APPENDIX 9

Appendix 9.1 MR9.1.2: Structual Design Standard.

1) Design Loads: Table A9.5 is applicable for Design Load.

Table A9.5 Design loads

Clause number	Load
5.1	Dead: steel
	concrete
5.2	Superimposed dead
5.1.2.2 & 5.2.2.2	Reduced load factor for dead and superimposed dead where this has a more severe total effect
5.3	Wind: during erection
	with dead plus superimposed dead load only,and for members primarily resisting wind loads
	with dead plus superimposed dead plus other appropriate combination 2 loads
	relieving effect of wind
5.4	Temperature: restraint due to range
	friction bearing restrain
	effect of temperature difference
5.6	Differential settlement
5.8	Earth pressure: retained fill and/or live load surcharge
	relieving effect
5.9	Erection: temporary loads
6.2	Highway bridges live loading: HA alone
6.3	HA with HB or HB alone
6.5	Centrifugal load and assosiated primary live load
6.6	Longitudinal load: HA and associated primary live load
	HB and associated primary live load
6.7	Accidental skidding load and associated primary live load
6.8	Vehicle collision load with bridge parapets and associated primary live load
6.9	Vehicle collision load with bridge supports
7	Foot/cycle track bridges: live load and parapet load
8	Railway bridges: type RU and RL primary and secondary live loading

2) Material

(1) Concrete
For the strength of concrete, maximum/minimum cement content and water-cement ratio, Table A9.6 is applicable.

(2) Reinforcement Bar
The characteristic strengths of reinforcement bars are as follows:

High tension steel : 460 N/mm^2
Soft steel : 250 N/mm^2

(3) PC Tendon
The characteristic strengths of PC tendon are as follow:

Steel wire, strand : 200 kN/mm^2
Steel bar, strand (19 wires) : 175 kN/mm^2

Table A9.6 Specifications for Designed Concrete Mix

Grade	55	50	45	40	35	30	25	20	15	10
Characteristic strength N/mm^2 at 28 days	55	50	45	40	35	30	25	20	15	-
Minimum cement content in kg/m^3 concrete	475	425	375	350	350	325	300	270	205	175
Maximum cement content in kg/m^3 of fully compacted concrete	550	550	550	550	550	550	550	550	550	550
Maximum water/ cement ratio	0.4	0.45	0.45	0.5	0.5	0.5	0.55	0.6	0.7	0.8

3) **Allowable slopes**

Allowable slopes in cutting and filling as indicated in Table A9.7 and Table A9.8 are applied respectively.

Table A9.7 Allowable Slopes in cutting

Material	Slope (Horizontal Distance to Vertical Rise)
Sand	2:1 to 5:1
Loose gravel or clay	1.5 :1
Loam,shale or similar soft rock	1 :1
Rock with clay seams	0.75:1
Jointed laminated or soft rock	0.5 :1
Massive competent rock	0.25:1

Table A9.8 Allowable Fill Slopes

Material	Slope (Horizontal Distance to Vertical Rise)
Sand loam,soft clay and loose sand	2:1 to 5:1
Ordinary earth	1.5 :1
Rock	1.25:1
Rock filling-hand pitched	1:1

4) Allowable bearing pressure

The values in Table A9.9 are used as the allowable bearing pressure for spread foundations and pile foundations during preliminary design.

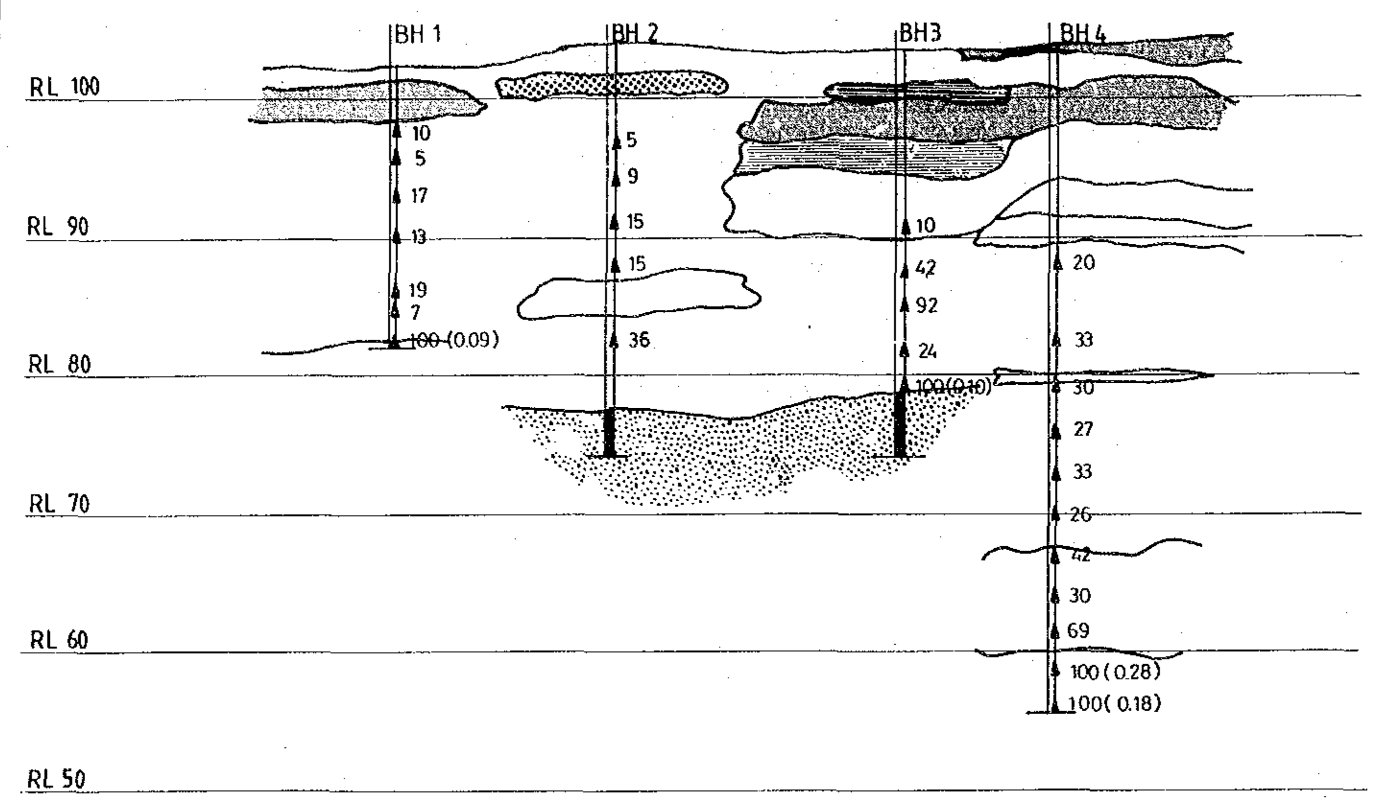
Table A9.9 Presumed Bearing Values under Vertical Static Loading

NOTE. These values are for preliminary design purposes only and may need alteration upwards or downwards. Reference must be made to other parts of the Code when using this Table.

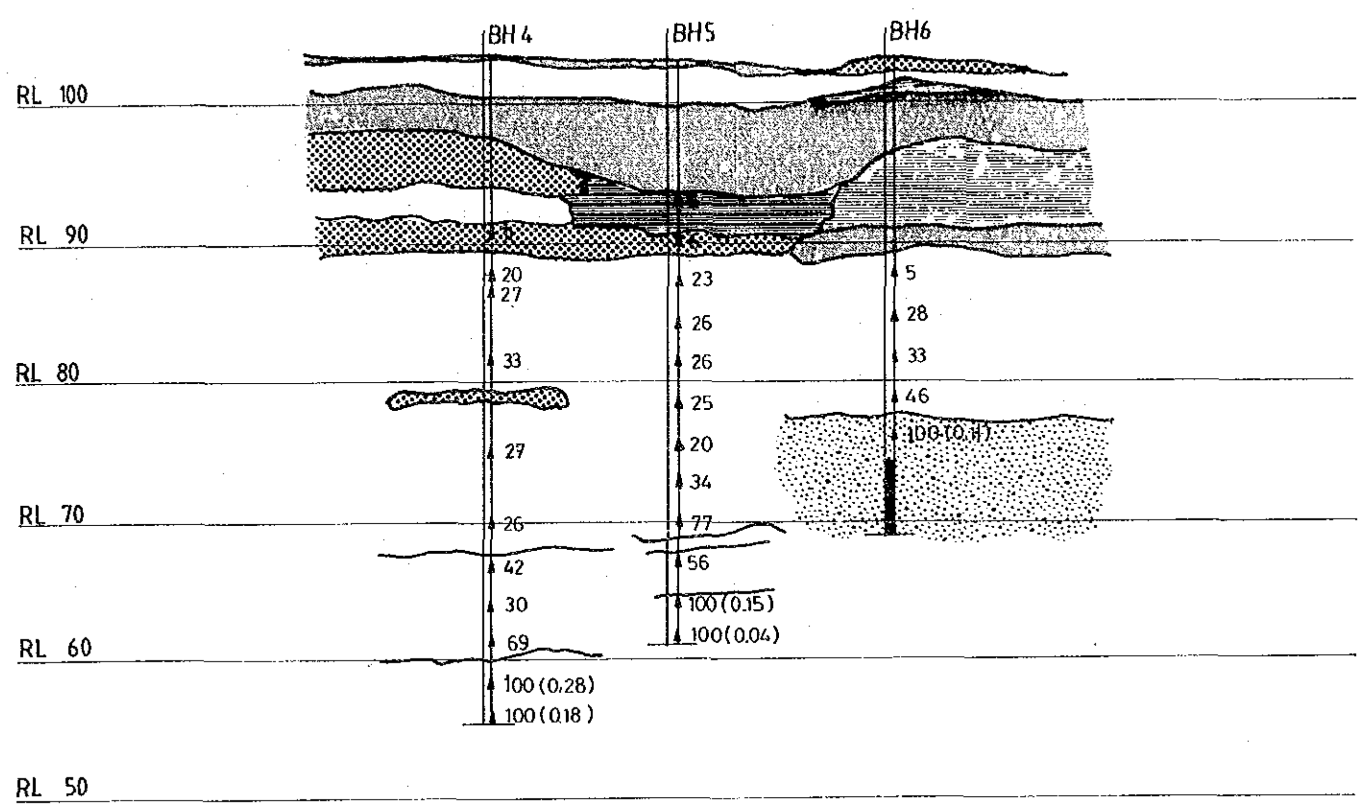
Group	Class	Types of Rocks and Soils	Presumed Bearing Values kN/m²†	Presumed Bearing Values tonf/ft²†	Remarks
I Rocks	1	Hard igneous rocks in sound condition	10 000	100	These values are based on the assumption that the foundations are carried down to unweathered rock
	2	Hard sandstones	4 000	40	
	3	Hard shales, hard mudstones and soft sandstones	1 000 to 2 000*	10 to 20	
	4	Soft shales and soft mudstones	600 to 1 000	6 to 10	
	5	Thinly bedded sandstones, shales	To be assessed after inspection		
	6	Heavily shattered rocks	To be assessed after inspection		
II Non-cohesive soils	7	Compact gravel, or compact sand and gravel	> 600	> 6	Width of foundations (B) not less than 1 m. Groundwater level assumed to be a depth not less than B below the base of the foundation.
	8	Medium dense gravel, or medium dense sand and gravel	200 to 600	2 to 6	
	9	Loose gravel or loose sand and gravel	< 200	< 2	
	10	Compact sand	> 300	> 3	
	11	Medium Dense sand	100 to 300	1 to 3	
	12	Loose sand	< 100	< 1	
III Lateritic soils (reddish brown to yellow friable material with profuse silty soil)	13	Soils with coarse material mixed with stone pieces	300 to 500	3 to 5	
	14	*Soil with fine granular material*	150	1.5	
	15	Soft and silty	100	1	
IV Cohesive Soils	16	Very stiff clays and *hard clays*	300 to 600	3 to 6	
	17	Stiff clays	150 to 300	1.5 to 3	
	18	Medium stiff clays	75 to 150	0.75 to 1.5	
	19	Soft clays and silts	< 75	< 0.75	
	20	Very soft clays and silts	Not applicable		
V	21	Peat and organic soils			
VI	22	Made ground or fill			

† 1 tonf/ft² = 107.25 kN/m².

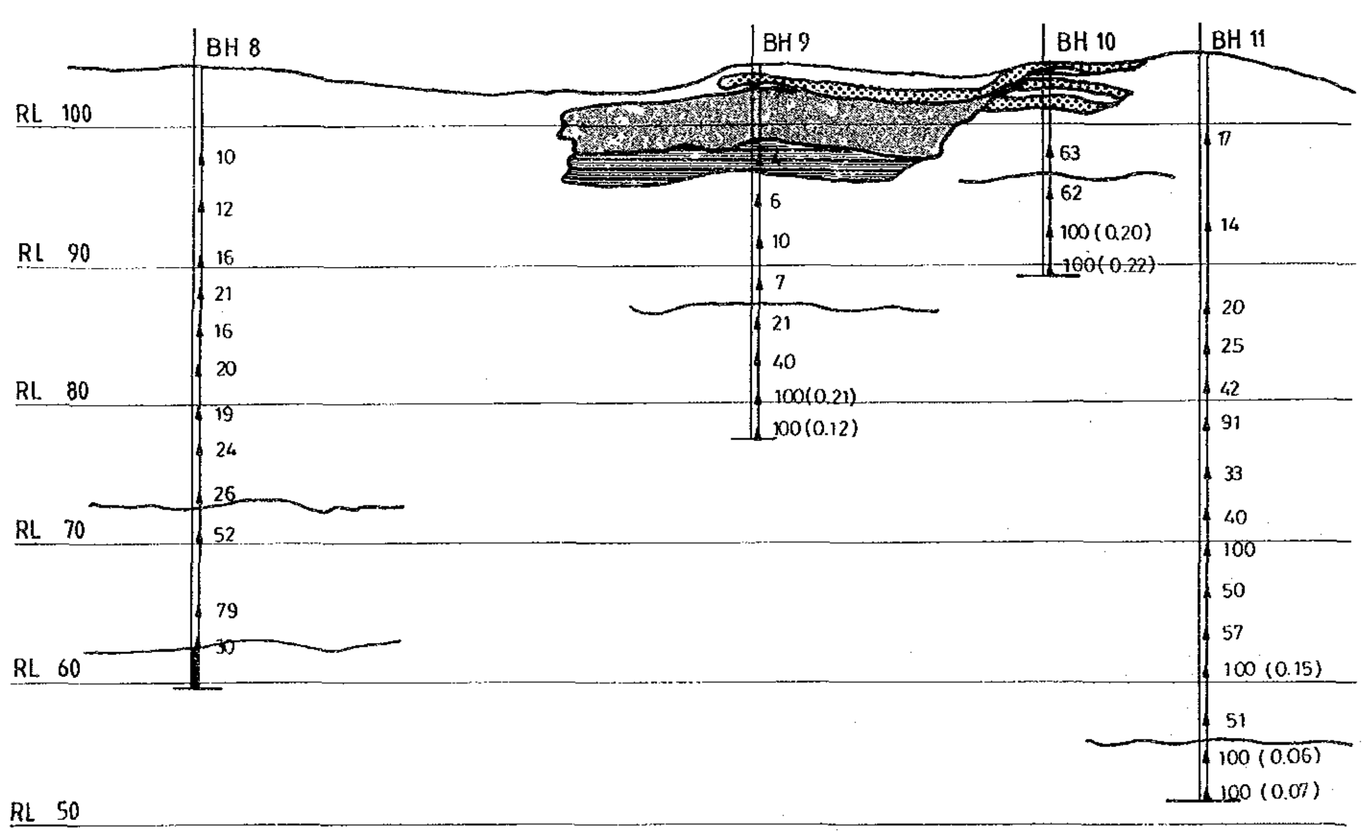
SECTION A

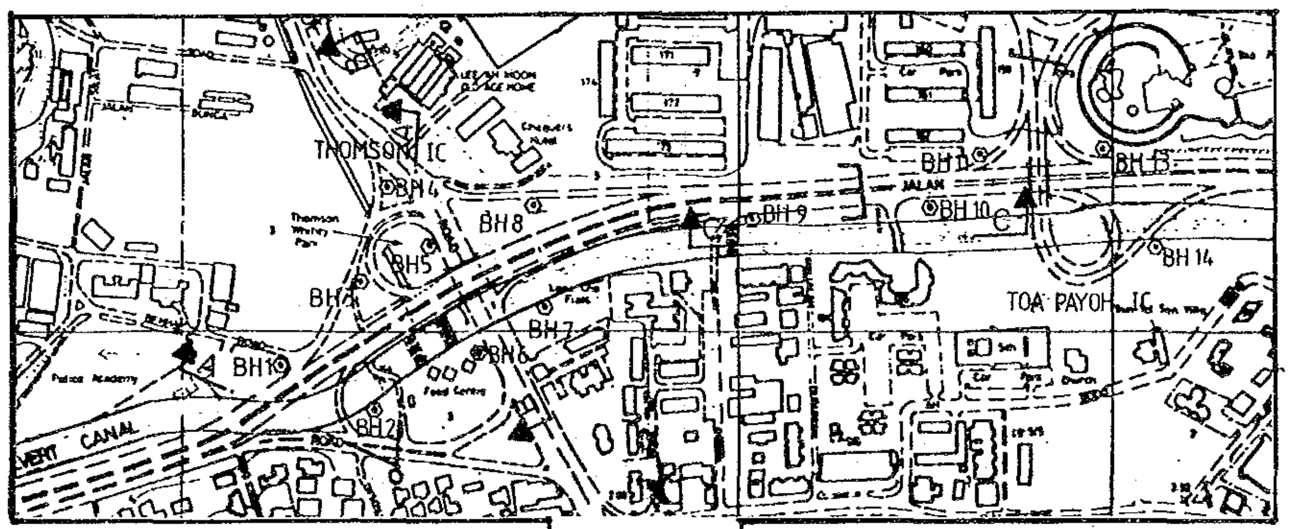


SECTION B



SECTION C





KEY PLAN

LEGEND:

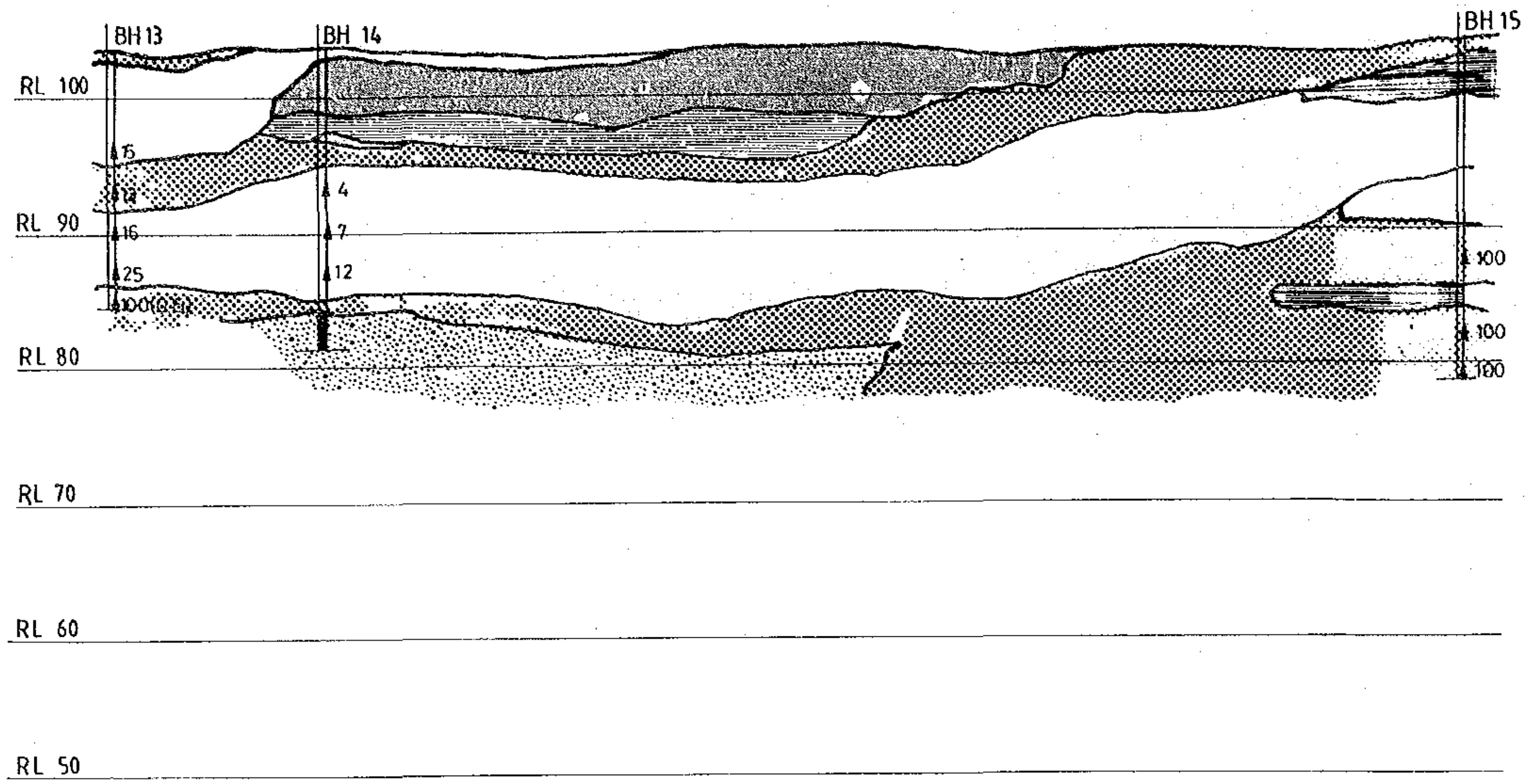
	Silty clay		Marine clay
	Sand, Sandstone		Peaty clay
	Silt , Siltstone		Decomposed granite

NOTE:
- Numbers beside borehole indicate N value for standard penetration resistance.
- 100(0.18) indicates 100 blows for 0.18m of penetration.

