: Pavement design not included in this project.

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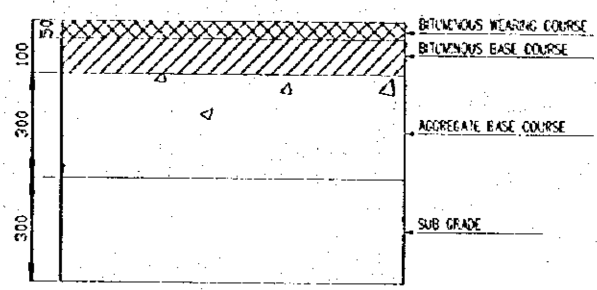

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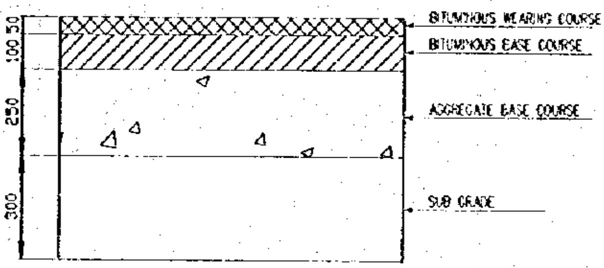

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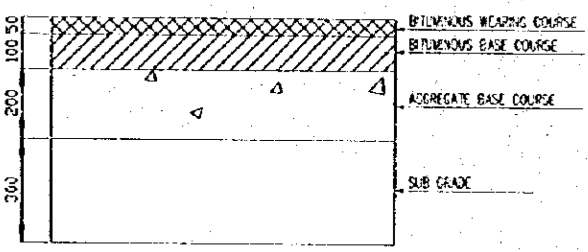

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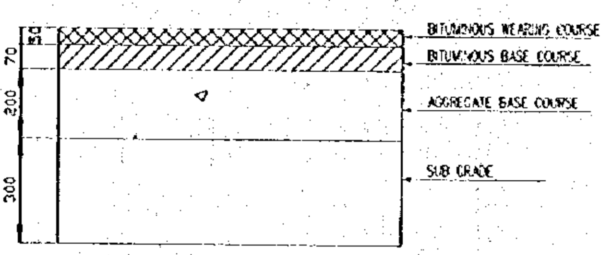

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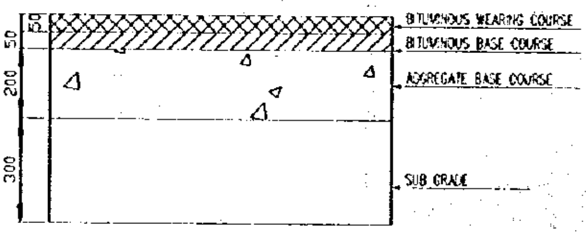

SN=0.143*10+0.055*20
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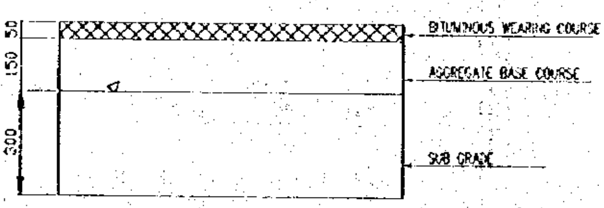
TYPE FOR SERVICE ROADS



SN=0.143*5+0.055*15
=1.54

Notes : Structural Layer Cofficients .

Bituminous courses (asphalt wearing course; asphaltic basecourse)	Base value,0.102;gradation class B,0.008;stability 1000kg,0.008;abrasion 30,0.005;a	
	layer coefficient = 0.143/cm thickness	
Aggregate basecourse	Base value,0.035; plasticity index,non-plastic,0.008; passing 75≤Em,8%,0.004; passing 4.75mm 60%,0.004; abrasion 35%,0.004;	
	layer coefficient = 0.055/cm thickness	

Figure 5.13 Type of Pavement Structure

5.2.3 Drainage

The drainage design of eight roundabouts were carried out in accordance with the design standards mentioned in Chapter 4.5 .

