9.6 Structure Design

The following structures shall be proposed in order to construct the OCH.

(a) Bridges for crossing rivers
(b) Viaducts for crossing existing major roads
(c) Viaducts for crossing existing minor roads
(d) Viaducts for crossing railways
(e) Overpasses for crossing over the OCH
(f) Culverts for crossing under the OCH

9.6.1 Basic Policy of Structure Design

The design basic policy for OCH bridges is considered below.

9.6.1.1 Bridge Design Standard

The RDA drew up a Bridge Design Manual in 1997. The purpose of this Manual is essentially to introduce basic bridge design concepts and to present technical for the guidelines bridge design for highway bridges.

The design of bridges and other related structures in Sri Lanka is carried out in accordance with British Standard (BS) 5400, with certain modifications to suit local conditions. Details on design method, conditions, prescriptions and rules are not described in this Manual. BS 5400 has been basically adopted for bridge design in Sri Lanka, together with other standards such as AASHTO and the Japan Road Association Specification for Highway Bridges (JRA-SHB) for ODA Projects.

Generally, loading is to conform and applied according to BS 5400 part 2. Bridges should be designed to resist the effect of HA or more than 30 units of HB live loading of BS 5400. Bending moment by this live load appears to be smaller than that by the "B live" loading of JRA-SHB for the simple sported bridge at each span length (see Fig. 9.26). Application of the B live loading of JRA-SHB is safer for the design of bridges. However, there is not a big difference between the final shape of a structure whether its based on the BS or JRA-SHB standard.

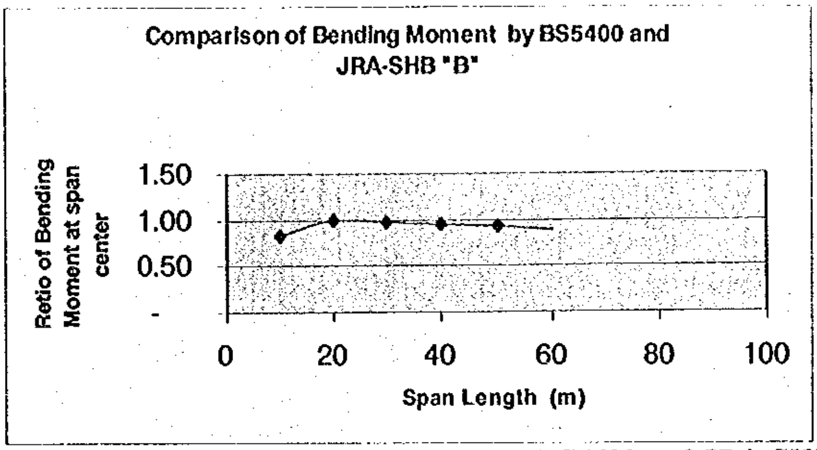


Fig. 9.26 Comparison of Bending Moment by the BS5400 and JRA-SHB "B"

9.6.1.2 Design Basic Conditions

(1) Cross Section of Bridges

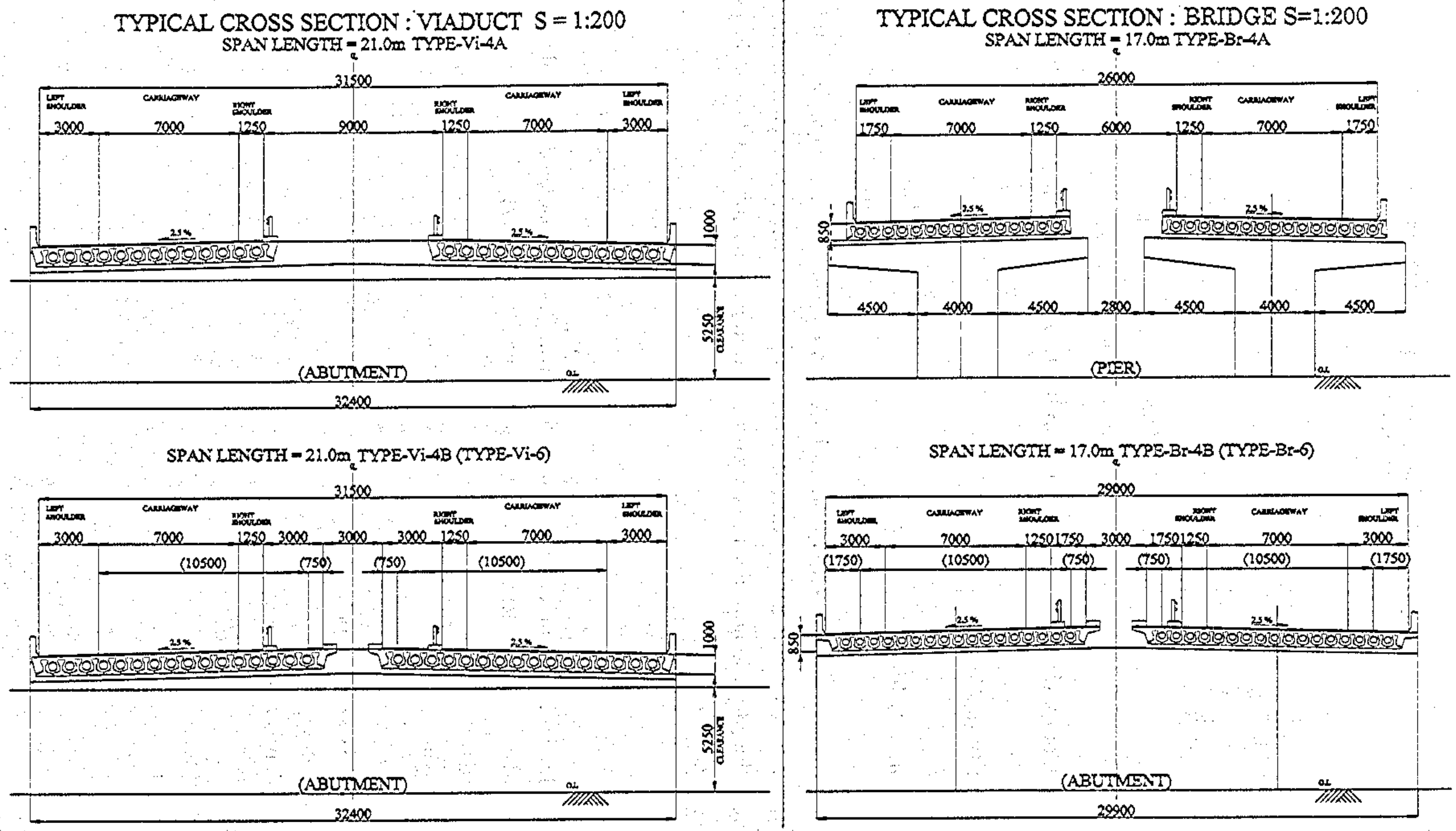
Two types of cross sections for OCH bridges based on the Geometric Design Standards of Roads in Sri Lanka are applied depending on total length. The width of separator and left shoulders are reduced for long bridges to cut costs, as well as to be able to widen to lanes in the future (see Tab. 9.7).

(2) Load

The following loads, which are described in BS5400 part 2, are considered in the design of bridges in accordance with the RDA Bridge Design Manual (RDA1997).

a) Dead Loads
b) Earth Pressure
c) Live Loads
d) Braking & Traction of Vehicles
e) Water Current
f) Floating debris & Impact
g) Wind
h) Temperature
i) Shrinkage

Tab. 9.7 Cross section of Bridges and Viaducts



NOTE: All substructures shall be able to be expanded to 6 traffic lanes.

(3) Crossing Condition

Crossings, of rivers (i.e., bridges) roads and railways (i.e., viaducts) are considered in the design of the OCH for this Study and are described below.

1) River crossing

For designing bridges, the following design items are required:

a) Width and cross- section of rivers
b) Highest water level
c) Maximum current velocity and maximum volume of flood discharge
d) Location or plan shore protection

These data have been obtained from field surveys, existing data, and hearings on residents living near rivers.

In Japan the height and minimum span length of a bridge crossing are decided using the clearance under the deck girder, standard span length, and river obstruction rate, which are prescribed based on the volume of flooding discharge. (See Tab. 9.8, Fig. 9.28.)

Tab. 9.8 Minimum Clearance under the Deck Girder (Japan)

Design flood Discharge Q (m^3/s)	Q < 200	200 <= Q < 500	500 <= Q < 2,000	2,000 <= Q < 5,000	5,000 <= Q < 10,000	10,000< = Q
Clearance under Girder (m)	0.6	0.8	1.0	1.2	1.5	2.0

However, in Sri Lanka, it is only required that the abutment and pier bearing level have a 1.0 m clearance above the highest flood level.

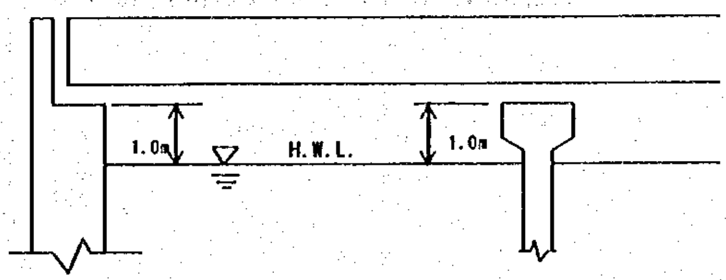


Fig. 9.27 Clearance between Bearing Level and H.W.L. (SLS)

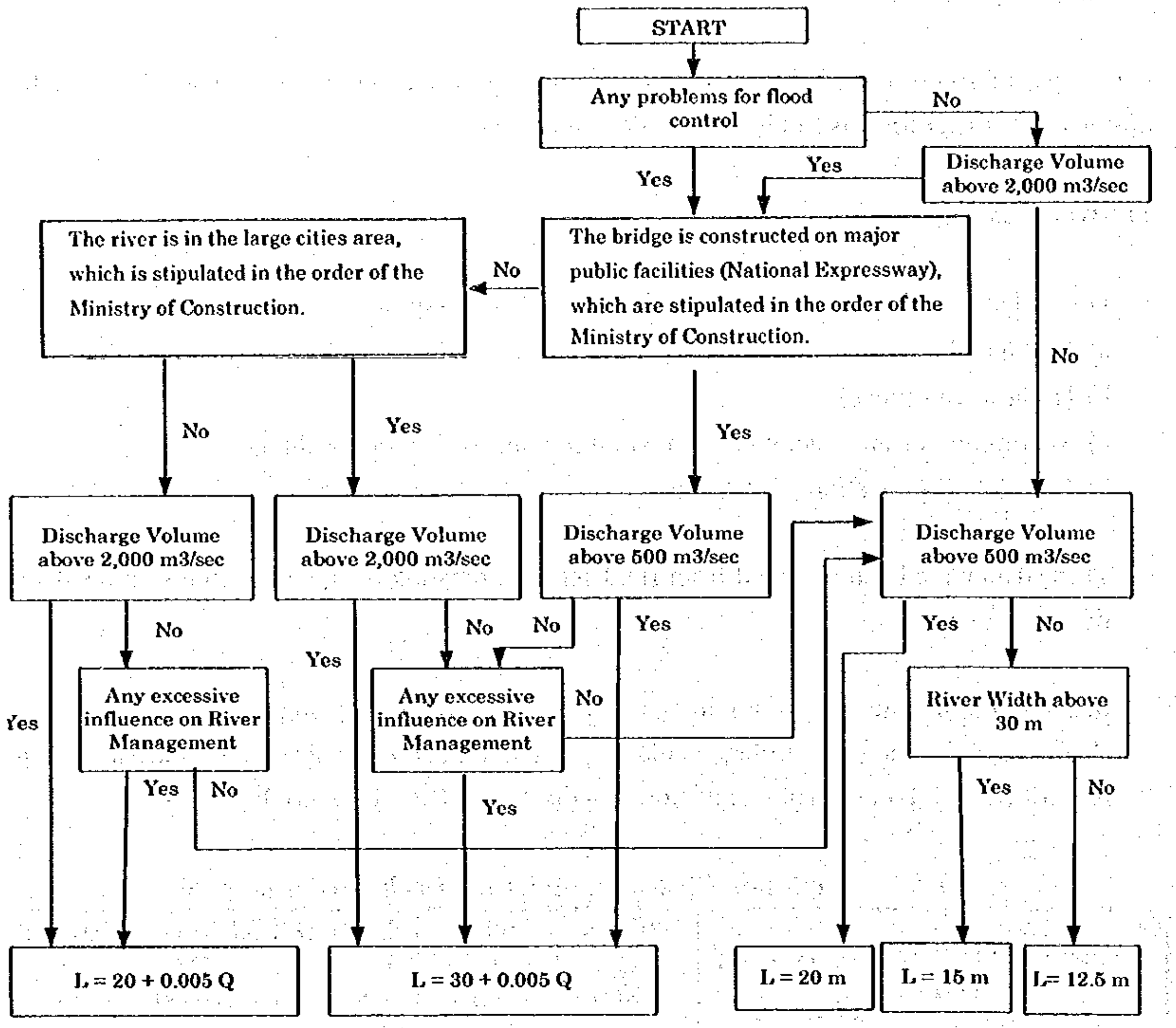


Fig. 9.28 Flow Chart to Determine Minimum Span Length (Japan Highway Public Corporation)

2) Road Crossing

For designing viaducts for crossing a highway, the following design items are required:

a) Minimum vertical clearance:5.25 m (Bridge Design Manual)
b) Road width: Existing road width or planning width

The vertical alignment of a viaduct is determined from the existing road level, clearance, and the viaduct girder height. Viaduct girder height is determined from the type of superstructure.

