4.3 Highway

4.3.1 General Description

The geometric design criteria basically follow the "Highway Design Manual" (Volume 1,1994) and the "Highway Design Standards" (Volume 1,1986) in Oman. These Government standards are used to the maximum extent when applicable. Otherwise, American, British and Japanese standards are referred to for items not covered in the above mentioned manual or standards.

4.3.2 Road Classification and Design Speed

The design speeds are based on road classification as shown in Table 4.31.

Table 4.31: Road Classification and Design Speed

Road Classification		Design Speed	Remarks
Highway:	Primary road	120 kph	Route No.1 and No.5
Crossroads:	Primary road	80	Route No.7 and No.9 (sections near R/As)
Crossroads:	Secondary road	80	
Service road:	Local road	60/40	40 kph for curved sections with small radii
Rampway:	Direct connection	80	at Aqr R/A
Rampway:	Diagonal connection	60	Diamond interchange
Rampway:	Outer connection	60/40	40 kph for curved sections with small radii
Roundabout/Turning road		40	Minimum 25 kph

4.3.3 Composition of Cross-section

(1) Highway

The existing cross section is shown in Figure 4.4.

The proposed highway cross section consists of two carriageways each with two 3.75m wide lanes, a 2.0m wide outer shoulder and a 1.2m inner shoulder, and with a 10.0 m wide median in between as shown in Figure 4.5. In the case of the bridge section, additional 0.75 m wide inspection ways are provided on both shoulders.

As the existing old carriageway on Batinah Highway is 7.0 m wide, a transition stretch for width adjustment will be provided joining the existing old carriageway with the proposed one.

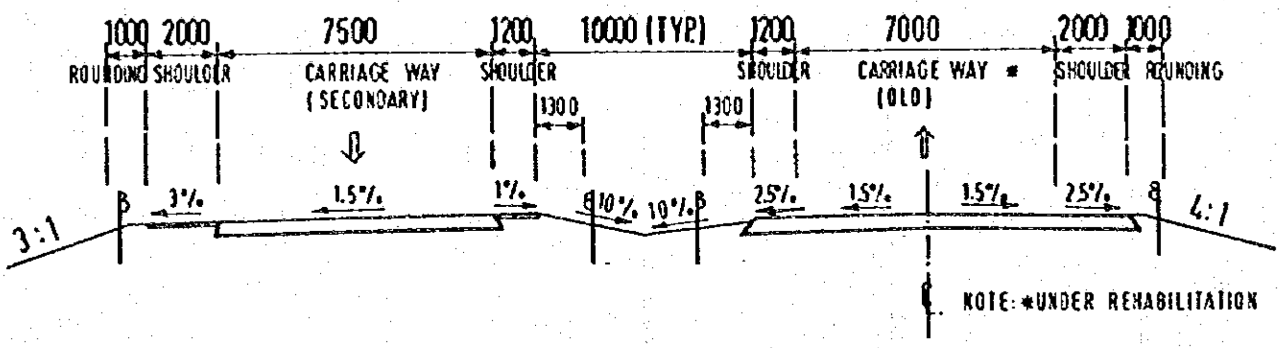


Figure 4.4: Typical Cross-section of Existing Batinah Highway

(2) Crossroads

Crossroads on Batinah Highway can be divided into four types, i.e. urban or rural roads with single carriageways, urban or rural roads with dual carriageways, according to their locations and traffic volumes. The proposed cross-sections for these road types are shown in Figures 4.6 and 4.7. The proposed widths of main cross-sectional items are summarized in Table 4.32.

Table 4.32: Proposed Widths of Main Cross-sectional Items of Crossroads

Road Classification		Carriage-way Width	Shoulder	Sidewalk /Verge	Median
Urban	Single Carriage-way	2 x 3.65 m = 7.3 m	1.0 m	2.0 m	-
	Dual Carriage-way	2 x 3.65 m = 7.3 m	1.0 m (O) 0.6 m (I)	2.0 m	2.0 m
Rural	Single Carriage-way	2 x 3.65 m = 7.3 m	1.0 m	1.5 m	-
	Dual Carriage-way	2 x 3.50 m = 7.0 m	1.0 m (O) 0.6 m (I)	1.5 m or 2.0 m	Vary

Notes : 1. Sidewalk is provided in urban area.
2. (O)= outer , (I) = inner

(3) Service Road

The proposed service road consists of a single carriageway with 3.50m wide lane of each direction and two 1.5m wide paved shoulders as shown in Figure 4.7.

(4) Rampway

The rampways are divided into four types according to number of lanes and type of grade separation. The proposed cross sections for these rampways are shown in Figure 4.8, and widths of main cross-sectional items are shown in Table 4.33.

Table 4.33: Widths of Main Cross-sectional Items for Rampway

Type of GradeSeparation	Number of Lanes	Carriageway	Shoulder	Sidewalk
Rampway at Grade	One	5.0 m	2.0 m (O) 1.0 m (I)	1.5 m or 2.0 m.
	Two	2 x 3.65 m = 7.3 m.	1.0 m.(O) 1.0 m (I)	1.5 m or 2.0 m
Highway at Grade : Bridge	One	5.0 m	2.0 m (O) 1.0 m (I)	-
Highway at Grade : Road	One	5.0 m	2.0 m (O) 1.0 m (I)	-

Notes : 1. The carriageway width is planned considering lane widening on assumed curves.
2. The highway at grade is applied at Aqr R/A
3. A 2.0 m wide sidewalk is provided along the outer shoulder in urban areas.
4. (O)= outer , (I) = inner

(5) Roundabout

The proposed cross-section consists of a single carriageway with two 4.5m-wide lanes, two 1.0m-wide shoulders and a 1.5m or 2.0m-wide sidewalk along both shoulders as shown in Figure 4.6. The carriageway width was planned considering lane widening on assumed curves.

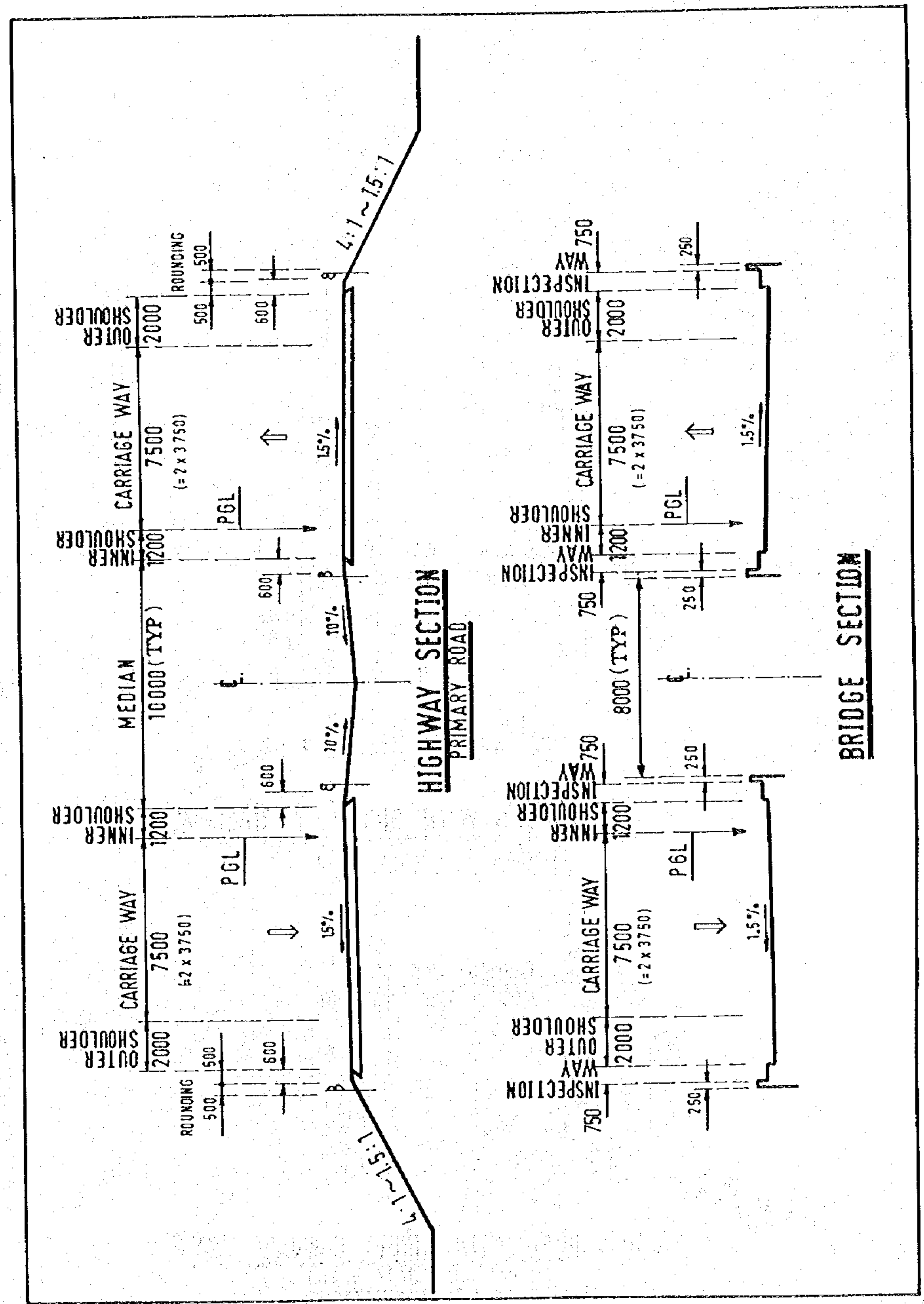


Figure 4.5: Typical Cross-Sectional Details of Proposed Highway and Bridge

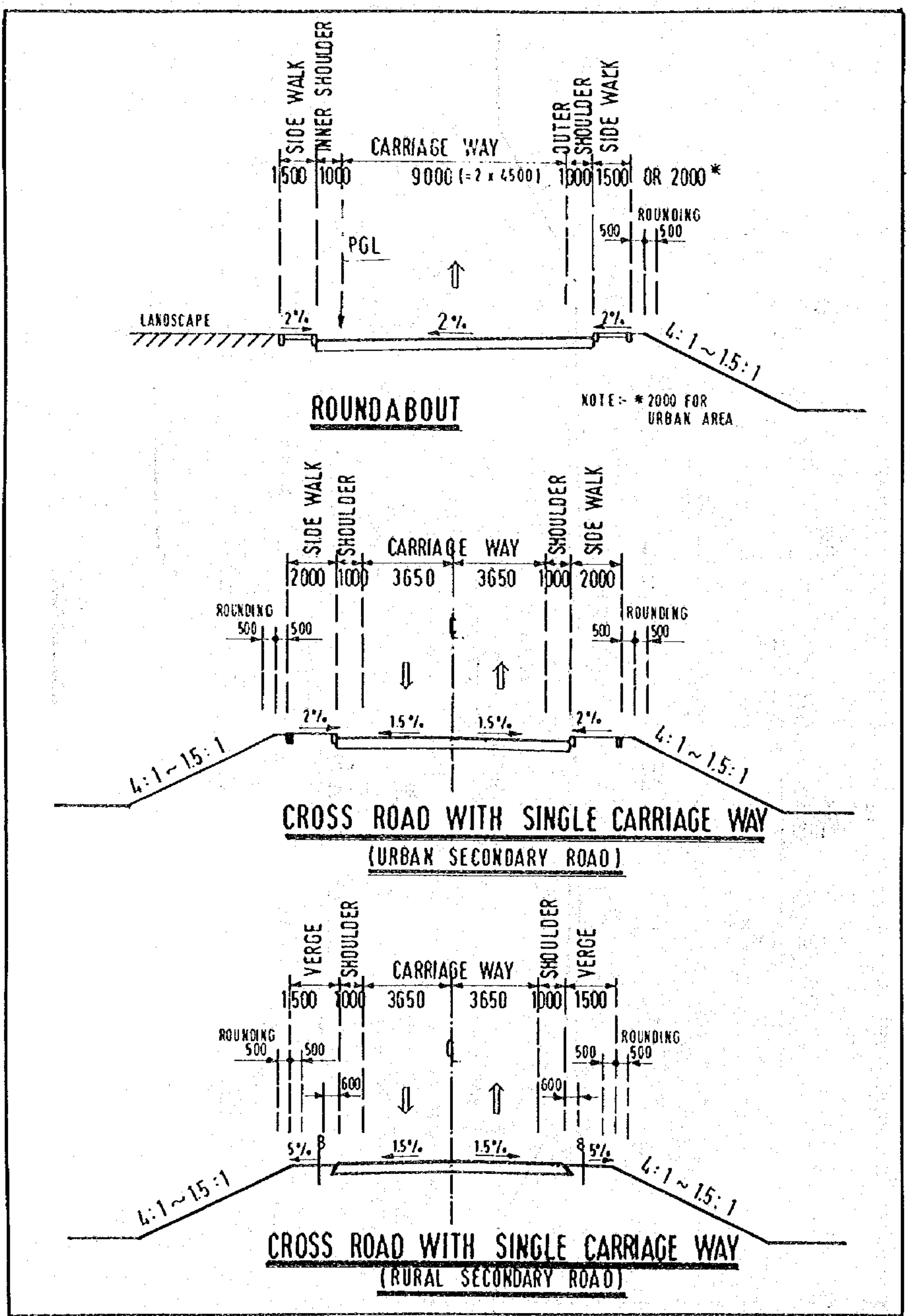


Figure 4.6: Typical Cross-Sectional Details of Proposed Cross Roads and Roundabout

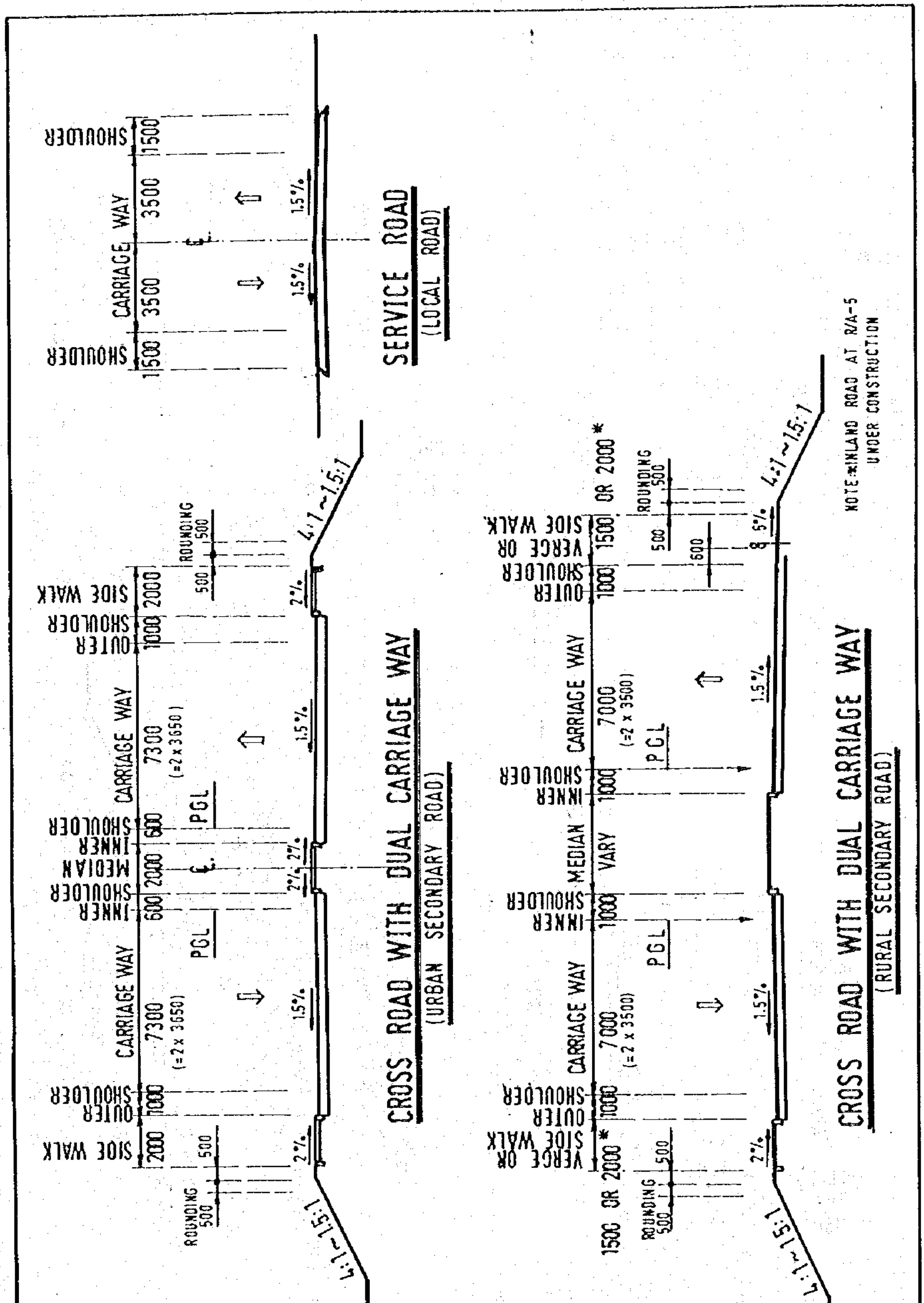


Figure 4.7: Typical Cross-Sectional Details of Proposed Dual Carriageway Cross-Road

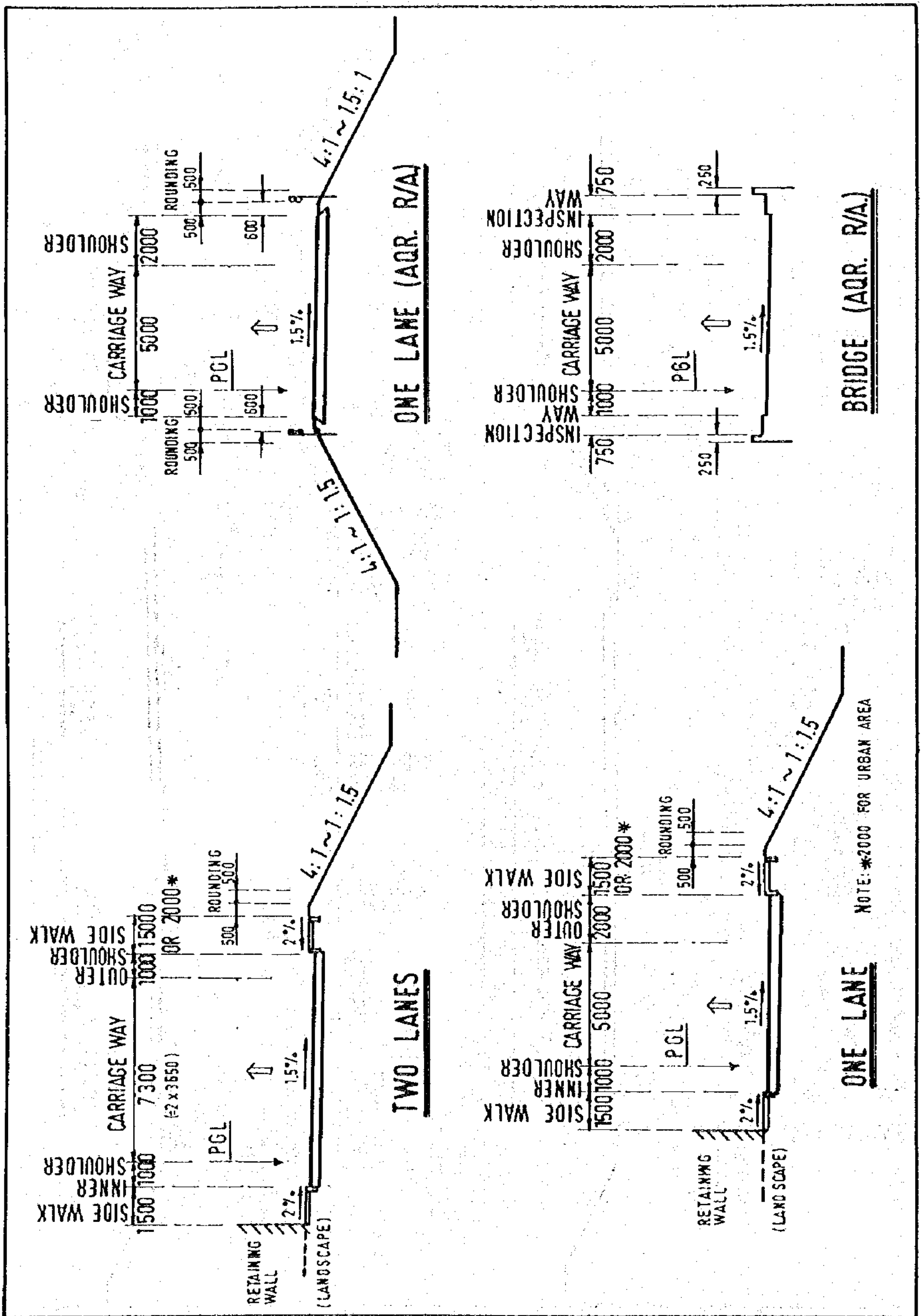


Figure 4.8: Cross-Sectional Details of Proposed Rampways

4.3.4 Elements of Design

(1) Sight Distance

The minimum stopping sight distance of each design speed is shown in the following table. The minimum passing sight distances are also given in the table. These distances are applied to the design of 2-lane roads.

