5.3 Brief Notes on Geometric Design Standard

(1) General

Since the geometric design standards of each classified road must reflect the desired goals identified by the Department of Public Works (JKR) and Malaysia Highway Authority (MHA), it is possible to apply uniformed standards.

JKR and MHA have already prepared the following geometric design standards, i.e.:-

- A Guide on Geometric Design of Roads issued in 1986 (JKR);
- A Guide to the Design of At-Grade Intersections issued in 1987 (JKR);
- A Guide to the Design of Interchanges issued in 1987 (JKR);
- A Guide to the Design of Cycle Track issued in 1986 (JKR); and
- Design Standard for Interurban Toll Expressway System of Malaysia (MHA).

The recommended geometric design standards for the project roads are mainly derived from the abovementioned guides. Some necessary supplements are made. Table 5.3.1 tabulates the recommended design standards.

Brief notes on the main items of the standards for throughway and ramps at interchanges are described below (the same general sequence of descriptions in the JKR Guide is followed).

Table 5.3.1 Design Control and Element of Roads

Items	Road	Throughway			Ramp		
		Southern Part of Middle Ring Road II	Shah Alam Highway	North-South Link	Semi-Direction	Loops and Diagonal	Loops and Diagonal
Design Control	Design Standard	Arterial (U5)	Arterial (U5)	Expressway (R6)	-	-	-
	Design Vehicle	Truck Combination (WB-50)	Truck Combination (WB-50)	Truck Combination (WB-50)	Truck Combination (WB-50)	Truck Combination (WB-50)	Truck Combination (WB-50)
	Design Speed (km/h)	80	80	120	60	50	40
	Design Daily Capacity (veh/day/Lane)	11,700	9,400	8,800	7,200	7,500	7,500
Element of Design	Sight Distance (m)	140	140	285	85	65	45
	Lane Width (m)	3.50	3.50	3.75	3.50	3.50	3.50
	Outer Shoulder Width (m)	3.00 (1.50)	3.00 (1.50)	3.00 (1.50)	3.00 (1 Lane) 0.75 (2 Lanes)	3.00 0.75	3.00 0.75
	Inner Shoulder Width (m)	0.75	0.75	0.75	0.75	0.75	0.75
	Crossfall of Travelled Way (%)	2.5	2.5	2.5	2.5	2.5	2.5
	Crossfall of Outer Shoulder (%)	4	4	4	4 (1 Lane) 2.5 (2 Lanes)	4 2.5	4 2.5
	Type of Pavement	Asphalt Concrete	Asphalt Concrete	Asphalt Concrete	Asphalt Concrete	Asphalt Concrete	Asphalt Concrete
	Maximum Superelevation (%)	10	10	7	7	7	10
	Minimum Radius (m) Max.Grade(%) (Desirable) (Absolute)	230 4 7	230 4 7	650 2 5	125 5 8	85 6 8	50 7 10
Remarks		( ) Value for bridge and viaduct section, of length more than 100m					

(2) Design Controls

(a) Road Classification

The recommended category of each project road is shown in Table 5.3.2.

Table 5.3.2 : Category of Project Roads

Project Road	Area	Design Standard	Terrain	Landuse
Southern part of Middle Ring Road II (MRR-II)	Urban	U5	Flat	I
Shah Alam Highway	Urban	U5	Flat	I
North South Expressway Link (N-S Link)	Rural	R6	Flat	-

(b) Design Vehicles

The physical characteristics of vehicles and the proportions of variously sized vehicles using the roads are positive controls in geometric design. Design vehicles are selected motor vehicles with the weight, dimensions and operating characteristics used to establish highway design controls for accomodating vehicles of designated classes. For purposes of geometric design, each design vehicle has larger physical dimensions and larger minimum turning radius than all vehicles in its class.

The designation of design vehicle for each road component is made considering the future landuse along the corridor of each road and the characteristics of future traffic.

Project Road	Design Vehicle	Symbol
MRR-II	Truck Combination	WB-50
Shah Alam Highway	Truck Combination	WB-50
N-S Link	Truck Combination	WB-50

(c) Design Speed

Design speed is the maximum safe speed that can be maintained over a specified section of road. The design speed selected will directly affect many geometric elements, i.e. horizontal and vertical alignments, sight distance, provision of superelevation, etc. Other features such as carriageway width and roadside clearances are also influenced by design speed but to a lesser degree.

(i) Throughway

Design speeds of relevant expressway and highway which will be connected to the project roads are assumed as follows :-

Relevant Roads Connected to Project Roads	Classification	Design Speed (km/h)
Federal Route II	Highway (R5-I)	100
New Klang Valley Expressway	Expressway (R6-F)	120
North Klang Straits Bypass (Existing)	Undivided 2-lane(U2-I)	40
(Future)	Highway (U5-I)	80
KL-Seremban Expressway	Expressway (R6-F)	120
Northern Section of Middle Ring Road II	Expressway (U6-II)	80

The recommended design speed of each project road is established by considering the road category, topography and landuse of area and the design speed of relevant roads. The recommended design speeds are shown in Table 5.3.3.

Table 5.3.3 : Recommended Design Speed

Project Roads	Design Speed (km/h)
MRR-II	80
Shah Alam Highway	80
N-S Link	120

(ii) Ramp at Interchange

AASHTO standard, 1984 recommends the following ramp design speeds :-

Design Speed of Throughway	80 km/h	120 km/h
Ramp Design Speed		
- Upper range (85%)	68 km/h	102 km/h
- Middle range (70%)	56 km/h	84 km/h
- Lower range (50%)	40 km/h	60 km/h
Minimum Design Speed by Type of Ramp		
- Loops and diagonal	40 km/h	
- Semidirect connection	48 km/h	
- Direct connection	56 km/h	

Semidirect ramps are usually adopted for systems interchange and loops or diagonal ramps are often adopted for service interchange. Design speed of 60km/h for Systems IC is adopted. For Service IC, design speed of 50km/h and 40km/h are adopted for North-South Link and MRR-II/Shah Alam Highway respectively. The availability of Right-of-way (ROW) as well as the economical and functional viewpoints are taken into consideration to recommend the abovementioned design speeds.

(iv) Capacity

To determine the required number of traffic lanes, the capacity of each project road is analyzed based on future traffic characteristic factors. The concept and methodology used for the analysis are based on the "Highway Capacity Manual" of the Highway Research Board, USA.

Some adjustments are made to reflect local conditions based on the results of studies accomplished by "A Guide on Geometric Design of Roads of Malaysia" and "Road Design Standard" of Japan. These studies are used because similar operating conditions are found in Malaysia and Japan. The design capacity of each project road is presented in Table 5.3.4.

Table 5.3.4: Analysis of Design Road Capacity

Description		Throughway			Ramp	
		Southern part of Middle Ring Road II	Shah Alam Highway	North South Link	Semi-Direction	Loops and Diagonal
Design Speed (km/h)		80	80	120	60	40
Terrain or Grade		Flat	Flat	Flat	4%	5%
Capacity Under Ideal Conditions (PCU/Hour/Lane)		2000	2000	2000	2000	2000
Design Level of Service		C	C	C	C	C
Coefficient of Service Level		0.75	0.75	0.70	0.70	0.75
Maximum Service Flow Rate (PCU/Hour/Lane)		1500	1500	1400	1400	1500
Width of Lane (m)		3.50	3.50	3.50	3.50	3.50
Lateral Clearance (m)	Roadside	3.00	3.00	3.00	3.00	3.00
	Median	0.75	0.75	0.75	0.75	0.75
Heavy Vehicles	Rate of H.V.%	20	20	20	20	20
	Composite Passenger Car Equivalency	2.5	2.5	2.5	3.8	4.3
Coefficient	Width of lane	1.00	1.00	1.00	1.00	1.00
	Lateral clearance	0.97	0.97	0.97	0.97	0.97
	Heavy Vehicle	0.77	0.77	0.77	0.64	0.60
	Driver Population	1.00	1.00	1.00	1.00	1.00
	Total	0.75	0.75	0.75	0.62	0.58
Service Flow Rate (Veh/Hr/Lane)		1125	1125	1050	868	900
Design Hourly Volume Ratio (%)		8	10	10	10	10
Directional Distribution Ratio (%)		60	60	60	60	60
Design Daily Capacity (Veh/Day/Lane)		11700	9400	8800	7200	7500

The following brief notes may warrant the values adopted in Table 5.3.4.

Rate of Heavy Vehicles

According to the traffic survey conducted in April 1985, hourly traffic volumes by eight types of vehicles were counted, namely; sedan, taxi, small van, lorry (2 axles), lorry (3 axles and above), minibus, large bus and motor cycle.

For the purpose of capacity analysis, sedan, taxi, small van and minibus are regarded as passenger car, lorries as truck and large bus as bus. Motor cycle is not included in the analysis because of the provision of cycle track. Heavy vehicles are assumed to consist of the abovementioned truck and bus. Table 5.3.4 shows the rate of heavy vehicles for expressway and highway varying at the range of 17% and 23% while the range for minor arterial road is at 6% to 17%. Thus, a rate of 20% for expressway and highway and 10% for minor arterial roads are adopted.

Passenger Car Equivalency

Adjustment factors for heavy vehicles (FHV) by each road type are calculated on the assumption that the passenger car equivalency for each vehicle type is shown below :-

Type of Vehicle	Passenger Car Equivalency
Passenger Car	1.0
Truck	2.5
Bus	3.0

Using the composite passenger car equivalencies by road types and the average rate of heavy vehicles (determined based on existing traffic composition); the average FHV values are obtained as 0.77 for expressway and highway and 0.85 for minor arterial road.

Composite passenger car equivalencies for ramp of interchange are assumed to be 3.8 for semi-direction and 4.3 for loop and diagonal respectively due to steeper grade.

Peak Hour Factor and Directional Distribution Ratio

Peak hour factor varies at the range of 7.2% and 9.7% while directional distribution ratio at peak hour varies from 51% to 69%. Generally, a higher standard road has lower peak hour factor and directional distribution ratio and vice-versa for the lower road. According to the actual observations as shown in Table 5.3.5, design hourly volume ratio of 8%, which is derived from the actual peak hour factor, and directional distribution ratio of 60% are applicable to expressway and highway, while 10% and 65% are applicable to minor arterial roads.

Table 5.3.5: Traffic Characteristics in Project Area (Excluding Motor Cycle)

Classification of Road	Jalan Cheras (No.3) Arterial	KL-Seremban Exp (No.1) Expressway	Federal Route (No.18) Highway	Jalan Puchong (No.14) Minor Arterial	Jalan Klang Lama (No.6) Minor Arterial
24 hours traffic (veh/day)					
Passenger Car (Pc)	24,948 (83%)	18,769 (77%)	63,483 (83%)	11,158 (83%)	46,918 (94%)
Trucks (Pt)	4,445 (15%)	5,009 (21%)	11,680 (15%)	1,922 (14%)	2,004 (4%)
Buses (Pb)	651 (2%)	538 (2%)	1,570 (2%)	371 (3%)	943 (2%)
Total	30,044 (100%)	24,316 (100%)	76,733 (100%)	13,451 (100%)	49,865 (100%)
Peak hour traffic (veh/hr)					
Peak time	17.00-18.00	7.00-8.00	8.00-9.00	7.00-8.00	17.00-18.00
Both	2,165	1,967	6,520	965	4,819
Dominant Direction	1,361	1,221	3,674	492	3,310
Rate of Heavy Vehicle (%)	17	23	17	17	6
Adjustment Factor for Heavy Vehicles FHV	0.79	0.74	0.79	0.79	0.91
Peak Hour Factor (%)	7.2	8.1	8.5	7.2	9.7
Directional Distribution Ratio at Peak Hour (%)	62.9	62.1	56.3	51.0	68.7

Note : FHV = 1/(1.0 x Pc + 2.5 x Pt + 3.0 x Pb)

(3) Elements of Design

(a) Sight Distance

Stopping sight distance is the sum of two distances :-

- The distance traversed by the vehicle from the instant that the driver sights an object necessitating how to make a stop to the instant that the brakes are applied (Brake Reaction Time); and
- The distance required to stop the vehicle from the instant that the brake application begins (Braking Distance).

2.5 seconds is used for the former and the later is dependent on the initial speed and the coefficient of friction between tires and pavement.

The following equation is used for the calculation of stopping sight distance.

$$D = 0.694 \times V + 0.00394 \times \frac{V^2}{f}$$

Where

D : Stopping sight distance (m)
V : Initial speed (km/h)
f : Coefficient of friction between tires and pavement

Stopping sight distances by each design speeds on the wet conditions are shown in Table 5.3.6.

Table 5.3.6 : Stopping Sight Distance on Wet Pavement

Design Speed (km/h)	Initial Speed		Friction Coefficient on Wet Pavement	Stopping Sight Distance (m)	
	%	km/h		Calculated	Adopted
120	100	120	0.28	285.9	285
80	100	80	0.30	139.6	140
60	100	60	0.33	84.6	85
50	100	50	0.35	62.8	65
40	100	40	0.38	44.3	45

Sight distance is defined as the distance along a roadway that an object of specified height (h = 0.15m) is continuously visible to the driver with eye-height of 1.07m above the road surface. Sight distance should be at least where the driver or vehicle stops in this distance, that is, stopping sight distance.

At ramp terminal and at-grade intersection, longer sight distance than stopping sight distance is required due to safe entry or exit. The adopted sight distances by each design speed are shown in Table 5.3.7.

Table 5.3.7 : Sight Distance by Type of Road

Description	Sight Distance (m)
N-S Link, Throughway Vd = 120km/h	285
N-S Link, Ramp Terminal Vd = 120km/h	425
MRR-II/Shah Alam Highway, Throughway Vd = 80km/h	140
MRR-II/Shah Alam Highway, Ramp Terminal Vd = 80km/h	210
Semi-direction Ramp Vd = 60km/h	85
Loop/Diagonal Ramp Vd = 50km/h	65
Loop/Diagonal Ramp Vd = 40km/h	45
Frontage Road, Throughway Vd = 40km/h	45
At-grade Intersection Vd = 40km/h	100

(b) Maximum Superelevation, Minimum Radius and Value of Superelevation on Curvature

These three factors together with the design speed are closely related to each other. The design speeds of 100km/h, 80km/h, 60km/h and 40km/h were recommended as discussed previously for expressway, highway/arterial, ramps and minor arterial roads.

The relation between minimum radius and maximum superelevation is calculated from the following formula :-

$$R = \frac{V^2}{127(i+f)}$$

Where -

R : Radius (m)
V : Design Speed (km/h)
i : Superelevation (m/m)
f : Side Friction Factor

Maximum allowable side friction factors are decided as shown in Table 5.3.8 considering comfort of drivers and traffic safety.

Table 5.3.8 : Maximum Allowable Side Friction Factor

Design Speed (km/h)	120	80	60	50	40
Expressway/Highway	0.10	0.12	0.16	0.16	0.16
Other Roads	-	-	0.16	-	0.16

Absolute maximum side friction factor of 0.4 may be used in order to check the safety on curves assuming that a vehicle is being operated at an excessive speed (10 km/h higher than the design speed).

Table 5.3.9 : Maximum Superelevation and Minimum Radius

Type of Road	Throughway			Ramp		
Design Speed (km/h)	120	80	40	60	50	40
Maximum Allowable Side Friction Factor (f)	0.11	0.12	0.16	0.16	0.16	0.16
Maximum Superelevation (i maximum) %	7	10	6	7	7	10
Minimum Radius (m)	650	230	60	125	85	50
Side Friction Factor if 10km/h higher than design speed	0.14	0.18	0.27	0.23	0.26	0.29
Absolute Maximum Side Friction Factor	0.40	0.40	0.40	0.40	0.40	0.40

Crossfall of 2.5% applicable to carriageway is mainly determined by drainage requirements. The minimum curvature which requires superelevation is determined by setting consistently low friction factor values, considering the effect of crossfall.

Side friction factor of 0.04 for Expressway/Highway and 0.16 for other roads are used to determine sharpest curve without superelevation as shown in Table 5.3.10.

Table 5.3.10: Sharpest Curve Without Superelevation

Type of Road	Throughway			Ramp		
Design Speed (km/h)	120	80	40	60	50	40
Side Friction Factor (f)	0.04	0.04	0.16	0.04	0.04	0.04
Crossfall (%)	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5
Sharpest Curve Without Superelevation (m)	7500	3500	100	2000	1300	800

It is warranted to use side friction factor $f = 0.16$ and maximum superelevation $i_{max} = 6\%$ for urban street where the high accessibility to adjacent buildings and facilities should be kept.

The method of distributing superelevation and side friction factor is examined and it is decided to adopt that superelevation and side friction factors are directly proportional to the degree of curve (refer to Figure 5.3.1).

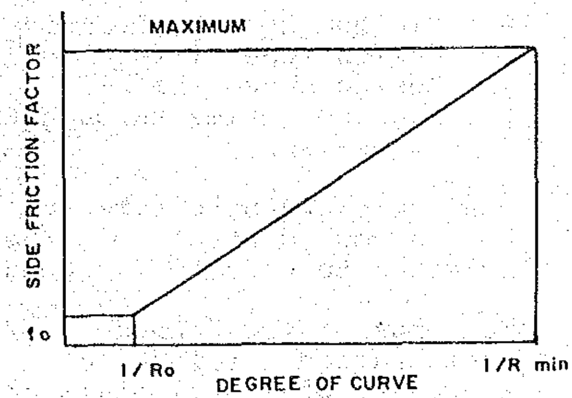


Figure 5.3.1 : Method of Distributing Side Friction Factor

Where
R min : Minimum radius
Ro : Sharpest curve without superelevation

Since snow and freezing never occur in Klang Valley, sufficient side friction can be expected even though there is a tendency for some drivers to travel faster on the flatter curves.

Besides its simplicity, this method has the following merits :-

- rider comfort for the slower moving;
- ease of merging and diverging at ramp terminals; and
- ease of construction

(c) Minimum Transition Curve Length

Transition curves are desirable on high speed roads between circular curves of substantially different radii and between tangents and circular curves.

The length necessary for controlling the steering on a curve is calculated from the following formula which provides required length for a natural and easy-to-follow path for drivers.

$$L = v \times t = \frac{V}{3.6} \times t$$

Where

L : Minimum transition curve length (m)
v : Design speed (m/sec)
V : Design speed (km/h)
t : Running time through the transition curve (sec)

Desirable running time through the curve to allow control of the steering is reported to be 3 to 5 seconds.

To make the change of centrifugal acceleration tolerable, the rate of increase of centripetal acceleration (P m/cu.sec) is examined by Short's equation:-

$$P = \left(\frac{V}{3.6}\right)^3 / L \times R$$

Where

P : Rate of increase of centripetal acceleration (m/cu.sec)
V : Design speed (km/h)
L : Minimum transition curve length (m)
R : Minimum curve radius (m)

Pmax = 0.5 m/cu.sec for Expressway/ Highway and Pmax = 0.75 m/cu.sec for other roads are adopted. Table 5.3.11 shows the minimum transition curve lengths and its rate of acceleration.

Table 5.3.11 : Minimum Transition Curve Length

Type of Road	Throughway			Ramp		
Design Speed Vd (km/h)	120	80	40	60	50	40
Running time t (sec)	5	5	3	5	5	5
Minimum Curve Radius (m)	650	230	60	125	85	50
Minimum Transition Curve Length L (m)	165	110	35	85	70	55
Rate of Increase of Centripetal Acceleration P (m/cu.sec)	0.35	0.43	0.65	0.44	0.45	0.50

(d) Minimum Horizontal Curve Length

These figures are designated to cover all the horizontal curve lengths, including transition curves, if any, and to be of sufficient length for drivers to comfortably adjust their steering to allow for the change in curvature.

Rider Comfort (tolerable limit)

$$L = 0.278 \times Vd \times t$$

Where

L : Minimum horizontal curve length (m)
Vd : Design speed (km/h)
t : Minimum required steering time on curve (sec), t = 6 sec

Design Speed (km/h)	120	80	60	50	40
Minimum length calculated (m)	200	133	100	83	67
Adopted Value (m)	200	140	100	85	70

In the case where the intersection angle (O) is small, 7 degrees or less, it is desirable to use longer horizontal curve length than the minimum required value of 7 degrees. Minimum horizontal curve length is calculated as follows :-

Minimum Secant Length, N min

$$N\ min = \frac{\theta_0 Lo}{6} = 0.020 \times Lo$$

Where :-
θ_0 : Intersection angle to govern minimum secant length $\theta_0 = 7° = 0.122$ rad
Lo : Minimum Transition Curve Length (m)

Type of Road	Throughway			Ramp		
Design Speed Vd (km/h)	120	80	40	60	50	40
Minimum Transition Curve Length (m)	165	110	35	85	70	55
Secant Length (m)	3.30	2.20	0.70	1.70	1.40	1.10

Minimum Horizontal Curve Length, L min

$$L\ min = 2 \times Lo = \frac{12\ N\ min}{\theta\ (rad)} = 688\ \frac{N\ min}{\theta}\ (degree)$$

Type of Road	Throughway			Ramp		
Design Speed Vd (km/h)	120	80	40	60	50	40
Minimum Secant Length (m) N min	3.30	2.20	0.70	1.70	1.40	1.10
Minimum Curve Length (m)	2300/θ	1500/θ	500/θ	1150/θ	950/θ	750/θ

The minimum value of θ is 2 if the intersection angle is less than 2 degrees.

(e) Maximum Gradient and Minimum Grade

Values of the maximum gradient are normally determined based on the condition that fully loaded trucks can keep climbing a slope and maintain a speed of at least half the design speed. The maximum gradient 2%, 4%, 5%, 6%, 7% for design speed 120km/h, 80km/h, 60km/h, 50km/h, 40km/h respectively are adopted.

When steeper gradients are provided, critical length of grade should be considered. The term "critical length of grade" is used to indicate the maximum length of a designated upgrade upon which a fully loaded truck can be operated without an unreasonable reduction in speed. For a given grade, lengths less than "critical" result in acceptable operation in the desired range of speeds. Table 5.3.12 shows the critical length of grade by each design speed.

Table 5.3.12 : Critical Length of Grade by Design Speed

Design Speed (km/h)	Grade (%)	Critical Length of Grade (m)
120	2	-
	3	500
	4	400
	5	300
80	4	-
	5	600
	6	500
	7	400
60	5	-
	6	500
	7	400
	8	300
50	6	-
	7	500
	8	400
	9	300
40	7	-
	8	400
	9	300
	10	200

With curbed pavement, longitudinal drain for stormwater on the carriageway requires a minimum grade. A desirable minimum grade for the usual case is 0.5%, but a grade of 0.35% may be used where there is a high-type pavement accurately crowned and supported on firm subgrade.

(f) Minimum Vertical Curve Length

Vertical curves effect gradual change between tangent grades in crest and sag curves and should result in a design that is safe, comfortable in operation, pleasing in appearance and adequate for drainage.

The major control for safe operation on crest vertical curves is the provision of ample sight distance for the design speed and rider comfort.

Headlight sight distance and rider comfort govern the length of a sag vertical curve.

