

CHAPTER 5

BRIDGE AND STRUCTURE DESIGN

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5.1 General

(1) Scope of Basic Design

The scope of the basic design of bridges and structures is as listed below.

- Selection of bridge/structural types
- Planning of bridge/structures (location, length, width)
- Initial design calculations for general formation
- Drawing of general view
- Quantity calculation
- Construction cost estimation

The basic design was executed without sufficient on-site topographic and geological data. Thus, before starting the detailed design, all basic design output shall be checked with site data and the planning of bridge/structures confirmed with the RDA again.

(2) Design Criteria

Bridges and other structures shall be designed basically by RDA Standard, but also taken reference from British Standard (BS), Japanese bridge/structural design standards and other manuals for criterion which is not mentioned in RDA Standard. Much consideration should be made with local conditions such as live load, temperature, wind and clearance regulations.

(3) Bridge Type Comparison

Bridge and structural type shall be decided via a comparison based on the feasibility study. Items to be compared consist of the superstructure, substructure, foundation, and road widening. Note that a special comparison shall be carried out for the Kelani River Bridge due to it being a high-cost long bridge.

(4) Hydrological Study

A hydrological/hydraulic study shall be carried out for the design of drainage structures and for setting of the length of the Kelani Bridge. Note that the calculations of the high water level (HWL) for Kelani River and the estimation of the flood area will affect the bridge/embankment design.

(5) Design Items

The items to be designed are as listed below.

- Kelani River Bridge
- OCH bridges (including ramps) crossing over local roads, channels, etc.
- Overpasses over the OCH
- Box culverts for crossing local roads
- Pipe culverts for drainage
- Retaining walls and other structures
- Drainage structures for OCH

5.2 Design Criteria

5.2.1. Design Standards

The design standards for the OCH Project are listed below.

- Main standards from RDA
 - Geometric Design Standards of Roads (1998)
 - Bridge Design Manual (1997)
 - Standard Specifications for Construction and Bridges (1989)
 - Bridge Construction Manual (1997)
- Reference standards
 - British Standard BS 5400 (1978 - 2000)
 - Specification of Highway Bridges (Japan Road Association, 1996)
- Underpass Structures
 - Design Manual for Roads and Bridges (British Highway Agency, 1989)

In spite of this, regarding criteria for “longitudinal force”, BS 5400 is adopted and the criteria of the RDA Manual are not applied as agreed upon with the RDA.

5.2.2. Geometric Criteria

(1) Road Classification

The bridges in OCH are categorized according to the road classification given in the Geometric Design Standards of Roads, with the design live loads varying with the said classification.

Table 5.2.1 Road Classification

	Road Classification	Design Live Load
Highway bridges	A – class road	HA and HB Live load
Overpass bridges	A, B – class road	HA and HB Live load
Ditto	C, D, E – class roads	HA Live load

(2) Effective Road Width for Highway Bridges

Table 5.2.2 Effective Road Widths for Highway Bridges

(Unit : mm)

	1st Stage (4-lane operation)	Final Stage (6-lane operation)
Road Embankment	11,250 = 1,250 + 2 @3,500 + 3,000	14750 = 1250 + 3 @ 3,500 + 3000
Minor Bridges	Ditto	ditto

(3) Bridge Clearance

1) Minimum Vertical Clearance

Table 5.2.3 Minimum Vertical Clearance

Bridge	Crossing Item	Vertical clearance (Horizontal Clearance) (mm)	Remarks
Overpass Br.	OCH	5,100	Southern Hwy.
Highway Br.	Railway (horizontal clearance)	5,487 (above rail level) (7,620)	vertical clearance (away from the center of the outer track)
Hwy. Br., UP	Class A, B Road	5,100	
Ditto	Class C, D Road	5,100 (4,800)	(): Absolute minimum
ditto	Class E Road or less	4,500	
ditto	Pedestrian Road	3,000	

2) Horizontal Clearance

Horizontal clearance from the edge of a Road Clearance to the face of a substructure shall not be less than 3.0m for bridges crossing over an OCH ramp way. As for bridges crossing over the CKE, horizontal clearance shall not be less than 1.0m, which is in accordance with the design of the CKE project.

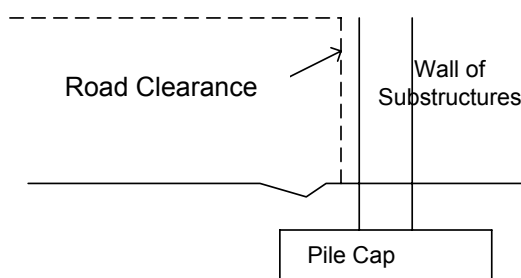


Fig. 5.2.1 Relationship between Road Clearance and Substructure

3) Relationship between Railway Clearance and Substructure

According to the letter of 05.09.2004 from SRI LANKA RAILWAYS, the vertical clearance required above the railway is 18ft. Minimum horizontal distance from the center of a rail to any structure should be 25ft. Hence,

- Vertical clearance $H=5,487\text{mm}$ (18ft)
- Horizontal clearance $L=7,620\text{mm}$ (25ft)

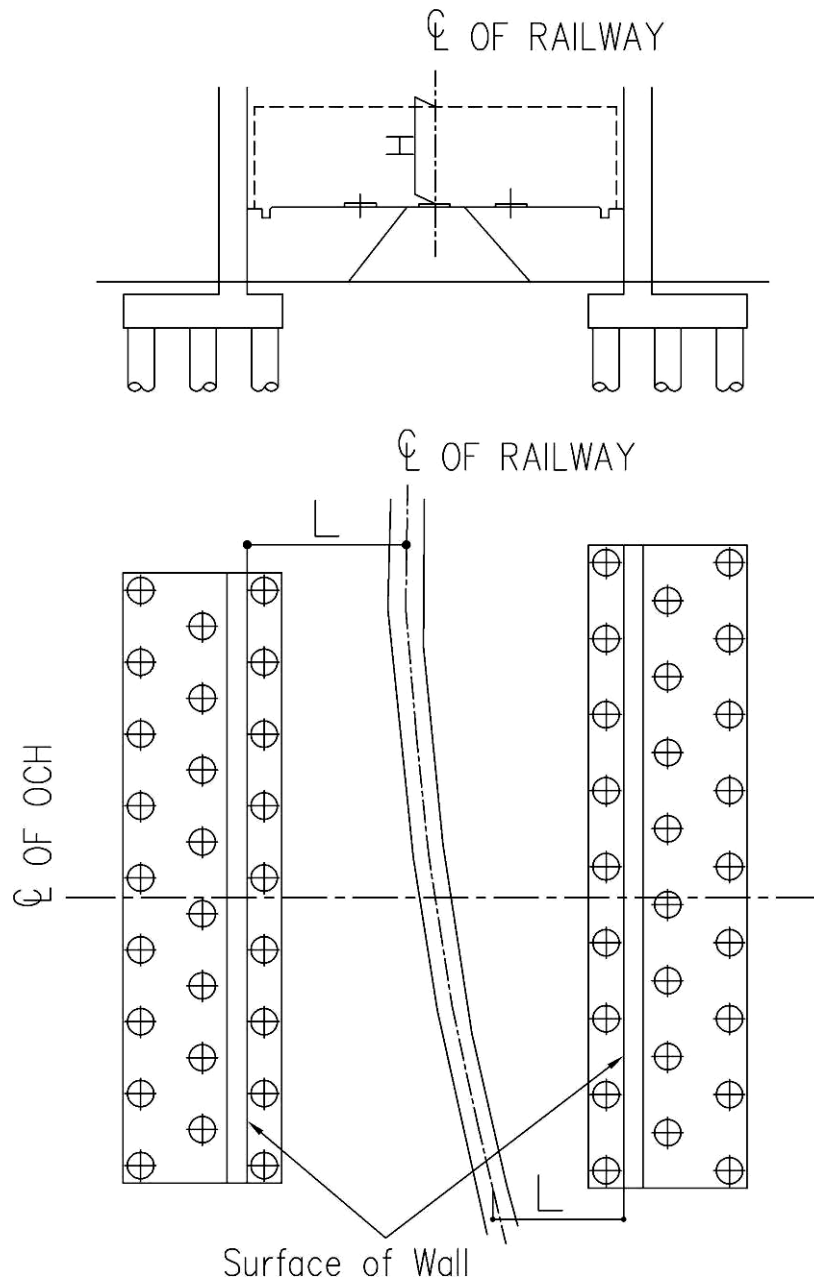


Fig. 5.2.2 Relationship between Railway Clearance and Substructure

4) Navigation Clearance and Free Board (Kelani River)

- Height : 4.75 m from N.W.L. (Normal Water Level)
- Width : 10.50 m (4.75+1.00+4.75)
- Free Board : 1.20 m above H.F.L.

5) Minimum Bridge Span in Kelani River

According to Japanese Standards, minimum bridge span in a river measured perpendicular to the river flow is as shown **Fig. 5.2.3**, with emphasis on avoiding damage from floating logs and debris. Minimum bridge span is calculated below.

$$L = 20 + 0.005 Q \quad Q : \text{discharge (m}^3/\text{s)}$$

As the discharge of Kelani River is approximately 2,800 m³/s, the minimum span is 34.0 m.

$$L = 20 + 0.005 \times 2,800 = 34.0 \text{ m} \quad \Rightarrow \quad 35.0\text{m}$$

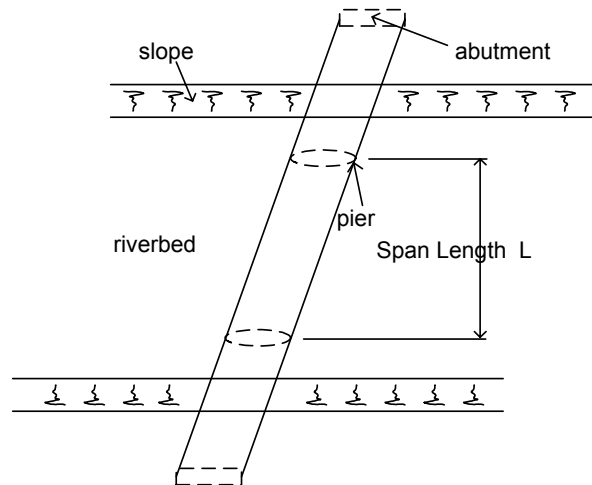


Fig. 5.2.3 Measurement of Minimum Span Length

5.2.3. Design Load

Design loads shall be defined by both the Bridge Design Manual (RDA, 1997) and BS 5400 Part-2 (1978).

Permanent Load

- 1 Dead Load and Superimposed Dead Load
- 2 Earth Pressure
- 3 Shrinkage and Creep
- 4 Differential Settlement
- 5 Water Current
- 6 Buoyancy

Transient Load

- 7 Live Load (main)
- 8 Live Load (sub)
- 9 Footway and Cycle Track Live Load
- 10 Wind Load
- 11 Temperature
- 12 Erection Load
- 13 Floating Debris and Logs

- Note - Earthquakes are not considered in Sri Lanka
- Combinations of loads are considered by BS 5400 Part-2

(1) Dead Loads and Superimposed Dead Loads

Table 5.2.4 Dead Load Intensity

Type of Load	Item	Unit	Value	Remarks
Dead load	Reinforced concrete	kN/m ³	25.0	
	Pre-stressed concrete	kN/m ³	25.0	
	Plane concrete	kN/m ³	23.5	
	Asphalt pavement	kN/m ³	23.0	
	Steel	kN/m ³	78.5	
	Compact sand	kN/m ³	19.0	
	Loose sand	kN/m ³	16.0	
Superimposed Dead load	Pavement	mm	50	
	Bridge parapet	kN/m	7.60	
	Handrail	kN/m	1.00	
	Public utilities	kN/m	None	
	Others	kN/m	None	

(2) Earth Pressure

As for the earth pressure that acts on an abutment, only active earth pressure will be taken into account and passive earth pressure will not be considered. Note that surcharge loading due to live loading shall be considered as follows:

HA Live Load	10.0 kN/m ²
HB Live Load (30 units)	12.5 kN/m ²

The coefficient of earth pressure K_a is calculated as follows:

$$K_a = (1 - \sin \theta) / (1 + \sin \theta)$$

θ : friction angle of back fill soil

(3) Shrinkage and Creep

Loss of pressure due to shrinkage and creep shall be considered in the design of pre-stressing force, bending moment and deflection of girders.

(4) Differential Settlement

Differential settlement shall be disregarded in the structural design as the pile end reaches into sufficiently stiff stratum. However, special consideration is needed for the connection between the structures and embankments.

(5) Water Current

The horizontal force of water current shall be calculated with the RDA manual and is as given below.

$$P = K \times W \times V^2 / (2g)$$

$$= 52 \times K \times V^2$$

Where

P:	intensity of pressure	(kg/m ²)
W:	unit weight of water	(kg/m ³)
V:	velocity of current	(m/sec)
G:	acceleration of gravity	(m/sec ²)
K:	a constant depending on the shape of pier	

(6) Buoyancy

In computing the effect of buoyancy, the appropriate water level shall be taken into account.

(7) Live Load (main)

The HA live load (normal load) is applied to all bridges and the HB (abnormal load) to only bridges of Class A and B roads together with the HA load.

1) HA Load

Three kinds of loads are considered in the design for the HA load.

- Uniformly distributed load (UDL) : Intensity varies by load length
- Knife edge load (KEL) : 120 kN/lane * 2 lanes
- Single wheel load : 100 kN at the severest position for local effect

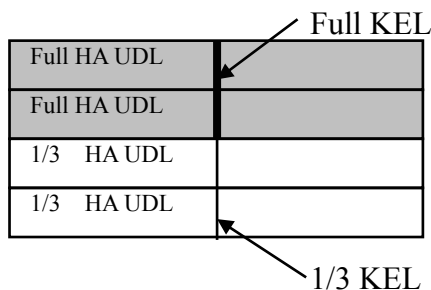


Fig. 5.2.4 HA Loading

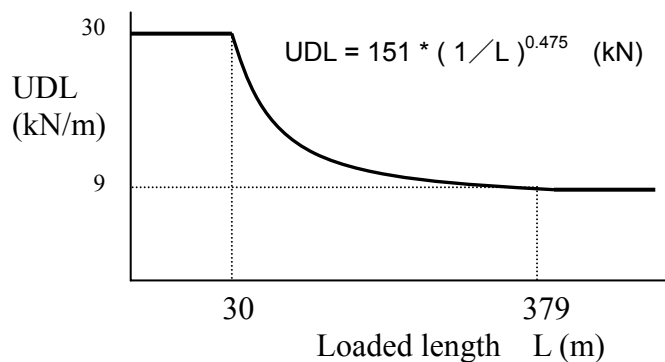


Fig. 5.2.5 Intensity of UDL

2) HB Load

By RDA manual, 30 units of HB loads should be applied in design.

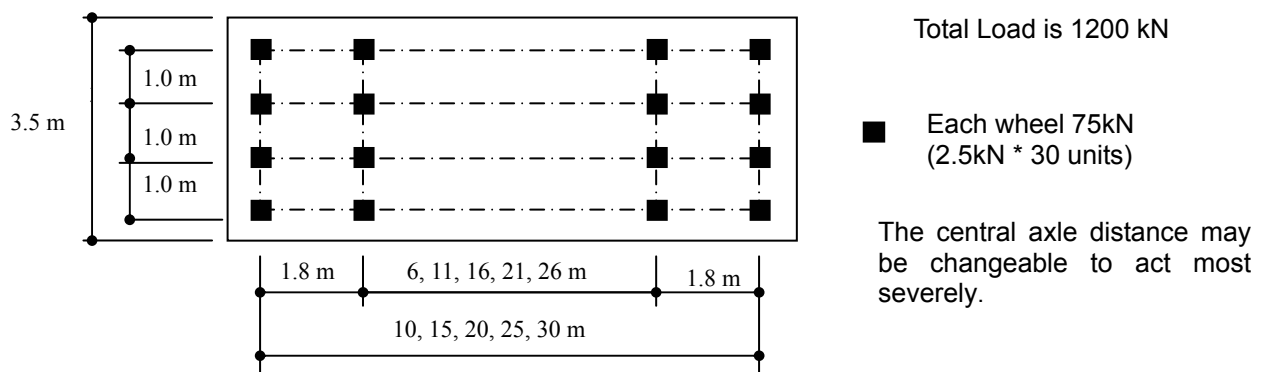


Fig. 5.2.6 Distribution of HB Load

(8) Live Load (sub)

1) Centrifugal Force

The nominal centrifugal load F_c and associated vertical load V_c shall be considered for curved bridges and structures.

$$F_c = 30000 / (r + 150) \text{ kN}$$

$$V_c = 300 \text{ kN}$$

Where, r is the radius of curvature of the lane (m)

2) Longitudinal Force

The longitudinal force resulting from traction or braking is also taken into account.

$$\text{HA: } P_a = 200 + 8 \times L \ (\leq 700) \text{ kN}$$

$$\text{HB: } P_b = 25\% \text{ of HB vertical load}$$

Where L is the loaded length (m)

3) Skidding Load

A horizontal load of 250 kN due to skidding shall be considered in the design with the HA load.

4) Vehicle Collision Load

i Collision with parapets

Four wheels of 25 units of HB loading (250 kN) shall be considered for all positions.

ii Collision with bridge supports

Table 5.2.5 Collision Load with Bridge Support

Type of load	Load normal to the carriageway below	Load parallel to the carriageway below	Point of application on bridge support
Load transmitted from guard rail	150 kN	50 kN	Any one bracket attachment point, or for free standing fences any one point 0.75 m above carriageway level
Residual load above guard rail	100 kN	100 kN	At the most severe point between 1 m and 3 m above carriageway level

(9) Footway and Cycle Track Live Load

This type of load will vary with the loaded length and intensity of the UDL in the HA load.

$$\begin{aligned} L \leq 30 \text{ m} & \quad q = 5.0 \text{ kN/m}^2 \\ L > 30 \text{ m} & \quad q = 5.0 \times (\text{UDL} / 30) \text{ kN/m}^2 \end{aligned}$$

If the road bridge supports a footway, the live load intensity shall be 80% of the preceding load.

(10) Wind Load

Wind load P shall be calculated according to BS 5400 Part-2.

$$P = 0.613 \times V_c^2 \times A \times C_d \quad (\text{N})$$

Where,

V_c: maximum wind gust speed (m/s)

A: the solid area (m²)

C_d: the drag coefficient

V_c is estimated via mean hourly wind speed (zone-3) V and the coefficient of horizontal wind loaded length ($L \leq 20\text{m}$ with the height of 10m) S₂.

$$V_c = V \times S_2 = 22.2 \times 1.56 = 35 \text{ (m/s)}$$

(11) Temperature

1) Effective Bridge Temperature

Effective bridge temperature shall be taken into consideration using the RDA Bridge Design Manual in the section dealing with the continuous bridges and temperature stress.

2) Frictional Bearing Resistance due to Temperature Change

Ten percent of the dead load from the superstructure shall be considered in the design of substructures (longitudinal direction). This ten percent is the minimum friction coefficient for gum type sliding bearings (which is in accordance with Japanese design standards).

(12) Erection Load

Erection load shall be taken into account in the design if necessary, especially in the case of the cantilever erection method.

(13) Floating Debris and Impact from Logs

1) Floating Debris

Where debris is likely, an allowance shall be made for force exerted by debris with a minimum depth of 1.2 m. The amount of debris for any one span shall be one half of the sum of the adjacent spans for a maximum of 22.0 m where the deck is not submerged. In calculating the force from debris, the formula for water current shall be used with the value of the constant K equal to 1.0.

2) Log Impact

The impact from logs shall be calculated using the RDA manual while referring to Japanese standards.

$$P = 0.1 \times W \times V$$

Where,

P: collision force (t)

W: weight of drifting item, $W=2t$ is assumed (t)

V: surface velocity of the water (m/s)

5.2.4. Design of Structures

(1) Design Class for Pre-stressed Concrete Structure

The bridges of the OCH Project are located inland and are therefore unaffected by seawater. Hence, bridges are to be designed as Class 2 structures.

(2) Verification Formula

Bridges and structures shall be designed using the formula below for two limit states; namely, the "Ultimate Limit State" and "Serviceability Limit State".

$$R^* \geq S^*$$

$R^* = f$ unction (f_k / γ_m) : design resistance

$S^* = \gamma_{f3} * \text{effect} (\gamma_{fL} * Q_k)$: design load effect

f_k : nominal strength of the material (by available material)

Q_k : nominal load (by BS5400 Part-2)

γ_m : partial safety factor (by BS5400 Part-4)

γ_{f3} : partial inaccurate factor (by BS5400 Part-4)

γ_{fL} : partial load factor (by BS5400 Part-2)

(3) Properties of Materials

1) Concrete

Table 5.2.6 Concrete Strength

Classification	Characteristic Strength (N/mm ²)		Young's Modulus (kN/mm ²)	
	At transfer	Serviceability	At transfer	Serviceability
PC Girder	36	50	29.8	34.0
Crossbeam	24	35	25.1	29.5
RC Slab	-	35	-	29.5
RC Panel	-	35	-	29.5
Abutment, Pier	-	30	-	28.0
Bored Pile	-	30	-	28.0
RC Driven Pile	-	30	-	28.0

Poisson's Ratio: 0.20
Temperature Coefficient: $12 * 10^{-6}$
Stress-Strain Curb for Design: BS 5400 Part 4, Figure.1

2) Steel

Table 5.2.7. Steel Strength

Classification	Characteristic Strength (N/mm ²)		Young's Modulus (kN/mm ²)	
	At Transfer	Serviceability	At Transfer	Serviceability
G460	-	460	200	200
12S15.2B 12S12.7B 7S12.7B	-	1850	200	200
1S28.6 1S21.8	-	1800	200	200

Poisson's Ratio: 0.30
Temperature Coefficient: $12 * 10^{-6}$
Stress-Strain Curb for Design:
BS 5400 Part 4, Figure.2 (Reinforcement), Figure.3 (PC Strand)

3) Constants for Backfill Soil

Internal friction of angle $\phi = 30$ degree
Unit weight $\gamma = 19$ kN/m³
Cohesion $c = 0$ kN/m²

(4) Load Combinations

Load combinations for design shall be carried out in 5 groups. The partial load factor γ_{fL} is summarized in **Table.5.2.8**

Table 5.2.8. (1) Load Combinations with Appropriate γ fl

Clause No	Load	Limit State	γ fl for Load Combinations					
			1	2	3	4	5	
5.1	Dead load: Steel	ULS*	1.05	1.05	1.05	1.05	1.05	
		SLS	1.00	1.00	1.00	1.00	1.00	
	Concrete	ULS*	1.15	1.15	1.15	1.15	1.15	
		SLS	1.00	1.00	1.00	1.00	1.00	
5.2	Superimposed dead load	ULS+	1.75	1.75	1.75	1.75	1.75	
		SLS+	1.20	1.20	1.20	1.20	1.20	
5.1.2.2 5.2.2.2	Reduced load factor for dead and superimposed dead load where this has a more severe total effect	ULS	1.00	1.00	1.00	1.00	1.00	
5.3	Wind: during erection	ULS		1.10				
		SLS		1.00				
	With dead plus superimposed dead load only, and for members primarily resisting wind loads	ULS		1.40				
		SLS		1.00				
	With dead plus superimposed dead plus other appropriate combination 2 loads	ULS		1.10				
		SLS		1.00				
	Relieving effect of wind	ULS		1.00				
		SLS		1.00				
5.4	Temperature: restraint due to range	ULS			1.30			
		SLS			1.00			
	Frictional bearing restraint	ULS					1.30	
		SLS					1.00	
	Effect of temperature difference	ULS			1.00			
		SLS			0.80			
5.6	Differential settlement	ULS	To be assessed and agreed between the engineer and the appropriate authority					
		SLS						
5.8	Earth pressure: retained fill and/or live load	ULS	1.50	1.50	1.50	1.50	1.50	
		Surcharge	SLS	1.00	1.00	1.00	1.00	1.00
			Relieving effect	ULS	1.00	1.00	1.00	1.00
5.9	Erection: temporary load	ULS		1.15	1.15			
6.2	Highway bridge live load: HA alone	ULS	1.50	1.25	1.25			
		SLS	1.20	1.00	1.00			
6.3	HA with HB or HB alone	ULS	1.30	1.10	1.10			
		SLS	1.10	1.00	1.00			

* fl shall be increased to at least 1.10 and 1.20 for steel and concrete respectively to compensate for inaccuracies when dead loads are not accurately assessed.

+ fl may be reduced to 1.2 and 1.0 for the ULS and SLS respectively subject to approval of the appropriate authority.

++ This is the only secondary live load to be considered for foot cycle track load bridges.

Note. For loads arising from creep and shrinkage, or from welding and lack of fit, see page 3, 4 and 5 of this standard.

ULS: ultimate limit state, SLS: serviceability limit state

Table 5.2.8. (2) Loads Combinations with Appropriate γ fl

Clause No	Load	Limit State		γ fl for Load Combinations				
				1	2	3	4	5
6.5	Centrifugal load and associated primary live load	ULS	Each secondary live load shall be considered separately together with the other combination 4 loads as appropriate				1.50	
		SLS					1.00	
6.6	Longitudinal load : HA and associated primary live load	ULS					1.25	
		SLS					1.00	
	HB and associated primary live load	ULS					1.10	
		SLS					1.00	
6.7	Accident skidding load and associated primary live load	ULS					1.25	
		SLS					1.00	
6.8	Vehicle collision load with bridge parapets and associated primary live load	ULS					1.25	
		SLS					1.00	
6.9	Vehicle collision load with bridge supports ++	ULS				1.25		
		SLS				1.00		
7	Foot/cycle track bridges : live load and parapet load	ULS	1.50	1.25	1.25	1.25		
		SLS	1.00	1.00	1.00	1.00		
8	Railway bridges : type RU and RL primary and secondary live loading	ULS	1.40	1.20	1.20			
		SLS	1.10	1.00	1.00			

*fl shall be increased to at least 1.10 and 1.20 for steel and concrete respectively to compensate for inaccuracies when dead loads are not accurately assessed.

+ fl may be reduced to 1.2 and 1.0 for ULS and SLS respectively subject to approval of the appropriate authority .

++ This is the only secondary live load to be considered for foot cycle track load bridges.

Note. For loads arising from creep and shrinkage, or from welding and lack of fit, see page3, 4 and 5 of this standard.

ULS: ultimate limit state, SLS: serviceability limit state

(5) Partial Load Factor (γ f3)

γ f3 = 1.00 (serviceability limit state)

1.10 (ultimate limit state)

(6) Material Factor (γ m)

Table 5.2.9. Material Coefficient

Material	Type of Stress	Serviceability Limit		Ultimate Limit
		RC	PC	RC, PC
Concrete	Triangular or near-triangular compressive stress distribution	1.00	1.25	1.50
	Uniform or near-uniform compressive stress distribution	1.33	1.67	1.50
	Tension	Not applicable	1.25 pre-tensioned 1.55 post-tensioned	1.50
Reinforcement	Compression tension	1.00	Not applicable	1.15
PC Strand	Tension	Not applicable	Not required (not to be checked)	1.15

(7) Stress Limitation for the serviceability limit state

Table 5.2.10. Stress Limitation

Material	Type of Stress	Serviceability Limit		At Transfer
		RC	PC	PC
Concrete	Triangular or near-triangular compressive stress distribution	0.50 fcu	0.40 fcu	0.50 fci but \leq 0.40 fcu
	Uniform or near-uniform compressive stress distribution	0.38 fcu	0.30 fcu	0.40 fci but \leq 0.30 fcu
	Tension	-	0.45 fcu ^{0.5} pre-tensioned 0.36 fcu ^{0.5} post-tensioned	1.0
Reinforce- Ment	Compression tension	0.75 fy	Not applicable	-
PC Strand	Tension	Not applicable	Not required (not to be checked)	0.75 fpy pre-tensioned 0.70 fpy post-tensioned

Note: fcu is the characteristic strength of concrete at serviceability limit state (N/mm²)
fci is the characteristic strength of concrete at transfer (N/mm²)
fy is the characteristic strength of reinforcement (N/mm²)
fpy the characteristic strength of PC strand (N/mm²)

(8) Crack Width

The width of cracks must be checked for serviceability limit states. Since the OCH Project is located in an inland area unaffected by seawater, design crack width must be equal to and or less than 0.25 mm (severe state).

(9) Load Distribution for PC-I Girder

The design of a PC-I girder requires consideration of load distribution by cross beams. The Guyon-Massonnet theory, or grid calculation with a computer program, shall be applied to calculate load distribution.