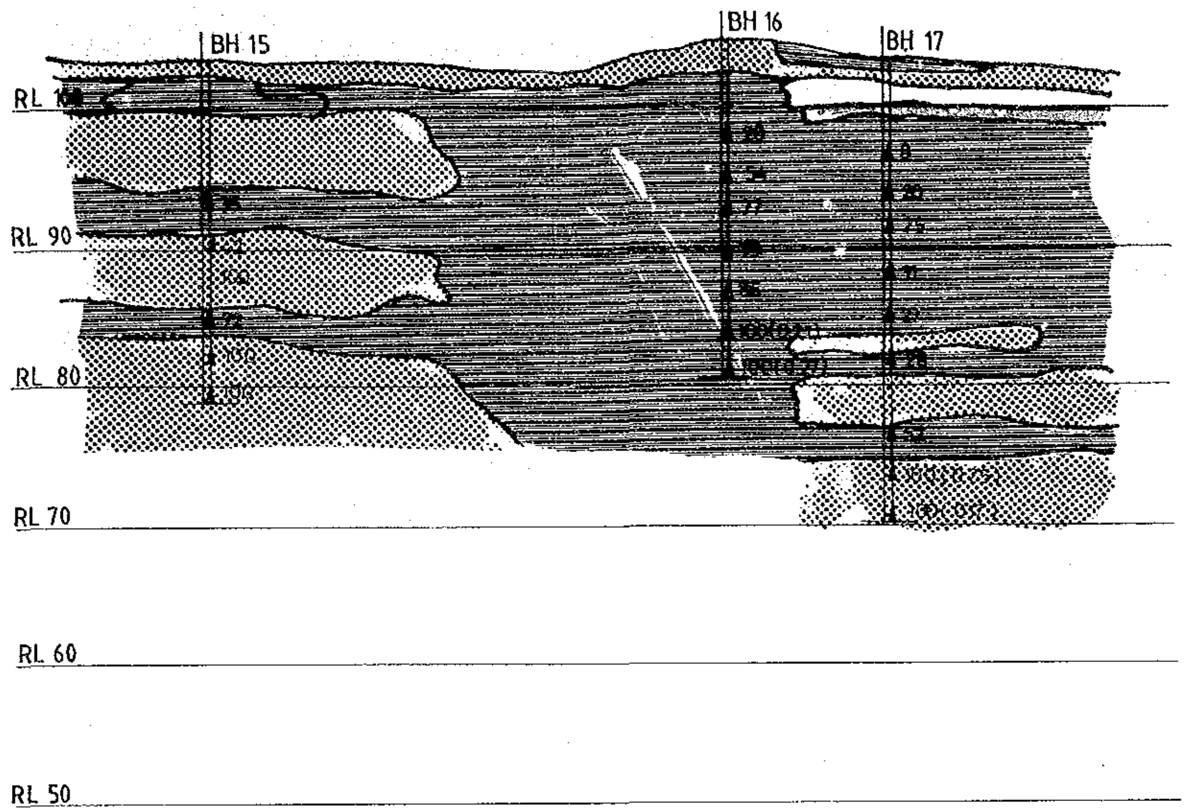
Appendix 9.2. MR9.4.2: Soil profile along PIE (1/2)

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

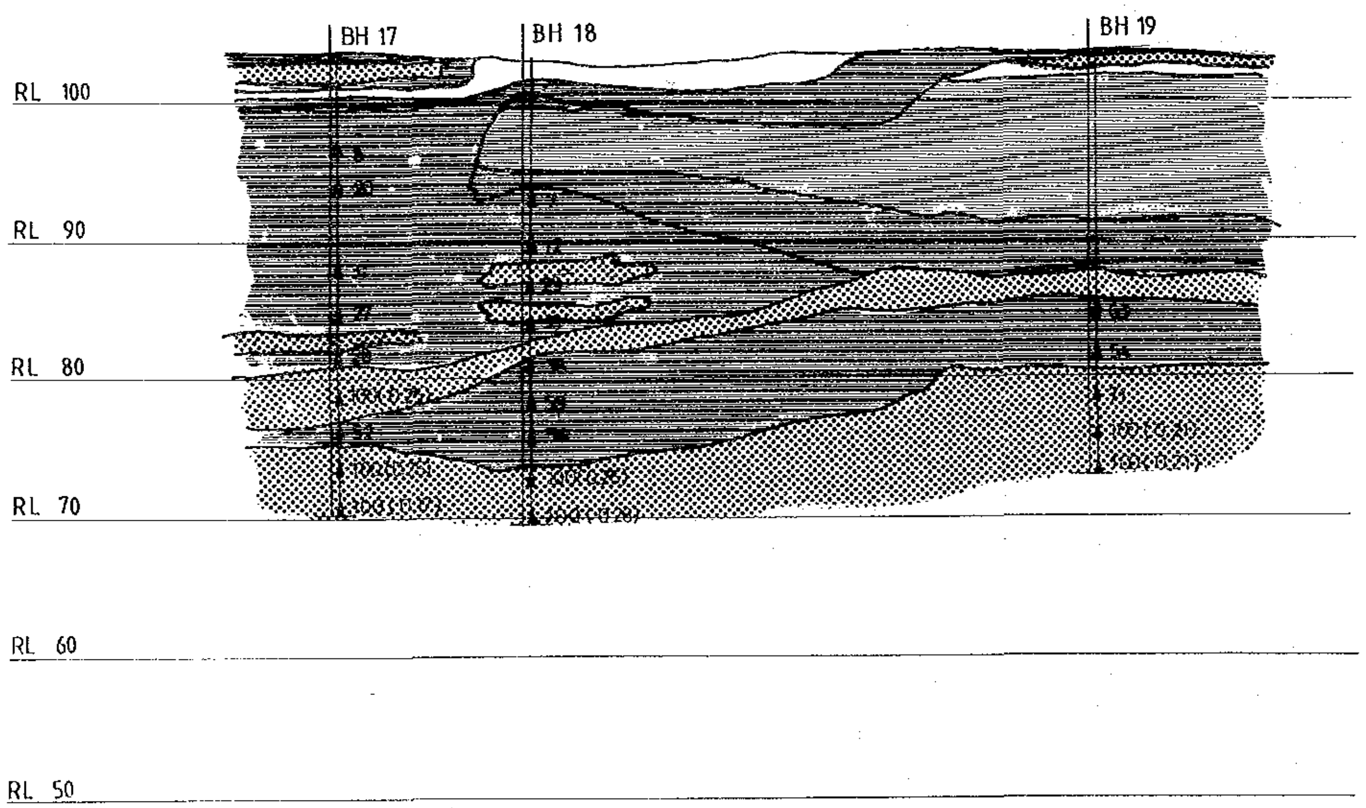
SECTION D.

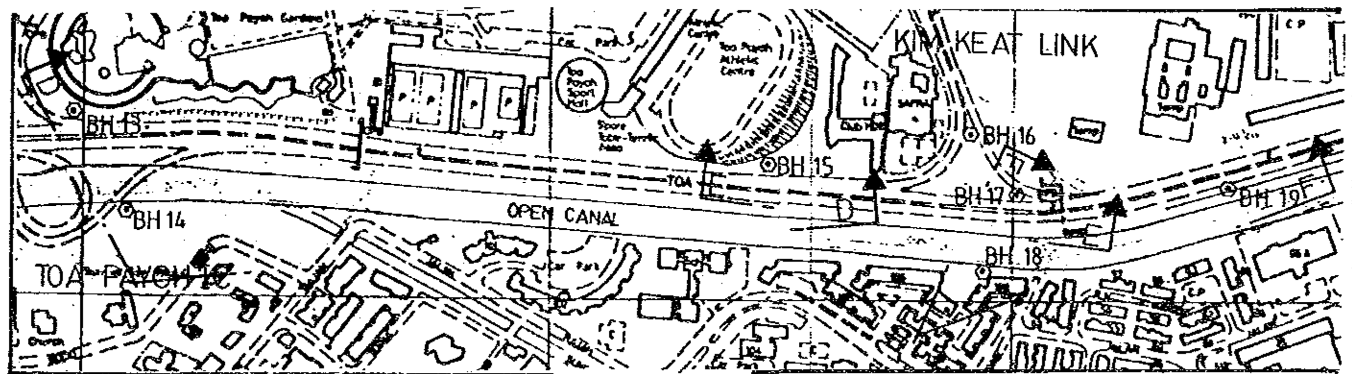


SECTION E



SECTION F.





KEY PLAN

LEGEND:

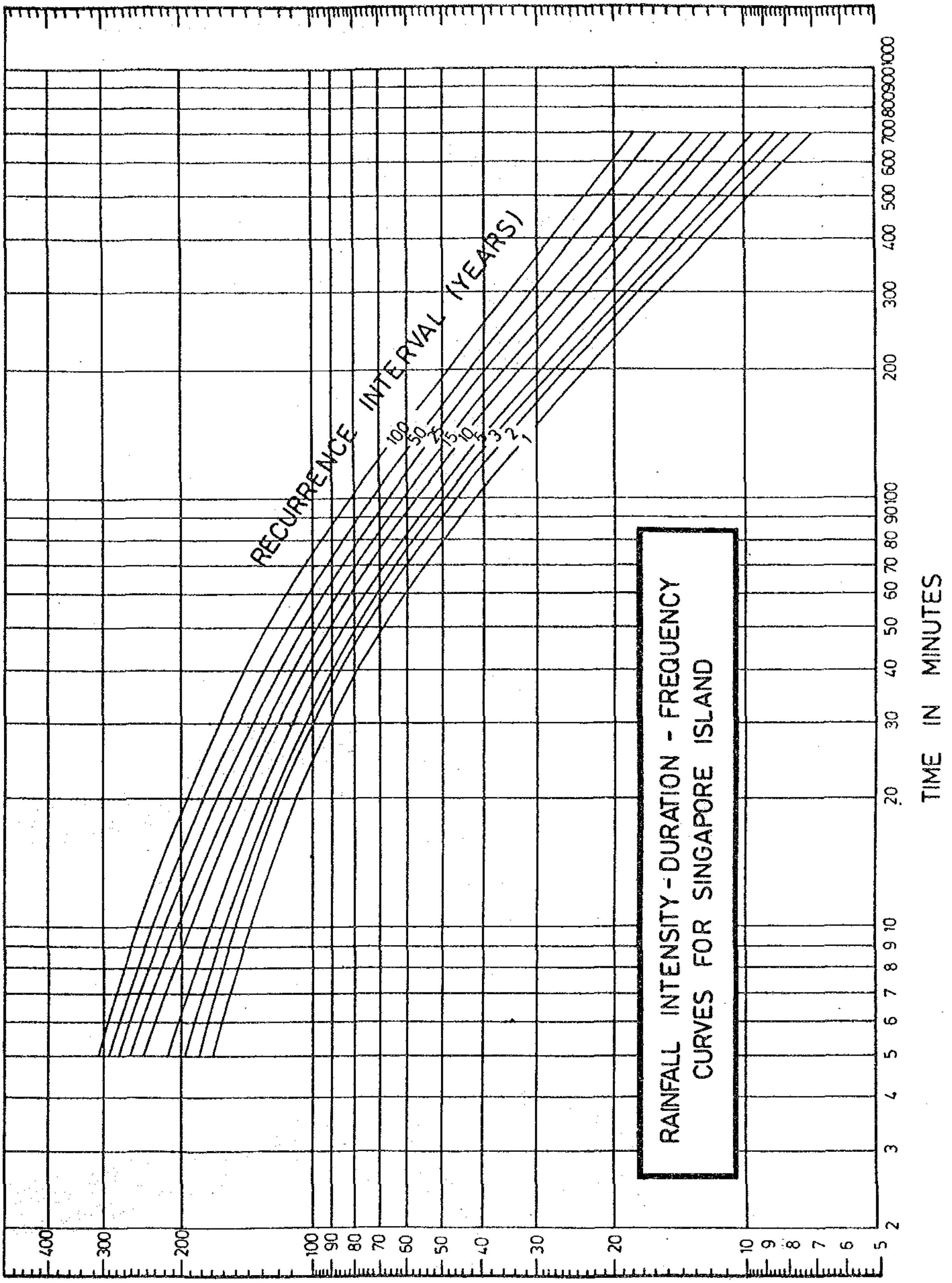
	Silty clay		Marine clay
	Sand, Sandstone		Peaty clay
	Silt, Siltstone		Decomposed granite

NOTE: • Numbers beside borehole indicate N value for standard penetration resistance.
•100 (0.18) indicates 100 blows for 0.18 of penetration.

Appendix 9.2. MR9.4.2: Soil profile along PIE (2/2)

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

Appendix 9.3. MR9.5.1: Rainfall intensity relative to duration & frequency



Appendix 9.4 MR9.6.1: Construction procedure of Thomson IC

Main items of the construction procedure are shown in the figure below:

Start

↓

Road Works for at-grade ①

↓

Switching of east bound on ramp ②

↓

Demolition of on ramp on flyover ②

↓

Construction of flyover on PIE, service road and on ramp ③

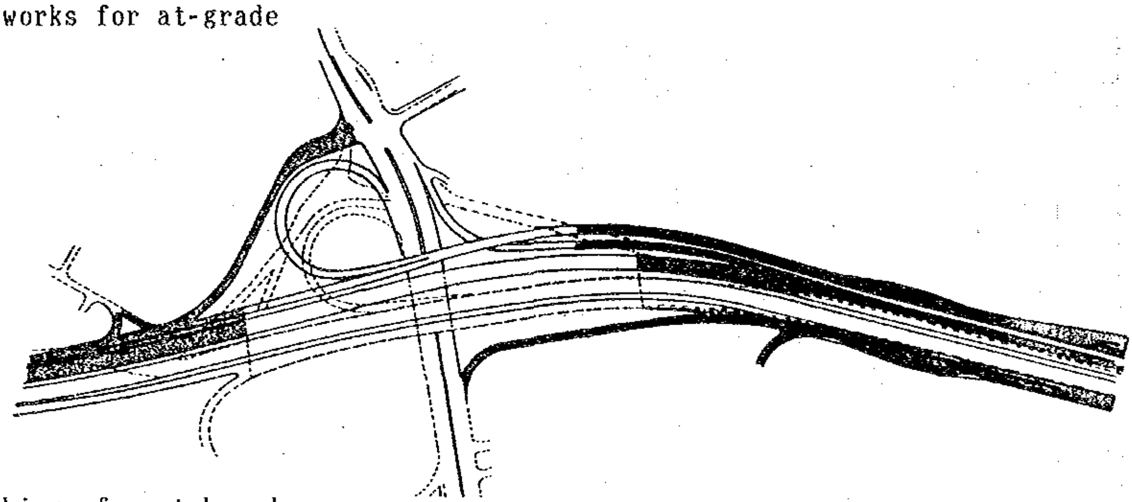
↓

Transfer of median strip
Setting of divider ④
Pavement works

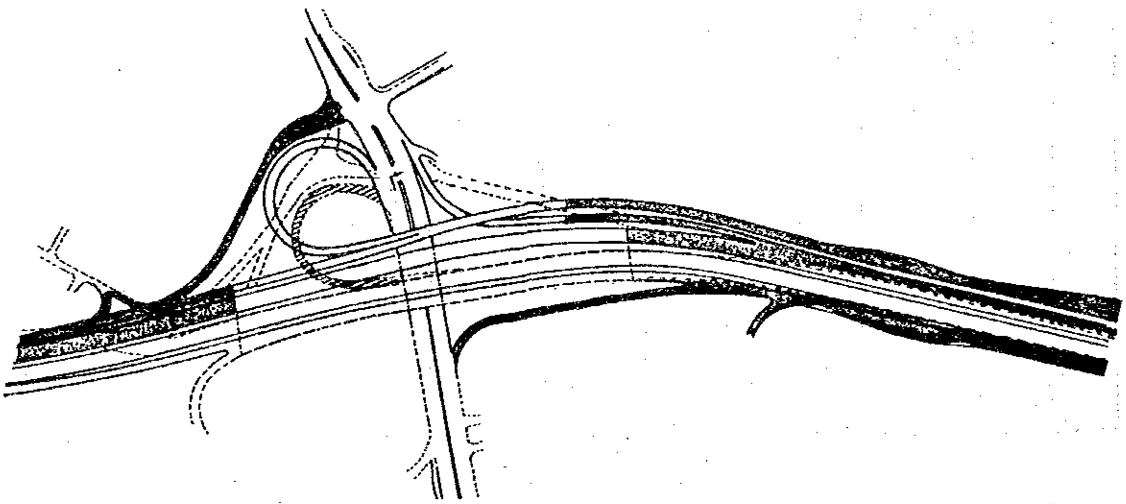
↓

End

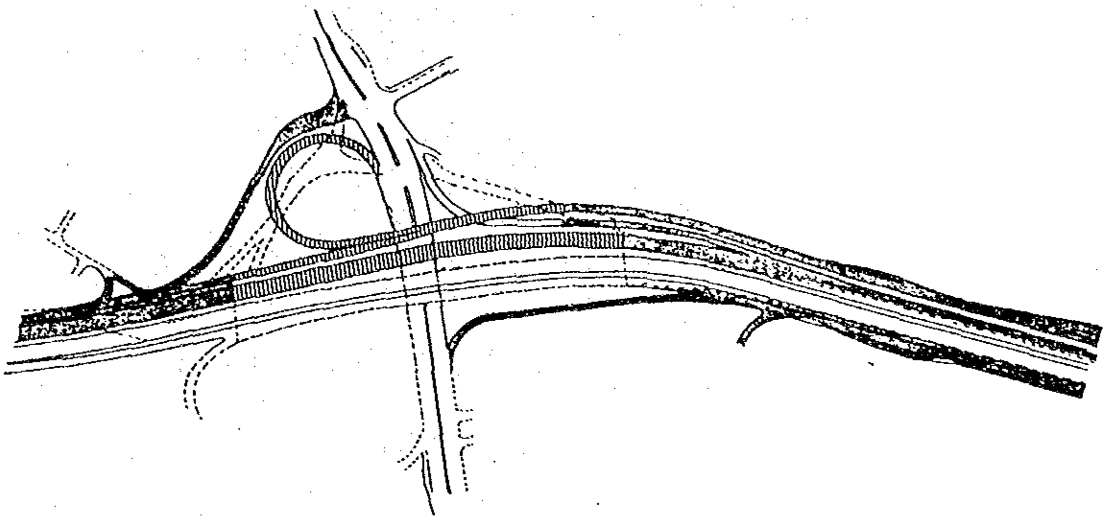
① Road works for at-grade



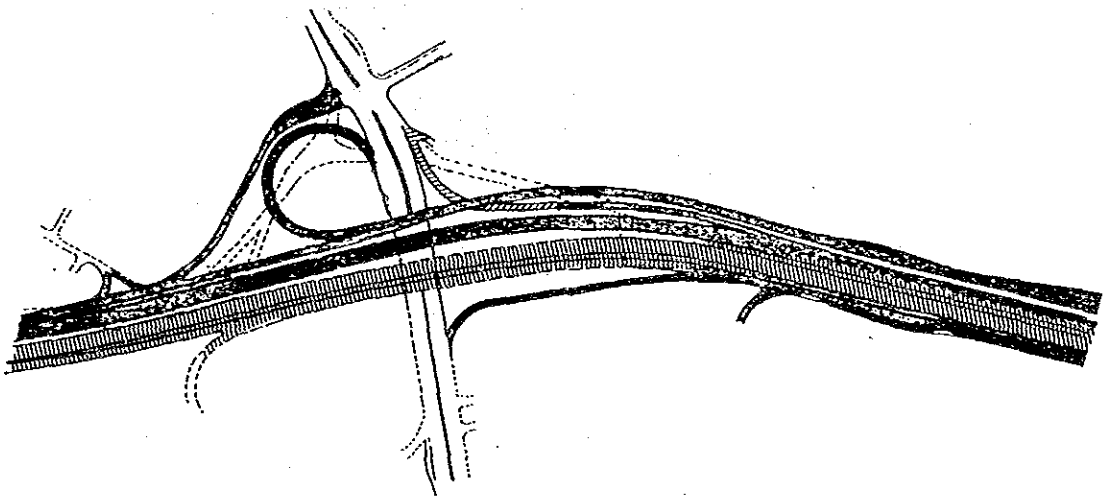
② Switching of east bound on ramp
Demolition of on ramp on flyover



③ Construction of flyover on PIE, service road and on ramp



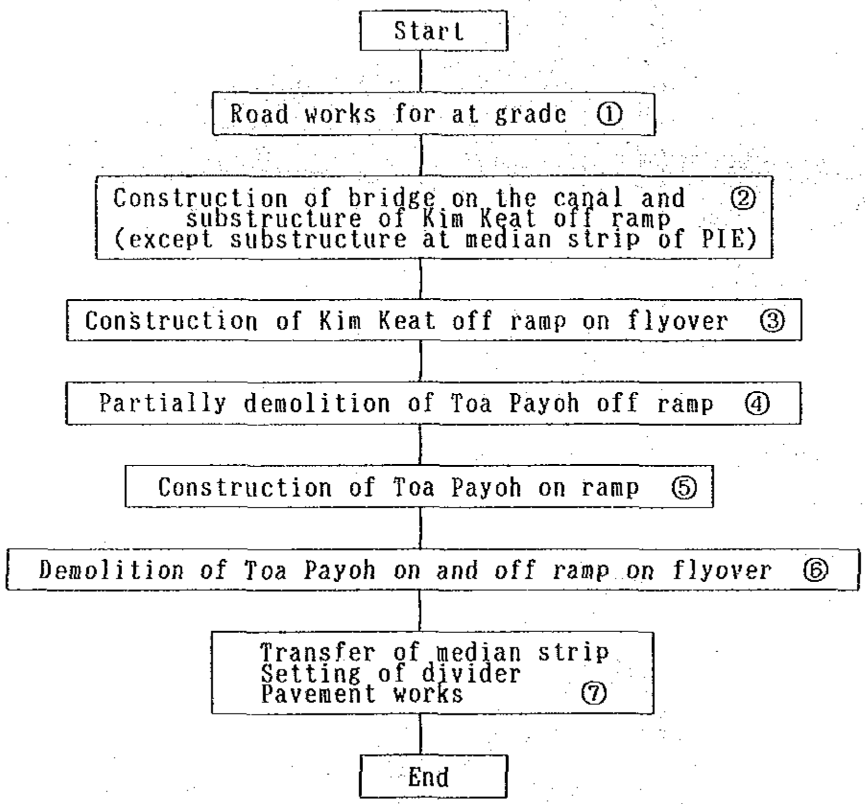
④ Transfer of median
Setting of divider
Pavement works



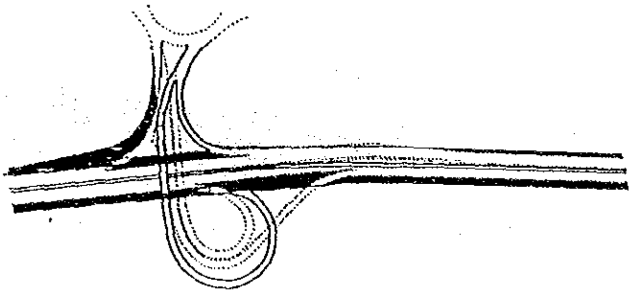
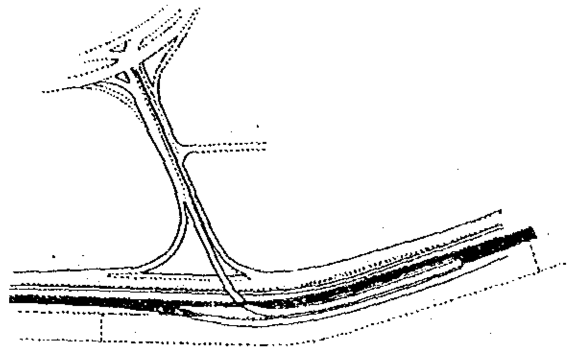
Appendix 9.5 MR9.6.1: Construction procedure of Kim Keat IC

Construction Procedure of Toa Payoh IC and Kim Keat IC

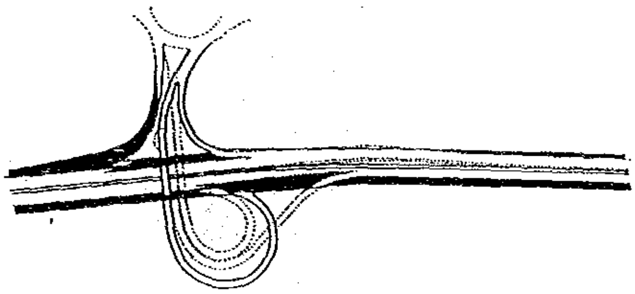
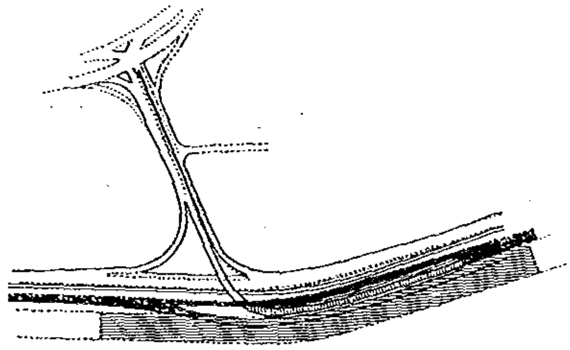
Main items of the construction procedure are shown in the figure below:



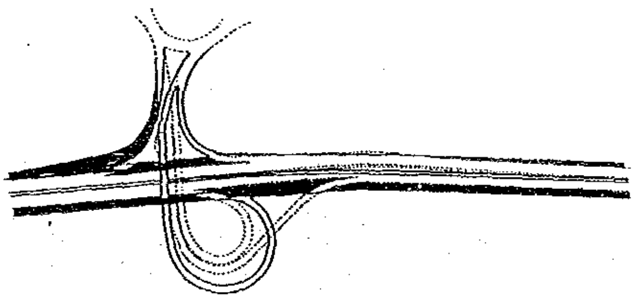
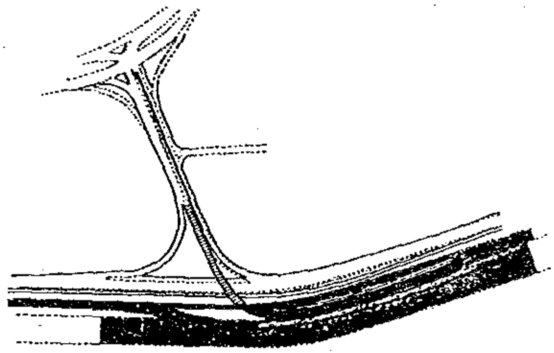
① Road works for at-grade

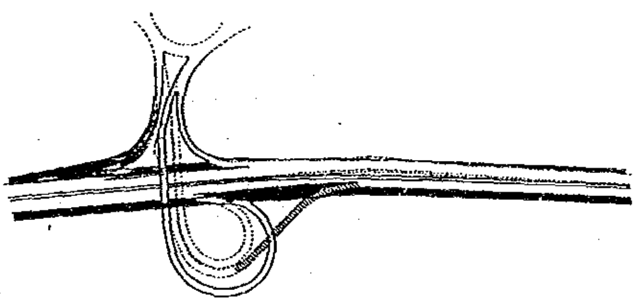
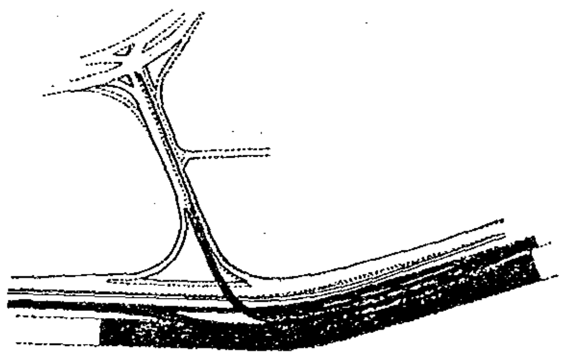
② Construction of bridge on the canal and subsructure of Kim Keat off ramp (except substructure at median strip of PIE)