(1) Crossing Culvert

The crossing culvert consists of pipe culverts and box culverts.
Extension of existing culvert or need of new construction are judged from the following factors:

-The regular overburden, namely 500 mm for pipe culvert and 300 mm for box, culvert is kept when these culverts are extended.
- The existing class of pipe or the existing dimension (thickness) can bear the additional earth pressure due to embankment.

The basic policies for the detailed designed are shown below.

- The drainage slope and dimension are basically the same as to the existing ones in order to keep the discharge constsnt.
- In the case of new construction, the existing adjacent culverts are replaced by single culverts.
- The drainage slope is more than 0.3%. At this gradient, velocity to more than 1m/sec could be obtained.
-The invert level at an inlet/outlet is set in order to maintain minimum overburden fill.
-The detour of waterway is considered, if high construction cost and complicated implentation are expected in extending or newly constructing at the same place.

The results of study are shown in Tables 5.34(a) to 5.34(i),and Figure 5.14 regarding the detour at Sohar roundabout .

(2) Median Drainage

The median drainage consists of ditch linings, catch pits and pipes.
The capable water flow volume of the designed ditch lining with 1 % gradient is 1.2 m3/sec, which is more than the volume of the discharge (refer to Table 5.35). On the other hand, the analysis of pipes are similar to crossing pipe; the results being shown in Tables 5.34(a) to 5.34(i) .

(3) Landscaping Area Drainage

The landscaping area drainage consists of ditch linings, catch pits and pipes .
This drainage is provided at the front of an abutment.(i.e. the landscaping area outside of roundabout)
The analysis of pipes are shown in Tables 5.34(a) to 5.34(i) .

(4) Roundabout Drainage

The roundabout drainage consists of offlet ducts at an interval of 20m along the inner roundabout ditch linings, catch pits, and pipes.
This drainage is provided at Barka Al Khaburah, Saham, Sohar and Falaj Al Qabail Roundabouts. The analysis of pipe is shown in Tables 5.34(b), 5.34(d), 5.34(e), 5.34(f), and 5.34(g) .

(5) Open Channel

The rip-rap open channel is provided at A'Naseem Garden and Sohar due to the detouring of the existing waterway. The dimensions and slope are determined by the upstream discharge .The details of open channel at Sohar are shown in Figure 5.14.

(6) Irish Crossing

The Irish crossing is provided at new service roads of the following roundabouts A'Naseem Garden, Al Khabrah, Saham, Sohar, Falaj Al Qabail and Aqr.
The structure is similar to the existing ones.

Table 5.34 (a) : Culvert Study Results

No. of R/A : R/A-2 Name of R/A : A' Naseem Garden

Station	Proposed Culvert				Existing Culvert				Remarks
	Dimension (m)	Slope(%)	Discharge(m3/s)	Renovation Method	Dimension (m)	Slope(%)	Discharge(m3/s)	Overburden(m)	
A 0+760									
B 0+760	ϕ 0.75 * 1 CELL	1.20	1.320	New Construction	ϕ 0.75 * 1 CELL	1.20	1.320	0.295	
A 0+765									
B	ϕ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.050	-------	For Median
A 1+062									For Landscape
B	ϕ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	Area
A 1+066					ϕ 0.90 * 1 CELL	1.30	2.235	0.074	Change of
B 1+066	□ 2.00 *1 * 2 CELL	0.30	11.501	New Construction	□ 2.00 *1 * 1 CELL	0.67	8.594	0.318	Location *
						TOTAL	10.829		
A 1+348									For Landscape
B	ϕ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	Area
A 1+695									
B	ϕ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.099	-------	For Median
A 1+785					ϕ 0.75 * 2 CELL	1.37	2.822	0.141	
B 1+785	□ 2.00 *1 * 1 CELL	0.30	5.751	New Construction	ϕ 0.75 * 1 CELL	0.97	1.187	0.307	
						TOTAL	4.009		

Notes: * If the overburden is maintained,the existing pipe of class M and box culvert with a slab of 200m thicnkess cannot be held by the additional earth pressure caused due to embankment with 6m in height.