Table 5.2.11. Design Crack Width

Environment	Examples	Design Crack Width
<u>Extreme</u> Concrete surfaces exposed to: corrosive action of sea water or water with a pH<=4.5	Marine structures Structures in contact with moorland water	0.10 mm
<u>Very severe</u> Concrete surfaces directly affected by: de-icing salts Seawater spray	Walls and structure supports adjacent to the carriageway Parapet edge beams Concrete adjacent to the sea	0.15 mm
<u>Severe</u> Concrete surfaces exposed to: driving rain alternate wetting and drying	Walls and structure supports remote to the carriageway Bridge deck soffits Buried parts of structures	0.25 mm
<u>Moderate</u> Concrete surfaces above ground level and fully sheltered against all of the following: rain de-icing salts sea water spray Concrete surfaces permanently saturated by water with a pH>4.5	Surface protected by bridge deck water-proofing or by permanent formwork Interior surface of pedestrian subways, voided superstructures or cellular abutments Concrete permanently under water	0.25 mm

(10) Calculation of Pre-stressing Force

1) Loss of Pre-stress due to Friction

$$P_x = P_i \times e^{-(\mu \alpha + \lambda x)}$$

Where,

P_x: tension force of PC Strand at Design Section

P_i: Jacking force

μ: Friction coefficient per 1 radian angle change

α: Angle change (radian)

λ: Friction coefficient per 1 m long

x: Distance between jacking point to design section (m)

Table 5.2.12. Friction Coefficient

	λ	μ
PC Wire	0.004	0.30
PC Strand	0.004	0.30
PC Bar	0.003	0.30

2) Loss of Pre-stress due to Slip

Loss of pre-stress due to slip ΔP is calculated as below.

i In case of no friction between sheath & strand

$$\Delta P = E_p \times A_p \times \Delta l / l$$

Where,

l: Length of PC strand

Δl : Slip

A_p : Area of PC strand

E_p : Young's Modulus of PC strand

ii In case of friction between Sheath & strand

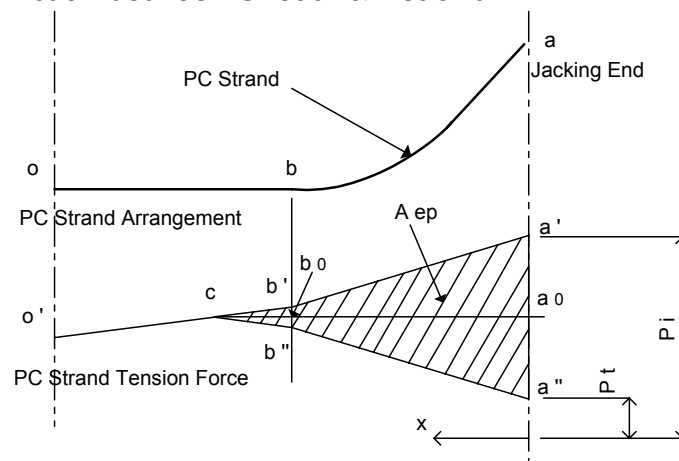


Fig. 5.2.7 Loss of Pre-stress due to Slip

$$\Delta l = A_{ep} / (A_p \times E_p)$$

Where,

A_{ep} : area as shown in **Fig. 5.2.7**.

3) Loss of Pre-stress due to Elastic Deformation

Loss of pre-stress due to elastic deformation in post-tensioned method $\Delta \sigma_p$ is calculated as shown below.

$$\Delta \sigma_p = (1/2) \times n \times \sigma_{cpg} \times (N-1) / N$$

Where, n: Ratio of Young's Modulus $n = E_s / E_c$

E_p : Young's Modulus for PC strand

E_c : Young's Modulus for concrete at transfer

σ_{cpg} : Concrete stress immediately after pre-stressing at centroids of PC strands

N : Number of PC strands (number of jackings)

4) Loss of Pre-stress due to Creep and Shrinkage

Loss of pre-stress due to creep and shrinkage $\Delta \sigma_{p\phi}$ is calculated as shown below.

$$\Delta \sigma_{p\phi} = \frac{n \times \phi \times \sigma_{cp} + E_p \times \epsilon_s}{1 + n \times \sigma_{cpt} / \sigma_{pt} \times (1 + \phi / 2)}$$

Where,

ϕ : Creep Coefficient (2.6)

ϵ_s : Degree of Dry Shrinkage (200×10^{-6})

n: Ratio of Young's Modulus $n = E_s / E_c$

σ_{cp} : Concrete stress due to permanent load (dead load and pre-stressing force immediately after pre-stressing) at centroids of PC strands

σ_{pt} : Tensile stress of PC strands immediately after pre-stressing

σ_{cpt} : Concrete stress immediately after pre-stressing at the centroids of PC strands

5) Loss of Pre-stress due to Relaxation

$$\Delta \sigma_{pr} = \gamma \times \sigma_{pt}$$

Where,

σ_{pt} : Tensile stress of PC strands immediately after pre-stressing

γ : Ratio of relaxation (0.025)

(11) Design of Members

1) Serviceability Limit State

The following two points are to be checked for serviceability limit state:

- design crack width
- stress limitation

2) Ultimate Limit State

i Resistant moment

For flexure members, bending moments shall be such that:

$$M \leq M_r$$

Where, M_r : ultimate resistant moment

ii Resistant shear force

For shear force, shear reinforcement shall be provided in accordance with Clause 6.3.4.4 of BS 5400: Part. 4. Minimum shear reinforcement should be provided in the form of links such that:

$$(A_{sv} / s_v) \times (0.87 \times f_{yu} / b) = 0.40 \text{ N/mm}^2$$

Where,

f_{yu} : characteristic strength of link reinforcement but not greater than 460 kN/mm²

A_{sv} : total cross sectional area of the leg of the links

s_v : link spacing along the length of a beam

When shear stress (or v) due to ultimate load exceeds v_c , the shear reinforcement should be such that:

$$A_{sv} \geq b \times s_v \times (v + 0.4 - v_c) / (0.87 \times f_{yu})$$

Where links are used, the area of the longitudinal steel in the tensile zone should be such that:

$$A_s \geq V / (2 \times 0.87 \times f_y)$$

Where,

A_s : effectively anchored longitudinal tensile reinforcement and pre-stressing tendons (excluding de-bonded tendons) additional to that required at the ultimate limit state for other purposes

f_y : characteristic strength of longitudinal reinforcement and pre-stressing tendons not greater than 460 kN/mm^2

(12) Stability Analysis of Pile Foundation

The methodology for stability analysis for pile foundations is not specified in BS 5400 and BS 8004. Therefore, the displacement method commonly used in Japan is adopted. With this method, pile reaction and displacement can be calculated. Note that the calculation of pile stability assumes the following:

- Axial compressive force borne by piles does not exceed allowable axial compressive bearing capacity of pile.
- Axial pull-out force borne by pile does not exceed allowable pull-out capacity of pile.
- Horizontal displacement borne by piles does not exceed 15 mm to avoid plasticity of ground.

1) Allowable bearing capacity of pile

The allowable bearing capacity of a pile is calculated in accordance with BS 8004.

i Ultimate pile bearing capacity

$$R_u = f \times A_s + A_b \times q$$

Where,

R_u : ultimate bearing capacity (kN)

A_s : surface of pile shaft (m^2)

A_b : area of pile tip (m^2)

f : average skin friction or adhesion per unit area of shaft at the condition of full mobilization of frictional resistance (kN)

q : ultimate value of resistance per unit area of pile tip due to shearing stress of soil (kN/m^2)

$$f \times A_s = \sum f_i \times U \times l_i$$

Where,

f_i : skin friction (kN/m^2)

Sand $f_i = 5 \times N$ ($f_i \leq 200$)

Clay $f_i = 10 \times N$ ($f_i \leq 150$)

Skin friction of soft soil ($N \leq 2$) is to be neglected.

N : blowcount of SPT

ii Allowable pile bearing capacity

$$R_a = 1/n \times (R_u - W_s) + W_s - W$$

Where,

R_a : allowable bearing capacity of a pile (kN)

n : safety factor (=2.5)

A safety factor of 2.5 is normally used for foundation verification for standard conditions; therefore, n = 2.5 is used for this design (PILE DESIGN and CONSTRUCTION PRACTICE, M.J. Tomlinson)

W_s : effective weight of soil to be replaced with a pile

W : effective weight of a pile in the ground

iii Allowable pile uplift capacity

$$P_a = 1/n \times P_u$$

Where,

P_a : allowable uplift capacity of a pile (kN)

n : safety factor (=6)

A safety factor of 6 is normally used for foundation verification for standard conditions; therefore, n = 6 is used for this design (PILE DESIGN and CONSTRUCTION PRACTICE, M.J. Tomlinson)

P_u : ultimate uplifting resistance of a pile

$$P_u = f \times A_s$$

2) Allowable Horizontal Displacement

Horizontal displacement at the top of a pile shall be checked in order to avoid adverse effects on superstructure and ground plasticity in front of a pile. Allowable horizontal displacement shall generally be less than 1 % of the pile diameter or 15mm, whichever is bigger in order to ensure against lateral forces.

5.3 Bridge Type Selection

5.3.1. Selection Criteria

Bridge type in the basic design shall be selected applying the criteria described below.

Criteria-1 Basic Concept of Feasibility Study

1. In principle, the selection of concrete bridges will be given priority over steel bridges to promote easy procurement and maintenance.
2. Based on bridge span, the most economical structure will be selected.
3. Use composite girders with slab concrete to promote an efficient bridge structure.
4. Use a continuous bridge road surface to reduce the no. of expansion joints and cost.

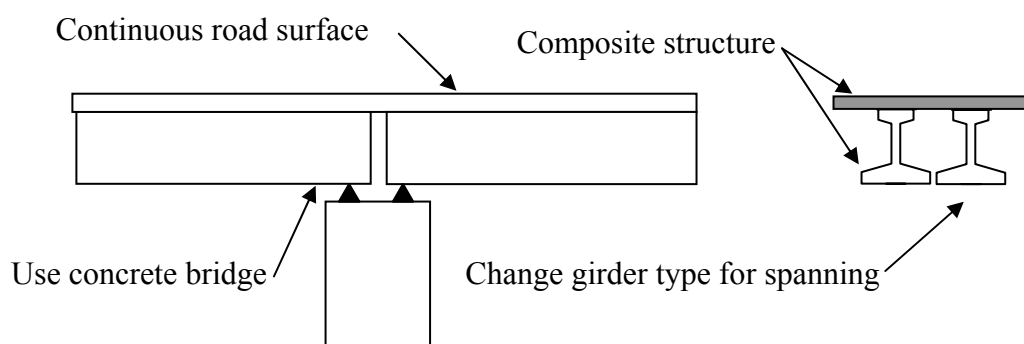
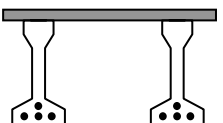
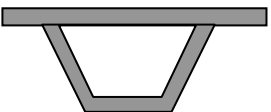


Fig. 5.3.1 Concept of Bridge Type in Feasibility Study

Criteria-2 Detail design of Southern Highway Project

In the Southern Highway project, two bridge types were selected (see **Table 5.3.1**).

Table 5.3.1 Bridge Types in Southern Highway

PC-I Composite Girder (short-/middle-span bridge)	PC-Box Continuous Girder (long-span bridge)
	

5.3.2. Superstructure

The bridge types selected for the OCH Project mainly comprise 2 types: the PC-I girder and PC-Box girder (see **Table.5.3.2**). A list summarizing OCH bridges is given in **Table.5.3.3**.

Table 5.3.2 Proposed Bridge Types for OCH

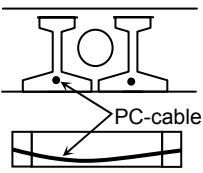
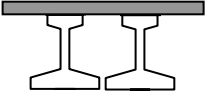
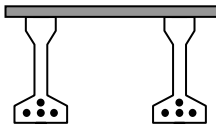


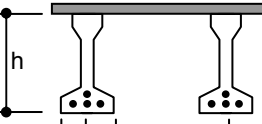


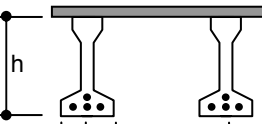

Sri Lanka Construction Experience	<p>Ragama Flyover Standard Beam Pre-cast, Pre-tension (+ Post-tension)</p>  <p>3.5m + 16m + 3.5m Modified on site to extend the length L = 19 m</p>	<p>Baseline Bridge (Gampaha Flyover) Composite Pre-cast, Pre-tension</p>  <p>Beam length to be fabricated and extended L = 23 m (25 m)</p>	<p>Getambe Bridge Composite Pre-cast Post-tension</p>  <p>Constructed firstly by foreign contractor and next by local L = 28.2 m</p>	<p>Friendship Bridge PC-Box Girder Cast-in-site Post-tension</p>  <p>Constructed by foreign contractor L = 5 @ 32.5 m</p>																								
<p>OCH Project Basic Design</p>	<p>Small/Middle Bridge Pre-cast</p>  <p>(Exp.J)</p> <p>Slab and girder to be connected (or Exp.J) (skew angle $\geq 80^\circ$)</p>	<p>(Composite PC-I girder) Post-tension</p>  <table border="1" data-bbox="949 1064 1189 1176"> <thead> <tr> <th>L</th> <th>h</th> <th>b</th> <th>B</th> </tr> </thead> <tbody> <tr> <td>35</td> <td>2000</td> <td>900</td> <td>2.03</td> </tr> <tr> <td>25</td> <td>1600</td> <td>700</td> <td>2.03</td> </tr> <tr> <td>22</td> <td>1400</td> <td>650</td> <td>2.10</td> </tr> </tbody> </table> <p>(All Br. designed HA /HB)</p> <p>L \leq 35 m</p>		L	h	b	B	35	2000	900	2.03	25	1600	700	2.03	22	1400	650	2.10	<p>Long Bridge (PC-Box Girder) Cast-in-site Post-tension</p>  <p>Simple/Continuous girder L > 35 m</p>								
L	h	b	B																									
35	2000	900	2.03																									
25	1600	700	2.03																									
22	1400	650	2.10																									
<p>Southern Hwy. Detail Design</p>	<p>Small/Middle Bridge Pre-cast</p>  <p>Slab & girder to be connected</p>	<p>(Composite PC-I girder) Post-tension</p>  <table border="1" data-bbox="901 1400 1189 1568"> <thead> <tr> <th>L</th> <th>h</th> <th>b</th> <th>B</th> </tr> </thead> <tbody> <tr> <td>35</td> <td>1900</td> <td>1100</td> <td>2.00</td> </tr> <tr> <td>30</td> <td>1950</td> <td>800</td> <td>2.40</td> </tr> <tr> <td>27</td> <td>1575</td> <td>710</td> <td>2.00</td> </tr> <tr> <td>25</td> <td>1300</td> <td>700</td> <td>2.00</td> </tr> <tr> <td>21</td> <td>1100</td> <td>600</td> <td>2.00</td> </tr> </tbody> </table> <p>L \leq 35 m</p>		L	h	b	B	35	1900	1100	2.00	30	1950	800	2.40	27	1575	710	2.00	25	1300	700	2.00	21	1100	600	2.00	<p>Long Bridge (PC-Box Girder) Cast-in-site Post-tension</p>  <p>Continuous girder L = 45 + 70 + 45 m</p>
L	h	b	B																									
35	1900	1100	2.00																									
30	1950	800	2.40																									
27	1575	710	2.00																									
25	1300	700	2.00																									
21	1100	600	2.00																									

Table 5.3.3 Bridge List

Category	ID	Cross Items	Class	Bridge Length	Span Arrangement	1 st stage total bridge	kew Ang	Bridge Type			
								Type	Span	Slab	
Highway Bridge	H1	CKE	A	85.0	3@ 25 + 25 + 35	4 lane	80-00-00	PC-I	simple	Exp. J	
	H2	CKE Ramp Way	"	25.0	1@	4 lane	90-00-00	PC-I	simple	Exp. J	
	H3	A3	"	38.0	1@	6 lane	90-00-00	PC-Box	simple	Exp. J	
	H4	Railway	"	25.0	1@	4 lane	67-02-08	PC-I	simple	Exp. J	
	H5	B168	"	33.0	1@	4 lane	90-00-00	PC-I	simple	Exp. J	
	H6	A1	"	25.0	1@	4 lane	90-00-00	PC-I	simple	Exp. J	
	H7	Bypass of A1	"	46.0	1@	6 lane	90-00-00	PC-Box	simple	Exp. J	
	H8	channel before Kelani	"	33.0	1@	4 lane	90-00-00	PC-I	simple	Exp. J	
	H9	Kelani	"	206.0	6@ 33 + 4@35 + 33	4 lane	80-00-00	PC-I	3 span continuous		
	H10	A110	"	35.0	1@	4 lane	80-00-00	PC-I	simple	Exp. J	
	H10B	Drainage	"	25.0	1@	4 lane	90-00-00	PC-I	simple	Exp. J	
	H11	B240	"	35.0	1@	4 lane	90-00-00	PC-I	simple	Exp. J	
	H12	Railway	"	25.0	1@	4 lane	85-00-00	PC-I	simple	Exp. J	
	H13	IC of A4	"	26.0	1@	4 lane	90-00-00	PC-I	simple	Exp. J	
H14	A4	"	93.0 / 80.0	1@	33.0+60.0 / 20.0+60.0	lane / 6 lar	90-00-00	PC-I, PC-Box	simple	Exp. J	
Ramp Way Bridge	CKE	R1	-	A	37.0	1@	14.50	90-00-00	PC-Box	simple	Exp. J
	A1 / Ramp3	R2	-	"	48.0	1@	14.50	90-00-00	PC-Box	simple	Exp. J
	A1 / Ramp7	R3	-	"	45.0	1@	14.50	90-00-00	PC-Box	simple	Exp. J
	Kelani / Up	R4	-	"	33.0	1@	7.00	90-00-00	PC-I	simple	Exp. J
	Kelani / Down	R5	-	"	33.0	1@	7.00	90-00-00	PC-I	simple	Exp. J
	A4 / Ramp5	R6	-	"	51.0	1@	14.50	90-00-00	PC-Box	simple	Exp. J
	A4 Ramp-1	R7	-	"	26.0	1@	7.00	85-36-40	PC-I	simple	Exp. J
Overpass Bridge	O1	Local Road	D	42.00	2@ 2@21.0	6.50	90-00-00	PC-I	2 span continuous		
	O2	"	D	42.00	2@ 2@21.0	6.50	68-41-43	PC-I	simple	Exp. J	
	O3	"	D	42.00	2@ 2@21.0	6.50	78-03-50	PC-I	simple	Exp. J	
	O4	"	C	42.00	2@ 2@21.0	10.0	90-00-00	PC-I	2 span continuous		
	O5	"	C	74.00	4@ 15.0+2@21.0+17.0	10.0	90-00-00	PC-I, Pre-tension Slab	2 span continuous / simple for pre-tension		
	O6	"	C	42.00	2@ 2@21.0	10.0	90-00-00	PC-I	2 span continuous		
	O7	"	B3	42.00	2@ 2@21.0	13.0	90-00-00	PC-I	2 span continuous		
	O8	"	C	42.00	2@ 2@21.0	10.0	90-00-00	PC-I	2 span continuous		
	O9	"	B3	42.00	2@ 2@21.0	13.0	62-00-00	PC-I	simple	Exp. J	
	O10	"	B3	42.00	2@ 2@21.0	13.0	72-48-56	PC-I	simple	Exp. J	
	O11	"	B3	42.00	2@ 2@21.0	13.0	70-12-30	PC-I	simple	Exp. J	
	O12	"	C	42.00	2@ 2@21.0	10.0	90-00-00	PC-I	2 span continuous		
	O13	"	B2	42.00	2@ 2@21.0	21.2	85-00-00	PC-I	simple	Exp. J	
	O13B	"	D	42.00	2@ 2@21.0	6.5	90-00-00	PC-I	2 span continuous		
	O14	"	D	42.00	2@ 2@21.0	6.5	90-00-00	PC-I	2 span continuous		
	O15	"	E	42.00	2@ 2@21.0	5.9	90-00-00	PC-I	2 span continuous		
	O16	"	C	42.00	2@ 2@21.0	10.0	90-00-00	PC-I	2 span continuous		
O17	"	C	42.00	2@ 2@21.0	10.0	90-00-00	PC-I	2 span continuous			

5.3.3. Substructure and Foundation

(1) Abutment

In the feasibility study, after a comparison of abutment types, the reverse-T type was selected as the most suitable type for reasons of economy, simplicity and ease of construction. In the basic design also, the Reverse-T should be selected as the standard abutment (see **Table 5.3.4**).

Table 5.3.4 Comparison of Abutment Types


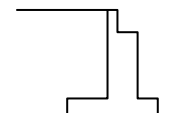
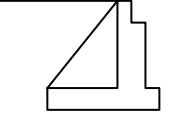
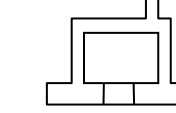
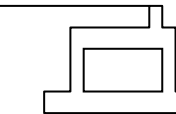
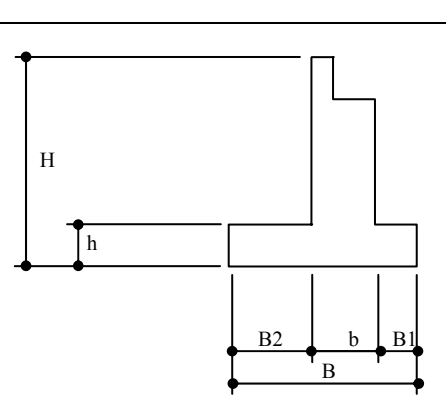
	Tape and Shape	Applicable Height (m)	Characteristic
Gravity-type		$H \leq 5$	- Simple structure - Easy construction - Heavy
Reversed T type		$5 < H < 14$	- Economic - Easy construction
Counter-fortified Buttressed type		$10 \leq H$	- Economic - Intricate construction - Difficulty in back filling
Rigid-framed type		$10 \leq H \leq 15$	- Complicate structure - Expensive
Box type		$15 \leq H$	- Large-scale structure - Complicated structure - Expensive

Table 5.3.5 General Formation of Abutment (m)

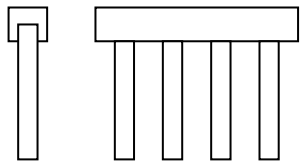
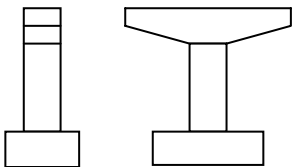
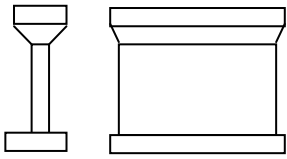
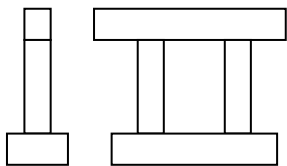
	H	B	b	H	B1	B2
	5.0	4.0	0.8	1.0	1.0	2.2
	6.0	4.5	0.9	1.1	1.2	2.4
	7.0	5.0	1.0	1.2	1.3	2.7
	8.0	6.0	1.1	1.3	1.6	3.3
	9.0	6.5	1.2	1.4	1.7	3.6
	10.0	7.0	1.3	1.5	1.8	3.9
	11.0	8.0	1.4	1.6	2.0	4.6
	12.0	9.0	1.5	1.7	2.3	5.2

(2) Pier

Piers were compared in the feasibility study and the most appropriate type chosen based on site conditions and acting forces. In the basic design, wall-type piers are chosen as the most suitable for piers both on the ground and in the river for the following reasons.

- On the ground Almost all the piers are located on the median of the OCH and pier thickness should therefore be minimized.
- In the river
(Kelani) To avoid interference with water flows, the pier shape is important and pier thickness should therefore be minimized.

Table 5.3.6 Comparison of Pier Types

Type	Figure	Characteristics
Pile bent type pier		<ul style="list-style-type: none"> - Simple structure with capped pile head - Weak horizontal force and flexible structure - Unsuitable for piers in river where scouring is expected - For light-weight superstructure - Lowest cost
Column type pier		<ul style="list-style-type: none"> - General construction - Diameter of column is big - Blocks large area of river crossing
Wall type Pier		<ul style="list-style-type: none"> - General construction - Shape appropriate the direction of the river flow - Pier thickness can be minimized
Rigid framed pier		<ul style="list-style-type: none"> - Generally used for wide super-structure - Unsuitable for piers in rivers

General formation for initial design is here.

- mainly for piers on the ground
- changeable by the calculation

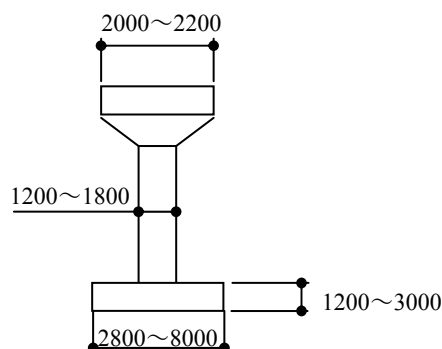


Fig. 5.3.2 General Formation of Pier

(3) Foundation

Foundation type may vary to the site conditions but spread footing and pile foundation should be majority in this OCH project. In the pile foundation, Cast-in-site RC pile should be selected by many advantages and applied to the site respectively by the pile length.

Table 5.3.7 Comparison of Foundation Types

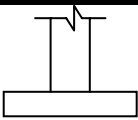
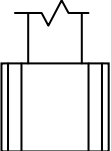
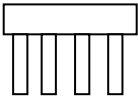
Depth of Soil Stratum	Foundation Type	Remarks
3.0 m to 4.0 m	Spread Footing 	- Open cut or cofferdam is required for excavation to the bearing stratum
4.0 m to 6.0 m	Caisson Foundation (Cylinder Well, side-by-side caissons) 	- Filled cofferdam is required for piers in rivers. Dewatering should be considered - If bearing stratum is not flat, special treatment is required to set the caisson at level
Deeper than 6.0 m	Pile Foundation 	- Pile type and diameter should be selected based on on-site conditions

Table 5.3.8 Comparison of Pile Types

Pile Type	Applicable Length, Dimension	Procurement of Material	Characteristics
RC square pile	5m to 10m □ 0.35m, □ 0.45m	Available in Sri Lanka	- Unsuitable for changes in bearing stratum - Applicable to small bearing capacity - Joining is difficult and limited in length - Common for small bridges in Sri Lanka - Economical construction cost
Cast-in-site RC pile	10m to 60m φ 0.6m to φ 1.5m	Available in Sri Lanka	- Suitable for changes in bearing stratum - Applicable for large bearing forces - No joining necessary and applied for long piles - Common for large bridges in Sri Lanka - Very economical
Steel pile	5m to 60m φ 0.3m to φ 1.5m	Imported	- Applicable for large bearing forces - Joining to long piles is possible - Uneconomical
PC pile	5m to 25m φ 0.3m to φ 1.0m	Imported	- Applicable for small bearing capacity - Uneconomical

5.3.4. PC-I Girder Arrangement

(1) Prefabrication

Prefabrication of PC-I girders shall be carried out, especially when many bridges are constructed, because of the following advantages:

- Fabrication cost can be minimized via repetitious work
- Minimization of construction term via reduction in on-site work
- Increase in safety via reduction in high-positioning site works

Examining the past construction experience of Sri Lanka, many of the bridge parts in the OCH Project can be prefabricated. Prefabrication is very popular in other countries, especially when many PC-I girder bridges are to be constructed.

Past Construction Experience: Only pre-cast girders were prefabricated

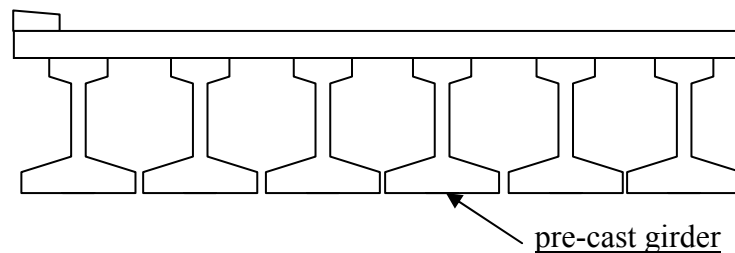


Fig. 5.3.3 Past Construction Experience

Proposed Construction Method: As many bridge parts as possible are prefabricated.

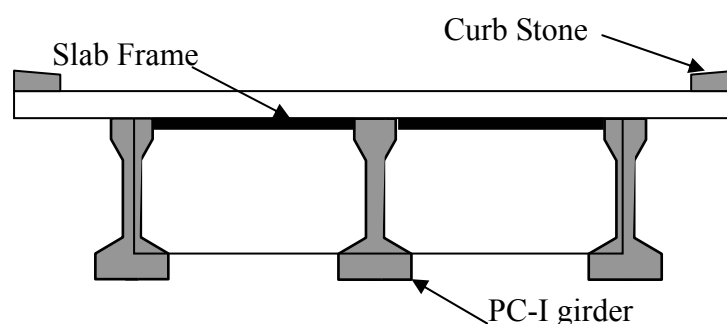
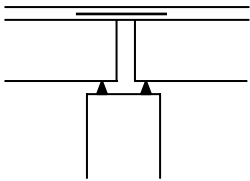
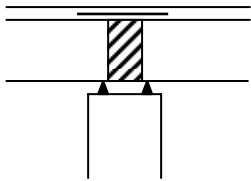
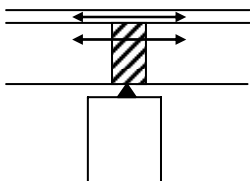


Fig. 5.3.4 Proposed Construction Method

(2) Connection of Slabs

Slabs should be connected as much as possible in order to eliminate expansion joints, reduce cost, and increase slab durability. As shown in **Table 5.3.9**, there are basically three connection methods. After a comparison, the “RC Connection” method has been selected.