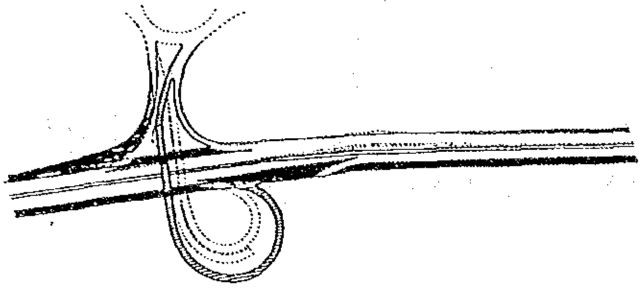
③ Construction of Kim Keat off ramp on flyover

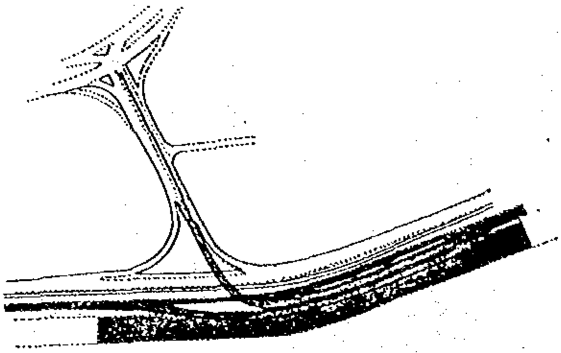



④ Partially demolition of Toa Payoh off ramp

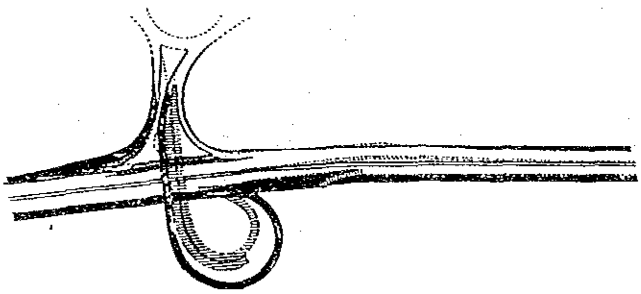



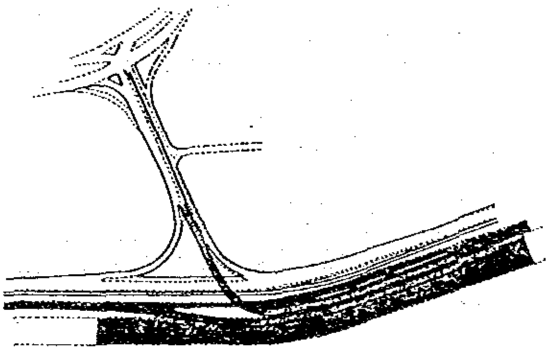
⑤ Construction of Toa Payoh on ramp



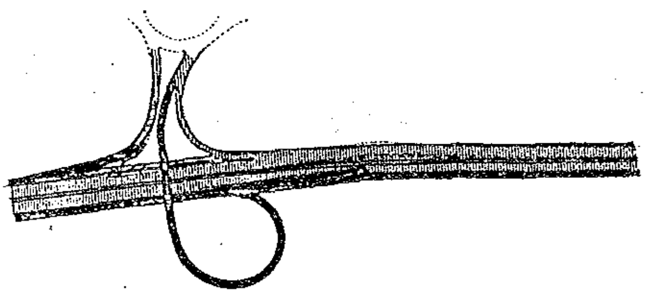


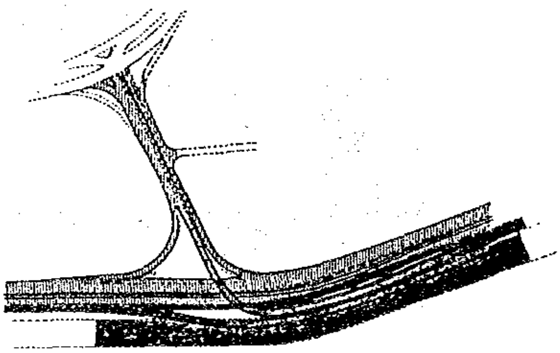
⑥ Demolition of Toa Payoh on and off ramp on flyover





⑦ Transfer of median strip
Setting of divider
Pavement works





Appendix 9.6 MR9.6.2: *Economic & aesthetic study of standard viaduct*

1) Economic Characteristics

Construction costs are calculated based on 5 cases with span lengths ranging from 20m to 40m at an interval of 5m. The result are shown in Table A9.6.1 and Fig.A9.6.1 . It is assumed that the superstructure is a PC post-tension composite beam, the substructure is column type and the foundation is PC precast square piling.

The following conclusions can be drawn from Table A9.6.1 and Fig.A9.6.1.

- Total construction costs increase with an increase in the span length. The rate of increase is especially obvious when the span length exceeds 30m.

-Construction costs for the superstructure increase linearly with the length of the span.

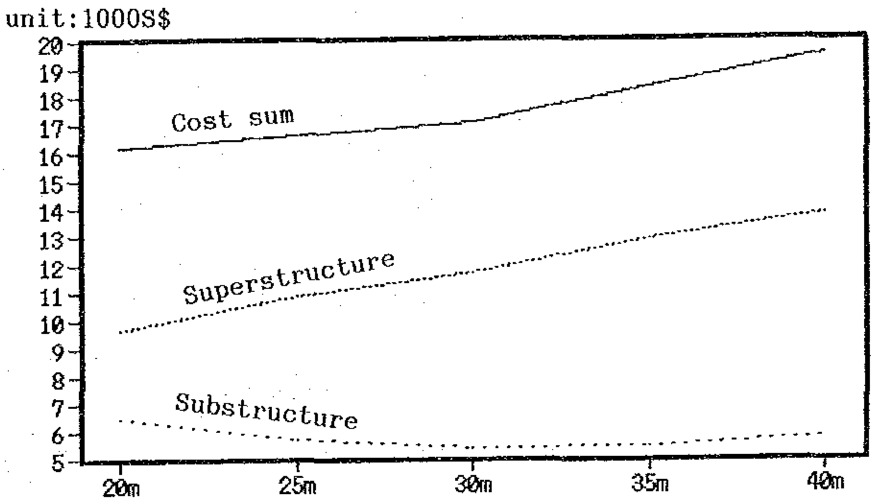
-Construction costs for the substructure and the foundation are lowest when span length is 30m.

Table A9.6.1 Relationship between Span length and Construction cost

UNIT:S$/m

Span length(m)	20	25	30	35	40
Superstructure	9,700	10,900	11,700	12,900	13,800
Substr.+Found.	6,500	5,700	5,400	5,400	5,800
Total cost	16,200	16,600	17,100	18,300	19,600

Fig.A9.6.1 Relationship between Span length and Construction Cost



Judging from the above economic characteristics, the most suitable span length is 30m and below.

2) Aesthetic Characteristics

Aesthetics is very important factor when building structures. As it is very difficult to rebuild, it is essentially necessary to discuss adequately the fundamental dimensions such as span length, structure type etc. Here, we shall focus our discussions on the most important factors affecting aesthetics.

The relationship between span length and girder depth.

Once the girder type and material have been decided upon, the girder depth in relation to span length is determined by normal practice. The relationship between span length (L) and the depth of the superstructure (girder depth + height of railing 1m) (h) is the major factor affecting the aesthetics. That is, if the h/L ratio is high, it gives people an impression that the viaduct is heavy and thick. If the h/L ratio is low, a slender impression is given. In the case of this viaduct, the relationship between h and L is as follows.

Table A9.6.2 The relationship between span length and depth of superstructure

L (m)	20	25	30	35	40
h (m)	2.4	2.7	3.0	3.3	3.6
h/L	0.120	0.108	0.100	0.094	0.090

L = Span length

h = Gider depth + Hight of railing(=1m)

From the above table, it can be seen that it gives slender impression with an increase in span length. As in the case of aesthetics of viaduct, the effect of h is greater than that of this (h/L) ratio.(Fig.A9.6.2)

The relationship between span length and space below the beam

The relationship between span and the height of the space below the beam forms a rectangular space at one end. It is intended that the ratio 1:1.618 of golden section is adapted this rectangular of KLE and PIE viaduct. However, as construction site are relatively flat, the pier appears to be high. Based on the relationship between the span and the height below the beam as shown in Fig.A9.6.3 and Table A9.6.3, the following are comments regarding aesthetics:

-If the proposed height (Hs) is 7.5m or below as measured form the ground, the viaduct appears to bend downward regardless of span length.

-The viaduct looks balanced if Hs =10m. However, it still appears to bend downward a little once the span length exceeds 35m.

-When Hs = 12.5m, the number of columns appears more pronounced when span is short. In this case, it is desirable that span length is greater than 30m.

-When Hs is greater or equal to 15m, the viaduct looks out-of-balance if span length is equal to less than 35m.

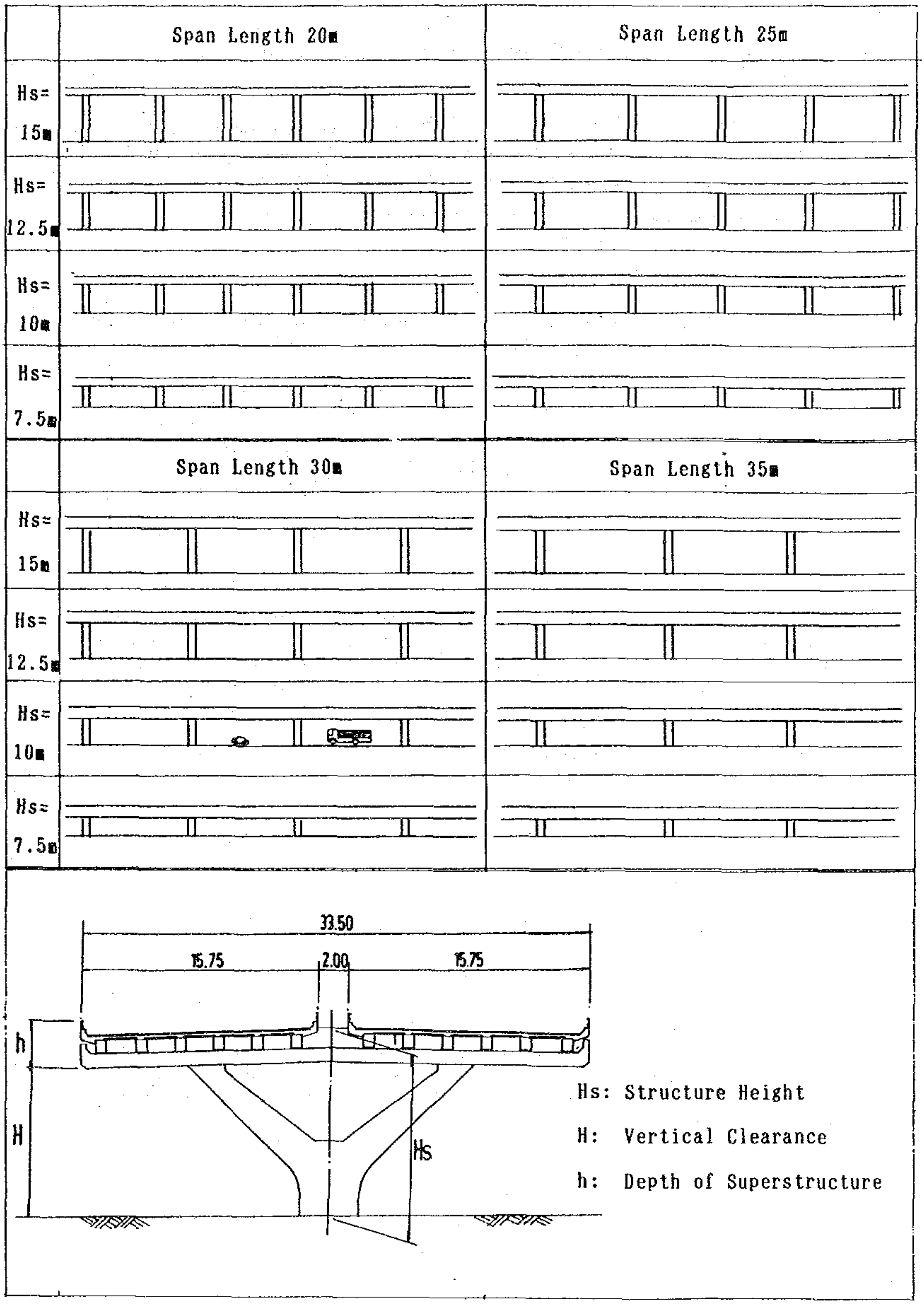


Fig.A.9.6.2 Comparison of viaduct spanning profile

The suitable relationship between the span length and height below the girder is summarised in Table A9.6.3 .

Fig.A9.6.3 Structure rise and recommendable span length

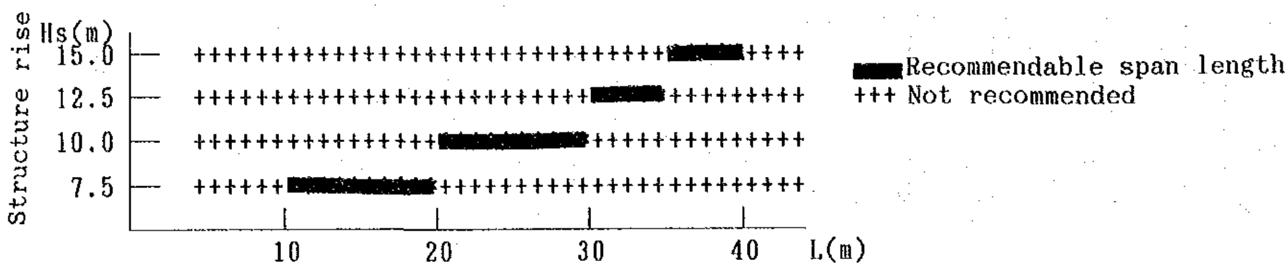


Table A9.6.3 The relationship between height below the girder and depth of the superstructure

Structure rise Hs(m)	Recommendable span L(m)	Hight below girder H(m)
7.5	~ 20	~ 5.6
10.0	20 ~ 30	8.1 ~ 7.5
12.5	30 ~ 35	10.0 ~ 9.7
15.0	35 ~	12.2 ~

It is said that oppressive appearance is strengthened with high ratio of the depth of superstructure to height below the girder, In this case, such ratio is found by changing the span length from 20m to 35m at 5m interval. By comparing ratios, such as those given from Fig.A9.6.4 to Fig.A9.6.7, the suitable ratio for aesthetics can be extracted.

Table A9.6.4 The ratio of the height below girder to the depth of the superstructure

Span length(m)		20	25	30	35
Hs (m)	7.5	0.43	0.51	0.60	0.70
	10.0	0.30	0.35	0.40	0.46
	12.5	0.23	0.26	0.30	0.34
	15.0	0.18	0.21	0.24	0.27

Hs : Structure rise

Judging from Table A9.6.4, The oppressive appearance is strengthened when the ratio of h/H is greater than 0.4 or below, therfore the ratio of the height below the girder (h) to the depth of superstructure is recommended 0.4 or below.