Table 5.34 (b) : Culvert Study Results

No. of R/A : R/A–3 Name of R/A : Barka

Station		Proposed Culvert				Existing Culvert				Remarks
		Dimension (m)	Slope(%)	Discharge(m3/s)	Renovation Method	Dimension (m)	Slope(%)	Discharge(m3/s)	Overburden(m)	
A	0+769									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.058	-------	For Median
A	1+066									For Landscape
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	Area
A	1+245									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	For Roundanout
A	1+347									Change of
B	1+348	φ 0.75 * 1 CELL	1.15	1.293	New Construction	φ 0.75 * 1 CELL	1.15	1.293	0.120	Location *
A	1+351									For Landscape
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	Area
A	1+689									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.025	-------	For Median
A	1+980									
B	1+980	□ 2.00 *1 *12 CELL	0.34	73.465	Extension	□ 2.00 *1 *12 CELL	0.34	73.465	1.263	

Notes: * If the overburden is maintained,the existing pipe of class M and box culvert with a slab of 200m thicnkess cannot be held by the additional earth pressure caused due to embankment with 6m in height.

Table 5.34 (ca) : Culvert Study Results

No. of R/A : R/A-5　　　Name of R/A : Al Muladdah

Station		Proposed Culvert				Existing Culvert				Remarks
		Dimension (m)	Slope(%)	Discharge(m3/s)	Renovation Method	Dimension (m)	Slope(%)	Discharge(m3/s)	Overburden(m)	
A	0+268									
B	0+272	□ 2.00 *1 * 2 CELL	0.37	12.773	New Construction	□ 2.00 *1 * 2 CELL	0.37	12.773	0.008	
A	0+332									
B	0+337	φ 0.60 * 2 CELL	0.85	1.226	Extension	φ 0.60 * 2 CELL	0.85	1.226	0.669	
A	0+413									
B	0+418	□ 2.00 *1 * 2 CELL	0.23	10.071	Extension	□ 2.00 *1 * 2 CELL	0.23	10.071	0.389	
A	0+608									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.010	-------	For Median
A	0+655									
B	0+661	□ 2.00 *1 * 1 CELL	1.00	10.499	Extension	□ 2.00 *1 * 1 CELL	1.00	10.499	0.360	
A	0+926									For Landscape
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	Area
A	1+210									For Landscape
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	Area
A	1+477									
B	1+482	φ 0.60 * 1 CELL	0.91	0.634	New Construction	φ 0.60 * 1 CELL	0.91	0.634	0.428	
A	1+518									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.014	-------	For Median

Notes: * If the overburden is maintained,the existing pipe of class M and box culvert with a slab of 200m thicnkess cannot be held by the additional earth pressure caused due to embankment with 6m in height.

Table 5.34 (d) : Culvert Study Results

No. of R/A : R/A-8 Name of R/A : Al Khaburah

	Station	Proposed Culvert				Existing Culvert				Remarks
		Dimension (m)	Slope(%)	Discharge(m3/s)	Renovation Method	Dimension (m)	Slope(%)	Discharge(m3/s)	Overburden(m)	
A	0+417.0									
B	0+417.0	φ 0.60 * 1 CELL	1.04	0.678	Extension	φ 0.60 * 1 CELL	1.04	0.678	0.555	
A	0+670.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.031	-------	For Median
A	0+794.5									
B	0+794.5	□ 2.00 *1 * 3 CELL	0.82	28.523	Extension	□ 2.00 *1 * 3 CELL	0.82	28.523	0.680	
A	0+968.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	For Landscape Area
A	1+ 60.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	For Roundanout
A	1+252.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	For Landscape Area
A	1+328.5									
B	1+328.5	φ 0.60 * 1 CELL	0.75	0.576	New Construction	φ 0.60 * 1 CELL	0.75	0.576	0.270	
A	1+540.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.031	-------	For Median
A	1+916.5									
B	1+916.5	φ 0.60 * 1 CELL	0.33	0.382	New Construction	φ 0.60 * 1 CELL	0.33	0.382	0.319	