The following equations are used for the calculation of vertical curve length and radius of vertical curve.

(i) Rider Comfort (tolerable limit)

$$L = \frac{Vd}{3.6} \times t$$

Where :-
L : Vertical curve length (m)
Vd : Design speed (km/h)
t : Minimum required time, t = 3 sec.

(ii) Crest type (eye height he=1.07m, object height ho=0.15m)

$$L = \frac{D^2 \times i}{405} \text{ or } R = \frac{100 \times D^2}{405}$$

Where
L : Vertical curve length (m)
D : Sight distance (m)
R : Radius of vertical curve (m)
i : Algebraic difference in grade (%)

(iii) Sag type (headlight height h=0.61m upward divergence $\delta=1^\circ$)

$$L = \frac{D^2 \times i}{122 + 3.49 \times D} \quad \text{or} \quad R = \frac{100 \times D^2}{122 + 3.49 \times D}$$

Where
L : Vertical curve length (m)
D : Sight distance (m)
R : Radius of vertical curve (m)
i : Algebraic difference in grade (%)

Table 5.3.13 shows minimum vertical curve and radius of vertical curve.

Table 5.3.13: Minimum Vertical Curve Length

Type of Road		Sight Distance (m)	Rider Comfort (m)	Crest Curve: Vertical Curve Length (m)	Crest Curve: Radius of Vertical Curve (m)	Sag Curve: Vertical Curve Length (m)	Sag Curve: Radius of Vertical Curve (m)
Design Speed Vd=120km/h	Throughway	285	100	200 x i	20,000	70 x i	7,000
	Ramp Terminal	425	100	440 x i	44,000	110 x i	11,000
Design Speed Vd=80km/h	Throughway	140	70	48 x i	5,000	32 x i	3,000
	Ramp Terminal	210	70	109 x i	11,000	52 x i	5,000
Design Speed	Vd = 60km/h	85	50	18 x i	2,000	17 x i	2,000
	Vd = 50km/h	65	40	10 x i	1,000	12 x i	1,200
	Vd = 40km/h	45	35	5 x i	500	7 x i	700
At-Grade Intersection		100	35	25 x i	2,500	21 x i	2,000

(g) Minimum Radius of Curve not Requiring Transition Curves

The minimum radius of curve for which no transition curves are required is calculated by using the following formula:-

$$R = \frac{1}{24} \times \frac{L^2}{S}$$

Where

S : Shift in meters between curve and tangent
L : Transition curve length (m)
R : Radius of circular curve (m)

Maximum shift Smax = 0.20m is applied to the above formula and then minimum radius R min is calculated as follows :-

Table 5.3.14 : Minimum Radius of Curve Not Requiring Transition Curves

Type of Road	Design Speed (km/h)	Minimum Transition Length (m)	Minimum Radius (m)
Expressway/ Highway,Throughway	120	165	5,500
	80	110	2,500
	60	85	1,500
Ramp	50	70	1,000
	40	55	600
Frontage Road	40	35	250

(h) Crossfall of Carriageway and Shoulder

Considering the advantage in rapidly draining the pavement during rainstorms, a crossfall of 2.5% is adopted as a standard on expressway/ highway and other roads.

Normal crown arrangement is applied to the roads except at sections on bridges that require a good appearance from the side. Normally, no drainage pipes are to be located outside the bridge in maintaining a good aesthetic view. This is achieved by reversing the normal crossfall and providing drainage facilities on the inner sides of the two bridges.

A crossfall of 4% is adopted for the treated outer shoulders of expressway/ highway in order to use them effectively for surface rain water flow.

(i) Lane Width and Marginal Strip

To accomodate desirable clearance between vehicles running in parallel or passing at a design speed of 120km/h and 80km/h, 3.75m and 3.50m lane width respectively are recommended considering a maximum vehicle width of 2.60m.

0.50m marginal strips on both sides of carriageway is also recommended to make the edge of carriageway obvious and to increase the safety and comfort to drivers.

On a 6-lane divided highway, the middle lane of the three lanes on each direction is recommended to have a wider width of 3.75m to lessen wheel concentrations and to increase driver's comfort.

(j) Shoulders

(i) Shoulder Width of the Throughway

Considering the functions of the shoulder, as well as land acquisition condition and service level of expressway and highway, 3.0m outer shoulders and 0.5m inner shoulders are recommended in this study. In viaduct and bridge, of length more than 100m, the effective outer shoulder may be reduced to 1.5m wide.

(ii) Shoulder Width of Ramps

The same shoulder widths as in expressways and highways are adopted to one lane one way ramp because in the one lane one way ramp, semi-trailer can manage to pass by even if a truck stops or parks on the left side of carriageway. However, a reduced width of 0.75m for outer shoulder for 2-lane one way ramp is recommended from an economical viewpoint.

(k) Medians

The median width is expressed as the dimension between the through-lane edges and includes the inner shoulders, if any. The principal functions of a median are as follows :-

(i) to provide the desirable freedom from the interference of opposing traffic;

(ii) to minimize headlight glare;

(iii) to provide open green space;

(iv) to provide space for pier construction of grade-separation structures;

(v) to provide space for speed change and storage of right-turning and U-turning vehicles; and

(vi) to provide a reserved width for future lanes.

A standard median of 12.5m wide for North-South Link and a standard median of 11.5m wide for Shah Alam Highway/MRR-II respectively are recommended considering future additional lanes. In case of providing future lanes, a standard median of 5.0m wide with 4.0m being raised for N-S Link and 4m wide with 3m being raised for Shah Alam Highway/MRR II respectively will be kept as a median.

(l) Outer Separation, Borders and Frontage Roads

The outer separation is the area between the through-carriageway and a frontage road. The border is the area between the through-carriageway or a frontage road and the right-of-way.

Frontage roads are often required to maintain local service and to collect and distribute ramp traffic entering and leaving the access-controlled highway/expressway. The outer separation or border provides sideslopes, drainage, guardrails, lighting standards, signs, planting space, access control faces, retaining wall or stone masonry, cycle tracks, ramps and toll gates, if any. The outer separation or border may also provide for noise abatement measures in sensitive areas.

In Shah Alam area, an outer separation of 15m wide is recommended to provide buffer zone between the highway and the adjacent area and to accomodate a high standard of ramp design and toll gates, if necessary.

(m) Exclusive Cycle Track

The exclusive cycle track is provided in the stretch where a high standard road is estimated to have a considerable volume of motorcycles, as the exclusive cycle track may contribute to increase safety, comfort and mobility of a highway largely. However, it is also inevitable that an exclusive or restricted cycle track makes interchanges and viaducts complicated yet expensive.

Therefore, the exclusive cycle track is recommended to be provided to Shah Alam Highway and the western section of MRR-II as a high rate and volume of motor cycles heading towards Kuala Lumpur is forecasted. Since the North South Link is designated as a part of bypass to connect Kuala Lumpur-Seremban Expressway with Kuala Lumpur-Tanjung Malim Expressway, the number of motorcycles will be negligible that provision of cycle track may not be warranted (c.f. the average trip length of motor cycle is shorter than that of motor cars).

In the eastern section of MRR-II (Jalan Cheras to Kuala Lumpur-Seremban Expressways), viaducts and interchanges will be required due to the restricted land conditions, railway overpassing and connection with major roads. Motorcyclists will be restricted on this stretch and be forced to use a frontage road from the economic viewpoint.

(n) Horizontal and Vertical Clearances

(i) Horizontal Clearance

Each case of horizontal clearance limit illustrated in Figure 5.3.2 indicates at least 0.25m additional clearance beyond the outer edge of the shoulder except in the case where a 3.0m width outer shoulder is provided.

(ii) Vertical Clearance

As shown in Figure 5.3.2, 5.3m headroom including future resurfacings is applicable for high standard roads. The minimum clearance at electrified railway crossing is 6.5m high above railway level.

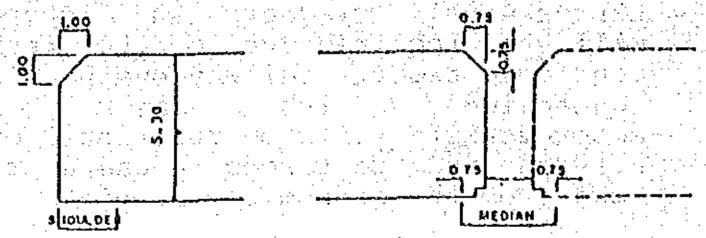
(o) Typical Cross Section

The typical cross sections are proposed based on the recommended design standard and proposed right-of-way.

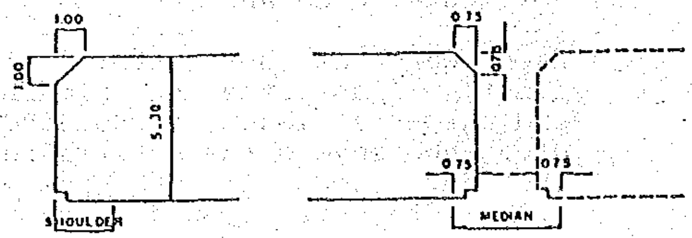
Figure 5.3.3 presents the proposed typical cross sections for Shah Alam Highway in Klang Area. 4-lane Shah Alam Highway with 4-lane frontage road as shown in Figure 5.3.4 can manage to pass the severe land condition in the vicinity of Kim Chuan Interchange without any major violation of developed land and demolition of buildings.

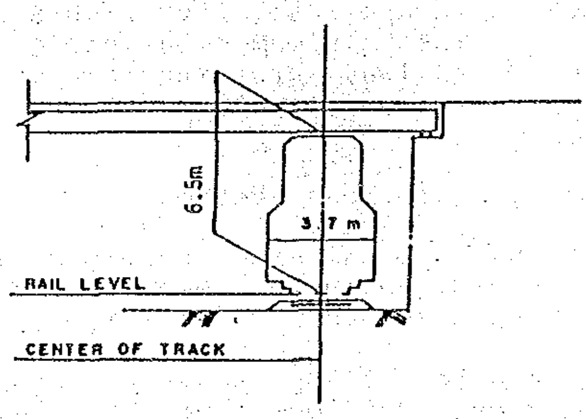
On the existing Jalan Bukit Kemuning in Shah Alam, Shah Alam is proposed to be built as shown in Figure 5.3.5.

EMBANKMENT SECTION



BRIDGE SECTION





MINIMUM CLEARANCES AT RAILWAY

Figure 5.3.2 : Clearance Limits

14.25m wide outer separations are recommended to provide buffer zones and to accomodate ramps and toll gates, if necessary. Frontage roads on both sides are required to maintain local service as well as to enter and leave from Shah Alam Highway.

Figures 5.3.6 and 5.3.7 show the typical cross sections for Shah Alam Highway in Puchong and Bukit Jalil area respectively.

Figures 5.3.8 through 5.3.10 present the proposed typical cross sections for southern part of Middle Ring Road II.

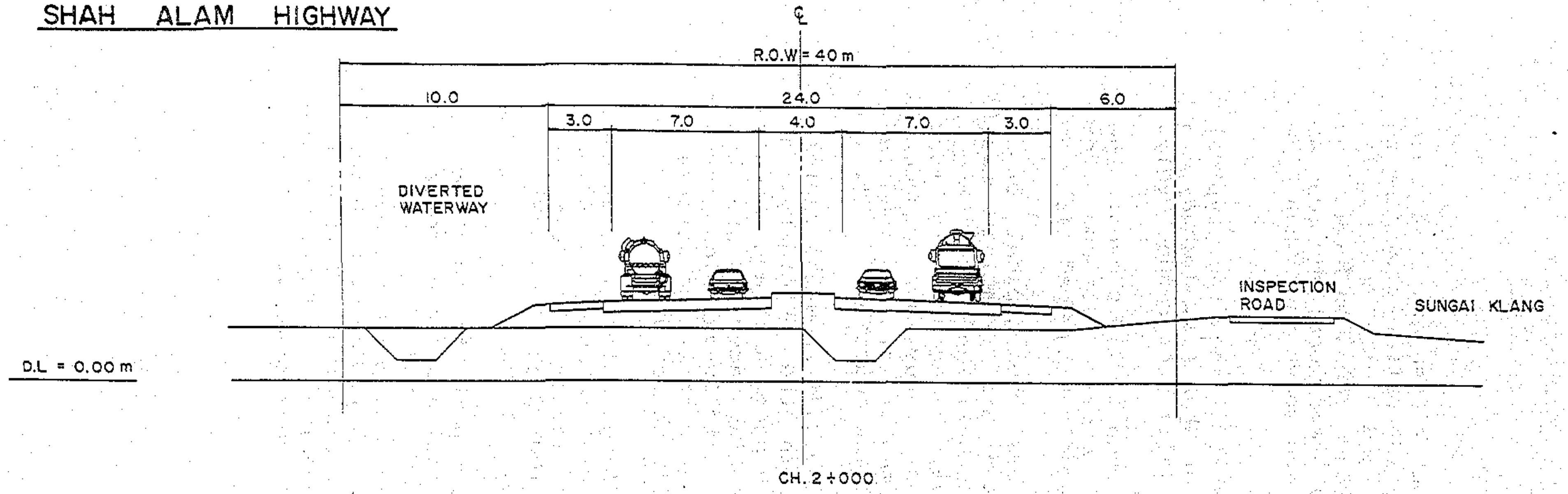
Figure 5.3.8 shows the typical cross section in between Sri Petaling East Interchange and Cendekiawan Interchange; a 6-lane viaduct with 2-lane frontage road in a 40m wide right-of-way is proposed to maintain the function of existing road and to accommodate the introduction of LRT.

Figures 5.3.9 and 5.3.10 show the typical cross sections in the vicinity of Cendekiawan Interchange; a 6-lane viaduct with diverted 10m wide waterway and LLN high voltage cable in Sungai Midah area and a 6-lane viaduct with 2-lane frontage road in a 30m wide right-of-way.

In between New Klang Valley Interchange and Subang West Interchange, a 6-lane North-South Link shares the existing right-of-way of TUDM-Shah Alam road as shown in Figures 5.3.11 and 5.3.12.

Since the southern part of North-South Link runs in agricultural and forestry areas, no frontage road as shown in Figures 5.3.13 and 5.3.14 are planned in an entire stretch. A 13.25m wide border is mostly used for sideslope treatment to avoid such expensive structure as retaining wall and stone masonry.

SHAH ALAM HIGHWAY



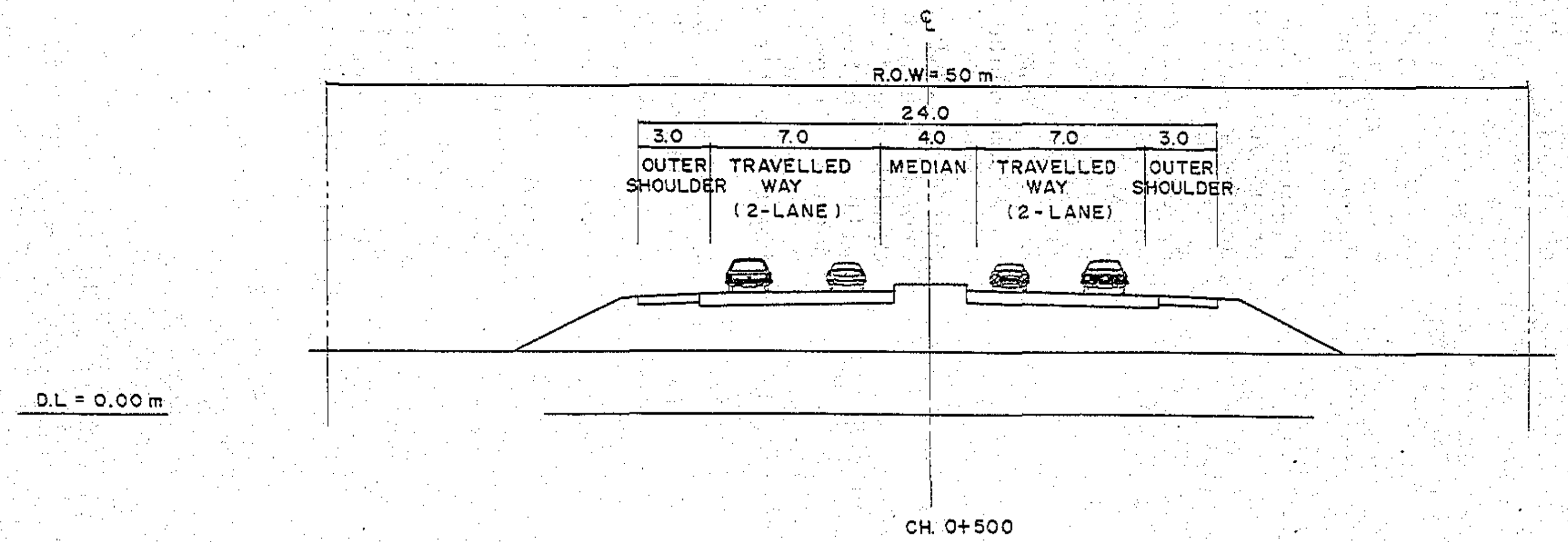


Fig.5.3.3 TYPICAL CROSS-SECTION FOR 4-LANE ROAD IN KLANG AREA	LEGEND:	SCALE:
THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY		

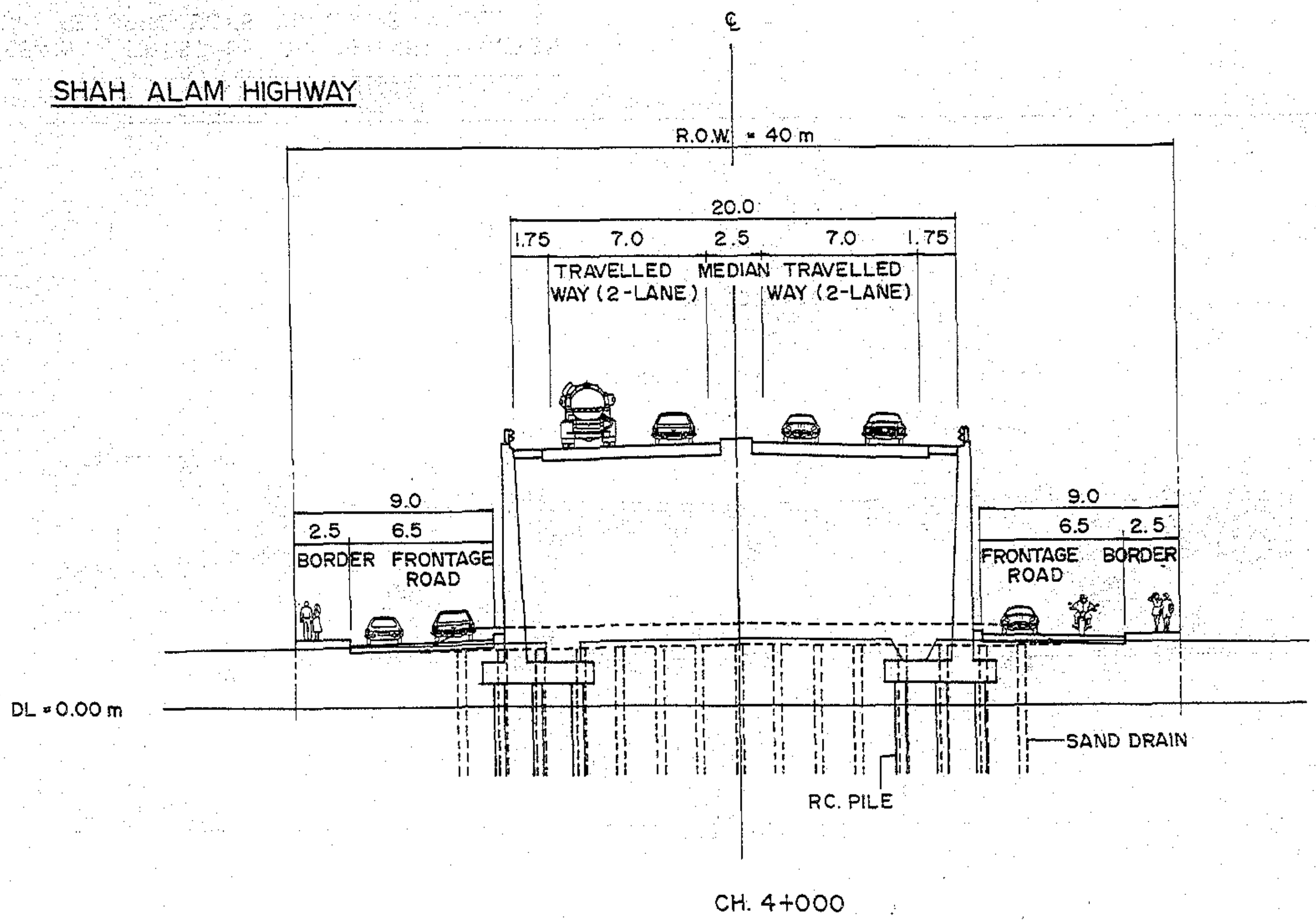
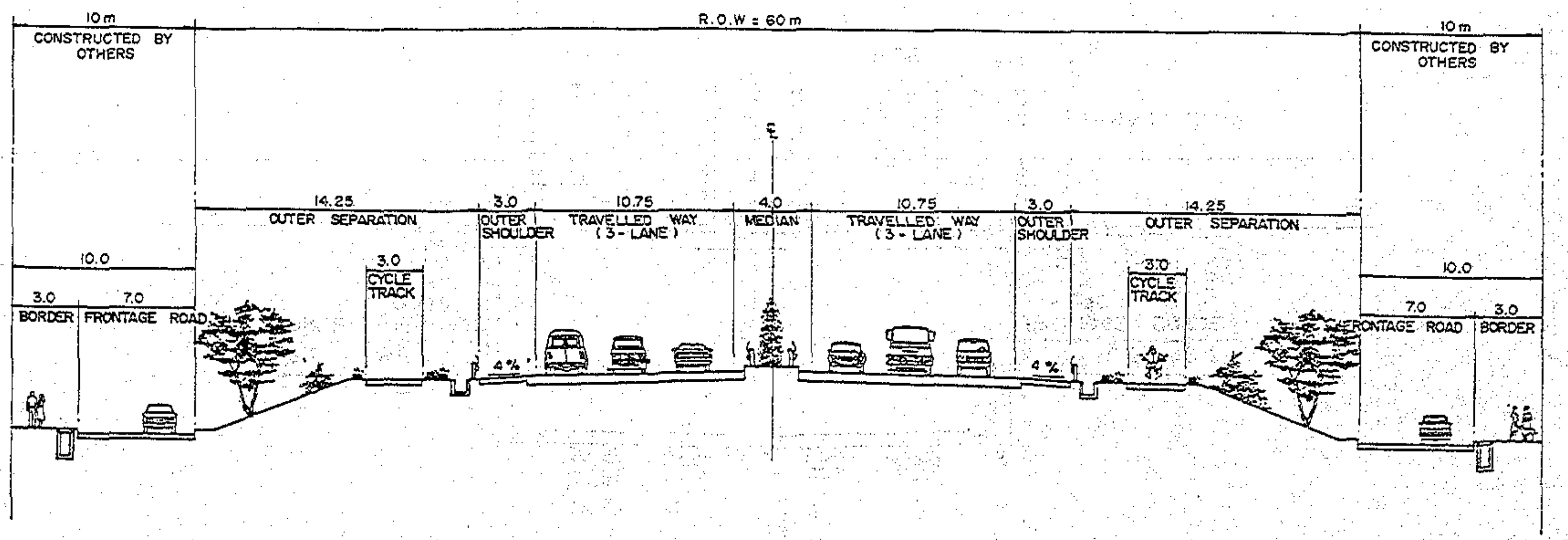