Table 5.3.9 Comparison of Slab Connection Method

Item	Slab Connection	RC Connection	PC Connection
General View	by steel reinforcement 	by steel reinforcement 	by PC cable 
Continuity of Slab Girder	Continuous Separated	Continuous Continuous	Continuous Continuous
Bearing	Two	Two	One
Structural Behavior	Acts as two separate beams	Depends on the spring effect of the bearings	Clearly a continuous beam
Construction Control	Easier	Easy	Need to replace bearing
Construction Cost	More economical	Economical	Expensive
Maintenance Cost	More	Less	Least
Application to Composite structure	Difficult application	Easily applicable	Easily applicable
Judgment	2	1	3
Reason	- Slab less durable - Needs more maintenance - Not popular	- Very popular - Increases slab durability - Easy to construct	- Difficult construction - Initial cost expensive - Needs much pre-stressing

Based on Japanese standards, the RC Connection can be applied under the following conditions:

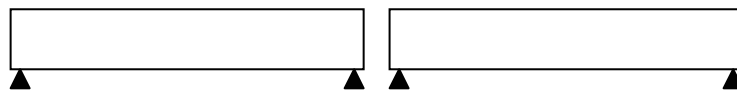
- Span length shall be equal or less than 35 m
- Each span shall be almost equal in length
- The skew angle of bridges shall not be less than 80 degrees

If the above conditions cannot be satisfied, both slabs and girders are separated and expansion joints are needed. The construction steps for this are summarized in **Fig. 5.3.5**.

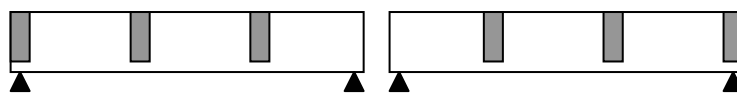
Step-1: Pre-cast PC-I girder with post-tensioning



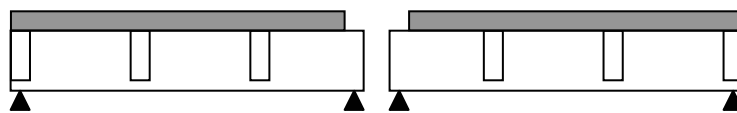
Step-2: Launch PC-I girder on the two bearings



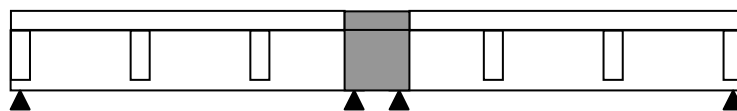
Step-3: Erect both intermediate and end diaphragms



Step-4: Pour intermediate slab



Step-5: Pour connection diaphragm and slab



Step-6: Induce pre-stressing in connection diaphragm

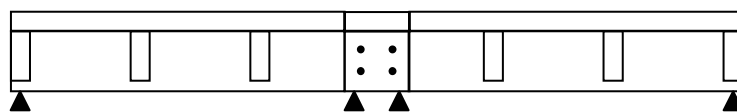


Fig. 5.3.5 Construction Steps for RC Connection

5.4 Kelani River Bridge

5.4.1. General Conditions

(1) Bridge Length

By the Hydrological study of Kelani River, the difference of the bridge length cannot affect the flood HWL. Thus the bridge length shall be decided about 200 m including the next bridge over the local road B214. This is a reasonable arrangement of bridge/embankment and was also proposed in the feasibility study.

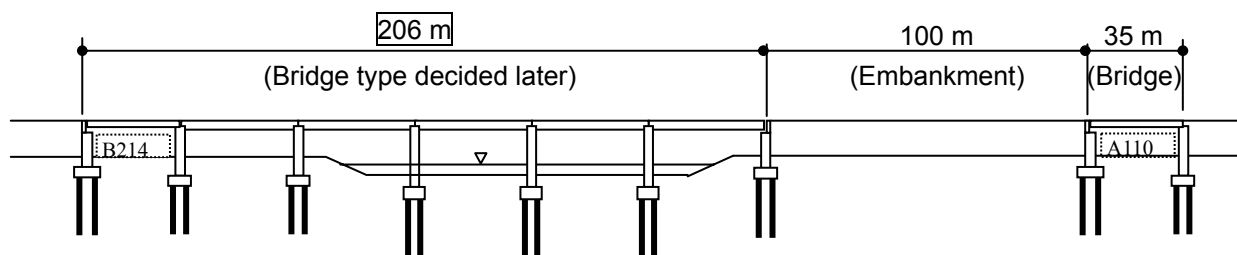


Fig. 5.4.1 Kelani River Bridge

(2) Clearance of the Bridge

Vertical Clearance

Elevation of Kelani Bridge shall be checked to satisfy these requirements.

- At the road B214 (Classification B) 5.10 m from the local road
- Navigation clearance (Southern Hwy.) 4.75 m (= 15 ft) from M.S.L.
- Free board on the river 1.20 m from H.F.L.

Minimum Bridge Span

Bridge span shall be decided to satisfy these minimum span requirements.

- Navigation clearance (Southern Hwy.) 6.0 m wide
- Flood flow (Japanese Standard) 35.0 m

(3) Road Width Widening

Road width widening on the Kelani river bridge shall be made inside same as the widening in the road embankment, so that the road center and IC alignment need not be changed and the construction cost can be minimized.

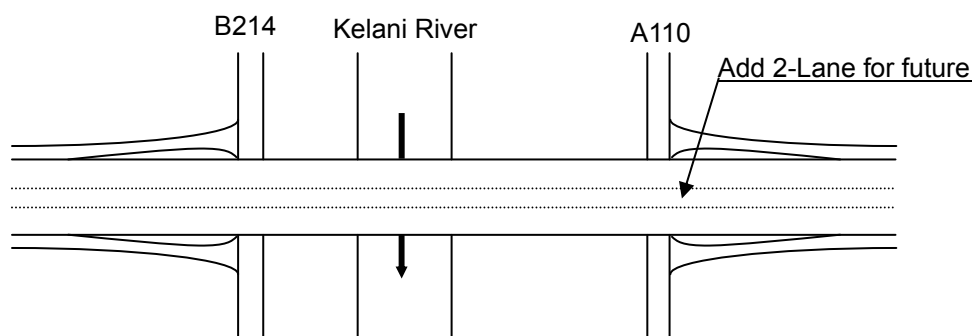


Fig. 5.4.2 Road Alignment

(4) Structures

Superstructures

- Construct as a minimum width in the 1st stage if possible
- Include some steel bridge types in the comparison

Substructures

- Construct as a full width in the 1st stage because of the difficulty of additional construction in the 2nd stage
- Select wall type piers to avoid interference of river flow

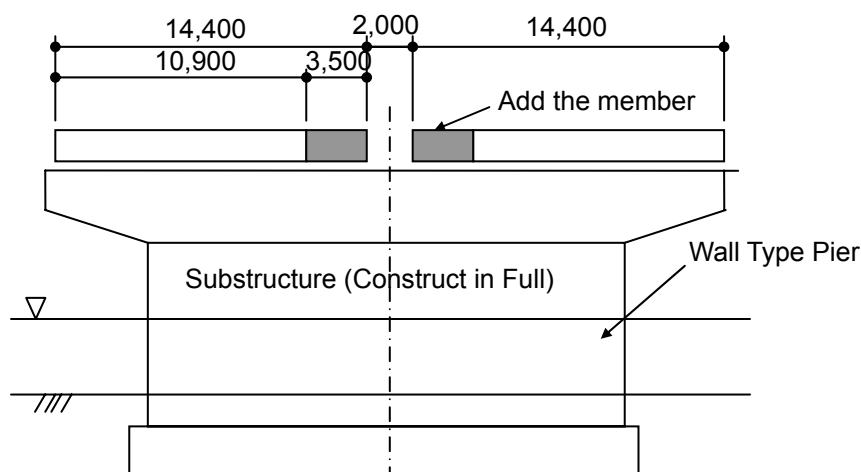


Fig. 5.4.3 General Image of Kelani Bridge

5.4.2. Comparison of Bridge Type

Four types of bridge below shall be compared, evaluated with many items and decided the best alternative in **Table 5.4.1.** and **Table 5.4.2.** for cost estimation.

Alternative -1 ; PC-I Girder Bridge

Alternative -2 ; PC-Box Bridge + PC-I Girder Bridge

Alternative -3 ; Steel Truss Bridge + PC-I Girder Bridge

Alternative -4 ; Steel Arch Bridge + PC-I Girder Bridge

Table 5.4.1. Comparison of Bridge Type for Kelani River

General View		Construction Cost	Construction Difficulty	Durability / Maintenance	Others
		Point = 40 (1st) + 10 (2nd) = 50 1st stage Ratio Point 1.00 Point 40 Poi/Rat 40.0 2nd stage Ratio Point 3.33 Point 10 Poi/Rat 3.0 Total cost Ratio Point 1.00 Point 50 Poi/Rat 50.0	Super-str. Ranking A The girders are very easily erected by the crane and applied those in the river with temporary jety. Sub-str. Ranking C The three piers stand in the middle of the river, a lot of construction works should be needed in the water. Ranking (A), Score = 43 Ranking (C), Score = 20	Durability Ranking C Even if 3 piers in the river were damaged by the flood and moved slightly, girders above are well connected each other and less chance for collapse. Maintenance Ranking B Same image as the bridges in the upper Kelani river and give gentle image to the resident. But no impact for the driver and make them boring while driving. Ranking (B), Score = 12 Ranking (D), Score = 4	Point = 10 Tec-Transfer Ranking D Typical bridge type of PC-I Girder has less impact for technical transfer into Sri Lanka.
		Ratio Point 1.75 Point 40 Poi/Rat 22.9 2nd stage Ratio Point 1.00 Point 10 Poi/Rat 10.0 Total cost Ratio Point 1.48 Point 50 Poi/Rat 33.8 Ranking (C), Score = 33	Super-str. Ranking C Need scaffolding or special erection equipment to support temporarily large weigh of concrete. Sub-str. Ranking B The two piers for the main span stand in the river but positioned near the ground and easily constructed. Ranking (A), Score = 12 Ranking (C), Score = 12	Durability Ranking B Even if 2 piers in the river were damaged by the flood and moved slightly, girder above is continuous and no chance for collapse. Maintenance Ranking A Give a gentle image to the resident even slightly different from the upper stream bridges. But no impact for the driver and make them boring while driving. Ranking (A), Score = 20 Ranking (B), Score = 8	Tec-Transfer Ranking B Majority of mid span concrete bridge transfer is useful.
		Ratio Point 1.28 Point 40 Poi/Rat 31.3 2nd stage Ratio Point 2.94 Point 10 Poi/Rat 3.4 Total cost Ratio Point 1.21 Point 50 Poi/Rat 41.3 Ranking (B), Score = 35	Super-str. Ranking B Need temporary supports in the river if 2 piers in the river were damaged but small scale supports are enough by the light weight of steel girders above have to resist for collapse by the bearings. Sub-str. Ranking B The two piers for the main span stand in the river but positioned near the ground and easily constructed. Ranking (B), Score = 16 Ranking (D), Score = 8	Durability Ranking D Truss bridge is a very typical type of steel bridge and may become good experience in Sri Lanka. Maintenance Ranking C Acting as a monument and give the drivers strong impression. But bridge shape is straight and less comfortable than arch bridge. Ranking (C), Score = 6	Tec-Transfer Ranking C Truss bridge is a very typical type of steel bridge and may become good experience in Sri Lanka.
		Ratio Point 2.01 Point 40 Poi/Rat 19.9 2nd stage Ratio Point 2.56 Point 10 Poi/Rat 3.9 Total cost Ratio Point 1.78 Point 50 Poi/Rat 28.1 Ranking (D), Score = 24	Super-str. Ranking D Need many temporary supports in the river and a tall crane to erect upper member of the arch bridge. Sub-str. Ranking A The two piers for the arch bridge are large scale but easily lot of maintenance works needed on the ground. Ranking (D), Score = 8 Ranking (B), Score = 16	Durability Ranking A Piers have less chance of damage because they exist on the ground, not in the river. Maintenance Ranking C Exposed steel bridge for long spanning may become epoch-making experience for the bridge construction in Sri Lanka. Ranking (A), Score = 10	Tec-Transfer Ranking A Arch steel bridge for long spanning may become epoch-making experience for the bridge construction in Sri Lanka.

Table 5.4.2 Cost Estimation

Alternative	stage	Super/ Sub	Item	Quantity	m2	tf	M¥/unit	M¥	MRs		
Alternative-1 PC-I Girder	1st stage	Superstructure	PC-I	A = 10*200*2	4000		0.150	600	429		
			Substructure	Abut				M = 2 * 38	76	54	
			Pier-G	M = 4 * 22				88			
			Pier-R	M = 6 * 28				168			
	Sum			932	666						
2nd stage	Superstructure	PC-I	A = 3.5*200*2	1400		0.150	210	150			
Total	Sum						1,142	816			
Alternative-2 PC-Box + PC-I	1st stage	Superstructure	PC-I Girder	A = 10*60*2	1200		0.150	180	129		
			PC-Box	A = 13.5*140*2				3780	0.300	1,134	810
			Substructure	Abut				M = 2 * 38	76	54	
			Pier-G	M = 4 * 22				88			
	Pier-R	M = 4 * 38	152								
Sum			1,630	1,164							
2nd stage	Superstructure	PC-I	A = 3.5*60*2	420		0.150	63	45			
Total	Sum						1,693	1,209			
Alternative-3 Steel Truss + PC-I	1st stage	Superstructure	PC-I Girder	A = 10*130*2	2600		0.150	390	279		
			Steel Truss	W = 0.350*10*70*2				490	1.000	490	350
			Substructure	Abut				M = 2 * 38	76	54	
			Pier-G	M = 4 * 22				88			
	Pier-R	M = 4 * 38	152								
Sum			1,196	854							
2nd stage	Superstructure	PC-I	A = 3.5*130*2	910		0.150	137	98			
		Steel Truss	A = 3.5*70*2	490		0.100	49	35			
	Sum						186	133			
Total	Sum						1,382	987			
Alternative-4 Steel Arch + PC-I	1st stage	Superstructure	PC-I Girder	A = 10*60*2	1200		0.150	180	129		
			Steel Arch	W = 0.530*10*140*2				1484	1.000	1,484	1,060
			Substructure	Abut				M = 1 * 38	38	27	
			Pier-G	M = 2 * 22				44			
	Pier-R	M = 2 * 63	126								
Sum			1,872	1,337							
2nd stage	Superstructure	PC-I	A = 3.5*60*2	420		0.150	63	45			
		Steel Arch	A = 3.5*140*2	980		0.100	98	70			
	Sum						161	115			
Total	Sum						2,033	1,452			

Summary of the cost

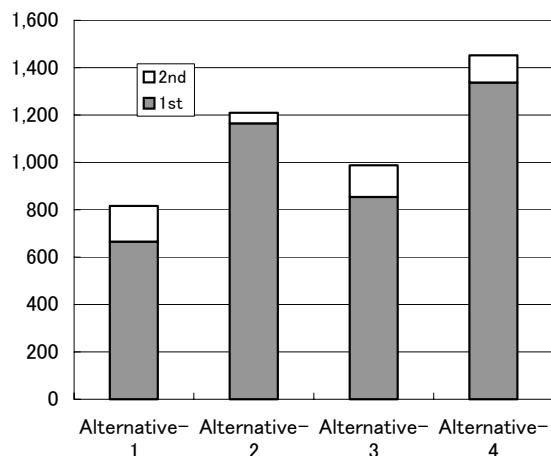
rate of Yen/Rs =

(MRs)

	1st	2nd	Total
Alternative-1	666	150	816
Alternative-2	1,164	45	1,209
Alternative-3	854	133	987
Alternative-4	1,337	115	1,452

Ratio of the cost

	1st	2nd	Total
Alternative-1	1.00	3.33	1.00
Alternative-2	1.75	1.00	1.48
Alternative-3	1.28	2.94	1.21
Alternative-4	2.01	2.56	1.78



5.5 Other Highway Bridges

(1) Bridge List

There are 14 bridges on the OCH highway and 7 ramp way bridges listed here.

Table 5.5.1 List of Highway Bridges

ID	Crossing Item	Length	Span		Bridge Type
H1	CKE	85.0	3@	25 + 25 + 35	PC-I
H2	CKE Ramp	25.0	1@		
H3	A3	38.0	1@		PC-BOX
H4	Railway	25.0	1@		PC-I
H5	B168	33.0	1@		PC-I
H6	A1	25.0	1@		PC-I
H7	Bypass of A1	46.0	1@		PC-BOX
H8	Channel	33.0	1@		PC-I
H9	Kelani	206.0	6@	33 + 4@35 + 33	PC-I
H10	A110	35.0	1@		PC-I
H10B	Drainage	25.0	1@		PC-I
H11	B240	30.0	1@		PC-I
H12	Railway	25.0	1@		PC-I
H13	IC of A4	26.0	1@		PC-I
H14	A4	91.0, 78.0	2@	33.0+58.0, 20.0+58.0	

Table 5.5.2 List of Ramp Way Bridges

ID	Ramp Name	Length	Span	Bridge Type
R1	CKE	37.0	Single Span	PC-I
R2	A1 / Ramp3	48.0	Single Span	PC-BOX
R3	A1 / Ramp7	45.0	Single Span	PC-BOX
R4	Kelani / Up	33.0	Single Span	PC-I
R5	Kelani / Down	33.0	Single Span	PC-I
R5	A4/ Ramp5	51.0	Single Span	PC-BOX
R6	A4/ Ramp5	26.0	Single Span	PC-i

(2) Road Width Widening

Highway bridges shall be widened the width inward for the 2nd operation same as road embankment because road alignment cannot be changed in the short length of the bridges. Basic concept of the road width widening is following.

Superstructure ; Construct as a minimum width as possible in the 1st stage and add the member in the 2nd stage. In case of being difficult for adding member in the 2nd stage, construct with full width in the 1st stage.

Substructure ; Construct full in the 1st stage because of the difficulty of additional construction in the 2nd stage

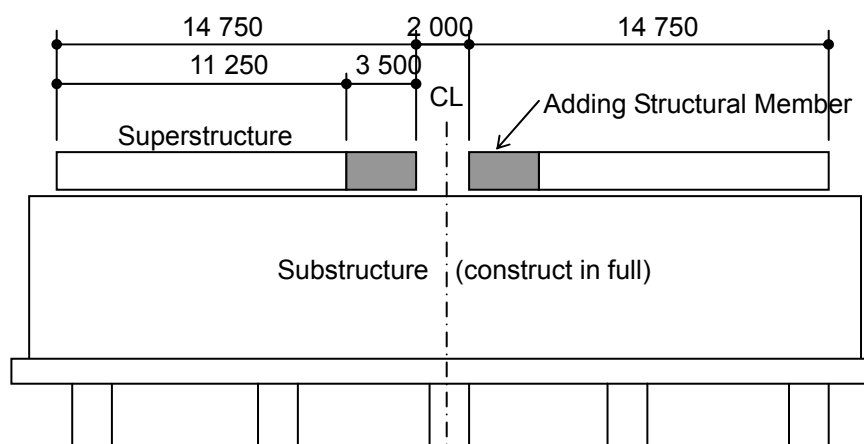


Fig. 5.5.1 Road Width Widening in the Structures

(3) Road Widening of PC-I Girder

PC-I Girder can be added in the 2nd stage as follows. To unite old and new bridges together, special care shall be considered in the design and construction method which are listed below.

- Keep required overlap length of reinforcement steel bar
- Unite old and new girders completely by cross beams
- Adjust the camber difference between old/new girders
- Special consideration on the creep/shrinkage of the new concrete

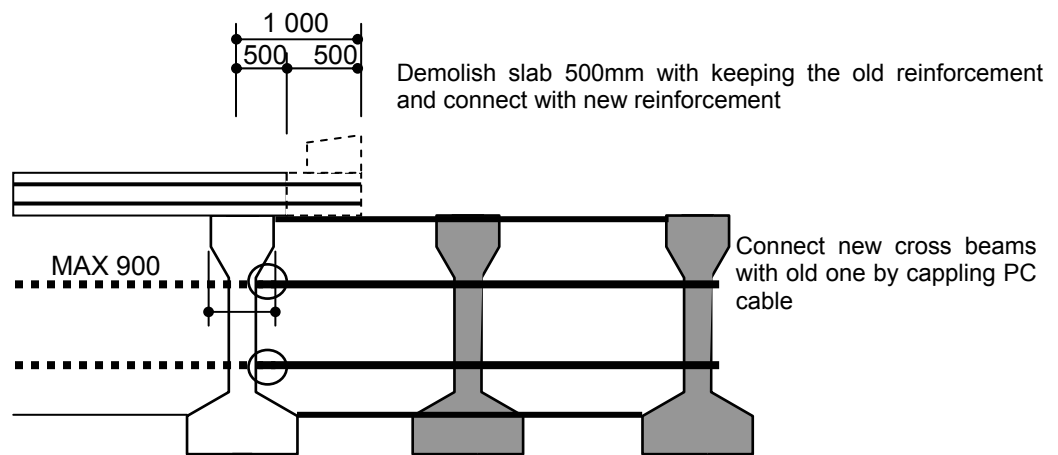
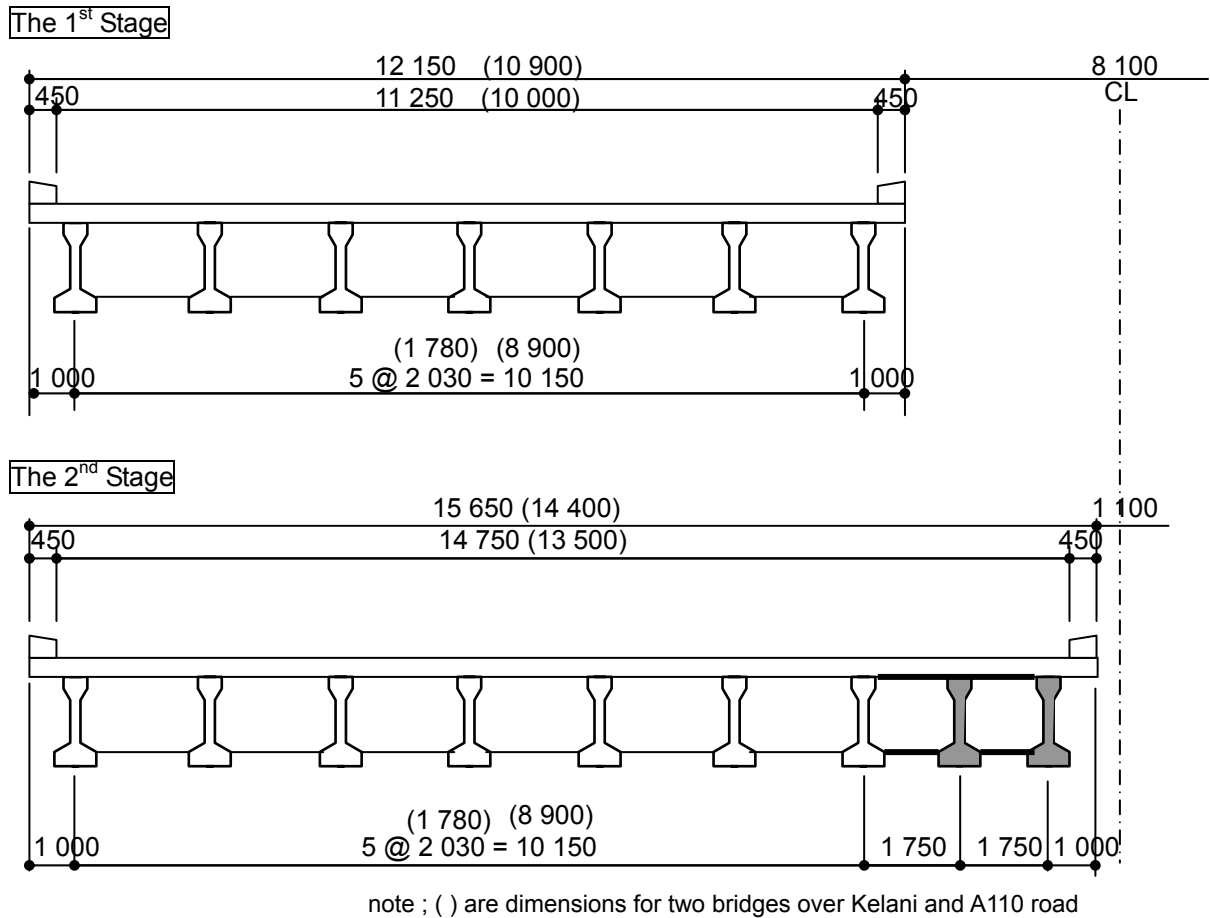


Fig. 5.5.2 Road Width Widening of PC-I Girder

(4) Road Widening of PC-Box Girder

By comparison of both structural types of PC slab and RC slab, the road widening of 3.5m is very difficult for both types. Hence PC-Box Girder shall be initially constructed as the full width.

Table 5.5.3 Comparison of PC and RC Slab

	PC Slab	RC Slab	Remarks
Span in cantilever	Max. 3.0 m	Max. 1.5 m	Japanese Standard
Span in simple/continuous	Max. 6.0 m	Max. 4.0 m	ditto
Concrete strength	Min. 30 kN/mm ²	Min. 21 kN/mm ²	ditto
Future road widening	very difficult for slab/ PC cable	very difficult on the girder	extension of the PC slab is less reliable
Initial construction	full width	full width	

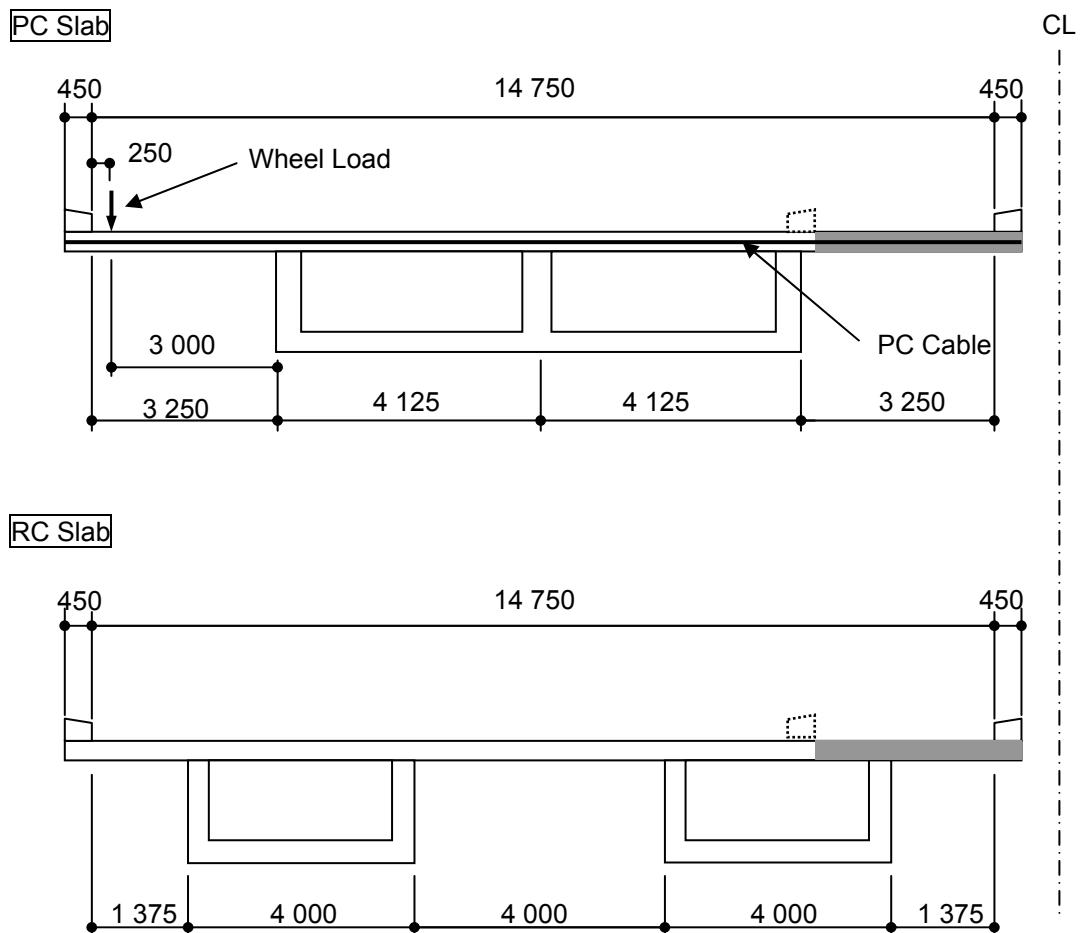


Fig. 5.5.3 Road Width Widening of PC-Box Girder

5.6 Road Crossing Structures

(1) Structural Width

The structural width shall be decided with Geometrical Design Standards, adjusted by the traffic volume and the future road improvement plan. The structural width by Standard is listed here and basically five types of structural width shall be selected in OCH.

