3.2 Design Conditions of Flyovers

3.2.1 Alignment of Flyovers and Roundabouts

(1) Type of Flyovers

The proposed flyovers can be divided into two basic types by virtue of the road to be the object of grade-separation as elaborated bellow:

a) Main road as object of grade separation (Batinah Highway)

This type of flyover consists of a main road designed to overpass a roundabout and its connecting crossroads. This type of flyover can further be divided into two types depending on whether there are obstacles such as outstanding monuments within the roundabout. In this design study, the type that has no monument will be referred to as Type A while that with the monument in the roundabout is referred to as Type B.

b) Crossroad as object of grade separation

The grade separation of crossroads with lower traffic volume is in fact economical, and ensuring steady traffic flow on the main roads at grade, if there are ample open spaces around a roundabout and along crossroads for such design.

However, considering the existing conditions of the roundabouts in question, this type of flyover is not applicable with the exception of Aqr R/A. This type is referred to in this study as Special Type.

The proposed type of flyovers for each roundabout is shown in Table 3.4. Comparing the results of the Feasibility Study on Flyovers, A'Naseem Garden R/A is changed from Type A to Type B, and Falaj Al Qabail from Type B to Type A.

(2) Alignment of Flyovers

The outline of alignment for each flyover type is illustrated in Table 3.4 and Figure 3.4. The main and special features of these flyover types are as follows;

Type A : The flyover passes directly through or near the center of a roundabout.
Type B : The flyovers are shifted to the both edges of a roundabout.
Special Type : The quadrant connector is provided at grade between the main roads. The existing minor roads to or from a roundabout are grade-separated by ramp bridges.

The alignments at the following roundabouts were altered from the results of F/S, considering the existing conditions of roundabouts.These conceptual designs are shown in Figure 3.5.

- A'Naseem Garden (R/A-2)
  Alteration from Type A to Type B due to the recent completed monument in the center of the roundabout.

- Al Muladdah (R/A-5)
  Comparing to the flyover proposed for this junction in the Feasibility Study, the design of the flyover at this location needs to minimize the area near the junction of the inland road with the roundabout which will be affected by the design.

- Sohar (R/A-12)
  Alteration but maintaining Type B with wider median for the large new monument under construction.

- Falaj Al Qabail (R/A-14)
  Alternation from Type B to Type A due to the difficulty of land acquisition including many houses and the low importance of the existing monument.

- Aqr (R/A-18)
  Raising the embankment of quadrant connector in order to install a crossing box culvert for new service road.

The vertical alignment is basically the same as the results of the F/S:
- Grade of 3% at both sides of a roundabout.
- Vertical clearance height 5.7m at the carriageway of a roundabout.
- Crest at the center of a roundabout and sag at both sides of a roundabout.
  For the details,refer to Fig.3.11.

In addition, minor alterations to the designs are as :
- Longer vertical curve length on crest considering the new Highway Design Manual.
- Longer vertical curve length on sag by eliminating the remaining short tangent to provide more comfortable driving.

(3) Alinement of Roundabout

The existing roundabouts are of elliptical shape in order to accommodate smooth flow of traffic on the Batinah Highway. With grade separation of the main highway, the traffic flow at the roundabout including rampways will change; i.e. the main traffic streams will be in fact to and from the crossroads. Hence, it is not necessary to retain the present configuration. It is preferable to provide an elliptical shape in the direction of the main traffic flow between a seaside crossroad and an inland crossroad, under the condition that there are ample open spaces at both sides of the roundabout and that there will be no difficulty in relocating any existing buildings.

An exception for the above case is the roundabout at Al Muladdah where the main traffic flow occurs between a rampway and a crossroad. The other roundabouts also have high traffic volumes between rampway and crossroad, although this direction is not the main traffic flow. Therefore, a continuous circular roundabout is proposed considering the possible land acquisition problems and the traffic flow pattern as mentioned above (reference to Figure 3.4).

Moreover, it is not economical to retain the existing roundabouts due to the following reasons.

- Most of the roundabouts will be demolished with the construction of foundation piers for the flyovers.
- As it is difficult to satisfy the required sight distance at the short radius stretch of the roundabout, the location of pier inside the roundabout will be much constrained. This fact will bring about an irregular span arrangement or longer spans. Furthermore, this situation is not good in terms of aesthetic considerations.

(reference to Figure 3.6)

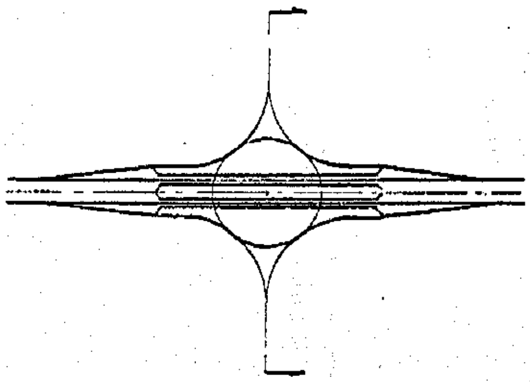
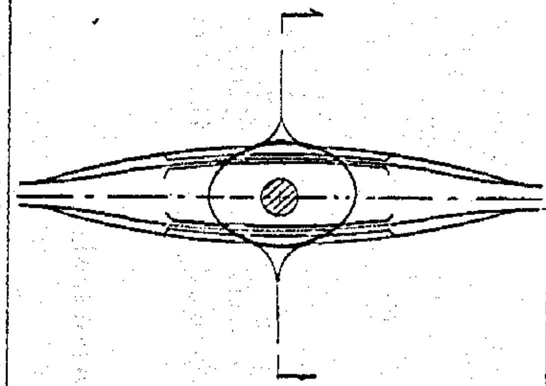
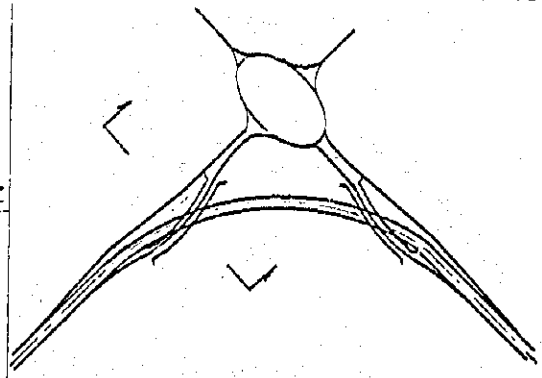
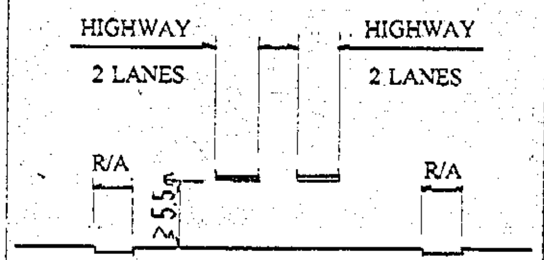
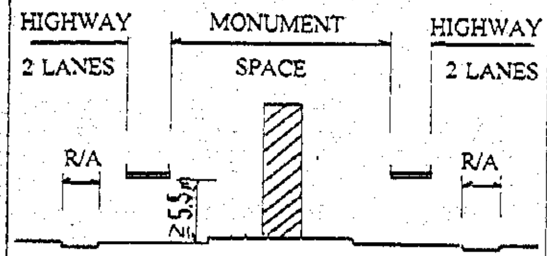
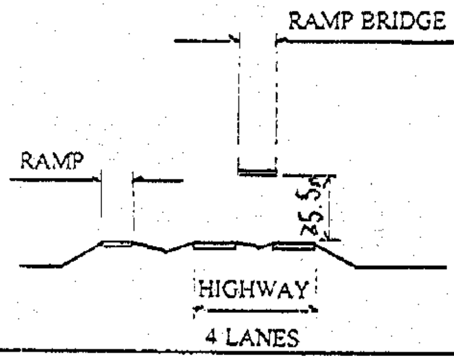
It is thus apparent from the above statements that a circular roundabout is preferable. However, in accordance with the result of the discussion between the MOC Technical Committee and JICA Study Team, the type/shape of roundabouts shall be as mentioned in Table 3.5.

Table 3.5 Type of Roundabout for Detail Design

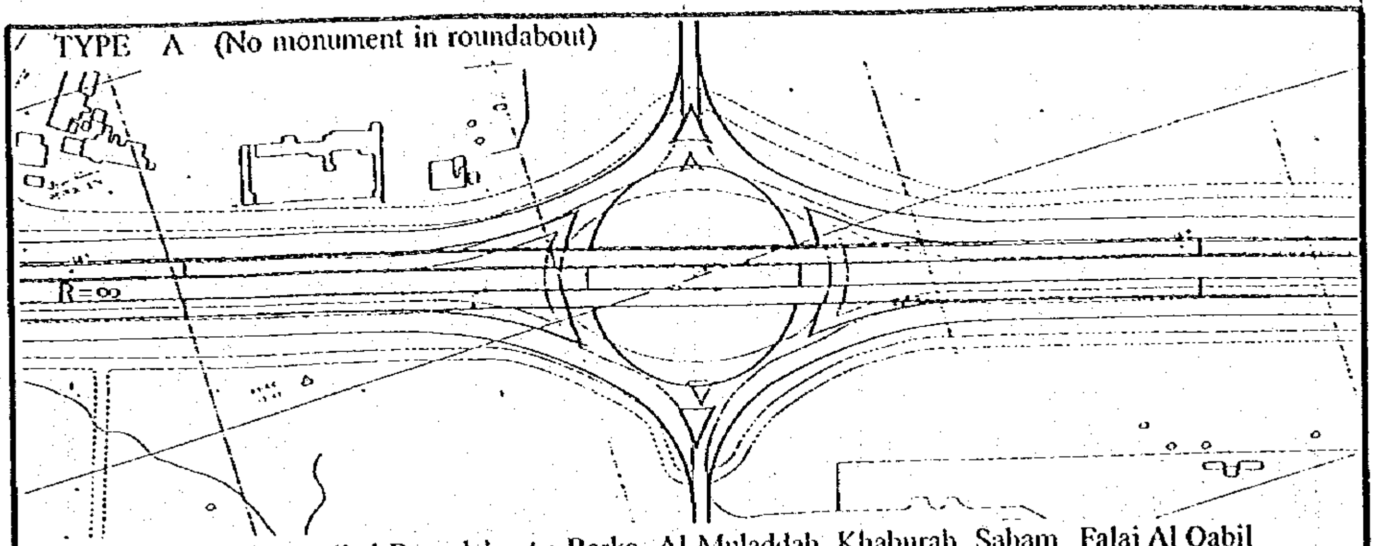
NO.of R/A	Name of R/A	Type of R/A	Monument in R/A
R/A-2	A'Naseem Garden	Existing Elliptical	Existing Monument
R/A-3	Barka	Modified to Circular	Nil
R/A-5	Al Muladdah	Existing Elliptical	Nil
R/A-8	Al Khaburah	Modified to Circular	Nil
R/A-10	Saham	Modified to Circular	Nil
R/A-12	Sohar	Modified to Large Elliptical	Under Construction
R/A-14	Falaj Al Qabail	Modified to Circular	Nil
R/A-18	Aqr	Special	Nil

Note: Sohar Roundabout is modified by altering the short radius only.