Fig. 5.3.4. TYPICAL CROSS-SECTION FOR 4-LANE ROAD NEAR KIM CHUAN I.C	LEGEND :	SCALE :
THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY		

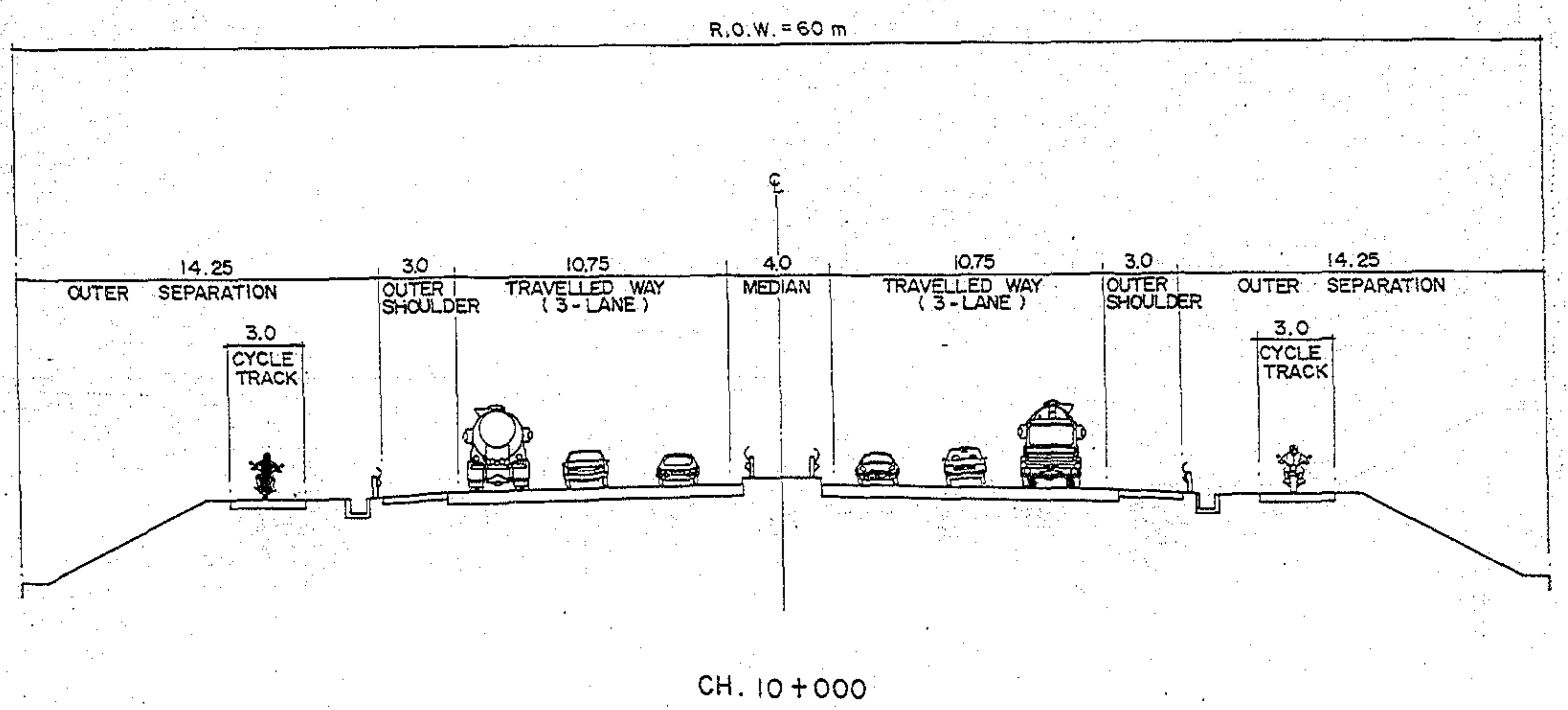
SHAH ALAM HIGHWAY



CH. 16 + 000

Fig. 5.3.5 TYPICAL CROSS-SECTION FOR 6-LANE WITH CYCLE TRACK AND FRONTAGE ROAD	LEGEND:	SCALE:
THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY		

SHAH ALAM HIGHWAY



TYPICAL CROSS SECTION FOR 6-LANE WITH CYCLE TRACK

Fig 5.3.6 TYPICAL CROSS-SECTION FOR 6-LANE WITH CYCLE TRACK	LEGEND:	SCALE:
THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY		

MIDDLE RING ROAD II

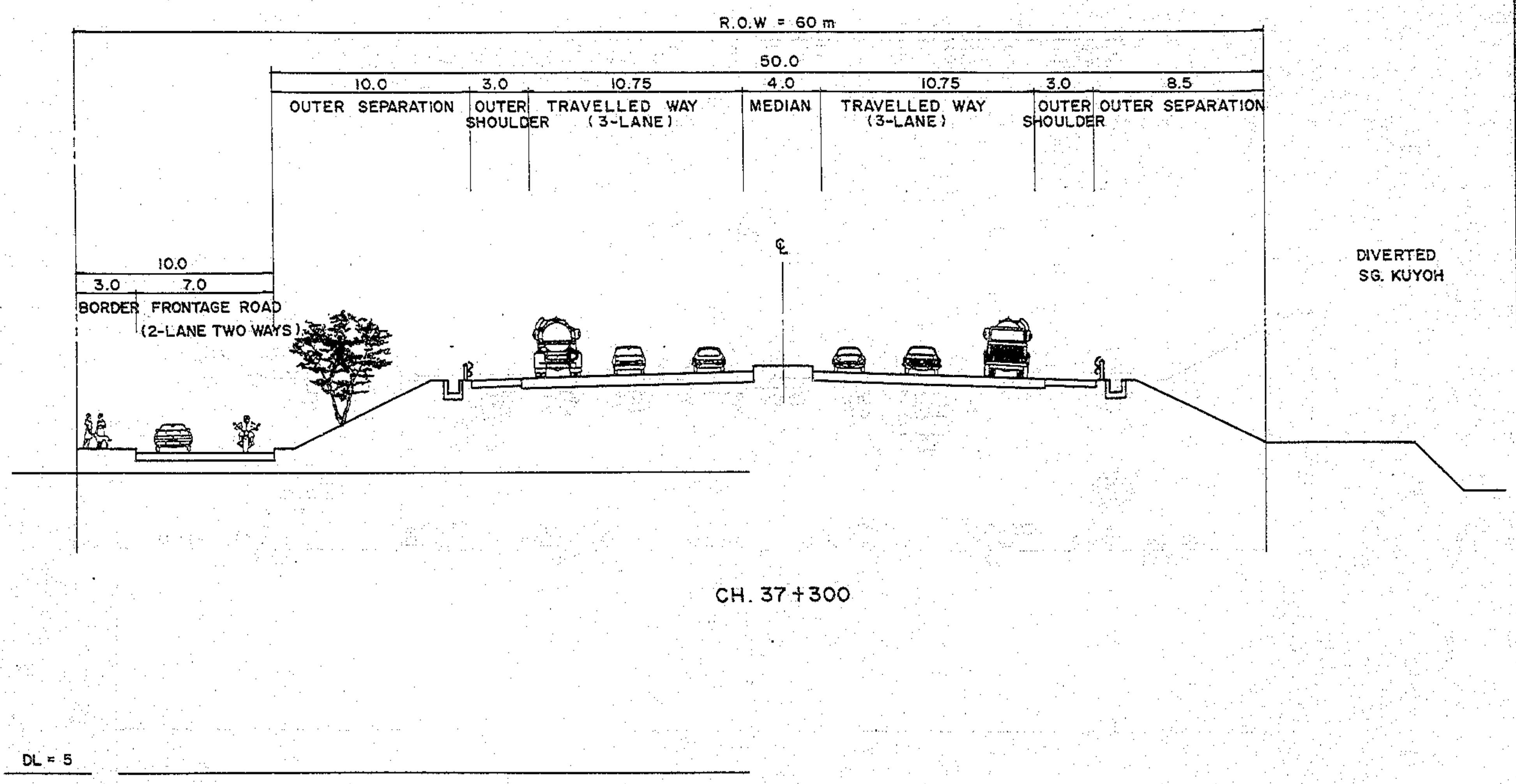


Fig.5.3.7 TYPICAL CROSS-SECTION OF 6-LANE ROAD WITHOUT CYCLE TRACK	LEGEND:	SCALE:	
THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY			

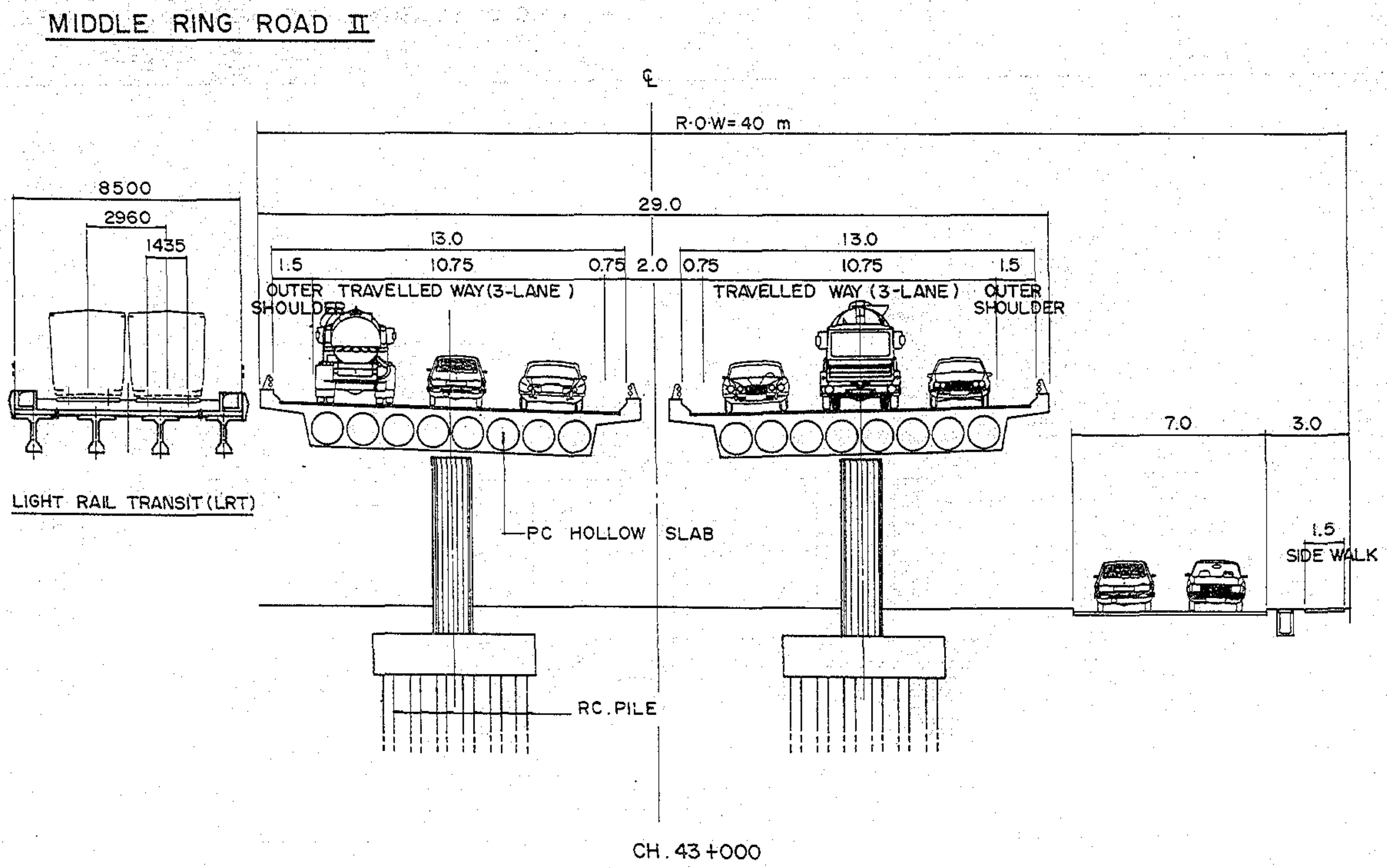


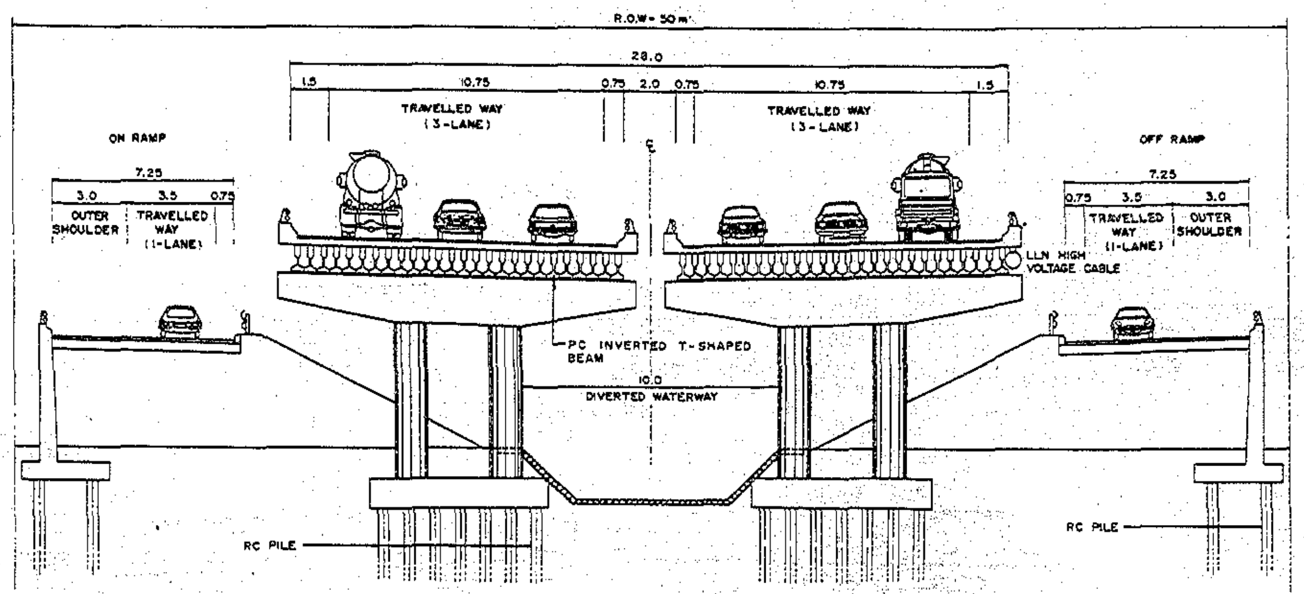
Fig: 5.3.8 TYPICAL CROSS-SECTION FOR 6-LANE VIADUCT WITH FRONTAGE ROAD

THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY

LEGEND:

SCALE:

MIDDLE RING ROAD II



CH. 44+760

Fig. 5.3.9 TYPICAL CROSS-SECTION WITH WATERWAY AT CENDEKIAWAN IC.	LEGEND:	SCALE:
THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY		

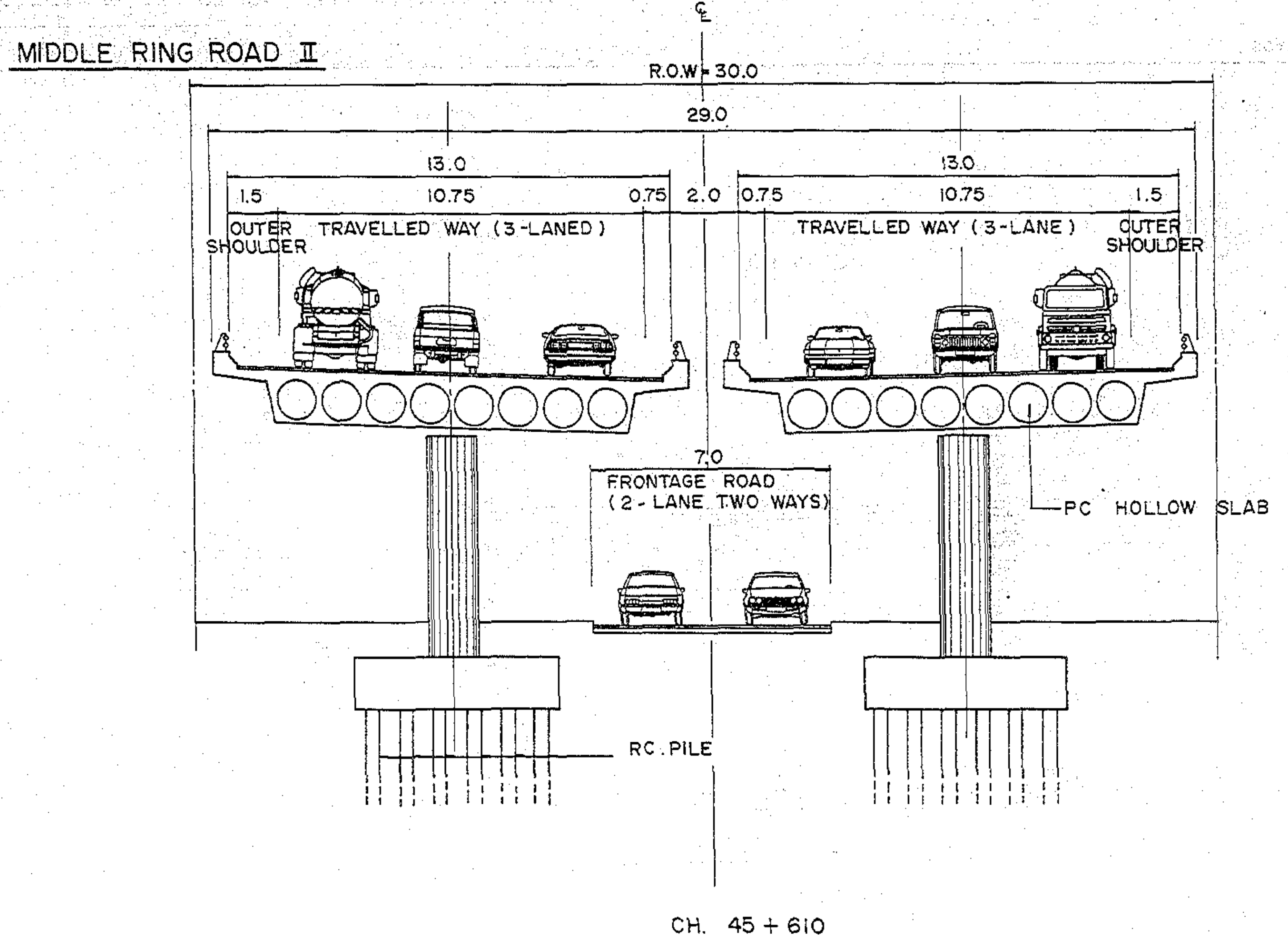


Fig.5.3.10 TYPICAL CROSS-SECTION WITH FRONTAGE ROAD NEAR CENDEKIAWAN IC	LEGEND:	SCALE:
THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY		

NORTH - SOUTH LINK

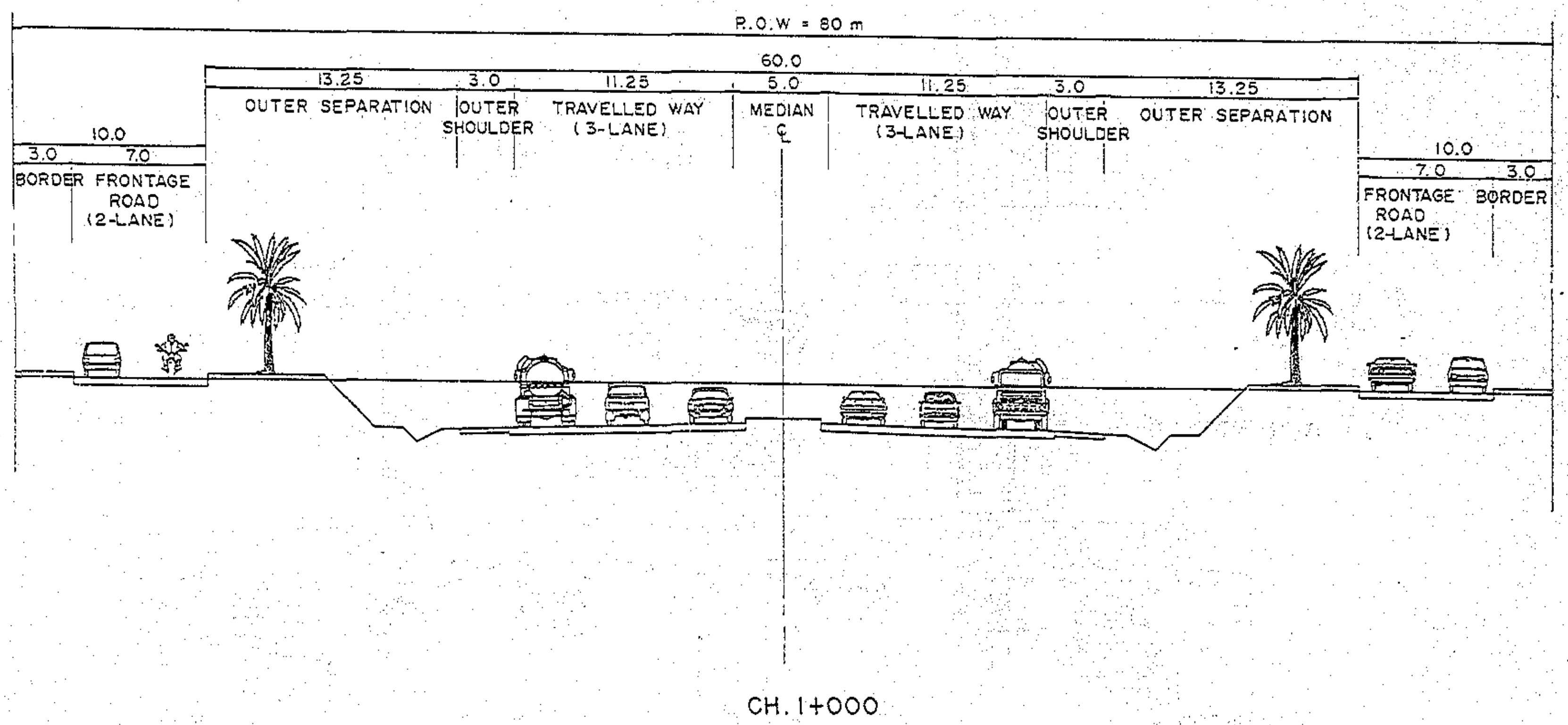
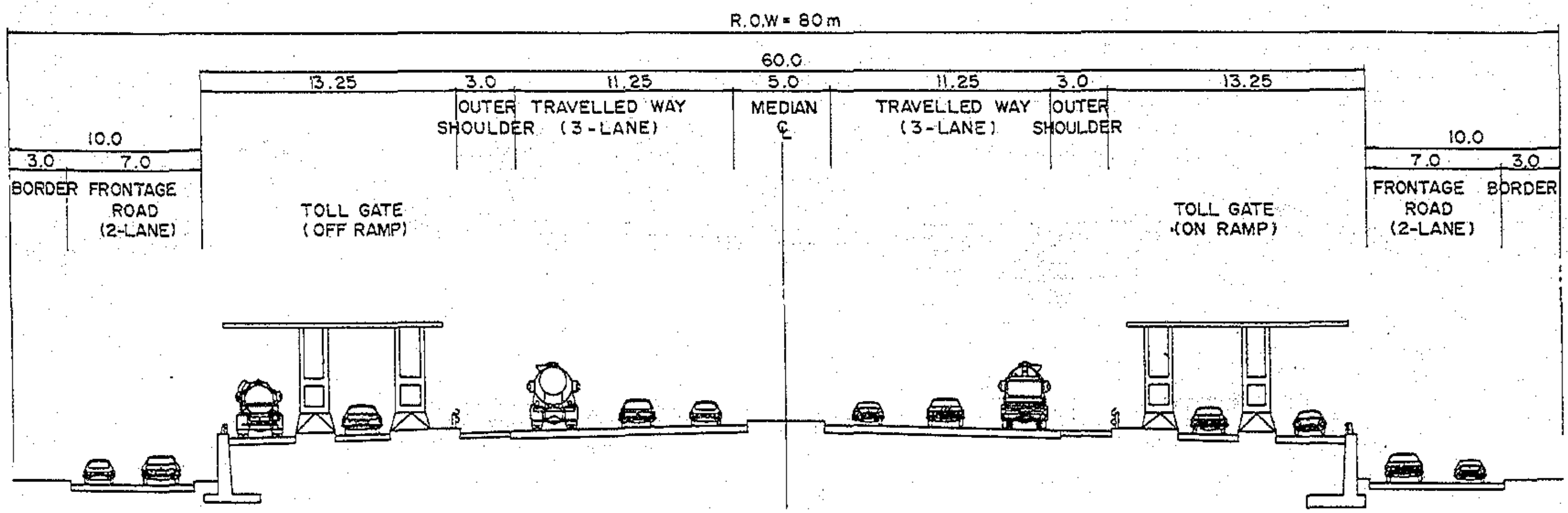