Table 5.6.1 Structural Width by Geometric Design Standard

Types	Berm (m)	Drain (m)	Shoulder (m)	Carriageway (m)	Median (m)	R.O.W (m)	Structural Width (m)	Classification
R0	---	0.9 x 2	3.0 x 2	10.5 x 2	1.2	30.0	28.2	A
R1	1.0 x 2 (0.0min)	1.5 x 2 (0.9min)	3.0 x 2 (2.4min)	7.4 x 2	1.2	27.0	22.0 (20.8min)	A
R2	0.6 x 2 (0.0min)	0.9 x 2	3.0 x 2 (2.4min)	7.4 x 2 (7.0min)	1.2	25.0	22.0 (20.0min)	A, B
R3	---	0.9 x 2	3.0 x 2	3.7 x 2	---	15.2	13.4	A, B
R4	1.2 x 2	0.9 x 2	2.4 x 2	3.1 x 2	---	15.2	11.0	B, C
R5	---	0.9 x 2	2.4 x 2	3.5	---	10.1	8.3	C, D
---			(1.0 x 2)	(3.5)			5.5	---

Table 5.6.2 Structural Width of OCH

Classification	Drain	Shoulder	Cycle lane	Carriage way	Median	Width of OP	Width of UP
B1	(0.45 x 2)	3.0 x 2	-----	7.4 x 2	1.2	Not applicable	
B2	(0.45 x 2)	1.5 x 2	1.5 x 2	7.0 x 2	1.2	21.2	-----
B3	(0.45 x 2)	1.5 x 2	1.5 x 2	3.5 x 2	-----	13.0	-----
C	(0.45 x 2)	1.5 x 2	-----	3.5 x 2	-----	10.0	10.9
D	(0.45 x 2)	1.5 x 2	-----	3.5	-----	6.5	7.4
E	(0.45 x 2)	1.2 x 2	-----	3.5	-----	5.9	-----

note : 1. "Drain" shall be applied on UP only

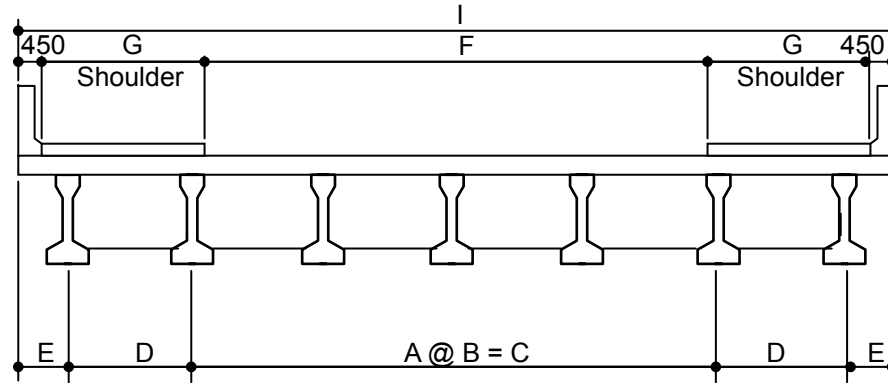
(2) List of Crossing Structures

Table 5.6.3 List of Crossing Structures

STA No.	ID No.		Proposed Road Width							OP	UP
	OP	UP	Road Class	Drain (UP only)	Shoulder (foot walk)	Cycle lane	Carriage way	Median	Road Width	Bridge Length	Inner Height
-(0+290)		U-1	D	0.45 * 2	1.5 * 2		3.5	---	7.4		5.1
0+192.0		U-2	D	0.45 * 2	1.5 * 2		3.5	---	7.4		4.8
1+545.0		U-3	D	0.45 * 2	1.5 * 2		3.5	---	7.4		4.8
3+714.0	O-1		D	---	1.5 * 2		3.5	---	6.5	42.0	
4+378.0		U-4	C	0.45 * 2	1.5 * 2		3.5 * 2	---	10.9		5.1
4+738.0	O-2		D	---	1.5 * 2		3.5	---	6.5	42.0	
5+075.0	O-3		D	---	1.5 * 2		3.5	---	6.5	42.0	
6+657.0	O-4		E	---	1.2 * 2		3.5	---	5.9	57.0	
6+850.0	O-5		E	---	1.2 * 2		3.5	---	5.9	57.0	
7+342.0	O-6		B3	---	1.5 * 2	1.5 * 2	3.5 * 2	---	13.0	48.0	
7+853.0		U-5	D	0.45 * 2	1.5 * 2		3.5	---	6.5		4.8
8+790.0		U-6	D	0.45 * 2	1.5 * 2		3.5	---	6.5		5.1
9+106.0	O-7		E	---	1.2 * 2		3.5	---	5.9	44.0	
9+415.0	O-8		C	---	1.5 * 2		3.5 * 2	---	10.0	42.0	
10+210.0	O-9		B3	---	1.5 * 2	1.5 * 2	3.5 * 2	---	13.0	42.0	
10+950.0		U-6	D	0.45+0.6	1.5 * 2		3.5	---	7.55		4.8
11+258.0	O-10		B3	---	1.5 * 2	1.5 * 2	3.5 * 2	---	13.0	42.0	
12+518.0	O-11		B3	---	1.5 * 2	1.5 * 2	3.5 * 2	---	13.0	42.0	
13+327.0		U-7	D	0.45 * 2	1.5 * 2		3.5	---	7.4		4.8
14+615.0		U-8	D	0.45 * 2	1.5 * 2		3.5	---	7.4		4.8
14+843.0	O-12		D	---	1.5 * 2		3.5	---	7.4	45.0	
15+233.0		U-9	E	0.45 * 2	1.2 * 2		3.5	---	5.9		4.8
15+860.0		U-10	E	0.45 * 2	1.2 * 2		3.5	---	5.9		4.8
16+990.0		U-11	D	0.45 * 2	1.5 * 2		3.5	---	7.4		4.8
18+015.0	O-13		B2	---	1.5 * 2	1.5 * 2	3.5 * 4	1.2	21.2	42.0	
20+105.0		U-12	D	0.45 * 2	1.5 * 2		3.5	---	7.4		4.8
21+640.0		U-13	D	0.45 * 2	1.5 * 2		3.5	---	7.4		4.8
23+940.0	O-13B		D	---	1.5 * 2		3.5	---	7.4	42.0	
25+014.0	O-14		D	---	1.5 * 2		3.5	---	6.5	42.0	
25+650.0	O-15		E	---	1.2 * 2		3.5	---	5.9	42.0	
26+299.0	O-16		C	---	1.5 * 2		3.5 * 2	---	10.0	42.0	
26+684.0	O-17		C	---	1.5 * 2		3.5 * 2	---	10.0	42.0	
27+061.0		U-14	C	0.45 * 2	1.5 * 2		3.5 * 2	---	10.9		5.1

(3) Overpass Structure

The arrangement of PC-I Girder for Overpass Bridge is shown here. For local road of the overpass bridge, the width of shoulder shall be used as foot walk.



Classification	F	G	I	A	B	C	D	E	Remarks
B2	18200	1500	22100	8	2100	16800	2100	550	HA, HB, Cycle lane
B3	10000	1500	13900	4	2100	8400	2100	650	HA, HB, Cycle lane
C	7000	1500	10900	3	1950	5850	1950	575	HA
D	3500	1500	7400	1	2100	2100	2100	550	HA
E	3500	1200	6800	1	2000	2000	2000	400	HA

Fig. 5.6.1 Arrangement of PC-I Girder

(4) Underpass Structures

The structures of Underpass Box culvert are as shown in **Fig. 5.6.2.** and **5.6.3.**

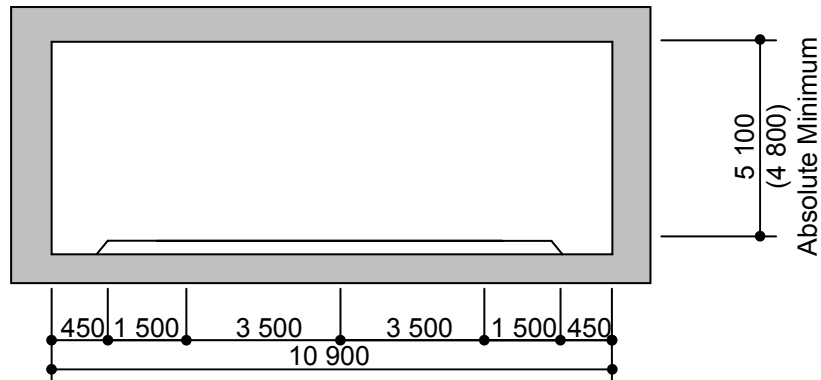


Fig. 5.6.2 Arrangement of Box Culvert for C Class Road

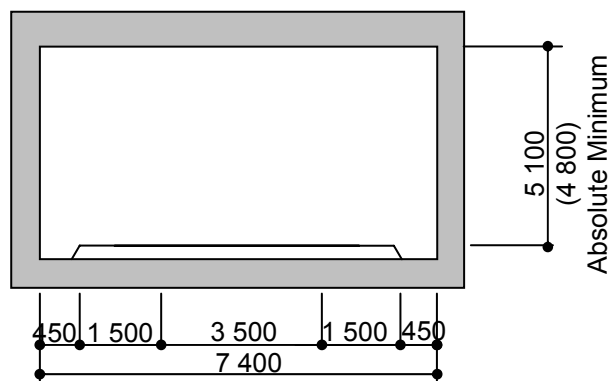


Fig. 5.6.3 Arrangement of Box Culvert for D Class Road

5.7 Retaining Walls

5.7.1. Introduction

This section of the report describes retaining walls and their design. Retaining walls are used where the R.O.W. is restricted by adjacent land use or where the toe of an embankment requires adjustment due to an adjacent structure's wing wall.

5.7.2. Selection of Retaining Wall Type

(1) General

The principal types of retaining wall generally in use are as follows:

- Masonry Concrete Walls
- Gravity Concrete Walls
- Reinforced Concrete Walls
- Reinforced Earth (e.g. Terre Armee)

(2) Characteristics and Considerations of Each Type of Wall

i Masonry Concrete Walls

- Limited to heights of less than 5m for embankments.
- Generally used at the toe of embankments to connect wing-walls and tipped fills smoothly.
- Minimum embedded depth is 30cm.
- Minimum berm width of 1m is required at the top of masonry walls.
- Adopted in the Southern Highway Project.

ii Gravity Concrete Walls

- Limited to heights of less than 5m.
- Minimum embedded depth is 50cm.
- Stepped type is conventionally used for normal highway in Sri Lanka

iii Reinforced Concrete Walls

- Where retaining height is more than 5m, reinforced concrete walls are adopted.
- Reinforcement concrete walls consist of "T-shaped" and "L-shaped" walls. The selection of the appropriate type of wall is dependent on highway geometry.
- Minimum embedded depth is 50cm.
- A pile foundation is used for walls whose foundation is in poor condition.

iv Reinforced Earth (e.g. Terre Armee)

- Limited to heights of less than 18m.
- It is possible to use a spread foundation even on relatively soft stratum. Thus, it is an economical structure as compared to a large-scale reinforced concrete wall.
- Independent concrete L-shaped wall with a barrier will be required.
- Minimum embedded depth is 40cm.



5.7.3. Design Criteria

(1) Reinforced Concrete Retaining Wall

1) Design Standard

- British Standard: “BS 5400: Part4” and “BS 8110”
- Design Manual for Roads and Bridges: British Highway Agency, 1989

2) Design Principles

i Earth Pressure

In order to calculate earth pressure the Sliding Plate Method is adopted, as it is the most practical method for analysis. This is especially true when retained ground is discontinuous.

ii Live Load Surcharge

Distributed horizontal/vertical surcharge force due to HA live load is considered in the design.

iii Effect of Water (Buoyancy)

Conditions with and without water are considered in confirming stability and in carrying out stress analysis. The water level adopted is either the annual flood level or existing ground level whichever is higher.

iv Limit State

The structure and surrounding soil is designed to perform satisfactorily for both the ultimate and serviceability limit.

•Ultimate Limit State

This limit state corresponds with the failure of the stem or the base of a retaining wall and is as defined in BS 5400 (Part 4) for concrete walls.

•Serviceability Limit State

This limit state corresponds with the overall stability and the acceptable limits of cracking

as described in BS 5400 (Part 4) for concrete walls.

v Partial Safety Factors for Loads

The partial safety factors γ_{FL} and γ_B are set based on BS 5400 Part2.

vi Pile Design

Since the existing foundation is unsuitable for a spread foundation, a pile foundation more than 10m in length is required. The pile design is based on the pile design used for bridge abutments.

3) Design Condition of the Reinforced Concrete Retaining Wall

i Back Fill

Soil Unit Weight: $\rho = 19 \text{ kN/m}^3$

Angle of Internal Friction: $\phi = 30 \text{ degree}$

ii Material Properties

Characteristic Strength of Concrete: $f_{cu} = 30 \text{ N/mm}^2$

Characteristic Strength of Reinforcement: $f_y = 460 \text{ N/mm}^2$

Cover to Steel: 75mm for bottom of base, 50mm for rests of members

Maximum Allowable Crack Width: 0.25mm

(2) Reinforced Earth

The design procedures consider the internal and external stability analysis separately.

1) Design Principles

i For internal stability, two failure mechanisms are considered:

- Failure by breakage of the reinforcing strips designed for by assuring that reinforcement cross section is adequate.
- Failure by pullout of the reinforcing strips designed for by assuring that reinforcement surface area and length are adequate.

ii For external stability, the structure is considered to behave as a gravity structure, and three classical failure mechanisms are analysed:

- Sliding of the structure on its base.
- Bearing capacity failure of the foundation soil.
- General failure of a zone including the reinforced earth structure-a slope failure.

5.7.4. List of Retaining Walls

The locations of major retaining walls are listed in the table below.

Table 5.7.1 Retaining Wall Location and Type Adopted

Location		Maximum Retaining Height (Wall Height) [m]	Length [m]	Selected Type (Main Structure)	Remarks
Sta 0+950 – 1+500	(Between main carriageway and ramp way; Both side of	11.0	451.5(L) 322.9(R)	Reinforced Earth (with L wall)	*Retaining height are more than 10m *Pile foundation will be required if it will be used reinforced concrete wall
	(Between ramp way and frontage road ; Left side)	9.5	355.5	Reinforced Earth (with L wall)	
Adjacent to the Abutment wing walls and adopted where masonry wall type would not be sufficient (eg.Sta 27+935)		12.5 (Sta 27+935)	6.6	Reinforced Concrete T Wall *	*Retaining height is more than 5m *Located adjacent to abutments, thus character of retaining wall structure was uniformed with the abutment structure.
Sta +920 – 1+210	(Between frontage road and adjacent land)	2.0	290 (L) 140 (R)	Gravity Concrete Wall	*Retaining height is less than 5m *R.O.W. is severely restricted by adjacent factory
Each tipped fill around the wing walls of bridges and underpasses		5.0	Various	Masonry Concrete Wall	*Set according to the form of tipped fill

*: Pile foundations were adopted if needed.

5.8 Culverts

5.8.1. Introduction

This clause describes culvert structures including boxes and pipes.
And box culverts consist of under-pass for the minor roads and drainage opening.

5.8.2. Basic Policy

(1) Application

1) Shape and Extent

i Under pass

Generally, box culvert is applicable its inner width is less than 14m.
Bridge structure may be more economical than box structure when the inner width exceeds 14m.

ii Drainage culvert

Type of the drainage culvert which transfers water across the road was selected by drainage capacity calculation.

If the discharge volume was relatively small, pipe culvert was adopted.

On the other hand, if the volume is significant, box culvert was required.

2) Minimum Diameter of Pipe Culvert

Minimum diameter of pipe culvert crossing the OCH main highway was decided as 900 mm taking the maintenance works into account.

However, for the minor road, smaller diameter such as 450 mm could be used.

(2) Consideration of the Future 6 Lane

Culverts were designed for the future 6-lane condition.

Especially in structural design, cover height at the 6-lane stage was taken into account.

5.8.3. Box Culverts

(1) Inner Dimensions

1) Under Pass Culverts

Following descriptions explain about under-pass (box culverts for road), which has side-ditches on both sides.

i Track-Clearance

In this study, all box-culverts were classified as C or D.

Details of culvert's inner dimensions for D-class road are shown in **Fig. 5.8.1**.

Fundamentally, minimum track-clearance (H_c) for all minor roads is 5.1m in the design, taking doable-decker bus into account. However, 4.8m of track-clearance is also acceptable to adopt where the track-clearance is restricted by the vertical alignment of the main highway.

ii Pavement and Super Elevation

• Pavement

SBST that was adopted for the normal section of the frontage/approach road (refer to “3.8 Pavement”) was used.

• Super Elevation

Upgrade from both portal, and 3.0% grade is provided.

iii Drainage

General widths of the ditches along the major underpass culverts had already mentioned in **Table 5.6.3** and minimum width of them is 0.45m.

Depths of them were adopted by drainage design and also were adjusted to existing roadside elevation. Minimum depth for drainage is 0.3m.

Drainage wall widths of side ditch were considered as follows:

- If ditch’s wall height (Hd) was equal or less than 0.8m, then wall was set inside the shoulder (see **Fig. 5.8.1**).
- If ditch’s wall height (Hd) was more than 0.8m, then safety fence was considered on top of the wall and wall was set outside of shoulder.

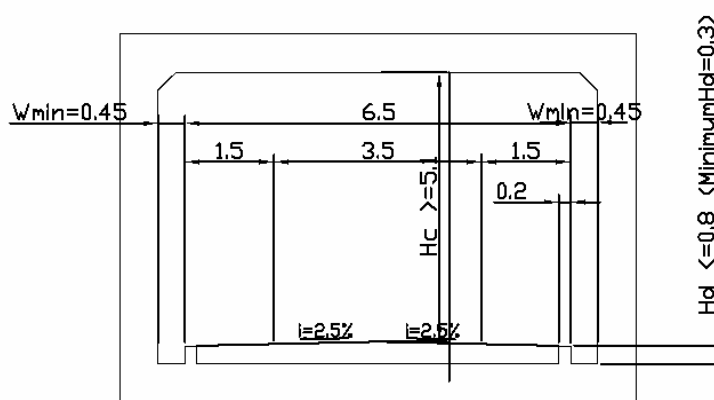


Fig. 5.8.1 Details of Inner Box Culvert (Class-D Road)

2) Drainage Culverts

Inner Dimensions of drainage culverts were decided in the “Chapter-4 Drainage”.

To discharge water effectively, culverts’ inner width / height ratios tend to become bigger than the ones that are designed for the normal condition such as ones in the hilly area, since the water flow condition on this flat and wet land is quite shallow of its depth.

(2) Intersection Angle

Generally, more than 70 degree of intersection angle (IA) between the mainline and culvert is desirable.

Where IA was less than 70 degree, both edge of the culvert were set 70 degree.

(3) Foundation

The spread foundations were adopted in every case in the design and settlement's influence to the inner dimensions weren't considered.

For the most of culverts' sites, countermeasure for the soft ground will be executed for the embankment prior to the culvert construction. In general, culvert's weight is lighter than the embankment soil, because of the hollow.

Therefore, the culverts' stabilities must be ensured by adopting the spread foundation.

"Replacement of soft soil with sand material" and "Replacement plus preloading method" were mainly planned for the embankment onto the soft soil area in the detailed design, and culverts' sections must adopt the same method as the embankment section. The culverts planned on the preload sections must be installed after the soil is consolidated. Surcharge fills are excavated before the culverts are installed.

(4) Design Criteria

1) Barrel

i Structural Design Standard

- British Standard "BS 5400"
- British Standard "BS 8110"
- "BD 31/01 The Design of Buried Concrete Box and Portal Frame Structures", British Highway Agency, 2001

ii Design Principles

■ Nominal Load

- Dead Load
- Superimposed Dead Load
- Temperature Effect
- Earth Pressures
- Primary Live Loads
- Secondary Live Loads
- Live Load Surcharges

■ The Partial Safety Factors for Loads

The partial safety factors for loads, γ_{FL} is tabulated in the **Table 5.8.1**, which is prescribed in the BD31/01. γ_B for SLS and ULS are 1.0 and 1.1 respectively.

■ Load Combinations

The three major load combinations were to be considered in design, which is given in the BD31/01.

■ Frame Analysis

Frame analysis using computer software was conducted to figure out the stress in each member.

Calculation is conducted one-cell, two-cells and three-cells. Even for the culverts whose numbers of cells are more than three, calculations on three cells were conducted, since the tendency of the stress distribution must not be different significantly.

iii Design Loads

■ Dead Loads

The nominal dead load consists of the weight of the materials and parts of the structure that are structural elements excluding superimposed materials.

■ Superimposed Dead Load

The nominal superimposed dead load consists of the weight of the road construction materials and soil cover above the structure and shall be applied as a uniformly distributed load.

$$\text{Maximum superimposed dead load intensity} = 1.15 \gamma H \quad (H < 8m)$$

$$\text{Minimum superimposed dead load intensity} = \gamma H$$

Where γ : bulk density of compacted fill or road construction materials, as appropriate.
H: height of cover from the top of the structure to the finished surface level.

Table 5.8.1 Load Combinations and γ_{fl}

LOADS	Limit State	γ_n for Combinations			
		1	3	4	
PERMANENT LOADS					
Weight of concrete	3.1.1	ULS* SLS	1.15* 1.00	1.15* 1.00	1.15* 1.00
Superimposed pavement construction (top 200mm)	3.1.2	ULS** SLS	1.75 1.20	1.75 1.20	1.75 1.20
Superimposed fill including pavement construction in excess of 200mm	3.1.2	ULS SLS	1.20 1.00	1.20 1.00	1.20 1.00
Horizontal earth pressure (using default earth pressure coefficients)	3.1.3	ULS SLS	1.50 1.00	1.50 1.00	1.50 1.00
Horizontal earth pressure (using earth pressure coefficients calculated in accordance with BS8002)	3.1.3	ULS SLS	1.20 1.00	1.20 1.00	1.20 1.00
Hydrostatic pressure and buoyancy	3.1.4	ULS SLS	1.10 1.10	1.10 1.10	1.10 1.10
Settlement	3.1.5	ULS SLS	1.20 1.00	1.20 1.00	1.20 1.00
LIVE LOADS					
Vertical Live Loads					
HA carriageway loading	3.2.1	ULS SLS	1.50 1.20	1.25 1.00	
HB carriageway loading	3.2.1	ULS SLS	1.30 1.10	1.10 1.00	
Footway and cycle track loads	3.2.2	ULS SLS	1.50 1.00	1.25 1.00	
Accidental wheel loading	3.2.3	ULS SLS	1.50 1.20		
Construction traffic	3.2.5	ULS SLS	1.15 1.00	1.15 1.00	
Horizontal pressure due to live load surcharge	3.2.6	ULS SLS	1.50 1.00	1.50 1.00	1.50 1.00
HA traction and associated vertical	3.2.7	ULS SLS			1.25 1.00
HB traction live loads	3.2.7	ULS SLS			1.10 1.00
Temperature range	3.2.8	ULS SLS		N/A 1.00	
Differential temperature	3.2.8	ULS SLS		1.00 0.80	
Parapet collision and associated vertical	3.2.9 3.2.10	ULS SLS	In accordance with BD 37		
Skidding					1.25 1.00
Centrifugal load live loads	3.2.11	ULS SLS			1.50 1.00

(1)* γ_{fl} shall be increased to at least 1.20 to compensate for inaccuracies when dead loads are not accurately assessed.
(2)** γ_{fl} may be reduced to 1.2 and 1.1 for ULS and SLS respectively subject to the approval of the appropriate authority.

■ Load Effects Due to Temperature

Buried structures with widths less than 5 times the span are to be considered as being open to the atmosphere and the effects of temperature are to be taken into account in accordance with BS 5400: Part 2.

For buried structures of a width greater than or equal to 5 times their span, the requirements of BS 5400: Part 2 are modified as shown in table below according to the BD31/01.

Table 5.8.2 Load Effect due to Temperature

Span to Width Ratio	Cover	Minimum and maximum effective temperature		Differential temperature	
				Temperature difference	Reduction factor
X_{clear}/L_t	H (m)	T_{min}	T_{max}		η
$\geq 0.2^*$	All depths	In accordance with BD 37		In accordance with BD 37**	N/A
< 0.2	$H \leq 0.6$	In accordance with BD 37		In accordance with BD 37**	N/A
	$0.6 < H \leq 0.75$	0°C	20°C	From BD 37, Figure 9, Group 4	0.5
	$0.75 < H \leq 1.0$	4°C	16°C	From BD 37, Figure 9, Group 4	0.33
	$1.0 < H \leq 2.0$	7°C	13°C	From BD 37, Figure 9, Group 4	Zero
	$H > 2.0m$	Temperature effects may be neglected			

■ Earth Pressures

The nominal horizontal earth pressures on the side walls of the structure shall be taken as follows:

- For Combination 1 and 3 loads
Maximum earth pressure = 0.6 yH
Minimum earth pressure = 0.2 yH
- For Combination 4 with traction
Disturbing earth pressure = 0.33 yH
Restoring earth pressure = 0.6 yH

where y = bulk density of compacted fill or road construction materials, as appropriate.

H = height of cover above the point of calculation.

■ Primary Live Loads

HA wheel load and the 30 units of HB load is applied for the OCH main carriageway including the ramp way in accordance with BS 5400: Part 2.

On the other hands, only HA wheel load is considered for the minor road in case its class is C/D.

■ **Secondary Live Loads**

The structure shall be designed to resist longitudinal loads and accidental skidding loads unless provision has been made for the transfer of such loads by the road slab. These loads shall be in accordance with BS 5400: Part 2 and only HB loading is to be considered. The load shall be multiplied by the following factor before it is applied directly to the top of the structure:

$$factor = \frac{span - height\ of\ cover}{span - 0.6m} \text{ but } > 0 \text{ and } < 1$$

2) **Parallel Wing Wall**

i **Structural Design Standard**

- British Standard “BS 5400”
- British Standard “BS 8110”

ii **Design Principles**

■ **Nominal Load**

- Earth Pressure
- Live Load Surcharges

■ **Methodology**

Active earth pressure (including live load surcharge) acting to the wing wall was analyzed by the Sliding Plate Method. Passive earth pressure was not taken into account.

Segments are assumed whose width is Δx (10cm was adopted in the design). And, earth pressure for the each segment is calculated (see **Fig. 5.8.2**).

Moment force at the joint is estimated as a sum of the earth pressure of each segment multiplied by each lever arm length.