Existing road width is critical for designing viaduct crossings. In this Study, the design parameters for Class A and B roads are used for major road crossings, while actual existing road width is used for minor local roads that do not have any road improvement plan.

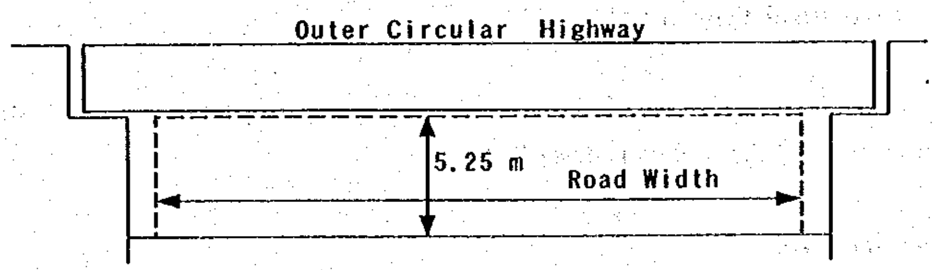


Fig. 9.29.1 Vertical Road Clearance

If the diversion of an existing road can not be carried out during OCH construction, the abutments of the OCH bridge should be set so that excavation does not affect the existing road, which will result in the length of the viaduct becoming longer.

3) Railway Crossing

There are two locations where the OCH for this Study crosses a railway: the Colombo - Kandy Line with a triple-track at Horape near the Halanduruwa marsh and the Colombo - Avissawella Line with a single track at Malapalla near Rt. A4.

For designing viaduct crossings over a railway, the following design items are required :
a) Minimum vertical clearance: 18' = 5.50
b) Structure gauge

As relocating a railway is impossible, the bridge length and construction method should be decided after fully considering the influence on railway traffic. The two affected lines are running on a high embankment in a paddy field or marsh. Hence, it is required that work be carried out for enough away from the foundations to reduce the influence on the railway at the time of OCH construction execution. (See Fig. 9.29.2)

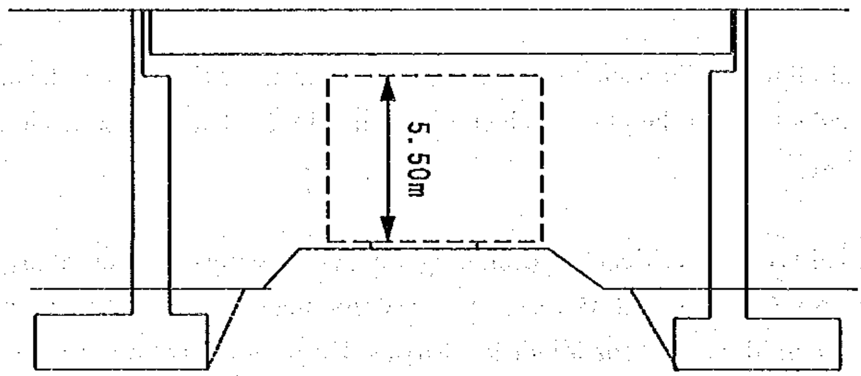


Fig. 9.29.2 Crossing over Railway

9.6.1.3 Structural Type of Bridge

Bridge/viaduct structures are divided into three parts: superstructure, sub-structure and foundation. Each of these parts is described below.

(1) Superstructure

The superstructure is largely either concrete or steel. Concrete bridges are classified into RC and PSC structures. For this Study, superstructure is selected by paying due attention to the following:

(a) Easy maintenance

- Steel bridges may suffer shortened service life due to corrosion.
- Painting of steel materials require periodical treatment, resulting in increased maintenance costs.
- Concrete bridges are free from surface corrosion and maintenance costs can be reduced.

(b) Low cost and superior economical feasibility

- Generally, steel bridges tend to be higher in unit price than concrete bridges for short spans. Especially, in Sri Lanka, it is very difficult to construct a steel bridge and materials need to be imported from other countries.

(c) Employing materials procurable in Sri Lanka

- Principal materials (aggregates, cement and reinforcing bars) must be easily available.

- The use of domestically produced materials will reduce the standard costs.

1) Applicable span for each type of bridge in Japan

The type of superstructure selected depends roughly on the span length of the bridge/viaduct. Tab. 9.10 shows the standard applicable span for each type of superstructure in Japan. Table 9.11(a) and (b) shows the standard applicable span for each type of PC bridge.

2) Standard beam in Sri Lanka

Standard pre-cast pre-tensioned beams are available from 4.3 m up to 16.23 m in Sri Lanka. Combinations of pre-tensioned and post-tensioned beams in pre-cast 16.23 m units are available for spans of 19 m. The maximum length of a beam that can be transported is approximately 16 m in Sri Lanka. Recently 23 m long pre-cast pre-tensioned beams have been designed for the Baseline Improvement Project. These are cast on-site.

Tab. 9.9 Standard Pre-cast Pre-tensioned Beam in Sri Lanka

Length (mm)	Dimension		Quantities	
	Width (mm)	Height (mm)	Concrete Volume (m^3)	Weight (kg)
8,230	600	355	0.94	2,240
9,756	600	355	1.11	2,670
10,746	600	355	1.21	2,910
12,270	600	600	1.62	3,890
13,500	600	600	1.78	4,280
	500	550	1.69	4,060
14,500	500	600	1.96	4,710
15,500	500	650	2.19	5,440
16,500	500	700	2.56	6,160

Insert Tab. 9.10

Tab. 9.10 Standard Applicable Span

	TYPE	SPAN																	Girder Height/span ratio
						50m					100m					150m			
Steel bridge	Simple composite girder			■	■	■													1/18
	Simple girder			■	■	■													1/17
	Continuous girder			■	■	■	■	■											1/18
	Simple box girder				■	■	■												1/22
	Continuous box girder						■	■	■	■	■	■							1/23
	Simple truss						■	■	■	■	■	■							1/9
	Continuous truss						■	■	■	■	■	■	■	■	■	■	■	■	1/10
	Deck langer girder						■	■	■	■	■	■	■	■	■	■	■	■	1/6.5
	Deck lohse girder							■	■	■	■	■	■	■	■	■	■	■	1/6.5
	Arch								■	■	■	■	■	■	■	■	■	■	1/6.5
PC bridge	Pretensioning Girder	■	■																1/15
	Hollow slab		■	■															1/22
	Simple T girder			■	■	■													1/17.5
	Simple composite Girder			■	■	■													1/15
	Connected Continuous Composite girder			■	■														1/15
	Continuous Composite girder			■	■	■													1/16
	Simple box girder			■	■	■													1/20
	Continuous box Girder (cantilever Type)							■	■	■	■	■	■	■	■	■	■	■	1/18
	Continuous box girder (support Type)				■	■	■												1/18
	…… type rigid frame			■	■	■													1/32
	Hollow slab		■																1/20
	Continuous Spandrel - filled arch		■	■															1/2

Tab. 9.11(a) Standard Applicable Span for PC Bridge

			Structural Type	Cross Section of girder	Erection Method	Applicable Span Length (20 40 60 80 100)	Maximum Span Length	Ggirder height/Span Ratio
Simple Girder	Precast Girder	Pretensioned Girder		Hellow slab girder	Crane Erection		(24)	1/24
				T girder	Crane Erection		(24)	1/18
		Posttensioned Girder		T girder	Crane Erection Errection Beam		(45)	1/16
				Composite girder	Crane Erection Errection Beam		40	1/15
	Cast in Place Girder			Hollow slab	All staging		54	1/22
				Box girder	All staging		69	1/17
Connection Girder	Precast Girder	Pretensioned Girder		Hollow slab girder	Crane Erection		(24)	1/24
				T girder	Crane Erection		(24)	1/18
		Posttensioned Girder		T girder	Crane Erection Errection Beam		41	1/16
				Composite girder	Crane Erection Errection Beam		40	1/15

Tab. 9.11(b) Standard Applicable Span for PC Bridge

	Structural Type	Cross Section of girder	Erection Method	Applicable Span Length (20 40 60 80 100 140 180)	Maximum Span Length	Ggirder height/Span Ratio
Continuous Bridge			All Staging Movable talseworks		45	1/22
			All Staging		60	1/20
			Movable talseworks		45	1/20
			Interemental launching method		69	1/16
			Cantilever method		170	*1/18 - 35
			All Staging Movable talseworks		39	1/17
Rigid Frame Bridge	T type rigid frame		All Staging Cantilever method		104	1/20
	Continuous rigid frame		All Staging Cantilever method		153	1/12
	Rigid frame with hinge connection		Cantilever method		240	*1/18 ~ 35
	Fixed bridge with hinge connection		Cantilever method		130	*1/17 ~ 49
	Rigid frame With V Pier		All Staging		70	*1/17 ~ 49
			Cantilever method			-
			All Staging		-	-

3) Basic selection of the bridge type for this Project

The OCH crosses over two major rivers, existing roads and railways. Span length of bridges is expected to be shorter than 35m. Generally, a concrete bridge is less expensive than a steel bridge for construction and maintenance for span lengths of less than 35 m.

Basic PSC beams are selected for this Study as shown in Tab. 9.12, taking into consideration economy, construction, maintenance and domestic material availability.

Tab. 9.12 Basic PSC Beam types for the Project

Span length (m)	Beam Type	Remarks
L < 10	Box culvert	
	Pre-cast pretension beam	Standard Beam in Sri Lanka
10 <= L < 17	Pre-cast pretension beam	Standard Beam in Sri Lanka
17 <= L < 25	Pre-cast pretension beam (Cast in site)	For Viaducts (Many beams are cast at same place)
	Post-tensioned T shape beam	
25 <= L < 30	Post-tensioned T beam	

A continuous bridge (connected beam) type is selected. Connected beams are supported at 2 points at a pier and/or abutment and connected together at the pier reinforcement. This type can reduce the number of expansion joints, construction cost and make for comfortable driving. (See Fig. 9.30.)