Table 3.4: Basic Flyover Types

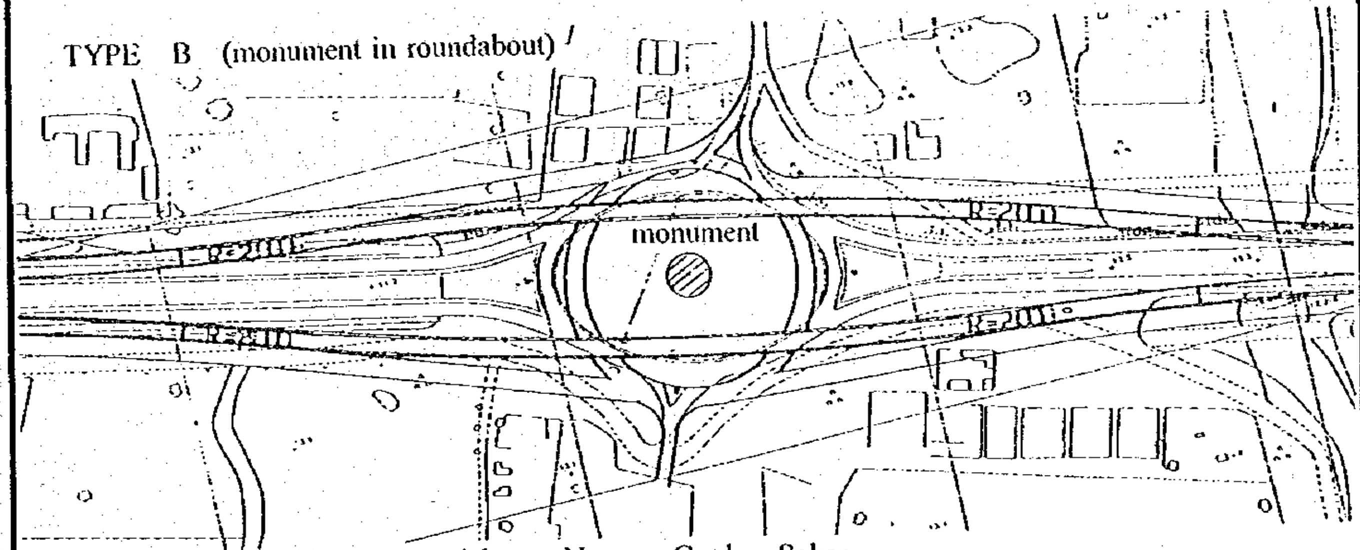
	TYPE A	TYPE B	TYPE SPECIAL
SKETCH			
TYPICAL CROSS SECTION			
DESCRIPTION OF TYPE	Straight alignment passing through center of re-structured circular R/A or existing R/A.	Flyover shifted to both edges of existing or modified.	Highway quadrant connection at grade. Existing road to or from R/A grade-separated by ramp bridges.
RELATIONSHIP TO MONUMENT	Monument not preserved	Almost all monument preserved	Existing monument preserved. New proposed flyover structure become symbol of regional identity
ADOPTED R/A	Barka, Al Muladdah, Al Khaburah, Saham, Falaj Al Qabail	A'Naseem Garden, Sohar	Aqr

TYPE A (No monument in roundabout)



Applied Roundabout : Barka, Al Muladdah, Khaburah, Saham, Falaj Al Qabil

TYPE B (monument in roundabout)



Applied Roundabout : Naseem Garden, Sohar

TYPE SPECIAL

Applied Roundabout : Aqr

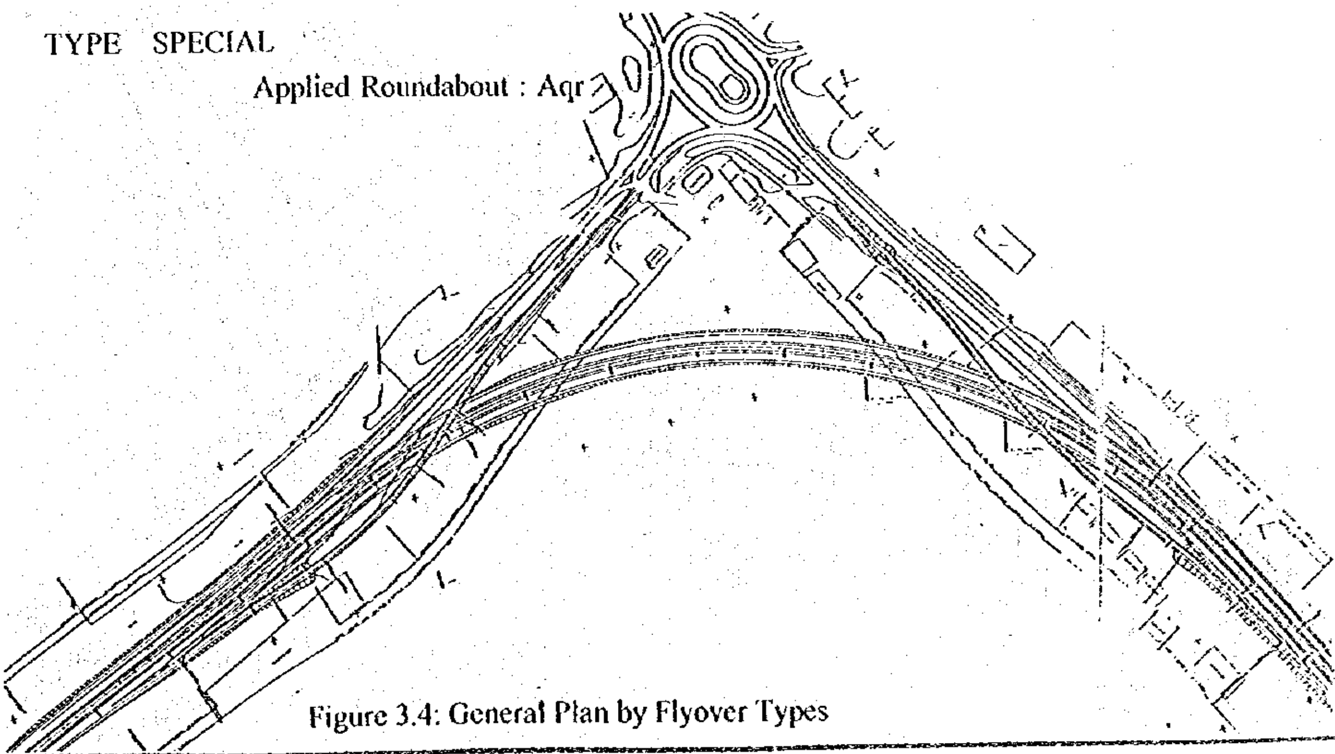


Figure 3.4: General Plan by Flyover Types

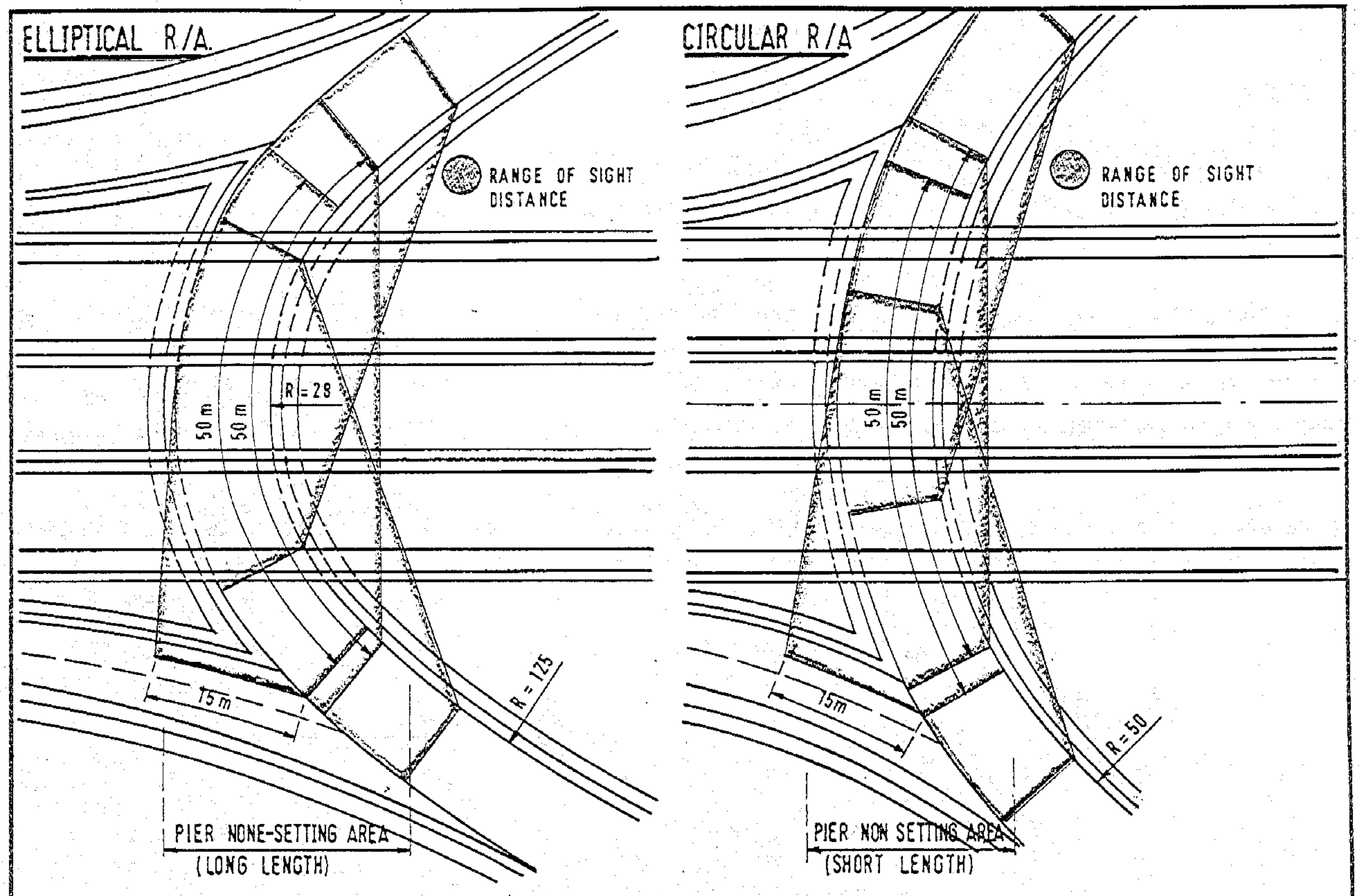


Figure 3.6:Sight Distance Related to Roundabout

3.2.2 Bridge Length and Span Arrangement

(1) Determination of Bridge Length

Bridge length for the detailed design of the proposed flyovers is determined in considerations of a number of factors. Some of these factors are the economics of construction, aesthetics, the present geometrics of Batinah Highway and the roundabouts.

a) Economic Aspects

In determining the bridge length, the study team carried out a comparative analysis on the economics in construction of the bridge inclusive of the approach wall of a spread footing type against a pile foundation type.

The comparative analysis conditions are set at:

1. Width - Carriageway: 10.7 m, Sidewalk: 2 x 1.2 m = 2.4 m,
   Effective width = 12.2 m.
2. Superstructure - simple post-tension PS girder
3. Span length - 25 m.
4. Sub-structure - Rigid frame pier type
5. Approach wall - Terre-armee wall
6. Foundation - Spread footing type
   - Pile foundation type
7. Comparative analysis section - Half bridge length and single direction roadway
8. Comparative bridge lengths - 4.5@25 m = 112.5 m to 7.5@25 m = 187.5 m

The comparative analysis results are shown in Figure 3.7. For all the bridge length alternatives, the spread footing types cost less than the pile footing types by a ratio of about 1:1.4.

For the spread footing types, cost per unit length of the approach is cheaper than the bridge. For this reason, the more the bridge section is shortened, the lower the total cost of grade separation would be estimated. For the four different bridge length cases of spread footing types shown in Figure 3.8, the cost ratios are found to be 1, 1.02, 1.04 and 1.07.

On the other hand, for the piled footing types which will be preferred in areas with poor geological conditions, cost per unit length of the approach is not much different from that of the bridge section. This is because for this type of bridge, the savings in shorter bridge section is offset by the cost of replacement done to a depth of 5 m under the approach which is needed to prevent subsidence and slip of the frictional fills. For this reason the costs of this type of bridges irrespective of their bridge lengths do not differ significantly as shown in Figure 3.9.