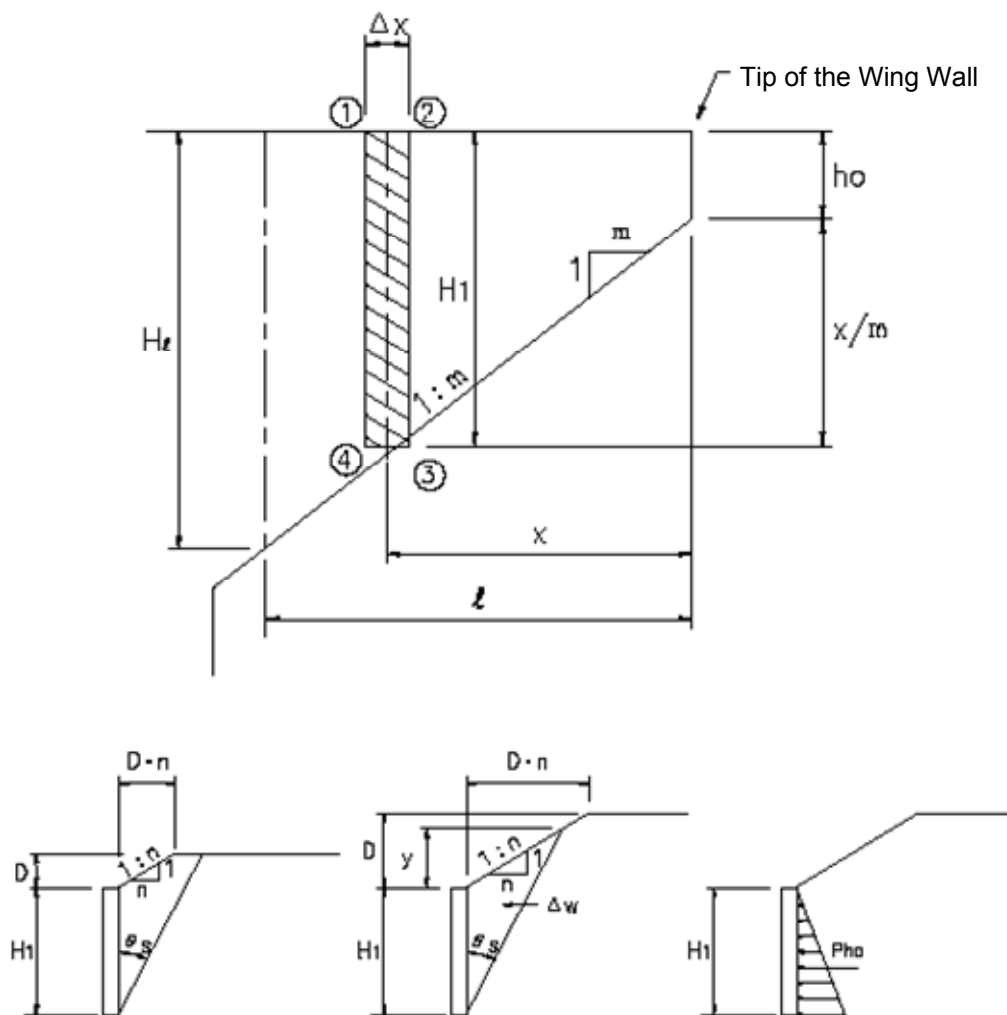


Fig. 5.8.2 Segment of Wing Wall

■ The Partial Safety Factors for Loads

The partial safety factors for wing wall followed the load case, which is prescribed as combination-1 in the “BS5400”.

■ Live Load Surcharge

Distributed horizontal/vertical surcharge force due to HA live load was considered in the design.

(5) List of Box Culvert

Lists of the Box Culverts for the main carriage way crossing and for minor roads and ramp way crossings are shown in **Table 5.8.3** and **Table 5.8.4** respectively.

Table 5.8.3 List of Box-Culverts (for Main Carriageway Crossing)

STA	Skew Angle	Culvert Dimensions in Metre				Remarks
		NB of Cells	B	H	Total Length	
-0+292.5	90	1	7.40	4.90	35.5	
0+080.0	90	1	7.40	5.50	62.5	
1+605.0	90	1	7.40	5.50	36.0	
1+940.0	90	1	3.50	2.50	38.5	
2+540.0	90	4	4.50	3.00	38.5	
3+340.0	90	2	3.00	2.25	37.5	
3+980.0	90	1	3.50	2.00	41.5	
4+378.0	90	1	10.90	5.60	59.0	
4+940.0	90	2	2.00	1.50	55.0	
5+320.0	90	2	2.00	1.75	56.0	
6+060.0	90	3	2.75	1.75	66.5	
7+955.0	90	1	9.00	7.00	43.0	
8+680.0	90	2	2.50	2.50	78.0	
9+760.0	90	2	3.25	2.00	39.5	
10+690.0	90	2	2.25	1.50	62.5	
12+300.0	90	1	3.00	2.25	38.5	
13+260.0	90	1	3.75	3.00	51.0	
13+324.0	90	1	7.40	5.50	41.5	
13+540.0	90	1	3.00	2.25	56.0	
13+953.0	90	1	2.50	2.25	58.8	
14+960.0	90	1	2.50	2.00	57.5	
15+700.0	90	1	8.45	6.50	44.5	
16+920.0	90	5	2.5	1.50	68.5	
16+990.0	90	1	7.4	5.20	35.5	
17+460.0	90	1	2.5	2.00	50.0	
17+640.0	90	1	2.5	2.00	46.0	
18+700.0	90	3	3.0	2.00	56.5	
19+900.0	90	4	3.0	2.00	53.0	
20+104.7	94	1	7.4	5.20	36.0	
20+750.0	90	2	3.0	2.00	50.0	
21+600.0	90	6	2.5	2.00	57.0	
21+640.0	90	1	7.4	5.20	35.5	
22+500.0	90	3	2.5	1.50	49.5	
26+150.0	90	3	3.0	2.00	36.0	
26+620.0	90	4	2.5	1.50	36.0	
26+900.0	90	1	2.0	2.00	50.5	
27+061.2	84	1	10.9	5.60	36.0	
27+255.0	90	1	2.0	2.00	68.5	
28+170.0	90	2	4.0	3.00	51.5	

Table 5.8.4 List of Box-Culverts (for Minor Road and Ramp Way Crossing)

STA		Skew Angle	Culvert Dimensions in Metre				Remarks
			NB of Cells	B	H	Total Length	
CKE IC RAMP 1			1	3.75	2.50	80.0	
CKE IC RAMP 2			1	7.40	5.90	38.5	
A1 IC Ramp			1	8.50	5.35	42.5	
<i>Minor Road</i>							
5+720			3	2.50	2.00	13.0	
0+085			3	2.00	1.50	10.0	
8+670	(STA of CKE)		2	2.50	2.00	32.0	
8+840			3	2.75	2.00	60.0	
13+330			3	2.50	2.00	8.0	
<i>A4 Ramp-5</i>							
0+305		103	2	4.50	3.00	80.5	
0+560		90	2	4.50	3.00	46.0	
0+900		90	2	4.50	3.00	38.5	
<i>Minor Road</i>							
16+990	-00+045	90	4	2.50	1.50	12.5	
16+990	00+050	90	2	2.50	1.50	13.5	
16+990	00+115	90	2	2.50	1.50	9.0	
20+105	-00+056	90	2	2.50	1.50	9.0	
20+105	00+046	90	3	2.50	1.50	9.0	
21+640	-00+040	90	2	2.50	1.50	10.0	
21+640	00+045	108	6	2.50	1.50	14.5	
23+940	-00+036	90	3	2.50	1.50	37.0	
23+940	00+032	90	1	2.50	2.00	31.5	
23+940	00+220	90	1	2.50	2.00	8.5	
25+650	-00+032	90	1	2.50	2.00	36.0	
25+650	00+032	90	2	2.50	2.00	34.0	
26+299	-00+034	90	4	3.00	2.00	41.5	
26+684	-00+043	96	5	3.00	2.00	38.0	
26+684	-00+142	90	1	3.50	2.00	15.5	
27+061	-00+044	97	4	3.00	2.00	7.5	
27+901	13+330 (A4)	90	2	4.50	3.00	36.5	

5.8.4. Pipe Culvert

(1) Inner Diameter

Inner diameters of pipe culverts are previously mentioned in Chapter 4.

(2) Design Criteria

1) Structural Design Standard and Manual

- British Standard BS 5911
- Design Manual for Roads and Bridges (British Highway Agency, 1989)
- A Design Manual for Small Bridges (Transport and Road Research Laboratory Overseas Unit; UK)

2) Pipe Strength Class

Pipe strength classes were followed the British Standard 5911:Part100.

Table 5.8.5 Crushing Test Loads for Concrete Pipe (KN/m)

NOMINAL SIZE OF PIPE DN	CLASS L		CLASS M		CLASS H	
	Works Proof Load	Maximum Load	Works Proof Load	Maximum Load	Works Proof Load	Maximum Load
450	20	25	35	44	41	52
600	20	25	46	58	54	68
900	46	58	67	84	85	106
1200	58	72	87	109	110	138
1500	63	79	96	120	122	153

3) Bedding Types

Bedding types were selected from the ones that normally used in the British Standard (see **Table 5.8.6**).

Table 5.8.6 Bedding Factors

Bedding Class	Description	Bedding Factors
B	180° Granular Bed	1.9
S	360° Granular Bed	2.2
A	120° Plain Concrete Cradle	2.6

But in case the cover soil depth was seriously big or seriously small, 360° concrete (plain or reinforced) surrounded type was used. Dimensions of 360° concrete surrounded type pipes were designed according to “A Design Manual for Small Bridges (Transport And Road Research Laboratory)”.]

(3) Selection of the Combination of Pipe Class and Bedding Class

In the design, combinations listed in the table below were adopted.

Table 5.8.7 Combination Types and Applicable Range of Cover Depth (in meter)¹

Pipe Strength Class	L	L	M	M	M	H	L
Bed Class	C-1	C-2	B	S	A	A	C-1
Bedding factor			1.9	2.2	2.6	2.6	
0.45	~0.5	~0.9	~3.0	~3.9	~4.9	~5.9	>5.9
0.6	~0.5	~0.9	~2.9	~3.8	~4.8	~5.8	>5.8
0.9	~0.5	~0.9	~3	~3.9	~4.9	~6.6	>6.6
1.2	~0.5	~0.9	~2.8	~3.7	~4.7	~6.3	>6.3
1.5	~0.5	~0.9	~2.8	~3.5	~4.5	~6.2	>6.2

note: "C-1" means reinforced concrete surrounded type and "C-2" means plain concrete surrounded type

(4) List of Pipe Culvert

List of the Drainage Pipe Culverts under the main carriage way are shown in **Table 5.8.8**.

Table 5.8.8 List of Pipe-Culverts (for Main Carriageway)

STA.	Skew Angle	No. of Cells	Inner ϕ in metre	Length in metre	Remarks
Mainline					
0+360	90	2	1.5	79	
2+260	90	2	1.2	37.5	
2+960	90	2	1.2	54.5	
7+160	90	1	0.9	40	
9+345	90	1	0.9	53.5	
10+530	90	2	1.2	56	
11+740	90	1	1.2	49	
11+935	90	1	0.9	52	
15+180	90	2	1.2	53	↑ BD Section
16+560	90	2	1.2	80.0	↓ DD Section
18+160	90	1	0.9	43.0	
18+320	90	1	1.5	44.5	
24+480	90	1	0.9	43.5	
24+680	90	1	1.5	41.5	
27+360	90	2	1.2	90.0	
Minor Road					
A110	0+070	90	1	1.5	22.0
16+990	-0+215	90	1	0.9	14.0
21+640	-0+100	90	2	0.9	9.0
21+640	-0+250	90	2	0.9	8.0
22+770	0+039	104	1	1.5	13.5
25+650	-0+111	126	1	0.9	15.0
26+299	-0+137	73	1	1.5	13.5
27+061	0+035	90	1	1.2	7.5
27+901	13+090	120	1	1.2	44.5

¹ Source: "A Design Manual for Small Bridges (Transport and Road Research Laboratory Overseas Unit; UK)", "Depth of cover charts (from ARC Pipes Company Catalog) "

CHAPTER 6

*PRELIMINARY
CONSTRUCTION PLANNING*

CHAPTER 6 PRELIMINARY CONSTRUCTION PLANNING

6.1 General

Construction planning is mainly comprised of establishing a construction method and preparing a construction time schedule. The results of this work are utilized in estimating construction costs and establishing a project implementation schedule.

6.2 Stage Construction Plan

Since the OCH project involves large-scale construction work, it is desirable both economically and technically to phase this work over a period of time. It is planned to construct the OCH in two stages in order to obtain optimal results in order to meet the traffic demand and investment scheduling:

- Initial Stage: Initial construction of a four-lane dual carriageway highway for the entire length of the OCH.
- Final Stage: Widening from four to six lanes sections requiring greater capacity due to increases in traffic demand.

The initial stage construction is planned to construct the outside two lanes of the three lane carriageway (on both sides) for the following reasons as shown in Fig. 6.2.1. The initial structure has the capacity to accommodate six lanes, but requires that the central median area be filled and paved.

- Removal of residences or businesses abutting the OCH is not required.
- Renovation of interchanges is not required.
- Less equipment and manpower is required.
- Improvement of traffic safety during the final construction stage is possible.
- There is less demolition and reconstruction of slope protection facilities.



Fig. 6.2.1 Construction Plan of Initial Stage

6.3 Construction Package

The embankment work of the OCH construction project has become huge volume for the construction of a highway with length of 29km. The route of the OCH has been planned mainly along the low line land such as paddy field to reduce a demolition of existing

buildings and houses and resettlement. High embankment is planned to avoid damage of road structures from floods. Many bridges on main carriageway for crossing over existing national and local roads and rivers and also many overpass bridges crossing over the OCH are designed. For these reasons the construction of OCH project is planned to divide into three packages to reduce the total construction period.

6.3.1. Construction Packages

The sections of three packages are as follows:

(Northern Section: *Basic Design section in this Study*)

Package 1: From Sta. 0-600 to Sta. 8+150 (Between Interchange with CKE (Ragama) and Interchange with route A1 (Kadawata))

Package 2: From Sta. 8+150 to Sta. 16+500 (Between Interchange with route A1 (Kadawata) and Interchange with route AB010 (Kaduwela))

(Southern Section: *Detail Design section in this Study*)

Package 3: From Sta. 16+500 to Sta. 28+500 (Between Interchange with route AB010 (Kaduwela) and Interchange with route A4 (Kottawa))

Locations of three packages are as shown in Fig. 6.3.1.

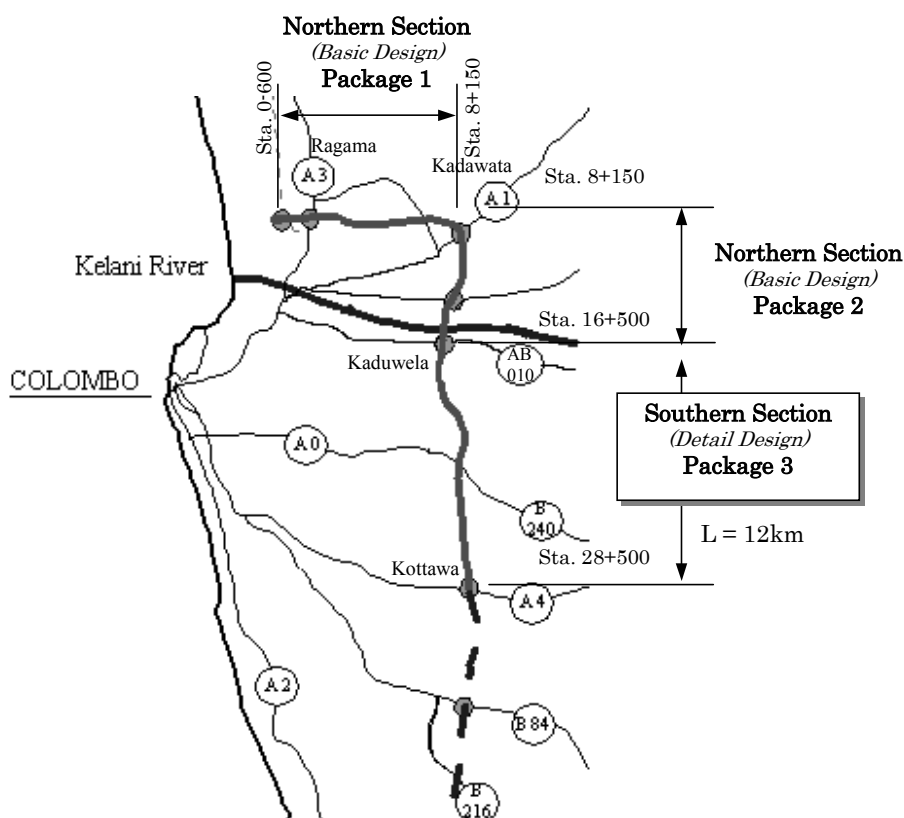


Fig. 6.3.1. Location of Three Packages

6.3.2. Major Work Items of Each Package

Major construction works of each package are as shown Table 6.3.1.

Table. 6.3.1 Quantities of Major Construction Works of Each Package

Item	unit	Northern (BD)		Southern (DD)	Total		
		Package 1	Package 2	Package 3			
Road Works	Cutting & Filling	cu.m	505,000	559,000	268,000	1,332,000	
	Embankment (Borrow material)	cu.m	2,487,000	1,586,000	*3,221,000	7,294,000	
	Countermeasure of soft soil	Replacement	cu.m	1,026,000	1,111,000	1,004,000	3,141,000
		RC Piling	m	132,800	-	107,700	240,500
	Aggregate Base	cu.m	53,700	51,200	83,500	188,400	
	Sub base	cu.m	44,800	44,700	68,700	158,200	
	Selected Martial	cu.m	45,900	38,100	72,900	156,900	
Asphalt Concrete	t	51,700	51,500	91,600	194,800		
Bridges	Highway & Ramp Bridges	No.	6	7	7	20	
	Overpass Bridges	No.	7	6	6	19	
Box Calvert	Underpass & Drainage	No.	13	15	37	65	
Interchange		No.	2	2	2	6	

* Including Horizontal Gravel Mat for soil improvement [2,540,000(borrow)+681,000(gravel mat)]

6.4 Highway Construction

6.4.1. General

The volume of earthwork in cutting and filling embankment is not balanced as shown in the above table and hence embankment materials and pavement materials, in large quantities have to be hauled from several borrow pits and metal quarries for the construction of the OCH.

The project area has a sufficient existing road network for the hauling of the said materials. However, the pavement strength of existing local roads is sometimes insufficient. Therefore, the haulage of materials should be carried out in such a manner to use main roads from borrow pits or material suppliers' quarries to the intersection of the OCH. At the job site, temporary road under the OCH as a pilot should be used as much as possible for transportation of materials. Where local roads are used for transportation, pavement strengthening/repairing of local road will be necessary during the construction period.

6.4.2. Highway Construction

To realize cost efficiency gains via a shorter construction period, the intensive use of mechanical equipment for construction will be adopted.

Highway construction will be executed after land acquisition is completed as shown below flowchart.

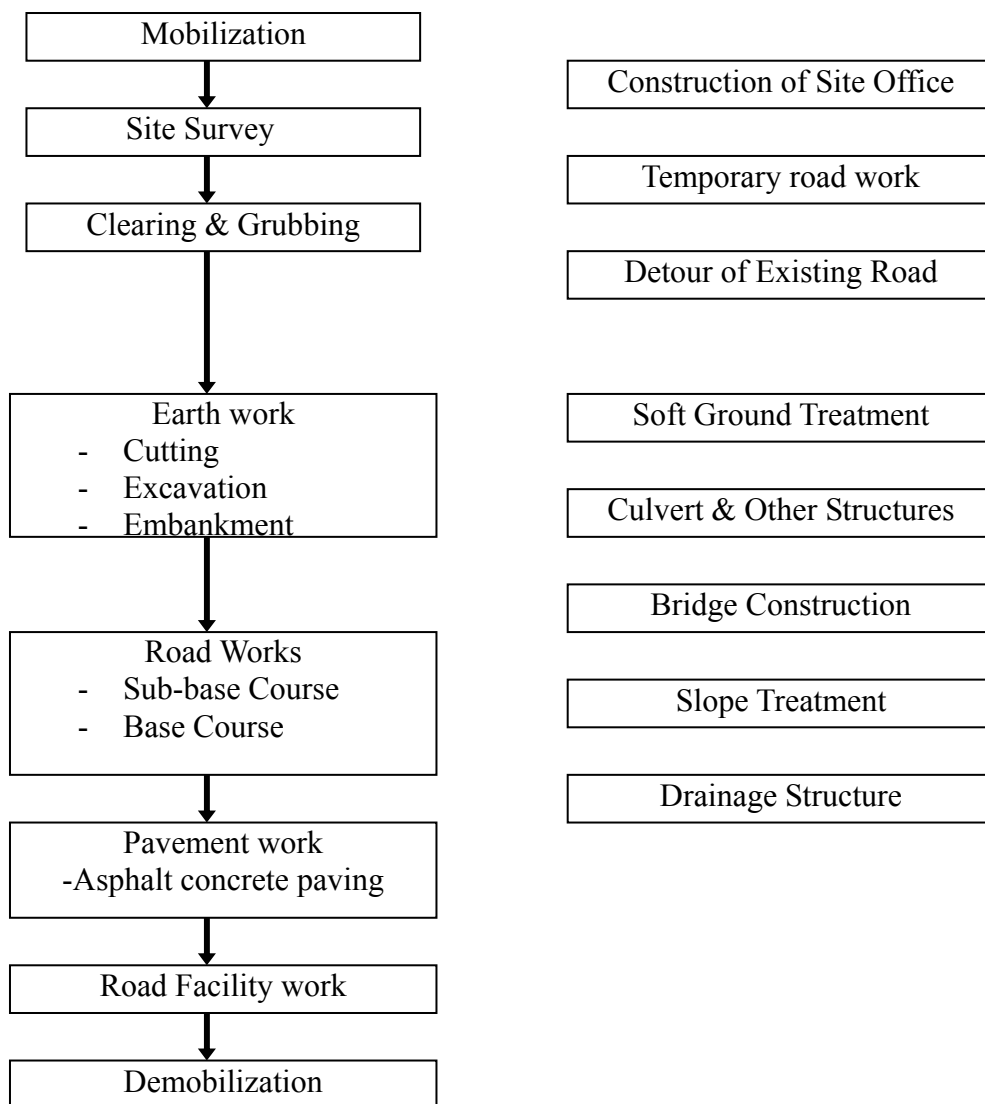


Fig. 6.4.1 Highway Construction Flow

6.5 Earthwork

6.5.1. Volume of Cutting and Filling

Earthwork volumes of each package are shown in the Table. 6.3.1. The OCH runs mostly through paddy and lowland area. The hilly and rolling area is only one-third of the Package 1 and half of the Package 2. The cutting area in the Package 3 is quite a small.

6.5.2. Major Equipment for Earthwork

The use of the following major earthwork equipment is planned for the OCH construction (Table. 6.5.1).

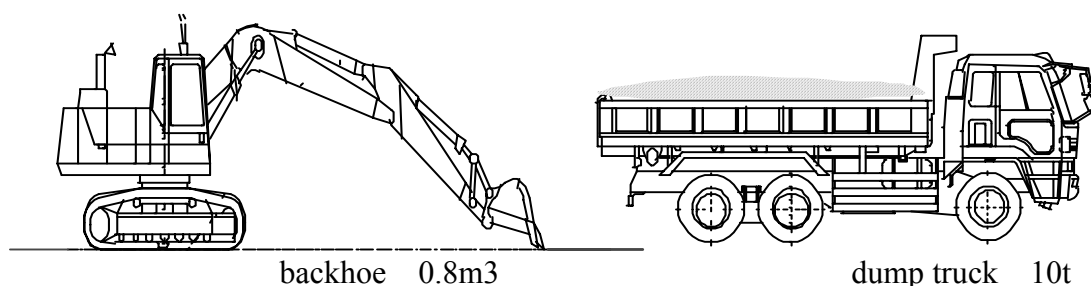
Table. 6.5.1 Earthwork Equipment

Main Work	Equipment	
	Hauling distance less than 100m	Hauling distance more than 100m
Clearing	Bulldozer	
Excavation	Bulldozer	Tractor Shovel
Loading	-	Tractor Shovel / Wheel loader
Hauling	Bulldozer	Dump Truck
Spreading	Bulldozer/Motor grader	
Compaction	Tamping Roller/Tire Roller	

6.5.3. Earthwork Procedure

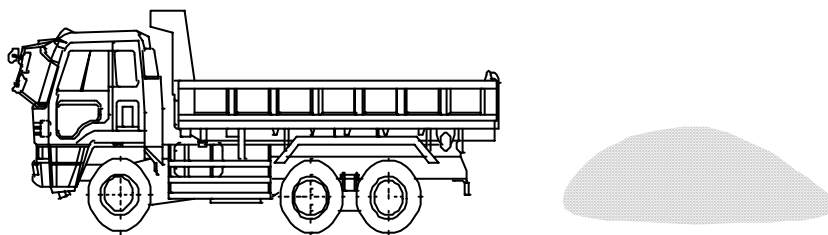
The earthwork is carried out as following manner.

① Excavation



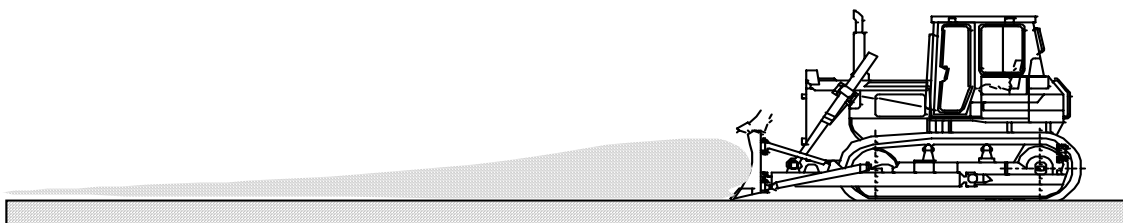
A deep excavation work will be necessary to take off unsuitable soil because a huge accumulation of rubbish covers the surface of subject roads, and in most cases a mixture of waste materials with soil penetrates deep into the roads.

② Dumping



Excavated soils will be carried to a dumping area designated by the Western Provincial Council for the protection of the environment.

③ Leveling



At a dumping area, dumped material will be spreaded evenly by the bulldozer.

6.6 Borrow Material / Borrow Pit Plan

The materials for embankment shall be supplied from borrow pits. The lists of existing borrow pits and metal quarries are shown in Table 2.3.7 and 2.3.8, Chapter 2.3.4.

6.7 Road Works and Pavement Works

After completion of earthwork, road work and pavement works will be carried out.

6.7.1. Subbase, Base Course Work

(1) Main Equipment

The following equipment will be used for the execution of pavement work shown in Table. 6.7.1.

Table 6.7.1 Pavement Work Equipment

Main Work	Equipment
Sub-grade Preparation	Motor Grader, Tire Roller, Macadam Roller
Sub-base	Motor Grader, Tire Roller, Macadam Roller
Prime/Tack Coats	Asphalt Distributor (Sprayer)
Surface Course	Asphalt Mixing Plant, Asphalt Finisher (paver), Macadam Roller, Tire Roller

(2) Material Sources

The sources for paving materials are shown in Table.6.7.2

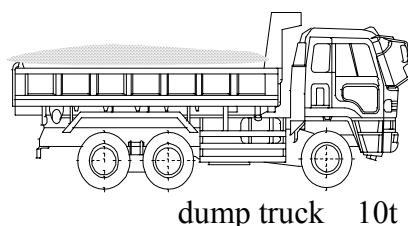
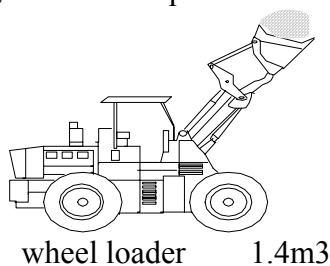
Table. 6.7.2 Sources of Paving Materials

Materials	Location of Quarry	Remarks
Gravel and Sand	Colombo Seashore*	Deposit: 500,000m ³
Sand		Deposit: 250,000m ³
Base Course Aggregate	Kaduwela	Granite
Course Aggregate	Northern Mahara	Granite
Course Aggregate	Northern Biyagama	Granite

*: Only to be permitted if environmental impacts negligible.

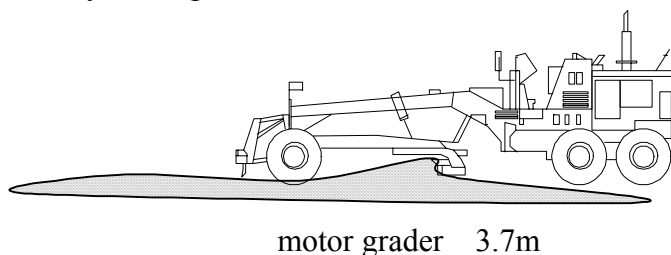
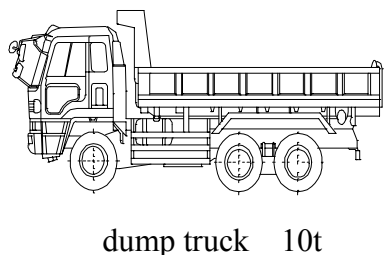
(3) Construction

Both base course and sub-base course are respectively formed by technically stabilized stones and crusher-run stones of 20cm of thickness. The stones will be prepared in a quarry located in the suburb of Colombo. The stones, after mixed in the quarry according to the set conditions, will be transported with dump trucks to each site.



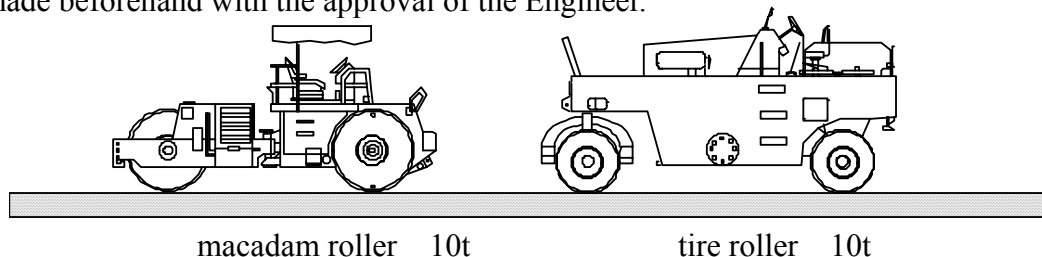
Dumping ⇒ Spreading & Watering

For both base course and sub-base course, materials will be laid with due attention to the separation of materials in order that one layer can get 20cm of uniform thickness.