Notes:

Table 5.34 (e) : Culvert Study Results

No. of R/A : R/A-10 Name of R/A : Saham

	Station	Proposed Culvert				Existing Culvert				Remarks
		Dimension (m)	Slope(%)	Discharge(m3/s)	Renovation Method	Dimension (m)	Slope(%)	Discharge(m3/s)	Overburden(m)	
A										
B	0+405.5	φ 0.40 * 1 CELL	1.15	0.242	Existing	φ 0.40 * 1 CELL	1.15	0.242	1.063	For Median
A	0+562.0									
B	0+561.0	φ 0.60 * 1 CELL	0.30	0.364	New Construction	φ 0.50 * 1 CELL	0.15	0.158		
A	0+660.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.125	-------	For Median
A	0+787.0									
B	0+787.0					φ 0.80 * 1 CELL	1.17	1.549	0.556	(1)*
A	0+880.0									
B	0+897.0					φ 0.80 * 1 CELL	0.16	0.573	0.324	(2)*
A	0+959.0									For Landscape
B	0+959.0	φ 0.60 * 1 CELL	0.40	0.420	New Construction	-------	-------	-------	-------	Area
A	1+61.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	For Roundanout
A	1+241.0									For Landscape
B	1+241.0	φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	Area
A	1+540.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.086	-------	For Median
A	1+663.0									φ 0.60
B	1+664.0	φ 0.55 * 1 CELL	0.49	0.369	Extension	φ 0.55 * 1 CELL	0.49	0.369	0.610	For Extention

Notes: * At present, water for virgin trees located at wadi spread, is provided from the seaside open channel through the existing pipe (2) . But due to additional earth pressure caused by embankment with more than 3m in height, pipe culverts(1)and(2)need to be re-constructed. However, without re-constructing, these are to be removed, and the water-supply for the trees at wadi spread is provided from the water collected at the inlet of pipe (1) through the ditch lining.

Table 5.34 (f) : Culvert Study Results

No. of R/A : R/A-12 Name of R/A : Sohar

	Station	Proposed Culvert				Existing Culvert				Remarks
		Dimension (m)	Slope(%)	Discharge(m3/s)	Renovation Method	Dimension (m)	Slope(%)	Discharge(m3/s)	Overburden(m)	
A	0+840									Change of
B	0+849	□ 2.00 *1 * 1 CELL	0.30	5.751	New Construction	□ 2.00 *1 * 1 CELL	0.09	3.150	0.175	Location
A	0+960									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.200	-------	For Median
A	1+266									For Landscape
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	Area
A	1+323									Change of
B	1+323	□ 2.00 *1 * 2 CELL	0.35	12.423	New Construction	□ 2.00 *1 * 2 CELL	0.12	7.274	0.136	Location
A	1+370									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	For Roundanout
A										
B	1+475	φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	For Roundanout
A										For Landscape
B	1+576	φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	Area
A	1+880									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.215	-------	For Median
A	2+012					φ 0.75 * 1 CELL	0.10	0.381	-------	
B	1+994	□ 2.00 *1 * 2 CELL	0.70	17.569	New Construction	□ 2.00 *1 * 2 CELL	0.56	15.714	-------	
	Seaside									
	Cross Road	□ 2.00 *1 * 2 CELL	0.35	12.423	New Construction	-------	-------	-------	-------	
	Seaside									Change of
	Service Road	□ 2.00 *1 * 2 CELL	0.35	12.423	New Construction	□ 2.00 *1 * 2 CELL	0.32	11.879	(0.610)	Location *
	Inland									Change of
	Cross Road	□ 2.00 *1 * 1 CELL	0.35	6.211	New Construction	□ 2.00 *1 * 1 CELL	0.30	5.751	-0.047	Location

Notes: * The location of inlet was altered due to the change of upstream water way,though it's overburden is maintained.