Items	Design Speed			
	120 kph	80 kph	60 kph	40 kph
Min.Stopping Sight Distance (m)	285	140	85	45
Min.Passing Sight Distance (m)	790	510	380	240

(2) Horizontal Alignment

a) Minimum Radius of Curve

The minimum radius of curve is given by the following formula;
$R=V^2/(1.266*(S+100f))$

Where,

R = Radius of curve(m)
V = Design speed(km/h)
S = Percentage superelevation(%)
Desirable max.S=8.0% and proposed max.S=6.0%
f = Side friction factor as shown in the following table.

Item	Design Speed			
	120 kph	80 kph	60 kph	40 kph
Max. Friction Factor	0.10	0.14	0.15	0.17

Therefore, the minimum radius of curves for each speed are shown as bellow;

Items		120 kph	80 kph	60 kph	40 kph
Min.Radius of Curve (m)	S = 8%	630	230	120	50
	S = 6%	710	250	135	55

b) Minimum Length of Curves

The minimum length of curve is twice the length of transition curve obtained from the paragraph (Minimum Length of Transition Curve) in the Highway Design Manual. Therefore, the values for each speed are shown in the following table.

Item	Design Speed			
	120 kph	80 kph	60 kph	40 kph
Min. Length of Curve(m)	200	160	130	90

c) Widening on Curves

It is not necessary to widen the lane width on curves on highways, rampways and roundabouts because the lane widths of these road types have already considered such widening. However, on the crossroads and service roads, such widening are required according to the following:

Lane Width	Radius of Curve		
	50 to 150 m	150 to 300 m	300 to 400 m
3.65 m	0.3 m/lane	-	-
< 3.65 m	0.6 m/lane	0.5 m/lane	0.3 m/lane

d) Minimum Length of Transition Curve

The length of transition curve is given by the following formula;

$$L = V^3/(46.7*q*R)$$

Where,

L = Length of transition curve(m)
V = Design speed(km/h)
q = Rate of increase of radical acceleration(m/s^3)
This value varies between 0.3 and 0.6m/s^3, and the higher values are utilized for shorter transition lengths.
R=Radius of curve (m)

The minimum lengths of transition curves for each speed are shown in the following table, when q = 0.6 and the minimum radius R(8%) are applied.

Item	Design Speed			
	120 kph	80 kph	60 kph	40 kph
Min. Length of Transition Curve(m)	100	80	65	45

e) Minimum Radius without Transition Curve

It is not significant to provide a transition curve when the shift reaches approximately 0.3m as practiced in Britain. (0.2m in Japan). In such cases, the minimum radius is calculated using the following formula:

$$S=1/24*L^2/R$$

Thus, $R=1/7.2*L^2$

Where,

S = Length of shift (0.3m)
L = Length of transition curve (m)
R = Radius of curve (m)

The minimum radii without transition curves for each speed are derived and shown in the following table where L is the minimum value.

Item	Design Speed			
	120 kph	80 kph	60 kph	40 kph
Min. Radius without transition curve(m)	1400	900	600	300

(3) Vertical Alignment

a) Maximum Gradient

The maximum gradients for each speed in level terrain are shown in the following table.

Item	Design Speed			
	120 kph	80 kph	60 kph	40 kph
Max. Gradient(%)	3	5	6	6

When gradient exceeds 2% and the length more than 500m, an additional lane must be provided.

b) Minimum Vertical Curve Length

The minimum vertical curve length is determined from the following formula;

$$L=K*A$$

Where,

L = Curve length(m)
K = Design speed related coefficient

(chosen from the following table)
A = Algebraic difference in grades(%)

Item	Design Speed			
	120 kph	80 kph	60 kph	40 kph
Min.Crest K Value	100*	33**	11.5	4
Min. Sag K Value	47	24	13	5.5

Notes: * The min.Crest K value of 100 for 120 kph is adopted in this study for the following reasons.

- The value is 94 in the former 1984 design standards.
- K = 200 mentioned in the Standards is the up limit judging from AASHTO where K is 88 to 164 for 112 kph.
- K = 100 and K=110 are commonly applied in Britain and Japan respectively.
- It is economical to apply the lower value because of shorten bridge and retaining wall length.

**The min. Crest K of 33 for 80 kph is adopted in this study for the following reasons.

- The value is 31 in the former 1984 design standards.
- K=49 mentioned in the Standards is the up limit judging from AASHTO where is 33 to 48 for 88 kph.
- K=30 is commonly applied in Britain (85 kph) and Japan (80 kph)
- It is economical to apply the lower value.
- The lower value is applied at R/A-18 to obtain smaller land acquisition.

(4) Crossfall

a) Normal Crossfall

The normal crossfall of 1.5% is applied on a straight road section from the crown on a single carriageway, and from the edge of the inner shoulder of a dual carriageway towards the edge of the outer shoulder due to the following reasons:

- The old carriageway of the existing highway has a 1.5% crossfall from the center towards the edge of the carriageway.
- The new carriageway of the existing highway has a 1.5% crossfall from the inner edge of carriageway towards the outer edge of the carriageway.
- A 1.5% crossfall follows the former 1984's design standards, although the new design standards has a 2.0% crossfall.
- When a crossfall of a carriageway and a shoulder is the same, it is easy to construct.

- A smaller crossfall is more desirable for vehicle travel, as long as there are no problems in drainage.

A crossfall of 2.0% is applied to the sidewalk towards the carriageway.

b) Superelevation

The percentage of superelevation required is derived from;

$$S=V^2/(2.828*R)$$

Where,

S = Percentage superelevation (%)
V = Design speed (km/h)
R= Radius of curve(m)

The proposed maximum superelevations are 6% for roads and 2% for roundabouts due to the following facts:

- 8% is the maximum value in the 1984 design standards.
- It is common practice to utilize a lower rate of superelevation, usually 4% to 6%.
- A lower maximum rate of superelevation or no superelevation is employed within an intersection area or where there is a tendency to drive slowly because of turning and crossing movements.

c) Minimum Radius for Normal Crown Section

The minimum radius of normal crown section (1.5%) is given by the following formula;

$$R=V^2/(1.266*(S+100f))$$

Where,

S = -1.5%
f = 0.030 (Reference to AASHTO)

The values applicable for each speed are shown in the following table.

Item	Design Speed			
	120 kph	80 kph	60 kph	40 kph
Minimum radius of curve (m) S = 1.5%	7600	3400	1900	850

d) Superelevation Run-off

The rates of a superelevation run-off vary by the location of a profile grade line (PGL). The PGL for each type of road is shown in the following table.

Type of Road	Location of PGL
Divided Highway and Crossroads with Dual Carriageway	Inner Edge of Carriageway
Undivided Crossroads with Single carriageway	Center of Carriageway
Rampway with 2-lanes and 1-way	Right Edge of Carriageway
Rampway with 1-lane and 1-way	Right Edge of Carriageway

The rates of a superelevation run-off for each type of road and for each speed are given in the former 1984 design standards, AASHTO and Japanese standards as shown in the following table.

Type of Road	Design Speed			
	120 kph	80 kph	60 kph	40 kph
Divided Highway and crossroads	1/200	1/150	1/125	-
Undivided crossroads	-	1/200	1/175	1/150
Rampway with 2 lanes	-	1/150	1/125	1/100
Rampway with 1 lane	-	1/200	1/150	1/100

The length of a superelevation run-off is given by the following formula;

$$Ls = B * I / q$$

Where,

Ls = Length of Run-off(m)
(i.e. Required Length of Transition Curve)
B = Width between Rotation Axis (i.e. PGL) and Edge of Carriageway(m)
I = Absolute Value of Algebraic Difference in Superelevation(m/m)
q = Rate of Superelevation Run-off(m/m)

e) Maximum Combined Gradient

The combined gradient is derived from the following formula;

$$S = (I^2 + j^2)^{0.5}$$

Where,

S = Combined gradient(%)
I = Crossfall or superelevation(%)
j = Longitudinal gradient(%)

The maximum combined gradient for all speeds is 10% in compliance with the new Highway Design Manual standards.

(5) Clearances

The limits of horizontal and vertical clearances of the proposed flyovers are illustrated in Figure 4.9. The vertical clearance height is taken as 5.7m considering the minimum clearance height and an overlay of zoom in the future.

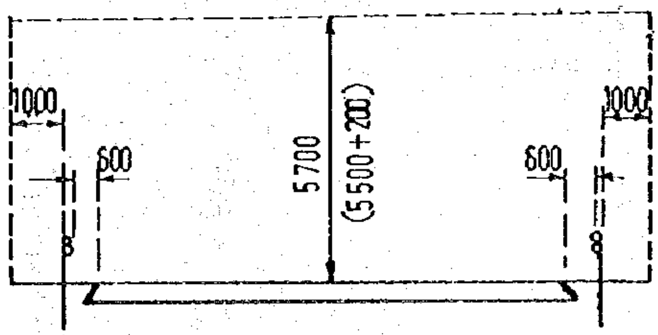


Figure 4.9: Vertical and Horizontal Clearances of Proposed Flyovers

(6) Summary of Road Geometric Design Criteria

The summary of road geometric design criteria is shown in Table 4.34.

Table 4.34: Summary of Road Geometric Design Criteria

ITEM	UNIT	DESIGN SPEED (km/h)			
		120	80	60	40
TERRAIN		Level	Level	Level	Level
SIGHT DISTANCE					
Min.Stopping Sight Distance	m	285	140	85	45
Min.Passing Sight Distance	m	790	510	380	240
HORIZONTAL ALIGNMENT					
Min. Radius of Curve	m	630	230	120	50
Min. Length of Curve	m	200	160	130	90
Min. Length of Transition Curve	m	100	80	65	45
Min. Radius without Transition Curve	m	1,400	900	600	300
VERTICAL ALIGNMENT					
Max. Gradient	%	3	5	6	6
Critical Length of Gradient	m	500	500	500	500
Min. K on Crest (VCL=KA)	m	100	49	11.5	4
Min. K on Sag (VCL=KA)	m	47	24	13	5.5
CROSSFALL					
Normal Crossfall	%	1.5	1.5	1.5	1.5
Max. Superelevation	%	8(6)	8(6)	8(6)	8(6)
Min. Radius for Normal Crown Section	m	7,600	3,400	1,900	850
Max. Rate of Superelevation Run-off					
Divided Road with Dual Carriageway	m/m	1/200	1/150	1/125	---
Undivided Road with Single Carriageway	m/m	---	1/200	1/175	1/150
Rampway with 2-Lanes	m/m	---	1/150	1/125	1/100
Rampway with 1-Lane	m/m	---	1/200	1/150	1/100
Max.Combined Gradient	%	10	10	10	10

Note : The value in ( ) indicates the proposed ones.

(7) Circular Roundabout

The circular roundabout geometric design criteria is summarized as shown below, and the geometric parameters are illustrated in Figure 4.10.

a) Entry width (e)

Add at least one but not more than two extra lane widths at entry.
Maximum 10.5m for single carriageway approach roads.
Maximum 15.0m for dual carriageway approach roads.

b) Approach half width (v)

Between 2.0m and 7.3m.

c) Average effective flare length (l')

Maximum 100 m.
Minimum 5m (urban).
25m gives good design for rural situations.
Total length of entry widening is approximately 2l'.

d) Sharpness of flare (S)

S = 1.6*(e-v)/l'
Between 0 and 2.9.

e) Entry angle (ϕ)

Between 20 and 60, but 30 is best.

f) Entry radius (r)

Between 6m and 100m.
20m provides good practical design.
If a lot of heavy vehicles, (r) not less than 10m.

g) Inscribed circle diameter (D)

Not less than 28m (not less than 40m for heavy goods vehicle).

h) Circulatory carriageway around roundabout

Width constant. Width 1.0-1.2 times greatest entry width.
Maximum 15m.

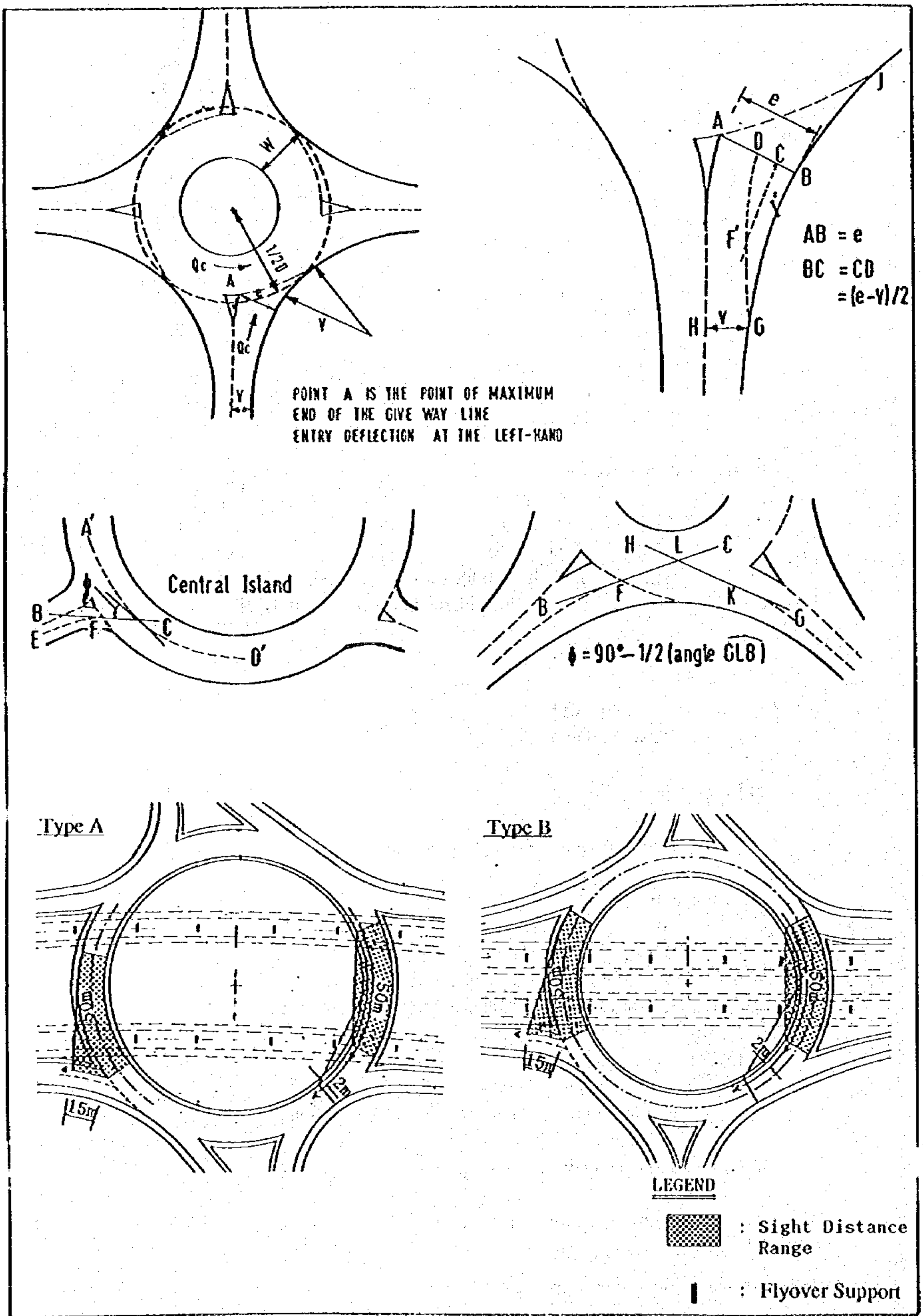


Figure 4.10: Geometric parameters and Visibility of Roundabout

i) Exit

Exit near side curb radius about 40m at mouth, but not less than 20m or greater than 100m. Exit wider at the beginning than width of downstream link.

j) Visibility: See Figure 4.10.

k) Pedestrian crossing

Pedestrian crossing points are preferably set back at least 15m from ICD line. The minimum width of crossing is 2.4m.

(8) Elliptical Roundabout

There is no details of the elliptical roundabout geometric design criteria in the standards mentioned at chapter 4.3.1. Consequently the following geometric parameters are derived from the reconnaissance of existing elliptical roundabouts and the analysis of the as-built drawings.

a) Entry width
Same as the circular roundabout.

b) Approach half width(v)
Same as the circular roundabout.

c) Entry radius(r)
See Figure 4.11

d) Entry angle
Not less than 10m.

e) Exist radius(r)
See Figure 4.11.

g) Exist angle
Not less than 20m.