Fig.5.3.11 TYPICAL CROSS-SECTION OF 6-LANE WITH FRONTAGE ROAD	LEGEND:	SCALE:
THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY		

NORTH - SOUTH LINK



CH. 2+650

Fig.5.3.12 TYPICAL CROSS - SECTION AT TOLL PLAZA AREA	LEGEND:	SCALE:
THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY		

NORTH-SOUTH LINK

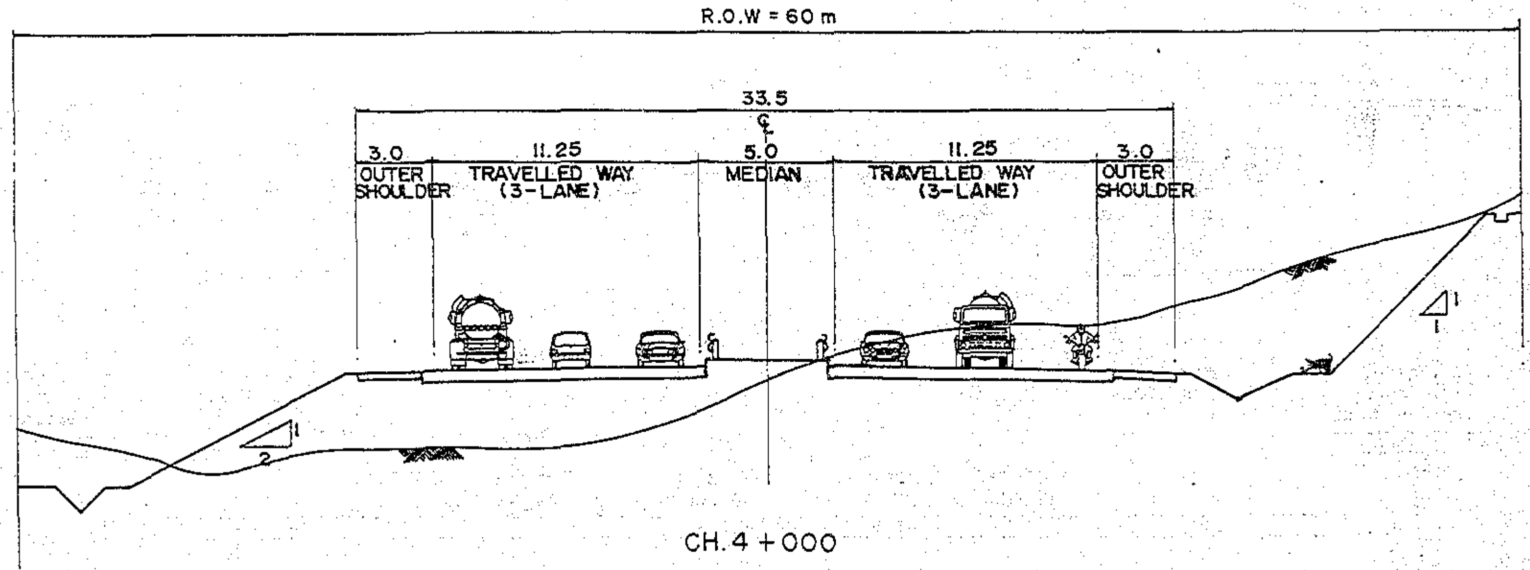


Fig.5.3.13 TYPICAL CROSS-SECTION FOR 6-LANE SCHEME

LEGEND:

SCALE:

THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY

NORTH-SOUTH LINK

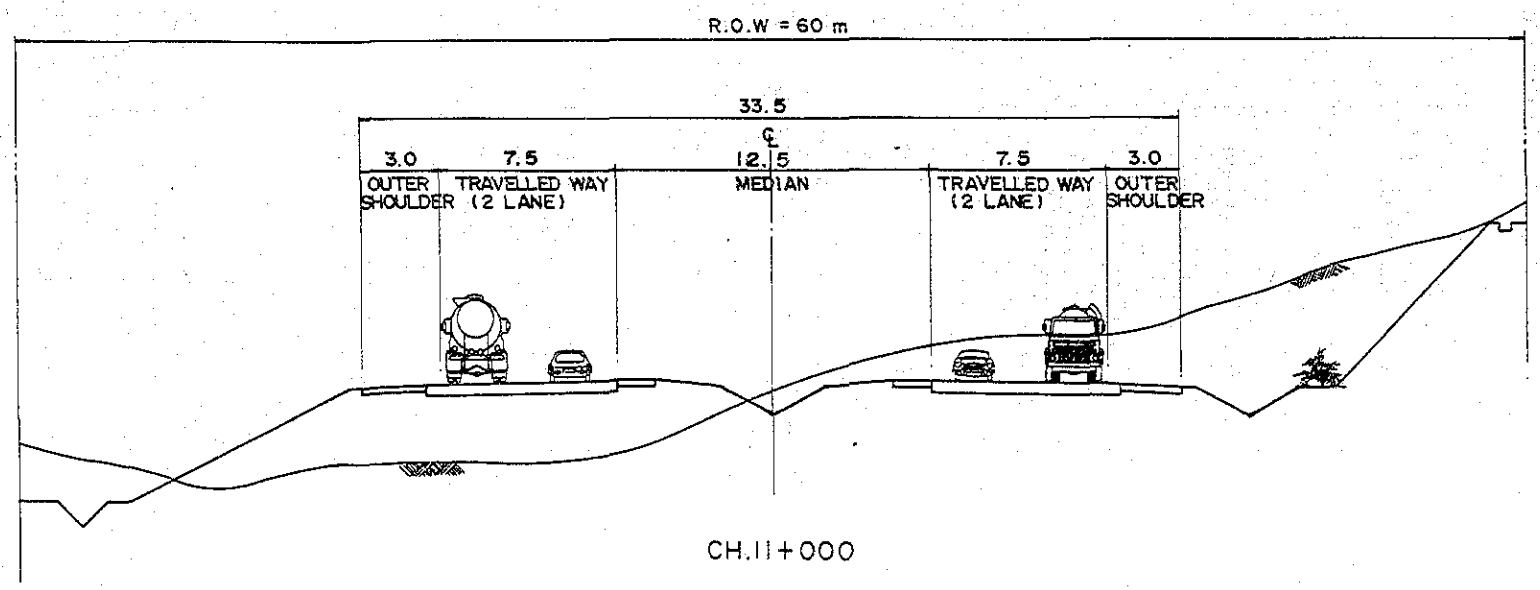
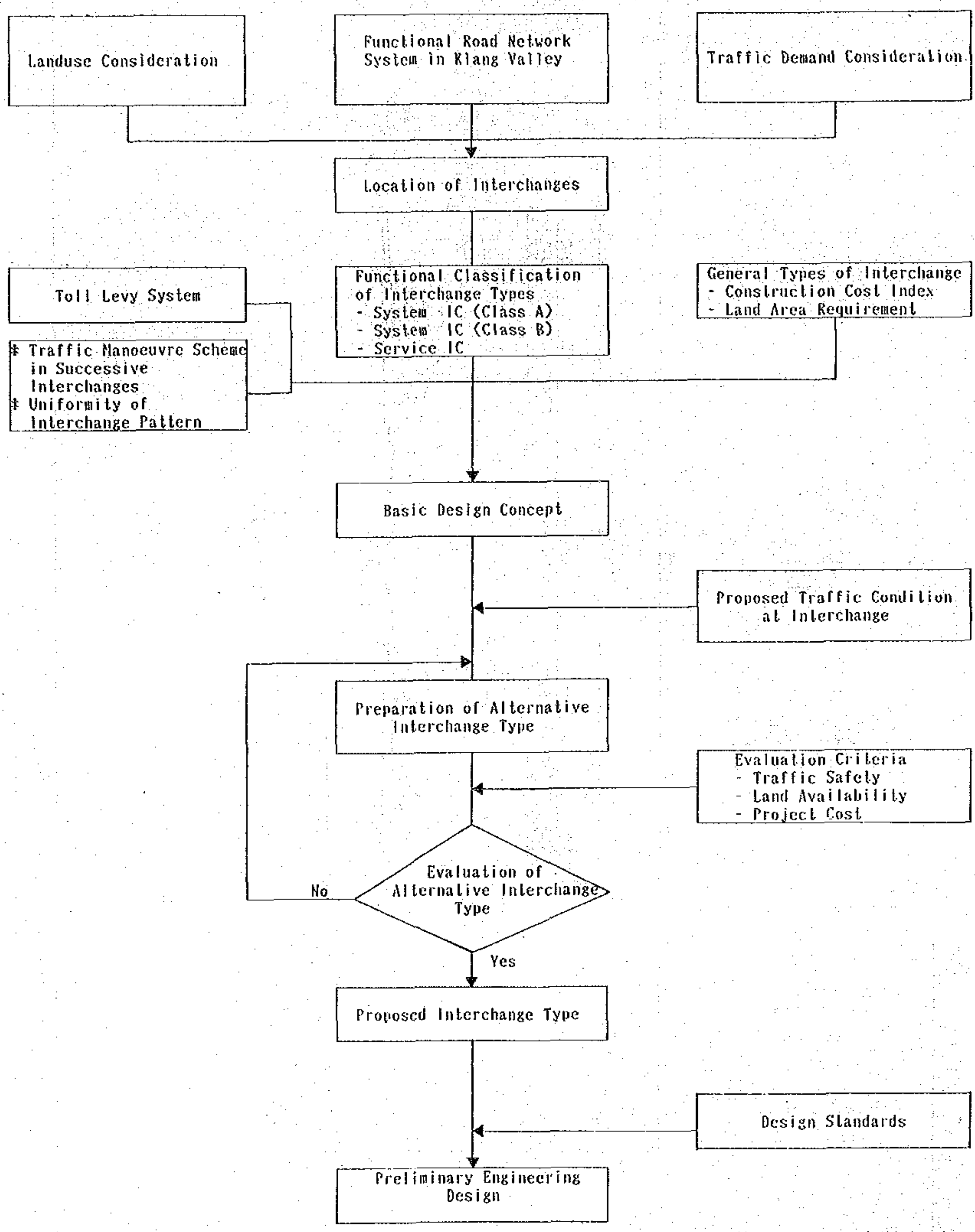


Fig. 5.3.14 TYPICAL CROSS-SECTION FOR 4-LANE SCHEME	LEGEND:	SCALE:
THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY		

5.4 Interchange Plan and Design

5.4.1 Study Methodology



5.4.2 Classification of Interchange by Function

Interchange types can be divided into two categories, namely, system interchange which connects an expressway or access control road to another access control road, and service interchange which connects an access control road to lesser facilities (such as primary, secondary, or local roads). A classification of intersection type according to class of roads crossing adapted from "JKR Arahan Teknik (Jalan)" is shown in Table 5.4.1.

Table 5.4.1: Classification of Intersection Types by Function

According to Class of Roads Crossing

(a) Rural Area

	EXPRESSWAY	HIGHWAY	PRIMARY	SECONDARY	MINOR
EXPRESSWAY					
HIGHWAY					
PRIMARY			S.I.	S.I./S.C.	S.C.
SECONDARY				S.C.	S.C.
MINOR					S.C.

(b) Urban Area

	EXPRESSWAY	ARTERIAL	COLLECTOR	LOCAL STREET
EXPRESSWAY				
ARTERIAL				
COLLECTOR			S.I.	S.I.
LOCAL STREET				S.I.

LEGEND:
IC. : INTERCHANGE
(System Interchange - Class A   Service Interchange)
System Interchange - Class B

S.I. : SIGNALIZED INTERSECTION
S.C. : STOP CONTROL

Source : Modified from JKR Arahan Teknik (Jalan) 12/87- A guide to the design of Interchanges

System interchanges can be further subdivided into two classes, that is, system interchange - Class A which connects an expressway to another expressway and system interchange - Class B which connects an expressway to highway/arterial or a highway to another highway.

The former will require a high design speed so that directional or semi-directional ramps are preferred to loop ramps. Manoeuvres on at-grade intersection are strictly not acceptable.

On the other hand, for system interchange - Class B, in order to ensure its high mobility, at-grade intersection will not be acceptable but loop ramp will be acceptable because of the lower design speed compared to that of system interchange-Class A.

For service interchange, i.e., an interchange between an expressway or highway and lesser facilities which will not require a high mobility, an interchange type costing lesser and requiring smaller land area such as a diamond type is usually preferred to cloverleaf type.

Analysis for interchange type determination will be made at the three service levels provided by system interchange - Class A, system interchange-Class B and service interchange respectively.

This Study involves twenty-two (22) interchanges on the three study roads, namely, Middle Ring Road II, Shah Alam Highway (both classified as highway/arterial) and North-South Link (classified as expressway). According to the categorization of interchanges by service level in terms of mobility, there are three (3) system interchanges - Class A located on North-South Link, five (5) system interchanges - Class B and fourteen (14) service interchanges on the study roads. The location of these interchanges and their descriptions are shown in Figure 5.4.1 and Table 5.4.2 respectively.

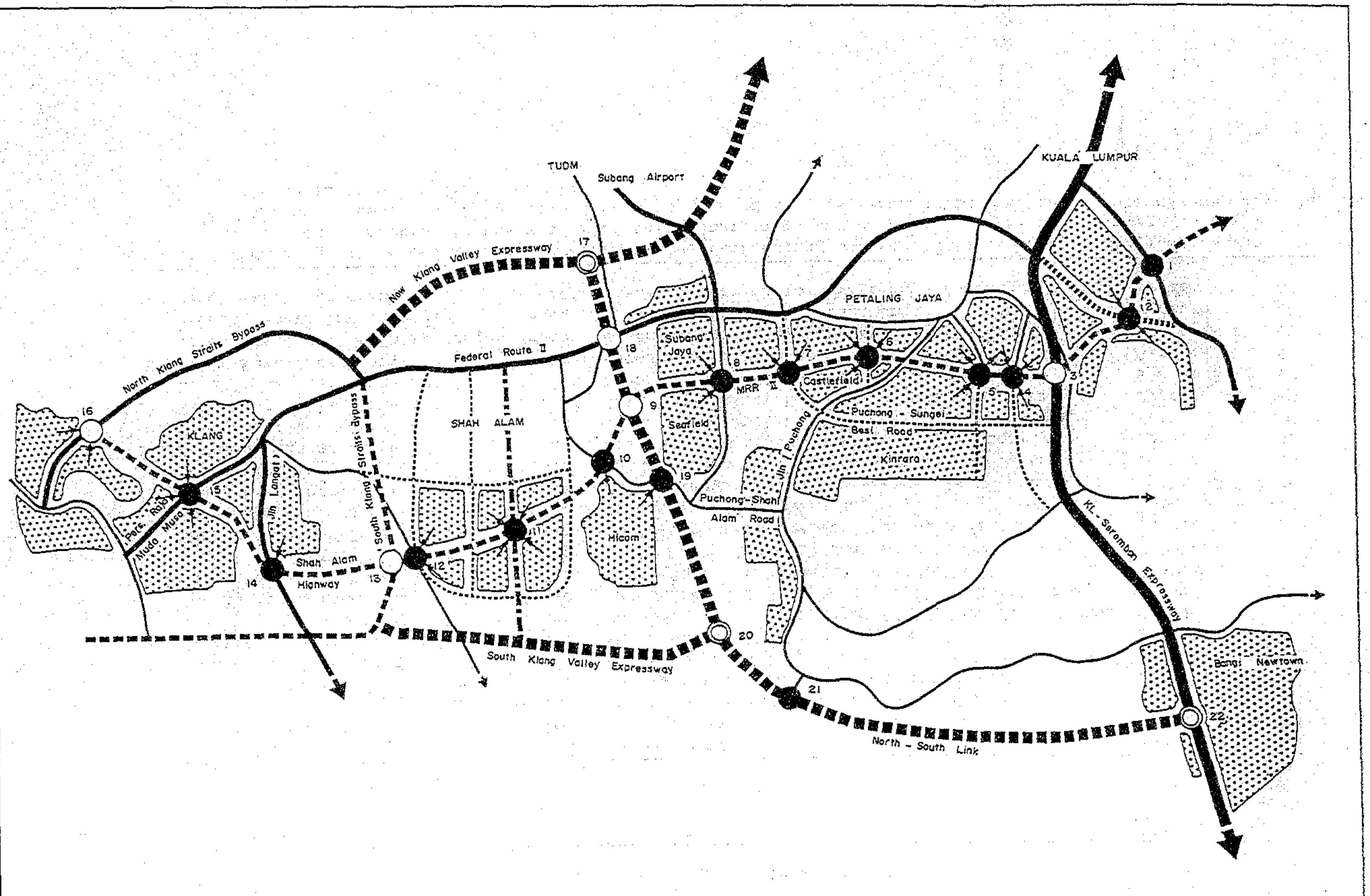


Figure 5.4.1 Proposed Toll Levy System on Project Roads (Ultimate Scheme)

THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY

LEGEND:
- EXPRESSWAY (FUTURE)
- EXPRESSWAY (EXISTING)
- HIGHWAY (FUTURE)
- HIGHWAY (EXISTING)
- PRIMARY (FUTURE)
- PRIMARY (EXISTING)
- SYSTEM INTERCHANGE (A)
- SYSTEM INTERCHANGE (B)
- SERVICE INTERCHANGE
- MAJOR ARTERIAL
- MINOR ARTERIAL

SCALE:

N

Table 5.4.2 List of Interchanges

No.	Name	No.of Leg	Location	Function	Design Speed (km/h)
1	Cheras Interchange	4-leg	Jalan Cheras/MRR II	Service	40
2	Cendekiawan Interchange	3-leg	Jalan Cendekiawan/MRR II	Service	40
3	Sri Petaling East Interchange	4-leg	Kuala Lumpur-Seremban Expressway/MRR II	System B	40
4	Sri Petaling West Interchange	4-leg	New Road to Bandar Baru Sri Petaling/MRR II	Service	40
5	Awan Besar Interchange	4-leg	Extension of Jalan Awan Besar/MRR II	Service	40
6	Kinrara Interchange	4-leg	Petaling Jaya-Puchong Road/MRR II	Service	40
7	Sunway Interchange	4-leg	Puchong-Sungei Besi Raod/MRR II/Shah Alam Highway	Service	40
8	Subang South Interchange	4-leg	Extension of Jalan Kewajipan/Shah Alam Highway	Service	40
9	Subang West Interchange	4-leg	North South Link/Shah Alam Highway	System B	50
10	Shah Alam East Interchange	4-leg	HICOM-Shah Alam Road/Shah Alam Highway	Service	40
11	Shah Alam South Interchange	4-leg	Shah Alam Central Route/Shah Alam Highway	Service	40
12	Shah Alam West Interchange	4-leg	Jalan Kebun/Shah Alam Highway	Service	40
13	Klang East Interchange	4-leg	South Klang Straits Bypass/Shah Alam Highway	System B	40
14	Langat Interchange	4-leg	Jalan Langat/Shah Alam Highway	Service	40
15	Kim Chuan Interchange	4-leg	Persiaran Raja Muda Musa/Shah Alam Highway	Service	40
16	Klang West Interchange	3-leg	North Klang Straits Bypass/Shah Alam Highway	System B	40
17	New Klang Valley Interchange	3-leg*	New Klang Valley Expressway/North-South Link	System A	60
18	Batu Tiga Interchange	4-leg	Federal Route II/North-South Link	System B	50
19	HICOM East Interchange	4-leg	Puchong Batu Tiga Road/North-South Link	Service	50
20	South Klang Valley Interchange	3-leg	South Klang Valley Expressway/North-South Link	System A	60
21	Puchong South Interchange	3-leg	Jalan Puchong/North-South Link	Service	50
22	Bangi West Interchange	3-leg#	Kuala Lumpur-Seremban Expressway/North-South Link	System A	60

Note : * TUDM-Shah Alam Road is also located at the intersecting point with North Klang Valley Expressway but no direct connection is planned, i.e. this interchange may be considered as being 4-leg two ways.
A direct access to Bangi Town Centre is planned at this terminus so that this interchange may be considered as being 4-leg two ways.

5.4.3 General Types of Interchanges

Typical three-leg interchanges are trumpet type and three-leg directional interchanges. Typical four-leg interchanges are diamond type, cloverleaf and directional interchanges.