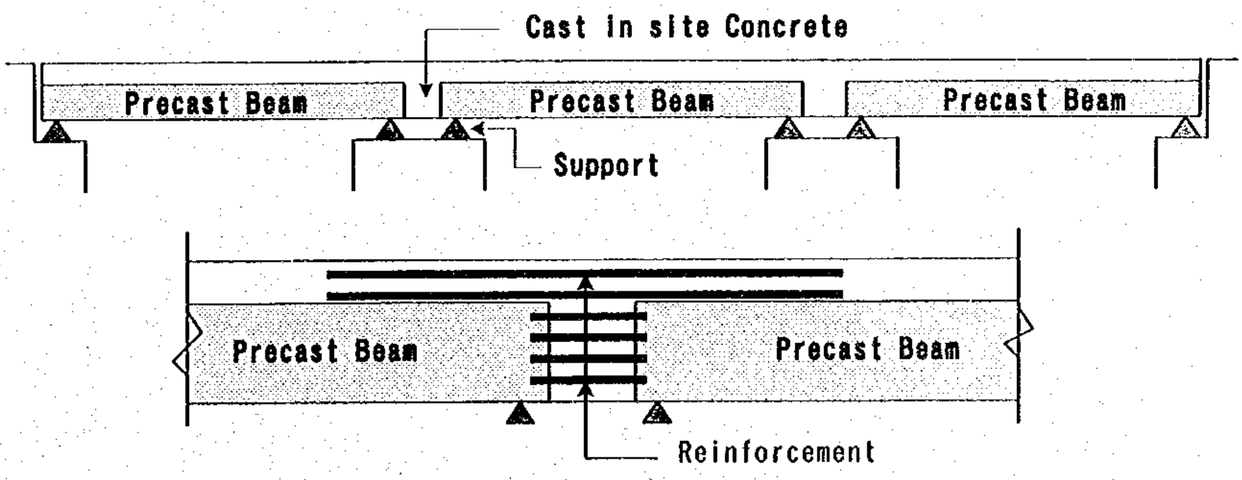


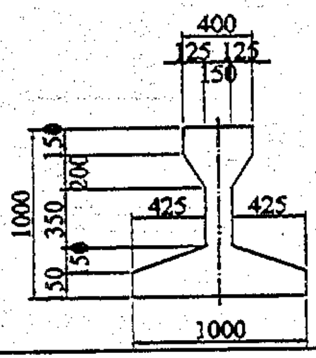
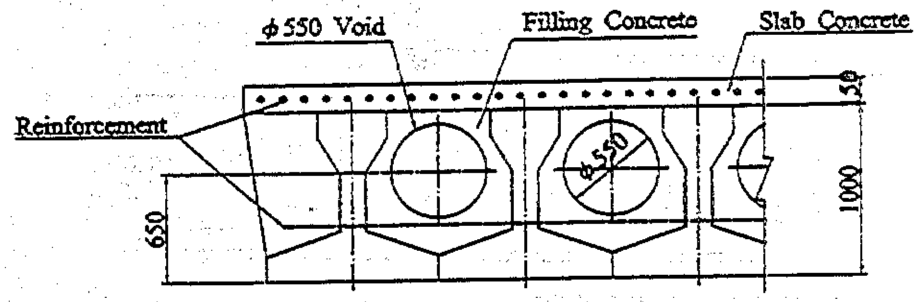
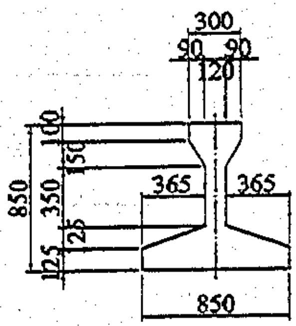
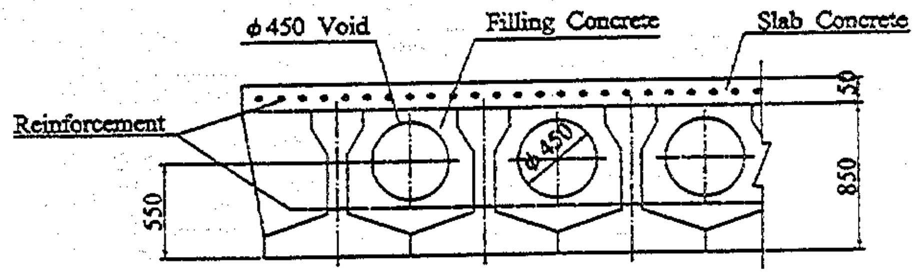
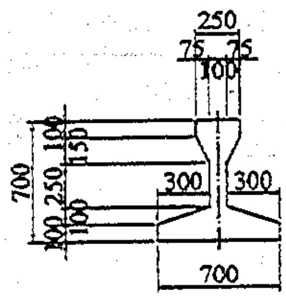
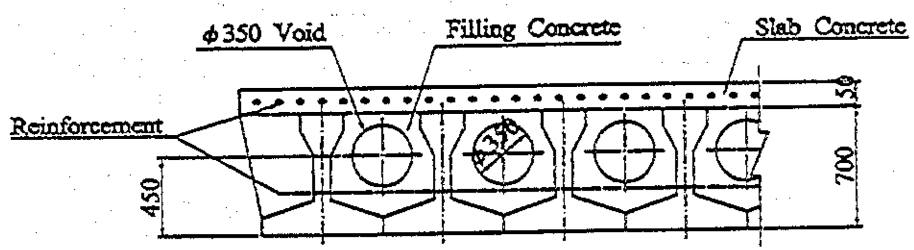
Fig. 9.30 Connection

4) Recommended PSC Girder

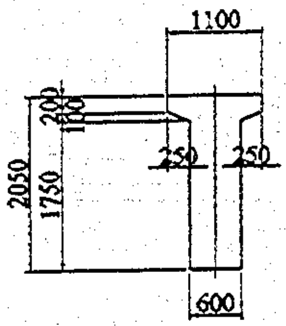
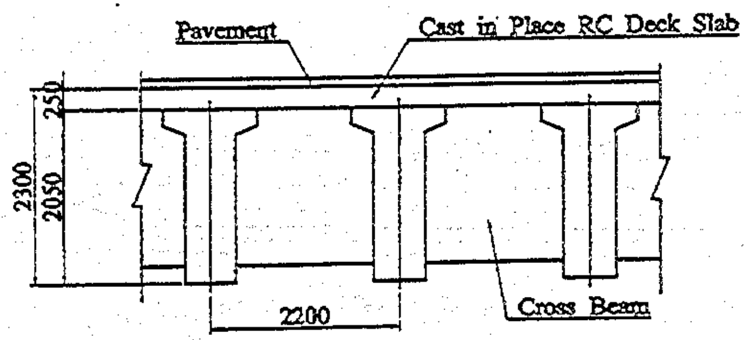
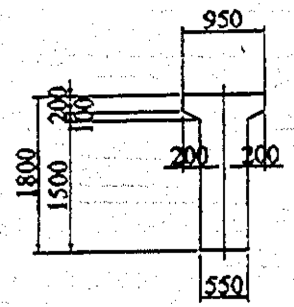
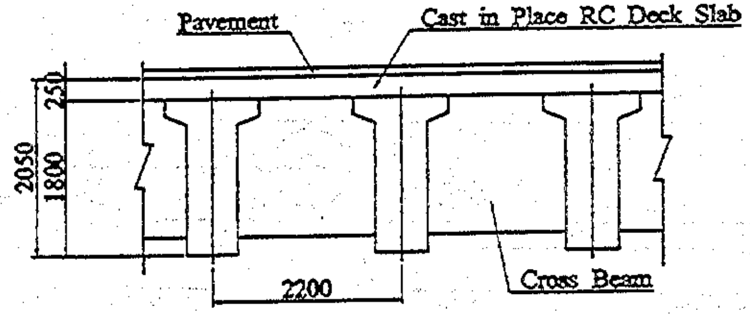
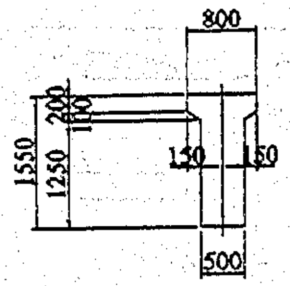
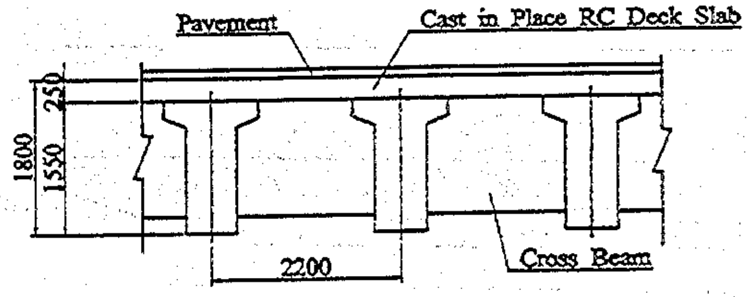
Most bridges in Sri Lanka are slab bridges. Namely, using pre-stressed concrete beams manufactured using pre-tensioning methods at two plants in the suburbs of Colombo. Reinforcements and hollow forms are arranged at site and cast-in-place concrete is poured to complete a bridge.

On the understanding that performance is substantially improved and that further enhancement of technical conditions is achieved, it is recommended that a composite slab bridge using pre-tension beams of relatively high reliability and a post-tension composite T girder be selected. The approximate sectional dimensions are shown in Tab. 9.13 (a) and 9.13 (b). In any case, on-site construction is characterized by the fact that only reinforced concrete work without pre-stressing is carried out.

TAB.9-13(a) Recommended PSC Girder

GIRDER LENGTH(m)	GIRDER SECTION (Pre-tensioning Method)	COMPOSITE SLAB SECTION
25.0		
21.0		
17.0		

TAB.9-13(b) Recommended PSC Girder

GIRDER LENGTH(m)	GIRDER SECTION (Pre-tensioning Method)	COMPOSITE GIRDER SECTION
35.0		
31.0		
27.0		

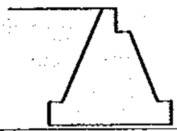
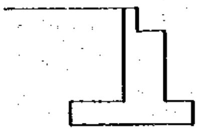
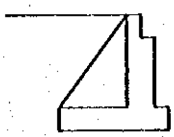
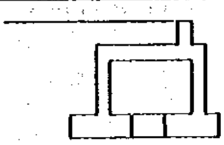
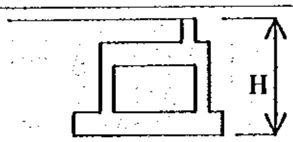
(2) Substructure

Abutments and piers shall be designed for bridge substructures. The types of abutments and piers selected are dependent on structural height, location (on land or in water), acting force (vertical and horizontal), and foundation type.

1) Abutment

The types of abutments selected based on structural height are as shown Tab. 9.14.

Tab. 9.14 Abutment Types for the Height

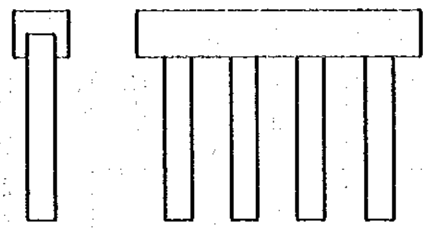
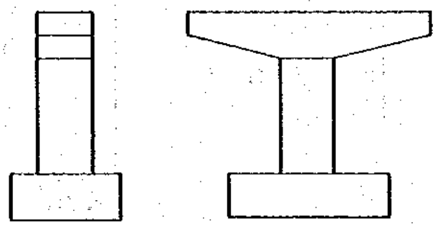
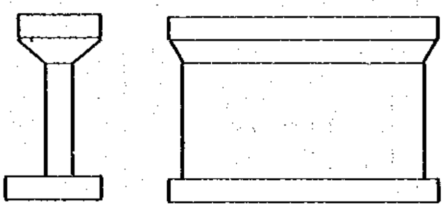
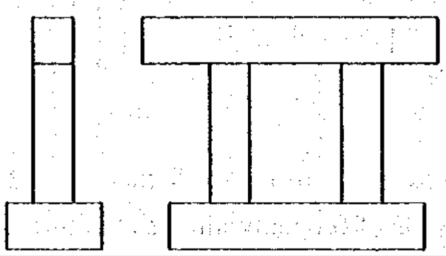
Tape and Shape		Applicable Height H (m)	Characteristic
Gravity-type		H <= 5	-Simple structure -Easy construction -Heavier weight
Reversed T Type		5 < H < 12	-Economic - Easy construction
Counterforted Buttressed type		10 <= H	-Economic -Intricate construction -Difficulty in buck filling
Rigid-framed Type		10 <= H <= 15	-Complicate structure -Expensive
Box Type		15 <= H	-Large scale structure -Complicate structure -Intricate construction -Expensive

Since the height of abutments is expected to be lower than the 12 m for the OCH, the reversed T type is selected for reasons of economy, simple structure and easy construction. However, a rigid-framed type shall be selected if the frontage road of the OCH has to pass along the abutment.

2) Pier

The types of piers selected are dependent on structural height, location (on land or in water), width of superstructure, and acting force (vertical and horizontal) and are as shown Tab. 9.15.

Tab. 9.15 Pier Types

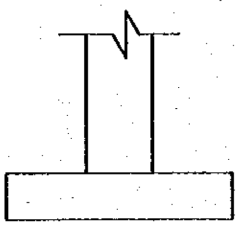
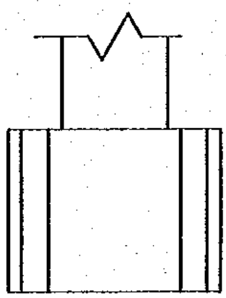
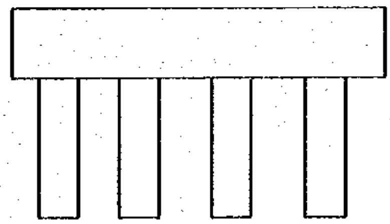
Type	Figure	Characteristic
Pile bent type pier		• Simple structure with capped pile head • Weak horizontal force and flexible structure • Unsuitable for piers in river where scouring is expected • For light-weight superstructure • Lowest cost
Column type pier		• General construction • Diameter of column is big • Blocks large area of river crossing
Elliptical column pier		• General construction • Shape appropriate the direction of the river flow
Rigid framed pier		• Generally used for wide super-structure • Unsuitable for piers in rivers

3) Foundation

The type of foundation selected depends on the conditions of the depth of bearing stratum, acting force (horizontal and vertical), and its location (on land or in river).

Three foundation types, or spread footing, pile foundation, and caisson, are applied for OCH bridges. Tab. 9.16 shows the applicable depth of suitable soil strata for each type of foundation.

Tab. 9.16 The Applicable Depth for Foundation Type

Depth of suitable soil stratum D (m)	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. • Where bearing stratum is not flat, special treatment is required to set the caisson at level.
Deeper than 6.0 m	Pile Foundation (Pre-cast RC or PC pile, H Steel, steel pipe, cast-in place concrete pile) 	Pile type and diameter should be selected based on on-site conditions.

9.6.2 Bridge Planning

9.6.2.1 Outline of Bridges for the Outer Circular Highway

(1) Location Map of Bridges

The location map of the main line and interchange bridges as planned for this Study is shown in Fig. 9.31.

(2) Type of Bridges

The outline of the types of bridges planned is shown in Tab. 9.17 – 9.20.