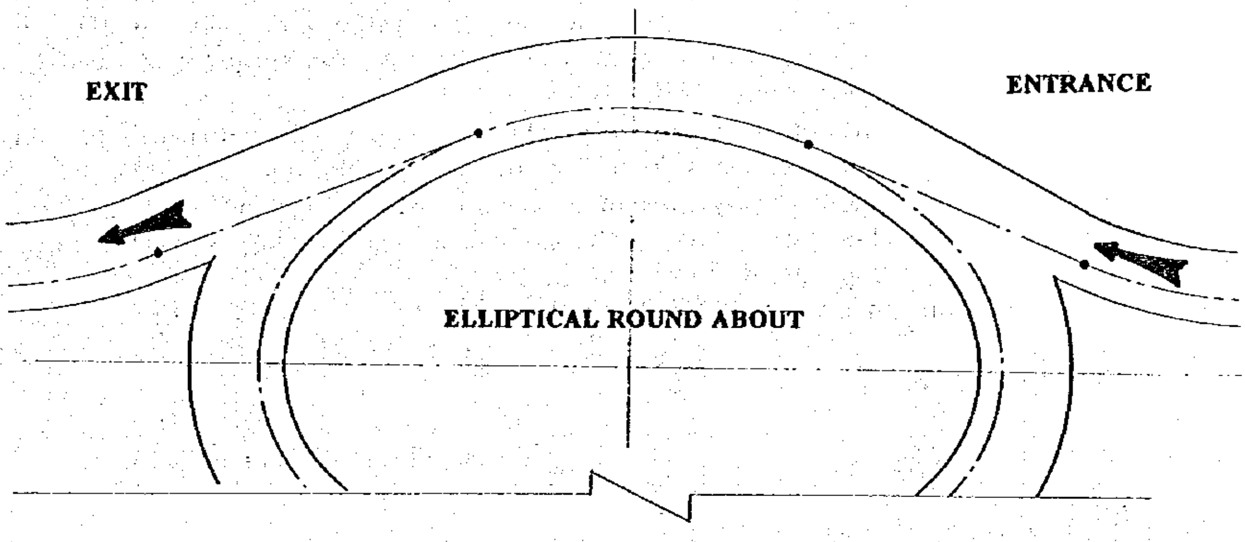


Figure 4.11: Entry and Exist Details for Elliptical Roundabout

(9) Segregation for right turning traffic

Segregation lanes for right turning traffic are provided where more than 50% of vehicles entering the roundabout are right-turning traffic. According to the results of traffic survey, it is necessary to provide this exclusive right-turn lane at the junction of the inland crossroads with the roundabout at Al Muladdah R/A towards Muscat, and at Sohar R/A from Muscat towards Sohar city area.

(10) Diverge/Merge at Grade-Separation

The terminal of a ramp is the portion adjacent to the through traveled way, including speed-change lanes, tapers, and islands. At the above portion, the ramp traffic diverges from or merges with high-speed through traffic.

Speed-change lanes are designed in two general forms, the taper type and the parallel type. The new 1994 Highway Design Manual uses the taper type for exits and the parallel type for entrances. The types of diverge or merge lanes in this project are classified as shown below on reference to the 1994 standards.

- Diverge(Parallel Type)
  Type D1/2 : 1 lane diverge, 2 lane mainline
  Type D2/2 : 2 lane diverge, 2 lane mainline
  The parallel type is applied in order to reduce the land acquisition area and to maintain the smooth traffic flow.

- Merge
  Type M1 : 1 lane merge , 2 lane mainline
  Type M4 : 2 lane merge , 2 lane mainline
  M4 is the proposed type considering the following matters;
  - An additional lane is provided to the downstream of a through way in the case of 2 lane merge according to the Highway Design Manual standards (M3). However, the traffic capacity of Batinah Highway with two lanes in each direction is sufficient to meet the demand of the traffic volume.
  - According to AASHTO standards, the minimum length of an auxiliary lane is 762m from the merging end. It is not economical to adopt this style due to the long construction site required.
  - The traffic demand volume of a ramp is slightly higher than the traffic capacity of a ramp with one lane.

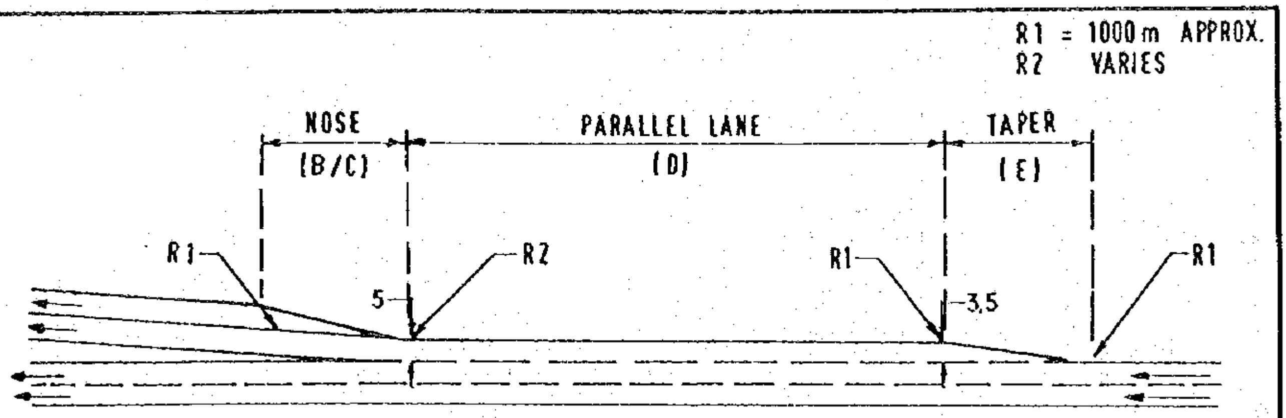
The requirements of above geometric design are illustrated in Figure 4.12.

(11) T-Junction

The requirements of geometric design for T-junction are illustrated in Figure 4.13.

(12) Bus Lay-By Layout

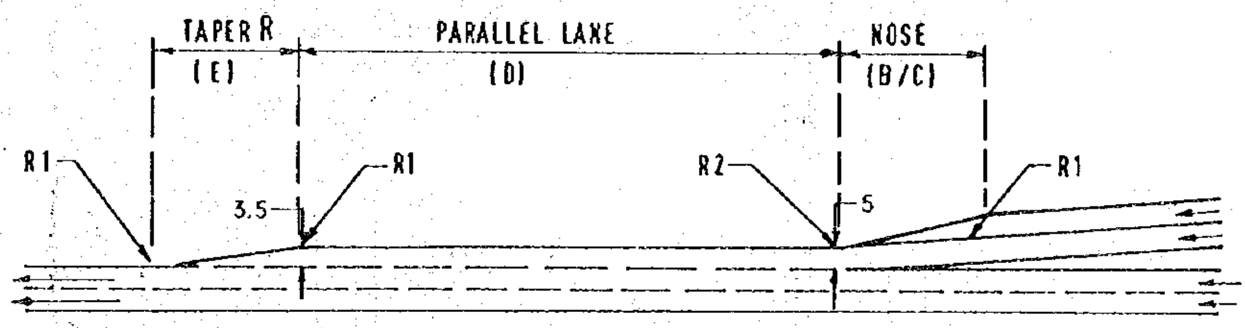
The requirements of geometric design for bus lay-by are illustrated in Figure 4.14.



MAINLINE	MINIMUM ANGLE NOSE TAPER (B)	NOSE LENGTH m (C)	MINIMUM PARALLEL LANE LENGTH m (D)	LENGTH OF PARALLEL LANE TAPER m(E)
RURAL DUAL CARRIAGEWAY DESIGN SPEED 120 km/h	1 : 15	80	95	75

NORMAL DIVERGE

(TYPE D1/2 - 1 LANE DIVERGE. 2 LANE MAINLINE)
(TYPE D2/2 - 2 LANE DIVERGE. 2 LANE MAINLINE)

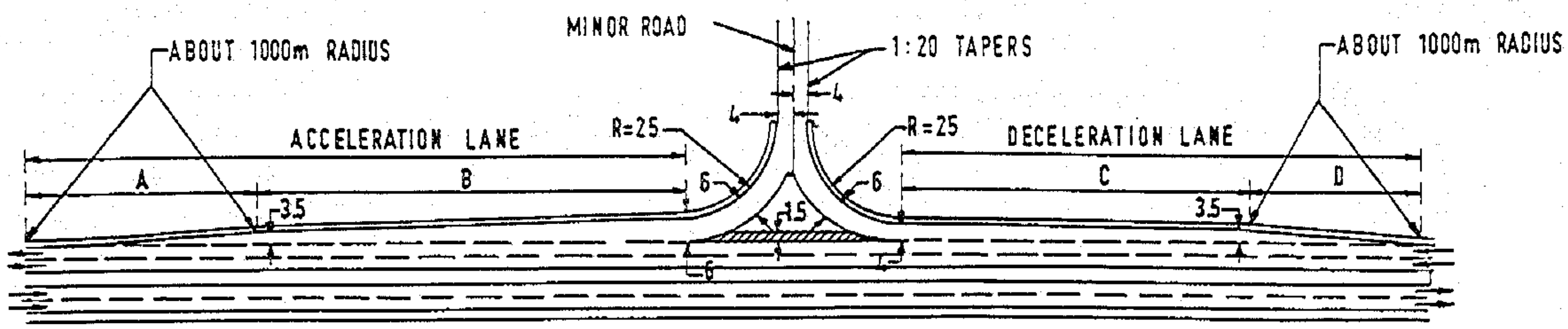


MAINLINE	MINIMUM ANGLE NOSE TAPER (B)	NOSE LENGTH m (C)	MINIMUM PARALLEL LANE LENGTH m (D)	LENGTH OF PARALLEL LANE TAPER m(E)
RURAL DUAL CARRIAGEWAY DESIGN SPEED 120 km/h	1 : 40	115	230	75

NORMAL MERGE

(TYPE M1 - 1 LANE MERGE. 2 LANE MAINLINE)
(TYPE M4 - 2 LANE MERGE. 2 LANE MAINLINE)
NOTE: M4 IS THE PROPOSED TYPE.

Figure 4.12: Diverge and Merge for Grade Separation



DESIGN SPEED OF MAIN ROAD (km/h)	LENGTH (m)			
	ACC. LANE		DECEL. LANE	
	A	B	C	D
60	60	40	40	60
80	70	140	50	70
100	90	280	80	80
120	100	370	90	100

NOTES:

1. DIMENSIONS ARE IN METRES
2. IF NO OPENING IS PROVIDED IN THE MEDIAN, PROVISION MUST BE MADE TO ALLOW VEHICLES TO TURN AROUND AT NEARBY ROUNDABOUTS OR GRADE SEPARATED INTERCHANGES. WHERE TURNING FLOWS ARE SMALL (<400 AADT) U-TURNS MAY BE USED, PROVIDED GENEROUS SIGHT LINES ARE AVAILABLE.
3. U-TURNS SHOULD NOT BE USED ON DUAL 3 LANE ROADS

PRIORITY JUNCTION WITH HIGH FLOWS ON MINOR ROAD

Figure 4.13: Junction Details

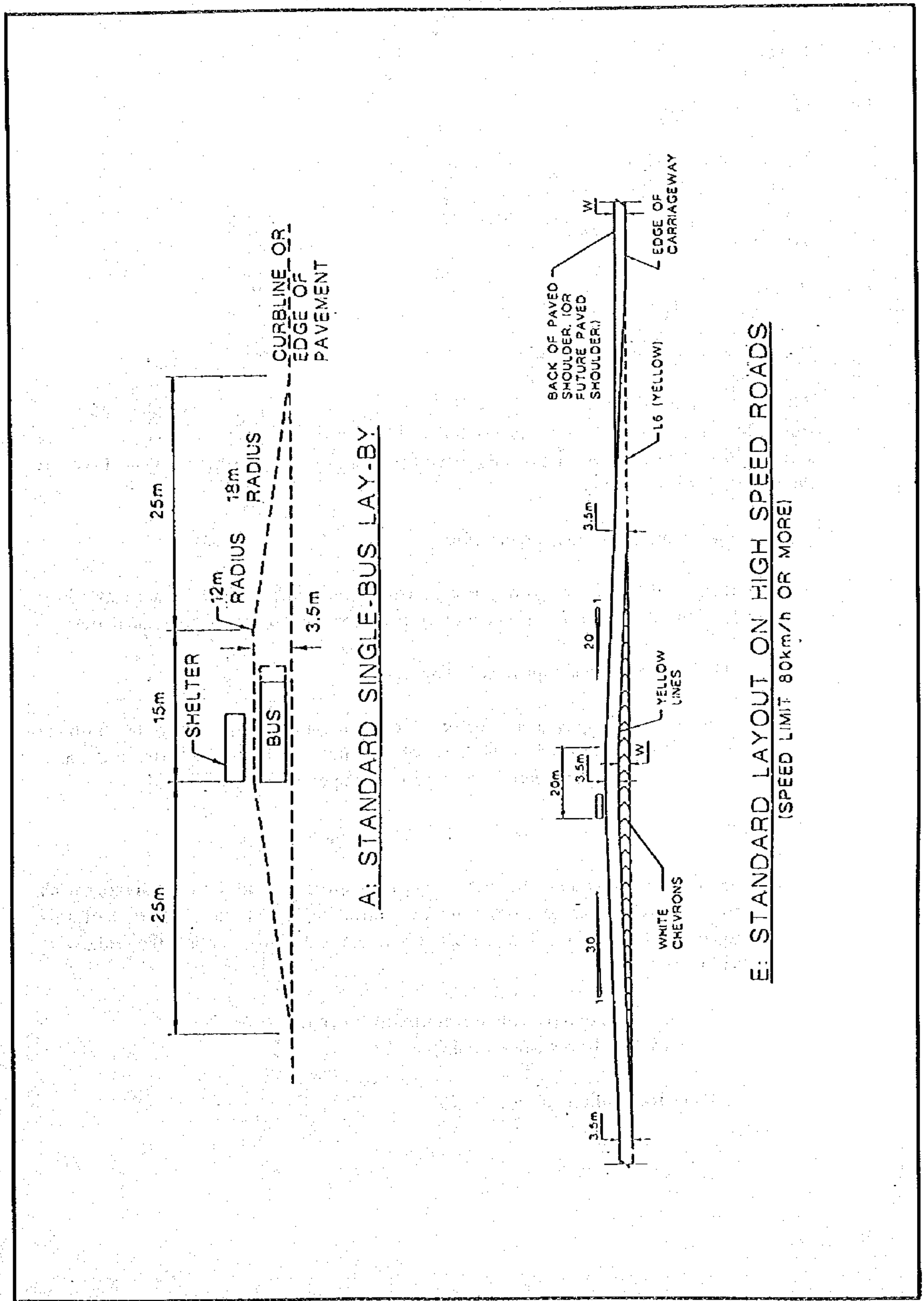


Figure 4.14: Bus Lay-By Layout

4.4 Pavement

4.4.1 General Description

The pavement design follows the Highway Design Manual (Pavement, Volume 1, 1994) based on AASHTO Interim Guide for Design of Pavement Structures 1972. The type of pavement to be adopted for this Study will be the asphalt pavement which is commonly used in Oman.

4.4.2 Elements of Design

(1) Roadbed Soils

The required numerical figures are the CBR value of subgrade and those values obtained from physical tests of material for granular subbase and aggregate base course. These values will be derived from the results of soil tests and the analyses of collected data at the first stage of this study.

(2) Equivalent Single Axle Load (ESAL)

The mixed traffic must be converted into an equivalent number of 18kip single axle load (18kip= 1,800lb =8,200kg). The procedure for accomplishing this conversion includes:

- Derivation of Load Equivalence Factors

There are load equivalence factors for each kind of axle under the terminal serviceability index 2.5 in the Manual. The index is a number between 0 and 5 which is based on a subjective assessment of the condition of the road.

- Conversion of Mixed Traffic to ESAL Applications

The daily traffic volume, the vehicle type composition and the growth rate for all classes of vehicle are derived from the traffic survey at the first stage of this project. Subsequently, the design ESAL is calculated under the following conditions.

* The design life of a pavement is normally 20 years.
* The ESAL for heavy truck is taken as 1.5.

- Lane distribution considerations

The distribution factor for each lane is shown in the following table.

Number of lane	Distribution Factor(%)
1	100
2	80 - 100
3	60 - 80

(3) Regional Factor

The regional factor is different depending on the weather conditions and subsoil drainage conditions. The factor in Batinah region is taken as 0.8.

(4) Structural Number (SN)

The structural number is derived from the chart in Figure 4.15.

(5) Combination of Layer Thicknesses

The given structural number should satisfy the SN derived from the following formula:

$$SN = a1*D1+a2*D2+a3*D3$$

where,

SN = Structural number for the total pavement
a1,a2,a3 = Layer coefficients for wearing course, base course and subbase materials respectively. There are these coefficients in the manual
D1,D2,D3 = Thickness of each layer in centimeter.

The minimum thickness of each layer is 50 mm for wearing course, 100 mm for base course and 150 mm for subbase. In addition, the subbase may be omitted where CBR of the subgrade is greater than 25%.

(6) Reference Drawings for Pavement Structure

The reference drawings for pavement structure are as followings and shown in Figure 4.16. These are:

- The typical pavement structure of highway .
- The pavement structures of Batinah Highway, crossroads and service road at the recently completed A'Naseem Garden R/A.