Span Length 25m

Span Length 30m

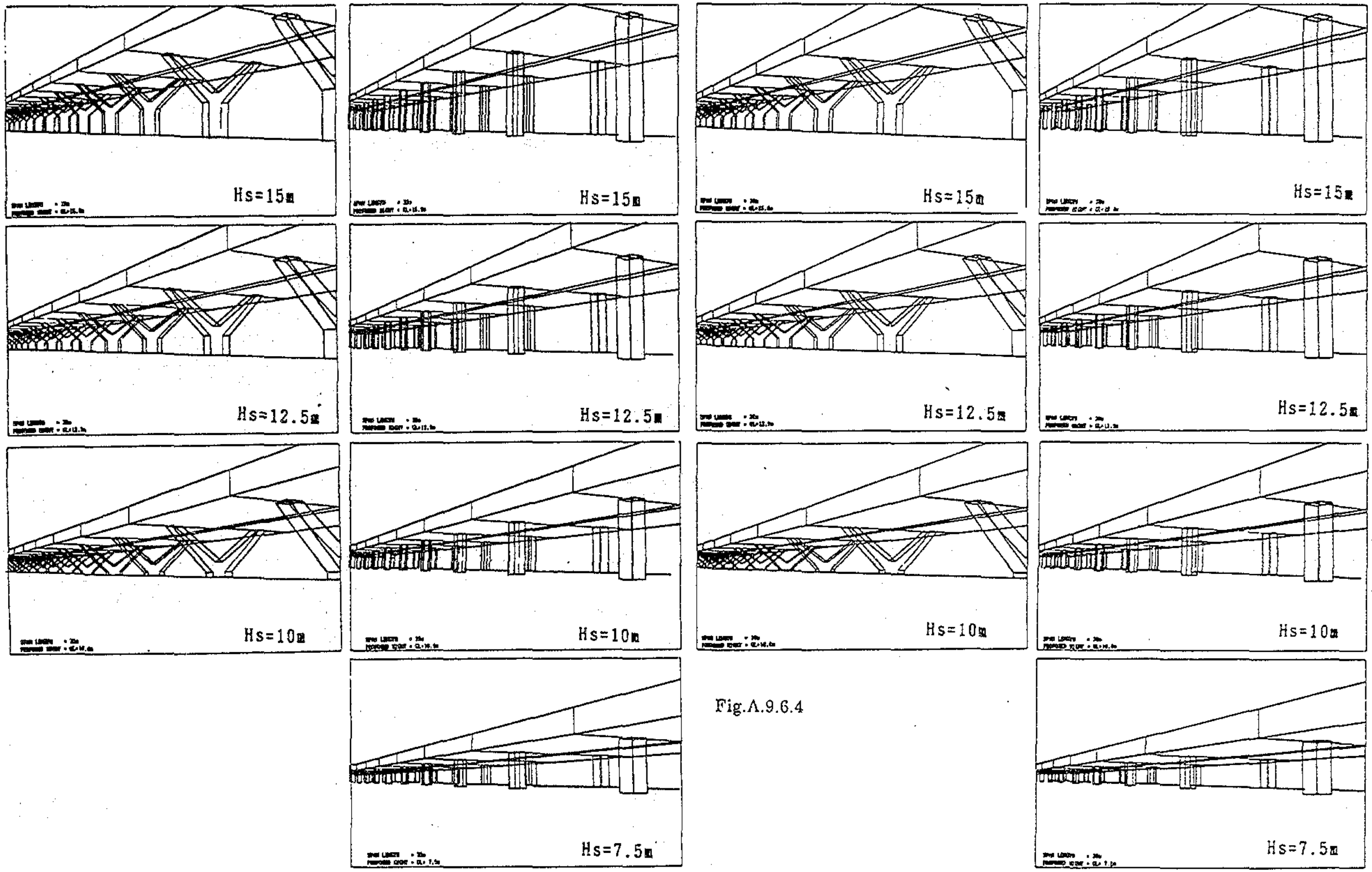


Fig.A.9.6.4

Span Length 35m

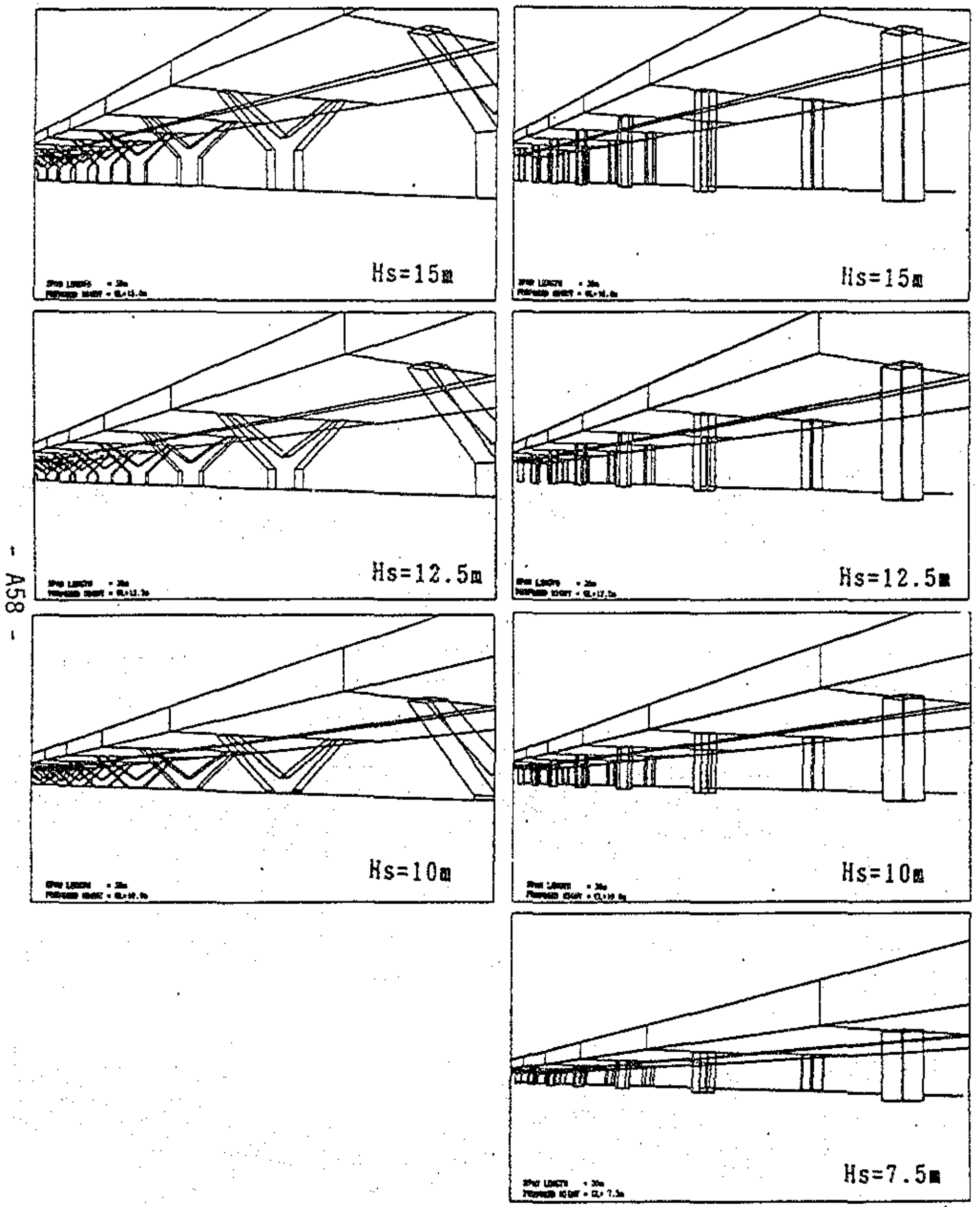


Fig.A.9.6.5

Span Length 25m

Span Length 30m

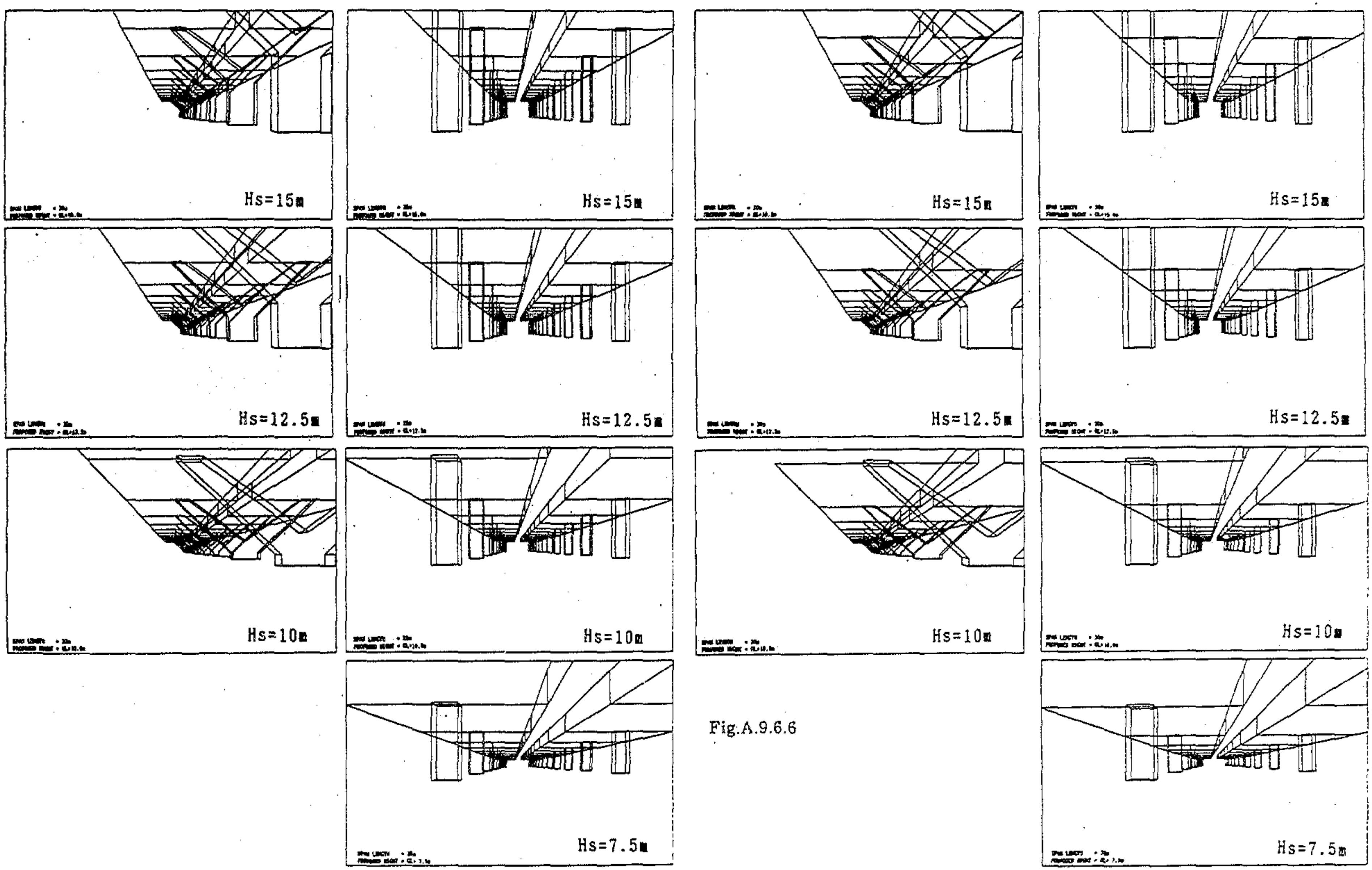


Fig.A.9.6.6

Span Length 35m

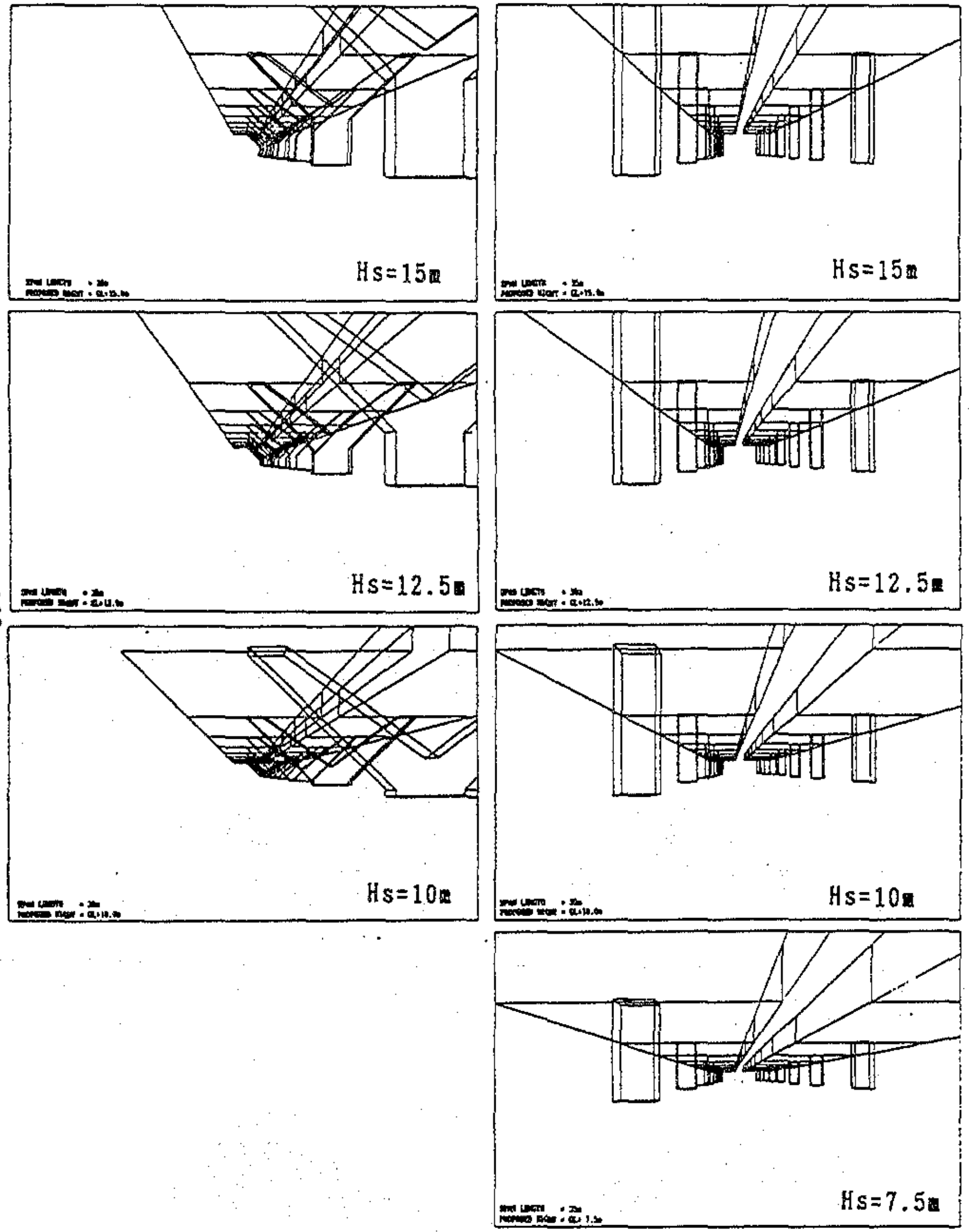


Fig.A.9.6.7

Appendix 9.7 MR9.6.2: Construction planning of underground work below highways under service

In the study project, tunnel construction is supposed to encounter many crossing works below the highways under traffic service. During construction, an affect to the current traffic should be reduced to as minimum as possible. Construction method is required to be selected as to reserve the current traffic. For the purpose of assuring the technical feasibility of the project, an outline of construction planning has been briefed in this paper.

Three methods as following are applicable for tunneling work to retain the current traffic of the overlying highway.

Method 1: Prpparing a detouring road, excavation by open cut, and building structures retained by sheeting.

Method 2: Catering traffic service by covering plate under which excavation and building are carried out, uncovering work is done in the night by controlling or stopping of traffic.

Method 3: Keeping the current traffic of the overlying road, a special method such as horizontal boring and building structure covered by roofing.

Three methods as above are characterized as indicated in Table A9.7.1. Individual methods have limitations on application. Selection of suitable method is dependent on the site condition.

Table A9.7.1 Characteristics of underground crossing work below road

	Advantage	Disadvantage	Limitations
1	Free use of overhead space for construct-tion. Working speed is fast.	Additional land for detour is required. Suspect of shut out collector road. Detour alignment does not always ensure comfortable traveling	Depend on the site condition Substituting by collector cause congest-ion in city.
2	No additional site is required. Applicable to soft ground area.	Construction space is limit-ted from overhead to cause uneasy work and decelerate. Night traffic is reduced in need of lane alteration.	Nothing parti-cular but tem-porary nuisan-ce by traffic stop during uncovered work
3	No excavation on road needless of restora-tion work to press construction schedule	Need special construction equipment resulted in high cost. Not applicable for cross section in larger scale.	Underground buried facili-ty often obst-ruct its appl-ication.

As a standard scheme, Method 1 should apply for the case where detouring can be attained, Method 2 for the case where detouring is not available, and Method 3 for the case where even night control on traffic is not allowed. The point of site assigned to the 3rd case has been clarified by the Counterpart of PWD as no place correspond to.

The most problematic point of site for crossing work in the KLE is where the underground work of trough structure is to be carried for depressed expressway stretch crossing near under the intersection of Nicoll Highway and Mountbatten Road. Around the area comparatively wide free land is available for construction to facilitate a detouring road. The same interchange need reforming work in concern with incorporated with rampways for KLE interchange. The reforming work is required to execute simultaneously with the underground work, drawing attention on the selection of detouring road.

In the underground work at Nicoll Highway and Mountbatten Road, Method 1 is recommended for the reason of speedy construction in order to press the working period while the work confuses the traffic condition at the intersection area.

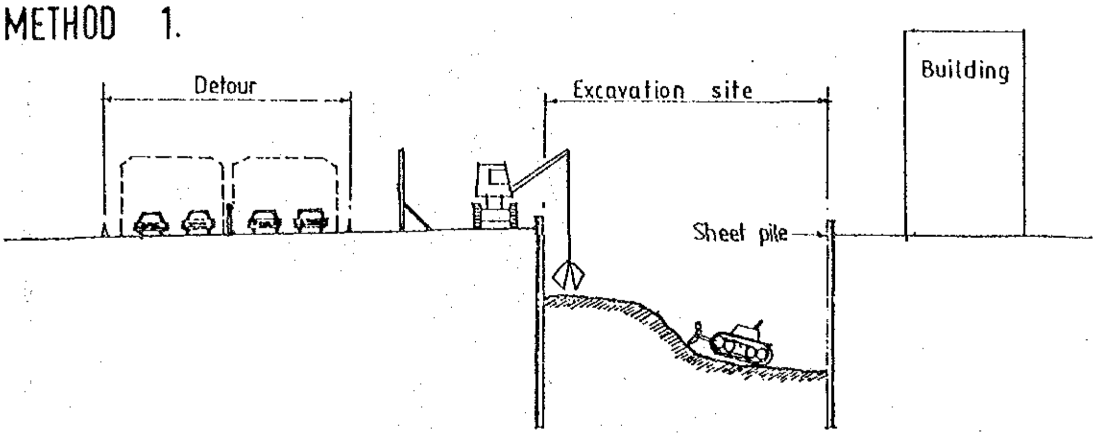
At the underground work crossing to Geylang Road where detouring is impossible, Method 2 is applied as shown in Figure A9.7.1. At the crossing work on the Sims Avenue, detouring is attained on the road side nearer to the MRT.

Table A9.7.2 breaks down the procedure flow of Method 2. According to this method lane alteration is necessary for catering night traffic during uncovered work in such ways as indicated in from Figure A9.7.2 to A9.7.4.

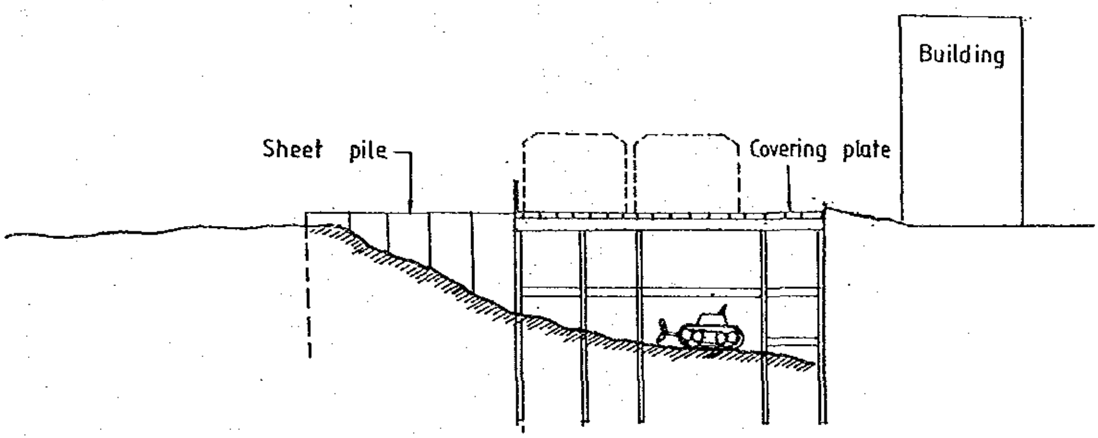
Table A9.7.2 Procedure of covered open cut method

	Working procedure	Daywork	Nightwork
1	Sheet piling		*
2	Demolition of pavement		*
3	Shallow excavation		*
4	Excavation under covering plate	*	
5	Waling and strutting	*	
6	Leveling and base preparation	*	
7	Building tunnel	*	
8	Backfilling	*	*
9	Dismantling wale and strut	*	*
10	Pavement and road surfacing		*

METHOD 1.



METHOD 2.



METHOD 3.

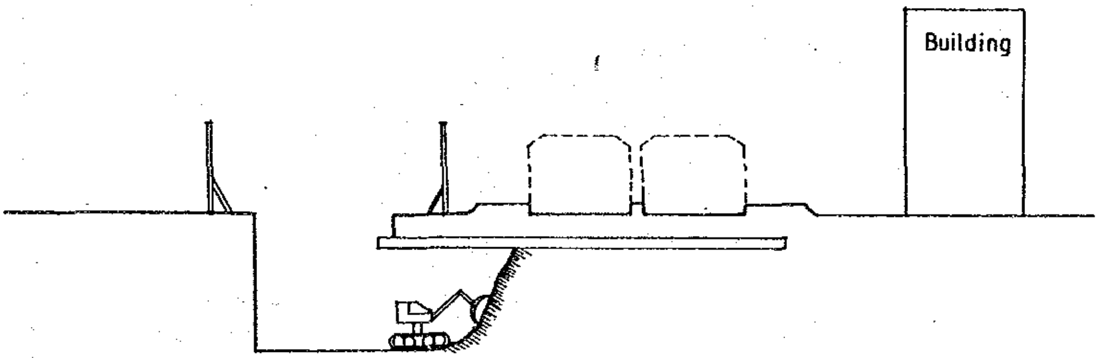


Fig.A.9.7.1 Tunneling methods below highway under service

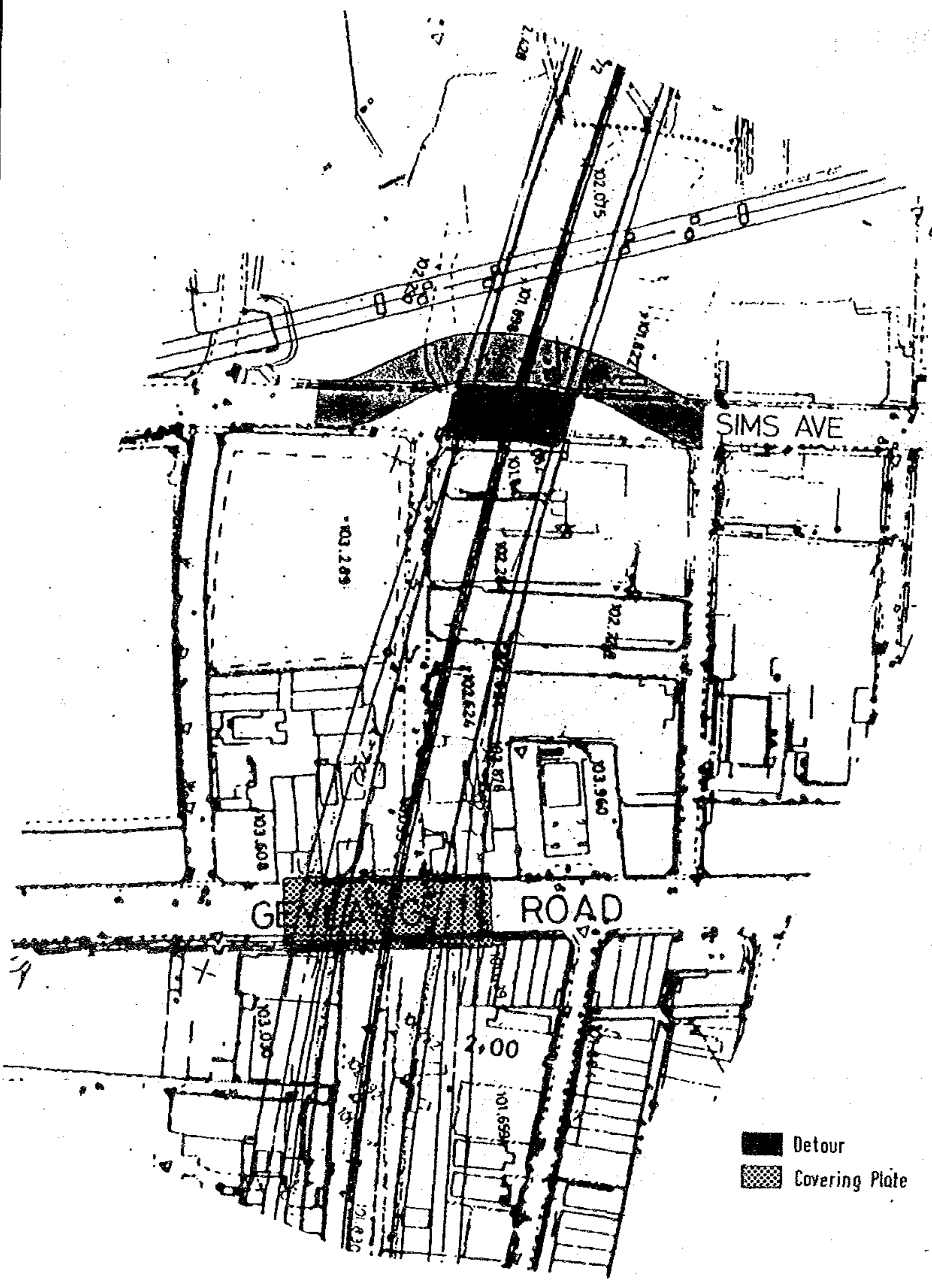


Fig.A.9.7.2
CROSSING POINTS AT GEYLANG ROAD & SIMS AVENUE

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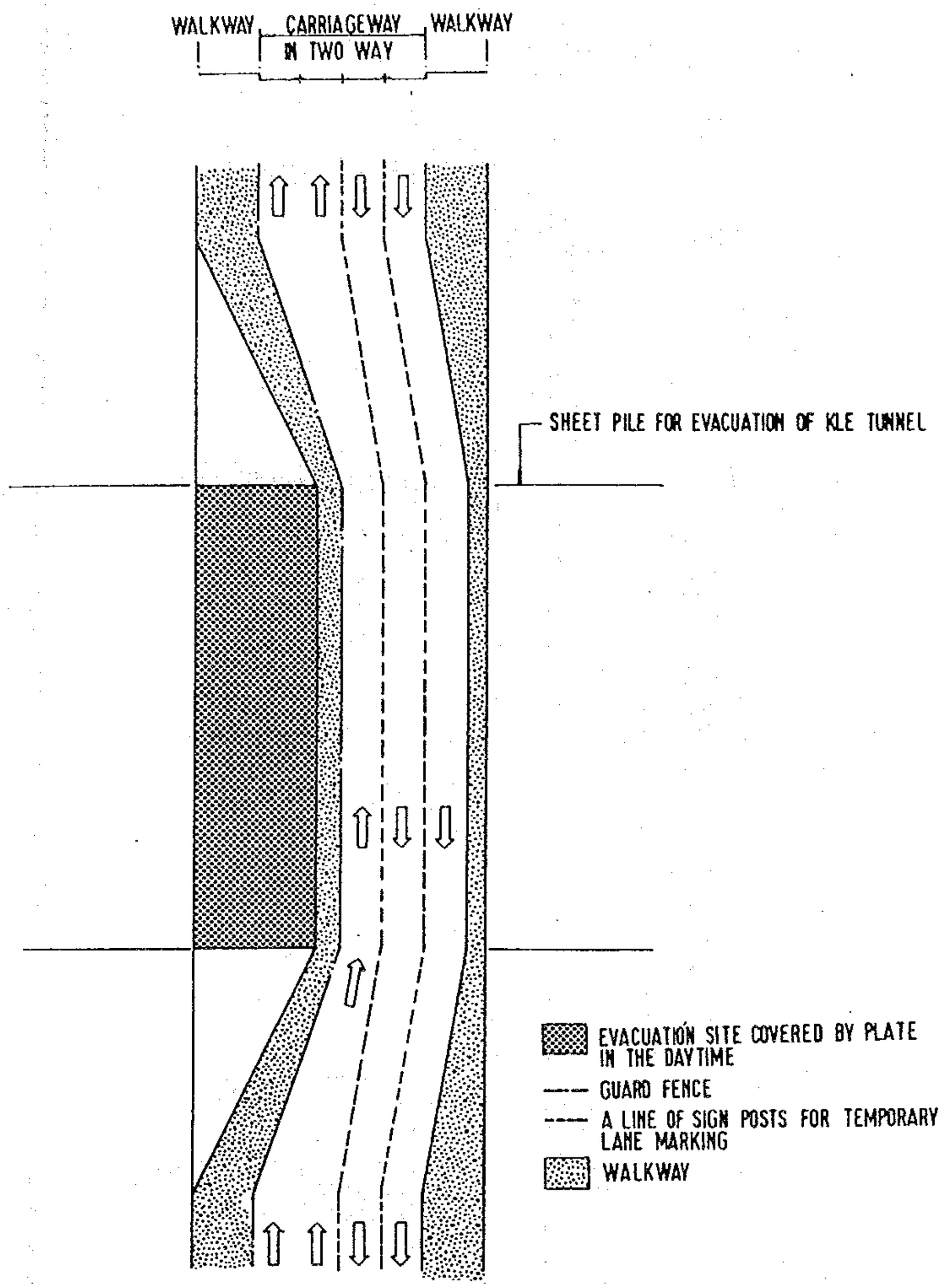

Fig.A.9.7.3 LANE ALTERATION DURING UNCOVERED WORK ON ROAD SIDE IN THE NIGHT

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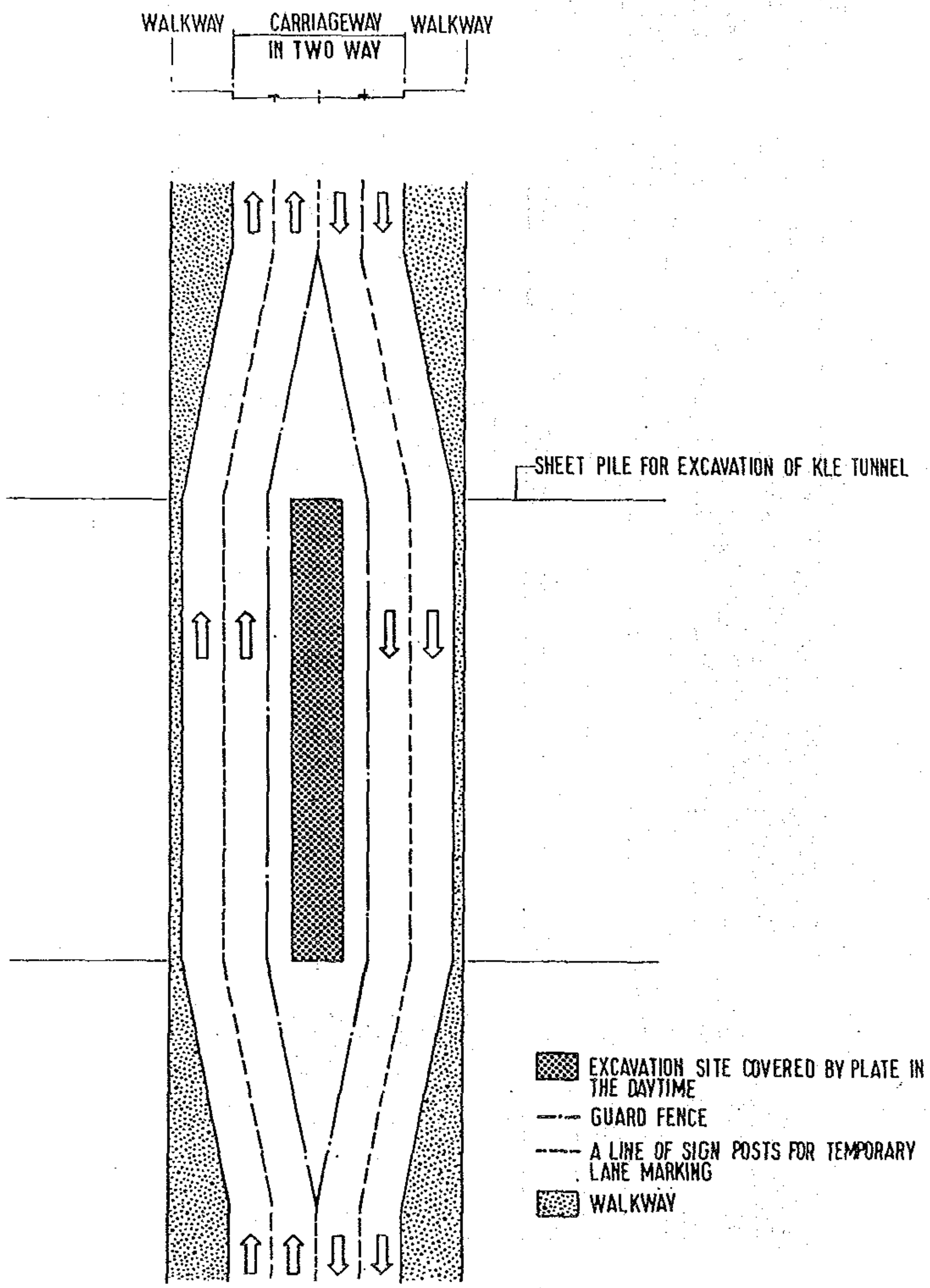