No.	CROSSING	STATION							LENGTH(m)
1	CKE	0	-	61	~	0	+	22	83.0
2	RAMPWAY	2	+	89	~	3	+	11	22.0
3	A3 RD.	9	+	12	~	9	+	52	40.0
4	RAILWAY	28	+	27	~	28	+	57	30.0
5	A1 Rd.	81	+	32	~	81	+	62	30.0
6	KELANI RIVER	159	+	82	~	161	+	79	197.0
7	A110 Rd.	162	+	89	~	163	+	11	22.0
8	RAILWAY	270	+	19	~	270	+	37	18.0
9	A4 RD.	276	+	5	~	276	+	50	45.0
10	A4 RD.	276	+	15	~	276	+	63	48.0
11	MINOR RD.	322	+	75	~	323	+	0	25.0
12	B84 RD.	337	+	82	~	338	+	12	30.0
13	MINOR RD.	366	+	94	~	367	+	16	22.0
14	A8 RD.	423	+	57	~	423	+	79	22.0
15	BOLGODA RIVER	442	+	70	~	443	+	72	102.0
16	CKE IC	10	+	13	~	12	+	13	40.0
17	CKE IC	-1	+	40	~	0	+	20	80.0
18	CKE IC	-1	+	40	~	0	+	20	80.0
19	A3 IC	9	+	10	~	9	+	40	30.0
20	A4 IC	276	+	15	~	276	+	60	45.0
21	STC JCT	19	+	18	~	22	+	5	47.0
22	STC JCT	19	+	16	~	24	+	6	90.0

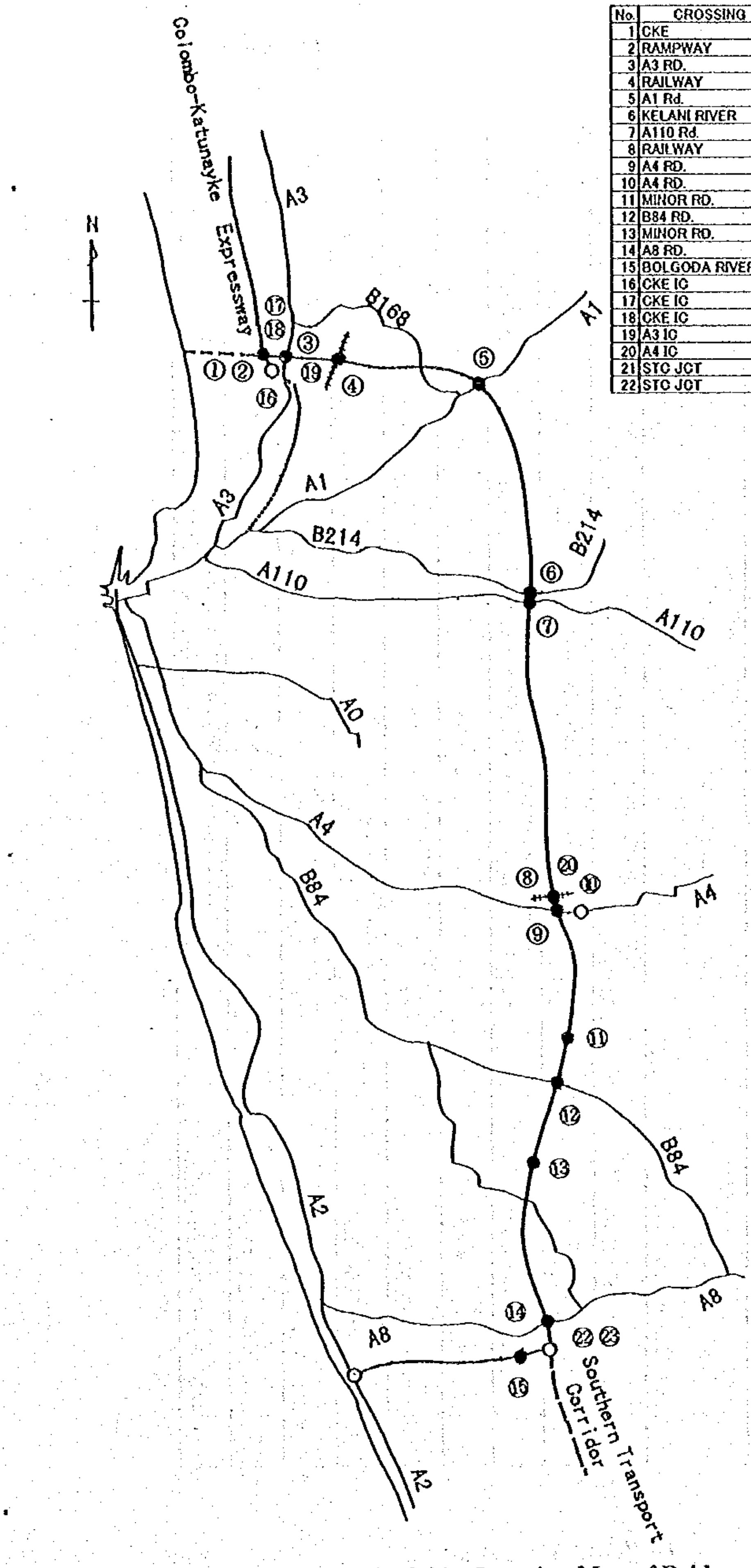


Fig. 9.31 Location Map of Bridges

Tab. 9.17 List of Bridges (Main Line)

NO.	STATION	LENGTH(m)	SUPERSTRUCTURE	SUBSTRUCTURE	FOUNDATION	REMARKS
1	0-61.0~0+22.0	83.0=20.5+2@21.0+20.5	Connected Continuous Pre-tensioned Girder	Abutment:Reversed-T Pier:T-type, Wall-type	Pile Foundation:Cast-in-place RC Pile	Interchange Crossing
2	2+89.0~3+11.0	22.0	Simple Pre-tensioned Girder	Reversed-T type	ditto	ditto
3	9+12.0~9+52.0	40.0	Simple Post-tensioned Box Girder	ditto	ditto	A3 Road
4	28+27.0~28+57.0	30.0	Simple Pre-tensioned T Girder	A1:Reversed-T type A2:Rigid-framed type	ditto	Railway Colombo-Kandy Line
5	81+32.0~81+62.0	30.0	ditto	Reversed-T type	Spread Foundation	A1Road
6	159+82.0~161+79.0	197.0=22.0+7@25.0	Connected Continuous Pre-tensioned Girder	Abutment:Reversed-T Pier on the land:T-type Pier in the river:Elliptical Column	On the land:Cast-in-place RC Pile In the river:Open Caisson	Kelani River
7	162+89.0~163+11.0	22.0	Simple Pre-tensioned Girder	Reversed-T type	Pile Foundation:Cast-in-place RC Pile	A110 Road
8	270+19.0~270+37.0	18.0	ditto	Rigid-framed type	ditto	Railway Colombo-Avissawella Line
9	276+5.0~276+50.0	45.0	Simple Post-tensioned Box Girder	Reversed-T type	ditto	A4 Road
10	276+15.0~276+63.0	48.0	ditto	ditto	ditto	ditto
11	322+75.0~323+0.0	25.0	Simple Pre-tensioned Girder	ditto	ditto	Minor Road
12	337+82.0~338+12.0	30.0	Simple Post-tensioned T Girder	ditto	ditto	B84 Road
13	366+94.0~367+16.0	22.0	Simple Pre-tensioned Girder	ditto	ditto	Minor Road
14	423+57.0~423+79.0	22.0	ditto	ditto	ditto	A8 road
15	442+70.0~443+72.0	102.0=6@17.0	Connected Continuous Pre-tensioned Girder	Abutment:Reversed-T Pier:Pile bent type	ditto	Bolgoda River

Tab.9.18 Bridge Comparison Between 4 Lanes and 6 Lanes

NO.	CROSSING	STATION	LENGTH (m)	SUPERSTRUCTURE (effective-width) 4 LANE	6 LANE	SUBSTRUCTURE (Abutment width) (m)	REMARKS
1	Interchange	0-61.0~0+22.0	83	11.25×2 1868m2	14.25×2 2366m2	32.4	P1,P2:T-type P3:Wall-type
2	ditto	2+89.0~3+11.0	22.0	11.25×2 495m2	14.25×2 627m2	32.4	
3	A3 Road	9+12.0~9+52.0	40.0	11.25×2 900m2	14.25×2 1140m2	32.4	
4	Railway	28+27.0~28+57.0	30.0	11.25×2 675m2	14.25×2 855m2	32.4	
5	A1Road	81+32.0~81+62.0	30.0	11.25×2 675m2	14.25×2 855m2	32.4	
6	Kelani River	159+82.0~161+79.0	197	10.00×2 3940m2	13.50×2 5319m2	29.9	P1,P2:T-type P3~P7:Caisson
7	A110 Road	162+89.0~163+11.0	22.0	11.25×2 495m2	14.25×2 627m2	32.4	
8	Railway	270+19.0~270+37.0	18.0	11.25×2 405m2	14.25×2 513m2	32.4	
9	A4 Road	276+5.0~276+50.0	45.0	11.25×2 1013m2	14.25×2 1283m2	32.4	
10	ditto	276+15.0~276+63.0	48.0	11.25×2 1080m2	14.25×2 1368m2	32.4	
11	Minor Road	322+75.0~323+0.0	25.0	11.25×2 563m2	14.25×2 713m2	32.4	
12	B84 Road	337+82.0~338+12.0	30.0	11.25×2 675m2	14.25×2 855m2	32.4	
13	Minor Road	366+94.0~367+16.0	22.0	11.25×2 495m2	14.25×2 627m2	32.4	
14	A8 road	423+57.0~423+79.0	22.0	11.25×2 495m2	14.25×2 627m2	32.4	
15	Bolgoda River	442+70.0~443+72.0	102.0	9.50×2 1938m2		22.9	P1~P5:Pilebent

Tab. 9.19 List of Bridges (IC and JCT)

NO.	STATION	LENGTH(m)	SUPERSTRUCTURE	SUBSTRUCTURE	FOUNDATION	REMARKS
16	10+13.0~12+13.0	40.0	Connected Continuous Pre-tensioned Girder	Abutment:Reversed-T Pier:Wall-type	Pile Foundation:Cast-in-place RC Pile	
17	-1+40.0~0+20.0	80.0=4@20.0	Connected Continuous Pre-tensioned Girder	Abutment:Reversed-T Pier:T-type, Wall-type	ditto	
18	-1+40.0~0+20.0	80.0=4@20.0	ditto	ditto	ditto	
19	9+10.0~9+40.0	30.0	Simple Pre-tensioned T Girder	Reversed-T type	ditto	
20	276+15.0~276+60.0	45.0	Simple Post-tensioned Box Girder	ditto	ditto	
21	19+18.0~22+5.0	47.0=2@23.5	Connected Continuous Post-tensioned Box	ditto	ditto	
22	19+16.0~24+6.0	90.0=25.0+30.0+35.0	ditto	Abutment:Reversed-T Pier:T-type, Wall-type	ditto	

Tab. 9.20 List of Interchange Bridges Area

NO.	CROSSING	LENGTH(m)	SUPERSTRUCTURE (effective-width)	SUBSTRUCTURE (Abutment width) (m)	REMARKS
16	10+13.0~12+13.0	40.0	14.5m 580.0m2	15.4	
17	-1+40.0~0+20.0	80.0	5.0m 400.0m2	6.9	
18	-1+40.0~0+20.0	80.0	3.0m 240.0m2	3.9	
19	9+10.0~9+40.0	30.0	6.9m 207.0m2	7.8	
20	276+15.0~276+60.0	45.0	2.0m 90.0m2	2.9	
21	19+18.0~22+5.0	47.0	7.0m 329.0m2	7.9	
22	19+16.0~24+6.0	90.0	7.0m 630.0m2	7.9	

9.6.2.2 Bridges Crossing Over Rivers

(1) Kelani River Crossing

1) Setting bridge length

The river width at the crossover point for the Kelani River is about 120 m and the Biyagama Road (B214) is about 60 m from its right bank. Economically, it may be possible to cross Rt. B214 by means of a single-span bridge and to build a road on the embankment for a section from this crossing to the right bank of the river. It was decided, however, to employ a bridge for this section in view of the following factors:

(a) Embankment length, excluding abutment back-filling, is more than 40 m at its longest. The workability of the embankment for such a short section is extremely poor.

(b) Unevenness of the bridge resulting from subsidence of a short-section embankment between bridges after opening for service may make for uncomfortable driving.

2) Superstructure

The span length of the superstructure was determined by taking the following points into account:

(a) To determine the span division of the superstructure, two existing bridges, one upstream and one downstream from this bridge, may serve as a guideline. The four-span Kaduwela Bridge, with a girder length of 23 m, is located about 1.4 km upstream of the planned bridge. The girder length of the proposed bridge will be at least as long as this.

(b) The bridge crosses the river portion where the depth is 3 m or more even in the dry season. It is therefore desirable to minimize the scale of the erection work. Pre-tensioning PSC beams are favorable in this respect because the weight per beam is small and the use of heavy machinery can be downsized correspondingly. Note that a maximum 19 m span length could be constructed from pre-tensioning PSC beams in Sri Lanka. Therefore, span length can be a maximum of 25 m for this bridge.

(c) The span length, based on Japanese River Standards referred to previously, is 34 m ($L = 20\text{ m} + 0.005\ Q = 34\text{ m}$, discharge volume; 2746 m3/sec). However, this will not be applied for reasons of cost and river management.

Therefore, a connected girder type of superstructure with a beam length of 25 m using pre-tensioning PSC beams will be employed without the use of expansion joints at supports, excluding abutments, in order to ensure improved driving comfort.