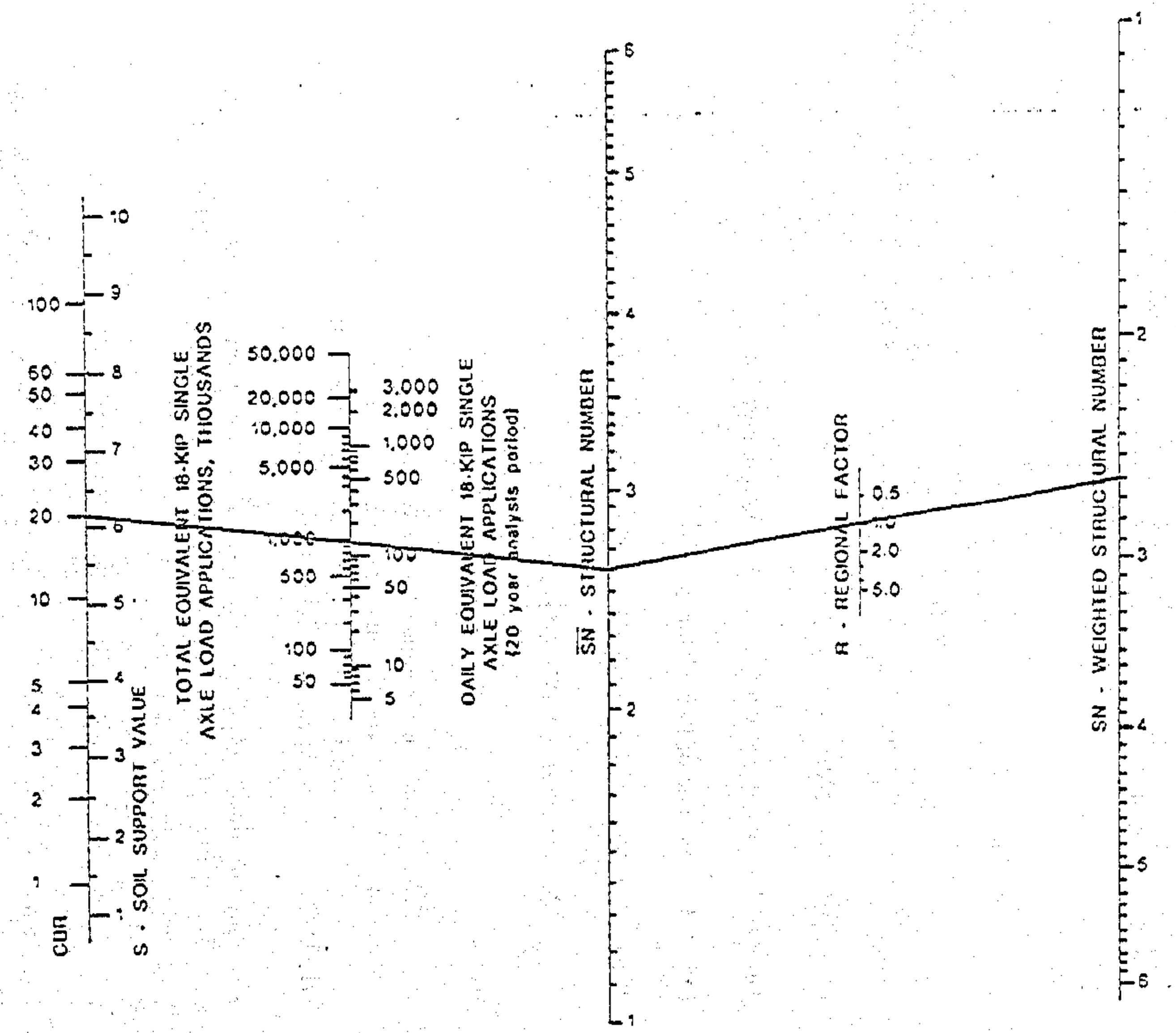


Figure 4.15: Chart For the Derivation of Structural Number of Pavement (SN)

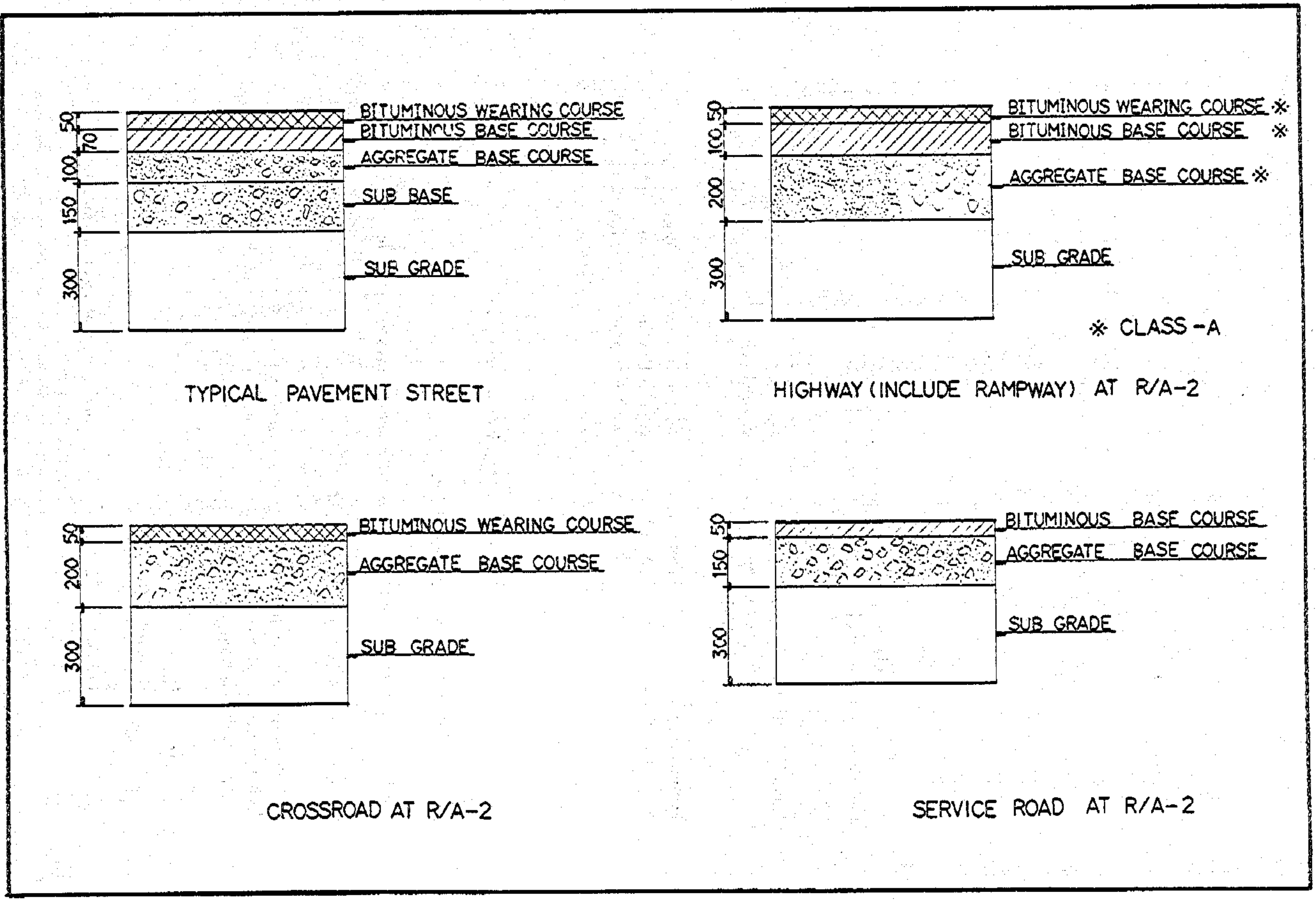


Figure 4.16: Pavement Details of Existing Batinah Highway

4.5 Drainage

4.5.1 General Description

The drainage design basically flood the new Oman Highway Design Manual standards. Drainage design consists of catchment discharges, open channels, Irish crossings and Irish Bridges, culvert, roundabout drainage and median drainage. The methods of each design and factors to be considered are mentioned here.

4.5.2 Hydraulic Method

(1) Flood Frequency

The following table shows the minimum flood frequencies to be accommodated in particular situations without damage to the road or drainage structure, or disruption to traffic.

Road Classification	Culverts, Irish Crossings & Irish Bridges	Channels & Ditches	Storm Sewer System
Primary Road	once in 50 years	once in 10 years	once in 5 years
Secondary Road	once in 50 years	once in 10 years	once in 5 years
Local Road	once in 20 years	once in 10 years	once in 5 years

(2) Catchment Discharges

There are two ways to calculate the discharge by catchment areas.

a) Catchment Area Greater Than 10 km^2

The discharge is derived from the Flood Frequency Curves as shown in Figure 4.17.

b) Catchment Area Less Than 10 km^2

The discharge value is derived from the rational method as shown below. This value should be compared against the value by using method above, and the lesser of the two discharge values is used for design purposes.

$$Q = 0.278*C*I*A$$

where,

Q = Peak discharge at the catchment outlet/road intersection (m^3/s)

C = Run-off coefficient as shown in the manual

I = Rainfall intensity for a specific frequency of storm (mm/h) as shown in Figure 4.18.

A = Catchment area contributing to the flow (km^2)

The time of concentration adopted to obtain [I] is derived from the Kirpich formula:

$$Tc = 0.0195 * L^{0.77} * S^{-0.385}$$

where,

Tc = Time of concentration (minutes)

L = Catchment main stream length (m)

S = Mainstream slope (m/m)

(3) Open Channels

An open channel is a man-made or natural channel (i.e. ,wadi) in which water flows with an uncovered surface. The existing open channels may have to be diverted in some places due to the grade separation plans.

The Manning Equation for open channel analysis is adopted as shown below.

$$Q = A * R^{2/3} * S^{0.5} / n$$

where,

Q = Discharge (m^3/s)

A = Cross-section of flow area (m^2)

n = Manning's roughness coefficient as shown in the manual

R = Hydraulic radius (A/WP where WP is the wetted perimeter of flow area (m))

S = Slope of channel bed (m/m)

(4) Irish Crossings and Irish Bridges

Within the scope of this study, Irish crossings will be those sections of the service roads with scouring protection provided on the bed of wadi, while Irish bridges will be the Irish crossings with box culverts on the highway section.

The detailed design of the above will consist of re-construction of Irish crossings and the extension of box culverts. The scouring protection is secured by means of riprap. The note of this design is to determine the potential scouring depth (D) and the width of downstream protection required (W). These can be determined by the following:

$$d_{max} = Z * [q^2 / Fbo]^{0.33}$$

where,

Z = Factor accounting for the local flow pattern,
Nose of bank or spur : 2.0 - 2.75
Flow at right angles to bank : 2.25
Flow parallel to bank : 1.5 - 2.0

q = Local discharge intensity (m^3/s / m width)

Fbo = Zero bed factor from figure specified in the design standards

d_{max} = maximum scouring depth measured from water level (m)

then, $D = d_{max} - Y$

where,

Y = water depth (at time of scour) (m)

Hence width of apron W = 2.236*D (m)

(5) Culvert

This study will introduce design for some new culverts and extension of many existing culverts. The detailed designs are carried out considering the following conditions:

— Standard sizes for concrete pipe culverts range from 600 mm to 1,050 mm diameter with increments of 150 mm.
— Box culverts vary in span from 1,000 mm to 4,000 mm with a maximum height of 4,000 mm. MOC has published standard structural culvert details for the above range of sizes related to the height of overburden.
— Two basic types of flow characteristic influence the potential discharge of a culvert. The flow is controlled at the culvert inlet or at the culvert outlet. These matters arementioned in details in the Omani Highway Design Manual.

(6) Roundabout Drainage

The catch pits are planned at the small ditch along the edge of a roundabout.

(7) Median Drainage

The median catch pit is provided at the following locations.

- Low point (except Irish Crossings)
- 250 m from high points and Irish Crossings
- 250 m maximum centers elsewhere.

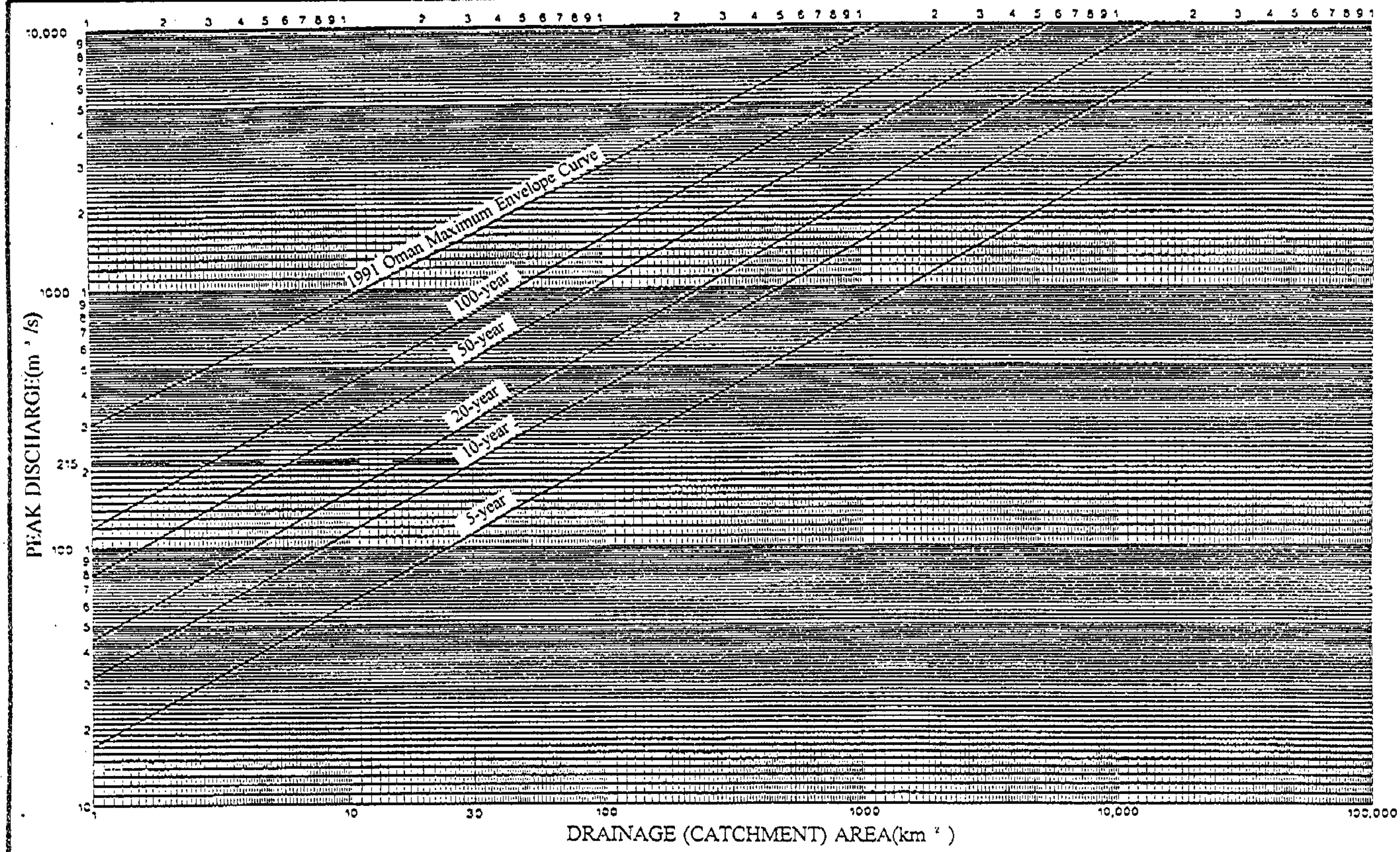


Figure 4.17: Flood Frequency Curves (A>10km2)

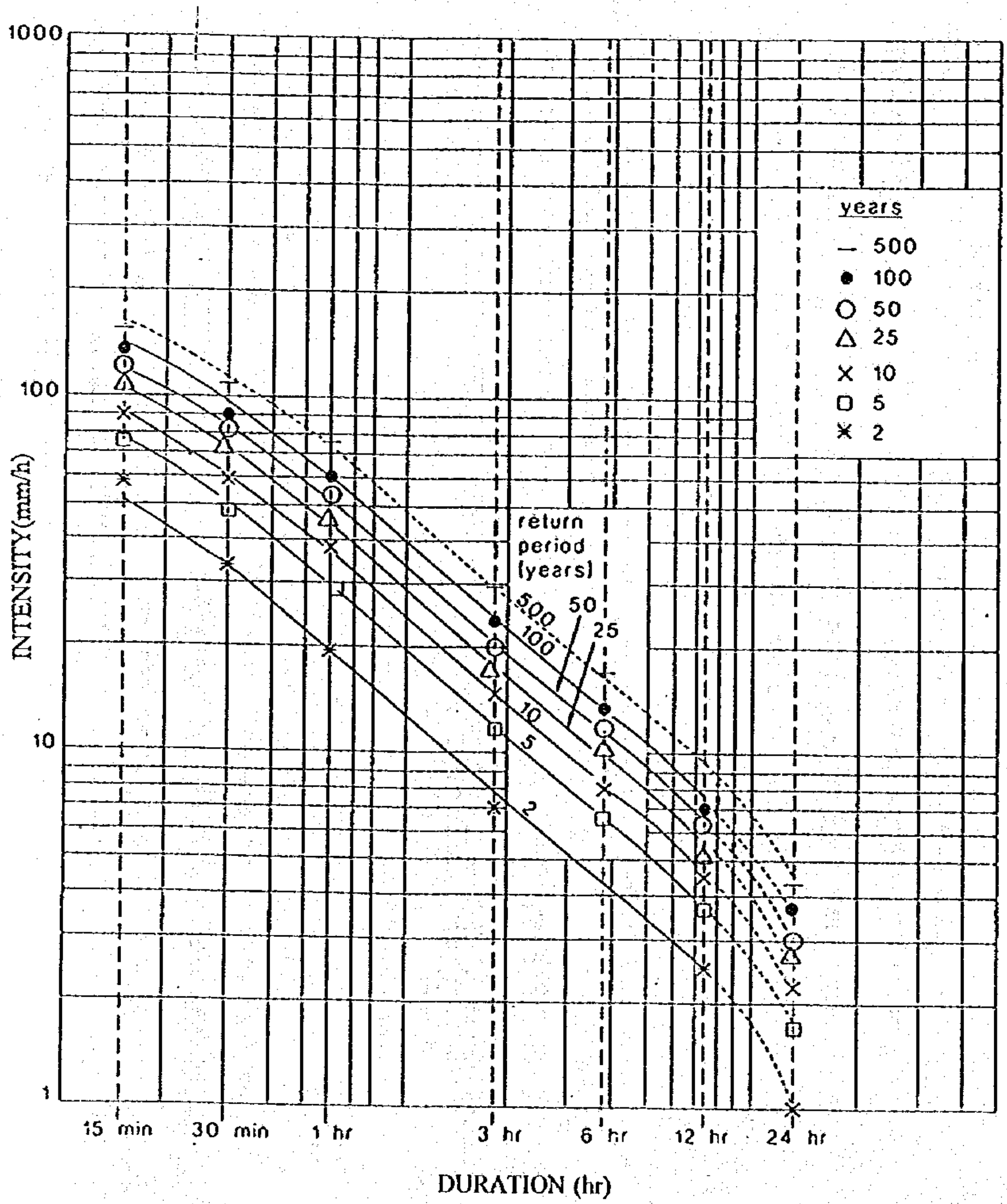


Figure 4.18 : Intensity-Duration -Frequency Relationship(A<10km2)

4.6 Road Facilities Standard

4.6.1 General Description

The road facilities design follows the new 1994 Highway Design Manual. The road facilities related to this project consist of safety barriers, traffic signs, road markings, delineators, street lighting and landscaping. This section discusses the scope of works and the matters to be decided in the design of these facilities.

4.6.2 Elements of Road Facilities

(1) Safety Barriers

The safety barriers are provided at the outer edges of certain highway sections and median under the following conditions:

— Sections where the embankments are higher than 3m.
— Other embankment areas where there is a potential hazard due to large culverts and so on.
— At obstructions such as bridge piers.
— In medians 11m wide or less where there are no curbs.
— In the median where there are lighting posts.

The type of barrier to be provided will normally be;
- W-beam (weak post) Type A in medians.
- Blocked out W-beam (strong post) Type C in verges

(2) Traffic Signs

Traffic signs will consist of information signs, warning signs, regulatory signs and supplementary signs for warning or regulatory signs. Most of the traffic signs applicable in Oman are given in the new Highway Design Manual. These signs are given specific identification numberings. In this design study, therefore, these standard specification numberings will be used to specify the type of traffic signs recommended. As for information signs, only English will be used and Arabic writings will not be included in the design drawings.

(3) Road Markings

Road markings will also include road studs. There are many road marking types with a specific identification number given in the design standards. When applicable, this numbering system may be used in the design drawings to designate the recommended type of markings.

(4) Delineators

Delineators consist of light reflective markers attached to guardrails, common delineators and Irish crossing markers. These different types of delineators will be used in the design.