Fig.A.9.7.4 LANE ALTERATION DURING UNCOVERED WORK AT ROAD CENTRE IN THE NIGHT

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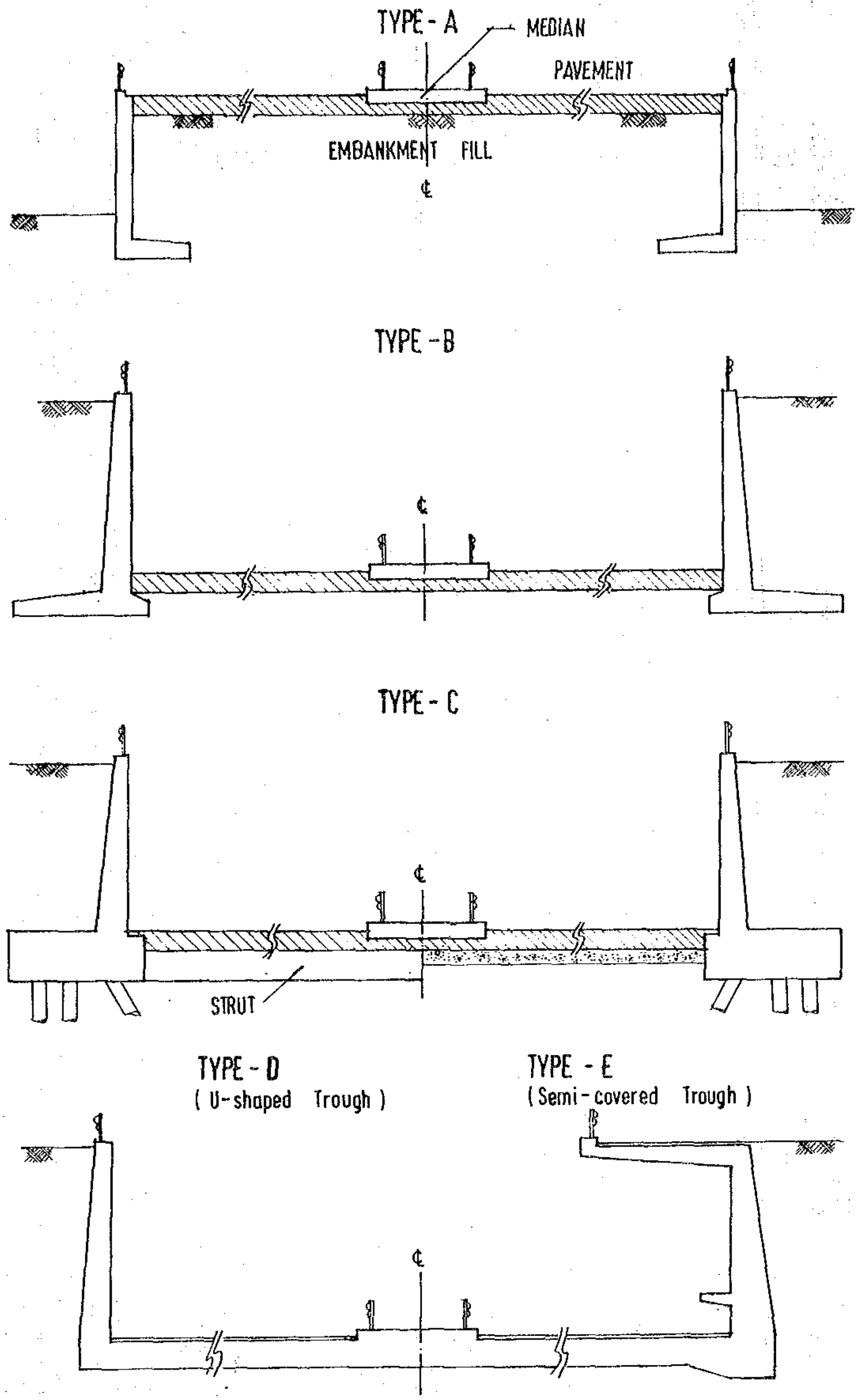
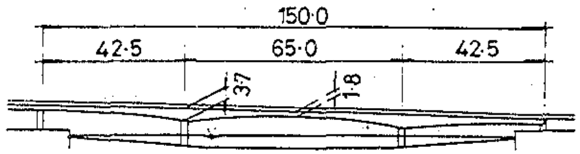
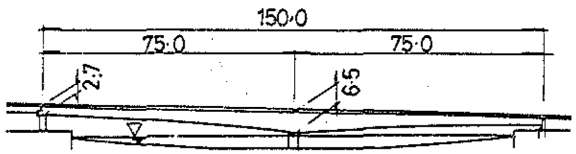
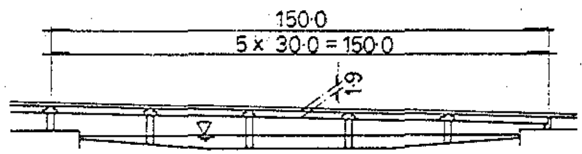


Appendix 9.8. MR9.6.2: Option of retaining wall

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

Appendix 9.9. MR9.6.3: Comparative study of structure for Geylang River Bridge

	3 continuous PC box girder bridge	2 continuous PC box girder bridge	Precast PC composite I beam bridge
Elevation			
Structual aspect	-All stresses in the girder are well balanced because of various girder depth. The maximum gider depth will be about 3.7m and it is not so thick. -As it forms an angle of 55 degrees with the river, reaction force is one-sided.This is solved by distributing the reaction by rubber shoes. So it had better not to apply rigid-frame type.	-The structure is balanced on stress distribution. As the bending momentum on the support is large, the girder depth becomes high about 6.5m -As it forms an angle of 55 degrees with the river , continuous type with rubber shoes is adopted to avoid a rigid-frame bridge. Thicker rubber shoes are needed to bear large reaction force.	-This alternative is applied precast beam.Girder depth is high due to simple beam. -As it is located near the sea, it is advisable to cover the bottom of the girder with slab to prevent salt damage.
Construction aspect	-Cantilever erection by form traveller or segmental construction will be adopted since the space below the girder is narrow and soil condition is weak. -Cantilever erection has many past records and is also suitable for various girder depth and curved bridge. -The control of girder deflection and concrete quality are easy for short segment ○	-As there is limited space below intermediate support and the soil condition is weak, segmental construction method will be applied. However yard for building segment is necessary close to the site. -Segmental construction method has many past records and is also suitable for girder depth bridge. -The control of girder deflection and concrete quality are easy for short segment. △	-The erection girder method will be applied. This method is normally applied when crossing a river or when there is a space limitation below the beams. Attention must be paid to this method especially when the gradient is steep. ○
Construction cost	S$ 8,415,000 (S$ 56,100/m) (1.06) ○	S$ 10,065,000 (S$ 67,100/m) (1.27) △	S$ 7,920,000 (S$ 52,800/m) (1.00) ◎
Aesthtic aspect	-For fitting in with the surrounding environment, this type has strong and slender appearance and is therefore the best of all the alternatives. -The ratio of the middle span to the side span is good. As the span number is an odd number, it appears on aesthetics to have continuity. -As girder depth of this type and standard viaduct are almost same, it appears to have continuity on the joint but it is difference of composition of girder between this type and standard viaduct. -The relationship between the span and the depth of superstructure is good for slenderness. ◎	-Thick girder depth gives heavy appearance. It does not fit in well with the surrounding environment. -As the number of spans is and even number, the bridge appears to be separated. -As girder depth of this type and standard viaduct are almost same, it appears to have continuity on the joint but it is difference of composition of girder between this type and standard viaduct. -The relationship between the span length and depth of superstructure is unbalanced on the viewpoint of slenderness. △	-It is difficult to create an impression that fits in with the surrounding environment due to straight girder. -As girder type and depth are same as standard viaduct, it's better on the viewpoint of continuity. -As the span member is an odd number, it appears to have continuity. -The relationships between span and height below the beam, height below the beam and depth of superstructure is good. However, shape of girder is complicated. ○
R.O.C.W.F	3.8% ○	4.0% ○	7.6% △
Evaluation	◎		

◎: Comparatively good ○: No problem △: Some problems

R.O.C.W.F=Reduction Of Cross-sectional Water Flow

Appendix 9.10 MR9.6.3: Structural consideration for trough crossing under MRT viaduct

At the crossing of KLE under MRT viaduct, the columns of MRT pier are to obstruct the course of trough wall by facing close to the carriageway of KLE. Although previous meeting has settled down to the countermeasure such as squeezing the width of carriageway by eliminating inspection clearance or outer shoulder as shown in Figure A9.10.1, it is noticed that MRT columns will be unilaterally loaded after shutting out the earth pressure on the other side by trough wall. The study team consider that a bit detail of structural design is necessary for the point.

Three methods are displayed as followings;

1. Unified structure of trough wall and MRT columns has such merits as counter support against outer push by earth pressure and simple construction, but has such a demerit as accompanying displacement with settlement or tilting in an occational case.

2. Embracing wall for trough of which bottom slab has circular holes for MRT columns coming inside with gap to allow individual displacement. It is a merit to allow the individual displacements between MRT structure and PWD structure. Demerit is a limitation of displacement stroke.

3. Embracing wall for trough of which bottom slab is fixed or side-touched to MRT columns coming inside without gap. Trough itself is to be fixed from displacement by piled foundation. Demerit is a cost increase by piled foundation.

The third method is recommendable for its reliability.(Fig.A9.10.4)

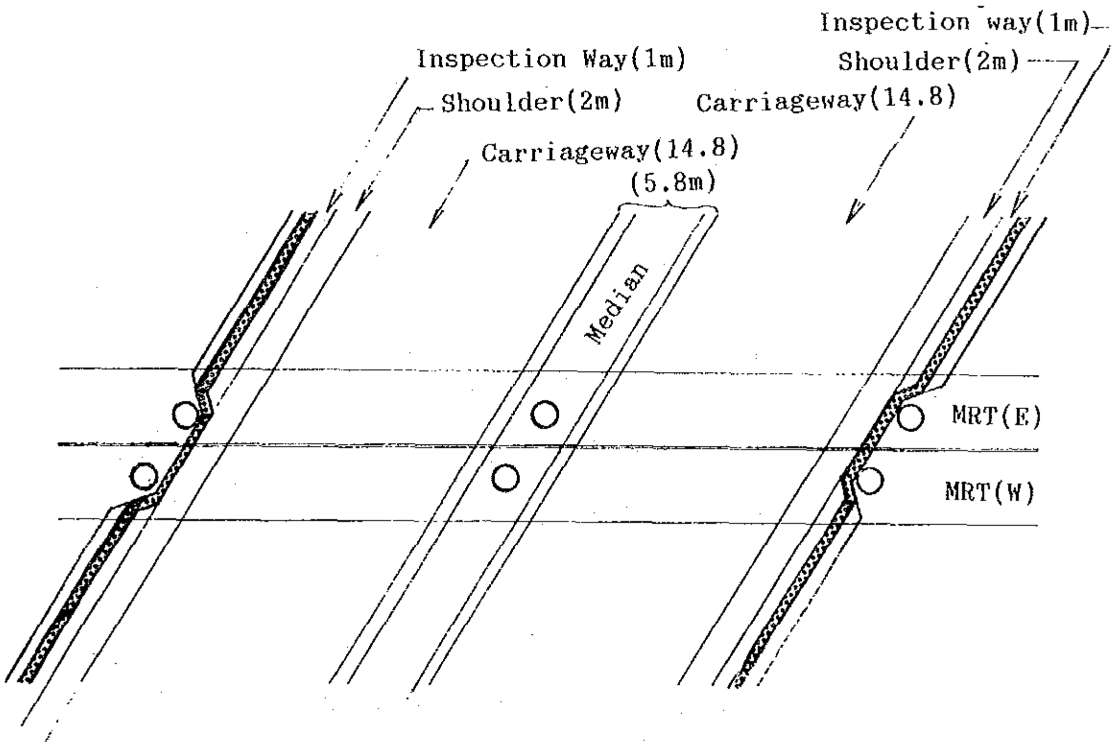


Fig. A9.10.1 Previous Plan for Trough below MRT

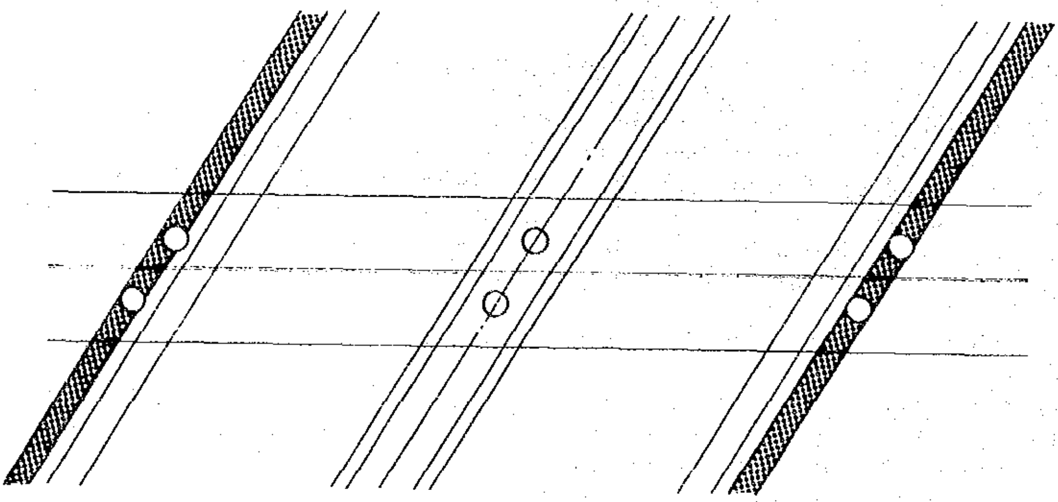


Fig. A9.10.2 Method 1 as an unified structure

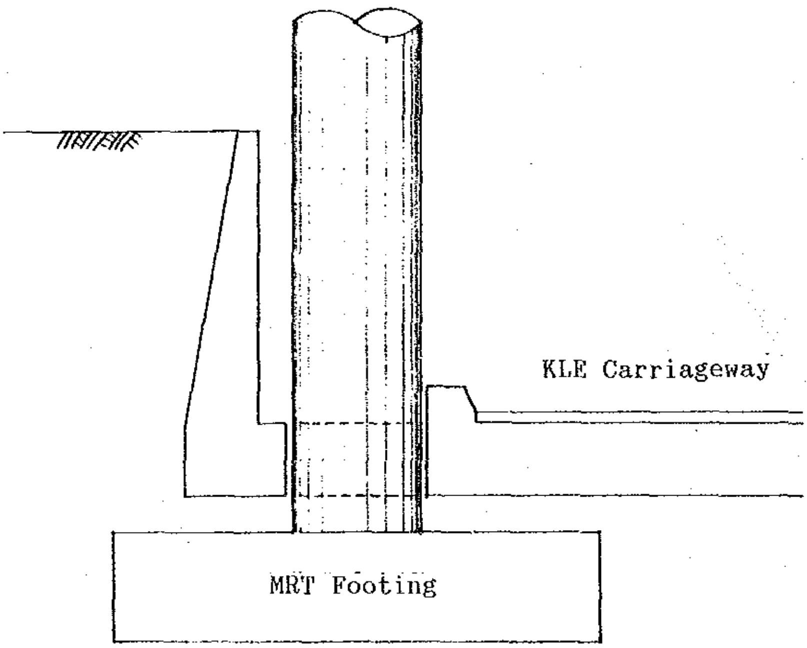


Fig. A9.10.3 Method 2 as a separated structure

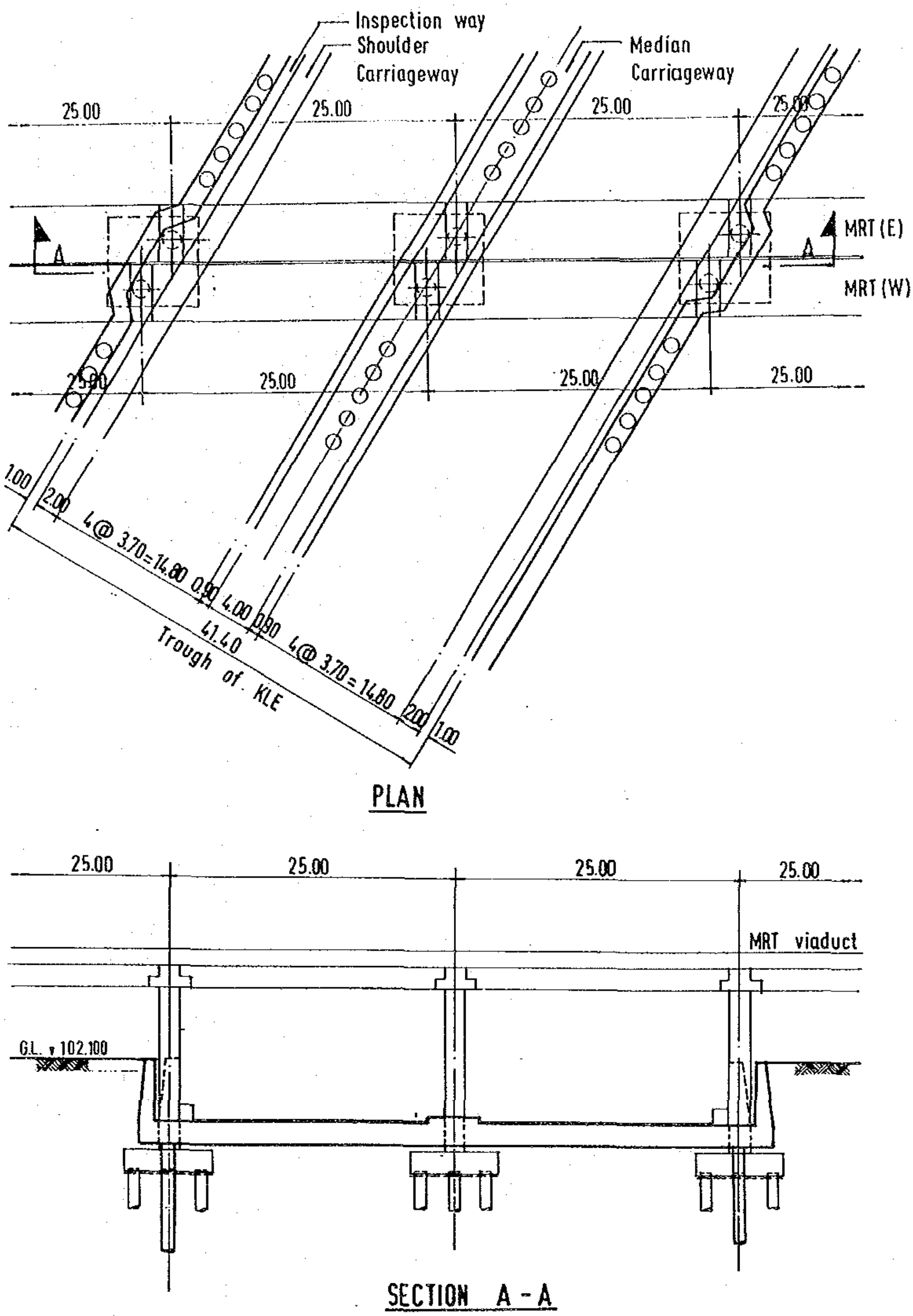


Fig. A9.10.4 Trough crossing under MRT viaduct

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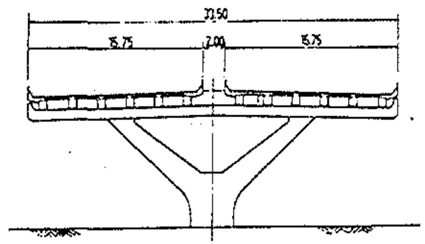
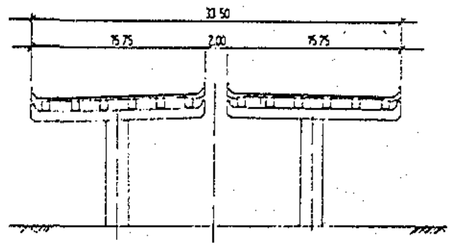
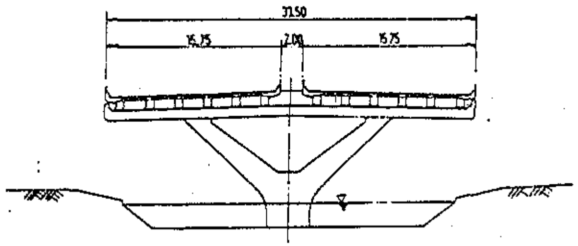
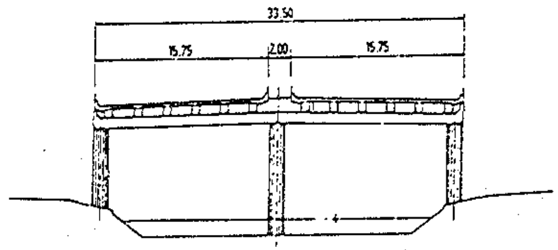
Appendix 9.11 MR9.6.3: Comparative study of pier type for Kallang Park Viaduct

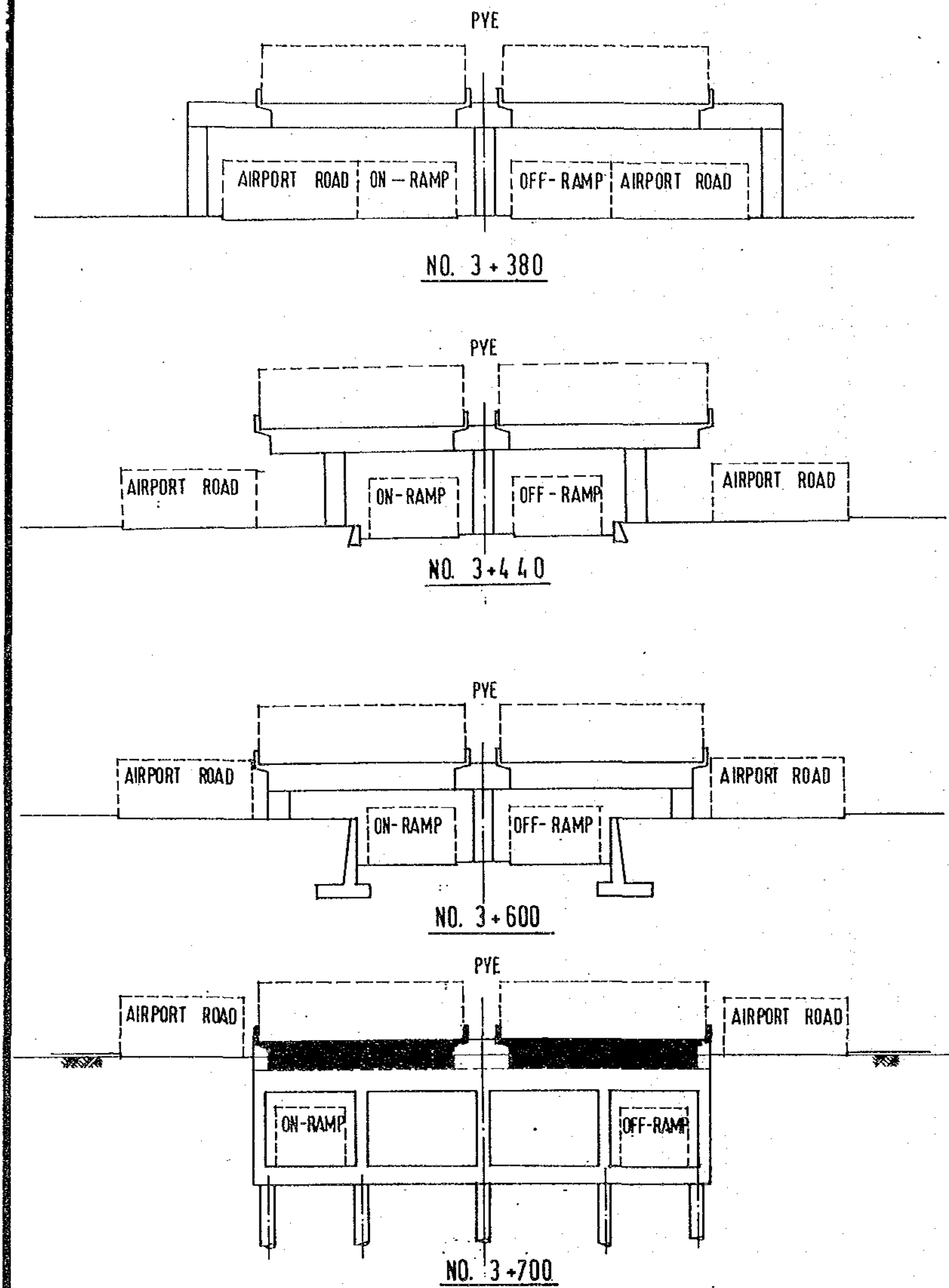
		Y-shaped pier type	2 columns pier type
Cross section			
Under construction	Traffic	-There is no need to detour traffic as there is no road running along the viaduct andthe viaduct over the crossing road is adapted a single span. No difference from the 2 column type. ○	-There is no need to detour traffic as thereis no road running along the viaduct and viaduct and over the crossing road is adapted a single span. No difference from the Y-shaped pier. ○
	Land acquisition	-There is no difference from the 2 column type since it is public land in the park and the width is also the same. ○	-There is no difference from the Y-shaped pier type since it is public land and the width is also the same. ○
	Construction cost	S$ 328,000 /pier (1.05) ○	S$ 313,000/pier (1.00) ◎
After service	Aesthetics	-In order to fit in the surrounding environment, it is better to dissolve the viaduct into the surrounding environment than emphasise it. In this case, it is better to lower the height of the viaduct. But the height of this type is reduced, only the diagonal member can be seen and this is not necessarily good on the aesthetics. It is also not advisable to raise the height of the viaduct. ○	-It is not advisable for the viaduct to be too high so as to fit in with the surrounding environment. A variation in the height of the 2 column type gives little impact to the appearance on the aesthetics. But, the side view will become complicated as the column number is much. The column type is advisable for continuity, of structure it will be adapted for the viaduct from north of Nicol IC. ◎
	Noise & Vibration	-As the width for ROW is the same, there is no difference. ○	-As the width for ROW is the same, there is no difference. ○
	Effectiveness of land usage	-ROW is the same as the 2 column type. But, in terms of effective land use under the viaduct, this is favourable compared with 2 column type. ○	-ROW is the same as that of the Y-shaped type.Use of land under the viaduct is limited by the section between 2 columns. ○
Evaluation			◎