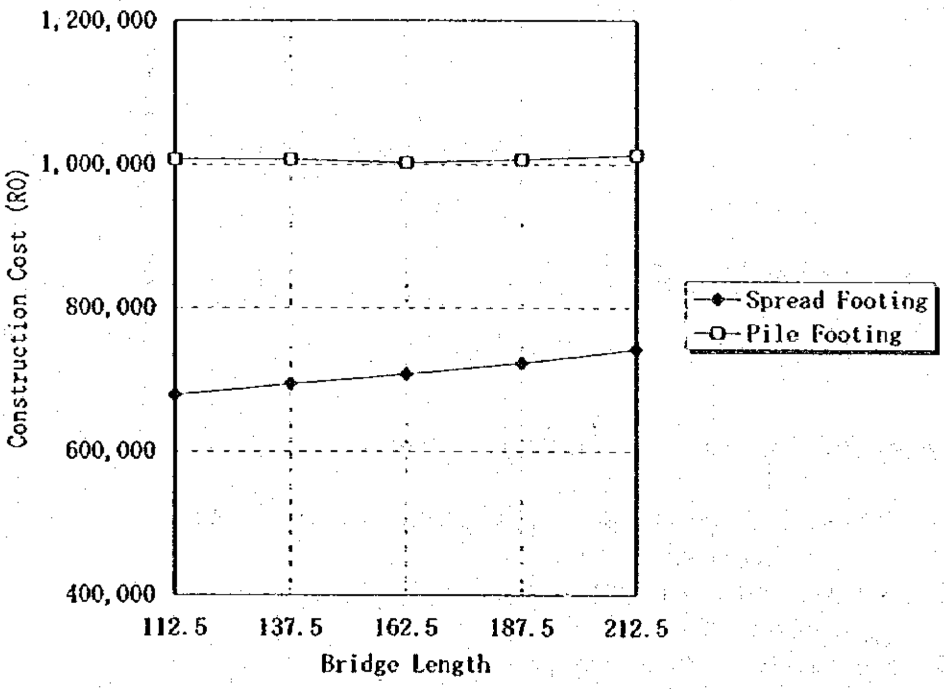
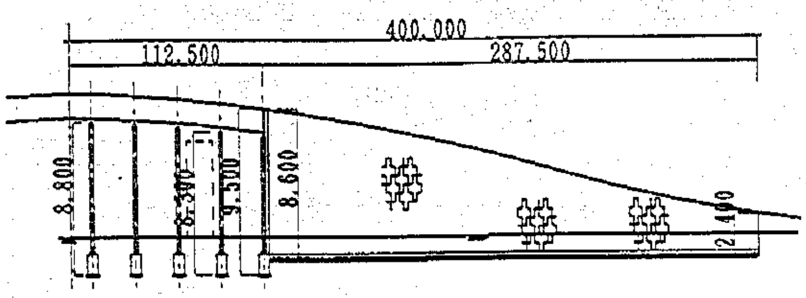


Figure 3.7 : Comparative Analyses of Cost Between Spread Footing and Piled Footing Bridges

b) Aesthetic Considerations

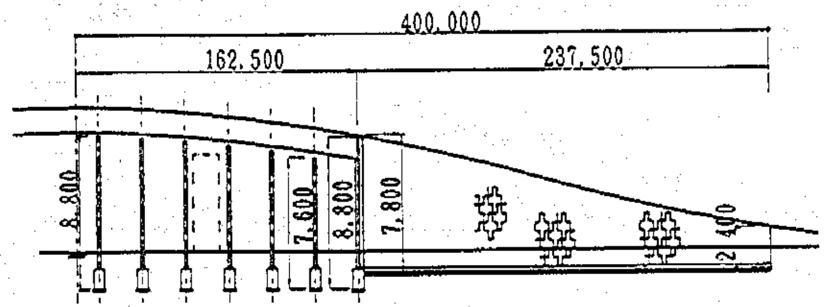
At the 8 study roundabouts, landscaping efforts to improve the aesthetics of these facilities have been taken by the respective local authorities. From the landscaping point of view, a minimum bridge length of about 250 m to 300 m is most desired in giving a sense of openness under the flyover and to ensure ample space under the girder. Existing flyovers in Muscat with similar bridge length for instance do display such characteristics. In addition to the above considerations, the geometrics of the existing roundabouts, sight distances of drivers and the surrounding landscaping elements, the balance of the overall bridge design have all pointed to the conclusion that a bridge length of about 250-300 m is the most appropriate. (Figure 3.10)

Bridge Length 2*112.5m=225.0m



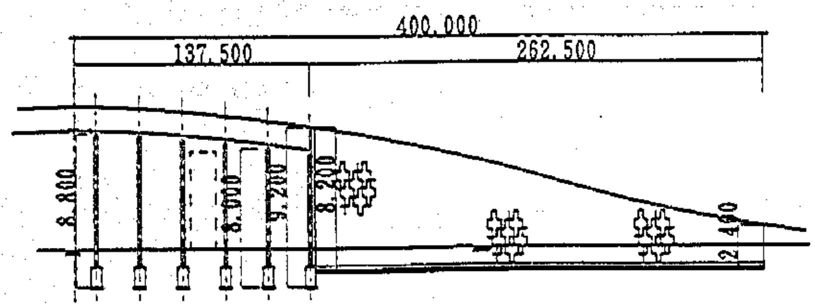
Construction Cost	678.313 RO

Bridge Length 2*162.5m=325.0m



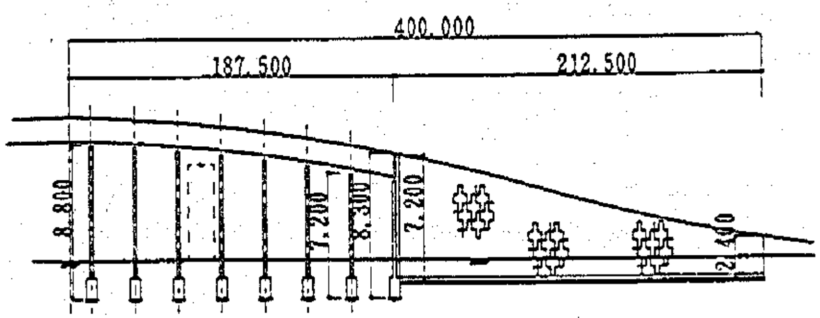
Construction Cost	707.519 RO

Bridge Length 2*137.5m=275.0m



Construction Cost	693.907 RO

Bridge Length 2*187.5m=375.0m



Construction Cost	722.796 RO

Figure 3.8: Economic Appraisal of Alternative Bridge Lengths for Spread Footing Types

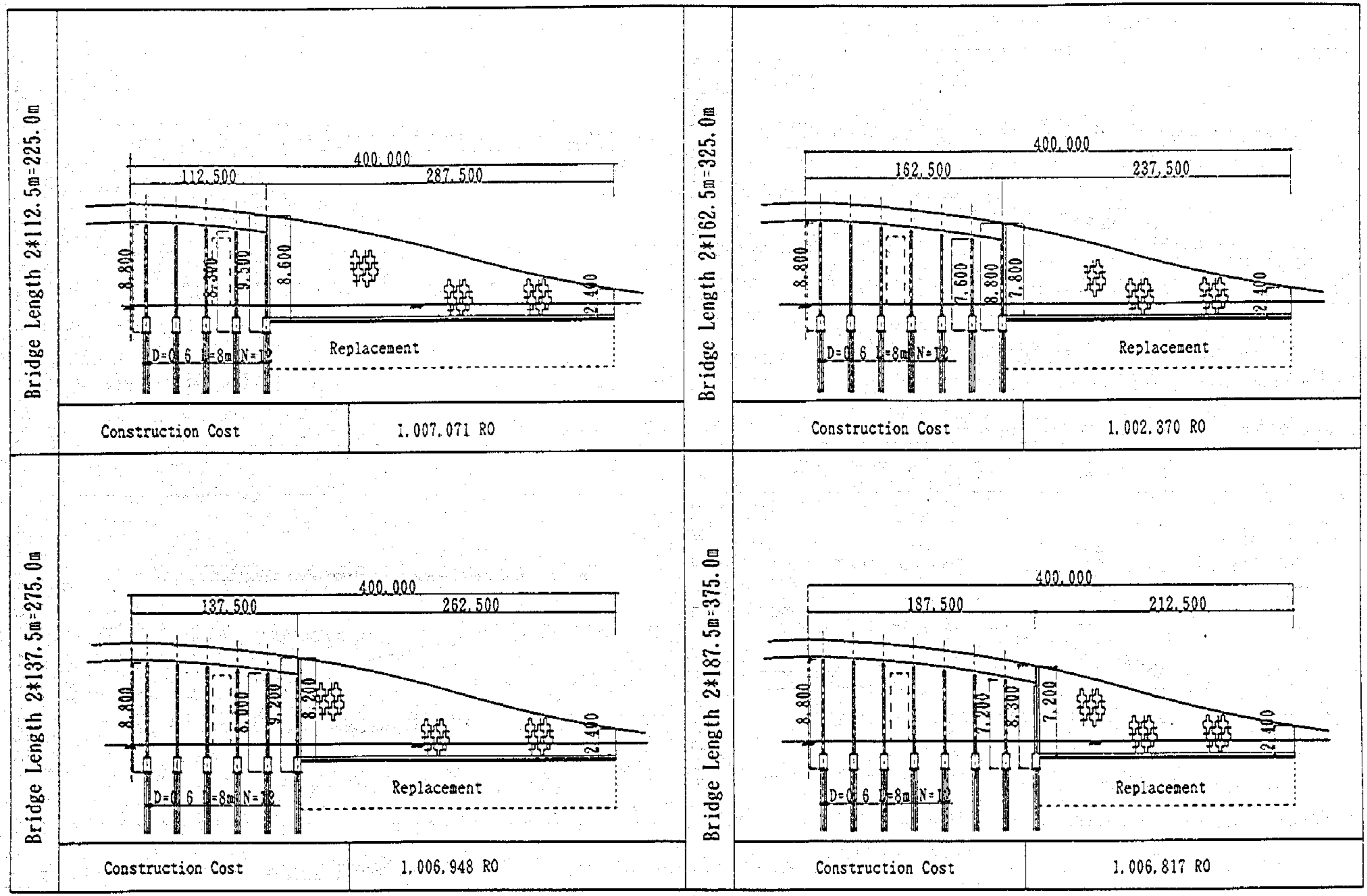


Figure 3.9: Economic Appraisal of Alternative Bridge Lengths for Piled Footing Types