(5) Street Lighting

The design for street lighting will be studied considering existing conditions. However, certain details such as electric cable arrangement or specifications of lighting post will not be included in this project. Hence, the location and the structure of service ducts are designed

(6) Landscaping

The conceptual design of landscaping will be proposed for each roundabout. However, the details for monument and public installations which are normally undertaken by Muscat Municipality or the Ministry of Regional Municipalities and Environment will not be included in this project.

CHAPTER 5

CALCULATION ANALYSIS
FOR BRIDGES AND HIGHWAY

CHAPTER 5 CALCULATION ANALYSIS FOR BRIDGES AND HIGHWAYS

5.1 Calculation Analysis for Bridges and Structures

5.1.1 Superstructure

(1) General Conditions

BRIDGE TYPE-A

Bridge type : Simple multi-hollow beam bridge
Girder type : Post-Tensioned Prestressed Concrete Hollow Girder

Girder length :	25.900m	31.900m	34.900m
Span length :	25.100m	31.000m	34.000m

Bridge width : 12.700m
Carriageway width : 7.500m
Live load : Special Truck B1, AASHTO increased 100%

BRIDGE TYPE-B

Bridge type : Three span continuous bridge
Girder type : Post-tensioned prestressed concrete 1-box 2-cell girder
Girder length : 29.9m+29.9m+29.9m
Span length : 29.5m+30.0m+29.5m
Bridge width : 10.000m
Carriageway width : 5.000m
Live load : Special Truck B1, AASHTO increased 100%

(2) Material Strength and Allowable Stresses

(a) Prestressing steel (SWPR7B)

Ultimate strength of prestressing steel	: fpu = 19,000 kgf/cm^2
Yeild point stress of prestressing steel	: fpy = 16,000 kgf/cm^2
Stress at short periods of time	: fpia = 14,400 kgf/cm^2
Stress at immediatelyafter seating	: fpta = 13,300 kgf/cm^2
Stress at service load after losses	: fpea = 11,400 kgf/cm^2

(b) Concrete

1) Girder

Compressive strength of concrete at 28 days	: fck = 400	kgf/cm^2
Compressive strength of concrete at time of initial prestress	: fci = 320	kgf/cm^2

a) Temporary stresses before losses due to creep and shrinkage

Compression		: f'cta = 180	kgf/cm^2
Tension		: fcta = -15	kgf/cm^2

b) Stresses at Service Load After Losses have occurred

Compression		: f'caa = 140	kgf/cm^2
Tension	(at dead load)	: f'cea = 0	kgf/cm^2
Tension	(at service load)	: fcea = -15	kgf/cm^2
Shear	(at service load)	: τ ca = 5.5	kgf/cm^2
Shear	(at ultimate load)	: τ cua = 53	kgf/cm^2
Diagonal tension stress	(at service load)	: fpea = -10	kgf/cm^2

2) Cast-in-place

Compressive strength of concrete at 28 days	: f'ck = 320	kgf/cm^2

a) Temporary stresses before losses due to creep and shrinkage

Compression	: f'cta = 140	kgf/cm^2
Tension	: fcta = -12	kgf/cm^2

b) Stress at service load after losses have occurred

Compression	: f'cea = 110	kgf/cm^2
Tension (all dead load)	: f'cea = 0	kgf/cm^2
Tension (all dead load and live load + impact)	: fcea = -12	kgf/cm^2

(c) Reinforcement

Yeild point stress of prestressing steel	: fsy = 3,000	kgf/cm^2
Allowable tensile stress	: fsa = 1,600	kgf/cm^2

(3) Others

(a) Modulus of elasticity

Prestressing steel	: f'caa	=	20.0	×	10^5	kgf/cm^2
Girder	: f'cea	=	3.1	×	10^5	kgf/cm^2
Girder	: fcea	=	2.86	×	10^5	kgf/cm^2
Cast-in-place	: τ ca	=	2.86	×	10^5	kgf/cm^2
Reinforcement	: τ cua	=	21.0	×	10^5	kgf/cm^2

(b) Coefficient of creep

Coefficient of creep of girder concrete : ϕ = 2.6

(c) Strain of concrete due to shrinkage

Strain of girder concrete due to shrinkage : ε s = 20 × 10^{-5}

(d) Relaxation of prestressing steel

Relaxation of prestressing steel : γ = 5.0 %

(2) Summary of bridge length and span arrangement

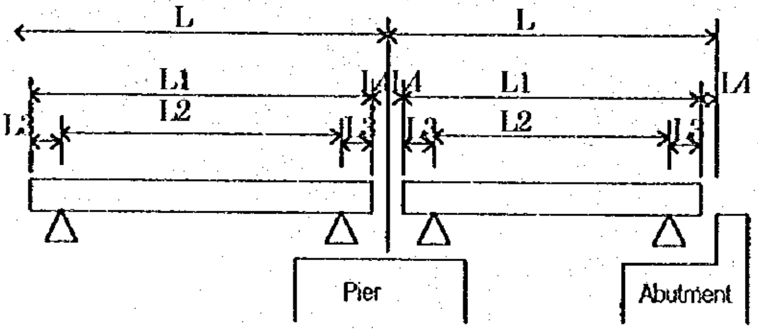
Flyover	Bridge Length and Span Arrangement
A'Naseem Garden	9 @ 32000 = 288000
Barka	11 @ 26000 = 286000
Al Muladdah	11 @ 26000 = 286000
Al Kaburah	11 @ 26000 = 286000
Saham	11 @ 26000 = 286000
Sohar	9 @ 35000 = 315000
Falaj Al Qabil	11 @ 26000 = 286000
Aqr	4 *3@30000=360000

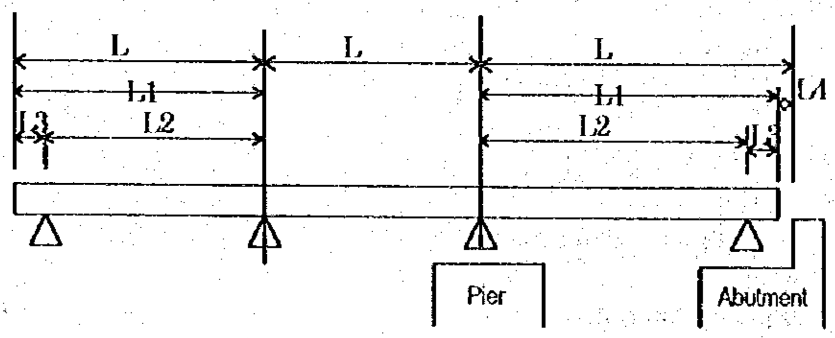
(3) Structural Type and Dimensions

Structural type and dimensions of the superstructure are shown in Figure 5.1.

(4)Structural Details

Required details of bridge length and span arrangement are shown below:





Where:

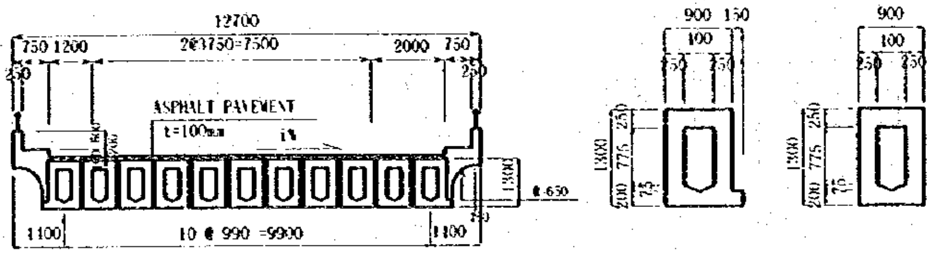
- L : Bridge span length
- L1 : Girder length
- L2 : Girder span length
- L3 : Girder edge overhang length
- L4 : Movable space

The following lengths are adopted for each superstructure.

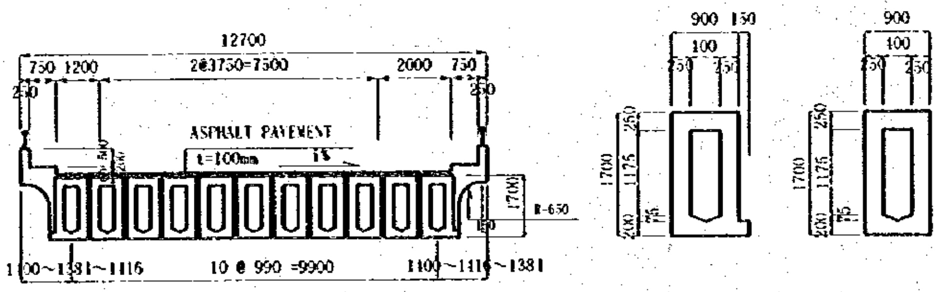
Table 5.1 Bridge Length Detail

	L	L1	L2	L3	L4	Application
25.1m	26.000m	25.900m	25.100m	400mm	50mm	A'Naseem Garden
31.0m	32.000m	31.900m	31.000m	450mm	50mm	Barka, Al Muladdah Al Khaburah, Saham Falaj Al Qabail
34.0m	35.000m	34.900m	34.000m	450mm	50mm	Sohar
3@30.0m	30.000m	29.900m	29.500m	400mm	100mm	Aqr

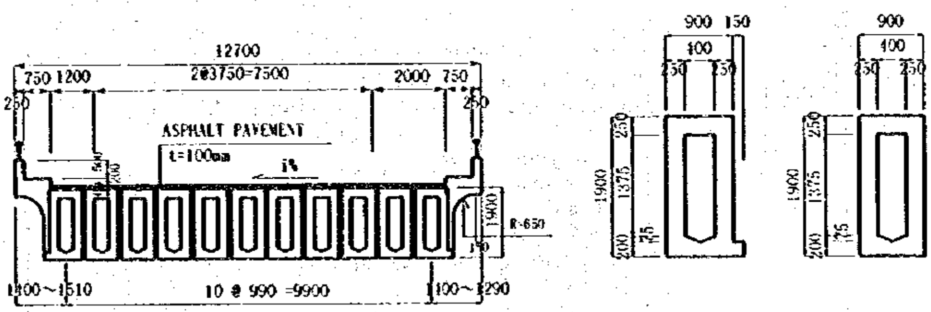
Span = 25.1 m (26.0 m)



Span = 31.0 m (32.0 m)



Span = 35.0 m (34.0 m)



Span = 3 @ 30.0 m (For Aqr)

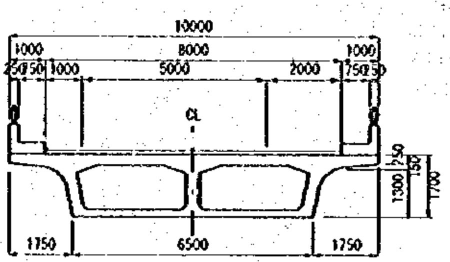


Figure 5.1 Structural Type and Dimensions

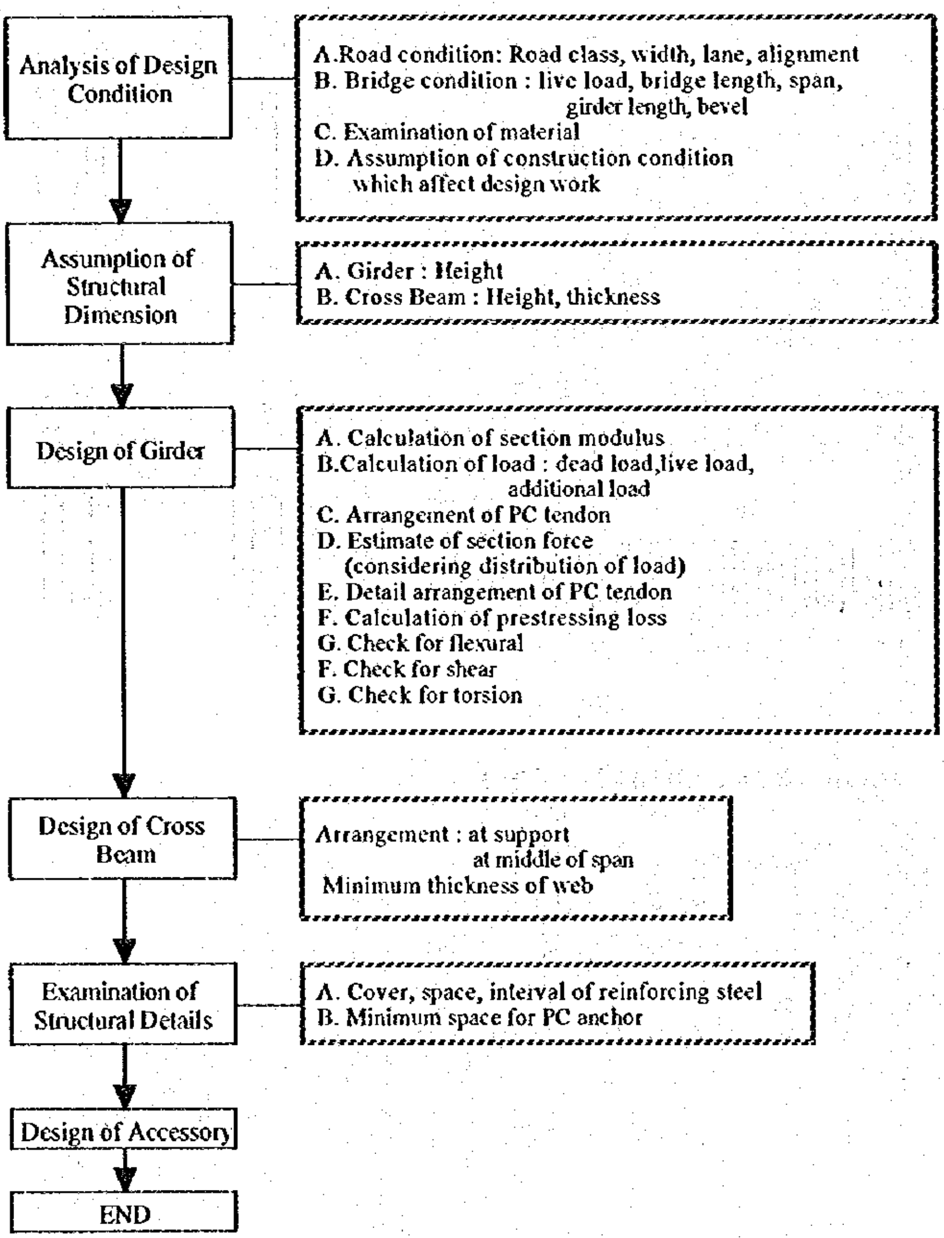
50mm movable space is enough from the following examination.

$$\Delta Lt = 0.96L + 10 \quad (mm)$$

L(m)	Δ Tl(mm)
25.1	34.10
31.0	39.76
34.0	42.64

(5) Calculation Method

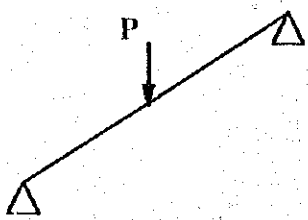
(a) Procedure for Design Work



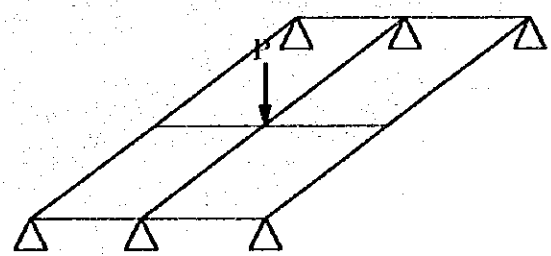
(b) Structural Analysis

As for structural analysis of superstructure, sectional forces were estimated assuming that its structure is gridwork and applied load is distributed. The Guyon-Massonnet method, which is based on the Plate Theory, was adopted as a load distribution method. Coefficients of load distribution are listed in Tables 5.2 to 5.5(b).
Some girders of bridges in Oman have been damaged by concentration of load on them due to few cross beam. Therefore, bridges with rigid cross beam for this detailed design are planned so that load would be fully distributed.
Application of load distribution is as follows:

Against self weight of girder



Against load after transverse prestressing
(dead load, live load)



1.Calculation of :
θ : Coefficient of Flexural Rigidity
α : Coefficient of Torsional Rigidity

↓

2.Calculation of the longitude of influence line as divided into eight (8) equal parts of the resistible width (2B)

↓

3.Calculation of the longitude of influence line at each girder center in case of loading on divided 8 equal parts of 2B