◎:Comparatively good ○:No problem △: Some problems

Appendix 9.12 MR9.6.4: Comparative study of pier type for Pelton Canal Viaduct

		Y-shaped pier type	3 columns pier type
Cross section			
Under construction	Construction aspect	-As a large footing is built in a narrow canal,a wide area needs to set cofferdam. The canal requires to be widen during construction. -Large scale of temporary works such as cofferdam will be necessary. -It is difficult to carry out the supporting work for Y-shaped pier in the canal. ○	-The footing size per each pier is smaller. It is easier to build the 3 column pier in the canal. -Temporary canal is not necessary during construction. The scale of temporary work is small. -Attention is required on the possibility of differential settlement since the footings are independent. Additional stress on the beam member should be avoided. ◎
	Construction cost	S$ 837,000 /pier(1.38) △	S$ 605,000/pier (1.00) ◎
After service	Aesthetics	-As the diagonal section of pier will not be lowered below the high tide level in order to show good appearance and to prevent the water flow , The height of the viaduct will be higher than that of the 2 column type. -Side view of the viaduct looks clear, neat and rhythmical since there is only 1 column. -The structure gives a forceful impression. ○	-Column width is too wide in comparison to the width of the canal. As such, the space below the viaduct appears to be even narrower. -The space below the viaduct looks clear and neat. The outer column cuts off the canal from the outside. -It gives slender impression since all the member of the substructure used is thin. -The side view of the viaduct becomes complicate because of the 3 column pier. ○
	Effectiveness of land usage	-Both banks can be used freely since piers are set in the canal. But, ROW is the same as that of the 3 columns type. ◎	-Land use on both banks is limited as the columns are set on both banks. But, ROW is the same as that of the Y shaped pier type. ○
Evaluation			◎

◎: Comparatively good ○: No problem △: Some poblems



Appendix 9.13 MR9.6.4: Structure plan for Airport Road IC (1/2)

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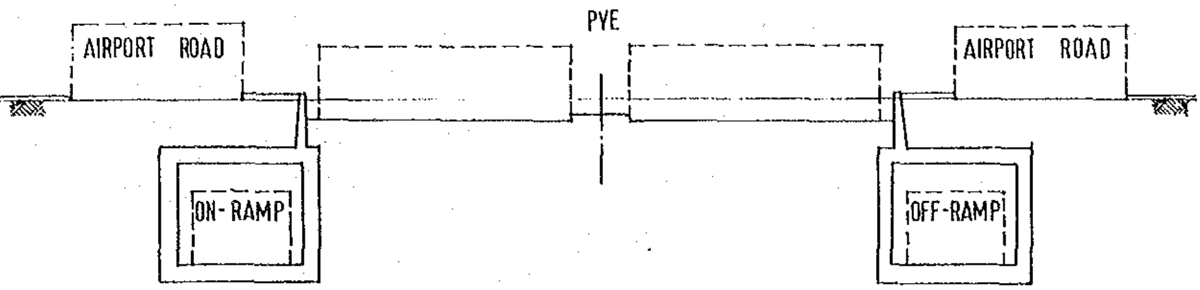
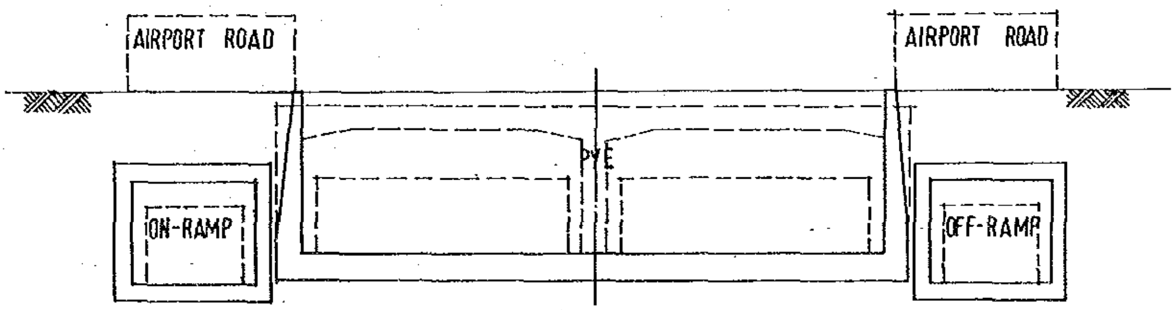
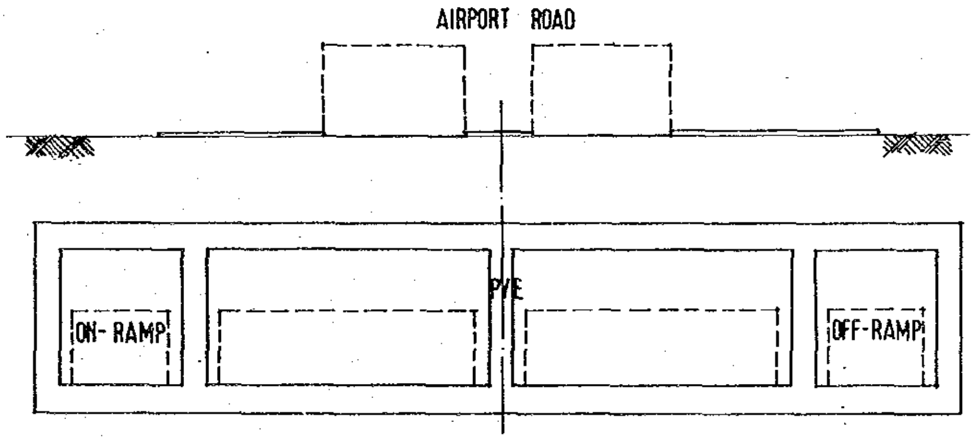


NO. 3 +880



NO. 4 + 000

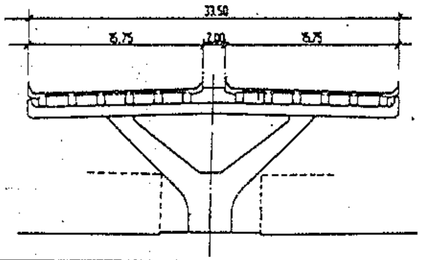
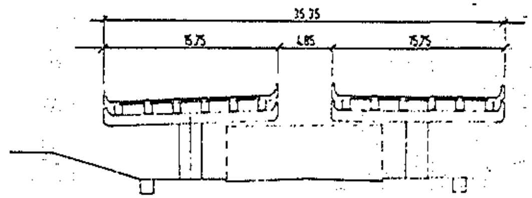


NO. 4 +100

Appendix 9.13 . MR9.6.4: Structure plan for Airport Road IC (2/2)

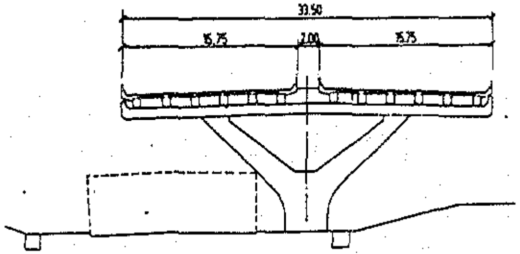
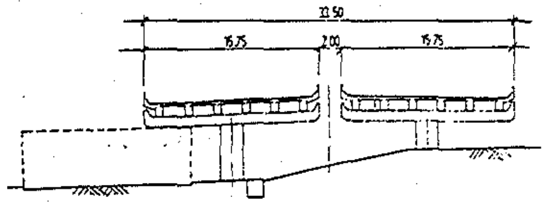
THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

Appendix 9.14 MR9.6.4: Comparative study of pier type for Defu Avenue 3 Viaduct(1/2)

		Y shaped pier type on the median of Defu Ave.		2 columns type of both sides of Defu Ave.	
Cross section					
Under Construction	Traffic management	-Defu Ave. will be detoured during foundation and substructure building . This road will be shifted at the proposed location after cmpletion. -During girder erection at night, both directions of traffic will travel on one side. -As the median will naturally be widenend (9m) because of Y shaped pier type, the traffic safety should be improved.	◎	-It will be necessary to detour Defu Rd. during substructure work at one side at a time. The number of detoure is much than any others alternatives. -During girder erection at night, both directions of traffic will travel on one side. -There is no median on the Defu Ave. after service. This is bad for traffic safety.	△
	Land acquisition	-The required width of the viaduct can be covered in the existing ROW.	◎	-The required width of the viaduct can be covered in the existing ROW.	◎
	Construction cost	S$ 350,000 /pier(1.09)	○	S$ 334,500/pier(1.04)	○
After service	Aesthetics	-Proposed height of the viaduct is necessary greater than 12.5m because of aesthetics and ensuring vertical clearance of Defu Ave. If height is lower than 12.5m, it will give the drivers an oppressive appearance. However, as one side is free, this impression is not as great as in the alternative with piers at both sides of Defu Ave. -Besides giving an appearance of strength and stability, the Y-shaped pier is also rhythmical.	○	-Although this alternative has the advantage of being lower in height, it will give drivers on Defu Ave. an oppressive appearance if it is too low. Moreover, as the road runs between piers at both sides, this appearance is emphasised. -As there are too many columns, the side view of the viaduct looks complicated.	△
	Effectivenesse of land usage	-As the piers set on the median, land use is maximised.	◎	-Land use is not effective as the columns are located on both sides.	○
Evaluation		◎			

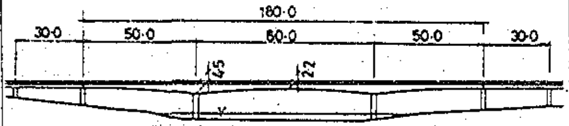
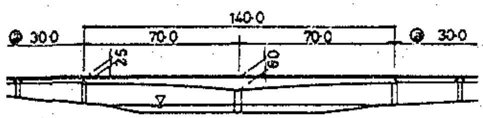
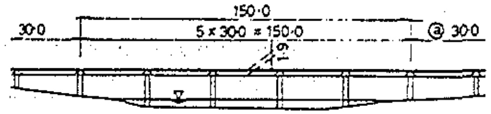
◎:Comparatively good ○:No problem △:Some poblems

Appendix 9.14 MR9.6.4: Comparative study of pier type for *Defu Avenue 3 Viaduct*(2/2)

		Y shaped pier type at the one side of Defu Ave.		2 Columns type at one side of Defu Ave.	
Cross section					
Under construction	Traffic management	-Defu Ave. will be detoured to the opposite side of construction site during the substructure work. -Detouring Defu Ave. will be difficult if girder erection by truck crane and a complete shut off the traffic at night will be required. If it willnot be necessary to shut off the traffic at night, erection girder method is adopted, but it is costly. -As the existing cross section will be same as proposed one, traffic safety does not change.	△	-Defu Ave. will be detoured to the oppsite side of the construction site during the substructure construction.The road will be shifted to the proposed location after completion. -2 lanes are shut off and the remaining 2 lanes operate in 2 directions during erection at night. -The existing cross section will be used for the proposed Defu Rd.Therefore the improvement of traffic safety cannot be expected.	○
	Land acquisition	-Additional land is needed 8m wide.	△	-Additional land is needed 14.5m wide.	△
	Construction cost	S$ 347,000 /pier (1.08)	○	S$ 321,000/pier (1.00)	◎
After service	Aesthetics	-This type gives the driver less oppressive appearance than Y shaped pier on the median. - Y shaped pier can only gives stability if the height of the viaduct is raised. -As regards the characteristics of Y shaped pier ,it gives an impression of strength and stability. At the same time, as there is only 1 column, the side view of the viaduct is rhythmical.	○	-This type gives much less drivers oppressive appearance than any other alternatives. -The cross section of this type is clear and neat structurally, however, the side-view of the viaduct looks complicated due to the number of columns. -The piers are set on slope, the space below the girder becomes narrow.	△
	Effectiveness of land usage	-As piers are set on one side, the opposite side can be used effectively. The area to be used is same as other alternatives.	○	-As the piers are standing on one side, the opposite side can be used effectively.	○
Evaluation					

◎:Comparatively good ○:No problem △: Some problems

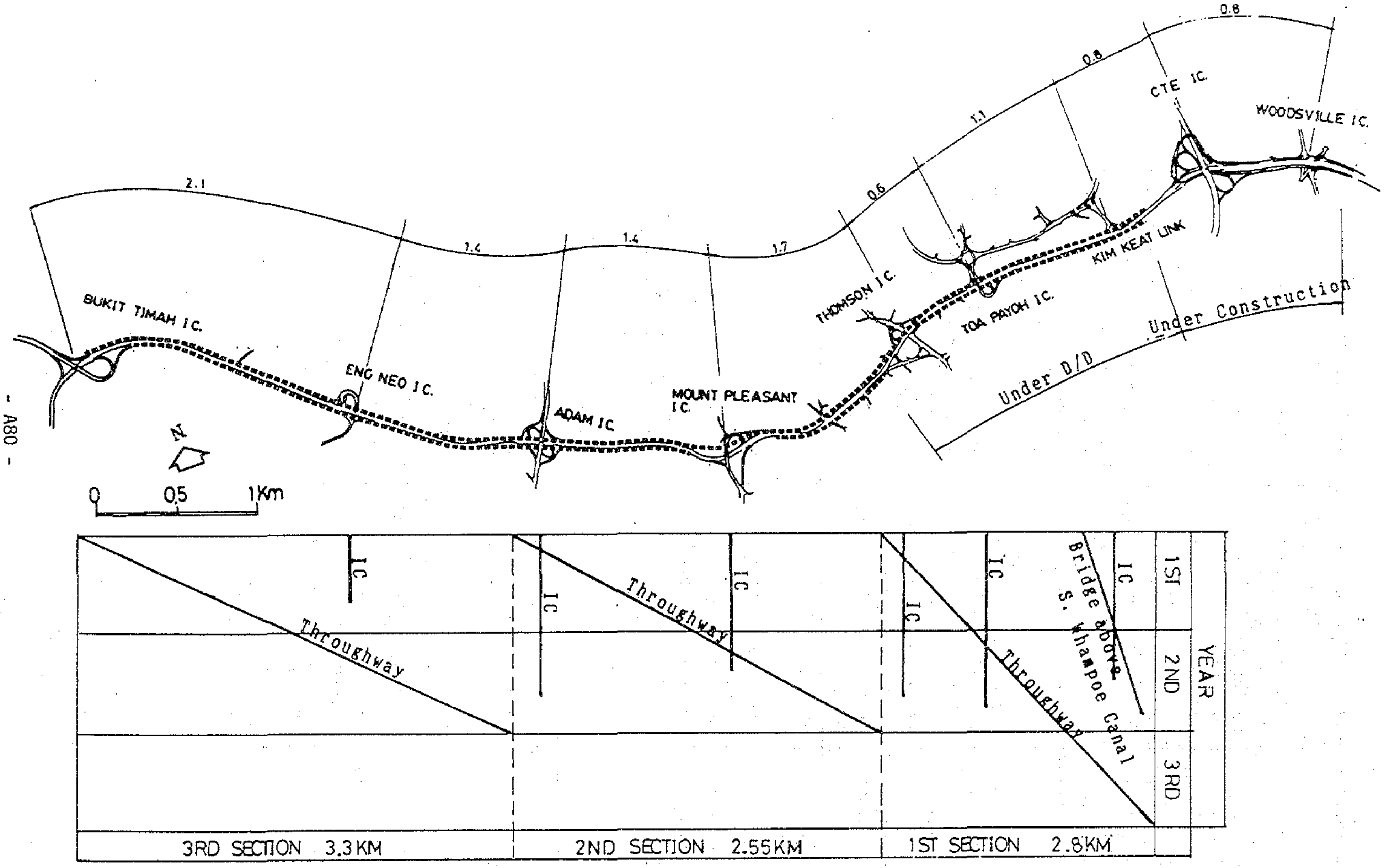
Appendix 9.15 MR9.6.4: Comparative study of structure for Serangoon River Bridge

	3 continuous PC box girder bridge	2 continuous PC box girder bridge	Precast PC composite I beam bridge
Elevation			
Structual aspect	-Stress distribution in the girder are well balanced because of various girder depth. The girder depth on the intermediate support will be about 4.5m. -It forms an angle of 77 degrees with the river. It is possible to apply a continuous rigid-frame type because of gentle angle and small change in temperture. But the substructure must be made as small as possible, therefore a continuous girder type is applied.	-The structure is balanced on stress distribution. The bending momentum on the intermediate support is large and therefore girder depth is high about 6.0m. -The angle of 77 degrees with the river, it is possible to apply a rigid-frame type because of gentle angle. But continuous girder type is applied to avoid stress caused by width difference on both carriageways being passed onto the substructure .	-This alternative is applied precast beam. Girder depth is high due to simple span. -As it is located near the sea with low-proposed height, it would be advisable to cover the bottom of the girder with slab.
Construction aspect	-Cantilever erection by using form traveller or segmental construction will be applied since a large scale temporary facilities is needed. Segment can either be built on the site or built in elsewhere and transported by sea. -Cantilever erection has many past records and is suitable for various girder depth and curved bridge. The control of girder deflection and concrete quality are easy for short segment construction. -Construction period is affected by the number of form traveller. The period can be shortened if 4 form travellers are used. ○	-Cantilever erection has many records and is also suitable for various girder depth bridge.The control of girder deflection and concrete quality are easy for short segment construction. -Construction period is affected by the number of form traveller. The period can be shortened if 4 form travellers are used. -2 form travellers are necessary.It is possible to apply reverse cantilever erection at the end section of the girder. △	-The erection girder method will be applied. This method is normally applied when crossing a river or when there is a space limitation below the beam. ○
Construction cost	S$ 10,944,000 (S$ 60,800/m) (1.18) ○	S$ 9,371,000 (S$ 66,900/m) (1.29) △	S$ 7,749,000 (S$ 51,700/m) (1.00) ◎
Aesthtic aspect	-The span above the river is set long to give a strong, slender appearance which fits in with the surrounding environment. -The ratio of the span from the middle one to the side one is good on aesthetics. As the span number is an odd number, it appears to have continuity. -As girder depth of this type and standard viaduct are almost same, it appears to have continuity on the joint, but it is difference of composition of girder between this type and standard viaduct. -The relationship between the span length and depth of superstructure is balanced for slenderness. ◎	-As the relationship between the girder depth and height below the girder is well balanced it gives stable appearance. -As the number of spans is an even number, the bridge appears to be separated. -As girder depth of this type and standard viaduct are almost same, it appears to have continuity on the joint, but it is difference of composition of girder between this type and standard viaduct. -The relationship between the span length and depth of superstructure is unbalanced for slenderness. △	-It is difficult to create an impression that fits in with the surrounding environment due to straight girder. -As girder type and depth are same as standard viaduct, it's better on the viewpoint of continuity. -As the span member is an odd number, it appears to have continuity. ○
R.O.C.W.F	3.3% ○	3.5% ○	5.0% ○
Evaluation	◎		

◎ : Comparatively good ○ : No problem △ : Some poblems

Appendix 9.16 MR9.7.1: Comparison of asphalt pavement and concrete pavement

Item	Asphalt Pavement	Concrete Pavement
Design Life Time	Design life time is 10 years. Maintenance and repair can lengthen life time.	Design life time is 20 years.
Durability against deformation and wearing	Rutting tends to occur due to deformation.	Deformation such as rutting hardly occurs. Generally has tough resistance against wearing friction.
Noise and Vibration	Comparing with concrete the noise and vibration is less.	There are some problems on vibration on the joint and noise due to rough surface.
Surface brightness	Light reflection is weak. Therefore a running safety in tunnel is less.	For night and tunnel it is bright.
Flatness	Better than concrete	
Construction Aspect	When comparing with concrete, restriction of works are little and working speed is fast.	Working machinery is big. Therefore followed by the restriction as below and working speed comparing to Asphalt pavement is slow. -Subgrade shall be handed over in good condition. -Bridge and structures shall be a few.
Easiness of Maintenance	Can be easily maintained by simple construction method.	Must apply rather big scale works. There is a problem on application of weak foundation areas.
Construction cost and Maintenance cost	Construction cost is lower economical than concrete pavement. As it is necessary to maintain constantly, total cost for about 20 years is sometimes costly.	Construction cost is more costly than asphalt pavement. In the case of reconstruction of pavment,maintenance cost is more costly than asphalt pavement.