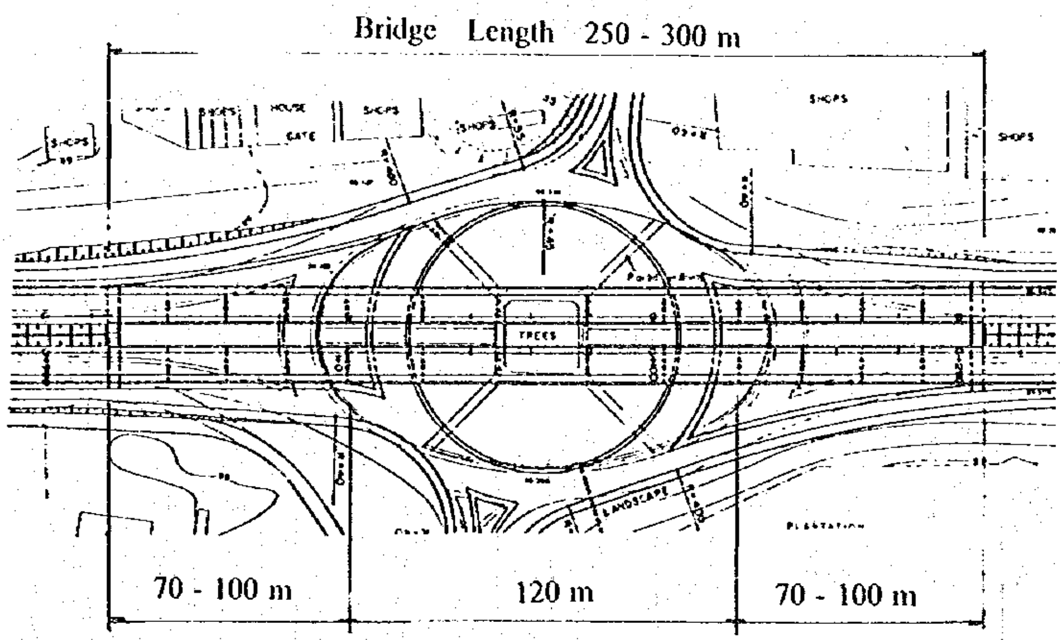


Figure 3.10: Recommended Bridge Length

c) Geometric Considerations

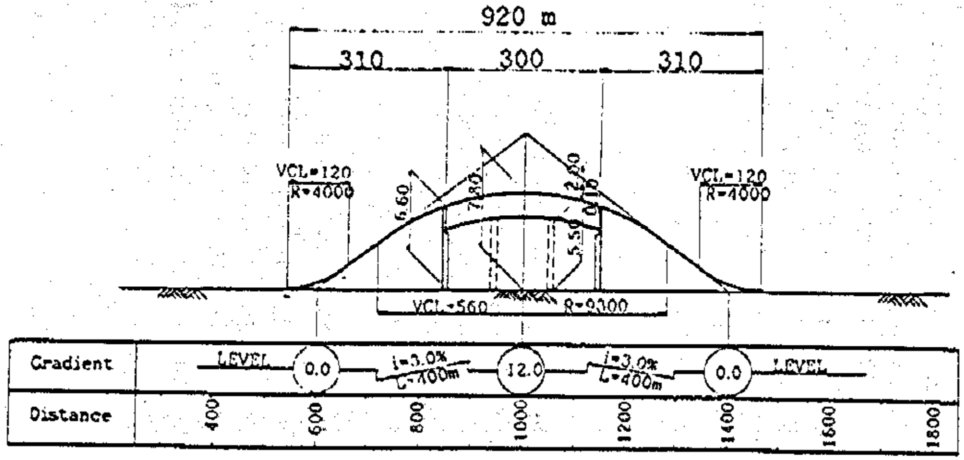
Highway geometrics and structural design standards are used for the planning of highway alignments such as the vertical alignment. In the previous F/S study, the Vertical Curve Lengths (VCL) and Vertical Curve Radii (VCR) of bridges inclusive of the approach roads that satisfy the requirements of a grade of 3% or 4% or 5% are given in Figure 3.11. However, considering the vertical clearance, approach road length and vehicle running behaviour, a grade of 3% is the most recommendable. Moreover, at this grade, a bridge length of about 300 m is most preferred. Examples of bridges with lengths of 250-300 m can be seen at many of the existing roundabouts in the Sultanate.

(2) Span Arrangements

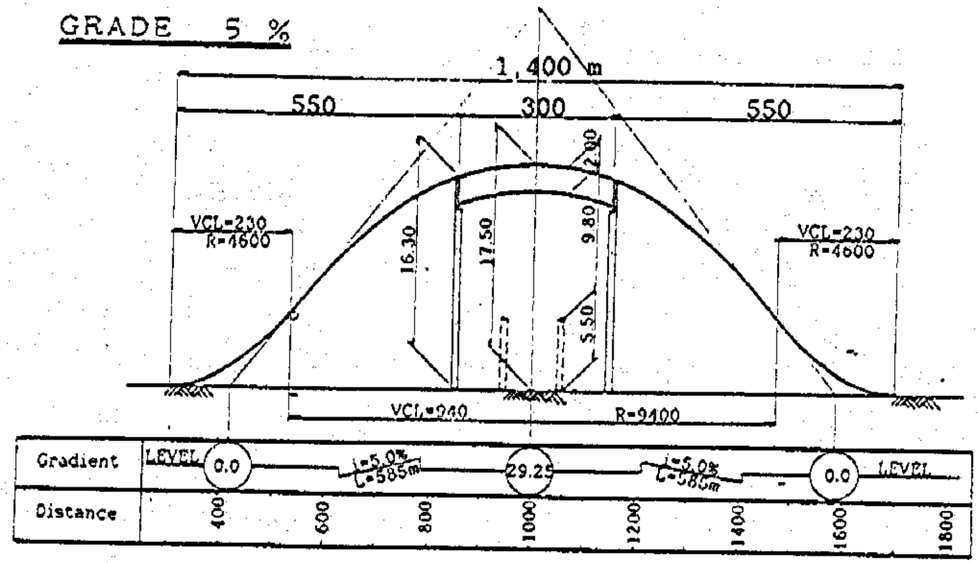
Span arrangement is chiefly dependent on the horizontal configuration of the roundabout and the geometric structure of roads. As the re-structured circular roundabout basicaly has a radius of 50 m, a girder length of 25-30 m is considered appropriate considering its costs and ease of construction. Additionally it is possible to apply the same girder length to the roundabout with elliptical shape.(reference to Chapter 3.2.1)

An uniform girder height will be most desirable from such perspectives as aethestics and girder casting work. Therefore, similar span length will be used for each flyover in principle. In case where this principle cannot be applied due to such constraints as the roundabout radius or distances, variation of span length may have to be considered. Irrespective of this however, the girder height will be kept the same through all the spans.

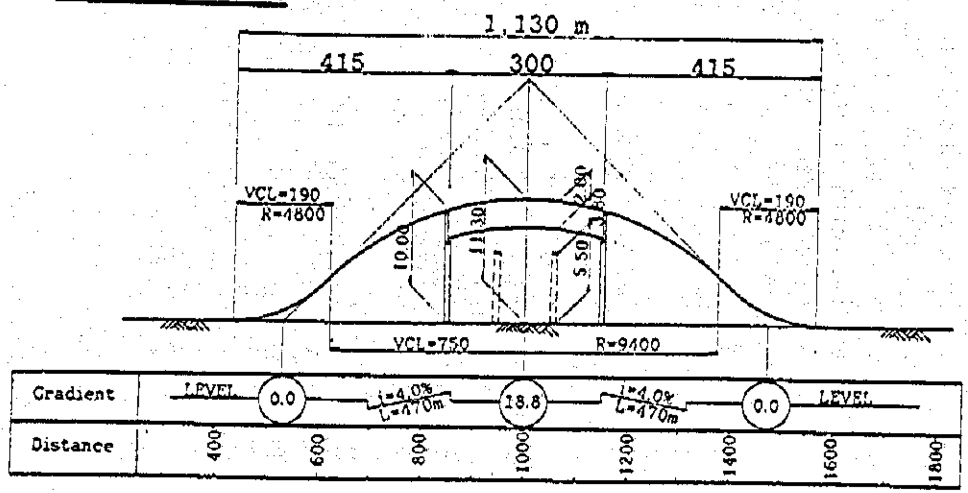
GRADE 3 %



GRADE 5 %



GRADE 4 %



Alternative of Vertical Alignment

Gradient		3 %	4 %	5 %
Vertical Curve (Crest)	Length	560 m	750 m	940 m
	Radius	9,300 m	9,400 m	9,400 m
Vertical Curve (Sug)	Length	120 m	190 m	230 m
	Radius	4,000 m	4,800 m	4,600 m
Flyover Length	Total	920 m	1,130 m	1,400 m
	Approach Bridge Approach	310 300 310	415 300 415	550 300 550
Crest Height		7.80 m	11.30 m	17.50 m
Recommend		◯	—	—

Notes:
1. Design Speed 120km/h
2. Vertical Curve Length
   Crest: $VCL = AS^2/426$
   Sug : $VCL = 2S - (152.4 + 3.5S)/A$

Figure 3.11: Analysis of Alternative Vertical Alignments and Their Requirements

3.2.3 Type of Bridges

Structural types for the proposed flyovers can be classified according to their respective super-structure, sub-structure, foundation and approach structural types.

These structural element types are proposed in this study to satisfy firstly, the design standards requirements for flyovers at roundabouts, and secondly, to achieve the best results in such factors as cost of construction, structural stability and structural aesthetics.

(1) Super-structure

In the F/S study, prestressed concrete (PS) bridge has been recommended as the most appropriate bridge type for the study flyovers. A bridge with span length of 20 m was found to be the most economical and the construction cost variation was also found to be very small for different span lengths varying from 20 m to 30 m.

Precast PS bridges with spans between 20 to 30 m can be classified into pre-tension girder bridge and post-tension girder bridge, according to the way the girders are constructed. As the names suggest, in the pre-tension girder, tension is applied before the concrete is cast, while in the latter, tension is only applied after the concrete has been cast. Their respective merits are discussed as follows:

a) Pre-tension Girders

1. Since these are commonly factory-manufactured in the factory, there is no problem with quality control.
2. Transportation to site is not a problem since girders up to 25 m in length are common.
3. Mass production in the factory is possible, resulting in great savings in construction time.
4. Tensioning facility at the factory is needed.

b) Post-tension Girders

1. Generally manufactured at designated yard near the construction site.
2. Great attention must be paid to quality control during manufacturing.
3. No transportation problem.
4. Construction period often dictated by the scale of manufacturing yard or stockyard that can be secured near the site.
5. Precast block method is increasingly used to manufacture this type of girder in recent years in view of the above problems.

In addition, by using all staging construction methods where girders are manufactured and hauled into the final positions on site, the post-tension girders have the following added features:

1. Girders with exceptional long span, if required, can be manufactured without any transportation problems,
2. Since there is no constraint on the shape of girders, they are most appropriate for curved bridges.
3. Strict quality control however is needed for the curing of concrete and tensioning the reinforcement steels at the yard.

In selecting the most appropriate type of girders to be used for the proposed flyovers, a survey of existing flyovers in Oman and hearings from local construction firms were conducted. The summary of findings of these surveys are:

1. Post-tension prestressed simple reversed T girders are most commonly used in recent years in Oman.
2. Most girders are simple girder with span of less than 30 m.
3. Transportation of girders up to 30 m is not a problem in Oman.
4. Generally, girders are manufactured in yards equipped with overhead covering facility near the construction site.
5. Truck crane is commonly used to haul and place the girder.

Based on the above survey results, the following recommendations are made:

1. Precast post-tension girders are recommended for the proposed flyovers in this study. Except for Aqr Roundabout, construction of the proposed flyovers will be carried out at the roundabouts by detouring or diverting traffic on the existing Batinah Highway and the crossroads. Since the flyovers are to be constructed over the existing roundabouts, the roadways will be used to set up the supporting scaffolding. Shortening of construction time and ensuring the safety of the supporting scaffolding are therefore important considerations.

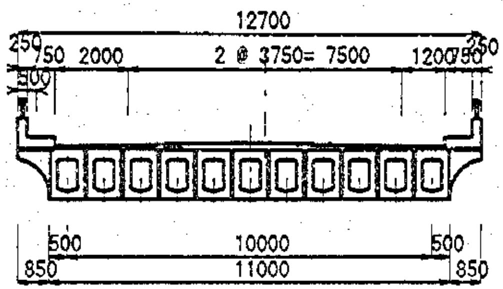
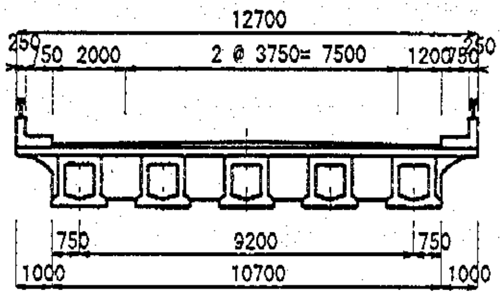
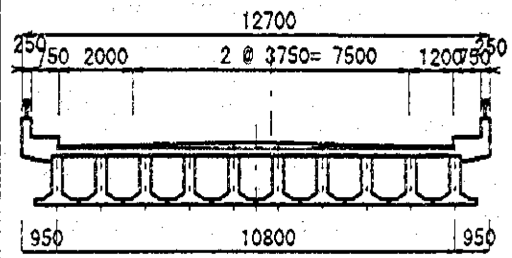
   The structural shape of the recommended girder is derived from a comparative analysis of three cross-sectional types shown in Table 3.6. In this table, the comparative analysis is done using the following factors:

   a) Girder height
   b) Ease in construction
   c) Structural stability
   d) Aesthetics
   e) Economic aspect

Except for Aqr R/A, Type-1 girder is recommended for the proposed flyovers. The major merits of Type-1 girder are its aesthetic features with its low girder height thus giving a slender side view as well as a continuous even under-view of the bridge. Type -1 is also considered as the type that matches best with the surrounding landscaping and the sub-structure elements. Cross-sectional details of super-structure of Type -1 to Type- 3 and that for Aqr R/A are shown in Figures 3.12 to 3.15.