The scale of the bridges can be compared as follows:

Kaduwela Bridge
Bridge length: 93 m; Span : 23 m, (four-span simple girder bridge)

Kelani Bridge
Bridge length: 150 m (river section); Span: 25 m, (six-span continuous girder bridge)

3) Substructure foundation type

The HWL of the Kelani River where the OCH bridge is to be erected is EL 5.4 m or more. The difference between the HWL and LWL is more than 5 m. The flow velocity is considerable not only during flooding, but also when the water level is high. Pile bent piers, multi-column pile foundation, or caisson can be considered for the pier foundation at this section. An open caisson with separate up and down lanes, however, will be used for the foundation at this section. There are three reasons for this:

(a) Pile bent piers and multi-column pile foundation piers tend to create eddy currents, which cause abnormal scouring around piers during floods. In addition, drift material such as driftwood, garbage, etc. may stick to piers, blocking the cross-sectional area of rivers and presenting a substantial hindrance to flows during a flood.

(b) The Kaduwela Bridge, about 1.4 km upstream of the OCH bridge, employs an open caisson foundation with two ø3.5 m piles in parallel.

(c) Considering the bearing layer depth, the length of the pier foundation of the river section is estimated to be about 8 m.

For the abutment and the pier on the right bank, ø1.0 m cast-in-place concrete piles will be used for the foundation of the abutment, as well as for the foundation of piers on the bank. The reasons for this are as follows:

(a) Abutment height reaches as high as about 9.5 m, with increasing horizontal force acting on foundation piles. It is considered economically advantageous to use piles with higher rigidity to reduce the total number of piles.

(b) The point bearing layer of piles is a hard gneiss layer. Existing pre-cast RC piles may be broken when driven into this layer.

(2) Bolgoda River Crossing

This bridge is erected less than 1 km from Lake Bolgoda. The HWL is EL 0.873 m (observation) and the LWL is about EL 0.0 m. River flow velocity is high. In the center of the LWL, water depth is about 2 m and the river width about 80 m.

Given the above conditions, a pile bent type (ø1.0 m cast-in-place RC piles with steel casing to serve as a pile cap), which is superior in workability and cost-effectiveness, will be used. For a superstructure appropriate for such a substructure, a connected girder type of bridge using pre-tensioning beams will be employed. Span length is 17 m x 6 spans and bridge length is 102 m, and the road intersects diagonally with the river. Since there will be no problem in terms of river management, a right bridge was planned. The clearance to the water surface is about 3 m at a normal water level and about 2 m at a high water level. The abutment foundation will be ø1.0 m cast-in-place RC piles for the river section.

9.6.2.3 Viaduct Crossing Over Existing Railways and Major Roads

(1) Railway Crossing

Viaduct length was determined on the condition that the excavation line of the substructure would not enter the inside of the railway ballast line. For foundation piles, ø1.0 m cast-in-place RC piles will be used to prevent adverse effects from vibration during work on the railway.

Abutments for railway crossings are designed as a rigid-frame type when the frontage road is adjacent to the railway.

(2) Major Road Crossings and Interchange Bridges

Tab. 9.18 and 9.20 show the type of superstructure adopted, which was determined according to bridge length. On the basis of boring data contained in the geological survey report, a spread foundation will be used for the bridge (81+32.0 – 81+62.0) crossing at Rt. A1

9.6.2.4 Overpass

Tab. 9.21 shows the survey station, width, length, and construction type for each overpass (main line overpass). After taking into account a 4.5 m median for 6-lane operation in the future, piers will be constructed in the middle of the median for economic reasons. Superstructure will consist of post-tensioned t-type girders and the bridge will be a connected girder type of structure. However, bridge span should be determined taking local conditions into account.

As, for the substructure, abutments will be an inverted T type while piers will be a T type. Since the height of most abutments will be as high as 10 – 12 m, ø1.0 m cast-in-place concrete piles will be used for the foundation, as is the case for the major OCH bridges. This type of foundation will also apply to piers.

Tab. 9.21 List of Overpasses

No.	STATION	WIDTH (m)	LENGTH (m)	SUPER STRUCTURE TYPE	FOUNDATION	REMARKS
1	37+10.0	5.5	52.50=2@26.25	Post-tensioned T-girder	Cast-in-place RC pile	Connected beam
2	44+70.0	"	35.50=2@17.50	Pre-tensioned girder	"	"
3	47+15.0	"	45.00=2@22.50	"	"	"
4	50+80.0	"	40.00=2@20.00	Pre-tensioned girder	"	"
5	57+30.0	8.0	35.50=2@17.50	"	"	"
6	66+55.0	5.5	35.50=2@17.50	"	"	"
7	73+40.0	10.0	45.00=2@22.50	"	"	"
8	91+20.0	5.5	35.50=2@17.50	"	"	"
9	101+20.0	"	27.00=2@27.00	Post-tensioned T-girder	"	"
10	111+55.0	10.0	36.00=2@18.00	Pre-tensioned girder	"	"
11	124+20.0	15.0	42.00=2@21.00	"	"	"
12	132+ 4.0	5.5	43.90=2@21.95	"	"	"
13	144+90.0	"	35.50=2@17.50	"	"	"
14	175+10.0	"	36.00=2@18.00	"	"	"
15	183+20.0	"	35.50=2@17.50	"	"	"
16	194+65.0	12.0	36.00=2@18.00	"	"	"
17	201+75.0	5.5	50.00=2@25.00	"	"	"
18	206+15.0	"	35.50=2@17.50	"	"	"
19	247+45.0	"	35.50=2@17.50	"	"	"
20	255+15.0	"	52.30=2@26.15	Post-tensioned T-girder	"	"
21	260+25.0	"	43.90=2@21.95	Pre-tensioned girder	"	"
22	264+20.0	"	43.90=2@21.95	"	"	"
23	282+50.0	"	35.50=2@17.50	"	"	"
24	292+46.0	"	35.50=2@17.50	"	"	"
25	308+23.0	"	35.50=2@17.50	"	"	"
26	315+54.0	"	35.50=2@17.50	"	"	"
27	350+ 0.0	"	35.50=2@17.50	"	"	"
28	355+73.0	"	43.90=2@21.95	"	"	"
29	360+66.0	"	35.50=2@17.50	"	"	"
30	371+10.0	"	35.50=2@17.50	"	"	"
31	378+50.0	"	52.50=2@26.25	"	"	"
32	380+15.0	15.0	52.50=2@26.25	"	"	"
33	384+14.0	5.5	50.00=2@25.00	"	"	"
34	391+ 0.0	"	35.50=2@17.50	"	"	"
35	395+51.0	"	35.50=2@17.50	"	"	"
36	403+ 0.0	"	35.50=2@17.50	"	"	"
37	410+40.0	"	35.50=2@17.50	"	"	"
38	428+37.0	"	35.50=2@17.50	"	"	"
39	436+65.0	"	44.00=2@22.00	"	"	"
40	458+40.0	"	30.00	Post-tensioned T-girder	"	Simple beam
41	486+50.0	"	28.50	"	"	"
42	493+90.0	"	28.50	"	"	"
43	500+80.0	"	28.50	"	"	"

9.6.2.5 Box Culverts

For box culverts, sectional dimensions will be determined from the dimensions of internal hollow spaces (internal hollow width x internal hollow height) and the overburden of culverts, by referring to the Standard Box Culvert Design Drawings established by the Ministry of Construction of Japan. Tab. 9.22 shows typical sectional dimensions.

Tab. 9.22 Box Culvert

Inner section W (m) x H (m)	Over burden (m)	Top slab (mm)	Floor slab (mm)	Side wall (mm)	Remarks
5.0 X 5.0	0.20 - 1.00	400	500	450	Haunch size 300 X 300
	1.00 - 2.00	450	550	500	
	2.00 - 2.75	500	600	550	
	2.75 - 3.50	550	650	550	
	3.50 - 4.50	600	700	600	
	4.50 - 5.50	650	750	650	
6.0 X 5.0	0.20 - 0.75	400	500	450	
	0.75 - 1.75	500	600	500	
	1.75 - 3.00	600	750	600	
7.0 X 5.0	0.20 - 0.75	450	550	500	
	0.75 - 2.00	600	700	600	
	2.00 - 3.25	700	850	650	

9.6.2.6 Drawings

Titles of drawings are as follows (Refer to appendix):

33 TYPICAL CROSS SECTION BRIDGE & VIADUCT
34 VIADUCT AT INTERCHANGE WITH MAJOR ROAD (4 LANE L=27M)
35 VIADUCT AT INTERCHANGE WITH MAJOR ROAD (2 LANE L=22M)
36 OVERPASS AT LOW EMBANKMENT SECTION
37 OVERPASS AT CUTTING SECTION
38 GENERAL VIEW OF KELANI GANGA BRIDGE (1)
39 GENERAL VIEW OF KELANI GANGA BRIDGE (2)
40 GENERAL VIEW OF BOLGODA GANGA BRIDGE
41 GENERAL VIEW OF RAILWAY CROSSING BRIDGE AT HORAPE
42 BOX CULVERT

9.7 Junction and Interchange Planning

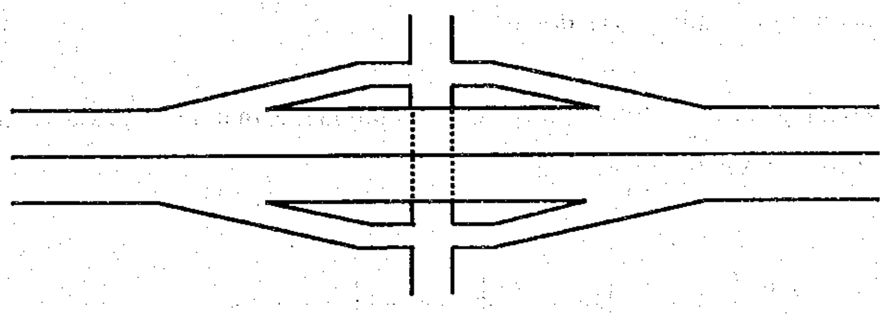
9.7.1 Design Daily Traffic Volume

The configuration of interchanges is based on forecasted traffic volumes for the year 2020.

9.7.2 Determination of Interchange Configuration

9.7.2.1 Interchange Configuration

Since the planned road will not be a toll road, no tollgates are necessary. Accordingly, the basic configuration of an interchange will be a diamond type. Since the connecting road and ramp intersection will be a level crossing, the configuration will be finalized by checking traffic capacity.



Diamond Type Interchange

Interchange configurations were decided applying Fig. 9.32, which describes the relationship between interchange type and access traffic volume and the through traffic volume of the connecting road. Based on this, it was discovered that the interchanges at A3, A1, and A4 cannot process the traffic volumes at these points using a diamond type interchange. Note, however, that a diamond type interchange has been selected for A1, since the Colombo - Kandy Expressway will have an interchange near by.

Based on the results of the above examination, the following types of junctions (JCT) and interchanges (IC) have been chosen.

(1)	CKE	:	Double trumpet type JCT
(2)	A3	:	Half trumpet type IC
(3)	A1	:	Diamond type IC
(4)	B214Road	:	Half diamond type IC
(5)	A110Road	:	Half diamond type IC
(6)	A4 Road	:	Basic: Half clover type IC
		:	Alternative: Double trumpet type IC
(7)	B84Road	:	Diamond type IC
(8)	A8 Road	:	Diamond type IC
(9)	STC	:	Y type JCT
(10)	A2 Road		Composite diamond (level crossing)

As for the interchange at Rt. A4, although a trumpet type is preferable in terms of forecasted traffic volumes, this Study recommends that a half clover type of interchange be constructed from the perspective of keeping costs down.

As for the interchange at Rt. A2, the Study Team recommends that a composite diamond type be employed for economic reasons.