Compaction

Concerning the machines used for a uniform laying of crushed stones to get a set compaction value and compaction frequency in base/sub-base courses, a test operation will be made beforehand with the approval of the Engineer.



macadam roller 10t

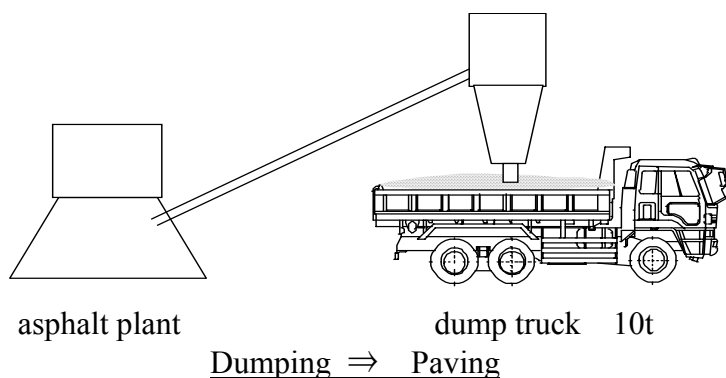
tire roller 10t

6.7.2. Asphalt Concrete Work

The procurement of hot-mix asphalt concrete is possible for the construction of asphalt treated base course and surface course.

Loading (asphalt plant)

There are several private asphalt plants in and around Colombo area, and from where asphalt mixed materials will be transported with dump trucks to each site.

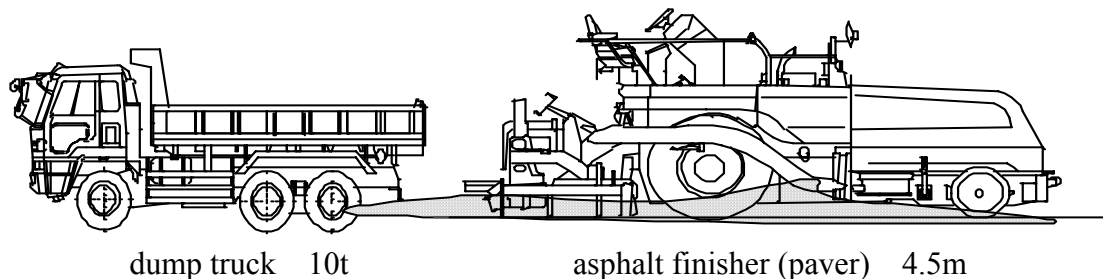


asphalt plant

dump truck 10t

Dumping => Paving

A starting time of trucks at asphalt plant will be arranged carefully to avoid that the trucks, after arriving at site, have to wait much time unnecessarily because to stay much time will bring about a fall of temperature of the mixed materials.

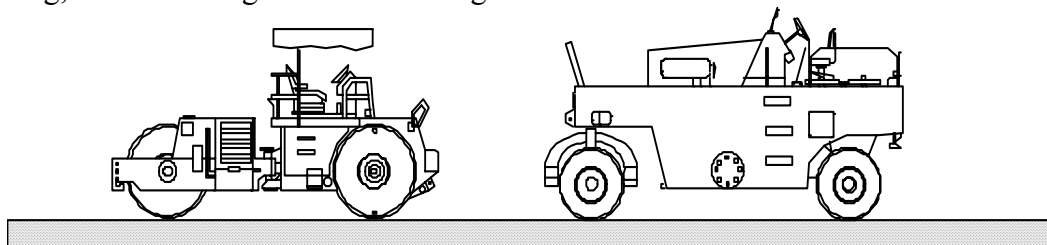


dump truck 10t

asphalt finisher (paver) 4.5m

Compaction & Watering

The hot mixture is compacted immediately after laying, in three stages, i.e., breakdown rolling, second rolling and finish rolling.



macadam roller 10t

tire roller 10t

6.8 Bridges

Pre-Stressed Concrete (PC) girder bridges are selected for main highway bridge and overpass bridge in the OCH project. Two type of PC bridges, PC I girder-bridge and box girder-bridge are planned. PC I girder bridge is selected for short span (span length equal and less than 35m) bridge and box girder bridge is selected for long span (span length more than 35m) bridge. Abutments and piers are selected transversed T type and foundations are spread type and pile foundations depends on their geological condition.

6.8.1. General

The works of the bridges can generally be subdivided into four components, namely Foundations, Beam Casting, Substructure and Superstructure. The sequence of works varies slightly between the various types and/or spans of bridges involved in this Project. There are generally four types of bridges including a single span railway overpass, a single and a double span road overpass and a multi-span river bridge. The following provides a description of the construction sequence and the methods proposed for the Foundation Works, as well as for the Concrete Works for Substructures and Superstructures, including the beam casting.

6.8.2 Foundation Works

The foundation works for bridges shall include excavation works down to formation level and the piling works under the pile cap structures.

In the following subsections are descriptions of the work methods employed for boring for bored pile works and driven Pca-RC-piles.

(1) Excavation

Excavation will be carried out in accordance with the most practical methods at each bridge location. In general, foundation works in concrete structures will not be programmed during wet seasons.

Excavation at abutment locations will be undertaken down to the formation levels. Either Pca-RC piles shall then be driven by diesel drop hammer and/or gravity drop type hammer,

or bored piles shall be concreted, or no piles will be provided depending on the requirements of each condition.

For road overpass bridges, subject to the ability to adequately divert traffic and maintain stable slopes down to the formation level of a pile cap, the preferred method of excavation will be an open cut excavation.

For foundation works and pile caps/spread footings in road bridges and for those of the railway crossing bridges, where it is required by the Contract to minimise the size of the excavation due to constraints such as for the maintenance of traffic lanes or ensure the stability of railway tracks in close proximity or other, the excavation shall make use of sheet pile cofferdams to protect the sides of the excavation as shown in Figure 6.8.1. The use of appropriate type sheet piles shall be determined by examining the depths of excavation and the soil conditions.

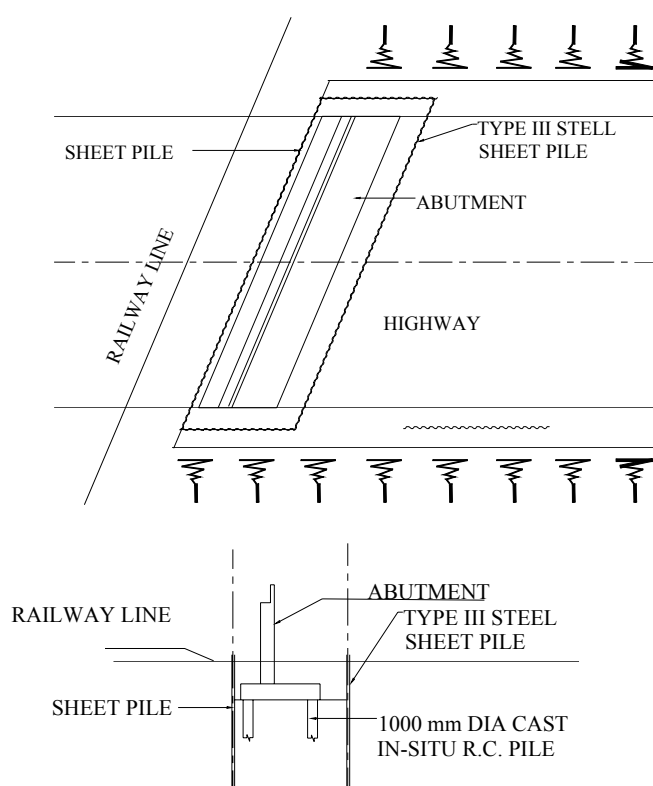


Fig. 6.8.1 Sheet Pile Cofferdam for Substructure Near Railway

Bulk excavation will be carried out using backhoe excavators and pumps will be maintained in the excavation pit to lower the water table, as required.

The excavated surface on which the structure is to be constructed, will be compacted to the specification requirement with either a Pedestrian Roller, a Jumping Rammer or a Plate Compactor prior to placing of lean concrete.

sizes. The first cage shall be lowered into the hole and the upper end shall be kept protruding out of the hole to enable the splicing of the subsequent cage onto it. Welding shall be used to secure the splice. The crane shall then further lower the spliced cages and continue with this procedure until the cage reaches the bottom of the hole.

iv Concreting

The Reverse-Circulation system shall be fitted with tremie pipes of varying lengths (ie. 3m, 1.5m, and 1m) and will be assembled to reach the bottom of the bored hole. Water and slurry inside of bored hole will be pumped under pressure through the tremie pipes to the bottom of the bored hole and will serve to lift out any loose matter by a combination of circulation and buoyancy. When this cleaning operation is completed, the tremie funnel will be fixed at the top of the tremie pipes and plugged at the base of the funnel.

Concrete will be transported to site in mixer trucks from the approved concrete batching plants. The concrete batching plants will produce the day-to-day concrete requirements, whether intended for cast in-situ or pre-casting related works. Concrete will be filled in the funnel, which will then be unplugged to send the concrete to the bottom of the hole through the tremie. Concrete will be discharged into the funnel by truck mixer and the concreting operation will proceed from bottom to top. The tremie will be kept some 3m into the concrete at all times and the rising concrete level will push up the water out of the hole. Tremie pipes will be removed successively. The concreting will be stopped approximately 0.5m above the cut-off level.

(3) Driven Piles

For driven piles, the following procedure is recommended.

i Setting up

Establish working platform by earthwork operations by cutting, filling and levelling to required elevation. Mobilise crane equipped with pile leader and diesel hammer and/or by gravity drop type hammer. Typical arrangement is shown on Figure 6.8.3.

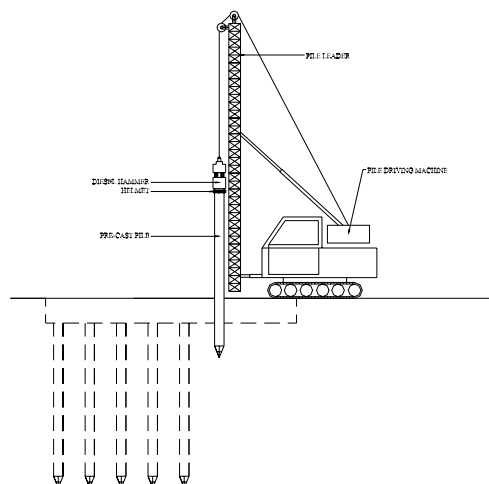


Figure 6.8.3 Typical Arrangement for Driven Pile

Proceed to driving of the testing piles at each site to determine the length of pile required.

Load the test pile and upon satisfactory results, a schedule of pile lengths shall be determined for fabrication purposes in the aim of minimising the need for splicing requirements and waste.

Proceed to the production of RC piles to suit.

ii Supply of RC Piles

The supply of RC piles can be readily obtained from various local manufactures in Colombo area, or alternatively, the RC piles can be manufactured in the casting yard.

iii Driving

Upon the delivery to the site of RC piles meeting the requirements determined, the driving equipment shall be mobilised to the site for the planting of the piles. Pile locations shall be set out over the pile cap area.

The pile driving machine shall be erected with the pile in place to be driven at the correct location and depth.

6.8.3 Sub-structure

The progressive completion of the foundation works will enable the subsequent works to proceed with the construction of the reinforced concrete substructures. These shall include the pile caps from which the T-Piers and abutment structures will then stem up. The construction of these substructures shall be in conventional reinforced concrete construction up to the superstructure. Backfilling of the abutments will be carried out as the abutment construction moves up to provide access to the subsequent superstructure works.

(1) Formwork

Ordinary water proofing quality plywood or coated plywood will be used for Formwork as followed by the Specification. Form ties with plastic cones will be used for securing of forms in place. Approved type of form oil will be applied on the formwork face prior to installation

Lift height will be determined in accordance with the construction joints approved by the Engineer and formwork shall be built to suit. Generally, the walls and piers shall be 1 to 5 lifts.

(2) Steel Reinforcement

All reinforcement will conform to the requirements of the specification and will be purchased from local manufacturers in sizes which will optimise as far as practicable the use of steel by minimising the number of splices required. Cutting and bending of bars shall be carried out on site at a bar bending yard and shall be carried out in accordance with the specifications and with the rules of practice.

All bars will be securely fixed with annealed wire and spacer blocks (mortar or concrete) made will be tied to reinforcement to ensure required concrete cover.

(3) Concreting

Concrete will be transported to site in mixer trucks from the approved concrete batching plants. The concrete batching plants will produce the day-to-day concrete requirements, whether intended for cast in-situ or pre-casting related works. In general, concrete shall be placed in accordance with the requirements of Technical Specifications and in a manner to suit the various conditions which may be encountered, using any or combination of the following techniques: concrete pump cars, cranes equipped with skip buckets of appropriate sizes, bins, chutes, or manually. In all methods used, slump values specified shall be maintained during placing and care shall be given to prevent segregation of the constituents. Compaction of concrete shall be by electric, mechanical or pneumatic drive, immersion type vibrators or formwork mounted type in accordance with the Technical Specifications. When concrete has sufficiently hardened, construction joint surfaces will be green cut by wire brush and water jets.

6.8.4 Superstructure

Initially, the site will be mobilised and land will be reserved for the beam casting activities near the bridge approaches. The land will be levelled by cutting and/or filling. The area will be topped off with granular material to form a clean and self-draining working pad.

For bridges using PC post-tensioned I-girders, a system of rails will be installed to enable the movement of girders with chain block to handle the beams. Steel formwork will be manufactured to conform to the cross-section of the PC I-girders and will be rotated around the bridge sites to cast the PC I-girders. Post-tensioning of the PC I-girders will be carried out in one step after they have reached adequate strength and prior to their erection. The pre-stressing of the beams will be in accordance with the requirements of the detailed design and the specification requirements.

Alternatively, for those bridges using cast in-situ post-tensioned box type girders, the pre-casting yard at the abutments will not be provided, as there is no requirement for such facilities.

(1) PC I-girder Bridge

As for the pre-cast post-tensioned bridge I-girders, they shall be constructed in an area offset from each bridge abutment under the supervision of the specialised staff. In general, for river bridges, and beams greater or equal to 25m in length will be launched into position directly from their manufacturing positions through a erection girder crane system in such a way that the beams are not over stressed during the handling process. For shorter beams, such as those for road overpass bridge, The PC I-girders will be erected by crane rather than by launching with the erection girder.

The superstructure works of the PC I-girder bridges shall proceed with the placing of the elastomeric bearing pads at the abutments and piers. An erection girder system set up on rails will launch the PC I-girders from the abutments to the first span. Figures 6.8.4

illustrate the arrangement of the erection girder system proposed. Once transported to the span being erected, the beams will be shifted into their final position over the elastomeric bearing pads with the aid of lateral winching system on rollers. Upon completing the erection of the first span the erection girder crane system shall be moved ahead to launch the following spans in series. Once the beams have all been installed the erection girder crane will be dismantled and moved to another bridge location requiring the services of the crane system.

In case of the bridge span is short and the access to the bridge is available, and the erection of the PC I-girders shall be carried out by mobile cranes as shown on Figure 6.8.5.

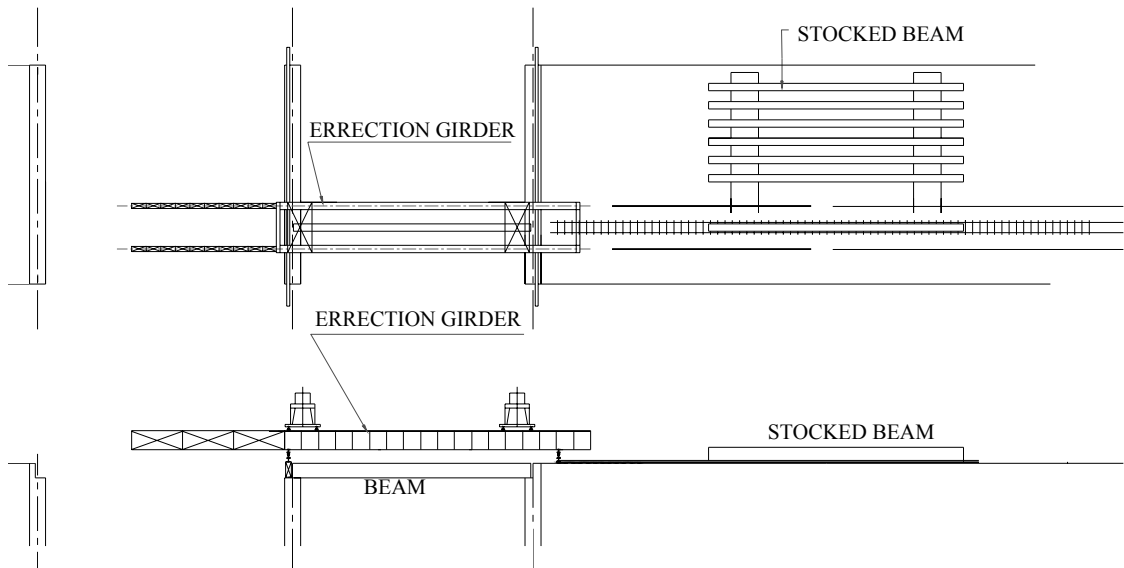


Fig. 6.8.4 Erection girder for PC I-girder

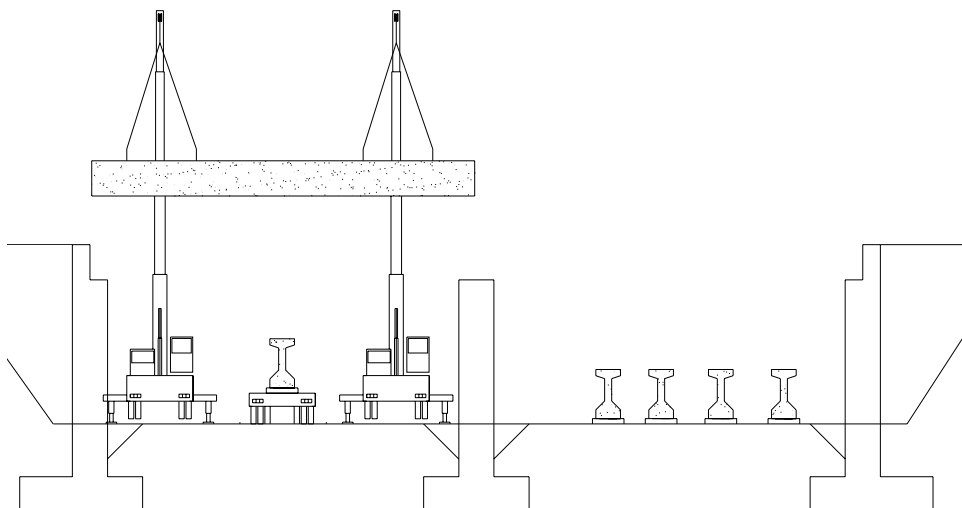


Fig. 6.8.5 Erection of PC I-girder by Mobile Crane

The transverse diaphragm beams will then be cast in-situ and post-tensioned after the required time and strength has been achieved. The construction of the deck slab shall over 75mm thick reinforced concrete plates placed in between the PC I-girders as shown on Figure 6.8.6 to 6.8.7.

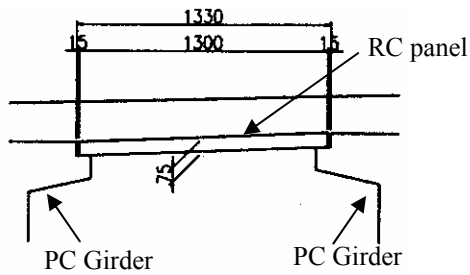


Fig. 6.8.6 RC Plate

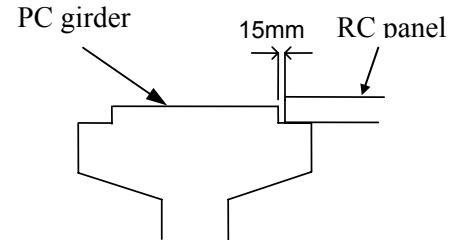


Fig. 6.8.7 Joint of RC Panel

For the cantilevered slabs, jack support or steel brackets installed on the edge of PC I-girder shall provide support for the scaffolding and formwork used for the slab construction shown in Figure 6.8.8 and 6.8.9.

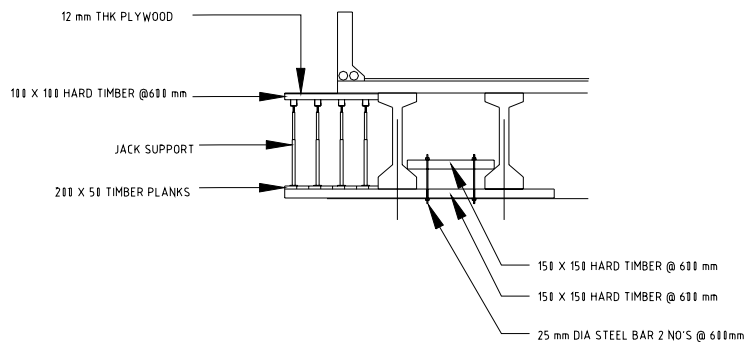


Fig. 6.8.8 Jack Support Type for Cantilever Slab

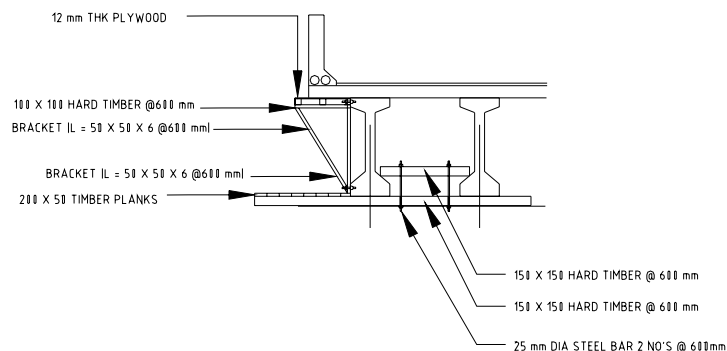


Fig. 6.8.9 Steel Bracket Type for Cantilever Slab

The slab shall have a broom type finish to enhance adherence between the concrete and the wearing course to follow. Finishing works including the approach slabs, reinforced concrete barrier and other miscellaneous construction shall be completed following the slab construction. The slope protection (ie. Mattress) will be placed over the embankment at the abutments, followed with all other miscellaneous finishing works associated with the bridge construction.

(2) Cast In-situ PC Box Girder Bridge

For the cast in-situ post-tensioned box girders bridges, the superstructure is constructed over a working platform as long and wide as the superstructure and required working space around as shown Figure 6.8.10. This platform is supported by a scaffolding system placed underneath and founded on the ground level below. With traffic, if any, diverted around the bridge through a temporary road and the working platform thus erected, the construction reinforced concrete box girder can then proceed.

This scaffolding system shall consist of a coated plywood deck over a series of wooden/steel beams. The latter of the beams shall be supported by a supporting system running continuous in both directions covering the box girder structure and working space above. The height of scaffolding is approximately 6 m.

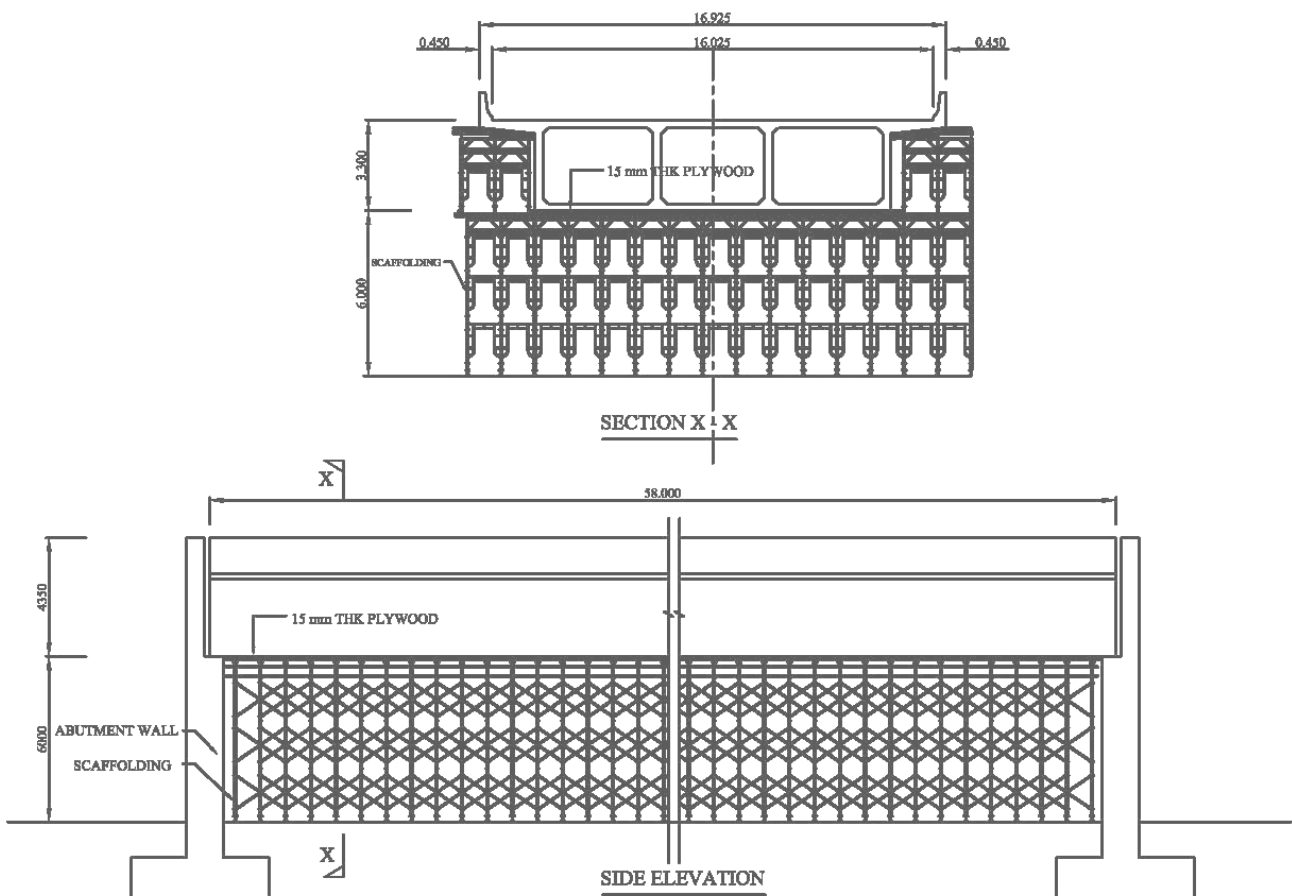


Figure 6.8.10 Scaffolding System for Post-tensioned PC Box Girder

6.9 Kelani River Bridge

The OCH is crossing over Kelani River around sta. 16+204. Kelani river bridge was designed with total bridge length of 206m (33.0m + 4@ 35.0m + 33.0m), two series of 3 spans PC connecting composite girder crossing over both Kelani river and the national road B214.

6.9.1. Temporary Bridge and Cofferdam

For foundation and substructure works associated with bridges over the river, work will commence with the erection of a temporary H-steel Bridge across Kelani River. Sideward extensions shall be provided from the main axis of the Temporary Bridge to provide access to the abutments and piers as necessary as shown in Figure 6.9.1.