2. For Aqr Roundabout, the proposed flyover is a ramp bridge with narrow widths to be constructed away from the existing roadway. As it is located at the gateway to Oman from the Emirates, aesthetic considerations are important. For these reasons, 2 to 3 span continuous, manufactured-on-site post-tension PS girders are recommended.

Table 3.6: Comparative Analysis of Super-structural Types For Flyovers

	Type 1 P. C. Box-Slab Section		Type 2 P. C. Box-Girder Section		Type 3 P. C. T-Girder Section	
Section of Superstructure						
Girder Height (H)	Span Length 20m	H= 1.10	Span Length 20m	H= 1.10	Span Length 20m	H= 1.10
	Span Length 25m	H= 1.30	Span Length 25m	H= 1.35	Span Length 25m	H= 1.50
	Span Length 30m	H= 1.50	Span Length 30m	H= 1.65	Span Length 30m	H= 1.80
Ease of Construction	Easy (No cast in-situ work) Short construction period --> Best	○	Cast in-situ work for cross beam Long construction period --> Fair	△	Cast in-situ work for slab Long construction period --> Good	△
Structural Stability	Most stable structure --> Best	○	Less stable than type 1 --> Good	○	Less stable than type 1 and 2 --> Fair	△
Aesthetics	Most slender girder height --> Best	○	Girder height thicker than type1 --> Good	△	Girder height thickest among the 3 types --> Fair	○
Economic Evaluation	Less economical than type 2 (Ratio=1.11) --> Good	△	Most economical (Ratio=1.00) --> Best	○	Less economical than type 2 (Ratio=1.13) --> Fair	△
Recommendation	Recommended	○	———	△	———	△

Note Condition: Span Length=20.0m to 30.0m Live Load: AASHTO HS20-44 increased 100%

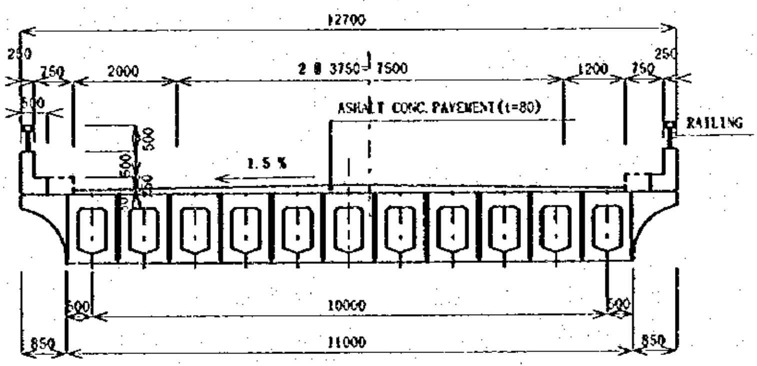


Figure 3.12: Cross-sectional Details of Super-structure Type 1 Girder

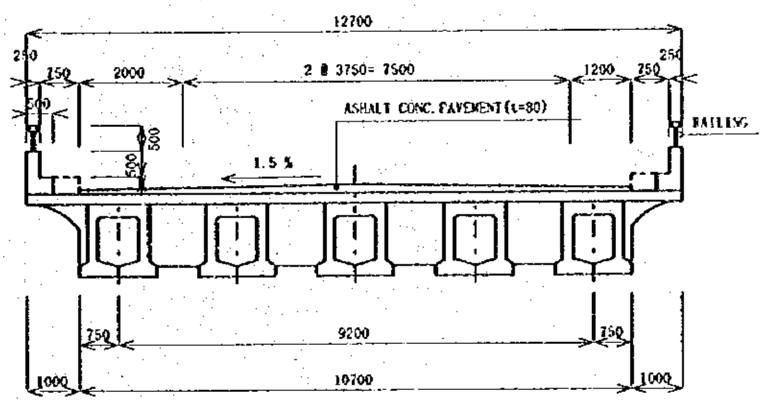


Figure 3.13: Cross-sectional Details of Super-structure Type 2 Girder

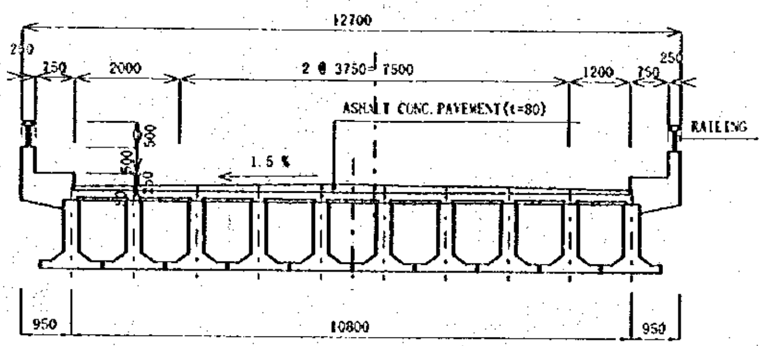


Figure 3.14: Cross Sectional Details of Super-structure Type 3 Girder

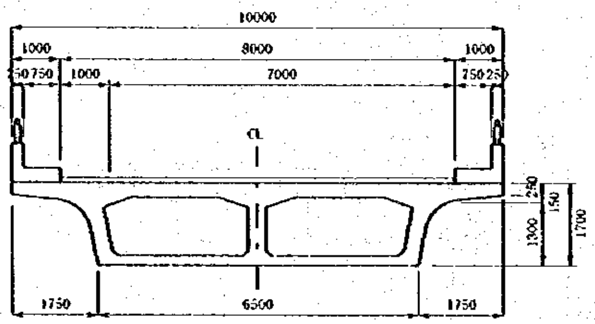


Figure 3.15: Cross-sectional Details of Super-structure Type 4 Girder For Aqr R/A

(2) Sub-structure

Based on the results of the Feasibility Study, the sub-structure types are selected based on the following factors:

a) Scale and width of the super-structure,
b) Matching the landscaping elements in the roundabout and the surrounding areas
c) Sight distance of vehicle travelling in the roundabout and on the cross-roads,
d) Structural stability and costs of construction.

Considering the above factors, excepting for Aqr R/A, the following structure types are recommended for the seven flyovers. Combination of these structural types are then selected for each of the flyovers.

Table 3.7: Sub-structure Elements and Types

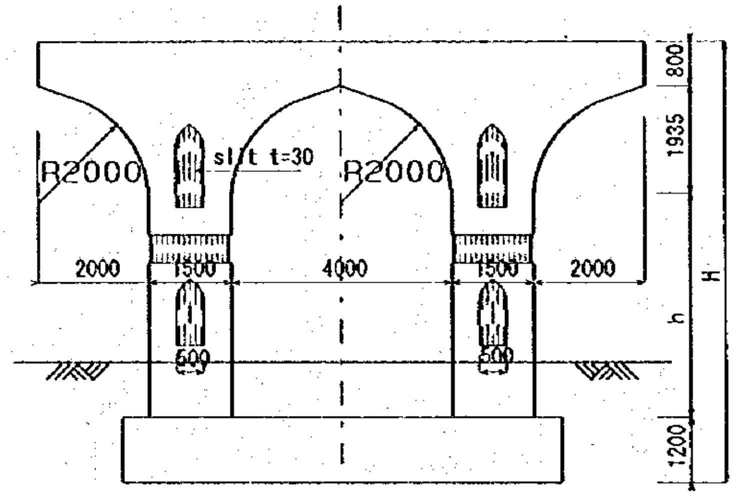
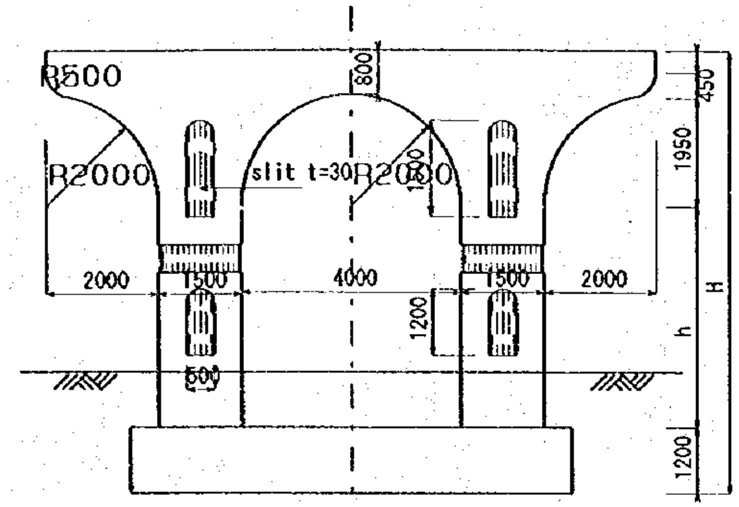
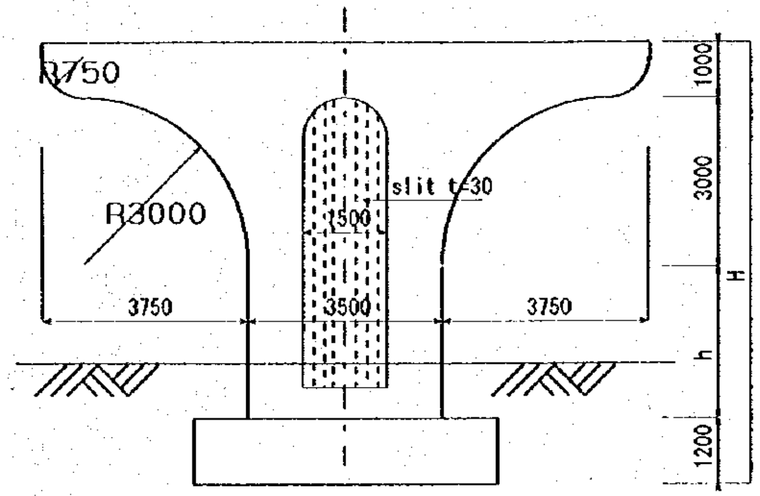
Structure	Type
Abutment	Reinforced Concrete Reversed T-shape
Pier	Reinforced Concrete T-Shaped Wall
	Reinforced Concrete Rigid Frame (2 column)

The proposed Aqr Flyover is located at the gateway to the UAE. and aesthetic consideration is therefore an important factor. The pier for this flyover is designed to match the width and shape of the super-structure. As a result, a curved wall is recommended for the bridge ends.

For the main section, a rigid frame 2-column sub-structure is proposed incorporating a symbolic tower design on one of the columns to achieve aesthetic effects.

The proposed sub-structure types for all the proposed eight flyovers are selected and shown in Figure 3.16.

Consequently, combining the proposed super-structure and sub-structural types for the flyovers, the cross-sectional details are shown in Figures 3.17 to 3.20.

Section of Sub-structure	Type - 1	Type - 2	Type - 3
	Rigid Frame (Two Column)	Rigid Frame (Two Column)	T - Wall
	 Recommended F/O : A'Naseem Garden. Sohar. Falaj Al Qabail.	 Recommended F/O : Barka. Al Muladdah. Al Khaburah.	 Recommended F/O : Saham. Combination with Type-2(for side span): Barka. Al Muladdah. Al Khaburah.