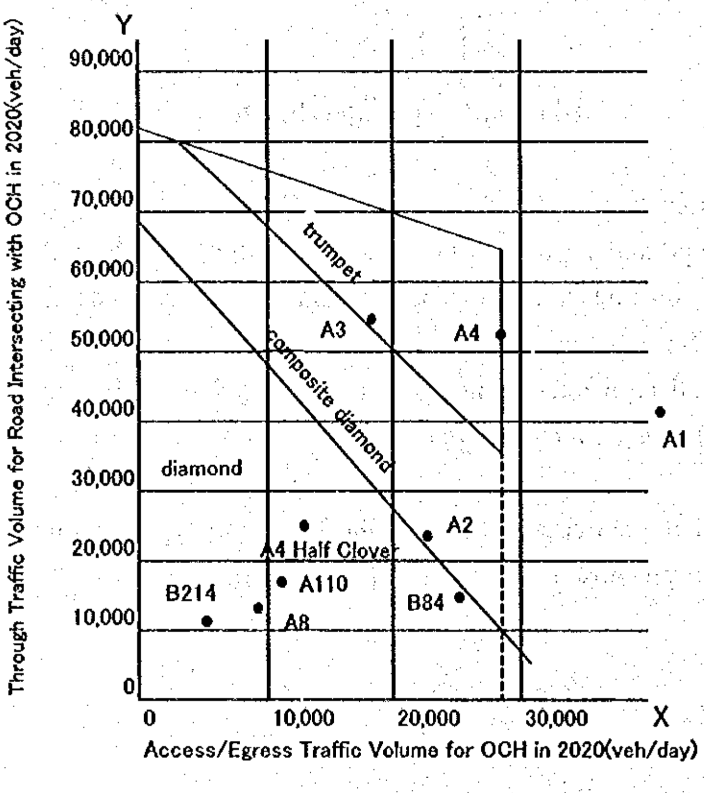


Fig. 9.32 Selection of Interchange Types

The traffic volume applied to determine interchange configuration is one half of the daily volume for the following reasons:

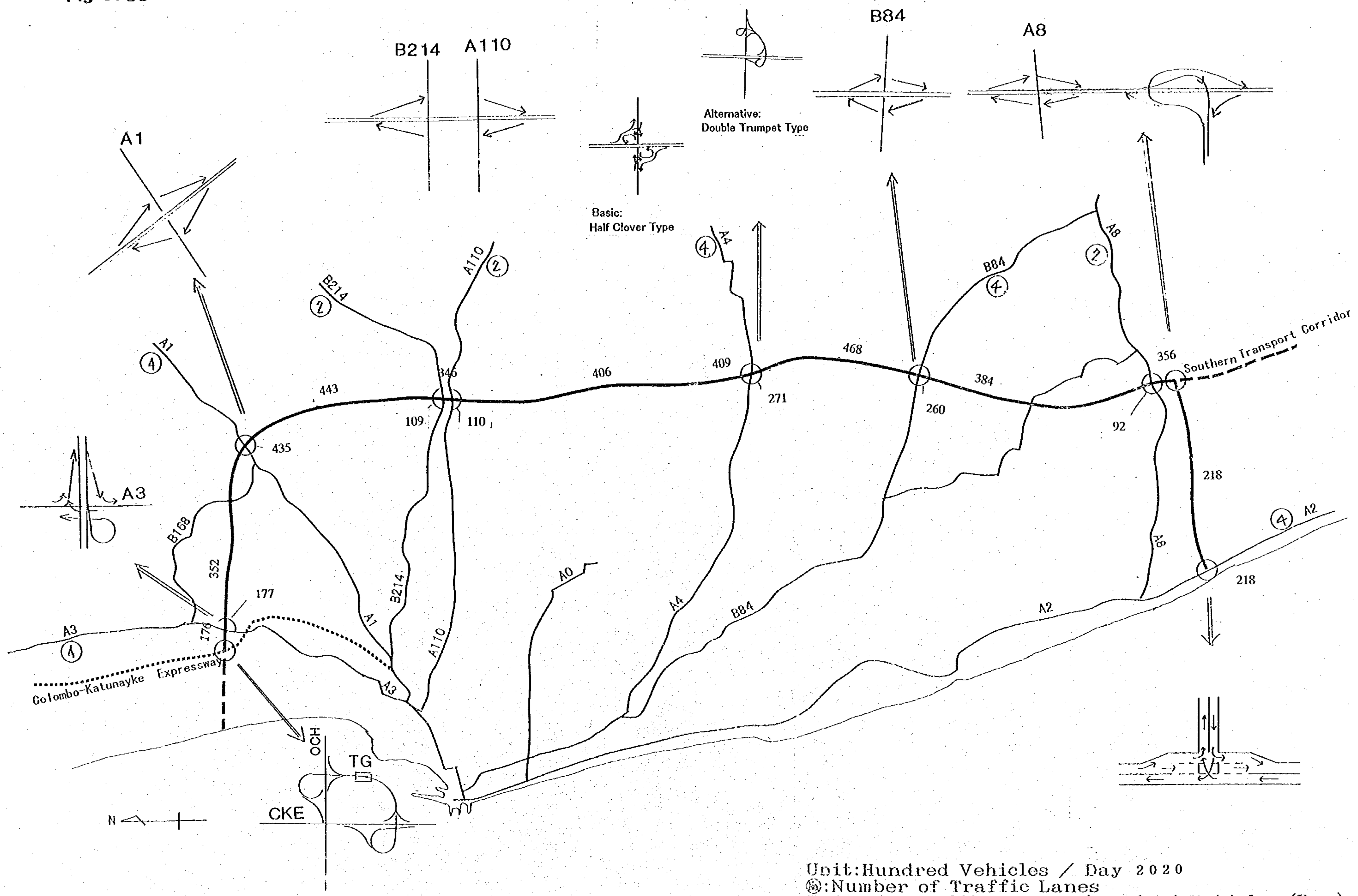
- The planned traffic volume (vehicles/day) is calculated by assuming a peak ratio of 7 %. This value is rather small compared to the 9 % for urban areas in Japan. The value for rural areas in Japan is 12 – 14 %.
- Capacity is determined from the peak hour.
- The forecasted traffic volume for a four-lane road (A3 road) in 2020 reaches 66,000 vehicles/day, which is quite large.
- The initial investment will be reduced to enable future reconstruction.

Tab.9.23 Selection of Interchange Type

Descriprion	Unit	Connection Roads								Remarks
		A3	A1	B214	A110	A4	B84	A8	A2	
		4Lanes	4Lanes	2Lanes	2Lanes	4Lanes	4Lanes	2Lanes	4Lanes	
Design Speed	km/h	80	80	80	80	80	80	80	80	
No.of Traffic Volume	Lanes	6	6	6	6	6	6	6	4	
Access Traffic Volume	veh/day	17,700	43,500	10,900	11,000	27,100	26,000	9,200	21,800	
Interchange Standard		First	First	First	First	First	First	First	First	
Design Speed for Local Road	km/h	60	60	60	60	60	60	60	60	
Design Speed for Ramp	km/h	40	40	40	40	40	40	40	40	
Ramp Standard		A	A	A	A	A	A	A	A	
Segregated/Non-segregated ramp		Seg.	Seg.	Seg.	Seg.	Seg.	Seg.	Seg.	Seg.	
No.of Ramp Traffic Lanes	Lanes	1	1	1	1	1	1	1	1	1200V/h/Lane
Width of Ramp	m	7	7	7	7	7	7	7	7	One way One Direction
Through Traffic Volume of Connection Road	veh/day	54,300	41,700	5,800	17,400	51,200	15,000	12,700	22,900	
Grade separated/ At grade		G.S.	G.S.	A.G.	A.G.	G.S.	A.G.	A.G.	A.G.	
Type of Interchange		Half Trumpet	Trumpet	Diamond	Diamond	Trumpet ※2	Diamond	Diamond	Composite Diamonds	

※1 Traffic volume is the forecast in year 2020.
※2 Establishing 2 level crossings makes traffic volume a half, therefore half clover type can be employed.

Fig 9.33 IC & JCT Types for the Outer Circular Highway



Unit:Hundred Vehicles / Day 2020
⓪:Number of Traffic Lanes
□:Access Traffic Volume (Hundred Vehicles/Day)

9.7.2.2 Length of Speed Change Lane

The length of acceleration/ deceleration lanes for each IC and JCT is shown below. Note that the standard and specified value for these lengths is shown below.

(1) Length of speed change lane of the main line and Colombo-Katunayake Expressway

"Geometric Standard of High-standard Arterial Highway, September, 1989"

- Length of speed change line and taper
  - * Design speed of Colombo-Katunayake Expressway : 110km/h
    Design speed of the Outer Circular Highway : 80km/h

Design speed of main line	110km/h	80km/h
Length of deceleration lane	90m	80m
Length of acceleration lane	180m	160m
Length of taper	60m	50m

- Access angle

Design speed of main line	110km/h	80km/h
Angle of exit	1/25	1/20
Angle of entry	1/40	1/30

(2) Length of speed change lanes of the national highway
(Explanation and execution of the Road Structure Ordinance, February, 1983)

- Length of speed change lane and taper
  - * The design speed of national highway is 60 km/h.

Acceleration area		Deceleration area	
Length of acceleration lane	120m	Length of deceleration lane	70m
Standard taper length of parallel acceleration lane	50m	Standard taper length of parallel deceleration lane	50m

9.7.2.3 Configuration of IC and JCT

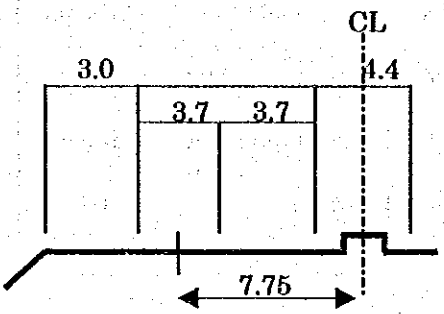
(1) Colombo-Katunayake Expressway JCT

For the OCH connection with the CKE, the double trumpet type will be employed since a tollgate is to be constructed. The configuration will be determined by taking into account the installation space of the booth and administration facilities. With this configuration, a toll-free road may be used for extension from the CKE to the seaside.

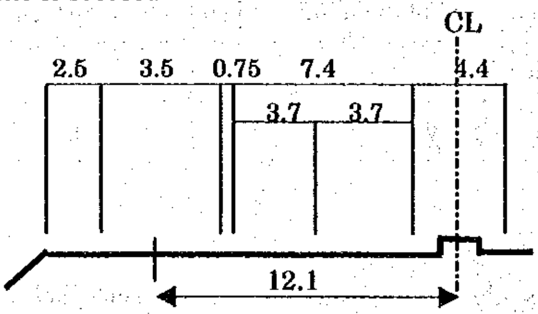
<Determination of the length of the speed change lane>

i) CKE side

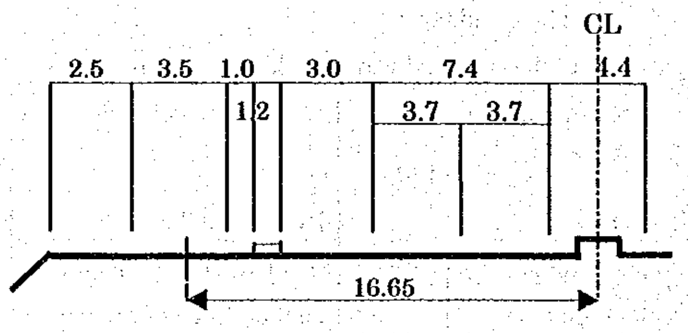
<Taper end>



<Portion where one lane is secured>



<Nose>

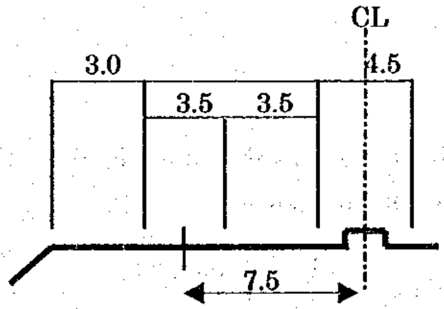


The length of the acceleration/deceleration lane is described below. From the table for the cross-section and speed-change line lengths shown above, the length of the speed change lanes of the CKE will be as follows:

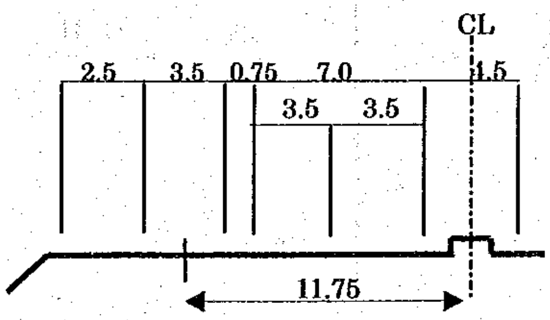
- Acceleration area: Taper length + Length of acceleration lane
  = 180 m + 60 m
  = 240 m
- Deceleration area:
  (Shift amount + angle of exit) + Length of deceleration lane
  = (12.1-7.75) + (1/25) + 90
  = 198.75   200 m

ii) OCH side

<Taper end>



<Portion where one lane is secured>



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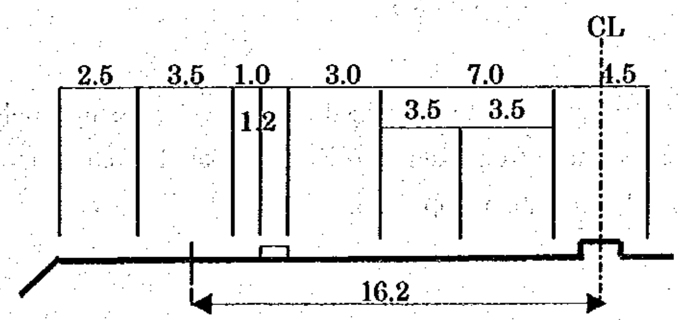


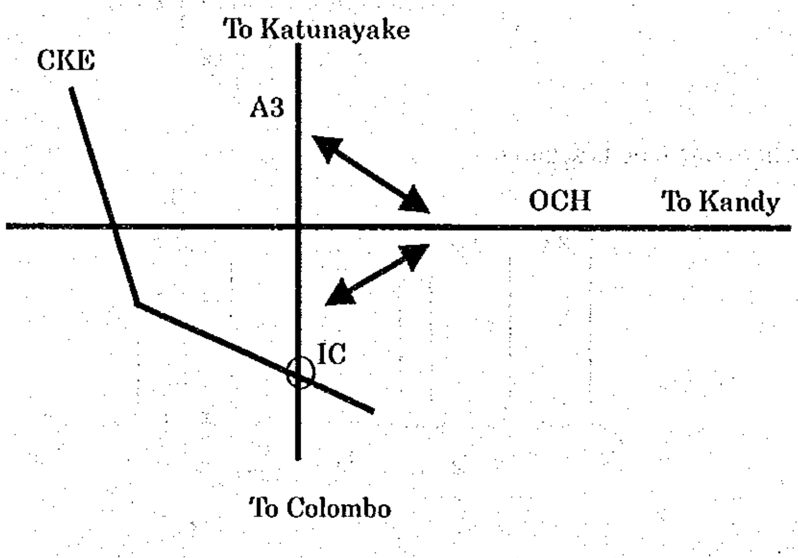
From the table for the cross-section and speed-change line lengths on the previous page, the length of speed change lanes for the OCH will be as follows :

- Acceleration area: Taper length + Length of acceleration lane
  = 160 m + 50 m
  = 210 m
- Deceleration area:
  (Shift amount / Angle of exit) + Length of deceleration lane
  = (11.75 - 7.5) / (1/20) + 80
  = 165 m

For the interchanges at Rt. A3, A1, B214, A110, A4, B84, and A8, the length of the acceleration/ deceleration lanes for the OCH was planned as shown above.