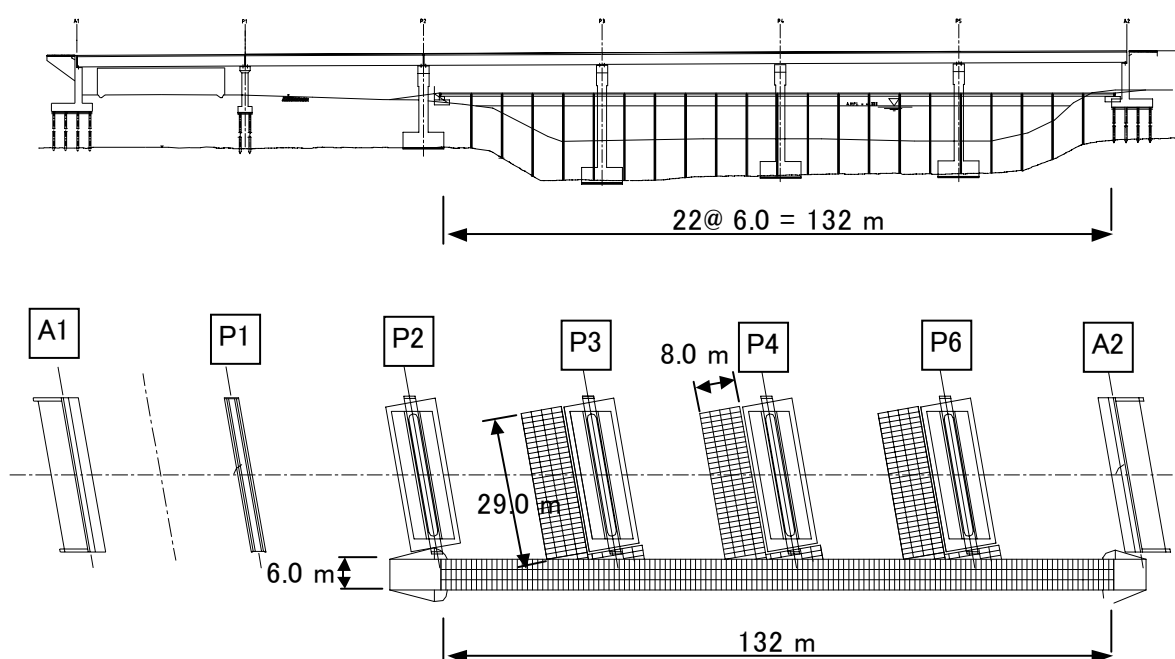


Fig. 6.9.1 Temporary Bridge for Construction Kelani River Bridge

To minimise the effect of the water to the works, it is desirable that the foundation works will be programmed to be carried out in dry seasons. However, for Kelani River bridge, it shall be carried out all through the year due to the construction period of piers (estimated period of 8 months for one pier) in the river using steel sheet pile cofferdam.

Two types of excavations are envisaged for the works. The first is the open cut type with or without side support, as each case requires, in locations where the cut-off levels of the RC piles are not affected by a high water table or the river flow.

The second method envisaged is to excavate within steel sheet pile cofferdams for piers located in the river and for those immediately adjacent to the river where they are susceptible to be affected by water bailing into the excavation as a result of high water table. The sheet pile cofferdam method comparison is shown in table 6.9.1. A typical arrangement of steel sheet pile cofferdam is depicted on Figure 6.9.2.

Table . 6.9.1 Pile cofferdam Method Comparison for Kelani River Bridge

Method	Steel sheet pile double cofferdam + Chemical grouting	Steel sheet pile double cofferdam + Jet grouting for watertight	Steel sheet pile single cofferdam (Water jet used also for pile driving)	Steel pipe sheet pile single cofferdam (Pre-drilling with rock auger)
Illustration				
Outline of the method	Steel sheet piles are driven with vibro hammer to achieve double cofferdam. As steel sheet piles do not penetrate into rock bed, chemical grouting is made within double cofferdam watertight.	Steel sheet piles are driven with vibro hammer to achieve double cofferdam. As steel sheet piles do not penetrate into rock bed, jet grouting is made within double cofferdam for watertight. Steel sheet piles and jet grout are fixed with dowel.	With the help of water jet, vibro hammer is used to drive steel sheet piles to penetrate into rock bed. Grout mortar at ends for watertight.	Steel pipe sheet piles are driven through advance drilling with rock auger to penetrate into the rock bed for 1.0 m. The sequence is "drilling with rock auger" – backfilling with sand – driving of steel pipe sheet piles. For joints and ends, watertight is achieved by mortar grouting.
Principal machinery	<ul style="list-style-type: none"> Crawler crane (50 t capacity) : 1 unit Vibro hammer (45kw) : 1 unit Grouting equipment (boring machine) : 5 units 	<ul style="list-style-type: none"> Crawler crane (50 t capacity) : 1 unit Vibro hammer (45kw) : 1 unit JG equipment (boring machine) : 3 units 	<ul style="list-style-type: none"> Crawler crane (50t capacity) : 1 unit Special vibro hammer (45kw) : 1 set Water jet equipment : 1 set 	<ul style="list-style-type: none"> Pile driver with auger : 1 unit Crawler crane (80t capacity) : 1 unit Vibro hammer (60kw) : 1 unit
Drive	Pile driving is possible with usual vibro hammer.	Pile driving is possible with usual vibro hammer.	Pile driving is possible with usual vibro hammer.	Pile driving is possible with usual vibro hammer.
Rocks mass (qu=1000kg/cm2)	For the weathered rock mass with qu=50kg/cm2, pile driving is possible when the water jet method is also used.	For the weathered rock mass with qu=50kg/cm2, pile driving is possible when the water jet method is also used.	For the rock mass with qu=1000kg/cm2, pile driving is possible with the special equipment when the water jet method is also used.	Pile driving possible up to the rock mass strength of about qu=500kg/cm2. Above this strength, the special method (direct piling method), etc. is necessary.
Watertight	Watertight to a certain degree, but not reliable	Reliable watertight	Watertight enabled though pump-up is necessary.	For joints and ends, complete watertight is possible by grouting.
Structural safety	Not enough safe because the end is not fixed	Safety ensured because of fixing with JG and dowel	Safety ensured because piles are fixed in rock bed.	Safe because piles are fixed in rock bed.
Removal of steel sheet piles	Pull-out and removal possible	Pull-out impossible. Cutting and partial removal	Pull-out and removal possible	Pull-out and cutting at arbitrary position, and removal possible
Contractor	Not specified	Not specified	Various types. Not specified	Possibly related to the specific contractor (general contractor)
Principal quantity	Steel sheet pile : A=2,824 m2 (loss) Grouting : V = 770 m3 Double cofferdam : W=12.2 t Filling soil : V=2,568m3 Internal excavation : V=2,144m3	Steel sheet pile : A=2,824m2 (loss) CJ grouting : V = 513m3 Double cofferdam : W=12.2t Filling soil : V = 2,568m3 Internal excavation : V=2,144m3	Steel sheet pile : A=1,398m2 (loss) Internal excavation : V=2,144m3	Steel pipe sheet pile : A=1,398m2 (loss) φ600x12mm Internal excavation : V=2,144m3
Temporary work cost ratio	130 million Rs (2.02)	187 million Rs (2.89)	65 million Rs (1.00)	157 million Rs (2.44)
Overall work period (including structural works)	12.0 months	14.3 months	8.0 months	10.5 months
Overall rating	Costs including grouting is considerably high and the work period of double cofferdam and grouting is long. Less reliable steel sheet pile end fixing structure ×	Reliability of steel sheet pile end fixing structure is considered to be without problem. The jet grouting cost is high and its work period is long. Besides, steel sheet piles cannot be pulled out. △	Steel sheet pile end fixing structure is considered to be reliable. Though complete cut-off cannot be expected, drainage is possible. Besides the work period is shorter and the work cost is relatively inexpensive. C	There is no problem in reliability of steel pipe sheet pile end fixing structure and cut-off. Rock excavation becomes difficult when its strength exceeds Qu=800kg/cm2. △

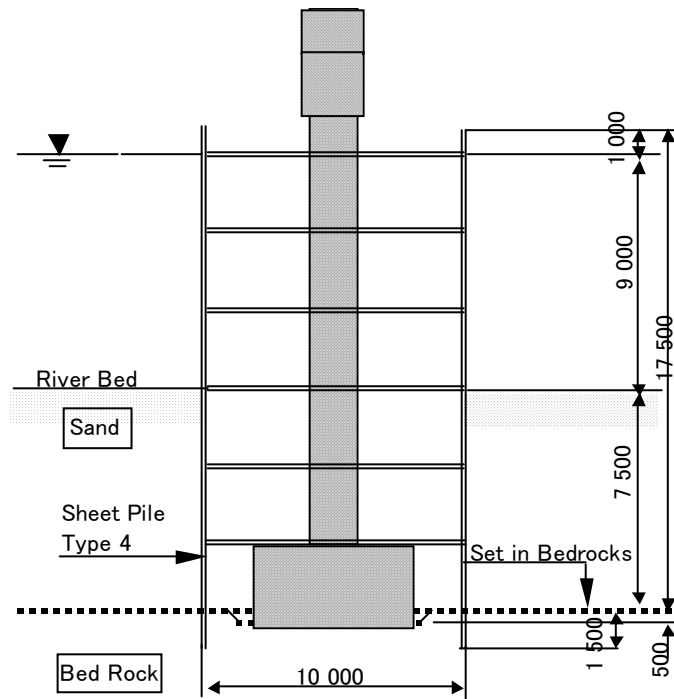


Fig. 6.9.2 Typical Arrangement of Steel Sheet Pile Cofferdam

Bulk excavation will be carried out using backhoe excavators or clamshells and pumps will be maintained in the excavation pit to lower the water table, as required.

6.9.2. Erection of PC I-girder

Erection of PC I-girders of Kelani River bridge shall be proceeded using an erection girder which is the same as PC I-girder bridge over 25m span's.

An erection girder system set up on rails will launch the PC I-girders from the abutments to the first span. Figures 6.9.3 and 6.9.4 illustrate the arrangement of the erection girder system proposed. Once transported to the span being erected, the beams will be shifted into their final position over the elastomeric bearing pads with the aid of lateral winching system on rollers. Upon completing the erection of the first span the erection girder crane system shall be moved ahead to launch the following spans in series.

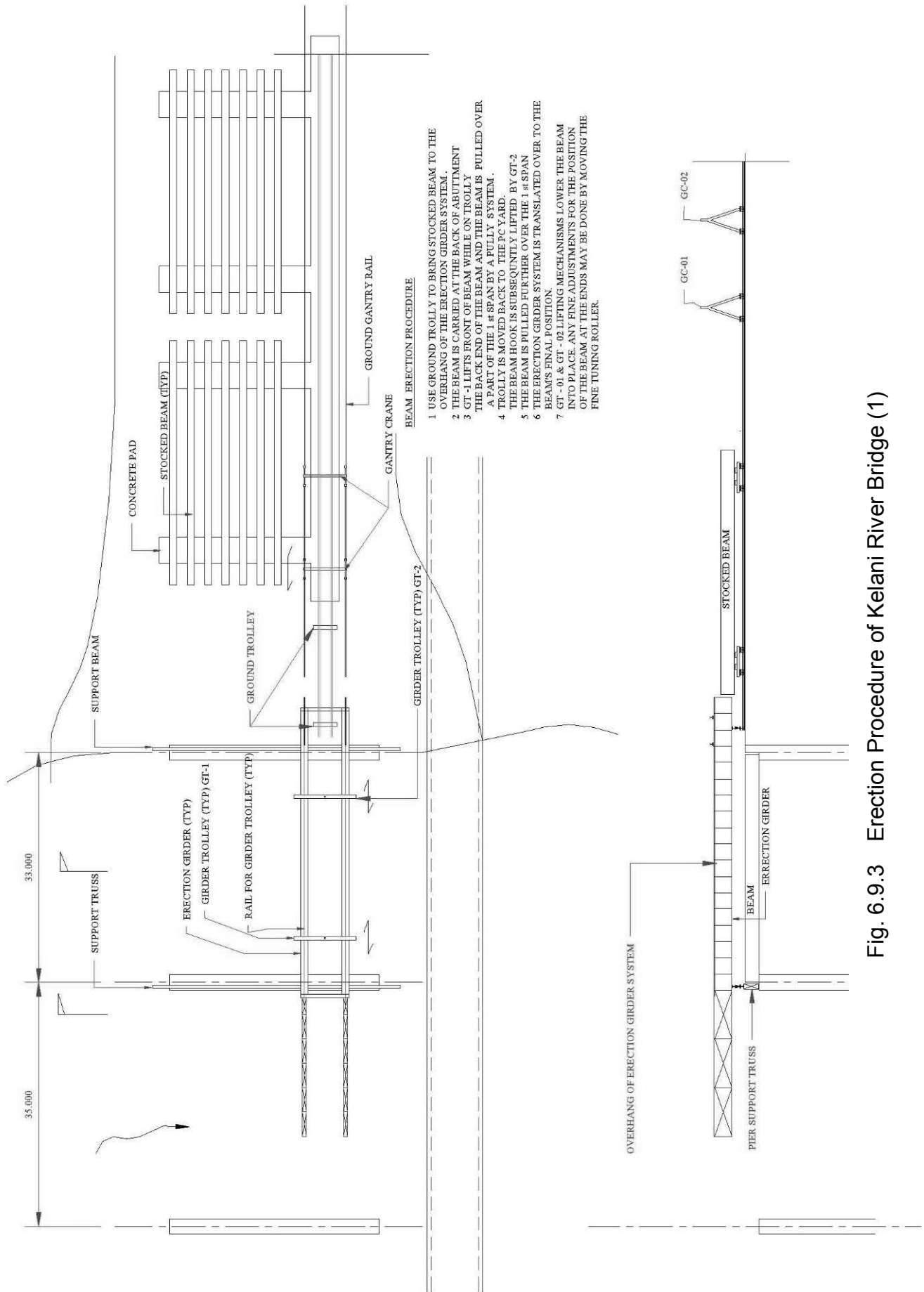


Fig. 6.9.3 Erection Procedure of Kelani River Bridge (1)

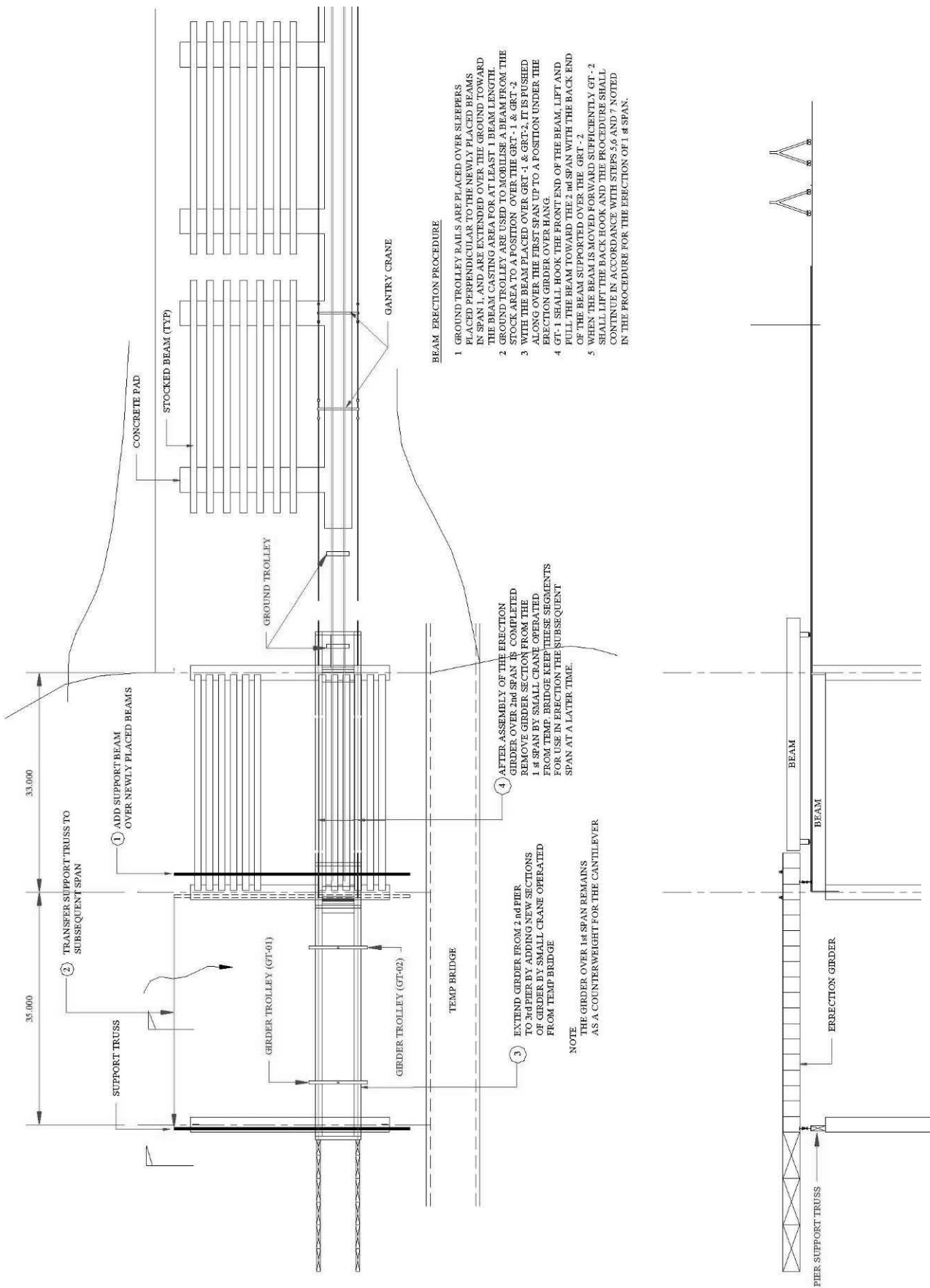


Fig. 6.9.4 Erection Procedure of Kelani River Bridge (2)

6.10 Construction Schedule

6.10.1. General

Taking into account the large volume of earthwork and number of bridge structures, the possible construction period was set at 4 years for each package.

The construction time schedules for each package are planned as shown in Table 6.10.2.

6.10.2. Effective Working Days

Working day ratio for the project is estimated according to rain days (daily rainfall over 10mm), Sunday and holidays. Table 6.10.1 shows detail data of above factors.

Table 6.10.1 Working Days Rate

Month		1	2	3	4	5	6	7	8	9	10	11	12
Rainy Day (Over 10mm)		5.75	3.25	5.75	8.00	11.50	6.50	4.00	4.25	6.00	12.50	11.50	5.25
Holiday	Sunday	4	4	4	4	4	4	4	5	4	4	4	4
	National Holiday	2	2	1	3	3	1	2	0	1	1	1	2
	Other Holiday				4								
Dates of overlapping holiday & rainy day		1.11	0.70	0.93	2.93	2.60	1.08	0.77	0.69	1.00	2.02	1.92	1.02
Monthly dates		31	28	31	30	31	30	31	31	30	31	30	31
Number of days worked		20.4	19.4	21.2	13.9	15.1	19.6	21.8	22.4	20.0	15.5	15.4	20.8
Rate of operation		0.66	0.69	0.68	0.46	0.49	0.65	0.70	0.72	0.67	0.50	0.51	0.67
Ave. of Operation Rate		0.62											

Rainy Season Avrage (4, 5, 10, 11) : **0.491**
 Dry Season Avrage (1, 2, 3, 6, 7, 8, 9,12) : **0.681**

* Rainfall data: Average btw. 2001 & 2003 (Homagama)

CHAPTER 7
PRELIMINARY
PROJECT COST ESTIMATES

CHAPTER 7 PRELIMINARY PROJECT COST ESTIMATES

7.1. General

Preliminary project cost is estimated for the basic design of the Northern section (Packages 1 and 2). To arrive at total Project cost, unit rates were prepared applying the Sri Lanka Highway Schedule of Rates (HSR) and the Japanese Cost Estimation Standard. When these two were not applicable, consultations were held with relevant contractors to obtain unit-cost information. In addition, costs were compared with those of recent major road construction projects funded by international donor agencies in Sri Lanka to confirm their reliability. Note that cost for each package is composed of:

- Construction Cost
- Engineering Services Cost (tender assistance/supervision services)
- Land Acquisition and Resettlement Cost
- Cost for Relocation of Public Utilities (electricity, telephone lines and water supply)

The basic assumptions and methods for estimating Project costs are as follows:

- 1) Private contractor(s) carry out all construction work.
- 2) The unit cost of each cost component is estimated by applying the HSR for fiscal year 2003, the Japanese Civil Work Estimation Standard of 2004, the Japanese Bridge Erection cost estimates of 2003, and information collected from interviews with relevant contractors. Note that the HSR is mainly for small-scale road works, while the Japanese cost estimation standards are mainly for determining PC bridge and large-scale roadwork costs.
- 3) When the HSR and Japanese standards are inadequate for providing the unit cost for a particular item, then interviews are held with local contractors to gather the necessary data to determine the appropriate cost.
- 4) Land acquisition cost is based on market prices and on data from the Sri Lanka Land Acquisition Department.
- 5) Physical contingency is estimated to be 10% of the total cost for construction and engineering services and includes an allowance for price escalation for labor, material and equipment.
- 6) Currency exchange rate: Rs. 1 = JPY 1.010 (average for November 2004)
- 7) Taxation
 - (a) Construction Works: 15% VAT
 - (b) Consulting Services: 15% VAT

7.2. Procurement

7.2.1. Labor Force

Local contractors carry out most of the general road work in Sri Lanka and hence there is an ample labor pool with skills in civil works, except for when specific skills in fields such as pre-stressed concrete are required. Note that there are several post-tensioned concrete bridges in this Project, but there are some local construction firms that have the capacity to undertake this work.

7.2.2. Supply of Machinery and Materials

As it is difficult to procure special machinery and high-grade materials to ensure the quality required for bridges in Sri Lanka, most of these materials and machinery will have to be imported.

(1) Construction Materials

Major materials required for the Project and their availability in Sri Lanka are as shown in the table below.

Table 7.2.1 Availability of Material in Sri Lanka

Material	Production & Supply in Sri Lanka	Availability in Sri Lankan Market	Price for Cost Estimation
Cement	Sufficient	Available	Market price
Reinforcement bar	Diameter (D≤32mm)	Available	Market price
Asphalt	Sufficient	Available	Market price
Shaped steel	Not produced	Only small size Available	Market price
PC strand cable	Not produced	Not available	Imported price
Bridge bearing	Not produced	Not available	Imported price
Expansion joint	Not produced	Not available	Imported price

(2) Ready-mixed Concrete and Asphalt

There are eight companies that can produce and supply ready-mixed concrete in the Colombo region. According to a survey of these plants, it was found that a sufficient volume of ready-mixed concrete for the Project is readily available. As for hot-mixed asphalt, there are several suppliers in the Colombo area and a survey of these plants also shows that they have the capacity to supply the required quantity for the Project.

(3) Construction machinery

Construction machinery includes those owned by private and public companies. Private contractors generally use their own machinery, while some companies lease. Heavy construction machinery such as 50-ton mobile cranes, together with large numbers of dump trucks and backhoes required for the Project, shall be imported to ensure the smooth implementation of the OCH's construction work.

7.3. Unit Cost

7.3.1. Labor

Table 7.3.1 shows the labor unit rates used in estimating construction cost, and includes allowances for social benefits, insurance, etc, and are based on an eight-hour workday.

Table 7.3.1. Unit Rates for Labor (2004)

Classification	Unit Rate (Rs)
Senior Engineer (20 years experience)	70,000/month
Engineer (10 years experience)	46,200/month
Junior Engineer (5 years experience)	31,500/month
Skilled Labor (technician)	630/day
Semi-Skilled Labor	560/day
Unskilled Labor	420/day

7.3.2. Materials

Table 7.3.2 indicates the unit costs for major construction materials. The cost for imported materials is based on the CIF for Colombo, including port handling and clearance charges and import duties. The cost of local materials is based on market prices in the Colombo area.

Table 7.3.2. Unit Rates for Major Materials (2004)

Item	Unit	Unit Rate (Rs)
Portland Cement	Ton	7,800
Ready-Mixed Concrete (Grade 30)	m ³	5,850
Reinforcement Steel Bar (Grade 460)	Ton	62,500
Hot-Mixed Asphalt	Ton	3,925
Petrol	Liter	70
Diesel	Liter	50

7.4. Quantity of Major Work

Highway construction consists of earthwork, pavement, bridges, road structures and other works. These major work items and their quantities are described in Chapter 6.

7.5. Cost Estimate for Compensation

7.5.1. General

The total number of structures affected, all of which are within 50 to 80 meters of the right of way (ROW) of the OCH, was estimated from a field survey using 1:5000 maps based on aerial photographs taken in 1999. Note that the total length of the OCH is 28.1 km and will extend from the Colombo-Negombo Road (A3) at Km 0.9 in the north to the Colombo-Rathnapura Road at Km 27.9 in the south. The OCH is to be designed as a limited-access road having four interchanges at designated locations to connect with the local road system.

Although it has not been possible to mark the centerline at some sections due to objections raised by local residents, a Social Impact Assessment Study for the OCH in February 2000 provides details of the costs for the demolition of residential, commercial

and other buildings, as well as for the costs of land acquisition within a 100 meter corridor based on aerial photographs and field surveys over a distance of about 48 km. The study also gives the average floor areas of different types of houses and other buildings for each administrative Divisional Secretariat unit. Note that the number and types of structures within 50 to 80 meters of the OCH's ROW for a distance of 28.1 km were estimated in a field survey in November 2001.

Residential properties were classified as two-storied houses/commercial structures, large single-storied houses/commercial structures, medium single-storied houses/commercial structures, small single-storied houses/commercial structures, and houses/commercial structures under construction. Non-residential buildings were classified according to their use (i.e., warehouses, factories, etc.). The approximate numbers of structures in the ROW were counted by walking along the trace with the help of 1:5000 scale maps. The actual number of houses and other structures will be known exactly only after the marking of the centerline and the fixing of pegs to demarcate the land area to be acquired by the surveyors, and after a list of the affected structures to be prepared by an Inventory Losses Survey is made available.

7.5.2. Average Floor Area of Houses and Other Structures

To estimate the costs for compensation of structures, the consultants referred to the average floor area for various types of houses and other structures collected during the field survey of 2000. The estimated floor areas for different types of houses in the field survey were: 1) a two-storied house/commercial structure (2500 sq. feet), 2) a large single-storied house/commercial structure (1500 Sq. feet), 3) a medium single-storied house/ commercial structure (1000 Sq. feet) and a small single-storied house/commercial structure (800 sq. feet). The proposed road will also affect non-residential structures; namely, a warehouse, school building, factory, container yard and a Mahila Samithi Center. The average floor area of these commercial structures and other buildings are based on the field survey of 2000 that used aerial photographs (1999).

7.5.3. Compensation Rates for Affected Structures

Compensation rates for houses and other structures are still preliminary and were obtained from construction companies and valuation officers. The compensation rate for each type of structure varies significantly according to the age of the structure, materials used, etc. Therefore, preliminary unit rates reflect the current market value of a structure or the construction cost of a similar unit to serve as a replacement. These preliminary rates are: 1) a two-storied house/commercial structure and other buildings (Rs. 1,850/sq.ft.), 2) large and medium single-storied buildings (Rs. 1,250/sq.ft.), and 3) small single-storied buildings (Rs. 1,000/sq.ft.). The table below indicates the cost estimates for compensation for the OCH.

Table 7.5.1. Compensation (Replacement Cost)for Houses & Other Structures for the OCH

Types	No.	Amount (Rs.)
<Houses>		
Two storied	11	51,152,500
Single storied, large	234	425,074,800
Single storied, medium	194	242,500,000
Single storied, small	49	39,200,000
Under Construction	3	2,250,000
Total	491	760,177,300
<Commercial Buildings>		
Two storied	6	51,796,300
Single storied, large	3	2,730,600
Single storied, medium	2	2,500,000
Single storied, small	8	6,400,000
Total	19	63,426,900
<Other Structures>		
Construction Yard	1	4,000,000
Factory	1	8,000,000
School	1	4,000,000
Warehouse	1	5,000,000
Other	0	-
Total	4	21,000,000
GRAND TOTAL	514	844,604,200

Note: Compensation means replacement cost for houses and other structures

7.5.4. Cost Estimates for Land Compensation

Land use along the trace for a 50-80 meter corridor was determined using 1:5000 scale map based on aerial photographs. Note that the planimeter was used to categorize land use into different types: gardens, built-up areas, paddy fields, coconut trees, rubber trees, and marsh.

Compensation rates for different land uses are based on average land values reported in a field survey conducted in 2000 (EIA report, page 152). Additional data regarding land values was obtained from the Land Acquisition Department.

According to the Social Impact Assessment (SIA) study, valuation officers establish the compensation rates. The field survey confirms that the land values mentioned in the SIA study are current land market values for the relevant divisional secretariats. The table below contains compensation estimates for the different categories of land for the OCH.

Table 7.5.2. Compensation (Replacement Cost) for Land for the OCH

Type of Land	Area (ha)	Amount (Rs.)
Garden	66.03	3,259,872,800
Paddy Field	77.50	73,781,800
Coconut Trees	6.04	41,255,900
Rubber Trees	0.79	1,729,200
Marsh	56.32	95,934,400
Total		3,472,574,100

7.6. Total Project Cost

The estimated cost for the OCH Project is comprised of construction costs (such as earthwork, pavement work, road structures, traffic facilities, bridges, culverts and drainage), land acquisition and compensation costs, engineering services cost, administration costs, and physical and price escalation contingencies.