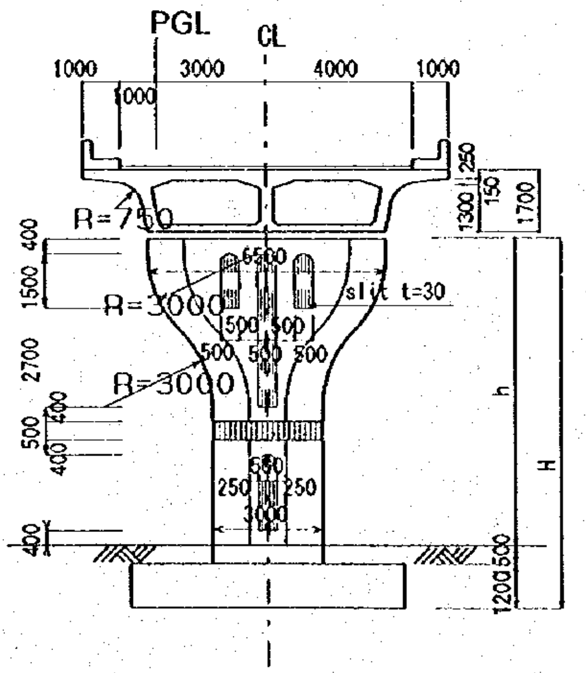
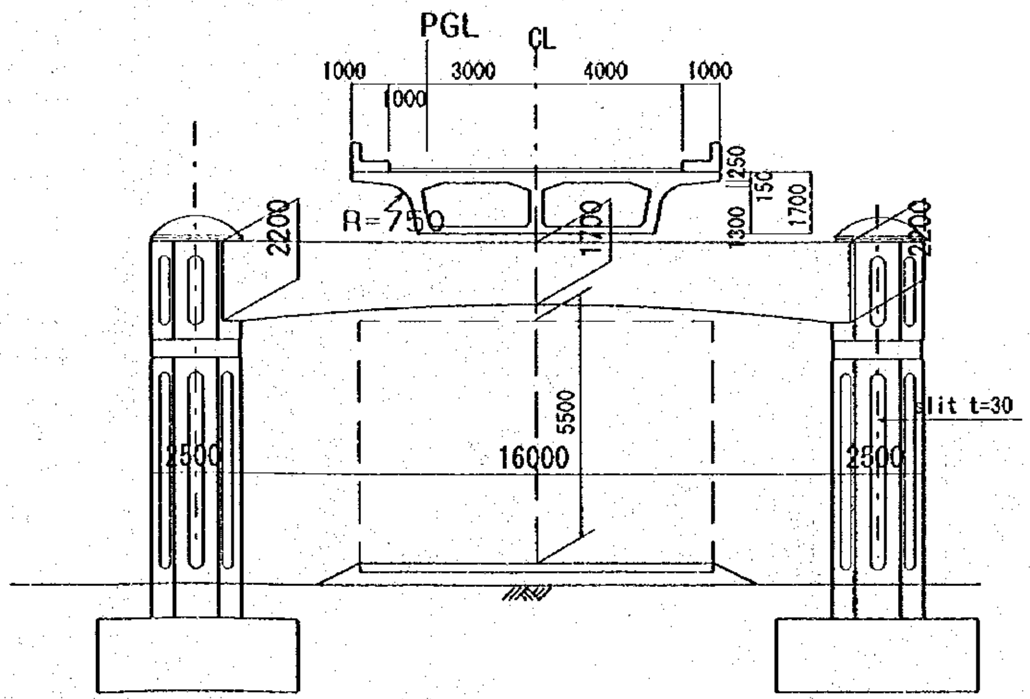
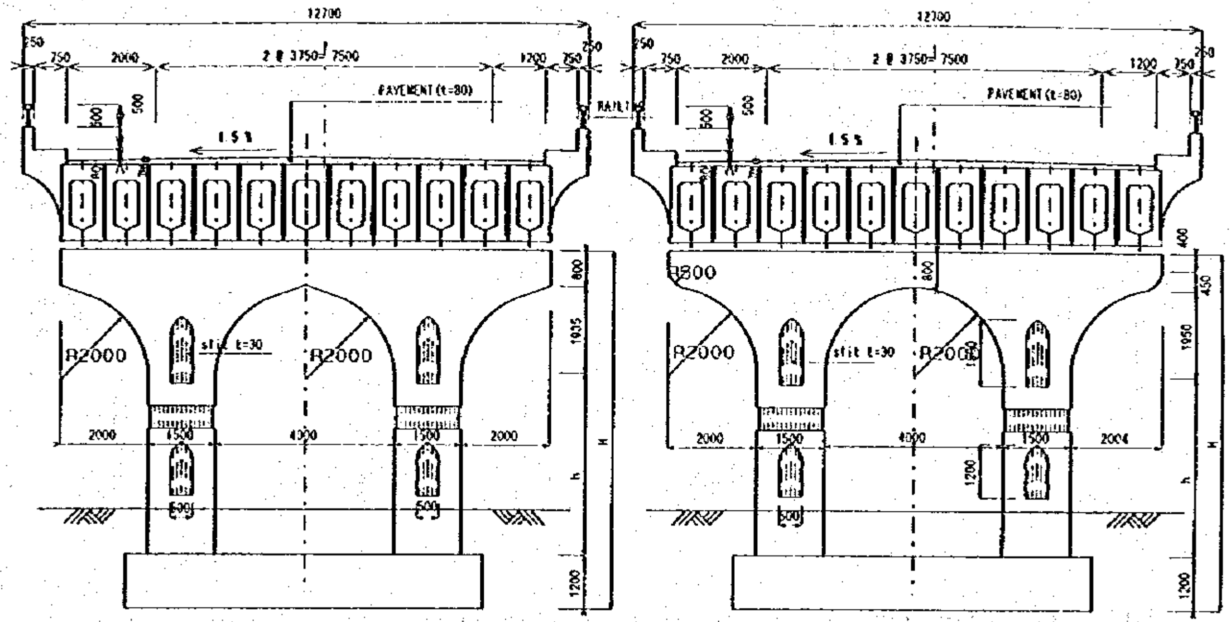
Section of Sub-structure	Type - 4 (Special)	Type - 5 (Special)
	T - Wall	Rigid Frame (Two Column)
	 Recommended F/O : Aqr	 Recommended F/O : Aqr

Figure 3.16 Recommended Types of Sub-structure for the Proposed Flyovers



Figures3.17:Cross-sectional Details of Super-structure Type-1 with Sub-structure Type-1 and 2.

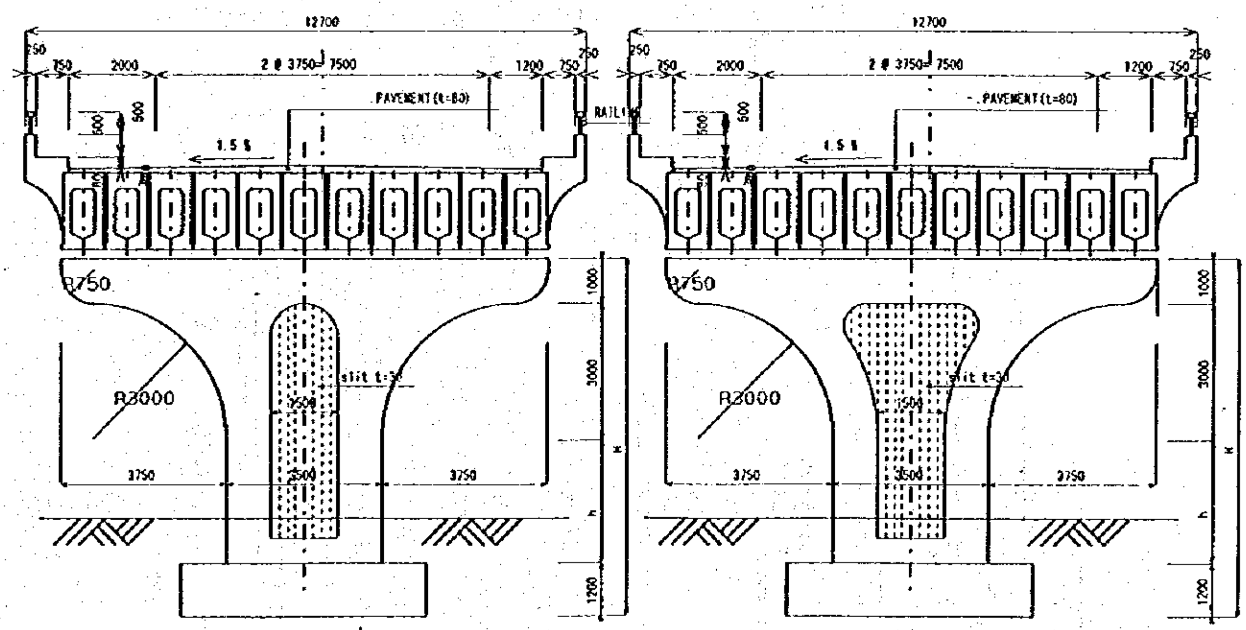


Figure 3.18: Cross Sectional Details of Super-structure Type-1 with Sub-Structure Type-3

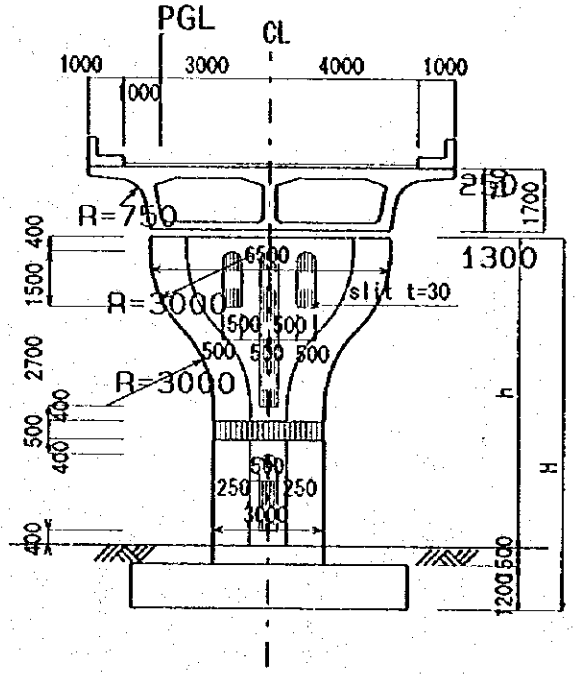


Figure 3.19: Cross-sectional Details of Super-structure Type-1 with Sub-Structure Type-4