Diamond type interchanges have numerous other configurations incorporating frontage roads and continuous collector or distributor roads. Diamond type interchanges with multiple levels may also be considered in urban area where space is limited.

A partial or half cloverleaf configuration containing cloverleaf type loops and diagonal ramps configuration can be readily modified to follow the predominant traffic flow direction. A full cloverleaf has an independent ramp for each interchanging movement. Weaving manoeuvers are generated on the stretch between loops. Therefore, contemporary full cloverleaf designs usually incorporate collector or distributor roads.

Directional interchanges are generally required at the intersections of high volume expressway in order to ensure high speed and capacity without weaving and at-grade intersections.

Directional interchange design is the assembly of one or more of the basic types or ramps.

Generally, ramp and connection are classified into the following four types as shown in Figure 5.4.2.

(1) Outer Connection

It diverges from the left lane of throughway and merges to another throughway from the left. This type is always adopted for the left-turning ramp.

(2) Semi-direct Ramp

It diverges from the left lane of throughway and turns to the right. This type has the advantage in observing the left diverging rule.

(3) Direct Ramp

It diverges from the right lane of throughway and turns to the right. This type is usually used to manage heavy and high speed traffic.

(4) Loop

It diverges from the left lane of throughway and turns to the right by a 270 degree left turn. This type is generally used for minor and low speed traffic.

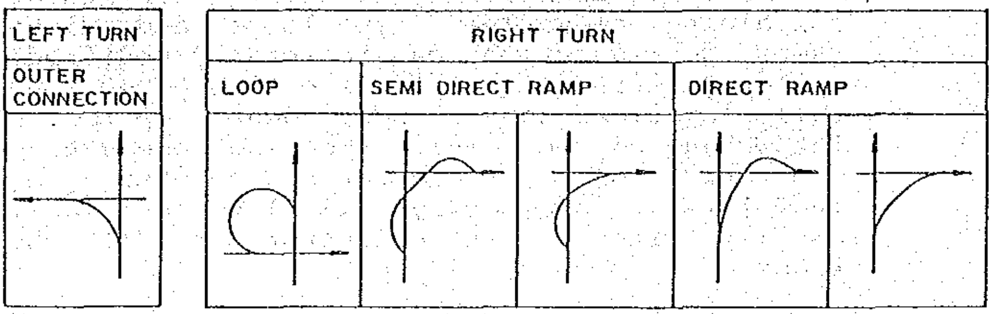


Figure 5.4.2: Types of Ramp and Connection

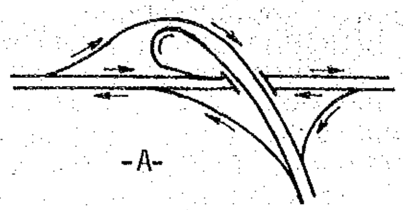
The layout for any specific ramp and type of traffic movement will reflect site conditions of topography and culture, cost and the degree of flexibility in traffic operation desired.

System interchange must provide high mobility for traffic using expressways. Design speed of rampway structured system interchange, according to the Arahan Teknik (Jalan), is at least half of that of throughway design speed. Design speed of the expressway network is planned to be 120km/h. So the design speed of rampway must ensure movement at 60km/h. In the case of having a loop ramp system interchange it will require a 125m minimum curve radius and excessive land area.

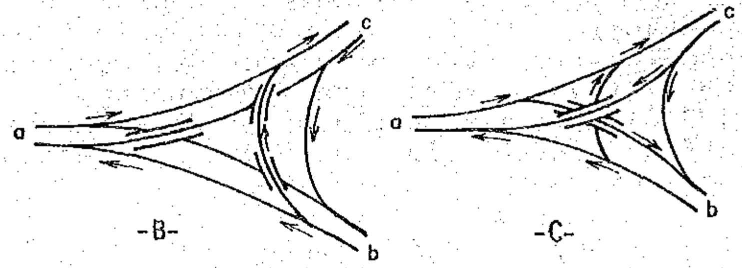
Figure 5.4.3 shows several interchange types for 3-leg designs. Among these interchange types, alternative designs consisting of trumpet type from single-structure type shown in Figure 5.4.3(A) and the types shown in Figures 5.4.3(D) and 5.4.3(F) from multiple structure types are chosen for a comparative analysis because the designs shown in Figures 5.4.3(B) and 5.4.3(C) must be planned with two connecting expressways at the same time and a three-level structure type has no obvious advantage such as the need to construct an interchange in adverse topographic condition in the study road corridor, these costly structures are not considered as alternatives from the beginning. Figure 5.4.3(G) is also neglected from standpoints of traffic safety in the weaving section and hindsight.

Among the many types of interchange configurations, ten (10) basic types considered to be practical for application to the study roads are shown in Table 5.4.3. A general comparison of their salient features, construction cost index and land area requirement is also summarised in Table 5.4.3. The cost index gives the relative cost of interchange types using a diamond type as base for system interchange - Class B and service interchange on one hand, and a single structure trumpet for system interchange - Class A on the other hand.

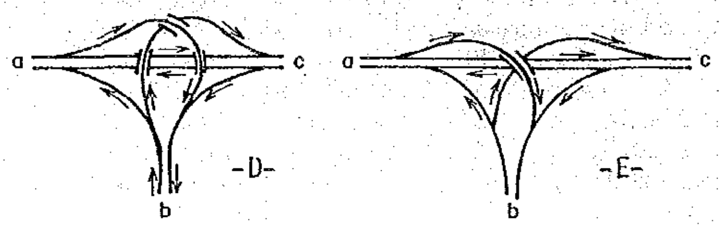
Single Structure Trumpet



3-leg Directional



3-leg Semi-directional



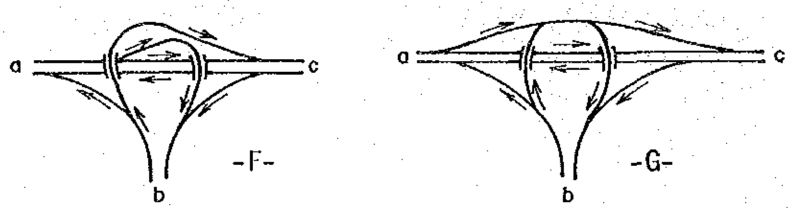
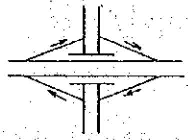
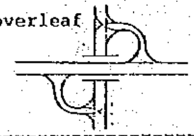
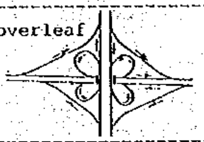
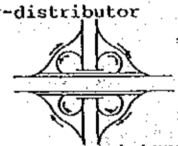
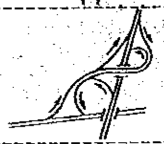
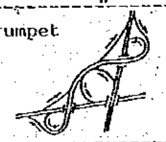
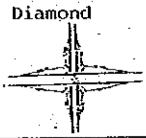
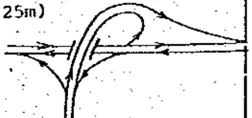
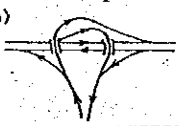
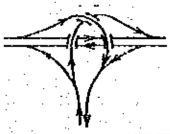


Figure 5.4.3: Interchange Types for 3-leg Designs

Table 5.4.3 Typical Configuration of Some Practical Types of Interchanges and Their Characteristics

	Layout Configuration	Salient Features	(1) Construction Cost Index	(2) Land Area (ha)
SERVICE IC AND SYSTEM IC - CLASS B (4 LEGS)	1. Diamond 	Turning movements on minor road may be controlled by signals. Traffic detour distance is shortest	1.00	4.0
	2. Half Cloverleaf 	Its two loop ramps configuration is readily adaptable to allow free movement in predominant direction. Turning movements on minor road may be controlled by signals	1.05	5.1
	3. Full Cloverleaf 	Its four loop ramps configuration allows free movement in all directions. There are two entrances and two exits on throughway. Weaving occurs between loop ramps	1.29	6.8
	4. Full Cloverleaf with collector-distributor roads 	Free movement in all directions through four loop ramps. There is only one entrance and one exit on throughway. No weaving	1.79	9.0
	5. Trumpet 	Loop ramp occurs at one point. Turning movement on minor road may be controlled by signals. Favourable configuration if there is great difference between traffic volume by direction. Toll gates can be located at a single point	1.56	7.5
	6. Double Trumpet 	Loop ramps occur at two points. All turning movements pass through one point. There is weaving traffic but toll gates can be located at a single point. No signalisation is necessary	1.89	10.5
	7. Three-level Diamond 	Allows free movement for through traffic of crossing roads. Can increase interchange capacity efficiently in an area with limited space	3.27	4.0
SYSTEM IC - CLASS A (3 LEGS)	8. Single Structure Trumpet (R = 125m) 	A simple structure commonly used for 3-leg intersection. Requires a large area which is influenced by the minimum curve radius due to design speed	1.00	15.4
	9. Two Structures Trumpet (R = 125 m) 	Separate roadways are provided for each right turning movement with two 2-level structures separating the ramps from through traffic	1.01	14.8
	10. Three Structures Trumpet (R = 125m) 	Two double jug-handle configuration usually applies where the crossing road is of considerable importance too. Requires the use of three structures thereby reducing land area	1.06	10.6

Note : (1) In the case of service interchange and system interchange - Class B, cost index is the relative cost of other interchange types when compared to diamond type taken as 1.00; in the case of system interchange - Class A, the cost of other interchange type is compared to that of single structure trumpet (R = 125m) when the later's cost index is taken to be 1.00.

(2) All interchanges are compared on equal basis with regards to all factors influencing the construction of the interchanges on flat terrain.

5.5 Design of Bridges and Other Structure

5.5.1 Design Standard of Bridges and Structures

(1) General

Prevailing bridge standard specifications and other structural design guidelines in Malaysia summarized below are adopted for the study.

- Guideline Book for Bridge Design (Buku Panduan Rekabentuk Jambatan)

  Concrete bridge design guideline published by the Design and Research section in the Public Works Department (JKR) in November 1985

- Interurban Toll Expressway System of Malaysia, Design Standard

  Comprehensive design standard of interurban toll expressway system published by the Malaysian Highway Authority in November 1986

For supplementary purpose, following standards are used as guidelines.

- Specifications of Highway Bridges published by the Japan Road Association
- Design Manual published by the Japan Road Authority
- Standard Specifications for Highway Bridges Published by the American Association of State Highway Officials (AASHTO)
- Series of Specifications and Codes Published by the British Standards Institution (BSI)

(2) Major Design Loadings

Major design loading criteria adopted in this study are as follows:-

(a) Dead Load

Structural Steel	.. 7.85 t/cu.m
Reinforced Concrete	.. 2.5 t/cu.m
Portland Cement Concrete	.. 2.3 t/cu.m
Asphalt Cement Concrete	.. 2.35 t/cu.m
Backfill Material	.. 1.8 t/cu.m
Embankment Material	.. 1.8 t/cu.m

(b) Live Load

(i) Type HA Load (Normal Loading)

This load approximately represents the effect of three vehicles, each 22 tons in weight, closely spaced, in each of two carriageway lanes, followed by 10 tons and 5 tons vehicles. A 25% allowance for impact is included. Type HA load consists of three components:-

(1) HA-udl load, uniformly distributed load
(2) HA-kel load, knife edge load acting across the width of lane
(3) HA-wheel load

HA-udl and HA-kel loads are given by charts and diagrams in conjunction with design lane width and loaded length. Standard cross-sectional loading is shown in Figure 5.5.1. The loaded length is usually the length of the base of the positive or negative portion, as the case may be, of the influence line diagram for the member under consideration.

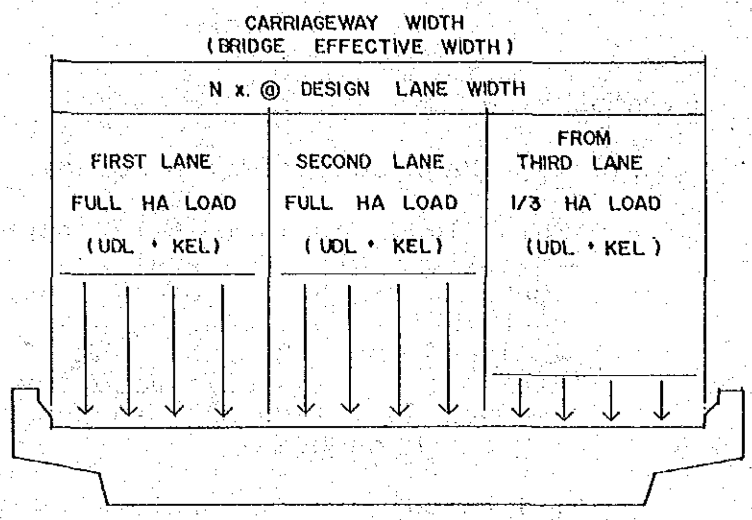
As for continuous construction, where the positive or negative portion of influence line appears in complicated shape, the maximum effect for the member under consideration is to be studied taking into account any possible combination of the separate loaded length. In such case the loaded length is the sum of the separate loaded lengths. Figures 5.5.3 and 5.5.4 show example of influence line loading on 2-5span and 4-5span continuous structures.

(ii) Type HB Load (Abnormal Loading)

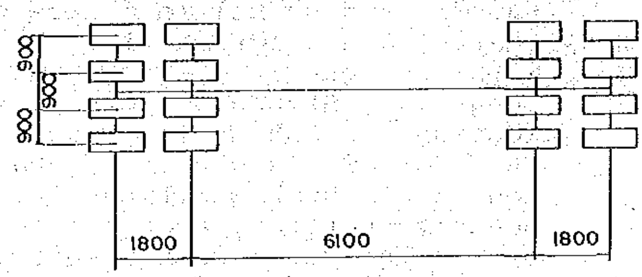
This load caters for safe passage of a single abnormally heavy vehicle (16 wheels, four axles) up to 180 tons and to be used when specified by the appropriate authority. The HB vehicle is shown in Figure 5.5.2.

The full HB load per axle is 450 KN (approximately 45 tons).

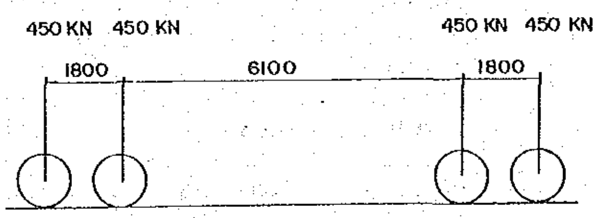
TYPE HA LOADING



THE HB VEHICLE



(1800 KN GROSS VEHICLE WEIGHT)
PLAN



PROFILE

Figure 5.5.1 : Type HA Loading
Figure 5.5.2 : The HB Vehicle

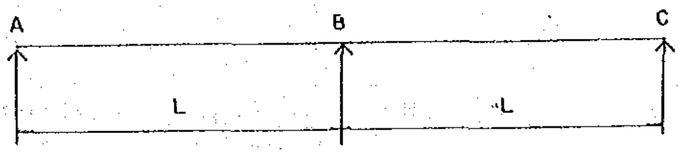
LEGEND :

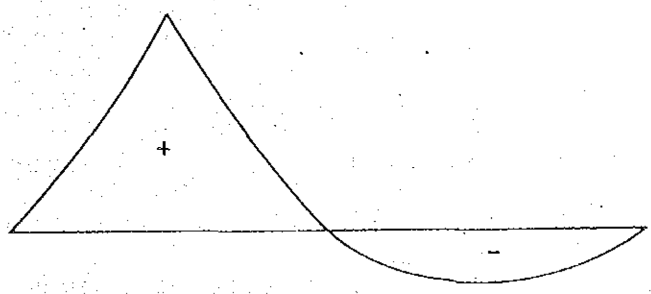
THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY

SCALE :

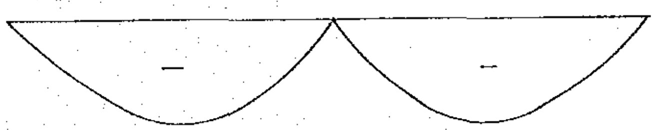
N

INFLUENCE LINES FOR 2-SPAN CONTINUOUS STRUCTURE



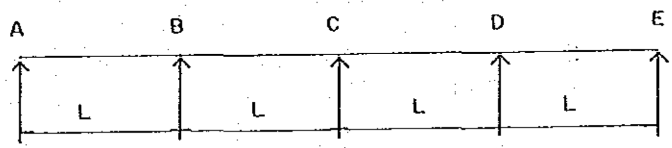


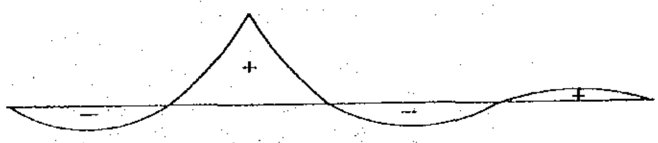
(a) SPAN MOMENT ON A-B CENTRE
LOADED LENGTH : L (A-B)



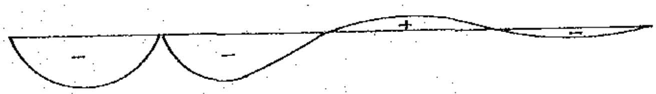
(b) SUPPORT MOMENT ON B
LOADED LENGTH : 2L (A-B-C)

INFLUENCE LINES FOR 4-SPAN CONTINUOUS STRUCTURE



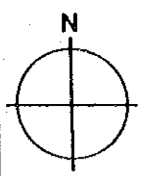


(a) SPAN MOMENT ON B-C CENTRE
LOADED LENGTH : L (B-C) or
2L (B-C, D-E)



(b) SUPPORT MOMENT ON B
LOADED LENGTH : 2L (A-B-C) or
3L (A-B-C, D-E)

FIG5.5.3 INFLUENCE LINES FOR 2-SPAN CONTINUOUS STRUCTURE FIG5.5.4 INFLUENCE LINES FOR 4-SPAN CONTINUOUS STRUCTURE	THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY
LEGEND :	SCALE :



Type HB load is often expressed in Units (1 unit = 10 KN, approximately 1 ton) per axle. The full type HB load is often referred to as 45 units.

As the case may be, 37.5 units or 30 units are adopted for design. No allowance for HB load impact is made.

(c) Loads due to Centrifugal Force

Where the bridge carriageway is curved, a load for centrifugal action of the vehicles (Fc) is considered in designing the members. Fc is given as follows:-

$$Fc = \frac{30,000}{r + 150} \text{ KN}$$

Where r = radius of lane (m)

This load is imposed on up to two lanes and any numbers anywhere every 50m in longitudinal direction.

(d) Tractive/Breaking Loads (Longitudinal Load)

This Loads represent traction and breaking force of vehicles.

The one force for all width of bridge shall be applied over an area 3.0m wide by 9.0m long, or the length of the bridge, whichever is less. The force shall be loaded at the level of the carriageway surface in longitudinal direction so as to cause the worst effect on the member under consideration. In conjuction with the span length the force ranges from 100 KN (approximately 10 tons) to 253 KN (approximately 25.3 tons).

(e) Seismic Loads

No seismic force is taken into consideration.

(f) Wind Loads

Wind forces though rarely significant in small-span and medium-span bridgeworks, can be critical in bridges like the suspension type where the span is large. Generally any structure which is sensitive to stability problems will inevitably tend to be more sensitive to wind loading.

(g) Load Due to Shrinkage, Temperature, & Creep

These are horizontal loads due to forces generate in the beams/slab caused by shrinkage, temperature changes and creep in the material.

(3) Standard Cross Sections of Bridge

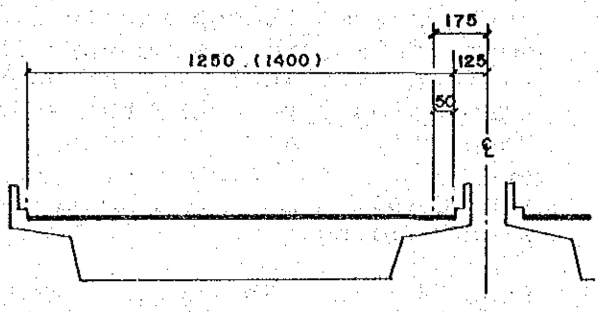
Standard cross sections of bridge are shown in Figure 5.5.5 as described in the Progress Report (1). Features are as follows:-

(a) On a 3-lane carriageway, the middle lane of the three lanes has a wider width of 3.75m to lessen wheel concentration and to increase driver's comfort.

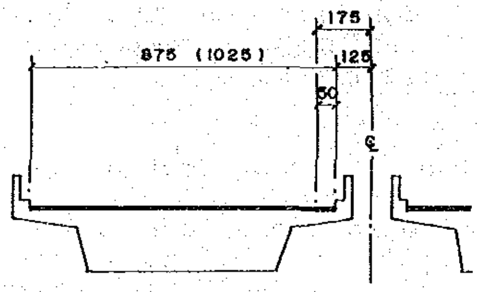
(b) In throughway, for viaducts and bridges of length more than 100m, reduced outer shoulder width of 1.5m is taken.

(1) THROUGHWAY BRIDGE

6-LANE (2x3 LANES)

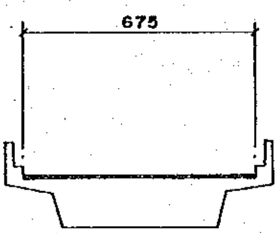


4-LANE (2x2 LANES)

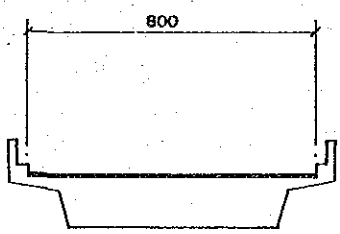


(2) RAMP BRIDGE

1-LANE



2-LANE



Figures in ( ) show the width where total length of bridge is less than 100 m

FIG. 5.5.5: STANDARD CROSS SECTIONS OF BRIDGES	THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY
LEGEND :	SCALE :

N

(4) Material and Allowable Stress

The use of major materials and each required strength are as follows in this study.

(a) Concrete

Class	Design Compressive Strength at 28 days	Use
A	400 kg/cm2	Pre-stressed Concrete Structure Casting on Site
B	300 kg/cm2	Steel Reinforced Superstructure
C	300 kg/cm2	Steel Reinforced Substructure
D	200 kg/cm2	Non Reinforced Substructure

(b) Reinforcing Steel

Type	Design Tensile Strength	Yield Strength
Round Bar	1400 kg/cm2	24 kg/mm2
Deformed Bar	1800 kg/cm2	30 kg/mm2

(c) Prestressing Steel

Name	Yield Strength	Breaking Strength
PC7-Wire Strand SWPR 7A T12.4	150 kg/mm2	175 kg/mm2

(d) Steel Pipe Pile

Diameter x Thickness	Design Tensile Strength	Yield Strength
610mm x 12mm	1400 kg/cm2	41 kg/mm2

(e) Steel Plate

Thickness	Design Tensile Strength	Yield Strength
12 - 32mm	1400 kg/cm2	41 kg/mm2

5.5.2 Study of High Embankment

(1) General

Maximum embankment height is examined by two different aspects; namely, slope stability analysis and consolidation settlement analysis.