Table 5.34 (g) : Culvert Study Results

No. of R/A : R/A-14 Name of R/A : Falaj Al Qabail

	Station	Proposed Culvert				Existing Culvert				Remarks
		Dimension (m)	Slope(%)	Discharge(m3/s)	Renovation Method	Dimension (m)	Slope(%)	Discharge(m3/s)	Overburden(m)	
A	0+976.5									φ0.90
B	0+975.5	φ 0.80 * 1 CELL	0.53	1.042	Extension	φ 0.80 * 1 CELL	0.53	1.042	0.879	For Extension
A	1+180.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.128	-------	For Median
A	1+207.5									φ0.90
B	1+202.5	φ 0.80 * 1 CELL	0.52	1.032	Extension	φ 0.80 * 1 CELL	0.52	1.032	0.811	For Extension
A	1+458.0									For Landscape
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	Area
A	1+468.0									
B	1+462.0	□ 2.00 *1 * 2 CELL	0.43	13.770	Extension	□ 2.00 *1 * 2 CELL	0.43	13.770	1.029	
A	1+623.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	For Roundanout
A	1+742.0									For Landscape
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	-------	-------	Area
A	2+ 28.0									
B	2+ 30.5	φ 0.60 * 1 CELL	0.94	0.645	Extension	φ 0.60 * 1 CELL	0.94	0.645	0.982	
A	2+170.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.133	-------	For Median
A	2+302.5									
B		□ 2.00 *1 * 3 CELL	0.57	23.780	Extension	□ 2.00 *1 * 3 CELL	0.57	23.780	0.798	

Notes:

Table 5.34 (h) : Culvert Study Results

No. of R/A : R/A-18 Name of R/A : Aqr Kind of Road :Highway

	Station	Proposed Culvert				Existing Culvert				Remarks
		Dimension (m)	Slope(%)	Discharge(m3/	Renovation Method	Dimension (m)	Slope(%)	Discharge(m3/	Overburden(m)	
A										
B	0- 90.0	□ 2.00 * 1 * 2 CELL	0.66	17.059	Extension	□ 2.00 *1 * 2 CELL	0.66	17.059		
A										
B	0+110.0	□ 2.00 * 1 * 3 CELL	0.66	25.589	Extension	□ 2.00 *1 * 3 CELL	0.66	25.589	0.610	
A										φ 0.90
B	0+240.0	φ 0.80 * 1 CELL	0.19	0.624	Extension	φ 0.80 * 1 CELL	0.19	0.624	0.580	For Extention
A	0+260.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.030	-------	For Median
A										
B	0+319.0	□ 2.00 * 1 * 1 CELL	0.69	8.721	Extension	□ 2.00 *1 * 1 CELL	0.69	8.721	0.387	
A	0+476.5									
B	0+479.0	□ 2.00 * 1 * 2 CELL	1.08	21.822	New Construction	□ 2.00 *1 * 2 CELL	1.08	21.822	0.155	
A	0+709.0									
B	0+702.0	□ 2.00 * 1 * 2 CELL	1.04	21.415	New Construction	-------	-------	21.415	-------	*
A	0+730.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.203	-------	For Median
A	0+879.6									
B	0+870.7	□ 5.00 * 4.8 * 2 CELL	0.50	393.959	New Construction	-------	-------	61.505	-------	**
A										
B	1+290.0	φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.171	-------	For Median
A	1+516.5									
B	1+496.0	φ 0.60 * 2 CELL	1.03	1.349	Extension	φ 0.60 * 2 CELL	1.03	1.349	1.269	
A	1+720.0									
B		φ 0.60 * 1 CELL	0.30	0.364	New Construction	-------	-------	0.032	-------	For Median