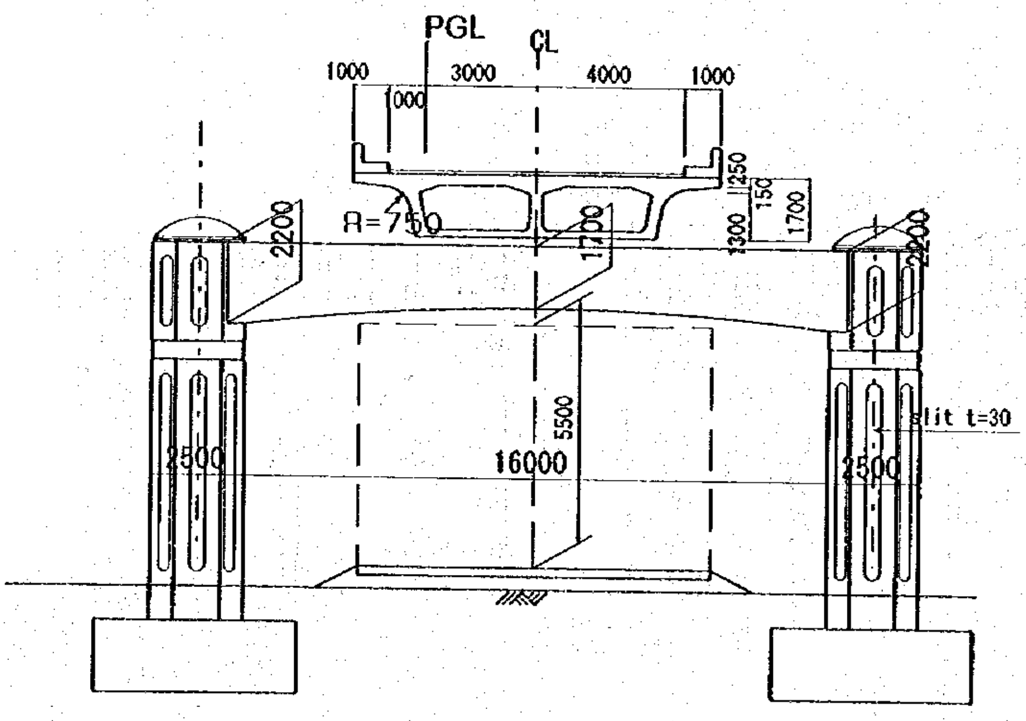


Figure 3.20: Cross-sectional Details of Super-structure Type-1 with Sub-Structure Type-5

(3) Foundation Types for The Sub-Structures

a) Basic Considerations

Foundation structure has the important function of transmitting loads from the super-structure and sub-structures down to the ground bearing layer. Foundation should therefore be stable under the various forces without giving way or shifting at the base. Spread footing is basically applied where there is a good and shallow bearing layer. Piled foundation is applied to penetrate to the good bearing layer except for areas where such bearing layer cannot be ascertained, or is too deep or in other special circumstances. A good bearing layer can be defined as :

1. Silty layer with a general N value of more than 20 (unconfined compressive strength q_u more than 4 kg f/sq.cm),
2. Sandy layer with a N value of more than 30.

Foundation structure can be classified according to their shapes, such as spread footing, caisson footing and piled footing. The application of each of these footing types depends on the loads, depth to the bearing layer and the surrounding conditions.

In general, given the scale of loading and the depth of bearing layer, the type of foundation footing applicable is summarized in Table 3.8.

Table 3.8: Type of Foundation Footings by Loading & Depth of Bearing Layer

Conditions		Spread Footing	Driven Pile		Drill Shaft
			RC Pile	Steel Cylinder Pile	
Loading (for each member of sub-structure)	< 500 ton	O	O	O	O
	> 500 ton	O		O	O
Bearing Layer Depth D_f in meter	0-5 m	O			X
	5-10 m		O	O	O
	10-20 m	X			O
Conditions of intermediate layer	N < 15		O	O	O
	15 < N < 30			O	O

Notes: O = most applicable, = applicable at times, X = not applicable

Results of soil investigation survey conducted in this Study at the 8 study locations indicated that the bearing layer could be found as shallow as 1 m below the surface at some locations or the deepest at 10 m below the surface.

For the design of the proposed 8 flyovers in this study, spread footing or piled footing foundations are therefore recommended.

In the Sultanate of Oman where probability of earthquake and horizontal forces on foundation are small, the scale of foundation can be decided based on the vertical bearing capacity. The spread footing therefore utilizes the vertical bearing of the entire surface area of the foundation. The piled footing on the other hand, utilizes the pile surface frictional forces and the pile tip bearing force as the total vertical bearing capacity. For these reasons, good vertical bearing capacity of piled footing cannot be achieved without a certain sufficient depth to the bearing layer. In this study, the cost of piled footing is found to be higher than spread footing under the present conditions on site.

During the construction stage, it is important to consider the environment around the construction site. In the case where the bearing layer is deep and piled footing is selected, gradient and scale of the cutting slopes must be carefully monitored. A large scale cutting area will required major traffic diversion measures, while steep slope gradient may pose landslide problems in rainy situation.

Generally speaking reaction through the superstructure will principally affect the bridge pier structure and earth pressure will mainly affect the bridge abutment and the retaining wall structures although loading scale of the abutment is larger than that of the retaining wall.

In this study, therefore, selection of foundation types is defined as follows:

- Bridge pier : spread footing is recommended at locations where the bearing layer is less than about 6.0 m below the surface and piled footing is recommended for locations where the bearing layer is deeper.
- Bridge abutment : spread footing is recommended at locations where the bearing layer is less than about 4.0 m below the surface and piled footing is recommended for locations where the bearing layer is deeper.
- Retaining wall : spread footing is recommended at locations where the bearing layer is less than about 4.0 m below the surface and piled footing is recommended for locations where the bearing layer is deeper.

The selection of the foundation type therefore depends on the results of the soil investigation which is described in Appendix III. At the time of this reporting, however, only partial results of the soil investigations are available. Please refer to Appendix III .

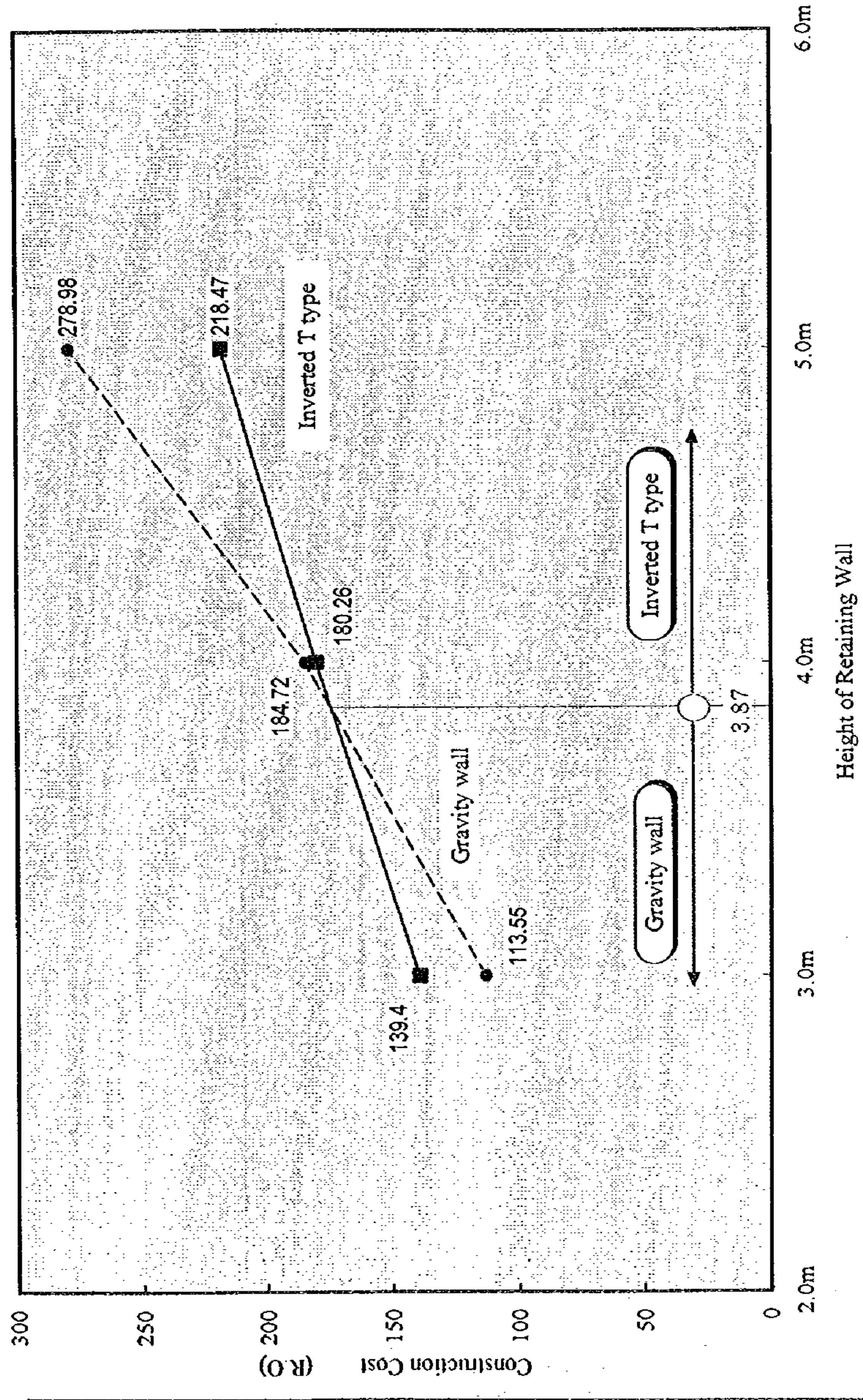


Figure 3.21 Economic Comparison of Retaining Wall Type

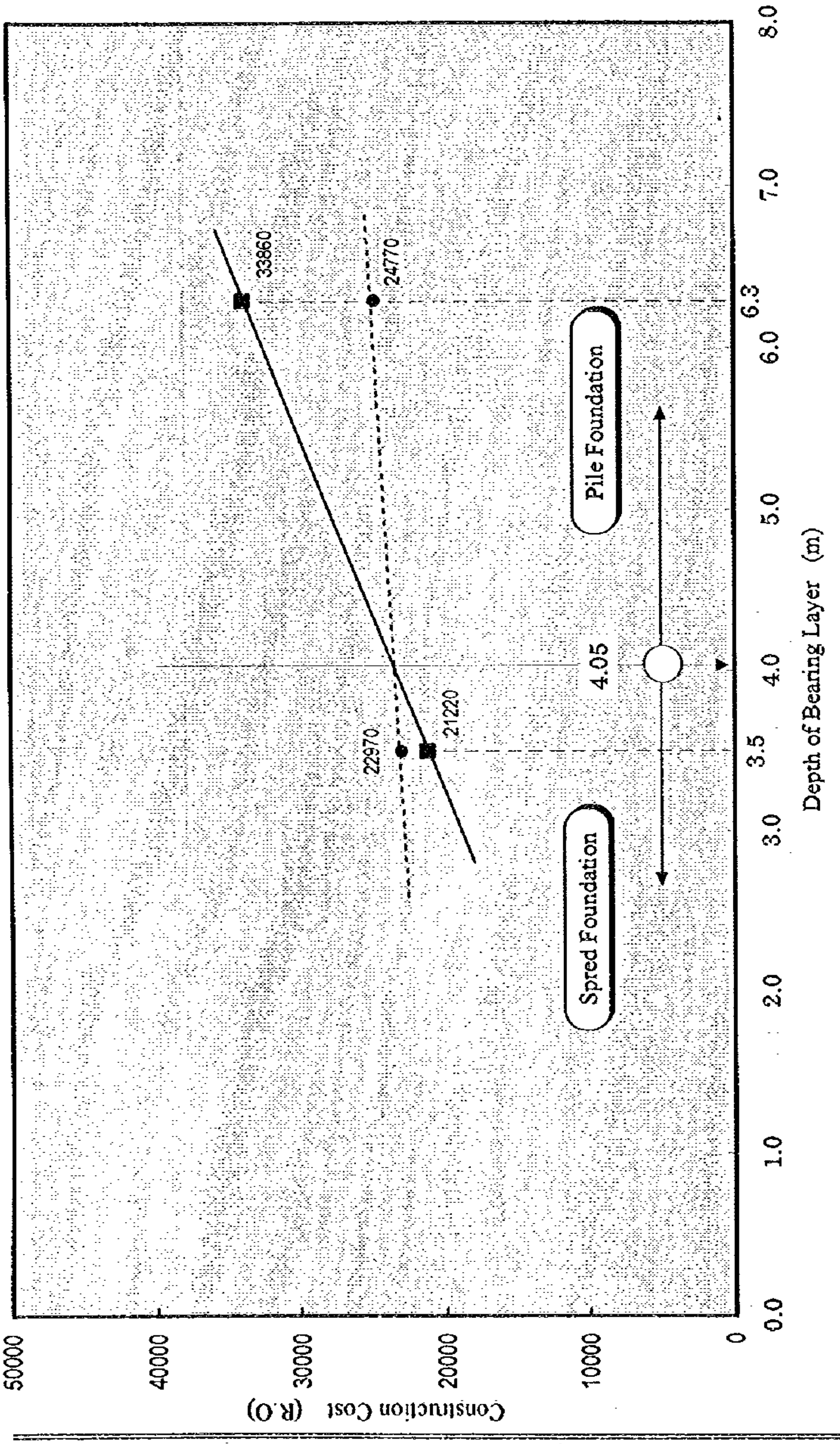


Figure 3.22 Economic Comparison on Foundation Type of Abutment

b) Comparison of Pile Types

In examining the type of piles used in structures in Oman, most of them are found to be concrete piles. In the northern Batinah Region, the bearing layer is fairly shallow in the range of about 5-10 m only.