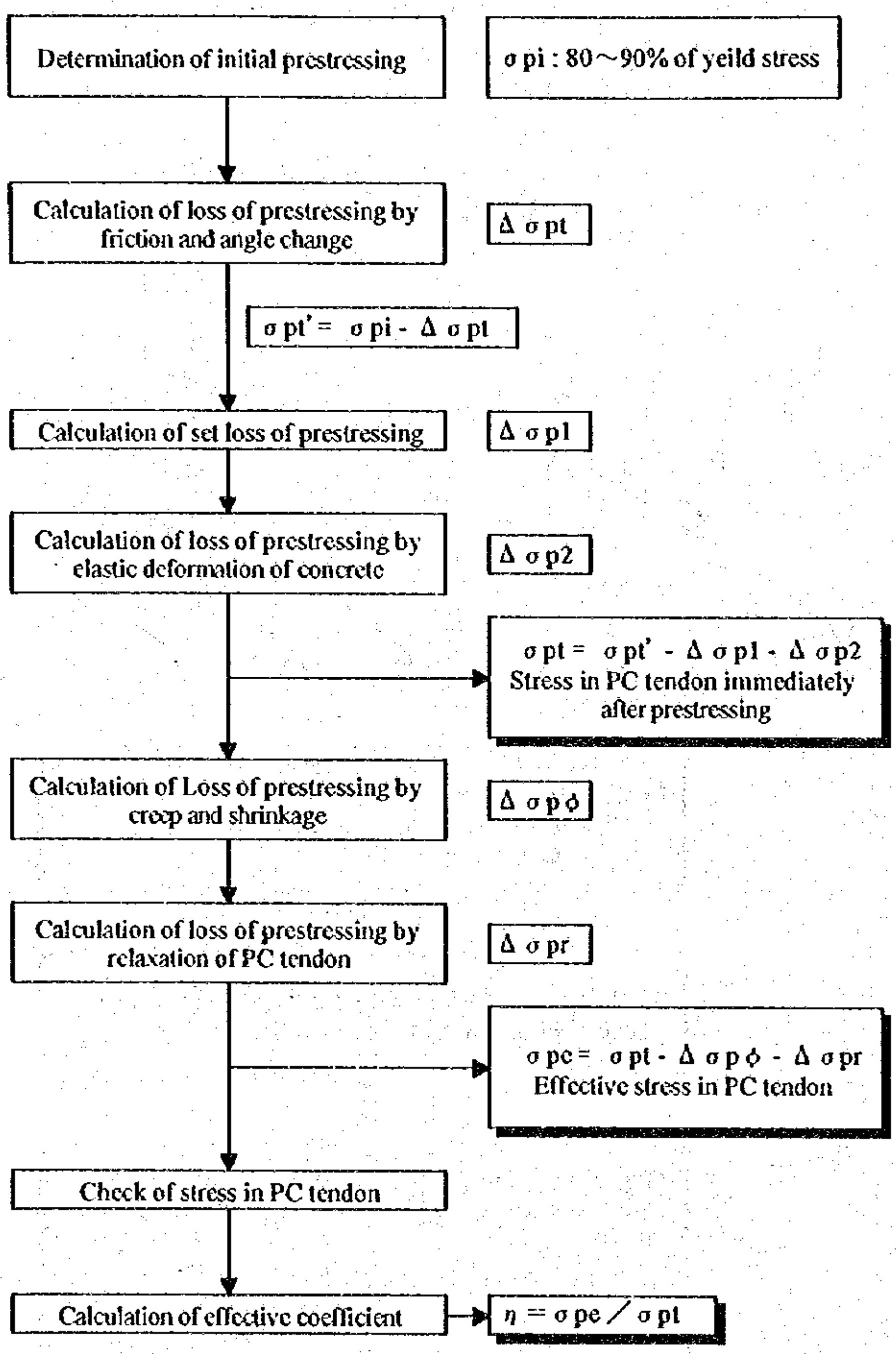
↓

4.Calculation of load distribution coefficient

↓

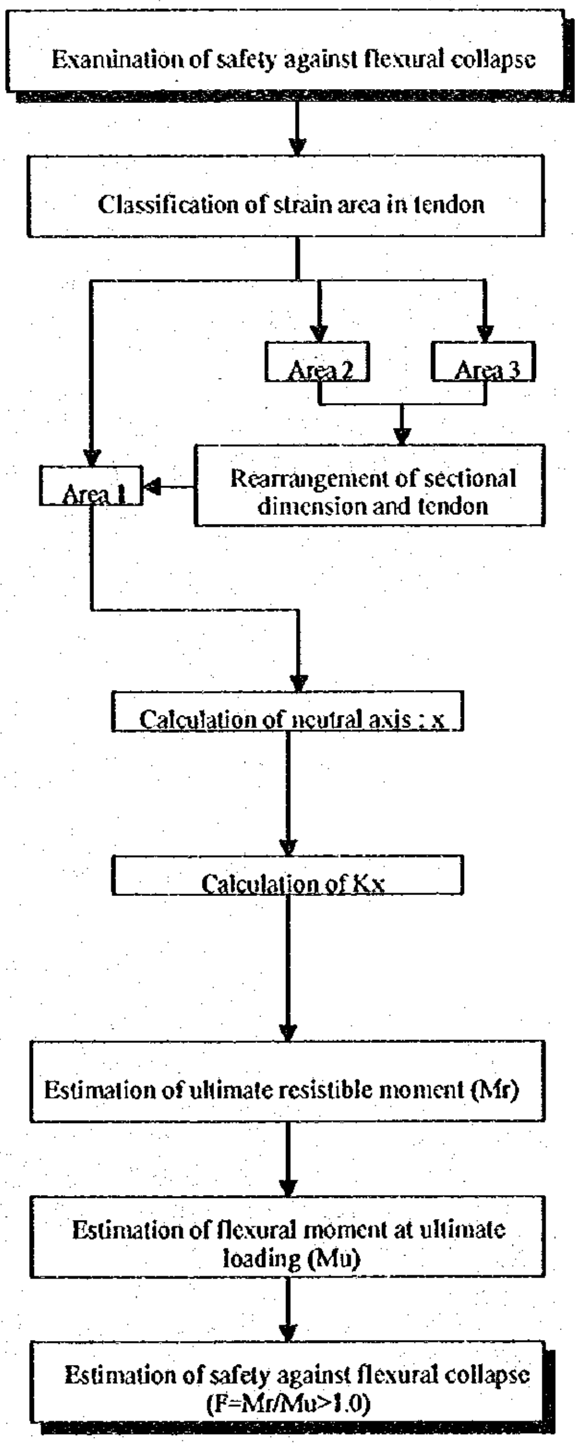
5. Estimation of sectional force
(by surface dead load, live load)

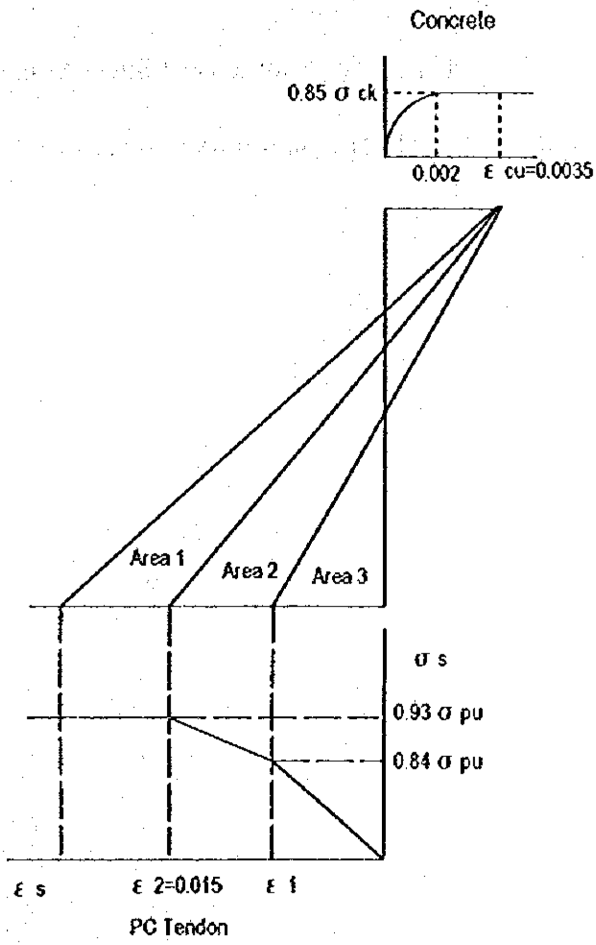
(c) Calculation of Effective Prestress



(d) Examination of safety against collapse

Prestressed concrete member will be examined for both cases of design loading and ultimate loading.





(6) Calculation of Load

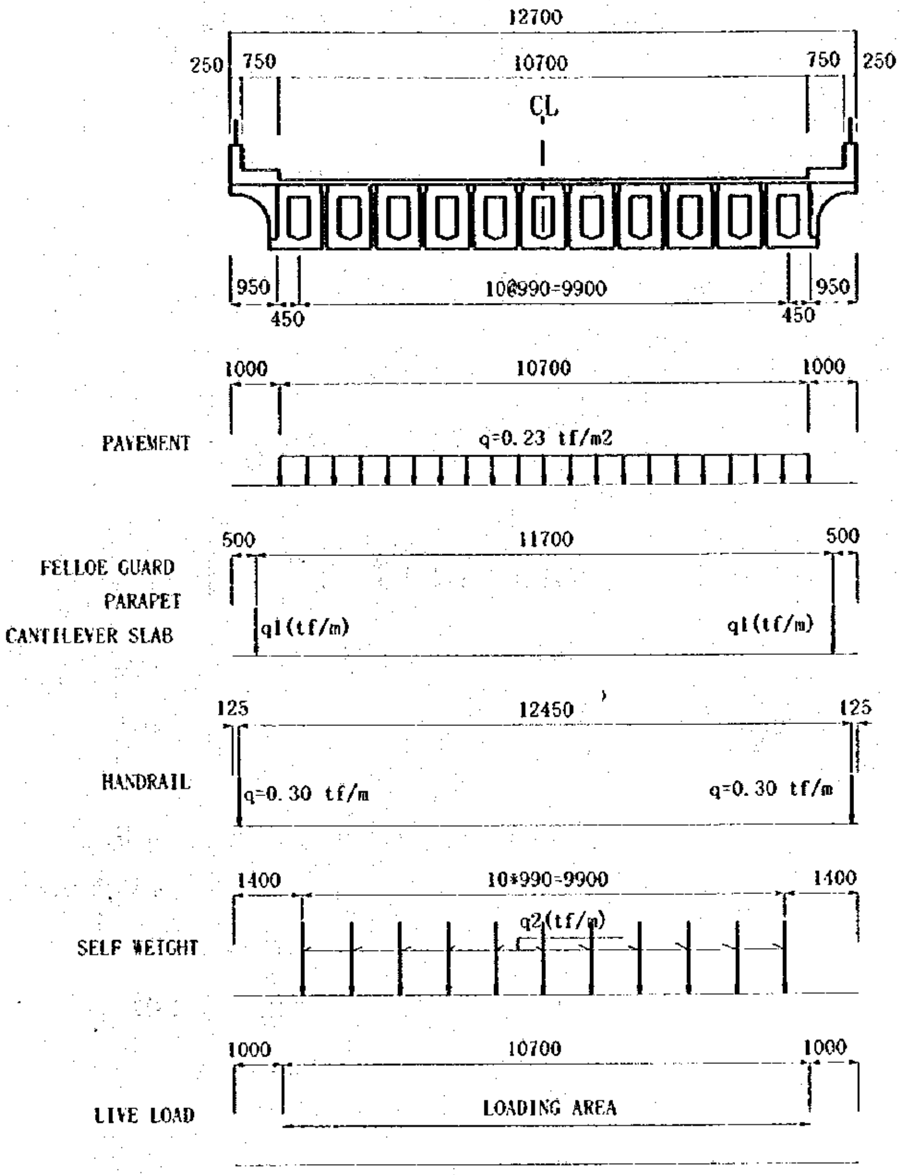
Assumed loading conditions of superstructure in longitudinal and transverse directions are shown in Figures 5.2 to 5.4.

(7) Summary of Calculated Reactions

Reactions which were calculated on the above conditions are listed in Tables 5.2 to 5.5(b). As for live load, reaction caused by AASHTO live loading at carriageway center for 25.1 m span is larger than by special truck loading and reaction caused by special truck loading is larger for other cases.
Detailed design of substructure is carried out using these reactions.

(8) Design Summary of Super Structures

Design summary of three types of bridges are shown in Table 5.6 to Table 5.8(b).

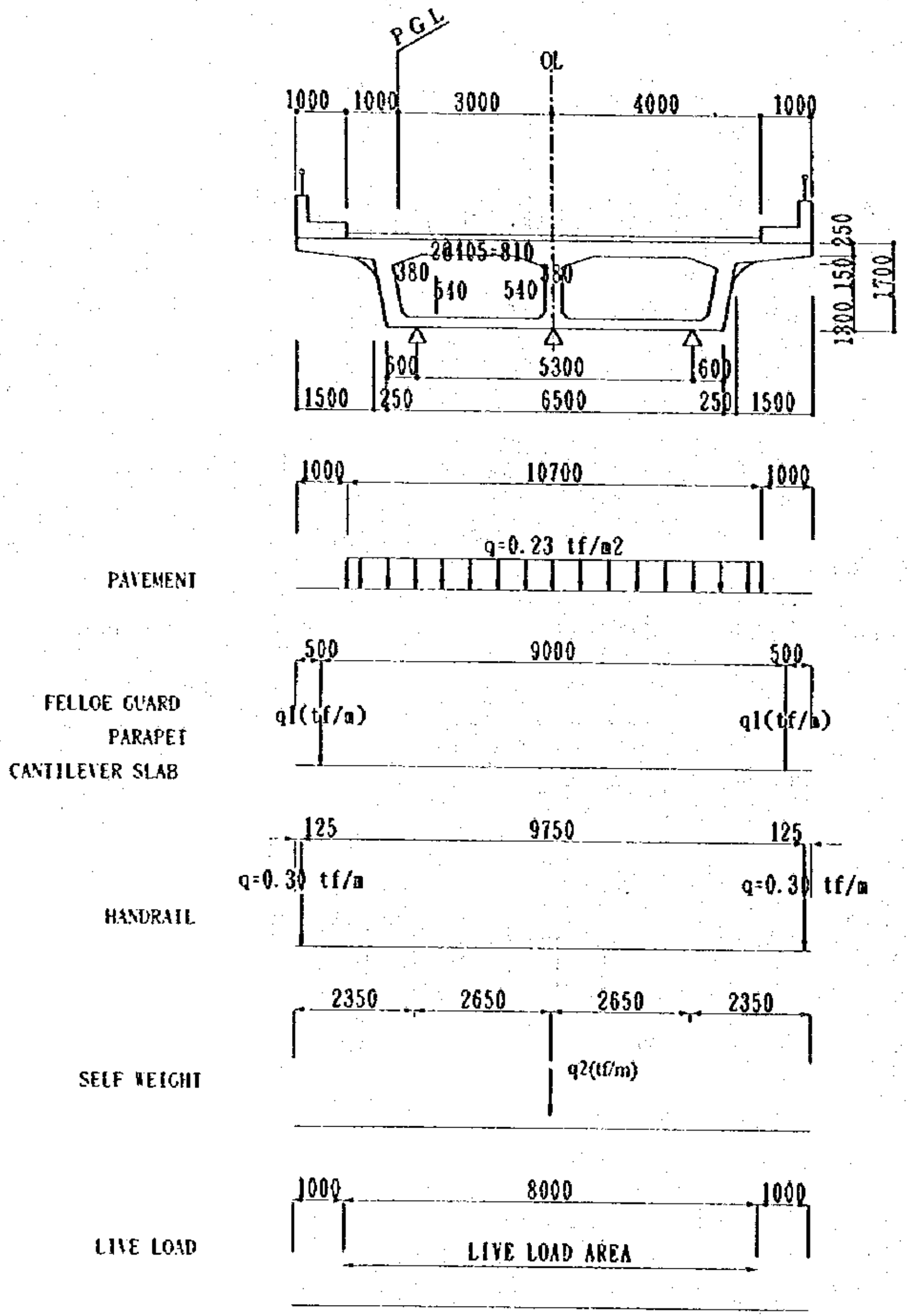


Where;

	q1(tf/m)
L=25.1m	3.291
L=31.0m	3.441
L=34.0m	3.516

	q2(tf/m)
L=25.1m	2.188
L=31.0m	2.688
L=34.0m	2.938

Figure 5.2 (a). Loading Condition for Super-structure in Cross Section (1)

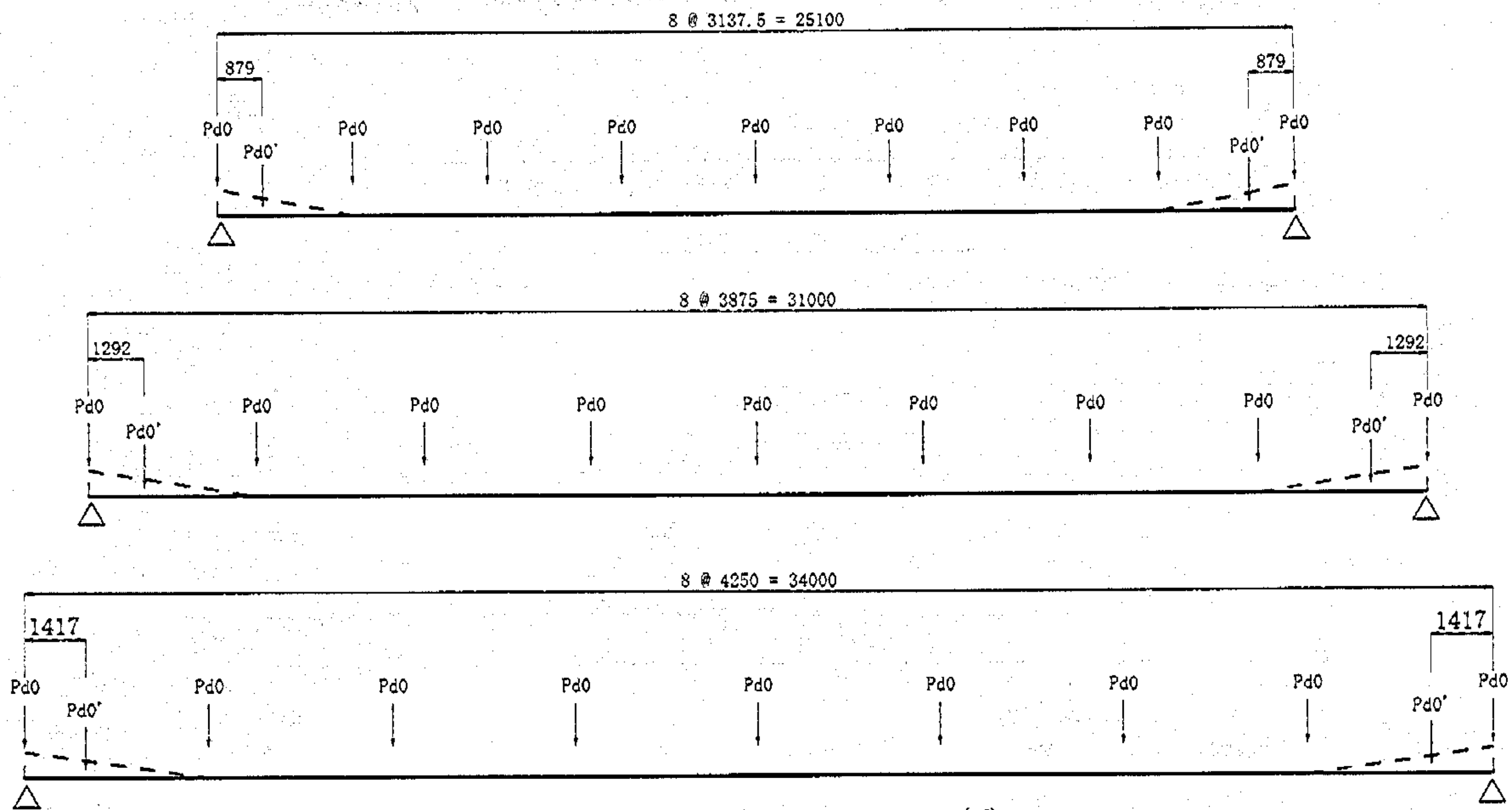


Where;

	q1 (tf/m)
L=3@30.0m	1.063

	q2 (tf/m)
L=3@30.0m	16.557

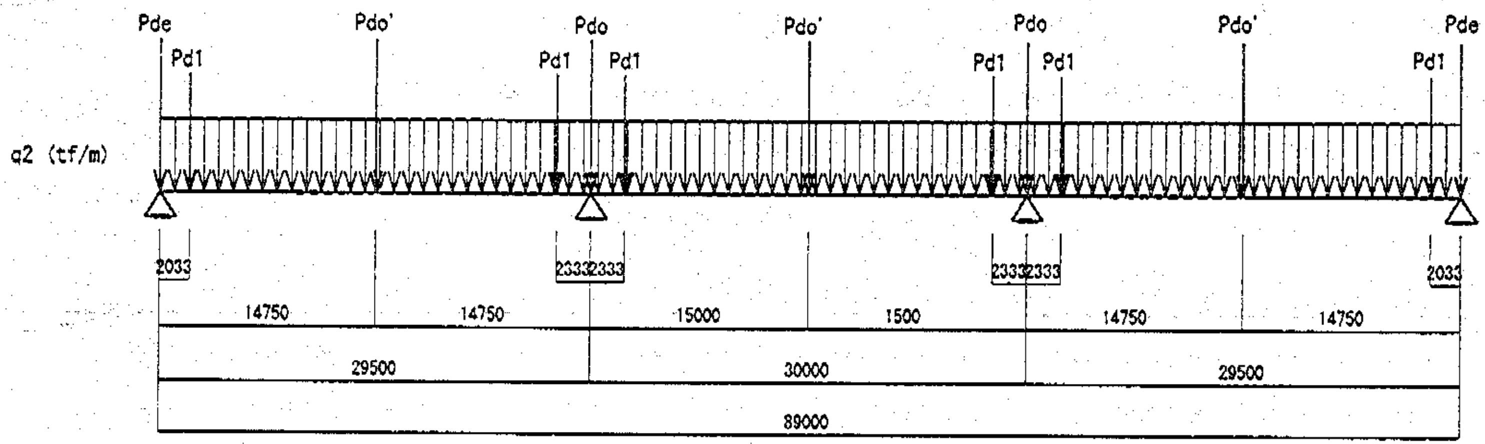
Figure 5.2 (b) Loading Condition for Super-structure in Cross Section (2)