Slope stability is evaluated by safe factors against landslide along assumed arc in road cross-section. Among others, the Sweeden method has been used for the analysis, in which embankment characteristics and subsoil conditions given by soil investigation are taken into account. The required safe factor is generally 1.2.

Consolidation settlement at the middle of the embankment base is given by sum of each consolidation settlement of particular clayey subsoil layer against considered embankment shape and weight. Degree of consolidation settlement progress is also studied.

Assumed embankment characteristics are as follows:-

Embankment Slope Gradient	...	1:2
Embankment Unit Weight	...	1.8 t/cu.m
Cohesion of Soil	...	3.0 t/sq.m
Internal friction angle of soil	...	10 degrees

The study results of each area are summarized hereafter.

Assignment of maximum embankment height to road stretches are shown in Figure 5.5.6.

(2) Klang West Interchange Area

Thick very soft alluvial clay layer (marine clay layer) exists. The thickness is about 20m. This marine clay does not have preconsolidation pressure. The void ratio and the consolidation index are very high. These characteristics are quite unsuitable for embankment work.

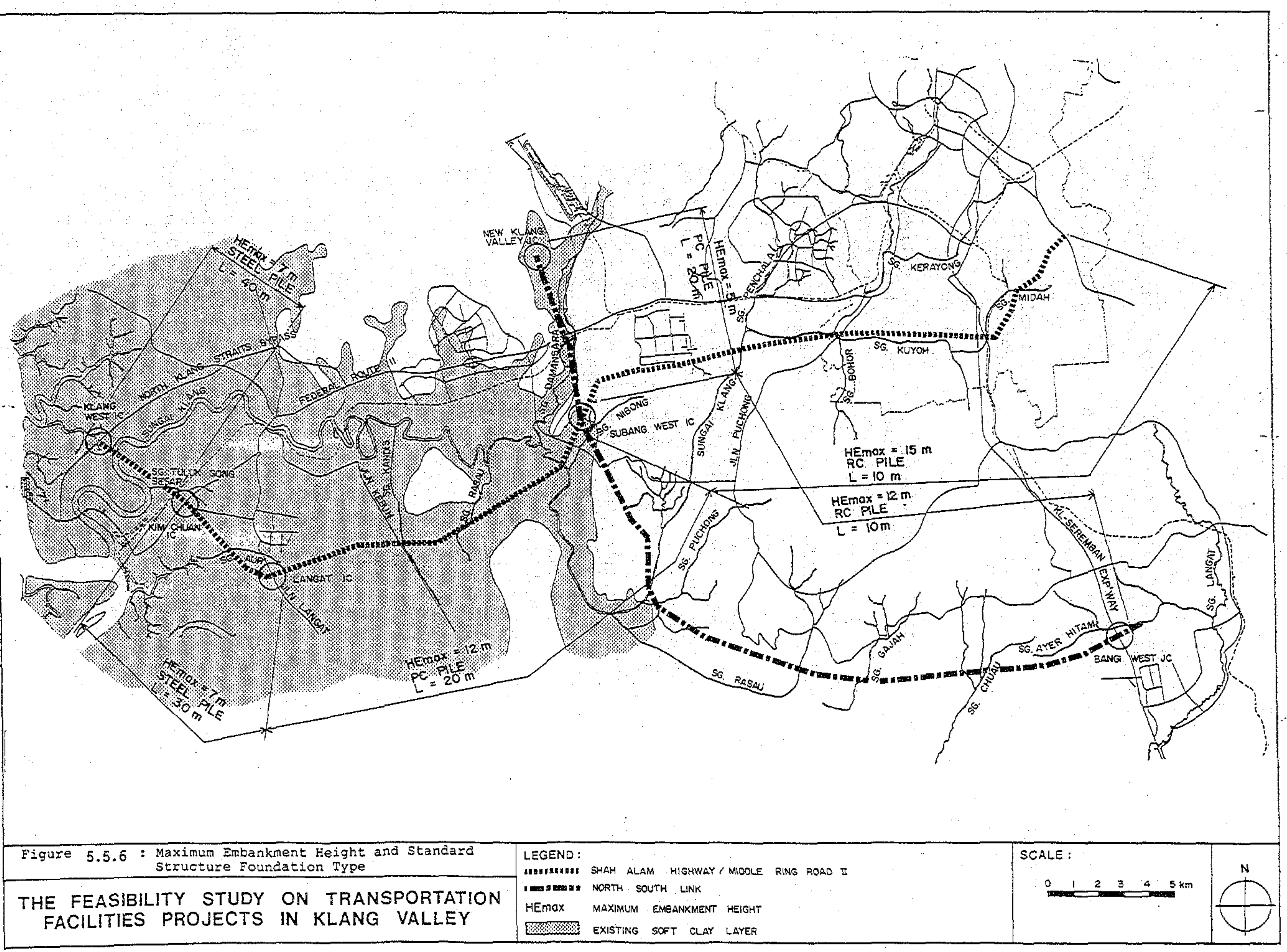


Figure 5.5.6 : Maximum Embankment Height and Standard Structure Foundation Type

THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY

According to slope stability analysis, the maximum embankment height is 7m. Consolidation settlement at the middle of the embankment base is as follows in conjunction with embankment height.

Embankment Height	Consolidation Settlement
7m	2.2m
3m	0.8m
1m	0.2m

On the other hand, progress of consolidation is very slow due to small Cv factor obtained from consolidation tests. Required time for consolidation is as follows:-

Degree of Consolidation	Time Required
50%	14 years
90%	61 years

One of the countermeasures for high embankment on such soft ground is to firstly provide to the embankment work a pre-loading embankment, which is constructed with required extra height. Pre-loading embankment expedites the progress of consolidation settlement and strengthens shearing resistance. However, considering very small consolidation progress, a pre-loading embankment countermeasure is not recommendable.

In order to accelerate consolidation and strengthen shearing resistance, among many foundation treatment, vertical sand drain method with sand mat (sand piling) is recommended as a realistic solution due to giving drastic reduction in consolidation draining distance. According to the study assuming full soft layer depth of sand piling, 40cm in diameter, driven on 1.8m x 1.8m grid points, consolidation settlement appears as follows in case of 7m embankment.

Period After Sand Piling	Consolidation Settlement	Remained Consolidation Settlement
2 months	0.8 m	1.4 m
4 months	1.2 m	1.0 m
6 months	1.5 m	0.7 m
8 months	1.7 m	0.5 m
10 months	1.9 m	0.3 m
Infinite	2.2 m	0 m

When eight months have passed after sand piling, only 0.5m consolidation settlement remains.

In the light of the abovementioned study, embankment height is to be limited to 7m, and abovementioned sand piling is to be provided for in advance of earthwork over 3m high.

Regarding bridge approach embankment exceeding 7m high, additional sand piling and loading berm should be properly installed.

(3) Kim Chuan Interchange Area

In this area, together with Klang West Interchange area very soft thick alluvial clay layer (marine clay layer) exist. The thickness is bigger than that in Klang West Interchange area.

According to slope stability analysis, the maximum embankment height is 7m.

Consolidation settlement by embankment height is shown below. The consolidation index is bigger than that of Klang West Interchange area, consolidaton settlement is quite big.

Embankment Height	Consolidation Settlement
7m	3.5m
6m	2.9m
2m	0.9m
0.5m	0.3m

Progress of consolidation is as follows:-

Degree of Consolidation	Time Required
50%	8 years
90%	98 years

The effect of full soft clay layer depth sand piling, 40cm diameter, driven on 1.8m x 1.8m grid points is as follows in case of 7m embankment.

Period After Sand Piling	Consolidation Settlement	Remained Consolidation Settlement
2 months	2.5 m	1.0 m
3 months	2.9 m	0.6 m
5 months	3.1 m	0.4 m
Infinite	3.5 m	0 m

When five months have passed after sand piling, 0.4m consolidation settlement remains.

In the light of the abovementioned study, embankment height is to be limited to 7m and abovementioned sand piling is to be provided for adequately in advance of earthwork over 2m high.

Regarding bridge approach embankment exceeding 7m high, additional sand piling and loading berm should be properly installed.

(4) Klang River Bridge Area (near SUNWAY Interchange)

Loose sand layer (10m thick) exists on relatively shallow bearing stratum surface. As for slope stability, 15m high embankment is still safe. Consolidation settlement is not expected due to sandy layer.

(5) Subang West Interchange Area

According to the geographical map, this interchange exists on the border between granite and Kenny Hill formation. Three meter thick clay layer exists. However, 15m embankment is still safe with 12cm consolidation settlement.

(6) New Klang Valley Junction

Here is only 3m to 4m thick soft clay layer. However, due to slope stability, analysis maximum embankment height is 5m. Consolidation settlement is relatively small as follows:-

Embankment Height	Consolidation Settlement
6m	0.5m
4m	0.4m
3m	0.3m

Therefore, 5m embankment can be provided. Regarding bridge approach embankment exceeding 5m high, full clay layer depth sand pile 40cm in diameter should be provided on 1.8m x 1.8m grid point.

5.6 Type of Pavement

Pavements can be divided into two broad classifications or types, namely, flexible and rigid. Generally the term "rigid pavement" is applied to the pavement structure which distributes loads to the subgrade having as one course of portland cement concrete slab of relatively high bending resistance. A commonly used definition is that "a flexible pavement is a structure that maintains intimate contact with distributor loads to the subgrade and depends on aggregate interlock, particle friction and cohesion for stability.

The following features of each type of pavement are taken into consideration to select type of pavement by type of road.

(a) Ease at Construction and Maintenance

A flexible pavement has an advantage over a rigid pavement in construction and maintenance. The very high skilled-labourers are needed in construction of rigid pavement such as to lay concrete slabs in exact position and to construct joints. Furthermore road with a rigid type pavement cannot be opened to traffic immediately after construction. A rigid type pavement is also unsuitable for paving in irregular sections *such as sharper curve, widening section, gore* and so forth.

(b) Resistance to Rutting and Wearing

A rigid pavement has an advantage to prevent damage to the pavement over a flexible pavement caused by oil and repeated wheel loads in regulated paths, especially at toll plaza.

(c) Stage Construction

If the project road is to be constructed in stages, a flexible pavement has an advantage over a rigid pavement. A rigid pavement, due to joints and usage of reinforcements, is unsuitable to be constructed in stages.

(d) Materials Used

The government has a policy to utilize portland cement for infrastructural development as much as possible so that the proposed rigid pavement for proposed roads will meet the demand of local product while imported materials are required to construct flexible pavement.

(e) Skid Resistance

Flexible pavement has an advantage over rigid pavement to keep high skid resistance during project life span. It is generally seen that flexible pavement has graded aggregates so that high skid resistance can be kept, while rigid pavement has gap-graded aggregates and harder cement mortar so that skid resistance will be reduced.

(f) Initial Investment

Initial cost to construct a rigid pavement is about 35% more than that of flexible type pavement. However, in general, a flexible pavement requires overlay for wearing course every five years but for a rigid pavement, an overlay is not required during design period.

(g) Difficulty in Repair

A rigid type pavement is more difficult and troublesome to repair than a flexible pavement, conventionally defects in a rigid type pavement are due to cracks, distortion and disintegration. In distortion, a fault is occured when two adjacent slabs have different elevation at joints or a crack caused by inadequate load transfer between slabs along with consolidation or shrinkage of underlying layers; or it may be due to jumping out of the foundation material. These faults can be repaired by filling the voids beneath the pavement with a high-softening point undersealing asphalt and resealing the joints and then raise the slabs to the original grade. These repairs are not easy to be carried out because these repair works will effect the stability of foundation and adjacent slabs.

In this Study, rigid pavement is recommended to adopt to toll plaza while the flexible pavement is considered for throughway, ramps, frontage roads and bridges.

5.7 Hydrological and Road Drainage Study

5.7.1 Hydrology

(1) General

The Study Area is located in the Klang River Basin with a catchment area of 1,288 sq.km wide and 120 km long.

The Klang River originates at an altitude of 1,330 m in the main range and collects its tributaries to pass both cities in Kuala Lumpur and Klang and finally flows into the Straits of Malacca.

The project roads cross the Klang River at four points and a number of its tributaries are shown in Figure 5.7.1. The Study aims to obtain necessary data for the design of bridges, finished grade of the planned road in flood prone areas and dimension of drainage structures.

The Hydrological Study has close relation with the following two studies:-

(i) Kuala Lumpur Flood Mitigation Project Drainage Improvements, Master Drainage Plan, 1978; and

(ii) Study on the Flood Mitigation of the Klang River Basin, 1988.

The hydrology used in the Study is fully referred to these two studies. Design standard in this Study has been based on the published design standard "Urban Drainage Design Standard and Procedures for Peninsular Malaysia".

The site survey and data collection were also carried out to supplement data and to prepare a proper basis for the preliminary design.

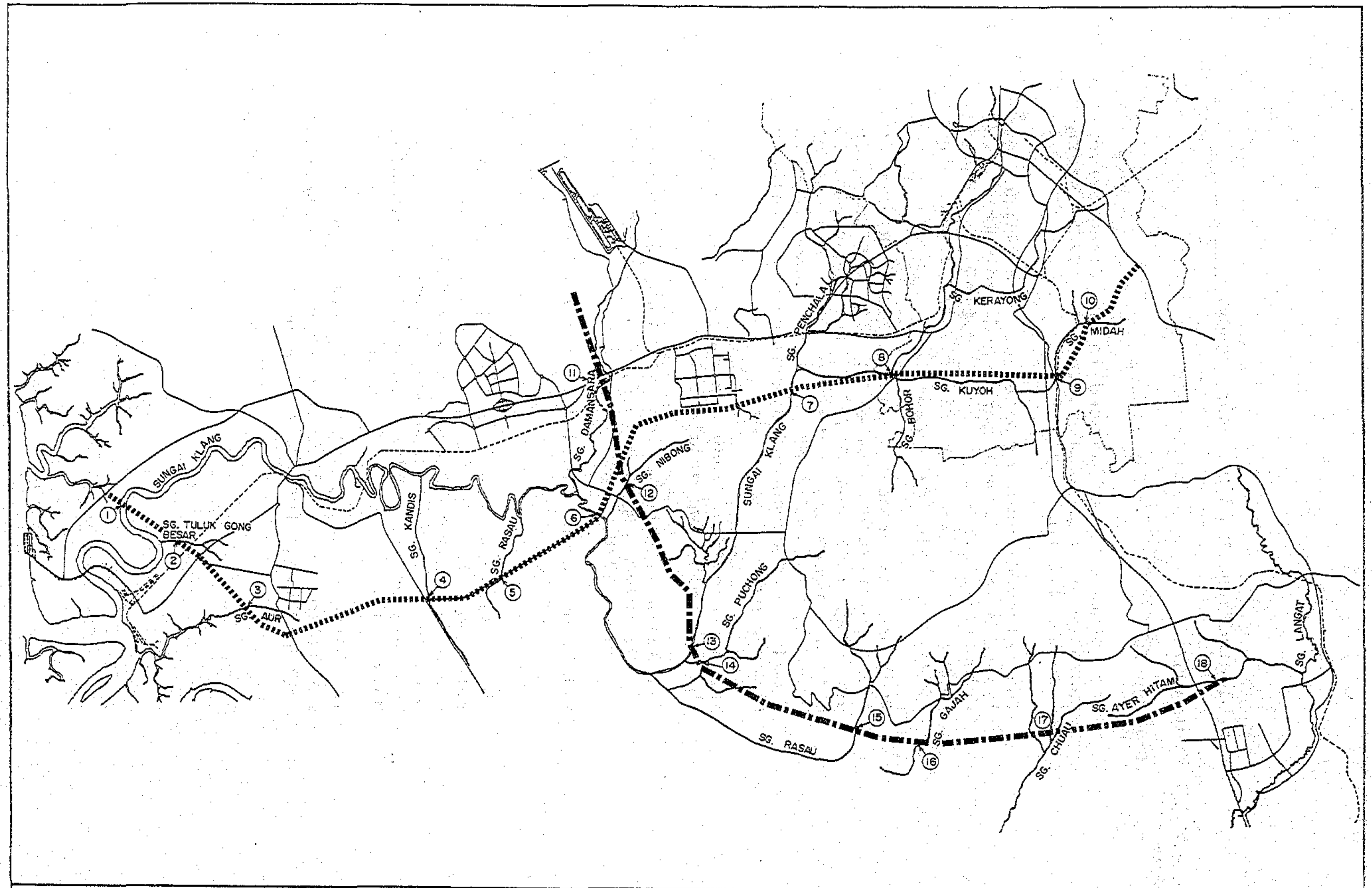


FIG 5.7.1: RIVERS RELATED TO THE PROJECT

THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY

LEGEND:

SHAH ALAM HIGHWAY / MIDDLE RING ROAD II

NORTH - SOUTH LINK

SCALE:

0 1 2 5 km

N

(2) Climate

The climate of the area is tropical with very little monthly variation and relative humidity. The average maximum daily temperatures is 32 degrees centigrade and the corresponding is minimum 23 degrees centigrade. Annual mean relative humidity is 81%. The annual mean discharge during the 1973-1985 period is 14.45 cu.m/s at SLAIMAN gauge. The maximum monthly mean discharge occurs in November and the minimum in February. The annual mean rainfall in the basin is approximately 2,250 mm, varying from 2,700 mm in the mountainous area to 1,850 mm along the main Klang River.

The maximum monthly rainfall generally occurs either in October preceding the northeast monsoon season or in April preceding the southwest monsoon season. Flash flood occasionally occurs in between two monsoons. in almost every month during intermonsoon season. The annual mean evaporation in the basin is approximately 1,070 mm.

Meteorological observatory in the Study Area is located at Petaling Jaya. The average values of monthly meteorological data such as temperature, relative humidity, evaporation, sunshine hours and wind speed in the recent 15 years are listed in Table 5.7.1 .

Table 5.7.1: Monthly Meteorological Data

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature degrees C (mean)	26.6	27.0	27.3	27.4	27.6	27.6	27.1	27.1	26.9	26.9	26.5	26.5	27.0
Humidity (%)	78.4	78.9	79.7	81.8	81.1	78.8	79.6	78.6	81.1	82.1	84.1	82.3	80.5
Evaporation (mm/day)	3.5	3.9	4.0	3.9	3.6	3.4	3.4	3.6	3.4	3.4	3.1	3.0	3.5
Sunshine Hours (hour)	5.9	6.3	6.5	6.1	6.2	5.5	6.1	5.9	5.2	5.3	4.4	4.7	5.7
Wind Speed (m/s)	1.0	1.0	1.1	1.0	1.1	1.1	1.2	1.2	1.1	1.2	1.0	0.9	1.1

Station : Petaling Jaya (Lat: 03 degrees 06' N, Long: 101 degrees 39' E, Alt: M.S.L. + 45.7m)
Source : Malaysia Meterological Service

(3) Rainfall

A number of observation stations exist in the basin and have been in operation for varying lengths of time. 26 annual maximum daily rainfall from three observation stations in the basin were analysed for the Study. Figure 5.7.2 shows the locations of the rainfall observatories and Table 5.7.2 presents recorded annual maximum daily rainfall in the basin.

Table 5.7.2 : Annual Maximum Daily Rainfall

MARKET STREET (3116004)		PUCHONG CROP (3016001)		RIVER MOUTH (3014084)	
Date	Depth (mm)	Date	Depth (mm)	Date	Depth (mm)
18 Nov 1961	54.4	6 Jan 1961	56.8	6 Jan 1961	66.1
30 Oct 1962	52.1	31 Oct 1962	52.1	30 Nov 1962	61.5
2 Dec 1963	73.8	2 Dec 1963	62.3	13 Nov 1963	54.0
3 Mar 1964	88.3	3 Mar 1964	81.1	3 Mar 1964	64.4
5 Apr 1965	47.0	24 Dec 1965	50.0	14 Feb 1965	40.3
25 Dec 1966	38.2	4 Dec 1966	46.5	4 Dec 1966	53.4
17 Jun 1967	39.1	17 Jun 1967	45.5	17 Jun 1967	54.1
12 May 1968	46.2	14 Dec 1968	39.1	22 Mar 1968	35.7
30 Mar 1969	54.9	30 Mar 1969	47.3	2 Jun 1969	39.6
2 Nov 1970	77.2	2 Nov 1970	52.9	2 Nov 1970	32.4
4 Jan 1971	117.3	4 Jan 1971	114.2	4 Jan 1971	118.9
16 Nov 1972	40.0	16 Nov 1972	51.0	16 Nov 1972	44.5
24 Feb 1973	67.5	24 Feb 1973	64.6	24 Feb 1973	50.5
8 Mar 1974	61.1	8 Mar 1974	48.2	8 Mar 1974	37.5
10 Feb 1975	35.4	16 Apr 1975	37.8	1 Nov 1975	44.3
25 Aug 1976	48.7	25 Aug 1976	47.0	25 Aug 1976	40.5
7 Oct 1977	77.0	7 Oct 1977	74.0	7 Oct 1977	64.7
19 Oct 1978	54.5	19 Oct 1978	38.1	19 Sep 1978	40.6
7 Jun 1979	102.5	7 Jun 1979	87.7	7 Jun 1979	66.9
15 Oct 1980	72.4	15 Oct 1980	56.5	15 Oct 1980	67.5
24 May 1981	61.3	24 May 1981	55.7	30 Apr 1981	41.2
17 May 1982	67.2	1 Nov 1982	67.0	11 Mar 1982	50.4
13 Nov 1983	87.3	13 Nov 1983	77.4	13 Nov 1983	51.4
5 Nov 1984	92.0	5 Nov 1984	65.4	5 Nov 1984	49.1
15 Nov 1985	52.5	15 Nov 1985	44.2	3 Dec 1985	34.5

Source : Study on the Flood Mitigation of the Klang River Basin by DID/JICA

STATION NUMBER	STATION NAME
2914120	LADANG GOLDEN HOPE
2917106	LADANG WEST COUNTRY BHG. BARAT
2917111	LADANG SEDGELEY
3014081	LADANG MIDLANDS
3014083	LADANG HIGHLANDS
3014084	PEJABAT JPT KLANG
3015078	LADANG BUKIT KEMUNING
3015082	LADANG HARON
3016075	LADANG BUKIT JALIL
3016076	LADANG KINRARA
3115053	LADANG ELMINA
3115079	PUSAT P. GETAH SG. BULOH
3116001	IBU PEJABAT KAJICUACA MALAYSIA
3116004	JPT WILAYAH PERSEKUTUAN
3117001	EMPANGAN AMPANG (AB)
3117070	PUSAT PENYELIDIKAN JPT AMPANG
3118069	PEMASOKAN AMPANG
3215035	LADANG STARTHAIRLIE
3215051	PUSAT MENGAWAL KUSTA NEGARA
3216001	KAMPONG SG. TUA (AB)
3217001	IBU BEKALAN KM 16 GOMBAK (AB)
3217002	EMPANGAN GENTING KLANG (AB)
3217064	JABATAN ORANG ASLI, ULU GOMBAK
3217065	LADANG WARDIEBURN
3218101	STN. JENALETRIK LLN. PONSOON
3318127	JANDA BAIK