(2) IC at Rt. A3

The interchange with Rt. A3 is as shown in Fig. 9.35. Only one-way service will be provided because of the nearby CKE interchange.



Because of the large traffic volume, it was judged that a level crossing would not be enough to handle the volume for the ramp from Kandy to Katunayake. Therefore, the configuration will consist of a half-diamond type with a loop ramp.

(3) IC at Rt. A1

Judging from the access traffic volume relative to Rt. A1, a diamond type of IC is difficult to realize a desirable connection with A1, meaning that a second interchange will become necessary. As the Colombo-Kandy Expressway will have an interchange nearby, and since the existing road runs thorough a dense residential area and it is difficult to improve, a diamond type JC will be applied without constructing a second interchange.

(4) ICs at Rt. B214, A110, B84, A8

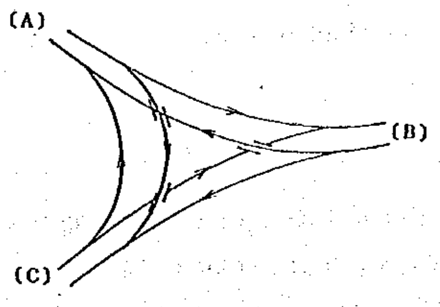
For Rt. B214, A110, B84, and A8 along the Kelani River, a level crossing was judged to be enough for each highway after considering the access traffic volume. Therefore, a diamond type was selected for the above four ICs. A half diamond type without an interchange on the Kelani River side will be applied for Rt. B214 road and A110. Nearby traffic will cross the river via an existing upstream bridge.

(5) IC at Rt. A4

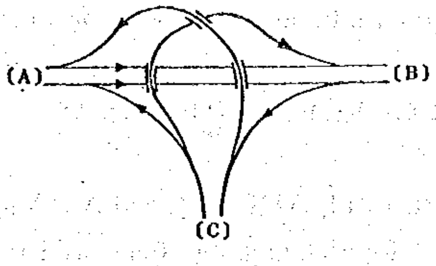
Because of the large (through) traffic volume on Rt. A4 and the access traffic volume to the OCH, a diamond type IC is difficult. Accordingly, a double trumpet type interchange is preferable. But because of economical reason, this study recommends half clover type. It also acceptable forecasted traffic volumes.

(6) Southern Transport Corridor JCT

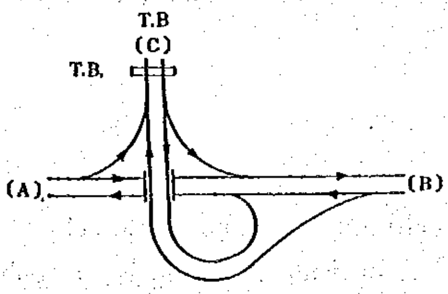
The OCH junction with the Southern Transport Corridor can be constructed in three different ways: direct Y - type, semi-direct Y-type, and trumpet type junctions.



Direct Y Type Junction



Semi-Direct Y Type Junction



Trumpet Type Junctions

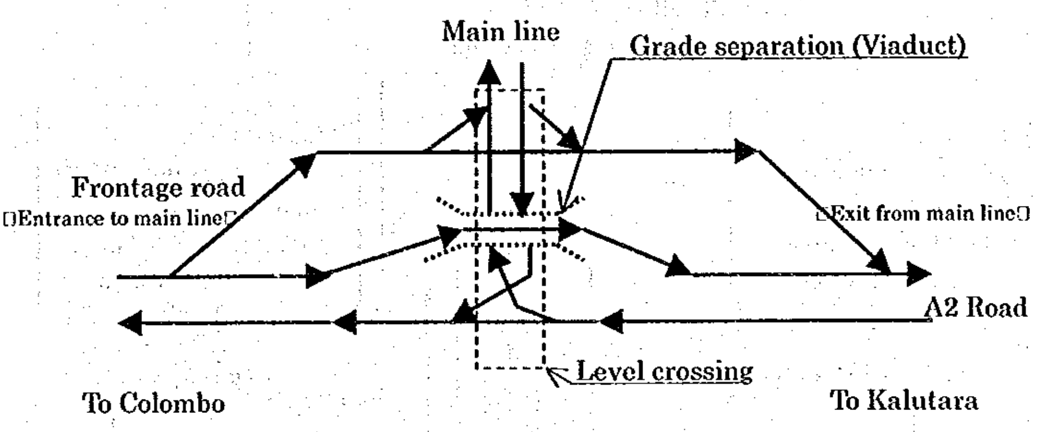
The semi-direct Y type is selected because of the following reasons:

- From the viewpoint of traffic safety, the semi-direct Y type or trumpet IC is desirable to allow for separation/merging on the left side of main traffic.
- The trumpet type has a large minimum radius of curve (R = 100 m) for the loop, requiring a larger area and is thus less economical than the semi-direct Y type.
- The semi-direct Y type intersects at three points and requires less land area.

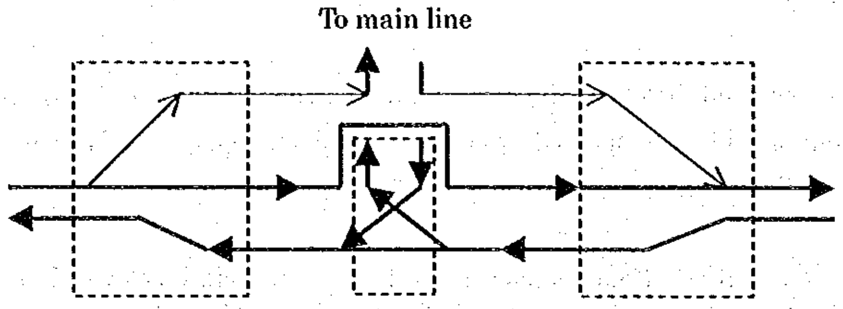
(7) IC at Rt.A2

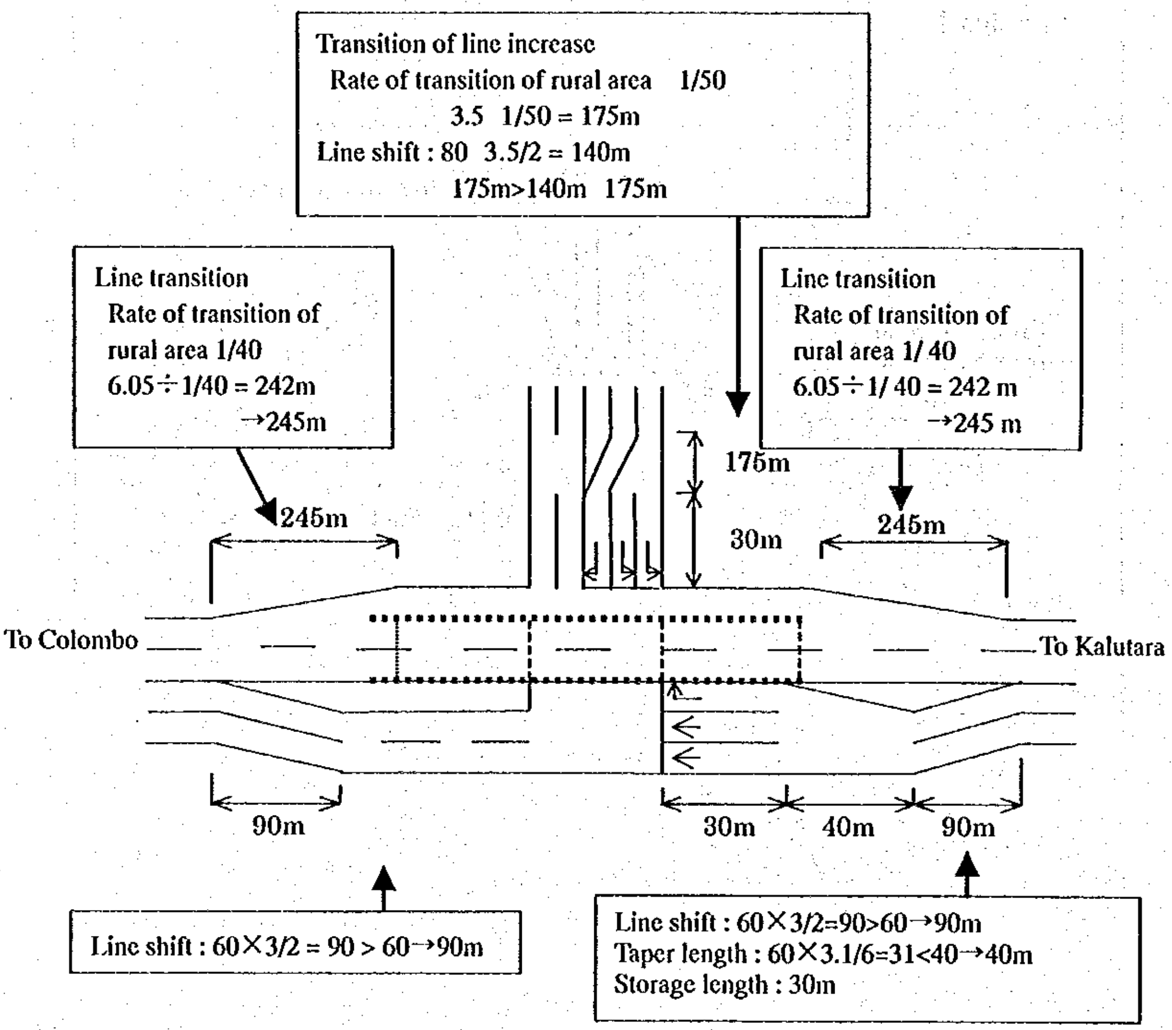
This study recommends level crossing construction initially, because of the cost reduction. And grade separation will be employed when traffic volume prospectively requires. The grade separation type is shown below.

- The Colombo —> Kalutara lane (down lane) of A2 will be elevated to eliminate with right turning vehicles heading in the direction of Colombo.
- The Kalutara —> Colombo lane (up lane) of A2 will be at-grade but be controlled by a signal.



The speed change area is shown below.





9.8 Design of Road Accessory Works

9.8.1 Frontage Road Construction Plan

On certain sections, existing road and community functions cannot be secured after the OCH and its interchanges are constructed. To solve this problem, the basic concept below will be applied.

<Basic concept>

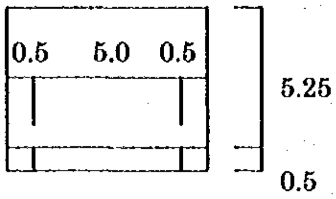
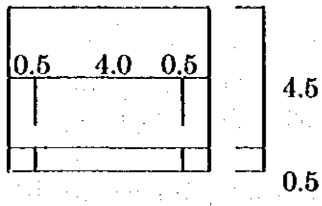
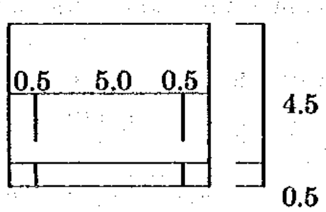
- A frontage road will be provided to compensate for any loss in existing road and community functions.
- Basically, frontage roads will be two-way, but only one-way traffic will be allowed at merging points with ramps (diamond type).
- Considering the convenience of roadside usage, crossing points will be provided about every 500 m to maintain existing functions.
- To minimize cost as much as possible, existing roads will be used together with the planned frontage road.

9.8.2 Intersection Structures

For locations where existing road and community functions cannot be maintained after the OCH and its interchanges are constructed, the following basic concept will apply:

> Crossing points will be provided about every 500 m to maintain existing road and community functions.

Box culvert design at these crossing points was determined as follows:

Concept	Illustration
(1) When existing road width is about 6 m or more, the section will be 6 m x 6 m, taking into account a clearance of 5.25 m + an additional height of 0.5 m for utilities.	
(2) For roads where agricultural traffic is predominant, the section will be 5 m x 5 m, taking into account a clearance of 4.5 m + an additional height of 0.5 m for utilities.	
(3) When a service road is to detour one-way traffic, the width will be the same as the service road to enable two-way traffic. The section will be 6 m x 5 m, taking into account a clearance of 4.5 m + an additional height of 0.5 m for utilities.	