(tf)

	Pd0	Pd0'
L=25.1m	0.545	0.795
L=31.0m	0.812	1.546
L=34.0m	0.946	2.000
	(cross beam)	(taper)

Figure 5.3 Loaging Condition for Super-structure in Longitudinal Direction (1)



(tf)

Pdo (Cross Beam at Support)	Pdo' (Intermediate Cross Beam)	Pde (End Cross Beam)	Pd1 (Inner Taper)
12.494	4.265	11.126	27.570

Figure 5.4 Loaging Condition for Super-structure in Longitudinal Direction (2)

Table 5.2 Summary of Reaction (Span 25.1m AASHTO)

Live Load : HS20-44(AASHTO) increased 100%

CASE-1 : Loading at Carriageway Edge

Unit : tf

	Dictribution Coefficient			Reaction							
	Curb Overhang	Pavement	Live Load	Girder	Cast-in-place	Curb Overhang	Pavement	Dead Load	Live Load	Total
	K1	K2	K3	Rd1	Rd2	Rd3	Rd4	ΣRd	Rl	ΣRd+Rl
G1	0.1964	0.9774	0.1054	31.2	0.6	8.4	2.9	43.1	20.4	63.5
G2	0.1882	0.9730	0.1027	30.2	1.2	8.0	2.9	42.3	19.9	62.2
G3	0.1812	0.9725	0.1000	30.2	1.2	7.7	2.9	42.0	19.4	61.4
G4	0.1760	0.9727	0.0973	30.2	1.2	7.5	2.9	41.8	18.9	60.7
G5	0.1727	0.9728	0.0944	30.2	1.2	7.4	2.9	41.7	18.3	60.0
G6	0.1716	0.9727	0.0914	30.2	1.2	7.3	2.9	41.6	17.7	59.3
G7	0.1727	0.9728	0.0883	30.2	1.2	7.4	2.9	41.7	17.1	58.8
G8	0.1760	0.9727	0.0851	30.2	1.2	7.5	2.9	41.8	16.5	58.3
G9	0.1812	0.9725	0.0818	30.2	1.2	7.7	2.9	42.0	15.9	57.9
G10	0.1882	0.9730	0.0785	30.2	1.2	8.0	2.9	42.3	15.2	57.5
G11	0.1964	0.9774	0.0752	31.2	0.6	8.4	2.9	43.1	14.6	57.7
Total				334.2	12.0	85.3	31.9	463.4	193.9	657.3

Rd3 = K1 * Rd3' Rd3'= 42.6 tf

Rd4 = K2 * Rd4' Rd4'= 3.0 tf

Rl = K3 * Rl' Rl'= 193.9 tf (29.0*3*0.9*2*1.238)

CASE-2 : Loading at Carriageway Center

Unit : tf

	Dictribution Coefficient			Reaction							
	Curb Overhang	Pavement	Live Load	Girder	Cast-in-place	Curb Overhang	Pavement	Dead Load	Live Load	Total
	K1	K2	K3	Rd1	Rd2	Rd3	Rd4	ΣRd	Rl	ΣRd+Rl
G1	0.1964	0.9774	0.0899	31.2	0.6	8.4	2.9	43.1	17.4	60.5
G2	0.1882	0.9730	0.0906	30.2	1.2	8.0	2.9	42.3	17.6	59.9
G3	0.1812	0.9725	0.0909	30.2	1.2	7.7	2.9	42.0	17.6	59.6
G4	0.1760	0.9727	0.0912	30.2	1.2	7.5	2.9	41.8	17.7	59.5
G5	0.1727	0.9728	0.0915	30.2	1.2	7.4	2.9	41.7	17.7	59.4
G6	0.1716	0.9727	0.0915	30.2	1.2	7.3	2.9	41.6	17.7	59.3
G7	0.1727	0.9728	0.0915	30.2	1.2	7.4	2.9	41.7	17.7	59.4
G8	0.1760	0.9727	0.0912	30.2	1.2	7.5	2.9	41.8	17.7	59.5
G9	0.1812	0.9725	0.0909	30.2	1.2	7.7	2.9	42.0	17.6	59.6
G10	0.1882	0.9730	0.0906	30.2	1.2	8.0	2.9	42.3	17.6	59.9
G11	0.1964	0.9774	0.0899	31.2	0.6	8.4	2.9	43.1	17.4	60.5
Total				334.2	12.0	85.3	31.9	463.4	193.7	657.1

Rd3 = K1 * Rd3' Rd3'= 42.6 tf

Rd4 = K2 * Rd4' Rd4'= 3.0 tf

Rl = K3 * Rl' Rl'= 193.9 tf (29.0*3*0.9*2*1.238)

Table 5.3 Summary of Reaction (Span 25.1m OMAN)

Live Load : Special Truck Type B1 (OMAN)

CASE-1 : Loading at Carriageway Edge

Unit : tf

	Dictribution Coefficient			Reaction						
	Curb Overhang	Pavement	Live Load	Girder	Cast-in-place	Curb Overhang	Pavement	Dead Load	Live Load	Total
	K1	K2	K3	Rd1	Rd2	Rd3	Rd4	Σ Rd	Rl	Σ Rd+Rl
G1	0.1964	0.9774	0.1551	31.2	0.6	8.4	2.9	43.1	27.2	70.3
G2	0.1882	0.9730	0.1424	30.2	1.2	8.0	2.9	42.3	25.0	67.3
G3	0.1812	0.9725	0.1295	30.2	1.2	7.7	2.9	42.0	22.7	64.7
G4	0.1760	0.9727	0.1165	30.2	1.2	7.5	2.9	41.8	20.4	62.2
G5	0.1727	0.9728	0.1033	30.2	1.2	7.4	2.9	41.7	18.1	59.8
G6	0.1716	0.9727	0.0902	30.2	1.2	7.3	2.9	41.6	15.8	57.4
G7	0.1727	0.9728	0.0773	30.2	1.2	7.4	2.9	41.7	13.6	55.3
G8	0.1760	0.9727	0.0647	30.2	1.2	7.5	2.9	41.8	11.4	53.2
G9	0.1812	0.9725	0.0523	30.2	1.2	7.7	2.9	42.0	9.2	51.2
G10	0.1882	0.9730	0.0404	30.2	1.2	8.0	2.9	42.3	7.1	49.4
G11	0.1964	0.9774	0.0285	31.2	0.6	8.4	2.9	43.1	5.0	48.1
Total				334.2	12.0	85.3	31.9	463.4	175.5	638.9

Rd3 = K1 * Rd3' Rd3'= 42.6 tf

Rd4 = K2 * Rd4' Rd4'= 3.0 tf

Rl = K3 * Rl' Rl'= 175.5 tf

CASE-2 : Loading at Carriageway Center

Unit : tf

	Dictribution Coefficient			Reaction						
	Curb Overhang	Pavement	Live Load	Girder	Cast-in-place	Curb Overhang	Pavement	Dead Load	Live Load	Total
	K1	K2	K3	Rd1	Rd2	Rd3	Rd4	Σ Rd	Rl	Σ Rd+Rl
G1	0.1964	0.9774	0.0880	31.2	0.6	8.4	2.9	43.1	15.4	58.5
G2	0.1882	0.9730	0.0894	30.2	1.2	8.0	2.9	42.3	15.7	58.0
G3	0.1812	0.9725	0.0908	30.2	1.2	7.7	2.9	42.0	15.9	57.9
G4	0.1760	0.9727	0.0921	30.2	1.2	7.5	2.9	41.8	16.2	58.0
G5	0.1727	0.9728	0.0930	30.2	1.2	7.4	2.9	41.7	16.3	58.0
G6	0.1716	0.9727	0.0933	30.2	1.2	7.3	2.9	41.6	16.4	58.0
G7	0.1727	0.9728	0.0930	30.2	1.2	7.4	2.9	41.7	16.3	58.0
G8	0.1760	0.9727	0.0921	30.2	1.2	7.5	2.9	41.8	16.2	58.0
G9	0.1812	0.9725	0.0908	30.2	1.2	7.7	2.9	42.0	15.9	57.9
G10	0.1882	0.9730	0.0894	30.2	1.2	8.0	2.9	42.3	15.7	58.0
G11	0.1964	0.9774	0.0880	31.2	0.6	8.4	2.9	43.1	15.4	58.5
Total				334.2	12.0	85.3	31.9	463.4	175.4	638.8

Rd3 = K1 * Rd3' Rd3'= 42.6 tf

Rd4 = K2 * Rd4' Rd4'= 3.0 tf

Rl = K3 * Rl' Rl'= 175.5 tf

Table 5.4 Summary of Reaction (Span 31.0m)

Live Load : Special Truck Type B1 (OMAN)

CASE-1 : Loading at Carriageway Edge

Unit : tf

	Dictribution Coefficient			Reaction						
	Curb Overhang	Pavement	Live Load	Girder	Cast-in-place	Curb Overhang	Pavement	Dead Load	Live Load	Total
	K1	K2	K3	Rd1	Rd2	Rd3	Rd4	Σ Rd	Rl	Σ Rd+Rl
G1	0.1873	0.9946	0.1668	47.7	0.8	10.3	3.7	62.5	34.8	97.3
G2	0.1846	0.9742	0.1517	46.5	1.6	10.1	3.6	61.8	31.7	93.5
G3	0.1816	0.9728	0.1364	46.5	1.6	10.0	3.6	61.7	28.5	90.2
G4	0.1794	0.9727	0.1211	46.5	1.6	9.8	3.6	61.5	25.3	86.8
G5	0.1781	0.9727	0.1059	46.5	1.6	9.8	3.6	61.5	22.1	83.6
G6	0.1776	0.9725	0.0906	46.5	1.6	9.8	3.6	61.5	18.9	80.4
G7	0.1781	0.9727	0.0755	46.5	1.6	9.8	3.6	61.5	15.8	77.3
G8	0.1794	0.9727	0.0604	46.5	1.6	9.8	3.6	61.5	12.6	74.1
G9	0.1816	0.9728	0.0454	46.5	1.6	10.0	3.6	61.7	9.5	71.2
G10	0.1845	0.9742	0.0306	46.5	1.6	10.1	3.6	61.8	6.4	68.2
G11	0.1873	0.9946	0.0163	47.7	0.8	10.3	3.7	62.5	3.4	65.9
Total				513.9	16.0	109.8	39.8	679.5	209.0	888.5

Rd3 = K1 * Rd3' Rd3'= 54.9 tf

Rd4 = K2 * Rd4' Rd4'= 3.7 tf

Rl = K3 * Rl' Rl'= 208.7 tf

CASE-2 : Loading at Carriageway Center

Unit : tf

	Dictribution Coefficient			Reaction						
	Curb Overhang	Pavement	Live Load	Girder	Cast-in-place	Curb Overhang	Pavement	Dead Load	Live Load	Total
	K1	K2	K3	Rd1	Rd2	Rd3	Rd4	Σ Rd	Rl	Σ Rd+Rl
G1	0.1873	0.9946	0.0897	47.7	0.8	10.3	3.7	62.5	18.7	81.2
G2	0.1846	0.9742	0.0903	46.5	1.6	10.1	3.6	61.8	18.8	80.6
G3	0.1816	0.9728	0.0909	46.5	1.6	10.0	3.6	61.7	19.0	80.7
G4	0.1794	0.9727	0.0914	46.5	1.6	9.8	3.6	61.5	19.1	80.6
G5	0.1781	0.9727	0.0918	46.5	1.6	9.8	3.6	61.5	19.2	80.7
G6	0.1776	0.9725	0.0919	46.5	1.6	9.8	3.6	61.5	19.2	80.7
G7	0.1781	0.9727	0.0918	46.5	1.6	9.8	3.6	61.5	19.2	80.7
G8	0.1794	0.9727	0.0914	46.5	1.6	9.8	3.6	61.5	19.1	80.6
G9	0.1816	0.9728	0.0909	46.5	1.6	10.0	3.6	61.7	19.0	80.7
G10	0.1845	0.9742	0.0903	46.5	1.6	10.1	3.6	61.8	18.8	80.6
G11	0.1873	0.9946	0.0897	47.7	0.8	10.3	3.7	62.5	18.7	81.2
Total				513.9	16.0	109.8	39.8	679.5	208.8	888.3

Rd3 = K1 * Rd3' Rd3'= 54.9 tf

Rd4 = K2 * Rd4' Rd4'= 3.7 tf

Rl = K3 * Rl' Rl'= 208.7 tf

Table 5.5(a) Summary of Reaction (Span 34.0m)

Live Load : Special Truck Type B1 (OMAN)

CASE-1 : Loading at Carriageway Edge

Unit : tf

	Dictribution Coefficient			Reaction							
	Curb Overhang	Pavement	Live Load	Girder	Cast-in-place	Curb Overhang	Pavement	Dead Load	Live Load	Total
	K1	K2	K3	Rd1	Rd2	Rd3	Rd4	ΣRd	Rl	ΣRd+Rl
G1	0.1863	0.9726	0.1709	57.1	0.9	11.4	3.9	73.3	38.6	111.9
G2	0.1838	0.9732	0.1549	55.8	1.8	11.3	3.9	72.8	34.9	107.7
G3	0.1817	0.9728	0.1389	55.8	1.8	11.2	3.9	72.7	31.3	104.0
G4	0.1800	0.9726	0.1237	55.8	1.8	11.1	3.9	72.6	27.9	100.5
G5	0.1751	0.9728	0.1068	55.8	1.8	10.8	3.9	72.3	24.1	96.4
G6	0.1788	0.9728	0.0907	55.8	1.8	11.0	3.9	72.5	20.5	93.0
G7	0.1751	0.9728	0.0747	55.8	1.8	10.8	3.9	72.3	16.9	89.2
G8	0.1800	0.9726	0.0588	55.8	1.8	11.1	3.9	72.6	13.3	85.9
G9	0.1817	0.9728	0.0430	55.8	1.8	11.2	3.9	72.7	9.7	82.4
G10	0.1838	0.9732	0.0272	55.8	1.8	11.3	3.9	72.8	6.1	78.9
G11	0.1863	0.9726	0.0115	57.1	0.9	11.4	3.9	73.3	2.6	75.9
Total				616.4	18.0	122.6	42.9	799.9	225.9	1025.8

Rd3 = K1 * Rd3'   Rd3'= 61.4 tf

Rd4 = K2 * Rd4'   Rd4'= 4.0 tf

Rl = K3 * Rl'   Rl'= 225.6 tf

CASE-2 : Loading at Carriageway Center

Unit : tf

	Dictribution Coefficient			Reaction							
	Curb Overhang	Pavement	Live Load	Girder	Cast-in-place	Curb Overhang	Pavement	Dead Load	Live Load	Total
	K1	K2	K3	Rd1	Rd2	Rd3	Rd4	ΣRd	Rl	ΣRd+Rl
G1	0.1863	0.9726	0.0900	57.1	0.9	11.4	3.9	73.3	20.3	93.6
G2	0.1838	0.9732	0.0905	55.8	1.8	11.3	3.9	72.8	20.4	93.2
G3	0.1817	0.9728	0.0909	55.8	1.8	11.2	3.9	72.7	20.5	93.2
G4	0.1800	0.9726	0.0913	55.8	1.8	11.1	3.9	72.6	20.6	93.2
G5	0.1751	0.9728	0.0916	55.8	1.8	10.8	3.9	72.3	20.7	93.0
G6	0.1788	0.9728	0.0916	55.8	1.8	11.0	3.9	72.5	20.7	93.2
G7	0.1751	0.9728	0.0916	55.8	1.8	10.8	3.9	72.3	20.7	93.0
G8	0.1800	0.9726	0.0913	55.8	1.8	11.1	3.9	72.6	20.6	93.2
G9	0.1817	0.9728	0.0909	55.8	1.8	11.2	3.9	72.7	20.5	93.2
G10	0.1838	0.9732	0.0905	55.8	1.8	11.3	3.9	72.8	20.4	93.2
G11	0.1863	0.9726	0.0900	57.1	0.9	11.4	3.9	73.3	20.3	93.6
Total				616.4	18.0	122.6	42.9	799.9	225.7	1025.6

Rd3 = K1 * Rd3'   Rd3'= 61.4 tf

Rd4 = K2 * Rd4'   Rd4'= 4.0 tf

Rl = K3 * Rl'   Rl'= 225.6 tf

Table 5.5(b) Summary of Reaction (Span 3@30.0m)

Live Load : Special Truck Type B1 (OMAN)

At End Pier (Re)

Unit : tf

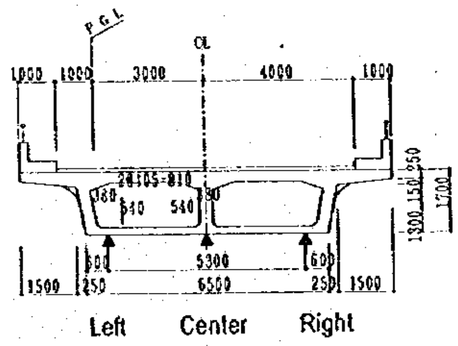
		Left	Centr	Right
Dead Load		97.2	97.2	97.2
Live Load		59.8	59.8	59.8
Total	Case1	157.0	157.0	157.0
	Case2	164.4	157.0	149.5

At Intermediate Pier (Rm)

Unit : tf

		Left	Centr	Right
Dead Load		194.4	194.4	194.4
Live Load		110.2	110.2	110.2
Total	Case1	304.6	304.6	304.6
	Case2	318.4	304.6	290.8

*Case 1 shwos the case live load is distributed uniformly
*Case 2 shows the case Live load is distributed eccentrically.