The estimated cost for the OCH is as shown below:

Table 7.6.1. Total Project Cost for the OCH

Unit: million RS				
No.	Work Item	Northern		Southern
		Package 1	Package 2	Package 3
A	Construction Cost			
1	Earthwork (including Soft Soil improvement)	3,580	2,491	4,977
2	Pavement & Base	536	518	744
3	Structure : Bridge	1,714	2,181	1,361
	: Box Culvert	450	277	557
	: Retaining Wall	29	0	45
4	Drainage	346	162	445
5	Incidentals & Facilities	534	484	518
6	Preliminaries, Dayworks, Provisional Sums	755	688	826
	Contingency (10% of 1-6)	794	680	947
A	Construction Cost Total	8,738	7,481	10,420
B	Engineering Services (incl. 10% of contingency)	598	512	676
	Total of A+B	9,336	7,993	11,096
C	Administration Cost of RDA	44	37	52
D	Land Acquisition & Resettlement	2,222	980	1,326
	TOTAL PROJECT COST	11,602	9,010	12,474

Note: Resettlement costs extracted from Resettlement Implementation Plan (March 2004)

CHAPTER 8
IMPLEMENTATION PROGRAM

CHAPTER 8 IMPLEMENTATION PROGRAM

8.1. General

The implementation program for the OCH project had been considered as consisting of three contract packages in the Basic Design of 2001. Package 1 was to consist of an 8.75km length of section from the Kelwarapitiya land reclamation area to Rt. A1 via CKE and Rt. A3. Package 2 was to consist of an 8.25km length of section from Rt. A1 to Rt. AB10 and include the construction of the Kelani Bridge. Finally, Package 3 was to consist of a 12.10km length of section from Rt. AB10 to Rt. A4 and link up with the STDP.

In this Study, the implementation program for the OCH Project has been re-considered and is to consist of two sections: the Southern Section, which is the same as the above Package 3, and the Northern Section, which consists of Package 1 and 2.

8.2. Construction Phasing

In the Study, the basic design and detailed design work of the OCH was conducted assuming that in the initial stages there would be a dual carriageway with four lanes that would ultimately be widened to six lanes. In this chapter, only the initial stage is considered.

8.3. Implementation Schedule

The Project implementation schedule should be consistent with the technical realities of a project and should ensure the proper sequencing of activities, taking into account institutional capabilities and the availability of resources for construction. The suggested implementation schedule for the Southern Section of OCH is shown in the bar chart in **Fig. 8.3.1**. The Northern Section, which will be implemented later, will require approximately the same processes. Note that the schedule is composed of a number of events and includes the following:

- **Procurement of Supervision Consultant**
After the conclusion of the E/N and L/A, a minimum of twelve months is required for the procurement of a consultant for construction supervision.
- **Acquisition and Resettlement**
The legal process for acquisition and resettlement should be undertaken in parallel with the detailed design. All land should be acquired and cleared prior to the award of the construction contracts.
- **Pre-construction**
According to the JBIC ODA loan process, four months is required for the pre-qualification of contractors prior to the tender procedure.
- **Contractor Selection**
Twelve months may be required for the two-envelope method.

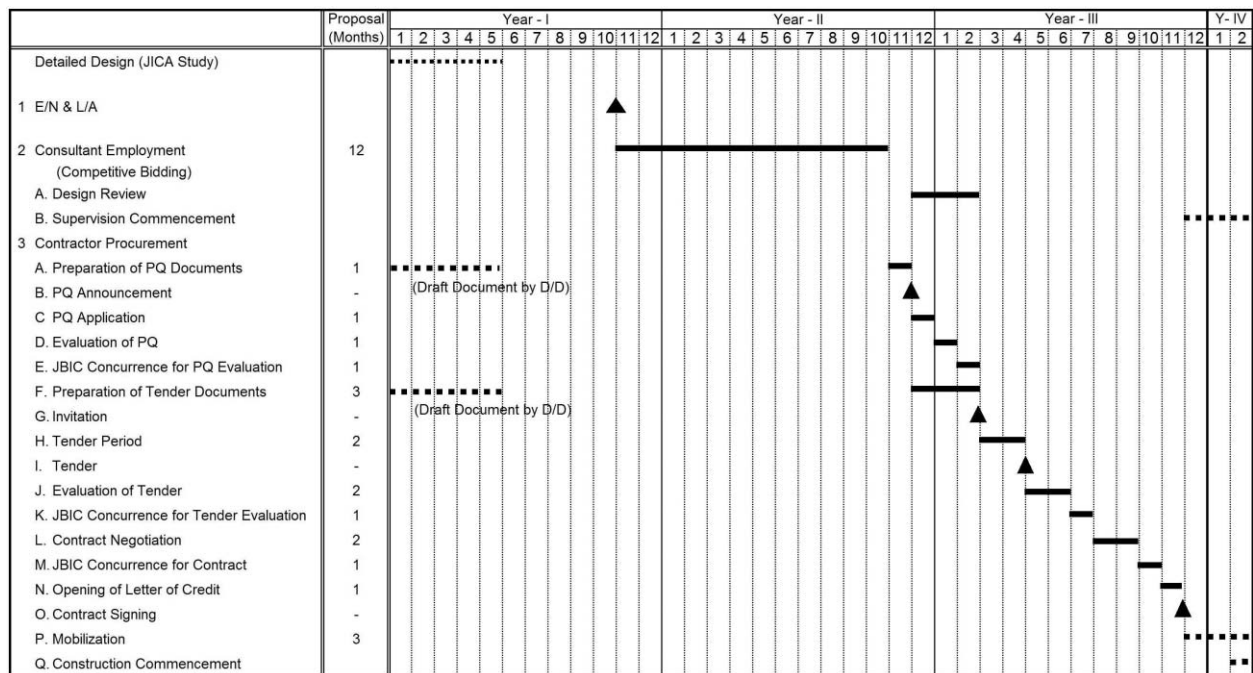


Fig. 8.3.1 Implementation Schedule for OCH

8.4. Cost and Disbursement Schedule

After finalizing the implementation schedule, the disbursement schedule will be established of total implementation costs for the initial stage construction at detailed design stage.

APPENDIX

APPENDIX 3.5

Traffic Demand Forecast at Interchange
(Data of Turning movements)

APPENDIX 3.5

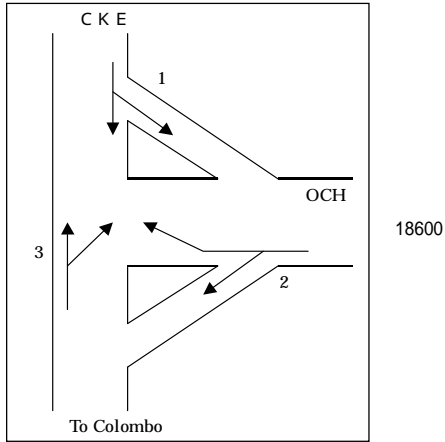
Traffic Demand Forecast at Interchange (Data of Turning Movements)

Daily Traffic Volume at Interchanges of Outer Circular Highway for 2020

Full OCH (CKE - A4)

(Unit: Veh)

Interchange 1 (OCH - CKE)



	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
1 Straight	18000	11500	0	0	4600	1900	6500	36.1
Left	5000	2900	0	0	1800	300	2100	42.0
2 Right	3100	1800	0	0	1100	200	1300	41.9
Left	8400	6100	0	0	1800	500	2300	27.4
3 Straight	20700	13500	0	0	4600	2600	7200	34.8
Right	2100	1100	0	0	900	100	1000	47.6

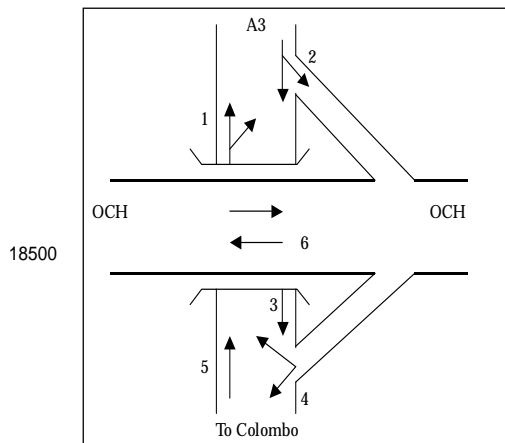
OCH IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH(S)-CKE	11500	7900	0	0	2900	700	3600	31.3
CKE-OCH(N)	0	0	0	0	0	0	0	0.0
CKE-OCH(S)	7100	4000	0	0	2700	400	3100	43.7
OCH(N)-CKE	0	0	0	0	0	0	0	0.0

CKE IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH-CKE	3100	1800	0	0	1100	200	1300	41.9
Colombo-OCH	2100	1100	0	0	900	100	1000	47.6
CKE-OCH	5000	2900	0	0	1800	300	2100	42.0
OCH-Colombo	8400	6100	0	0	1800	500	2300	27.4

Interchange 2 (OCH - A3)



	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
1 Straight	41100	22000	3500	7800	3200	4600	7800	19.0
Right	0	0	0	0	0	0	0	0.0
2 Straight	23600	11300	2300	5400	2400	2200	4600	19.5
Left	7500	5500	0	0	1100	900	2000	26.7
3 Straight	23600	11300	2300	5400	2400	2200	4600	19.5
4 Right	8200	6200	0	0	600	1400	2000	24.4
Left	0	0	0	0	0	0	0	0.0
5 Straight	32900	15800	3500	7800	2600	3200	5800	17.6
6 East	7000	4000	0	0	2600	400	3000	42.9
West	11500	7900	0	0	2900	700	3600	31.3

OCH IC(1)

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH(S)-A3	8200	6200	0	0	600	1400	2000	24.4
	0						0	0.0
	0						0	0.0
	0						0	0.0

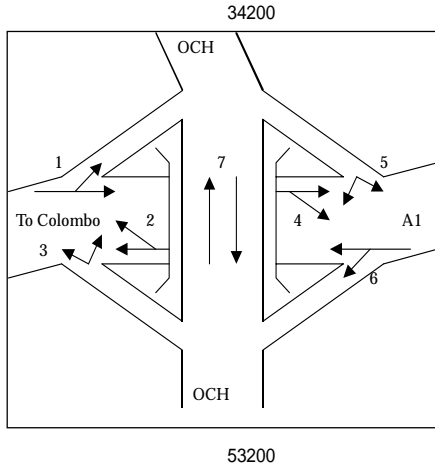
OCH IC(2)

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH(S)-A3	0	0	0	0	0	0	0	0.0
A3-OCH(S)	7500	5500	0	0	1100	900	2000	26.7
	0						0	0.0
	0						0	0.0

A3 IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH(S)-Colombo	0	0	0	0	0	0	0	0.0
Colombo-OCH(S)	0	0	0	0	0	0	0	0.0
A3-OCH(S)	7500	5500	0	0	1100	900	2000	26.7
OCH-A3	8200	6200	0	0	600	1400	2000	24.4

Interchange 3 (OCH - A1)



	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
1 Straight	15800	7800	900	2800	2300	2000	4300	27.2
Left	300	100	0	0	200	0	200	66.7
2 Straight	16000	7800	1500	3300	1800	1600	3400	21.3
Right	3100	1900	0	0	1000	200	1200	38.7
3 Right	7600	4600	0	0	2200	800	3000	39.5
Left	5800	3900	0	0	800	1100	1900	32.8
4 Straight	20300	10200	900	2800	3900	2500	6400	31.5
Right	3000	2200	0	0	500	300	800	26.7
5 Right	100	0	0	0	100	0	100	100.0
Left	2200	1200	0	0	900	100	1000	45.5
6 Straight	18900	9700	1500	3300	2700	1700	4400	23.3
Left	8300	5400	0	0	2300	600	2900	34.9
7 North	16300	12100	0	0	2300	1900	4200	25.8
South	12200	8300	0	0	2700	1200	3900	32.0

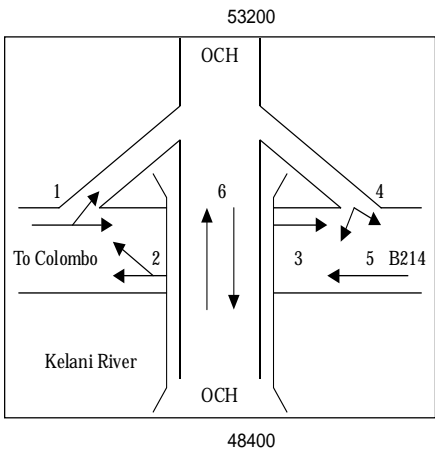
OCH IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH(N)-A1	2300	1200	0	0	1000	100	1100	47.8
A1-OCH(N)	3400	2000	0	0	1200	200	1400	41.2
A1-OCH(S)	11300	7600	0	0	2800	900	3700	32.7
OCH(S)-A1	13400	8500	0	0	3000	1900	4900	36.6

A1 IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH-Colombo	5900	3900	0	0	900	1100	2000	33.9
A1-OCH	11400	7300	0	0	3300	800	4100	36.0
Colombo-OCH	3300	2300	0	0	700	300	1000	30.3
OCH-A1	9800	5800	0	0	3100	900	4000	40.8

Interchange 4 (OCH - B214)

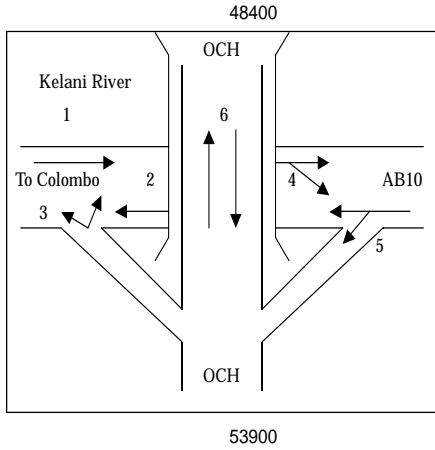


	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
1 Straight	5500	2600	400	1100	600	800	1400	25.5
Left	100	0	0	0	100	0	100	100.0
2 Straight	9300	4300	900	2100	700	1300	2000	21.5
Right	2200	1300	0	0	700	200	900	40.9
3 Straight	5500	2600	400	1100	600	800	1400	25.5
4 Right	600	300	0	0	300	0	300	50.0
Left	1900	1200	0	0	600	100	700	36.8
5 Straight	11000	5300	900	2100	1200	1500	2700	24.5
6 North	27300	19300	0	0	4500	3500	8000	29.3
South	21100	14400	0	0	4700	2000	6700	31.8

B214 IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
Colombo-OCH(N)	2300	1300	0	0	800	200	1000	43.5
OCH(N)-B214	2500	1500	0	0	900	100	1000	40.0

Interchange 5 (OCH - AB10)

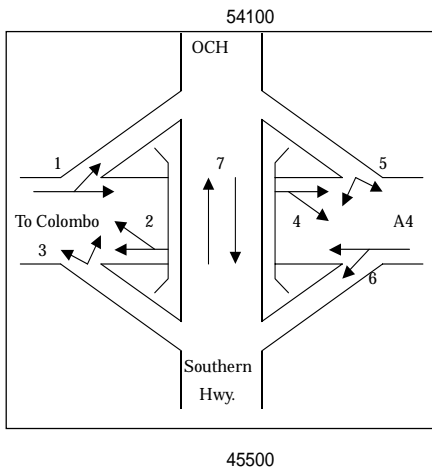


	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
1 Straight	7700	4300	300	800	1000	1300	2300	29.9
2 Straight	8500	4500	600	1300	700	1400	2100	24.7
3 Right	1200	700	0	0	200	300	500	41.7
3 Left	1100	700	0	0	200	200	400	36.4
4 Straight	7800	4300	300	800	800	1600	2400	30.8
4 Right	1100	700	0	0	300	100	400	36.4
5 Straight	8500	4500	600	1300	700	1400	2100	24.7
5 Left	2100	1500	0	0	300	300	600	28.6
6 North	27300	19300	0	0	4500	3500	8000	29.3
6 South	21100	14400	0	0	4700	2000	6700	31.8

AB10 IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
AB10-OCH(S)	3200	2200	0	0	600	400	1000	31.3
OCH(S)-Colombo	2300	1400	0	0	400	500	900	39.1

Interchange 6 (OCH - A4)



	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
1 Straight	19600	9600	900	2300	4700	2100	6800	34.7
1 Left	6500	4200	0	0	1500	800	2300	35.4
2 Straight	29200	17200	1700	3800	4000	2500	6500	22.3
2 Right	7700	5300	0	0	1500	900	2400	31.2
3 Right	2700	1800	0	0	700	200	900	33.3
3 Left	5900	4300	0	0	900	700	1600	27.1
4 Straight	19600	10100	900	2300	4400	1900	6300	32.1
4 Right	2800	1400	0	0	1000	400	1400	50.0
5 Right	4600	3600	0	0	600	400	1000	21.7
5 Left	4400	2400	0	0	1500	500	2000	45.5
6 Straight	32300	18900	1700	3800	4900	3000	7900	24.5
6 Left	3200	2000	0	0	1000	200	1200	37.5
7 North	15500	11200	0	0	1900	2400	4300	27.7
7 South	15400	10600	0	0	3300	1500	4800	31.2

OCH IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
A4-OCH(N)	14200	9500	0	0	3000	1700	4700	33.1
OCH(N)-A4	9000	6000	0	0	2100	900	3000	33.3
SH-A4	8600	6100	0	0	1600	900	2500	29.1
A4-SH	6000	3400	0	0	2000	600	2600	43.3

A4 IC

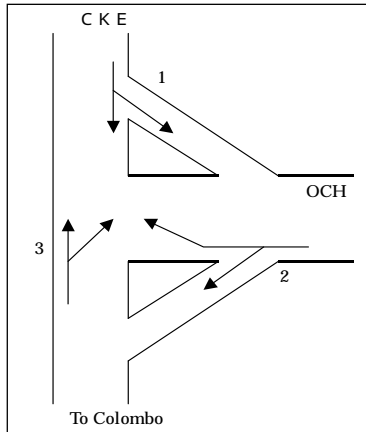
	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
Colombo-OCH	9300	5600	0	0	2500	1200	3700	39.8
OCH-A4	7100	4200	0	0	2200	700	2900	40.8
OCH-Colombo	10500	7900	0	0	1500	1100	2600	24.8
A4-OCH	10900	7300	0	0	2500	1100	3600	33.0

Daily Traffic Volume at Interchanges of Outer Circular Highway for 2027

Full OCH (CKE - A4)

(Unit:Veh)

Interchange 1 (OCH - CKE)



29100

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
1 Straight	21500	14000	0	0	5400	2100	7500	34.9
Left	6100	3800	0	0	1800	500	2300	37.7
2 Right	7400	4700	0	0	2200	500	2700	36.5
Left	9400	6900	0	0	1800	700	2500	26.6
3 Straight	24300	16100	0	0	5300	2900	8200	33.7
Right	6200	3400	0	0	2300	500	2800	45.2

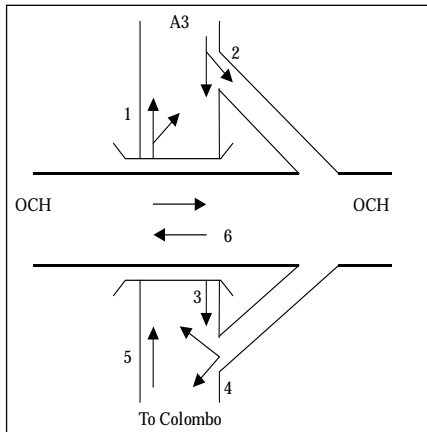
OCH IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH(S)-CKE	16800	11600	0	0	4000	1200	5200	31.0
CKE-OCH(N)	0	0	0	0	0	0	0	0.0
CKE-OCH(S)	12300	7200	0	0	4100	1000	5100	41.5
OCH(N)-CKE	0	0	0	0	0	0	0	0.0

CKE IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH-CKE	7400	4700	0	0	2200	500	2700	36.5
Colombo-OCH	6200	3400	0	0	2300	500	2800	45.2
CKE-OCH	6100	3800	0	0	1800	500	2300	37.7
OCH-Colombo	9400	6900	0	0	1800	700	2500	26.6

Interchange 2 (OCH - A3)



29000

49000

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
1 Straight	53100	28100	4500	10000	4400	6100	10500	19.8
Right	0	0	0	0	0	0	0	0.0
2 Straight	30000	14100	2900	7000	3000	3000	6000	20.0
Left	8800	6200	0	0	1600	1000	2600	29.5
3 Straight	30000	14100	2900	7000	3000	3000	6000	20.0
Right	11200	8600	0	0	1000	1600	2600	23.2
Left	0	0	0	0	0	0	0	0.0
5 Straight	41900	19500	4500	10000	3400	4500	7900	18.9
East	12200	7200	0	0	4100	900	5000	41.0
West	16800	11600	0	0	4000	1200	5200	31.0

OCH IC(1)

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH(S)-A3	11200	8600	0	0	1000	1600	2600	23.2
	0						0	0.0
	0						0	0.0
	0						0	0.0

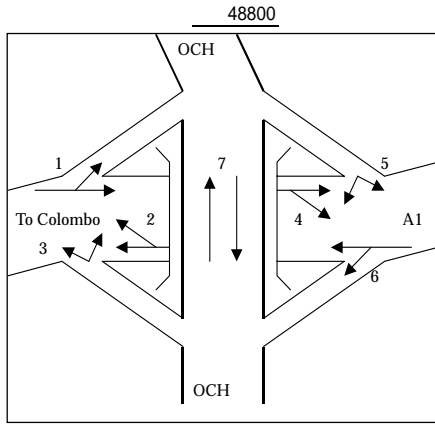
OCH IC(2)

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH(S)-A3	0	0	0	0	0	0	0	0.0
A3-OCH(S)	8800	6200	0	0	1600	1000	2600	29.5
	0						0	0.0
	0						0	0.0

A3 IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH(S)-Colombo	0	0	0	0	0	0	0	0.0
Colombo-OCH(S)	0	0	0	0	0	0	0	0.0
A3-OCH(S)	8800	6200	0	0	1600	1000	2600	29.5
OCH-A3	11200	8600	0	0	1000	1600	2600	23.2

Interchange 3 (OCH - A1)



	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
1 Straight	18200	8700	1200	3600	2600	2100	4700	25.8
1 Left	1200	600	0	0	600	0	600	50.0
2 Straight	19800	9200	2000	4400	2500	1700	4200	21.2
2 Right	7000	4700	0	0	1800	500	2300	32.9
3 Right	8700	5500	0	0	2200	1000	3200	36.8
3 Left	5700	4100	0	0	800	800	1600	28.1
4 Straight	23500	11700	1200	3600	4300	2700	7000	29.8
4 Right	3400	2500	0	0	500	400	900	26.5
5 Right	900	500	0	0	400	0	400	44.4
5 Left	5900	3200	0	0	2200	500	2700	45.8
6 Straight	25800	13400	2000	4400	3800	2200	6000	23.3
6 Left	10200	6700	0	0	2600	900	3500	34.3
7 North	19700	14800	0	0	2600	2300	4900	24.9
7 South	14100	9600	0	0	3100	1400	4500	31.9

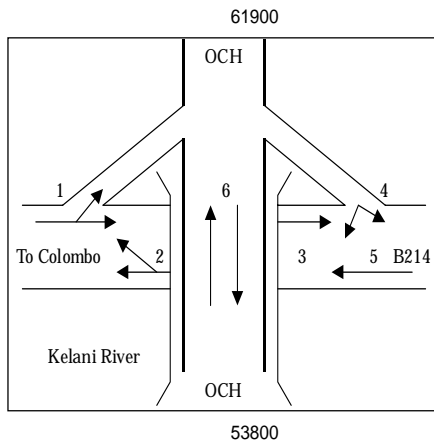
OCH IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH(N)-A1	6800	3700	0	0	2600	500	3100	45.6
A1-OCH(N)	8200	5300	0	0	2400	500	2900	35.4
A1-OCH(S)	13600	9200	0	0	3100	1300	4400	32.4
OCH(S)-A1	14400	9600	0	0	3000	1800	4800	33.3

A1 IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
OCH-Colombo	6600	4600	0	0	1200	800	2000	30.3
A1-OCH	17200	11400	0	0	4400	1400	5800	33.7
Colombo-OCH	4600	3100	0	0	1100	400	1500	32.6
OCH-A1	14600	8700	0	0	4400	1500	5900	40.4

Interchange 4 (OCH - B214)

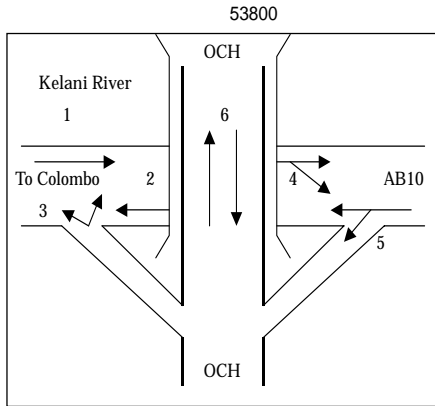


	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
1 Straight	6900	3200	500	1500	700	1000	1700	24.6
1 Left	100	0	0	0	100	0	100	100.0
2 Straight	11000	4900	1000	2500	1000	1600	2600	23.6
2 Right	4300	3100	0	0	800	400	1200	27.9
3 Straight	6900	3200	500	1500	700	1000	1700	24.6
3 Right	700	400	0	0	300	0	300	42.9
4 Left	3000	2100	0	0	600	300	900	30.0
5 Straight	14500	7600	1000	2500	1400	2000	3400	23.4
6 North	29700	21300	0	0	4700	3700	8400	28.3
6 South	24100	16400	0	0	5300	2400	7700	32.0

B214 IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
Colombo-OCH(N)	4400	3100	0	0	900	400	1300	29.5
OCH(N)-B214	3700	2500	0	0	900	300	1200	32.4

Interchange 5 (OCH - AB10)

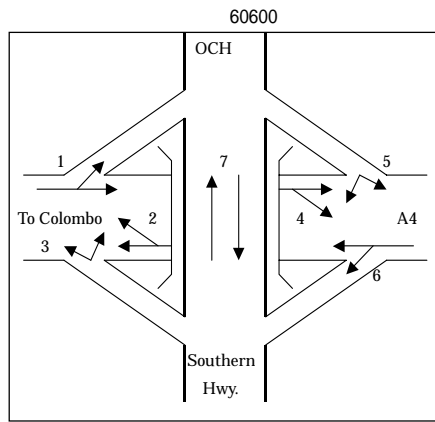


	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
1 Straight	8900	4900	400	1100	800	1700	2500	28.1
2 Straight	8600	4300	600	1500	600	1600	2200	25.6
3 Right	1700	1100	0	0	200	400	600	35.3
3 Left	1300	700	0	0	300	300	600	46.2
4 Straight	9100	4900	400	1100	700	2000	2700	29.7
4 Right	1400	1000	0	0	300	100	400	28.6
5 Straight	8600	4300	600	1500	600	1600	2200	25.6
5 Left	2400	1700	0	0	400	300	700	29.2
6 North	29700	21300	0	0	4700	3700	8400	28.3
6 South	24100	16400	0	0	5300	2400	7700	32.0

AB10 IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
AB10-OCH(S)	3800	2700	0	0	700	400	1100	28.9
OCH(S)-Colombo	3000	1800	0	0	500	700	1200	40.0

Interchange 6 (OCH - A4)



	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
1 Straight	22600	11300	1000	2500	5400	2400	7800	34.5
1 Left	6500	4200	0	0	1500	800	2300	35.4
2 Straight	31700	18400	1900	4200	4400	2800	7200	22.7
2 Right	7900	5500	0	0	1500	900	2400	30.4
3 Right	3500	2400	0	0	800	300	1100	31.4
3 Left	7700	5500	0	0	1200	1000	2200	28.6
4 Straight	22600	11800	1000	2500	5000	2300	7300	32.3
4 Right	3700	2000	0	0	1200	500	1700	45.9
5 Right	4100	3200	0	0	500	400	900	22.0
5 Left	5200	3000	0	0	1600	600	2200	42.3
6 Straight	35500	20700	1900	4200	5400	3300	8700	24.5
6 Left	4500	2800	0	0	1400	300	1700	37.8
7 North	18400	13400	0	0	2200	2800	5000	27.2
7 South	18500	12800	0	0	3800	1900	5700	30.8

OCH IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
A4-OCH(N)	14400	9700	0	0	3000	1700	4700	32.6
OCH(N)-A4	9300	6200	0	0	2100	1000	3100	33.3
SH-A4	11200	7900	0	0	2000	1300	3300	29.5
A4-SH	8200	4800	0	0	2600	800	3400	41.5

A4 IC

	Total	Pass	3-W	MC	Bus	Truck	Hv Nos	(%)
Colombo-OCH	10200	6200	0	0	2700	1300	4000	39.2
OCH-A4	8700	5400	0	0	2400	900	3300	37.9
OCH-Colombo	11800	8700	0	0	1700	1400	3100	26.3
A4-OCH	12400	8300	0	0	2900	1200	4100	33.1