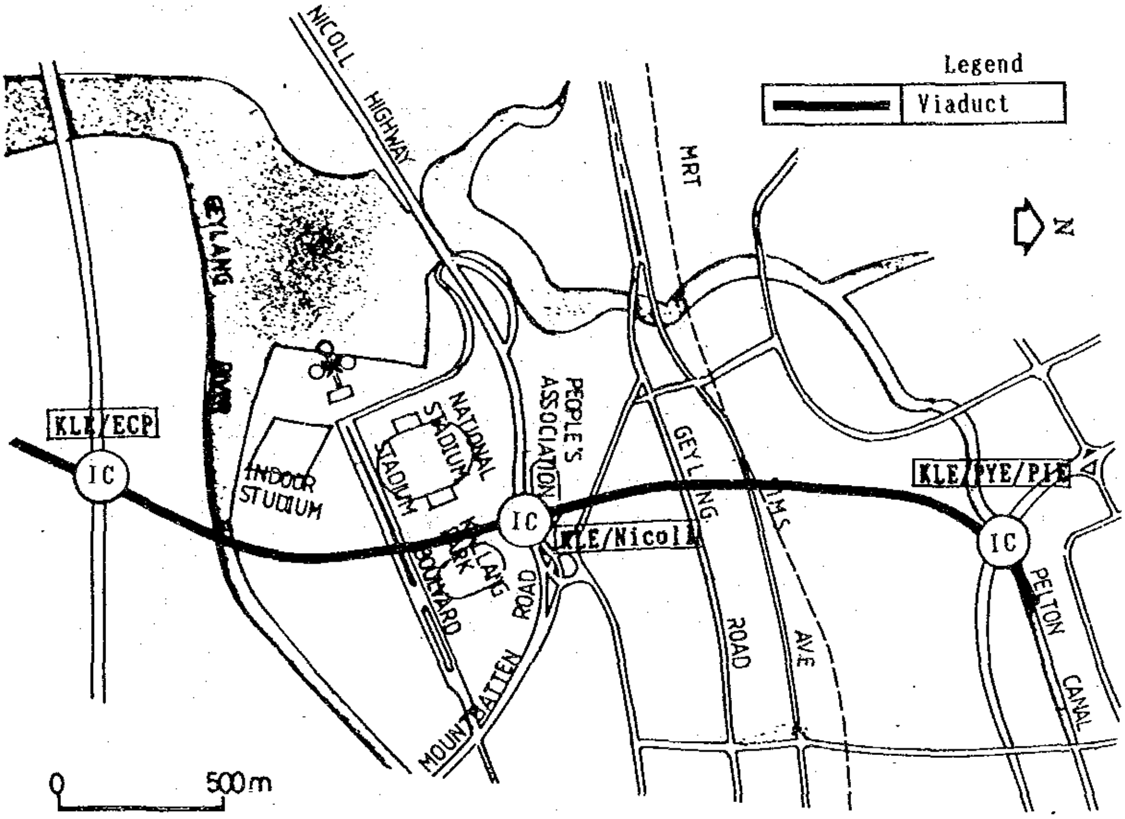


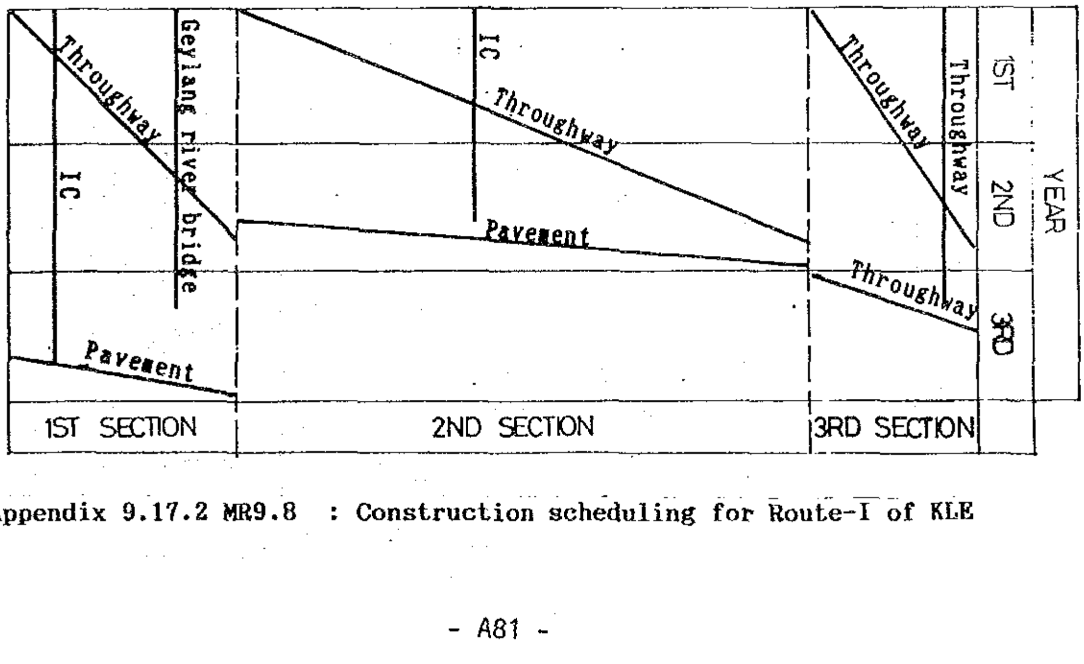
Appendix 9.17.1 MR9.8 : Construction scheduling for PIE

LENGTH OF EACH STRUCTURE TYPES

ROUTE 2 (VIADUCT) UNIT:(m)

	THROUGHWAY	INTERCHANGE			
		ECP IC	NICOLL HI -GHWAY IC	PYE/PIE IC	TOTAL
VIADUCT	2720	3655	1445	2095	7195
APPROACH	—	390	290	920	1600
AT-GRADE	—	3650	685	3350	7685
DEPRESSED	—	—	—	—	0
TUNNEL	—	—	—	—	0
TOTAL	2720	7695	2420	6365	16480



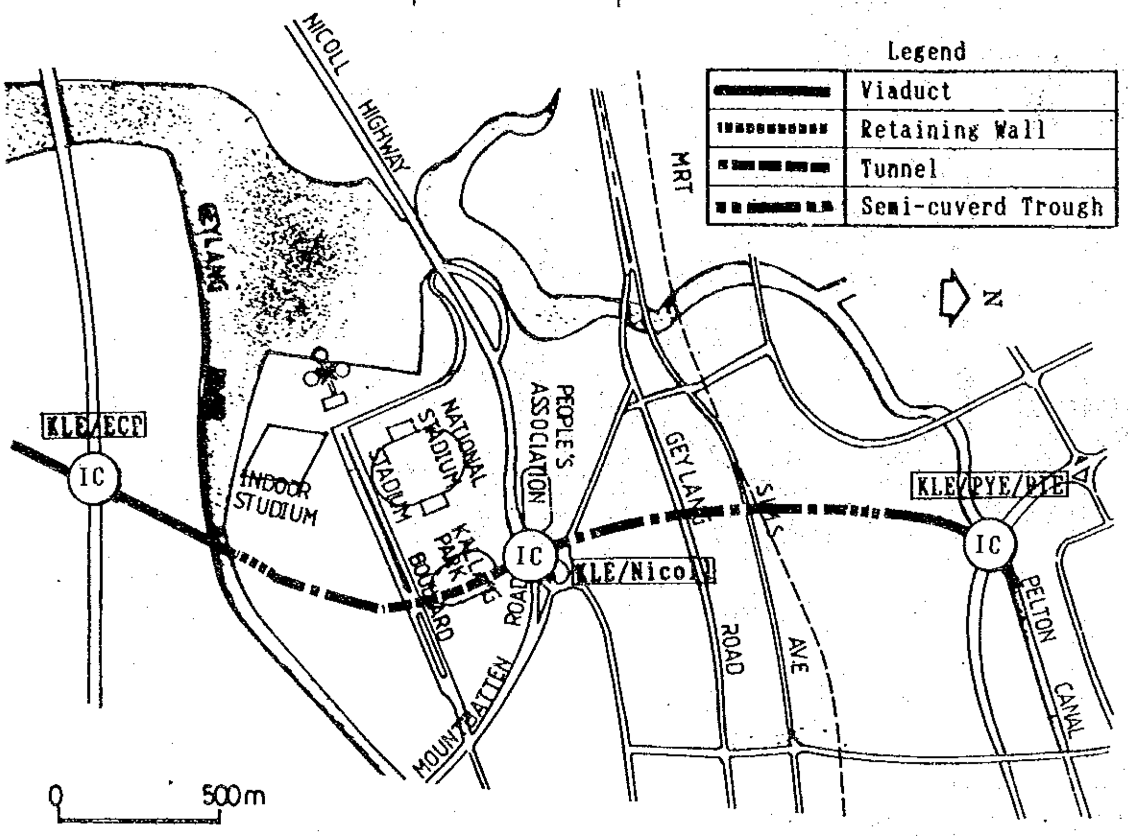


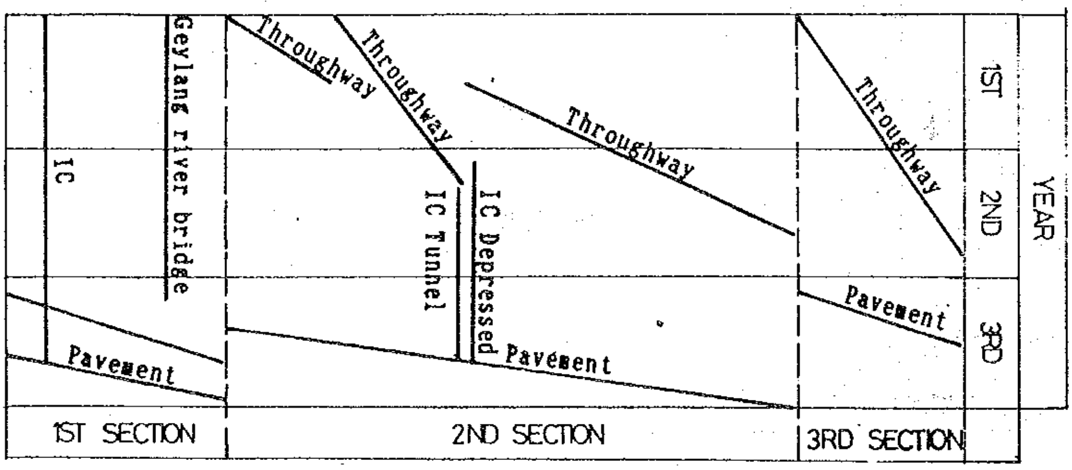
Appendix 9.17.2 MR9.8 : Construction scheduling for Route-I of KLE

LENGTH OF EACH STRUCTURE TYPES

KLE ROUTE 1 (TUNNEL) UNIT:(m)

	THROUGHWAY	INTERCHANGE			
		ECP IC	NICOLL HI -GHWAY IC	PYE/PIE IC	TOTAL
VIADUCT	675	3655		2095	5750
APPROACH	205	390		920	1310
AT-GRADE		3650		3350	7000
DEPRESSED	1410		1725		1725
TUNNEL	495		420		420
					0
TOTAL	2785	7695	2145	6365	16205





Appendix 9.17.3 MR9.8 : Construction scheduling for Route-II of KLE

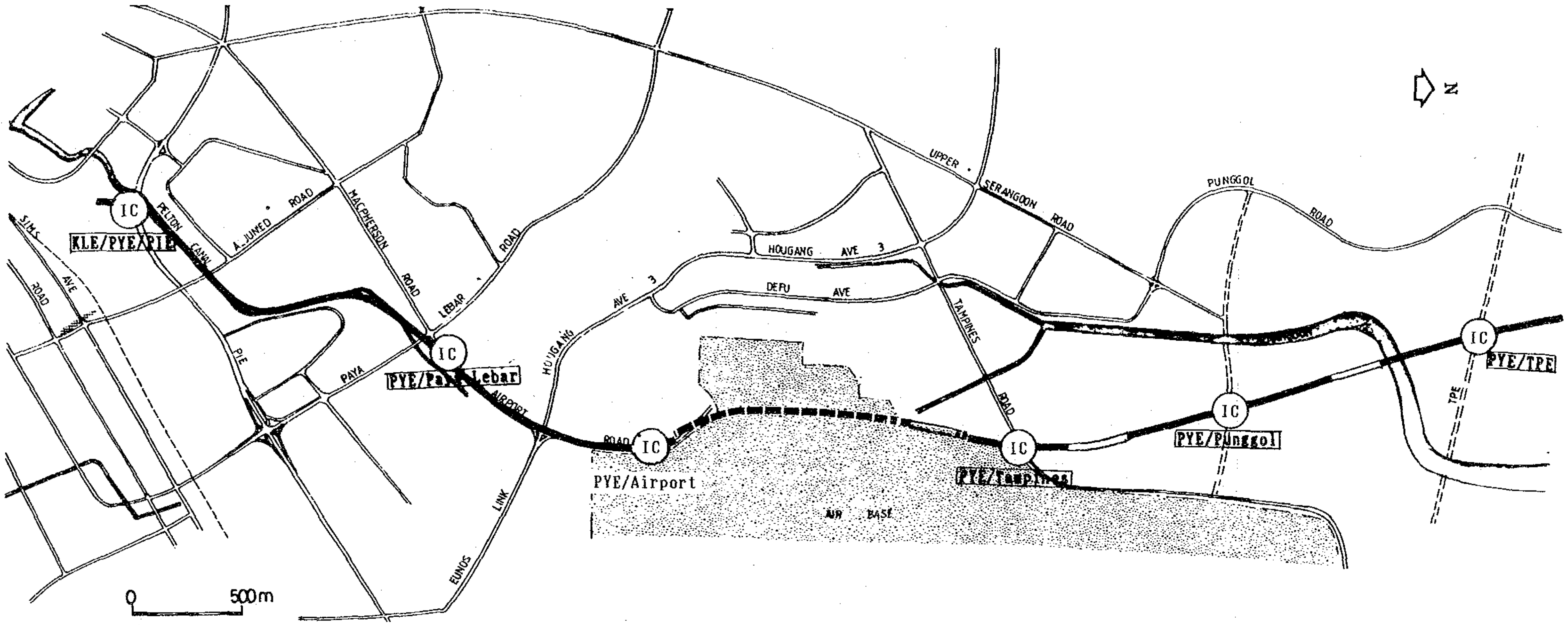
LENGHTH OF EACH STRUCTURE TYPE

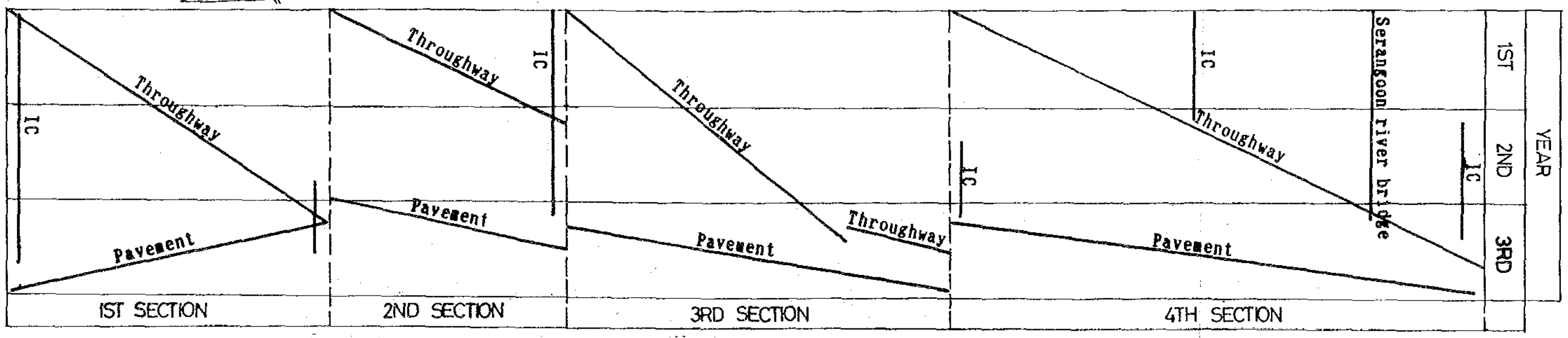
PYE ROUTE 1 UNIT:(m)

	THROUGHWAY	INTERCHANGE						
		KLE/PIE IC	PAYA LEBAR RD. IC	AIR PORT RD. IC	TAMPINESS RD. IC	PUNGGOL IC	TPE IC	TOTAL
VIADUCT	7130	2625	970	—	—	420	1975	5990
APPROACH	140	180	—	—	—	200	—	380
AT-GRADE	1030	70	720	—	1940	340	2035	5105
DEPRESSED	370	—	—	210	—	—	—	210
TUNNEL	1360	—	—	695	—	—	—	695
								0
TOTAL.	10030	2875	1690	905	1940	960	4010	12380

Legend

- Viaduct
- Retaining Wall
- Tunnel
- At-grade





Appendix 9.17.4 MR9.8 : Construction scheduling for Route-I of PYE

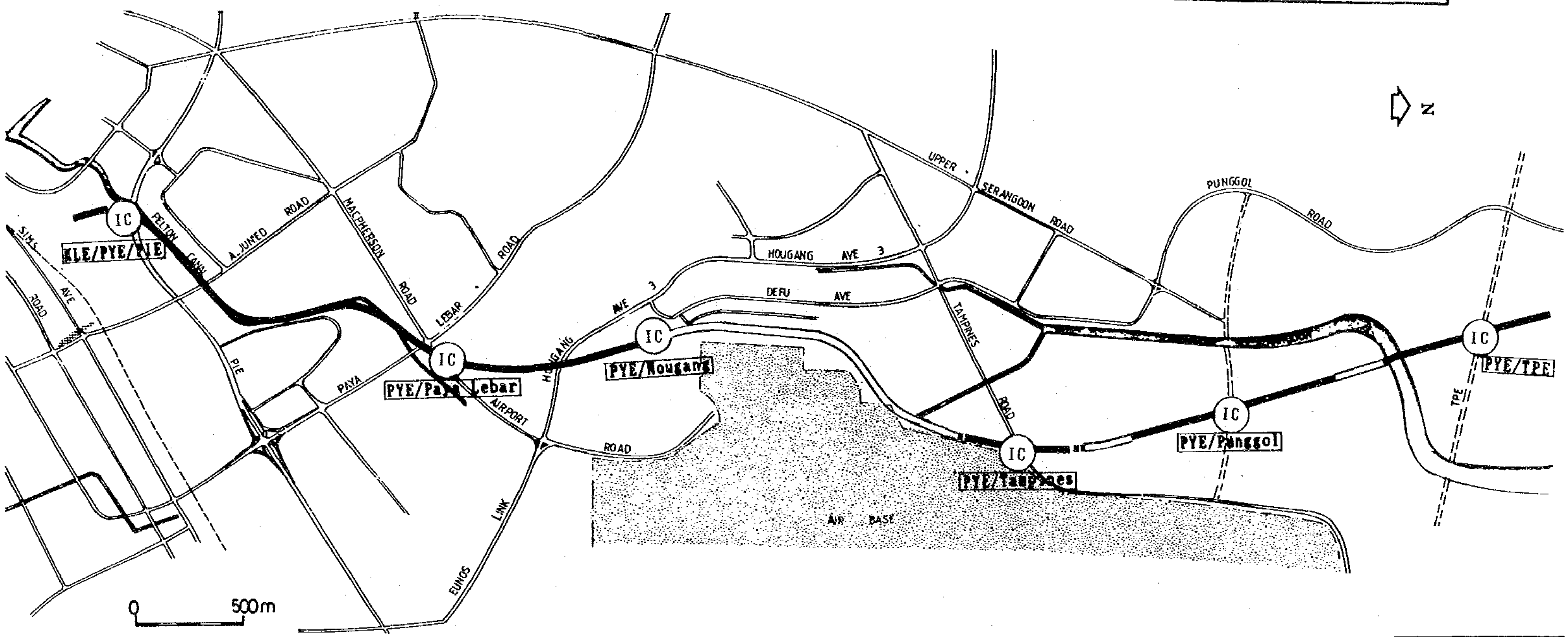
LENGHTH OF EACH STRUCTURE TYPE

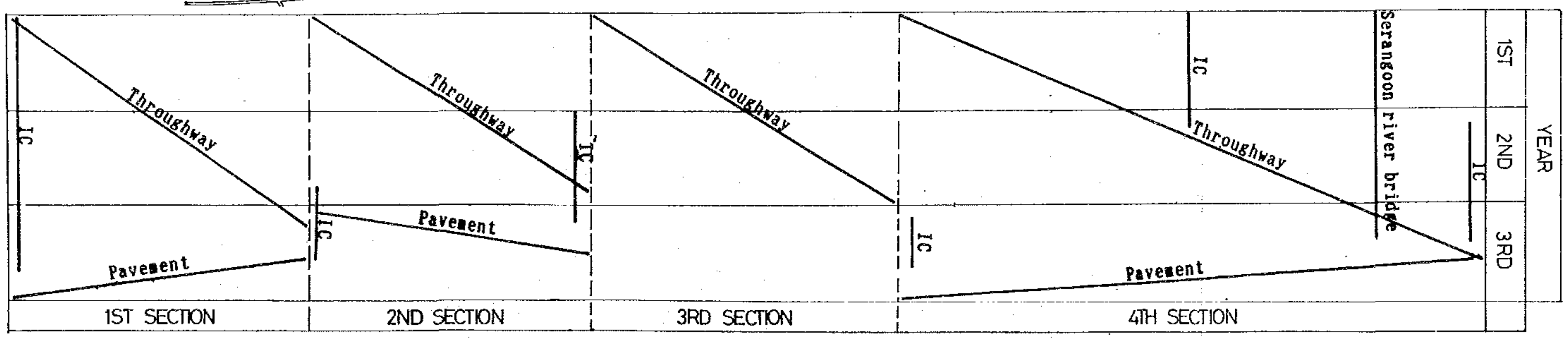
PYE ROUTE 2 UNIT:(m)

	THROUGHWAY	INTERCHANGE						
		KLE/PIE IC	PAYA LEBAR RD. IC	HOUGANG AVE. IC	TAMPINESS RD. IC	PUNGGOL IC	TPE IC	TOTAL
VIADUCT	6915	2625	1420	260	—	420	1975	6700
APPROACH	265	180	—	80	—	200	—	460
AT-GRADE	1830	70	410	—	1940	340	2035	4795
RC WALL	1150	—	—	—	—	—	—	0
DEPRESSED	—	—	—	—	—	—	—	0
TUNNEL	—	—	—	—	—	—	—	0
TOTAL	10160	2875	1830	340	1940	960	4010	11955

Legend

Viaduct	
Retaining Wall	
At-grade	





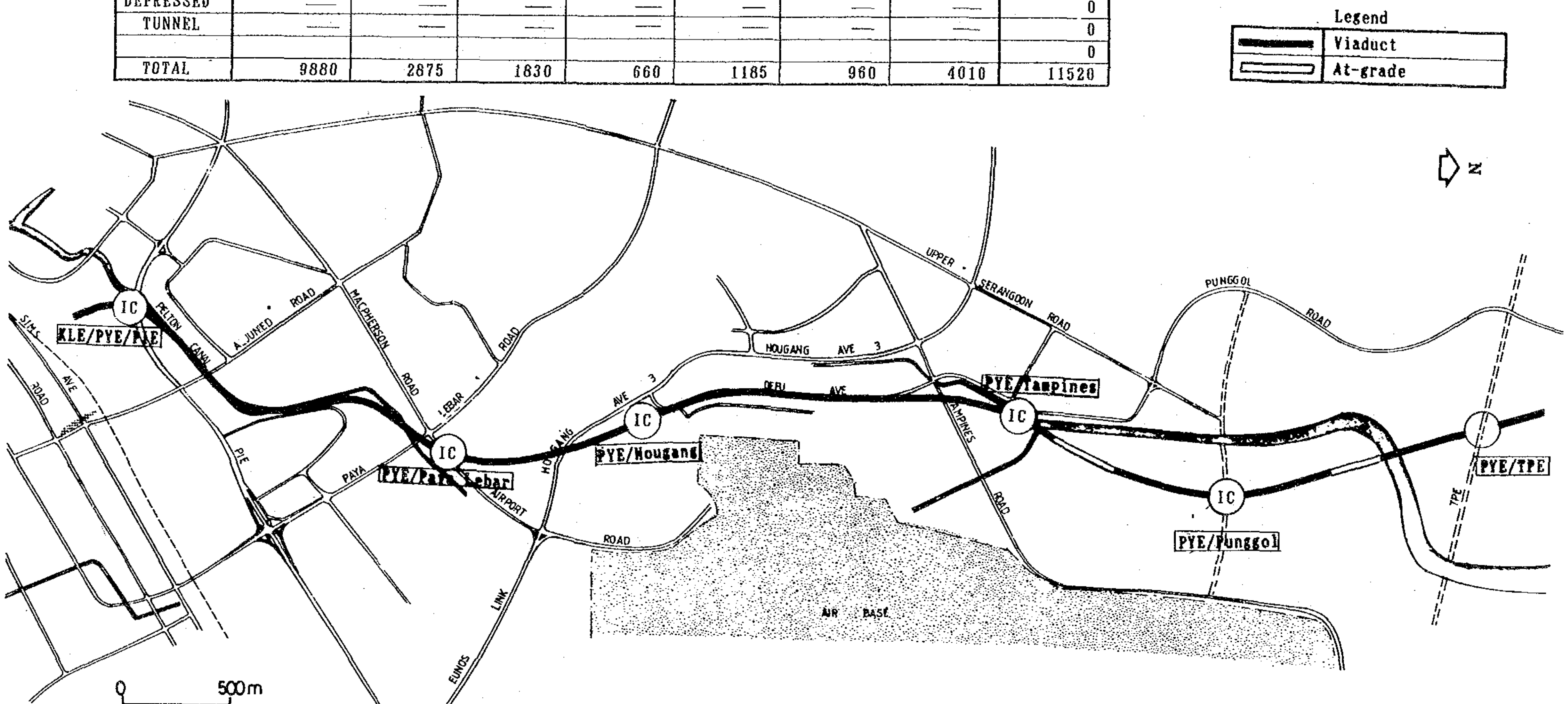
Appendix 9.17.5 MR9.8 : Construction scheduling for Route-II of PYE

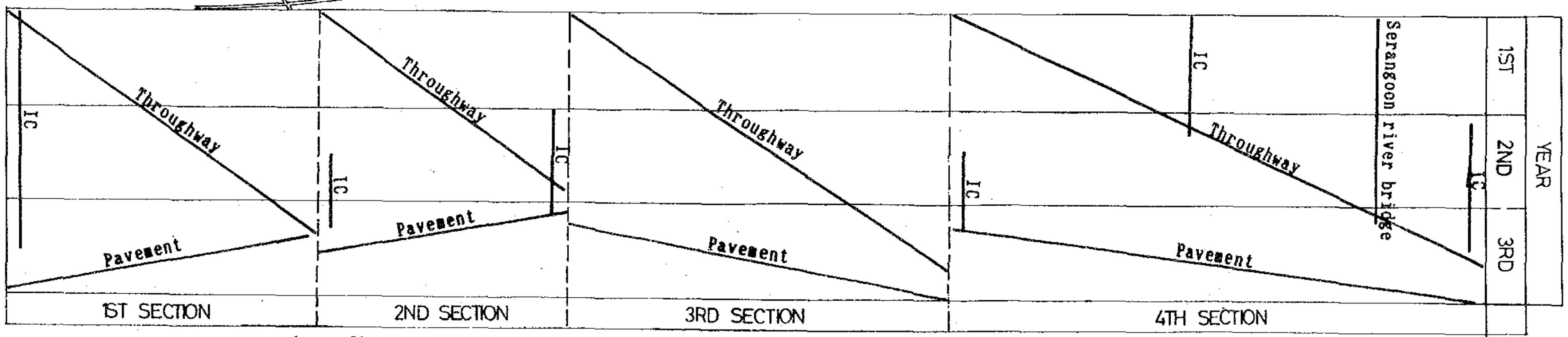
LENGHTH OF EACH STRUCTURE TYPE

PYE ROUTE 3

UNIT:(m)