Notes: * The discharge of the existing downstream box culvert (2m*1m*1sell)is 21.4m3.
** The discharge of the existing downstream box culverts (2m*1m*3cell and 2m*1m*2sell) is 61.5m3. On the other hand, the discharge of the proposed culvert is 84.7 m3 when the water-depth is 1.5m

Table 5.34 (i) : Culvert Study Results

No. of R/A : R/A-18 Name of R/A : Aqr Kind of Road :Rampway(Muscat-Aqr)

Station		Proposed Culvert				Existing Culvert				Remarks
		Dimension (m)	Slope(%)	Discharge(m3/s)	Renovation Method	Dimension (m)	Slope(%)	Discharge(m3/s)	Overburden(m)	
R	2+19.5									
L	2+19.0	□ 2.00 *1 * 1 CELL	0.69	8.721	Extension	□ 2.00 *1 * 1 CELL	0.69	8.721	0.387	
	23+ 7.0	□ 2.00 *1 * 2 CELL	1.04	21.415	Existing	□ 2.00 *1 * 2 CELL	1.04	21.415	0.498	
R	32+11.0									
L	32+12.0	□ 2.00 *1 * 3 CELL	1.62	40.090	Existing	□ 2.00 *1 * 3 CELL	1.62	40.090	0.412	
	41+ 3.5	□ 2.00 *1 * 2 CELL	1.04	21.415	Existing	□ 2.00 *1 * 2 CELL	1.04	21.415	0.495	

No. of R/A : R/A-18 Name of R/A : Aqr Kind of Road :Rampway(Dubai-Aqr)

Station		Proposed Culvert				Existing Culvert				Remarks
		Dimension (m)	Slope(%)	Discharge(m3/s)	Renovation Method	Dimension (m)	Slope(%)	Discharge(m3/s)	Overburden(m)	
	31+2.0	φ 0.60 * 2 CELL	1.30	1.516	Extension	φ 0.60 * 2 CELL	1.30	1.516	0.923	

Notes:

Table 5.35 Discharge for Median Drainage

		R/A-2 A' Naseem Garden		R/A-3 Barka		R/A-5 Al Muladdah		R/A-8 Al Khaburah	
		0+765	1+695	0+769	1+689	0+608	1+518	0+670	1+540
Median	Area(m2)	5960	6140	2300	2960	1250	1700	3713	3706
	Discharge(m3/s)	0.050	0.051	0.019	0.025	0.010	0.014	0.031	0.031
Road	Area(m2)	0	2690	2200	0	0	0	0	0
	Discharge(m3/s)	0.000	0.048	0.039	0.000	0.000	0.000	0.000	0.000
Total Discharge(m3/s)		0.050	0.099	0.058	0.025	0.010	0.014	0.031	0.031

		R/A-10 Saham		R/A-12 Sohar		R/A-14 Falaj Al Qabail		R/A-18 Aqr			
		0+660	1+540	0+960	1+880	1+180	2+170	0+260	0+730	1+290	1+720
Median	Area(m2)	4178	3047	14700	13600	4871	5203	3600	7883	7106	3800
	Discharge(m3/s)	0.035	0.025	0.123	0.113	0.041	0.043	0.030	0.066	0.059	0.032
Road	Area(m2)	5101	3425	4390	5750	4953	5075	0	7743	6290	0
	Discharge(m3/s)	0.090	0.061	0.078	0.102	0.088	0.090	0.000	0.137	0.111	0.000
Total Discharge(m3/s)		0.125	0.086	0.200	0.215	0.128	0.133	0.030	0.203	0.171	0.032

Notes: (1)Discharge consists of retaining wall section and the at-grade section.
(2)Rainfall intensity mentioned in Highway Design Manual is 75mm/h. (storm ; once in five years)
(3)Run-off coefficient is 0.40 for median and 0.85 for roads,refering to Highway Design Manual.