CHAPTER 10

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

CHAPTER 10 ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

10.1 Summary

10.1.1 Introduction

The purpose of the EIA is to ensure that the potential environmental consequences of the proposed OCH are recognized early for required mitigatory action, which will be taken into consideration in project planning and designs. The present EIA assesses the existing environmental conditions in the 2 km wide corridor encompassing the proposed 100m wide right of way, identifies significant impacts on the environment, evaluates alternatives to the proposed road and recommends mitigatory measures for identified significant adverse impacts. It also presents a monitoring plan and makes a recommendation on the environmental acceptability of the road project. An environmental cost benefit analysis, a land use map on 1:20,000 scale and a map containing the environmentally acceptable trace has also been included in the EIA. EIA was conducted according to Sri Lankan environmental laws and regulations and the Terms of References was elaborated by Central Environmental Authority (CEA) based upon the findings of IEE, which had been conducted by the JICA Study Team.

10.1.2 Methodology

The general methodology adopted in the EIA process is as follows:

-Analysis and understanding of the Terms of Reference (TOR)
-Identification of potential impacts and preparation of a relevance matrix.
-Survey and collection of available information
-Identifying the data to be collected and procedures to be adopted
-Conducting social, ecological and hydrological field surveys
-Preparing detailed land use map
-Conducting Air and Water quality and Noise level monitoring surveys
-Identification of significant impacts
-Comparison of alternatives
-Recommending mitigatory measures
-Formulating a monitoring plan
-Making recommendations on environmental feasibility of the project.

The EIA has examined all classes of roads and ferry crossings in the study area giving due consideration to the limitations in the existing road system. The government policy on the development of the road network is to minimize traffic congestion on existing trunk roads, particularly within the city of Colombo and promote regional development. The plans developed by the Urban Development Authority (UDA) are oriented towards shifting the urban functions and populations to the outer suburbs to assist in reduction of traffic congestion. The proposed OCH abides by the Government policy and conforms to the UDA plans.

10.1.3 Environmental Policy, Regulations and Guidelines

The legal requirement for the EIA is found in the National Environmental Act No. 47 of 1980 and No.56 of 1988. The legal authority for land acquisition is provided by the land acquisition Act No.9, the Road Development Authority Act No.73, the Urban Development Authority Act No.41, Urban Development Project (special Provisions Act No.2).

Resettlement issues, previous experience of resettlement and land acquisition have also been addressed in the EIA.

10.1.4 Existing Environment

The physical environment of the proposed project area was studied in detail by using available data and field surveys including sample analysis. While the proposed trace crosses the Kelani River and the Bolgoda Canal, the entire trace lies on the lowest peneplain, which is mainly flat, with a few low hills and undulations. The project area is in the wet zone, which benefits from the bimodal rainfall pattern of the country and contains a fair number of water bodies. A significant number of drainage paths cross the proposed trace. There are also several minor irrigation canals crossing the trace or traversing along the trace.

The ground water levels prevailing along the trace has also been recorded. Further, two hydrogeological units have been identified as closely associated wit the underlying geology.

The soils in the project area have been identified, and the general geology and mineral resources of the area has also been described. The water quality in the project area has been identified by field monitoring and using available data. Air quality and noise levels have been studied the same way.

Ecological resources have been recorded using available data and field surveys. The ecological habitats in the project area have been identified as Marshes, Paddy lands, Home gardens Plantation crops, Shrub-lands, Rivers, Streams and Lakes. The distribution of these habitats have been mapped and depicted in map 5-3-6, in EIA report volume II. The floral diversification of the project area has been established with regards to above habitats and the inventory of plants have been annexed in EIA report volume II of the project. Endemicity and the stability of plants with regard to abundance/threat have been included in the listing.

Invertebrates, fish, amphibians, birds and reptiles in the project area has been listed. Their endemicity and current status with regards to abundance/threat has been stated. The habitat of fauna in the project area has also been described.

With regard to present land use in the area, the compilation methodology of the 1:20,000 scale land use map has been detailed and the different land use areas have been quantified. Important sites, power lines, industrial sites, educational and religious places, burial grounds and recreational areas affected by the road trace have been enumerated and tabulated. The affected transport, irrigation canals, drinking water, electricity and telephone facilities, hospitals and health facilities, markets and other institutions have been identified. The general socio-economic conditions have been examined and described.

The socio-economic profile in the study area including demographic characteristics social infrastructure, cultural ties income generation and employment has been summarized under this sub heading while the data compiled through surveys are tabulated in EIA report volume II. Other infrastructure facilities such as roads has been identified and listed.

Anticipated Environmental Impacts

The anticipated impacts of the operational phase of the project have been identified with regard to the following physical, biological and social aspects of the environment.

10.1.5 Environmental and Social Impacts

1) Environmental Impacts

As a result of environmental impact assessment, the following adverse environmental impacts have been identified:

-Surface run-off and future flood water levels
-Irrigation and flood protection works
-Inundation levels in flood plains

-Future urbanization of the sub- catchments
-Water quality changes.
-Noise and vibration levels
-Air quality changes
-Loss of habitat
-Fauna and flora
-Fisheries and aquatic life
-Community severance
-Changes in property values
-Changes in accessibility and demand for schools, religious and business institutions.
-Effect on transportation
-Effect on special social groups
-Effect on households and businesses to be relocated
-Effect on employment opportunity
-Effect on accessibility
-Fragmentation of agricultural lands
-Loss of agricultural land and production
-Changes in economic and socio -economic situation

The significant impacts on the physical resources are disruptions to the drainage pattern by the effect of the road embankment on surface run-off and flood and inundation levels in the flood plains. However, these impacts which could cause severe environmental problems can be avoided or minimized with proper engineering designs that would allow for natural flow of surface run-off and floodwaters.

The significant adverse effect on the biological resources is the impact on wetlands around Bolgoda Lake system. In addition, construction activities may cause adverse effects on the ecosystems as well as fauna and flora.

2) Social Impacts

The social impact assessment was carried out to assess the likely impacts, especially adverse social impacts that may result from the implementation of proposed OCH. Three main methods were employed to collect data and information to analyze the social impacts. These are: data collection from Grama Niladharis within the study area-2 km corridor, focus group discussions with the community leaders along the identified 100 m road trace, and household survey on 432 families living along the road trace.

The analyses revealed that the proposed project might result in significant social impacts. The affect on properties in the 100-m trace will include:

-A large number of developed households
-A moderate number of businesses place
-A moderate number of industries
-A few educational institutions (schools)
-A few religious places
-A few cemeteries
-And some other developed properties in a rapidly developing area in general

Some of the major negative impacts on the existing socio-economic environment are as follows:

-A significant numbers of households have to be relocated and this will lead to various types of community severance. The long term established community relations would be affected.
-There will be physical as well as psychological shocks to the communities affected.
-The established livelihood system will be disrupted.
-Parts of land will be lost and some other land will be fragmented. The productivity of such lands will be affected.
-Some school buildings will be affected. This would be a problem for the children studying in the schools as well as for their parents.
-Religious places will be affected in some locations.
-The impact of construction activities has been studied in detail and haulage of construction material; emission of particles; sediment generation and noise are the significant impacts identified. Extraction of construction material, particularly sand, has been sited as a major problem.

Tab. 10.1 Summary of Environmental and Social Impacts

	PROJECT / ENVIRONMENT	Prep			Construction														Operation						
		geotech. investigat.	land surveying	land acquisition	const.material	site clearing	cut&fill	blasting&drilling	surfacing&paving	land reclamation	ditching&drainage	spoil disposal	asp.concrt.plants	bridge const.	culvert const.	agro.chem use	labour force	displace.&resettle.	traffic increase	encroachments	road accidents	hazard.material	road maintain.	roadside develop.	unforeseen acts
P	Min. Resources																								
Y	Soil				■	■	■					▨													
S	Landform			■			■		▨			▨													
I	Surface Water Quantity								▨			▨													
C	Ground Wat. Quant.			▨						▨															
A	Surface Wat. Quality										▨														
L	Ground Wat. Quality																								
	Air Quality						▨						▨						▨			▨			
	Noise Level	▨			▨		▨	■						▨	▨				▨						
	Hydrology			▨			▨				▨														
	Erosion & Siltation			▨	▨		▨																		
	Earth Stability				▨			■																	
	Irrigation & Flood Protec			▨																					
B	Flora-terrestrial					▨										▨				▨				▨	
I	Flora-aquatic				▨							▨				▨									
O	Fauna-terrestrial					▨	▨	▨											▨		▨			▨	
	Fauna-aquatic				▨			▨					▨			▨				▨		▨			
	Avifauna						▨																		
	Biodiversity				▨	▨	▨	▨								▨				▨				▨	
	Land use			■	■	■	■	▨	▨	▨	▨	▨				▨		■							
	Tenure			■		▨																			
	Settlement Pattern			■		▨	▨		▨	▨		▨						▨		▨				▨	
	Long term land use					▨	▨	▨	▨	■	▨							▨		▨				▨	
	Social struct.									▨							▨	▨		▨				▨	
	Popul.Migran.Settlem.									▨							▨	▨		▨				■	
S	Education																								
O	Access & Mobility								▨	▨				▨	▨			▨	▨					▨	
C	Access of Services																								
I	Public Health & Safety				▨		▨									▨			▨		▨	▨			▨
O	Housing			■						▨								▨							
E	Other Infrastruc. facilites									▨														▨	
C	Other transp.& Facil.									▨				▨	▨										
O	General Lifestyle									▨														▨	
N	Employment			■						▨							▨	▨		▨				▨	
O	Agriculture			■														▨		▨				▨	
M	Tourism																	▨		▨					
I	Income Distribution																			▨				▨	
C	Structures			■		▨	▨	▨		▨														▨	
	Business Volumes																			▨					
	Property Values			▨						▨								▨		▨				▨	
	Visual. & Landscape					▨	▨	■		▨				▨	▨								▨	▨	
	Hist.& Archaeo.Monu.																								
	Important Places					▨	▨	■		▨															

HIGHLY SIGNIFICANT ■
SIGNIFICANT ▨
COULD BE IGNORED □

10.1.6 Mitigation Measures

In a development project designed to be implemented in a highly a developed area, environmental impacts cannot be totally avoided. What is possible is to minimize such impacts to the extent possible. Therefore, mitigatory action for all the significant adverse impacts have been recommended.

The major action to be taken is to design the road trace to minimize the negative impacts on the communities and their properties and also wetlands. In the eventuality that the community is affected proper compensation should be offered to the affected communities. An effective compensation program should be implemented to the satisfaction of the affected people. Adequacy, timeliness and reliability are the main criteria to be fulfilled in implementation of the compensation program.

Overall, the RDA should employ a participatory approach to implement the mitigatory program in the field. For this an effective rapport should be built with the affected parties as well as with the grassroots level agency officials in the field. Working closely with divisional secretaries in the project area will be a necessary condition. With the experience RDA has gained in the past road development projects it should be able to handle the problems mentioned above with the assistance of other external expertise.

The impact on the drainage pattern can be avoided or minimized to an acceptable level by providing bridges culverts and other drainage structures of the required capacity where necessary.

The impact on Bolgoda wetlands has to be avoided by shifting the road trace away from the wetland system.

However, for the impact of sand extraction mitigation suggested may not be acceptable to all stakeholders considering the additional cost involved. Further investigation in this area maybe required.

10.1.7 Extended Environmental Cost Benefit Analysis

The Extended Cost Benefit Analysis has considered the financial and economic costs and benefits of the project and extended the analysis to Environmental Benefit Cost. The results of the analysis indicate that the project is feasible after environmental costs and benefits are considered.

10.1.8 Institutional Requirements and Environmental Monitoring Program

The institutional requirement for monitoring has been identified as the establishment of a project monitoring committee (PMC) which will be responsible for the implementation of the monitoring plan. The constitution of the PMC has been suggested and the required monitoring with regard to Flood levels, Air and Water quality, and Noise level, Biological aspects, Relocation and Resettlement have been detailed.

10.1.9 Conclusions and Recommendations

The conclusions reached are that whereas the proposed OCH is an economically viable necessity, its adverse environmental impacts mentioned above are significant. Hence, it is essential that the recommended mitigation be implemented under close monitoring.

Based on these conclusions a recommendation has been made to the effect that the project is environmentally acceptable provided that the environmentally acceptable road trace recommended in the EIA is considered and the mitigatory action implemented. Moreover, the contract documents should include environmental safeguards and recommended Project Monitoring Committee should closely monitor the implementation of the mitigatory measures.

Further investigation is required with regard to the extraction and source of sand at detailed design stage.

In addition, a resettlement plan including potential resettlement sites, compensation for different categories of people to be relocated and a time schedule should be formulated immediately after the determination of the final road alignment.

10.2 Environmental Impact Assessment Report

Environmental and Social Impact Assessment Report is attached to this Draft Final Report, which is to be submitted to Central Environmental Authority by RDA.

JICA