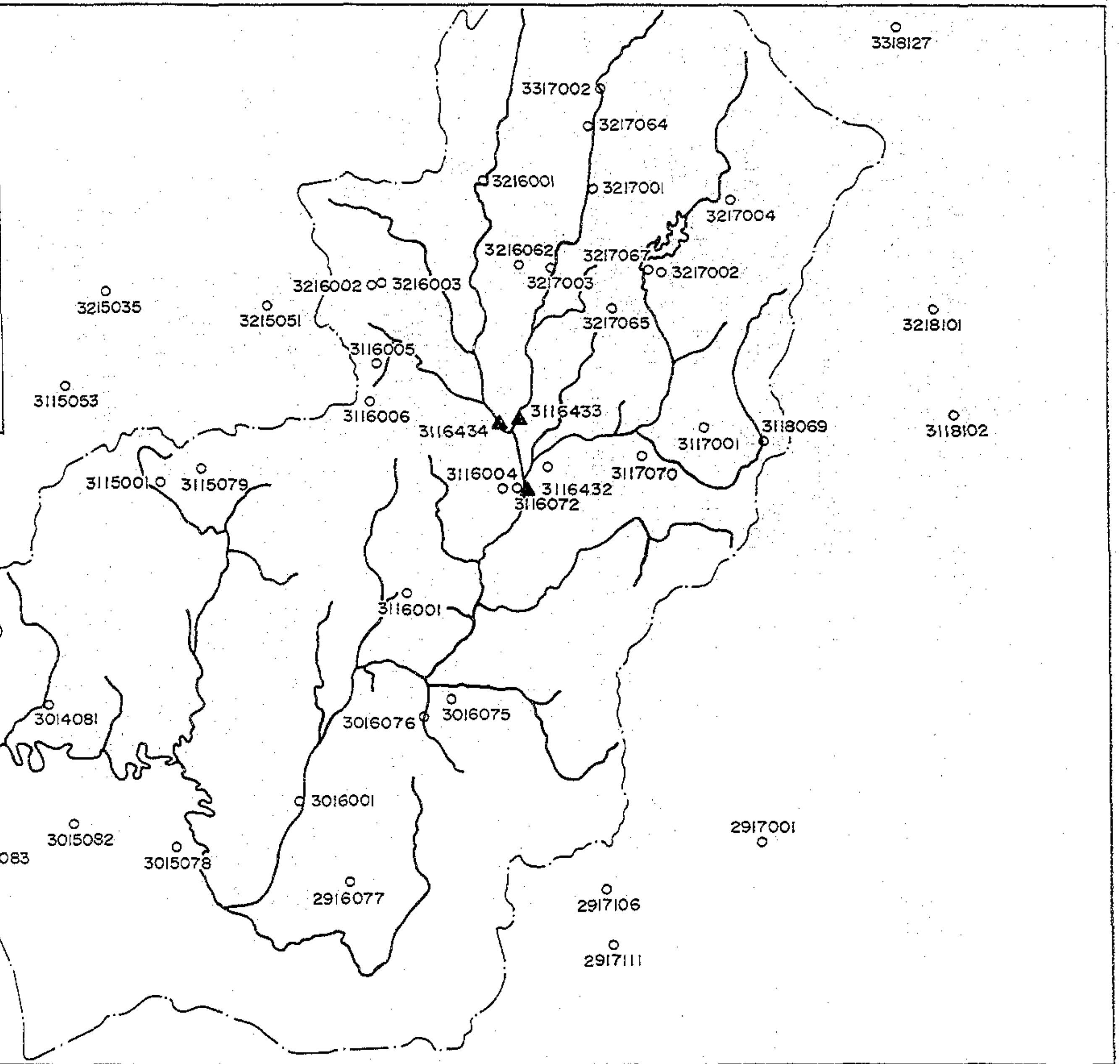


FIG. 5.7.2 LOCATION OF RAINFALL OBSERVATORIES

LEGEND:
○ RAINFALL STATION
▲ WATER LEVEL STATION

SCALE:

N

THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY

The maximum daily rainfall slightly varies at different places in the Klang Valley as shown in Table 5.7.3.

Table 5.7.3 : Maximum Daily Rainfall in Klang Valley

Station Name	Number	Return Period (Years) 2	5	10	20	30	50	100
Lapang Kinrara	3016076	93	124	144	163	174	178	206
Pejabat JPT	3014084	86	114	132	150	160	173	190

Source : Study on the Flood Mitigation of the Klang River Basin by DID/JICA

(4) Sea Level at Port Klang

The tidal movement has been observed at Port Klang by Department of Survey and Mapping since 1983. The tidal movement data are established and published.

Extreme High Water (Oct 1985)	..	+4.97 m
Mean High Water Spring	..	+4.22 m
Mean High Water Neap	..	+2.91 m
Land Survey Datum (L.S.D.)	..	+2.30 m
Mean Low Water Neap	..	+1.62 m
Mean Low Water Spring	..	+0.06 m
Extreme Low Water (March 1985)	..	-0.85 m

(Source : Record Cerapan Air Pasang Surut 1985)
** Note : All values are above Chart Datum Level (C.D.L.)

(5) Flood

One of the largest flood ever recorded occurred in January 1971. Inundated area has reached 124 sq.km (9.5% of the Klang River Basin) and 180,000 people have suffered damage from the flood.

The daily rainfall depths in the 1971 flood was recorded as follows:-

Unit: mm

Station Name	Number	1st	2nd	3rd	4th	5th
Pejabat Kajicuaca	3116001	26.2	27.9	41.4	161.3	34.8
JPT. Ampang	3117070	29.2	38.1	50.8	171.5	30.7
Lojiair Bukit Weld	3117071	36.6	50.8	101.6	103.1	77.2
Pemasokan Ampang	3110069	31.7	43.2	53.3	176.3	48.3
J.O.A. Ulu Gombak	3217064	54.4	37.6	57.9	76.7	36.1
Ladang Wardieburn	3217065	15.5	15.7	76.2	91.2	106.2

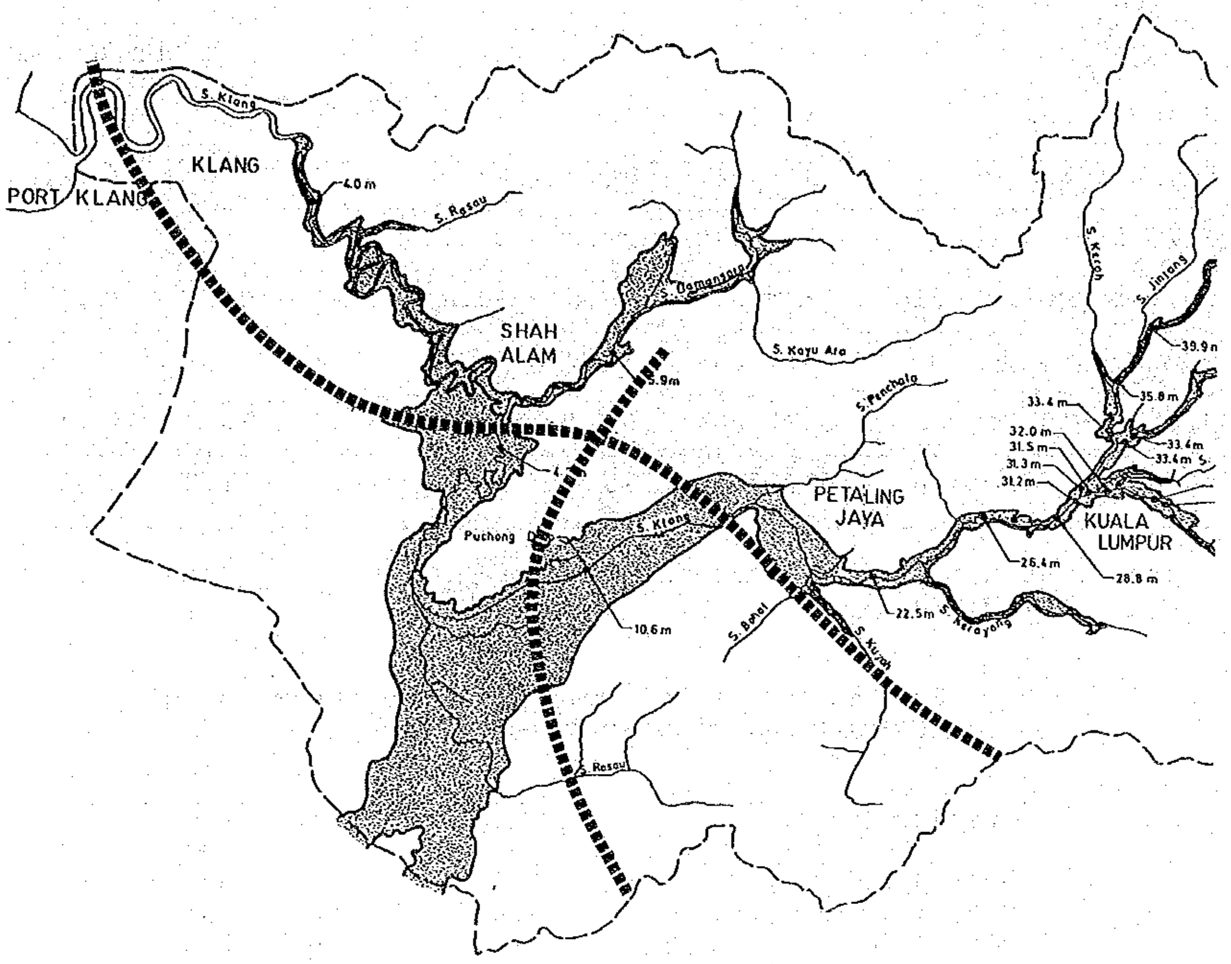
Source : Study on the Flood Mitigation of the Klang River Basin by DID/JICA

The water level recorded at three gauging stations was listed below.

Station Name	Number	Water Level
Sentul Railway Bridge	3116434	EL 33.834 m
Circular Road Bridge	3116433	EL 33.394 m
Market Street Bridge	3116432	EL 31.232 m

Source : Study on the Flood Mitigation of the Klang River Basin by DID/JICA

The flood in the town centre of Kuala Lumpur endured only a day, but in the downstream the flood duration lasted for five days. Figure 5.7.3shows the flooded area.



SOURCE : STUDY ON THE FLOOD MITIGATION OF THE KLANG VALLEY BASIN - JICA

FIG 5.7.3 : STUDY ROADS AND FLOODED AREA BY JANUARY 1971 FLOOD

THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY

LEGEND :

- CATCHMENT BOUNDARY
- RIVER
- DAM AND RESERVOIR
- INUNDATED AREA
- FLOOD WATER LEVEL (31.2m)

SCALE :

0 1 2 5 km

N

The design high water level of the Klang River is proposed by DID/JICA Study Team as shown in Figures 5.7.4 and 5.7.5. This high water level is based on the assumption that the permissible maximum discharge in the main stream of the Klang River at Market Street will not exceed 749 sq.m/s.

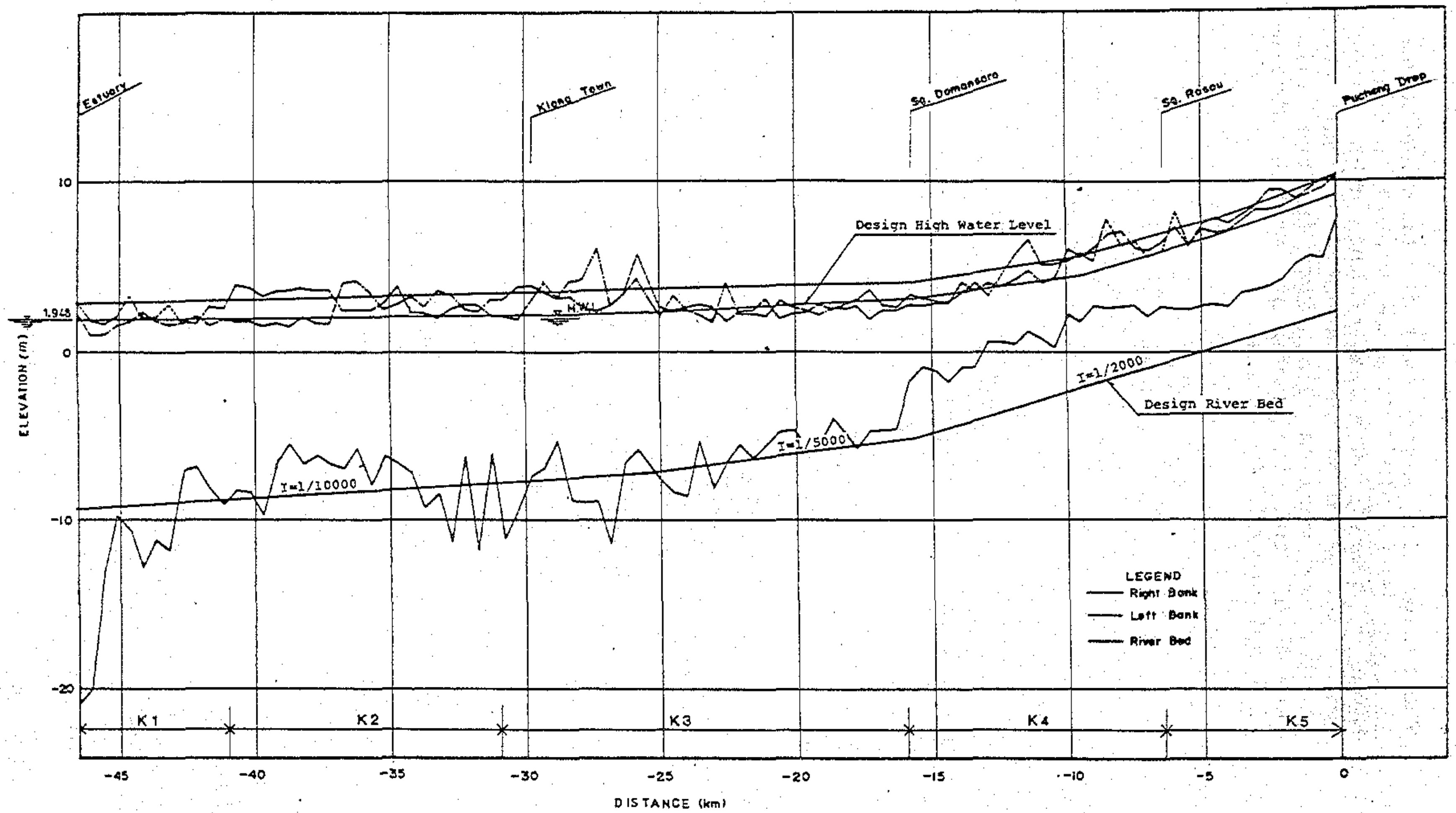


FIG 5.7.4	PLANNED LONGITUDINAL PROFILE OF SG.KLANG 1
STUDY ON THE FLOOD MITIGATION OF THE KLANG RIVER BASIN	

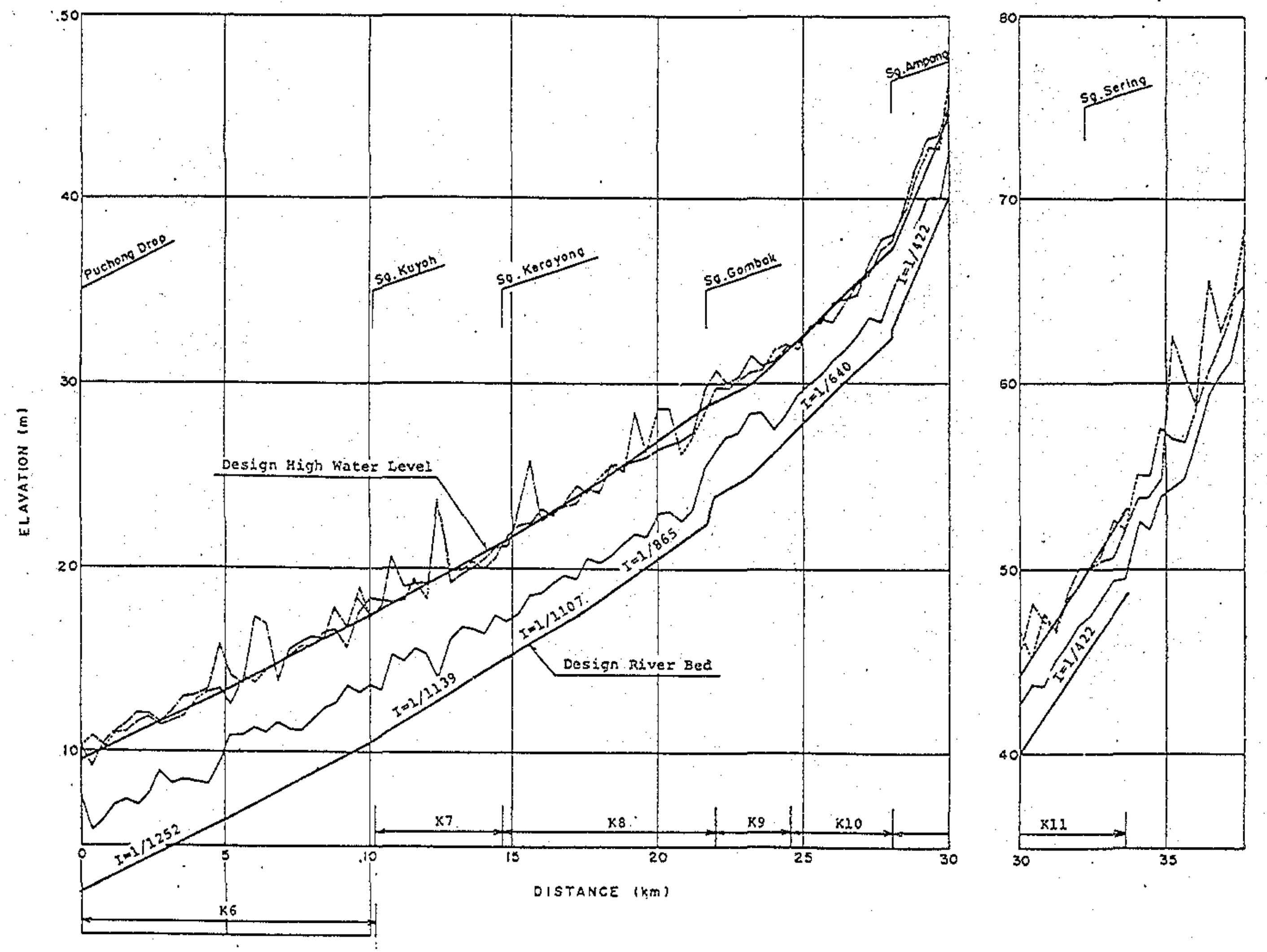


FIG 5.7.5 PLANNED LONGITUDINAL PROFILE OF SG.KLANG 2

STUDY ON THE FLOOD MITIGATION OF THE KLANG RIVER BASIN

5.7.2 Method to be Employed for Estimating Run-Off

Estimation of run-off for each drainage system or river/channel is based on the modified rational formula, together with the following investigations and studies.

- Comparison with the run-off estimated by other Government agencies;
- Site investigation for signs of flood water-levels in the areas;
- Information about flood water levels from the inhabitants in the area;
- Survey of the cross sections and slopes of the rivers and waterways; and
- Site investigation and flood study (i.e. maximum discharge and water surface levels) at the nearest existing bridge on the same rivers/waterways.

(i) Modified Rational Method

The formula to be used for peak runoff estimation shall be:-

$$Q = \frac{1}{3.6} \times Cs \times C \times i \times A$$

Where:-

Q - is the peak discharge in cubic meters per second of return period T years

C - is a runoff coefficient

Cs - is a storage coefficient

i - is the average intensity of rainfall in millimeters per hour for a duration equal to the time of concentration t , of a return period T years

A - is the catchment area in square kilometers

(ii) Run-off Coefficient

In estimating the run-off coefficient, a variety of geological and ground conditions are taken into consideration for each drainage area in view of the major differences that can exist between one area and another. The values determined are as listed below.

Type of Drainage Area	Coefficient of Run-off "C"
Road Surface (paved)	0.95
Embankment Slope	0.35
Grassland	0.30
Paddy Field	0.70
Cultivated Field	0.20
Inhabited Area	0.65

For catchments with composite landuses or surface characteristics, a weighted value of C may be calculated from this formula:-

$$C = \frac{A\ C + A\ C \ldots\ldots\ldots\ldots\ldots\ldots A\ C}{A}$$

Where C is the composite runoff coefficient,

A , A etc are in areas, each of relatively uniform landuse or surface character, comprising the total area A,

and C , C etc are the corresponding runoff coefficients.

(iii) Storage Coefficient (Cs)

As the catchment area gets larger the effect of channel storage on the attenuation of the flood wave becomes more pronounced. To allow for the channel storage effect the peak discharge calculated by the basic Rational Method Formula, Q = CiA shall be multiplied by a storage coefficient Cs.

Cs shall be determined as follows:-

$$Cs = \frac{2tc}{2tc + td}$$

Where:-

tc is the time of concentration

td is the time of flow in the drain

(iv) Rainfall Intensity

Figure 5.7.6 presents the rainfall intensity in Klang Valley.

For a given storm recurrence interval the rainfall intensity, i, is the average rate in millimeters per hour from a storm having a duration equal to the time of concentration, tc.

(v) Time of Concentration (tc)

The time of concentration is the time required for the water to flow from the most remote point of the catchment to the point being investigated.