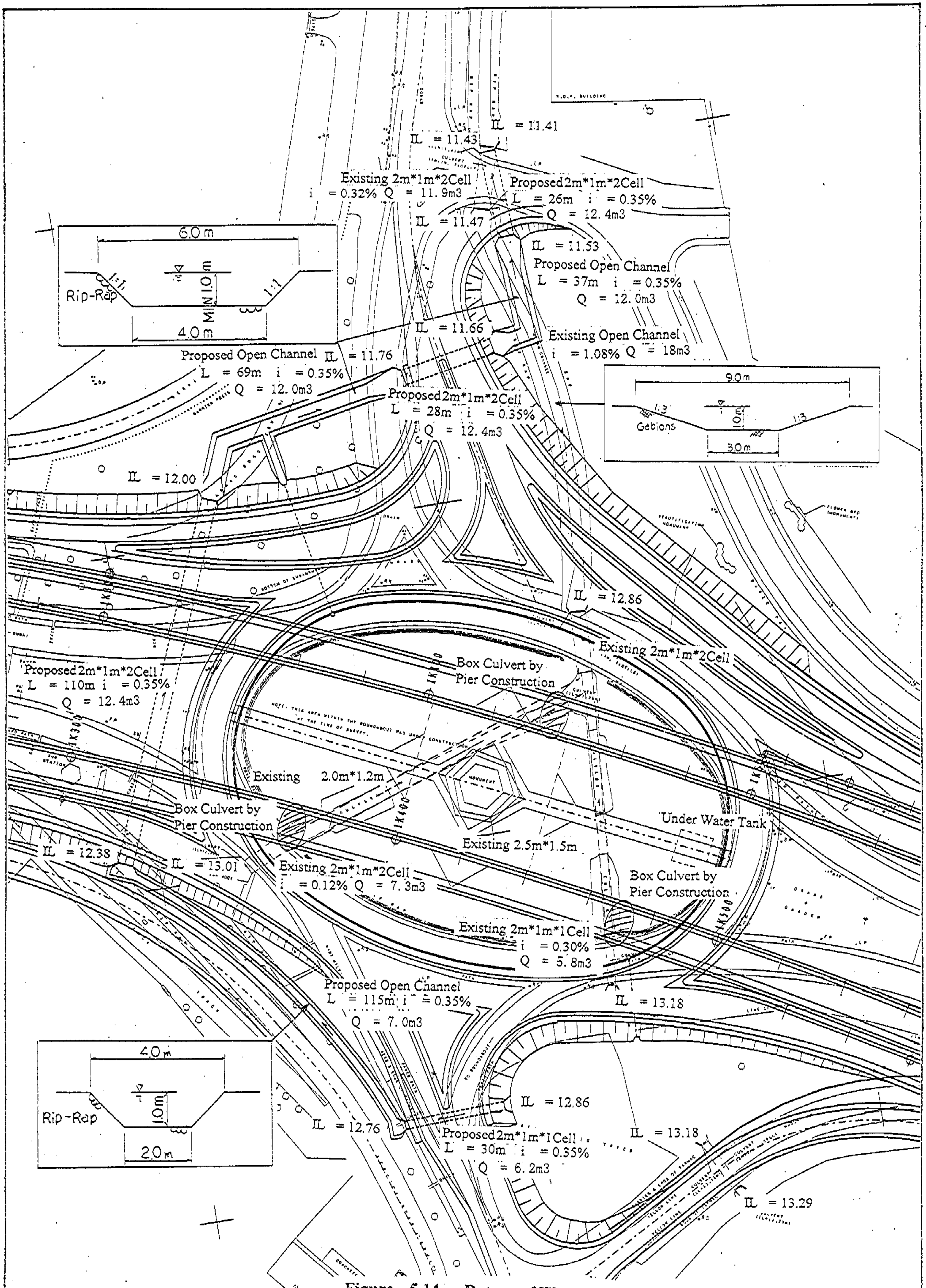


Figure 5.14 Detour of Water Way