	THROUGHWAY	INTERCHANGE						
		KLE/PIE IC	PAYA LEBAR RD. IC	HOUGANG AVE. IC	TAMPINESS RD. IC	PUNGGOL IC	TPE IC	TOTAL
VIADUCT	8955	2625	1420	490	335	420	1975	7265
APPROACH	925	180	—	170	110	200	—	660
AT-GRADE	—	70	410	—	740	340	2035	3595
DEPRESSED	—	—	—	—	—	—	—	0
TUNNEL	—	—	—	—	—	—	—	0
								0
TOTAL	9880	2875	1830	660	1185	960	4010	11520





Appendix 9.17.6 MR9.8 : Construction scheduling for Route-III of PYE

APPENDIX 11

Appendix 11.1 MR11.3 : Vehicle Operating Cost

Table A11.1.1 Representitve vehicles and characteristics

CATEGORY	REPRESENTATIVE TIPES	OPEN MARKET PRICE (S$)	FUEL TIPE	FUEL CONSUMPTION (km/litre)	ASSUMED LIFE (YRS)
CARS:					
0-1000cc	Toyota Starlet	10065	P	15.6-16.4	8
	Daihats Charade				
1001-1600cc	Honda Civic	14447	P	10.2-13.2	8
	Toyota Carolla				
	Nissan Pulsar				
	Toyota Corona				
1601-2000cc	Toyota Cressida	20555	P	8.1-11.5	8
	Mazda 626				
	Renaut 21				
2001-3000cc	Mercedes 300E	58885	P	7.1- 7.8	8
	BMW 730i				
3000cc-	Mercedes 560	112940	P	5.9- 7.4	8
	BMW 750				
MOTORCYCLES:	Yamaha	3100	R	16.0-35.0	10
	Suzuki				
	Honda				
	Kawasaki				
TAXIS:	Nissan	19500	D	7.0- 9.7	6
	Toyota				
LIGHT GVs:	Datsun	14500	R	10.0-13.0	15
	Daihatsu				
	Toyota				
	Isuzu				
MEDIUM/HEAVY GVs:					
3-5 tons	Nissan	15000	D	8.9-10.6	15
	Toyota				
5-10 tons	Isuzu	18000	D	7.0- 9.9	15
	Toyota				
10-15 tons	Nissan	40000	D	2.5- 6.5	15
15-20 tons	MItsubishi	50000	D	2.5- 6.5	15
20-30 tons	Isuzu	60000	D	2.5- 6.5	15
30 tons-		60000	D	2.5- 6.5	15
BUSES:					
SCHOOL	Toyota	43000	D	2.8- 5.0	16
PRIVATE	Mercedes	48500	D	7.6-11.8	17
	Isuzu				
HIRE	Tata	43000	D	7.6-11.8	16
	Mazuda				
EXCURSION	Mercedes	53000	D	2.5- 3.5	12
	Hino				
	Nissan				
OMNIBUS	Scania	121000	D	2.5-3.5	12
	Volvo				
	Mercedes				

P: Premium Petrol R: Regular Petrol D: Diesel

Table A11.1.2 Performance characteristics of vehicles(average)

CATEGORY	OPEN MARKET VALUE	ASSUMED LIFE (YRS)	FUEL TYPE	FUEL CONSUMED (km/l)	ANNUAL KM	AVERAGE SPEED (km/h)	NO. OF REGISTERED VEHICLES (000s) (Oct.1990)
CARS:							
0-1000cc	10065	8	P	16.00	20000	37	41.6
1001-1600cc	14447	8	P	12.00	20000	37	179.2
1601-2000cc	20555	8	P	10.00	20000	37	39.3
2001-3000cc	58885	8	P	7.50	20000	40	10.2
3000cc-	112940	8	P	7.00	20000	40	1.3
ALL CARS					20000	37	271.6
MOTORCYCLES:	3100	10	R	27.00	12000	37	120.8
TAXIS:	19500	6	D	8.50	90000	40	12.3
LIGHT GVs:	14500	15	R	11.50	26000	35	53.1
MEDIUM/HEAVY GVs:							
3-5 tons	15000	15	D	10.00	30000	35	31.5
5-10 tons	18000	15	D	9.00	40000	35	11.8
10-15 tons	40000	15	D	6.00	40000	33	2.1
15-20 tons	50000	15	D	4.50	40000	30	2.2
20-30 tons	60000	15	D	3.50	40000	30	3.0
30 tons-	60000	15	D	3.00	40000	30	2.2
ALL M/H GVs					35900	33	52.9
BUSES:							
SCHOOL	43000	16	D	3.50	30000	25	2.0
PRIVATE	48500	17	D	8.00	26000	25	1.8
HIRE	43000	16	D	8.00	30000	35	1.2
EXCURSION	53000	12	D	3.50	70000	35	1.0
OMNIBUS	121000	12	D	3.00	60000	20	3.2
ALL BUSES					50900	24	9.2

P: Premium Petrol R: Regular Petrol D: Diesel

Table A11.1.3 Current fuel prices

		PRICE (S$/litre)			
		CALTEX	ESSO	MOBIL	BP
Petrol,Premium	With Tax	1.222	1.222	1.222	1.222
	Without Tax	0.611	0.611	0.611	0.611
Petrol,Regular	With Tax	1.130	1.180	1.130	1.130
	Without Tax	0.560	0.590	0.560	0.560
Diesel	With Tax	0.642	0.642	0.642	0.642
	Without Tax	0.554	0.554	0.554	0.554

Fuel Prices were surveyed on 28 November 1990

Table A11.1.4 Economic project cost/benefit stream of PIE

NO	YEAR	PROJECT COSTS CAPITAL COSTS	MAINT. COSTS	TOTAL COSTS	BENEFITS SAVINGS OF VOC	SAVINGS OF TIME VALUE	TOTAL BENEFITS	INCREMENT BENEFITS
1	1990	0	0	0	0	0	0	0
2	1991	5852	0	5852	0	0	0	-5852
3	1992	35806	0	35806	0	0	0	-35806
4	1993	33231	0	33231	0	0	0	-33231
5	1994	11001	0	11001	0	0	0	-11001
6	1995	2280	219	2499	0	0	0	-2499
7	1996	0	219	219	985	8154	9139	8920
8	1997	0	219	219	985	8154	9139	8920
9	1998	0	219	219	985	8154	9139	8920
10	1999	0	219	219	985	8154	9139	8920
11	2000	0	361	361	985	8154	9139	8778
12	2001	0	361	361	985	8154	9139	8778
13	2002	0	361	361	985	8154	9139	8778
14	2003	0	361	361	985	8154	9139	8778
15	2004	0	361	361	985	8154	9139	8778
16	2005	0	361	361	985	8154	9139	8778
17	2006	0	361	361	985	8154	9139	8778
18	2007	0	361	361	985	8154	9139	8778
19	2008	0	361	361	985	8154	9139	8778
20	2009	0	361	361	985	8154	9139	8778
21	2010	0	361	361	985	8154	9139	8778
22	2011	0	361	361	985	8154	9139	8778
23	2012	0	361	361	985	8154	9139	8778
24	2013	0	361	361	985	8154	9139	8778
25	2014	0	361	361	985	8154	9139	8778
26	2015	0	361	361	985	8154	9139	8778
	TOTAL	88170	6871	95041	19700	163080	182780	87739
NPV	8%	66791	2075	68866	6094	50450	56544	-12322
	12%	58667	1259	59926	3727	30857	34584	-25342
	15%	53423	896	54319	2665	22065	24731	-29588

IRR 0.05966

B/C RATIO DISC A		
	8%	0.82107
	12%	0.57711
	15%	0.45528

Table A11.1.5 Economic project cost/benefit stream of KLE(Route-I)

NO	YEAR	PROJECT COSTS CAPITAL COSTS	MAINT. COSTS	TOTAL COSTS	SAVINGS OF VOC	BENEFITS SAVINGS OF TIME VALUE	TOTAL BENEFITS	INCREMENT BENEFITS
1	1990	0	0	0	0	0	0	0
2	1991	0	0	0	0	0	0	0
3	1992	0	0	0	0	0	0	0
4	1993	33150	0	33150	0	0	0	-33150
5	1994	0	0	0	0	0	0	0
6	1995	107018	0	107018	0	0	0	-107018
7	1996	111844	0	111844	0	0	0	-111844
8	1997	70006	0	70006	0	0	0	-70006
9	1998	0	2090	2090	58957	387837	446794	444704
10	1999	0	2090	2090	58957	387837	446794	444704
11	2000	0	2090	2090	58957	387837	446794	444704
12	2001	0	2090	2090	58957	387837	446794	444704
13	2002	0	2090	2090	58957	387837	446794	444704
14	2003	0	3211	3211	58957	387837	446794	443583
15	2004	0	3211	3211	58957	387837	446794	443583
16	2005	0	3211	3211	58957	387837	446794	443583
17	2006	0	3211	3211	58957	387837	446794	443583
18	2007	0	3211	3211	58957	387837	446794	443583
19	2008	0	3211	3211	58957	387837	446794	443583
20	2009	0	3211	3211	58957	387837	446794	443583
21	2010	0	3211	3211	58957	387837	446794	443583
22	2011	0	3211	3211	58957	387837	446794	443583
23	2012	0	3211	3211	58957	387837	446794	443583
24	2013	0	3211	3211	58957	387837	446794	443583
25	2014	0	3211	3211	58957	387837	446794	443583
26	2015	0	3211	3211	58957	387837	446794	443583
27	2016	0	3211	3211	58957	387837	446794	443583
28	2017	0	3211	3211	58957	387837	446794	443583
	TOTAL	322018	58615	380633	1179140	7756740	8935880	8555247
NPV	8%	194888	14614	209502	312734	2057258	2369992	2160490
	12%	154153	8055	162208	177860	1170020	1347881	1185673
	15%	130152	5342	135494	120637	793587	914224	778730

IRR 0.60034

B/C RATIO DISC. AT		
	8%	11.31249
	12%	8.309597
	15%	6.747352

Table A11.1.6 Economic project cost/benefit stream of KLE(Route-II)

NO	YEAR	PROJECT COSTS CAPITAL COSTS	MAINT. COSTS	TOTAL COSTS	SAVINGS OF VOC	BENEFITS SAVINGS OF TIME VALUE	TOTAL BENEFITS	INCREMENT BENEFITS
1	1990	0	0	0	0	0	0	0
2	1991	0	0	0	0	0	0	0
3	1992	0	0	0	0	0	0	0
4	1993	28796	0	28796	0	0	0	-28796
5	1994	0	0	0	0	0	0	0
6	1995	41382	0	41382	0	0	0	-41382
7	1996	110751	0	110751	0	0	0	-110751
8	1997	101099	0	101099	0	0	0	-101099
9	1998	0	618	618	58957	387837	446794	446176
10	1999	0	618	618	58957	387837	446794	446176
11	2000	0	618	618	58957	387837	446794	446176
12	2001	0	618	618	58957	387837	446794	446176
13	2002	0	618	618	58957	387837	446794	446176
14	2003	0	1026	1026	58957	387837	446794	445768
15	2004	0	1026	1026	58957	387837	446794	445768
16	2005	0	1026	1026	58957	387837	446794	445768
17	2006	0	1026	1026	58957	387837	446794	445768
18	2007	0	1026	1026	58957	387837	446794	445768
19	2008	0	1026	1026	58957	387837	446794	445768
20	2009	0	1026	1026	58957	387837	446794	445768
21	2010	0	1026	1026	58957	387837	446794	445768
22	2011	0	1026	1026	58957	387837	446794	445768
23	2012	0	1026	1026	58957	387837	446794	445768
24	2013	0	1026	1026	58957	387837	446794	445768
25	2014	0	1026	1026	58957	387837	446794	445768
26	2015	0	1026	1026	58957	387837	446794	445768
27	2016	0	1026	1026	58957	387837	446794	445768
28	2017	0	1026	1026	58957	387837	446794	445768
	TOTAL	282028	18480	300508	1179140	7756740	8935880	8635372
NPV	8%	166486	4562	171049	312734	2057258	2369992	2198943
	12%	130196	2501	132697	177860	1170020	1347881	1215183
	15%	109040	1652	110692	120637	793587	914224	803532

IRR 0.69299

B/C RATIO DISC.A		
	8%	13.85566
	12%	10.15755
	15%	8.259174

Table A11.1.7 Economic project cost/benefit stream of PYE(Route-I)

		PROJECT COSTS			BENEFITS			
		CAPITAL	MAINT.	TOTAL	SAVINGS	SAVINGS OF	TOTAL	INCREMENT
NO	YEAR	COSTS	COSTS	COSTS	OF VOC	TIME VALUE	BENEFITS	BENEFITS
1	1990	0	0	0	0	0	0	0
2	1991	0	0	0	0	0	0	0
3	1992	0	0	0	0	0	0	0
4	1993	0	0	0	0	0	0	0
5	1994	0	0	0	0	0	0	0
6	1995	0	0	0	0	0	0	0
7	1996	0	0	0	0	0	0	0
8	1997	0	0	0	0	0	0	0
9	1998	0	0	0	0	0	0	0
10	1999	0	0	0	0	0	0	0
11	2000	0	0	0	0	0	0	0
12	2001	7895	0	7895	0	0	0	-7895
13	2002	0	0	0	0	0	0	0
14	2003	49942	0	49942	0	0	0	-49942
15	2004	82536	0	82536	0	0	0	-82536
16	2005	91561	0	91561	0	0	0	-91561
17	2006	35863	551	36414	0	0	0	-36414
18	2007	120812	551	121363	0	0	0	-121363
19	2008	123339	551	123890	0	0	0	-123890
20	2009	80351	941	81292	0	0	0	-81292
21	2010	0	4399	4399	322726	3857559	4180285	4175886
22	2011	0	4769	4769	322726	3857559	4180285	4175516
23	2012	0	4769	4769	322726	3857559	4180285	4175516
24	2013	0	4769	4769	322726	3857559	4180285	4175516
25	2014	0	5026	5026	322726	3857559	4180285	4175259
26	2015	0	6755	6755	322726	3857559	4180285	4173530
27	2016	0	6755	6755	322726	3857559	4180285	4173530
28	2017	0	6755	6755	322726	3857559	4180285	4173530
29	2018	0	6755	6755	322726	3857559	4180285	4173530
30	2019	0	6755	6755	322726	3857559	4180285	4173530
31	2020	0	6755	6755	322726	3857559	4180285	4173530
32	2021	0	6755	6755	322726	3857559	4180285	4173530
33	2022	0	6755	6755	322726	3857559	4180285	4173530
34	2023	0	6755	6755	322726	3857559	4180285	4173530
35	2024	0	6755	6755	322726	3857559	4180285	4173530
36	2025	0	6755	6755	322726	3857559	4180285	4173530
37	2026	0	6755	6755	322726	3857559	4180285	4173530
38	2027	0	6755	6755	322726	3857559	4180285	4173530
39	2028	0	6755	6755	322726	3857559	4180285	4173530
40	2029	0	6755	6755	322726	3857559	4180285	4173530
	TOTAL	592299	127651	719950	6454520	77151180	83605700	82885750
NPV	8%	158627	13108	171735	679811	8125817	8805628	8633892
	12%	85844	4783	90627	249897	2987035	3236933	3146306
	15%	55132	2357	57489	123426	1475311	1598737	1541248

IRR 0.76607

B/C RATIO		
	8%	51.2743
	12%	35.7171
	15%	27.8093

Table A11.1.8 Economic project cost/benefit stream of PYE(Route-II)

NO	YEAR	PROJECT COSTS CAPITAL COSTS	MAINT. COSTS	TOTAL COSTS	SAVINGS OF VOC	BENEFITS SAVINGS TIME VALUE	TOTAL BENEFITS	INCREMENT BENEFITS
1	1990	0	0	0	0	0	0	0
2	1991	0	0	0	0	0	0	0
3	1992	0	0	0	0	0	0	0
4	1993	0	0	0	0	0	0	0
5	1994	0	0	0	0	0	0	0
6	1995	0	0	0	0	0	0	0
7	1996	0	0	0	0	0	0	0
8	1997	0	0	0	0	0	0	0
9	1998	0	0	0	0	0	0	0
10	1999	0	0	0	0	0	0	0
11	2000	0	0	0	0	0	0	0
12	2001	17253	0	17253	0	0	0	-17253
13	2002	0	0	0	0	0	0	0
14	2003	42703	0	42703	0	0	0	-42703
15	2004	75411	0	75411	0	0	0	-75411
16	2005	88227	0	88227	0	0	0	-88227
17	2006	29887	513	30400	0	0	0	-30400
18	2007	57931	513	58444	0	0	0	-58444
19	2008	58283	513	58796	0	0	0	-58796
20	2009	21727	903	22630	0	0	0	-22630
21	2010	0	998	998	380922	4468636	4849558	4848560
22	2011	0	1340	1340	380922	4468636	4849558	4848218
23	2012	0	1340	1340	380922	4468636	4849558	4848218
24	2013	0	1340	1340	380922	4468636	4849558	4848218
25	2014	0	1596	1596	380922	4468636	4849558	4847962
26	2015	0	1663	1663	380922	4468636	4849558	4847895
27	2016	0	1663	1663	380922	4468636	4849558	4847895
28	2017	0	1663	1663	380922	4468636	4849558	4847895
29	2018	0	1663	1663	380922	4468636	4849558	4847895
30	2019	0	1663	1663	380922	4468636	4849558	4847895
31	2020	0	1663	1663	380922	4468636	4849558	4847895
32	2021	0	1663	1663	380922	4468636	4849558	4847895
33	2022	0	1663	1663	380922	4468636	4849558	4847895
34	2023	0	1663	1663	380922	4468636	4849558	4847895
35	2024	0	1663	1663	380922	4468636	4849558	4847895
36	2025	0	1663	1663	380922	4468636	4849558	4847895
37	2026	0	1663	1663	380922	4468636	4849558	4847895
38	2027	0	1663	1663	380922	4468636	4849558	4847895
39	2028	0	1663	1663	380922	4468636	4849558	4847895
40	2029	0	1663	1663	380922	4468636	4849558	4847895
	TOTAL	391422	34001	425423	7618440	89372720	96991160	96565737
NPV	8%	111656	3775	115432	802399	9413029	10215429	10099997
	12%	62241	1445	63686	294960	3460213	3755173	3691487
	15%	40837	740	41577	145682	1709016	1854698	1813122

IRR 0.79489

B/C RATIO		
	8%	88.49742
	12%	58.96390
	15%	44.60895

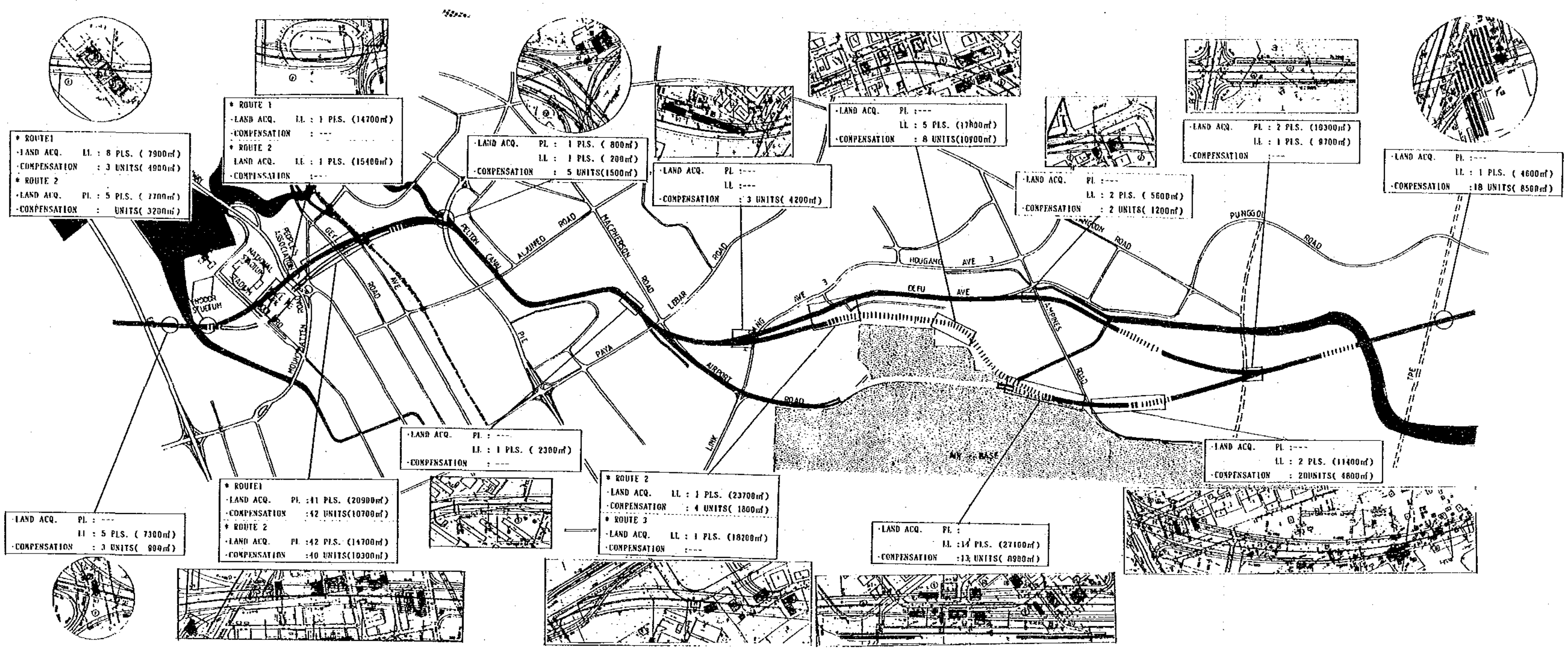
Table A11.1.9 Economic project cost/benefit stream of PYE(Route-III)

		PROJECT COSTS			BENEFITS			
		CAPITAL	MAINT.	TOTAL	SAVINGS	SAVINGS OF	TOTAL	INCREMENT
NO	YEAR	COSTS	COSTS	COSTS	OF VOC	TIME VALUE	BENEFITS	BENEFITS
1	1990	0	0	0	0	0	0	0
2	1991	0	0	0	0	0	0	0
3	1992	0	0	0	0	0	0	0
4	1993	0	0	0	0	0	0	0
5	1994	0	0	0	0	0	0	0
6	1995	0	0	0	0	0	0	0
7	1996	0	0	0	0	0	0	0
8	1997	0	0	0	0	0	0	0
9	1998	0	0	0	0	0	0	0
10	1999	0	0	0	0	0	0	0
11	2000	0	0	0	0	0	0	0
12	2001	7272	0	7272	0	0	0	-7272
13	2002	0	0	0	0	0	0	0
14	2003	41962	0	41962	0	0	0	-41962
15	2004	75981	0	75981	0	0	0	-75981
16	2005	89205	0	89205	0	0	0	-89205
17	2006	28624	523	29147	0	0	0	-29147
18	2007	85063	523	85586	0	0	0	-85586
19	2008	72533	523	73056	0	0	0	-73056
20	2009	32766	855	33621	0	0	0	-33621
21	2010	0	1083	1083	380922	4468636	4849558	4848475
22	2011	0	1435	1435	380922	4468636	4849558	4848123
23	2012	0	1435	1435	380922	4468636	4849558	4848123
24	2013	0	1435	1435	380922	4468636	4849558	4848123
25	2014	0	1663	1663	380922	4468636	4849558	4847895
26	2015	0	1815	1815	380922	4468636	4849558	4847743
27	2016	0	1815	1815	380922	4468636	4849558	4847743
28	2017	0	1815	1815	380922	4468636	4849558	4847743
29	2018	0	1815	1815	380922	4468636	4849558	4847743
30	2019	0	1815	1815	380922	4468636	4849558	4847743
31	2020	0	1815	1815	380922	4468636	4849558	4847743
32	2021	0	1815	1815	380922	4468636	4849558	4847743
33	2022	0	1815	1815	380922	4468636	4849558	4847743
34	2023	0	1815	1815	380922	4468636	4849558	4847743
35	2024	0	1815	1815	380922	4468636	4849558	4847743
36	2025	0	1815	1815	380922	4468636	4849558	4847743
37	2026	0	1815	1815	380922	4468636	4849558	4847743
38	2027	0	1815	1815	380922	4468636	4849558	4847743
39	2028	0	1815	1815	380922	4468636	4849558	4847743
40	2029	0	1815	1815	380922	4468636	4849558	4847743
	TOTAL	433406	36700	470106	7618440	89372720	96991160	96521054
NPV	8%	120024	4038	124062	802399	9413029	10215429	10091366
	12%	65934	1538	67472	294960	3460213	3755173	3687701
	15%	42792	784	43577	145682	1709016	1854698	1811122

IRR 0.83675

B/C RATI		
	8%	82.3410
	12%	55.6552
	15%	42.5618

APPENDIX 12



Appendix 12.1 MR12.2 : Land acquisition and Compensation

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

JICA