For urban storm water drains, the time of concentration (tc) consists of the time required for runoff to the flow over the ground surface to the nearest drain (to) and the time of flow in the drain to the point under consideration (td).

tc = to + td

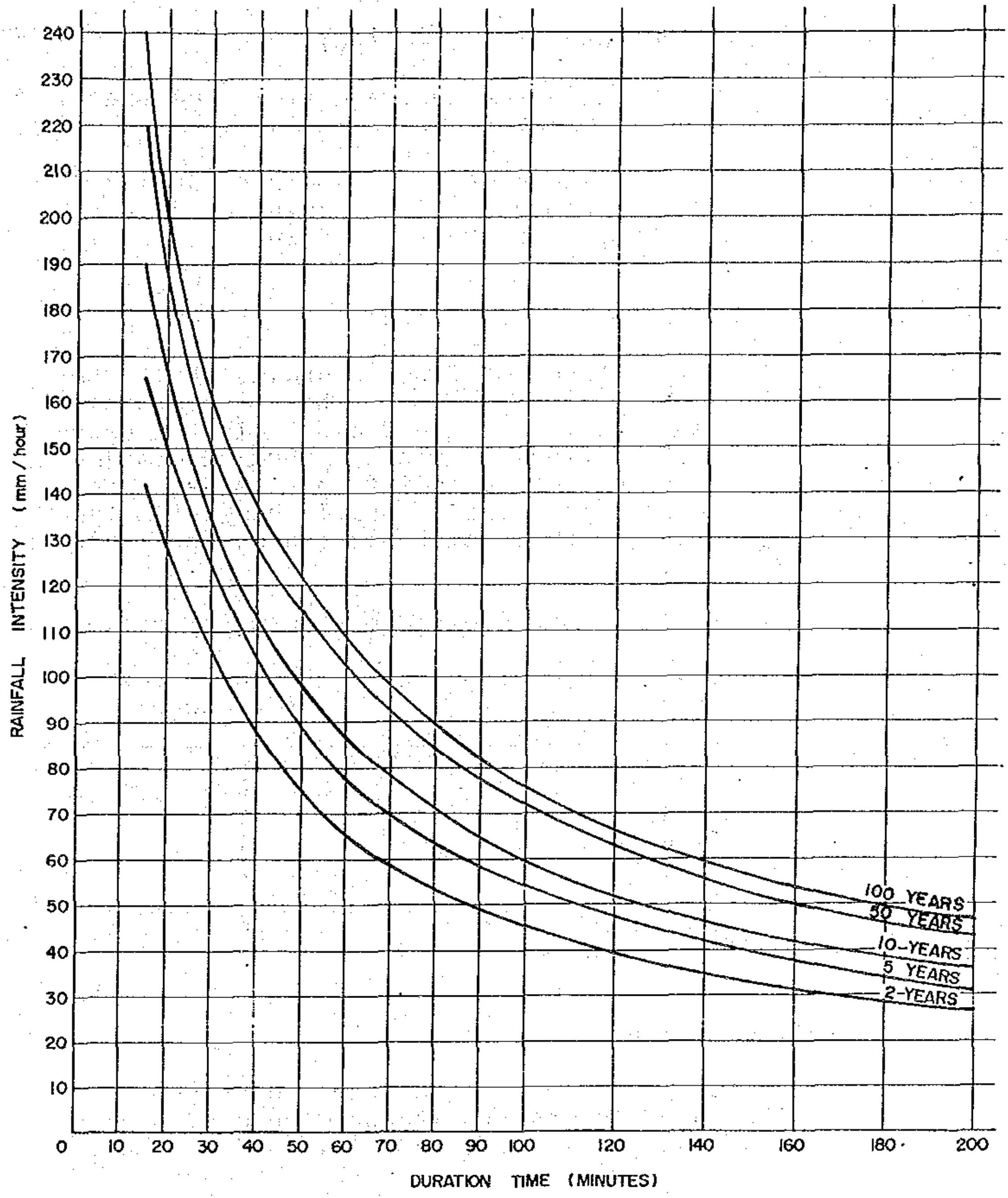


FIG. 5.7.6: RAINFALL INTENSITY - DURATION CURVE	THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY
LEGEND :	**SCALE :** N

(a) Overland Flow Time (to)

The time for overland flow (to) shall be estimated as follows:-

- Rolling area 15min to 30min
- Cut Slope 3min to 5min
- Urbanised Area 5min

(b) Drain Flow Time (td)

The time of flow in drains shall be estimated from the hydraulic properties of the drain. In the case of streams where the hydraulic properties are difficult to determine the time of flow shall be estimated using the velocities shown in Table 5.7.4.

Table 5.7.4 : Approximate Stream Velocities

Average Slope of Channel (%)	Average Velocity (m/second)
1-2	0.6
2-4	0.9
4-6	1.2
6-10	1.5
10-15	2.4

Source : DID Urban Drainage Design Standard

(vi) Catchment Area

Catchment area and the corresponding channel length are measured on maps having a scale of 1:25,000 and 1:10,000 whichever is available. For the roadway and roadside drainage, other plans to appropriate scales are used as necessary.

5.8 Design of Road Supporting Facilities

5.8.1 Traffic Signs

Traffic signs are one of the traffic control devices which are used to regulate, warn or guide road users. To be effective, traffic signs like other traffic control devices should meet the following five elementary requirements:-

(1) They should fulfill an important need
(2) They should command attention
(3) They should convey a clear, simple meaning
(4) They should give adequate time for proper response

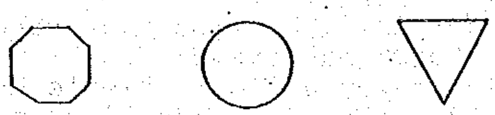
Three kinds of signs are designed and the designs are according to JKR standards as shown and specified in Manual on Traffic Control Devices. Standard Traffic Signs (Arahan Teknik (Jalan) 2A/85) and in Manual on Traffic Control Devices, Traffic Sign Applications (Arahan Teknik (Jalan) 2B/85). They are regulatory signs, warning signs and guide signs.

(1) Regulatory Signs

Regulatory signs inform road users of traffic laws or regulations and indicate the applicability of legal requirements that would not otherwise be apparent.

Regulatory signs are generally circular in shape except for the "BERHENTI, BERI LALUAN and ZON HAD LAJU" signs.

Regulatory

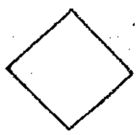


(2) Warning Signs

Warning signs are used when it is deemed necessary to warn traffic of existing or potentially hazardous conditions on, or adjacent to a highway.

Warning signs are generally diamond in shape *(square with one diagonal vertical), however,* there are a few which are rectangular. The colours shall be black symbols and borders on yellow background except for the signs "AWAS" and 'OBSTRUCTION MARKER'.

Warning



(3) Guide Signs

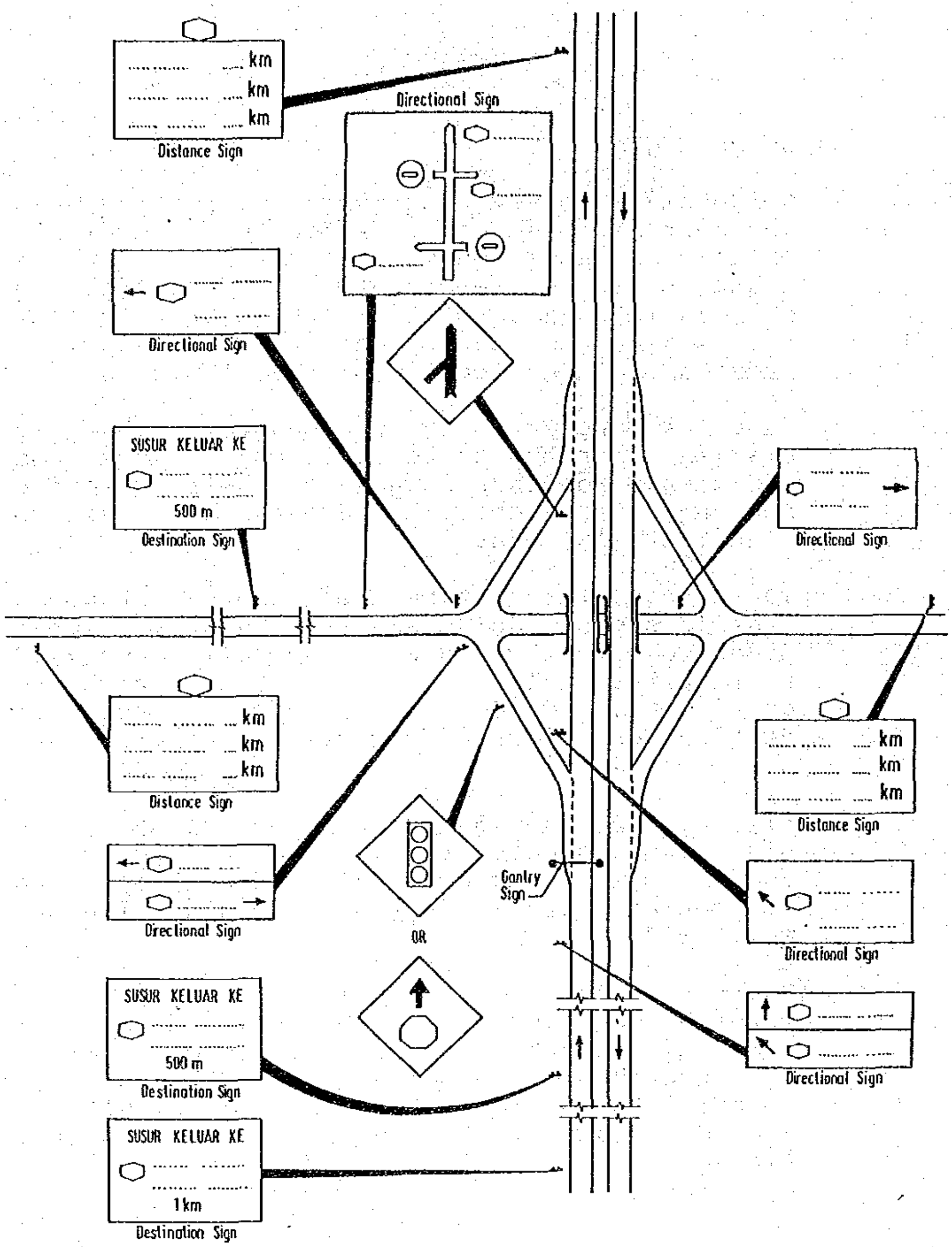
Guide signs convey to drivers information such as destinations and distances, services, facilities and route confirmation. These signs play an important role in informing drivers in advance of the correct traffic lane for making an exit or entry at On and Off ramps and of the locations of toll plazas.

Ease of operation at interchanges, that is clarity of paths to be followed, safety and efficiency depends largely on their relative spacing, the geometric layout and effective sign installations.

There are three types of signs, standard traffic signs, guide signs and gantry signs. Standard traffic signs are normally installed at ramp terminals, i.e. exits, entrances and gore areas. Guide signs generally consist of destination signs, directional signs and distance signs.

Figures 5.8.1 and 5.8.2 show the typical guide sign requirements for a diamond interchange and a full cloverleaf interchange as reproduced from "Arahan Teknik (Jalan) No.12/87".

Gantry signs are very effective at interchanges and should be provided at all ramp exits on the expressway approaches before the interchange, especially when the physical constraints of the site make it difficult to provide adequately for the normal directional signs.



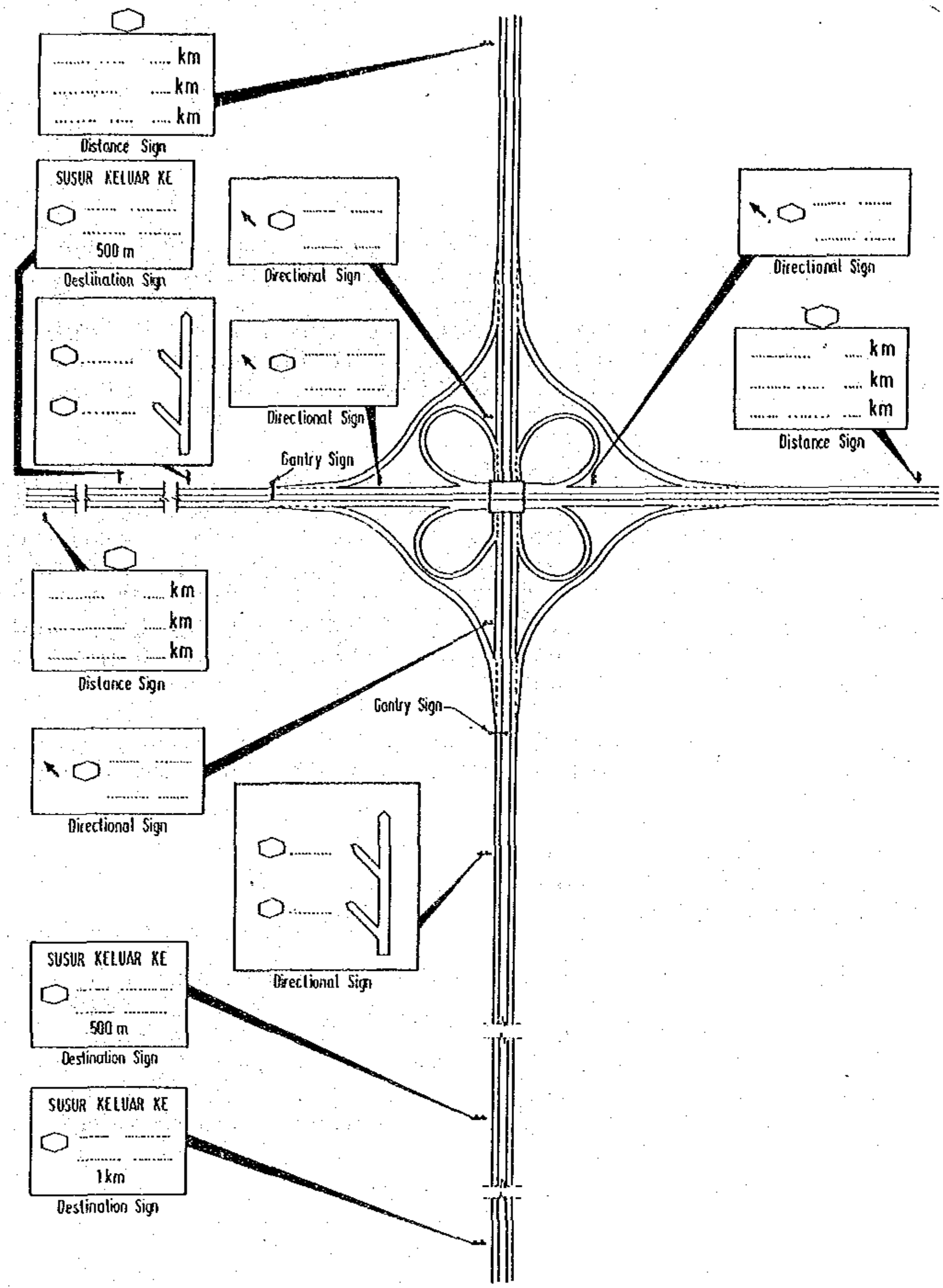
Source : JKR Standard

Figure 5.8.1 Typical Guide Sign Standard for Diamond Interchange

LEGEND :

THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY

SCALE :



Source : JKR Standard

Figure 5.8.2 Typical Guide Sign for Cloverleaf Interchange

LEGEND :

THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY

SCALE :

5.8.2 Traffic Markings

Traffic markings include all traffic lines (both longitudinal and transverse), symbols, words, object markers, delineators, cones or other devices, except signs that are applied or attached to the pavement or mounted at the side of the roadway to guide traffic or warn of an obstruction.

Road markings are particularly important to help in regulating traffic, warning or guiding road users. All road markings, like other traffic control devices should be uniform in design, position and application so that they may be recognized and understood immediately by all road users. Furthermore, all markings on highways shall be reflectorized.

Most of the traffic markings are painted on pavement and can be divided into the following types:-

(i) Longitudinal Lines
(ii) Transverse Lines
(iii) Other Markings

A longitudinal line consists of either an unbroken or a broken line or a combination of both marked in the direction of travel. The dimensions of longitudinal lines are shown in Figure 5.8.3. The thickness of the longitudinal lines should be 3mm to 5mm when applied by screeding and 1.0mm to 1.5mm when sprayed.

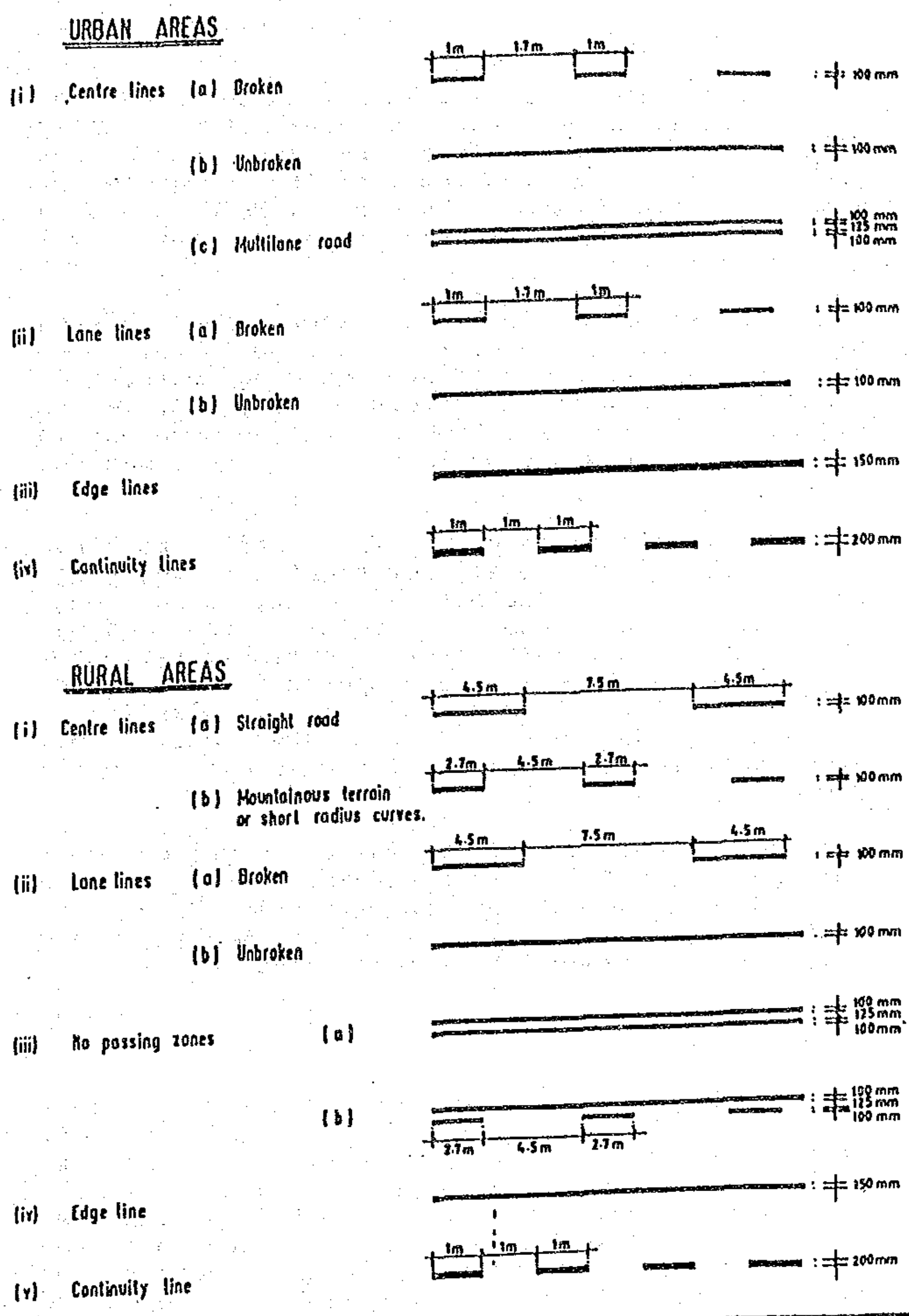


Figure 5.8.3 Dimensions of Longitudinal Lines

LEGEND :

THE FEASIBILITY STUDY ON TRANSPORTATION FACILITIES PROJECTS IN KLANG VALLEY

SCALE :

N

Transverse lines are marked across the road and are generally associated with intersection. They should be wider than longitudinal lines because of the narrowing which results from the low angle of which they are viewed. They shall be of non-skid materials and shall protrude 5mm above the level of the carriageway.

Other markings are included diagonal and chevron markings, words, numerals and symbols which are painted on pavements to convey guiding, warning or regulatory message to drivers. They should be elongated in the direction of traffic movement in order that they may be legible at the maximum distance.

Post delineators are one of the traffic markings which are effective aid for night time driving. The purpose of delineators is to outline the edge of the roadway and to indicate the roadway alignment. Post delineators are simply reflector units mounted on suitable supports and reflector units usually are made of glass, plastic or reflective sheetings. Post mounted delineators are beneficial for horizontal curves over five (5) degree.

The road markings shall be white and yellow only for some auxiliary areas according to the JKR existing standards, as specified in Manual on Traffic Control Devices. Road Marking and Delineation (Arahan Teknik (Jalan) 2D/85).

5.8.3 Road Lighting

Lighting may improve safety of a highway or street and the ease and comfort of operation thereon. Statistics indicate that night time accident rate is higher than that during day time hours, which, to a large degree, may be attributed to impaired visibility. There is evidence that in urban area and suburban area, where there are concentration of pedestrians, fixed source lighting tends to reduce accidents.

The recommended standard for road lighting and its application will be described as follows, based on the standard practised by Ministry of Construction (Japan).

(1) Design Standard of Road Lighting

(a) Location of Lighting Installation

The locations of the installation of lighting facilities are as follows:-

- Tollway, arterial and frontage road
- On/Off-Ramp including Toll Plaza and
- Underpass

(b) Design Illumination Intensities

The average intensity of illumination are as follows:-

- 15 lux for the Tollway, arterial and frontage road
- Minimum 20 lux for the toll plaza and
- 15 lux for underpass

(c) Selection of Luminaires

The types adopted are as follows:-

Location	Luminaire
Tollway, arterial and frontage road	Semi cut-off type
Toll Plaza	Flood light or semi cut-off type
Street	Box type

(2) Selection of Lighting Equipment

(a) Light Source

(i) Tollway, Arterial and Frontage Road

Low pressure sodium lamps have been proposed as the light source for both the toll road and arterial street for the following reasons:-

- High lunimous efficiency
- Minimum glare
- Economical lamp cost

(ii) Toll Plaza

High pressure sodium lamps are proposed as the light source for the toll plaza due to:-

- Low initial costs
- High average life
- Easy identification of colour
- Economical lamp cost
- Easy recognition of the location of on and off ramps

(b) Ballasts

(i) Ballast for low pressure sodium lamps

All ballasts for low pressure sodium lamps will be of the constant wattage and high power-factor type.

(ii) Ballast for high pressure sodium lamps

The ballast for high pressure sodium lamps will be of the power-factor correction, current limiting and low wattage losses type.

(d) Lighting Columns

The mounting position and height of luminaires is determined by the degree of road surface luminance required and the glare tolerance of drivers. The height and spacing of the columns are clearly independent and in order to keep the level of glare, low more powerful light sources must generally be placed higher from the road surface. The type of lighting standards recommended are shown in Table 5.8.1.

Table 5.8.1: Recommended Type of Lighting Standards

Location	Column Height	Overhang	Slope Angle
Tollway	13m	-1.5 to +1.5m (Lamp with over 0.6m Light source)	Under 5deg.
Rampways	13m	-1.5 to +1.5m (Lamp with over 0.6m Light source)	Under 5deg.
Large Toll	25m "high-mast lighting" *	-	-

Note: * High-mast lighting is recommended for large toll plazas with more than four booths because glare is relatively low and it is an economical way of lighting large areas.

(c) Foundations for Lighting Standards

Base plate type mounting is recommended because the standards are more easy to install and replace than the embedded type.

Excavation for the foundation can be carried out by earth auger or by direct excavation and the standard can be fixed using anchor-bolts secured in the foundation.

(3) Underpass Lighting

The aim of underpass lighting is to maintain good visibility for the street below a flyover or viaduct. The illumination intensity should be the same as for an arterial street or frontage road.

The preferred light source is low pressure sodium lamps with lead peaked type ballast and box type housing.