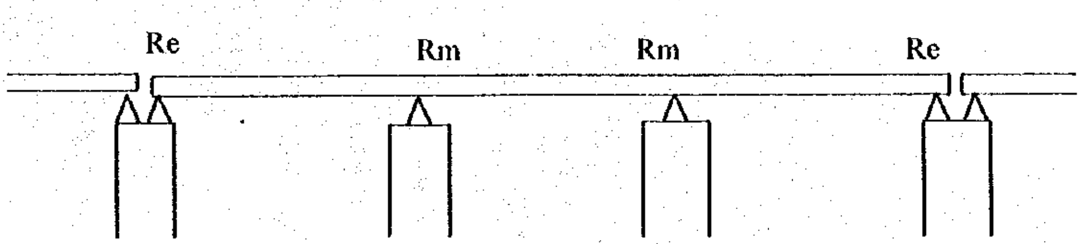
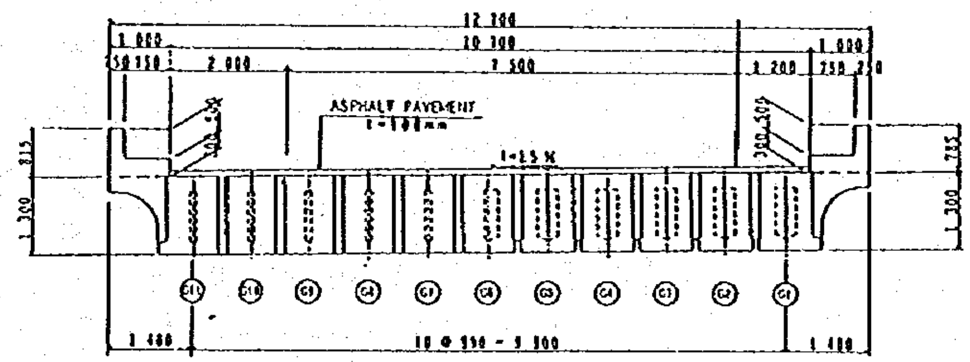


Table 5.6 DESIGN SUMMARY OF SUPERSTRUCTURE (L=25.1m)

Name of Bridge	Span 25.1m	Bridge Length	L= 286.000 m	Horizontal Alignment	∞	Bevel 90 degree	Bridge Width: Total Width	ΣW= 12.700 m	Design Seismic Coefficient: Longitudinal direction kh=
Structural Type	Simple Beam, Post-tensioned PC Hollow Girder (Slab)	Girder Length	l= 25.900 m	Span Arrangement	11@25.100m		Effective Width	W= 10.000 m	Perpendicular direction kh=

Main Girder	Number	11 Nos.	Girder Height	1.300 m	Maximum Deflection by Live	δL= 21.9 mm (1/ 1146)
	Interval	0.990 m	Ratio of Girder Height to Span(at Center of Span) H/L= 1/ 19.3		(at Support) H/L= 1/ 19.3	
Cross Beam	Number	7 Nos.	Interval of Cross Beam	3.1375 m	Height of Cross Beam	1.100 m

Cross Section Diagram



Design of Slab

Type of Deck Slab		Type of PC Tendon	1T-15.2(B)	Interval of Transverse Prestressing	mm
Specified Design Strength	σck= kgf/cm²	Rate of increase		k=	
Cantilever Section	Bending Moment	Slab Thickness	Combined Flexural Stress (kgf/cm²)		
Cantilever Section		mm	Upper	Lower	
Center of Span		mm	Upper	Lower	
Intermediate Support		mm	Upper	Lower	

Design of Main Girder

Applied Design Theory	Guyon Masonnet Method	Type of PC Tendon	12T-15.2(B)
Method of Girder Erection	Erection by Crane		

	Bending Moment (tf·m)	Location	Combined Flexural Stress (tf/cm²): Immediate after Prestressing	Combined Flexural Stress (tf/cm²): At Design Load	Allowable Stress (kgf/cm²): Immediate after Prestressing	Allowable Stress (kgf/cm²): At Design LOad
Design Section	426.3	Upper	25.2	134.1	-15≦ δ ≦180	-15≦ δ ≦140
		Lower	133.0	-2.3	-15≦ δ ≦180	-15≦ δ ≦140
Center of Side Span		Upper				
		Lower				
Intermediate Support		Upper				
		Lower				
Center of Main Span		Upper				
		Lower				

Shear Force	at Design Load	at Ultimate state	Diagonal Tension Stress	Stirrup	Vertical PC Tendon
End Support	70.7 tf	125.0 tf	-6.6 kgf/cm²		
Intermediate Support	tf	tf	kgf/cm²		

Reaction

Reaction	Abutment	Pier	R-max	R-min
Reaction by Dead Load : Rd	464.4	928.8	43.1	43.1
Reaction by Live Load : RL	193.9	139.9	27.6	4.6
Total Reaction : R	658.3	1122.7	70.7	47.7
Reaction for Bearing Pad				

(per Support)

Expansion Joint

Using Location	Type of Expansion Joint	Movable Space
at each support	Transflex Joint	mm

Main Materials

Item		Unit	Specification	Quantity	Quantity per 1 m³ of concrete
Concrete		m³	σck= 400 kgf/cm²	2891.9	
Form	External	m²		11573.3	
	Internal	m²		6095.7	
Reinforcing Bar		t		276.9	
Tendon	Longitudinal	t	10T-15.2(B)	136.5	
	Transverse	t	1T-15.2(B)	9.3	
	Vertical	t		-	
	Total	t		145.8	

Maximum Stress in Tendon	12681 kgf/mm²	σpa= 13300 kgf/mm²
Means for Transmission of Horizontal Force		

Remarks

Table 5.7 DESIGN SUMMARY OF SUPERSTRUCTURE (L=31.0m)

Name of Bridge	Span 31.0m	Bridge Length	L= 288.000 m	Horizontal Alignment	∞	Bevel	90 degree
Structural Type	Simple Beam, Post-tensioned PC Hollow Girder (Slab)	Girder Length	l= 31.900 m	Span Arrangement	9@31.000m		

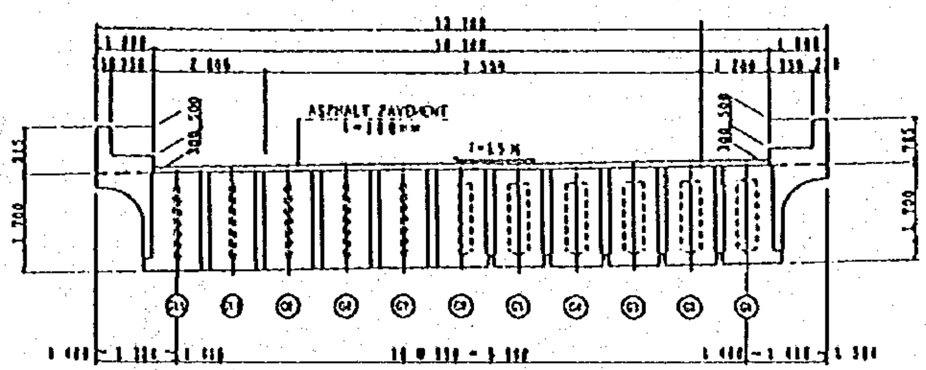
Bridge Width	Total Width	ΣW= 12.700 m	Design Seismic Coefficient	Longitudinal direction	kh=
	Effective Width	W= 10.000 m		Perpendicular direction	kh=

Main Girder	Number	11 Nos.	Girder Height	1.300 m	Maximum Deflection by Live	δL= 22.4 mm (1/ 1384)	
	Interval	0.990 m	Ratio of Girder Height to Span(at Center of Span) H/L= 1/ 18.2		(at Support) H/L= 1/ 18.2		
Cross Beam	Number	7 Nos.	Interval of Cross Beam	3.875 m	Height of Cross Beam	1.500 m	

Design of Slab

Type of Deck Slab		Type of PC Tendon	1T-15.2(B)	Interval of Transverse Prestressing	mm
Specified Design Strength	σck= kgf/cm²	Rate of increase	k=		
Cantilever Section	Bending Moment	Slab Thickness	Combined Flexural Stress (kgf/cm²)		
Cantilever Section		mm	Upper	Lower	
Center of Span		mm	Upper	Lower	
Intermediate Support		mm	Upper	Lower	

Cross Section Diagram



Design of Main Girder

Applied Design Theory	Guyon Masonnet Method	Type of PC Tendon	12T-15.2(B)
Method of Girder Erection	Erection by Crane		

	Bending Moment (tf・m)	Location	Combined Flexural Stress (tf/cm²) Immediate after Prestressing	Combined Flexural Stress At Design Load	Allowable Stress (kgf/cm²) Immediate after Prestressing	Allowable Stress At Design LOad
Design Section	697.4	Upper	28.8	129.8	-15≦δ≦180	-15≦δ≦140
		Lower	121.7	-4.3	-15≦δ≦180	-15≦δ≦140
Center of Side Span		Upper				
		Lower				
Intermediate Support		Upper				
		Lower				
Center of Main Span		Upper				
		Lower				

Shear Force	at Design Load	at Ultimate state	Diagonal Tension Stress	Stirrup	Vertical PC Tendon
End Support	97.2 tf	168.1 tf	-6.6 kgf/cm²		
Intermediate Support	tf	tf	kgf/cm²		

Reaction

Reaction	Abutment	Pier	R-max	R-min
Reaction by Dead Load : Rd	679.5	1359.0	62.5	62.5
Reaction by Live Load : RL	209.0	209.0	34.8	3.4
Total Reaction : R	888.5	1568.0	97.3	65.9
Reaction for Bearing Pad				

(per Support)

Expansion Joint	Using Location	Type of Expansion Joint	Movable Space
	at each support	Transflex Joint	mm

Main Materials

Item		Unit	Specification	Quantity	Quantity per 1 m³ of concrete
Concrete		m³	σck= 400 kgf/cm²		
Form	External	m²			
	Internal	m²			
Reinforcing Bar		t			
Tendon	Longitudinal	t	10T-15.2(B)		
	Transverse	t	1T-15.2(B)		
	Vertical	t			
	Total	t			

Maximum Stress in Tendon	12304 kgf/mm²	σpa= 13300 kgf/mm²
Means for Transmission of Horizontal Force		

Remarks

Table 5.8 (a) DESIGN SUMMARY OF SUPERSTRUCTURE (L=34.0m)

Name of Bridge	Span 34.0m	Bridge Length	L= 315.000 m	Horizontal Alignment	∞	Bevel	90 degree
Structural Type	Simple Beam, Post-tensioned PC Hollow Girder (Slab)	Girder Length	l= 34.900 m	Span Arrangement	9@34.000m		

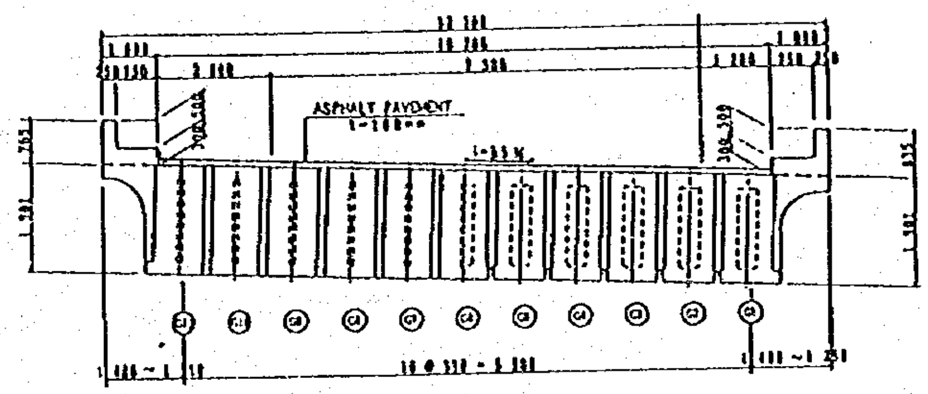
Bridge Width	Total Width	ΣW= 12.700 m	Design Seismic Coefficient	Longitudinal direction kh=
	Effective Width	W= 10.000 m		Perpendicular direction kh=

Main Girder	Number	11 Nos.	Girder Height	1.900 m	Maximum Deflection by Live	δL= 23.0	mm (1/ 1478)
	Interval	0.990 m	Ratio of Girder Height to Span (at Center of Span) H/L= 1/ 17.9		(at Support) H/L= 1/ 17.9		
Cross Beam	Number	7 Nos.	Interval of Cross Beam	4.250 m	Height of Cross Beam	1.700 m	

Design of Slab

Type of Deck Slab		Type of PC Tendon	1T-15.2(B)	Interval of Transverse Prestressing	mm
Specified Design Strength	σck= kgf/cm²		Rate of increase	k=	
Cantilever Section	Bending Moment	Slab Thickness	Combined Flexural Stress (kgf/cm²)		
Cantilever Section		mm	Upper	Lower	
Center of Span		mm	Upper	Lower	
Intermediate Support		mm	Upper	Lower	

Cross Section Diagram



Design of Main Girder

Applied Design Theory	Guyon Masonnet Method		Type of PC Tendon	12T-15.2(B)
Method of Girder Erection	Erection by Crane			

	Bending Moment (tf・m)	Location	Combined Flexural Stress (tf/cm²) Immediate after Prestressing	Combined Flexural Stress (tf/cm²) At Design Load	Allowable Stress (kgf/cm²) Immediate after Prestressing	Allowable Stress (kgf/cm²) At Design LOad
Design Section	869.0	Upper	36.7	133.5	-15≦ δ ≦180	-15≦ δ ≦140
		Lower	102.7	-15.0	-15≦ δ ≦180	-15≦ δ ≦140
Center of Side Span		Upper				
		Lower				
Intermediate Support		Upper				
		Lower				
Center of Main Span		Upper				
		Lower				

Shear Force	at Design Load	at Ultimate state	Diagonal Tension Stress	Stirrup	Vertical PC Tendon
End Support	111.9 tf	191.8 tf	-7.0 kgf/cm²		
Intermediate Support	tf	tf	kgf/cm²		

Reaction

Reaction	Abutment	Pier	R-max	R-min
Reaction by Dead Load : Rd	799.9	1599.8	73.3	73.3
Reaction by Live Load : RL	225.9	225.9	38.6	2.6
Total Reaction : R	1025.8	1825.7	111.9	75.9
Reaction for Bearing Pad				

(per Support)

Expansion Joint	Using Location	Type of Expansion Joint	Movable Space
	at each support	Transflex Joint	mm

Main Materials

Item		Unit	Specification	Quantity	Quantity per 1 m³ of concrete
Concrete		m³	σck= 400 kgf/cm²		
Form	External	m²			
	Internal	m²			
Reinforcing Bar		t			
Tendon	Longitudinal	t	10T-15.2(B)		
	Transverse	t	1T-15.2(B)		
	Vertical	t			
	Total	t			

Maximum Stress in Tendon	12418 kgf/mm²	σpa=	13300 kgf/mm²
Means for Transmission of Horizontal Force			

Remarks

Table 5.8(b) DESIGN SUMMARY OF SUPERSTRUCTURE (L=3@30.0m)

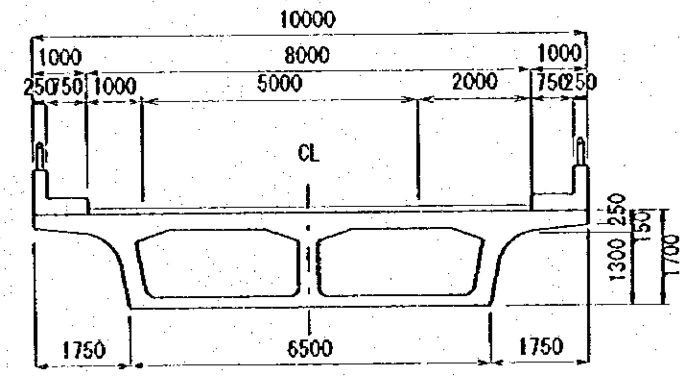
Name of Bridge	Span 3@30.0m	Bridge Length	L= 360.000 m	Horizontal Alignment	900m	Bevel	90 degree	Bridge Width	Total Width	ΣW= 10.000 m	Design Seismic Coefficient: Longitudinal direction kh=
Structural Type	3 span continuous post-tensioned PC box girder	Girder Length	l= 29.9m+30.0m+29.9m	Span Arrangement	4*(29.5m+30.0m+29.5m)				Effective Width	W= 8.000 m	Perpendicular direction kh=

Main Girder	Number	Nos.	Girder Height	1.900 m	Maximum Deflection by Live	δL= 23.0 mm (1/1478)
	Interval	m	Ratio of Girder Height to Span(at Center of Span) H/L= 1/ 17.9		(at Support) H/L= 1/ 17.9	
Cross Beam	Number	Nos.	Interval of Cross Beam	4.250 m	Height of Cross Beam	1.700 m

Design of Slab

Type of Deck Slab	RC Slab	Type of PC Tendon		Interval of Transverse Prestressing	mm	
Specified Design Strength	σ ck= kgf/cm²		Rate of increase	k=		
Cantilever Section	Bending Moment	Slab Thickness	Flexural Stress (kgf/cm²)			
Cantilever Section	6.49 tfm/m	500 mm	σ s	1011 kgf/cm2		
Center of Span	6.02 tfm/m	300 mm	σ s	1251 kgf/cm2		
Intermediate Support	5.30 tfm/m	500 mm	σ s	826 kgf/cm2		

Cross Section Diagram



Design of Main Girder

Applied Design Theory	Beam theory	Type of PC Tendon	12T-15.2(B)
Method of Girder Erection	All Staging Method		

Design Section	Bending Moment (tf・m)	Location	Combined Flexural Stress (tf/cm²): Immediate after Prestressing	Combined Flexural Stress (tf/cm²): At Design Load	Allowable Stress (kgf/cm²): Immediate after Prestressing	Allowable Stress (kgf/cm²): At Design LOad
Design Section		Upper				
		Lower				
Center of Side Span	2549.3	Upper	23.7	61.3	-15≦ δ ≦180	-15≦ δ ≦140
		Lower	89.9	6.1	-15≦ δ ≦180	-15≦ δ ≦140
Intermediate Support	-2203.4	Upper	49.8	2.8	-15≦ δ ≦180	0≦ δ ≦140
		Lower	4.3	50.5	-15≦ δ ≦180	-15≦ δ ≦140
Center of Main Span	1745.2	Upper	15.2	40.9	-15≦ δ ≦180	-15≦ δ ≦140
		Lower	77.3	15.7	-15≦ δ ≦180	-15≦ δ ≦140

Shear Force	at Design Load	at Ultimate state	Diagonal Tension Stress	Stirrup	Vertical PC Tendon
End Support	390.0 tf	tf	kgf/cm²	D19 ctc 250	
Intermediate Support	532.5 tf	904.1 tf	-7.2 kgf/cm²	D19 ctc 125	

Reaction

Reaction	Abutment	Pier
Reaction by Dead Load : Rd	297.1	696.2
Reaction by Live Load : RL	179.3	330.5
Total Reaction : R	471.0	1026.7
Reaction for Bearing Pad		

Expansion Joint	Using Location	Type of Expansion Joint	Movable Space
	at each support	Transflex Joint	mm

Main Materials

Item		Unit	Specification	Quantity	Quantity per 1 m³ of concrete
Concrete		m³	σ ck= 400 kgf/cm²	718.1	
Form	External	m²		1128.5	
	Internal	m²		915.6	
Reinforcing Bar		t		80.5	
Tendon	Longitudinal	t	12T-15.2(B)	17.6	
	Transverse	t			
	Vertical	t			
	Total	t		17.6	

Maximum Stress in Tendon	118.7 kgf/mm²	σ pa=	133 kgf/mm²
Means for Transmission of Horizontal Force			
Remarks			