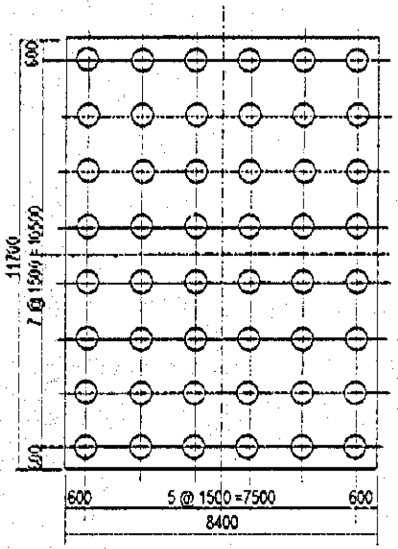
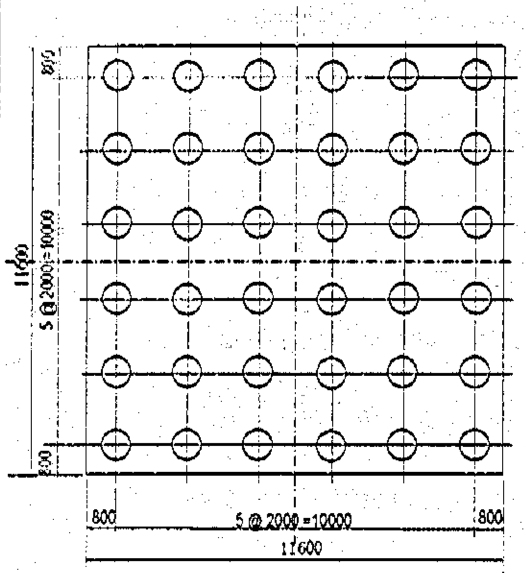
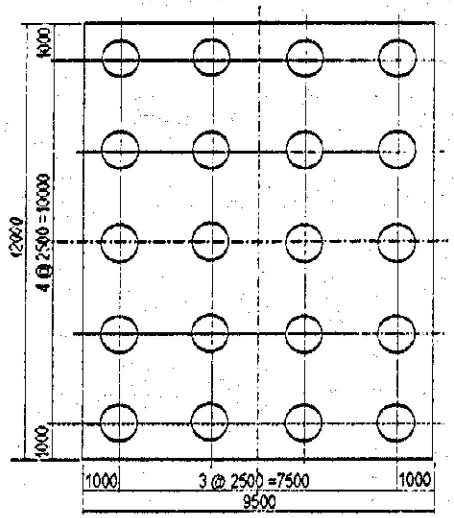
The selection of pile type depends on the following factors:

- Scale of the structure (size of super-structure, sub-structure or intensity of earthquake)
- Pile length (depth of bearing layer)
- Construction ability (experience, construction machinery, construction period)
- Structural Stability (reliability, geological conditions)

In deliberating the above four factors, the type of piles to be applied for the flyovers in this study is cast-in-place reinforced concrete circular type.

For a pier of a bridge with 35 m span length, the number of piles required for each of the pile types mentioned above are computed and the cost of construction compared. The results of this comparative analysis is given in Table 3.9. According to this table, diameter of the pile to be applied is ϕ 1,000 mm.

Table 3.9: Comparison of Pile Types

	Cast-in-Place Concrete Pile ϕ 600mm	Cast-in-Place Concrete Pile ϕ 800mm	Cast-in-Place Concrete Pile ϕ 1000mm
Arrangement Diagrm			
Number of Piles	48 Nos.	36 Nos.	20 Nos.
Cost	R.O 33,761 (1.08)	R.O 39,920 (1.27)	R.O 31,384 (1.00)
Remarks	Long construction time is required.		
Rating			○

(4) Approach Structure

a) Comparison of Retaining Wall and Terre-armee

Terre-armee has been used in many structures in Oman in the last 17 years. In selecting the most suitable structure for the approach wall in retaining the fill, a comparison study of retaining wall and terre-armee is carried out.

The conditions used in the comparative analysis are:

1. Height: height of wall 4.0 to 12.0 m,
   height of fill : 2.0 m to 10.0 m
2. Foundation conditions: good ground bearing conditions and using spread footing
3. Portion of structure used in cost computation: unit cost of 16.7 m width for single carrigeway

The results of this comparative analysis are given in Figure 3.23 and Table 3.10 below.

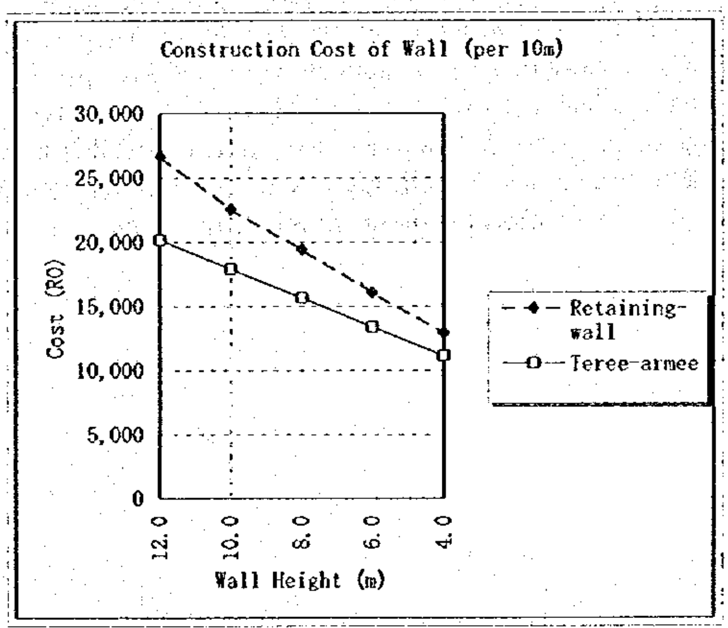


Figure 3.23: Comparison of Cost of Retaining Wall and Terre-armee

Table 3.10: Cost Comparison of Retaining Wall and Terre-armee

	Construction Cost(per 10m)				
Height(m)	12.0	10.0	8.0	6.0	4.0
Retaining-Wall	26,659	22,564	19,412	16,072	12,921
Teree-Armee	20,171	17,917	15,662	13,408	11,153

Irrespective of the height of fills, the cost of terre-armee is lower than the retaining wall type. In terms of construction time required, terre-armee is superior than retaining wall since no concreting work on site is required. Except for locations where the geological condition is poor, stability of fills is difficult to maintain and texture rendering of the wall surface is difficult to achieve, terre-armee is the preferred type of wall for the approach section of the proposed flyovers in this study.

Nevertheless, due to some corrosion problems faced by DGR on terre-armee in Oman, the final decision is to use retaining wall in the detailed design in this study. This is because DGR is awaiting the results of survey from appointed local consultants to investigate the cause and extent of corrosion problems in terre-armee in Oman. The detail design of the proposed flyovers using retaining wall is adopted as it allows future amendment to terre-armee if DGR decides to use terre-armee in future. The reverse is not possible as it will affect the design of other structures.

3.2.4 Consideration of Live Load for the Flyovers

The Highway Design Standards for Oman has been revised in 1994. Using this as the main reference, the following comparative study on live loads is carried out.

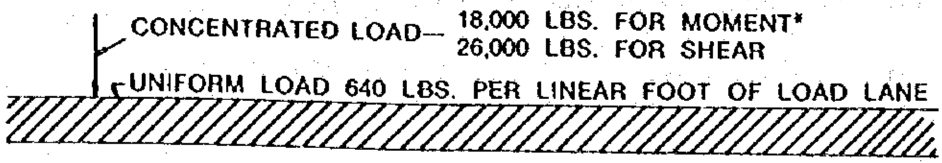
The revised manual states that " bridge carrying highway will be designed for truck and lane loading as specified in reference 13.1 but with the following amendments:

- In section 3.7, truck and lane loading will be HS20-44 increased by 100%. Bridges will also be checked for special trucks A as shown in Figure 13.3.
- The design of bridges on primary roads and street as listed in Appendix A will also be checked for special truck type B as shown in Figure 13.3. Other roads may also require these loads to be applied (eg.access to power stations, chemical plants, etc) where agreed upon with the client.
- Only one special truck will be applied to a bridge at one time.
- In section 3.8.2.1, the maximum impact factor will be 40%. For special truck type B, no impact factor will be applied."

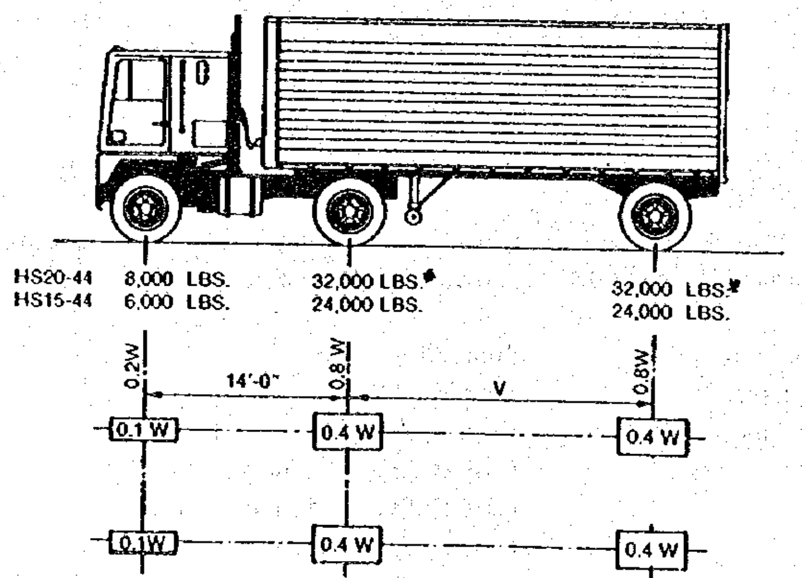
The loading concept of the above specifications is shown in Figures 3.24 to 3.26.

This live load specification in Oman is compared with those applied in Japan. The comparison is done for the following alternative conditions:

- Span interval	20m, 25m, 30 m
- Structure	Simple girder
- Alternative loading	Case A: AASHTO HSA(20)
	Case B: Special Truck Type A
	Case C: Special Truck Type B
	Case D: Japan TL25



H20-44 LOADING
HS20-44 LOADING



W = COMBINED WEIGHT ON THE FIRST TWO AXLES WHICH IS THE SAME AS FOR THE CORRESPONDING H TRUCK.
V = VARIABLE SPACING — 14 FEET TO 30 FEET INCLUSIVE. SPACING TO BE USED IS THAT WHICH PRODUCES MAXIMUM STRESSES.

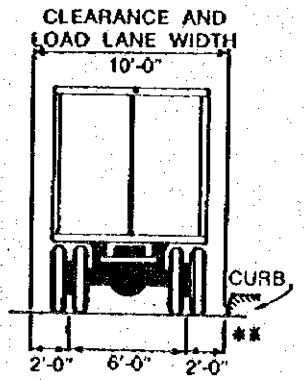


Figure 3.24 : Standard HS (20) Loading

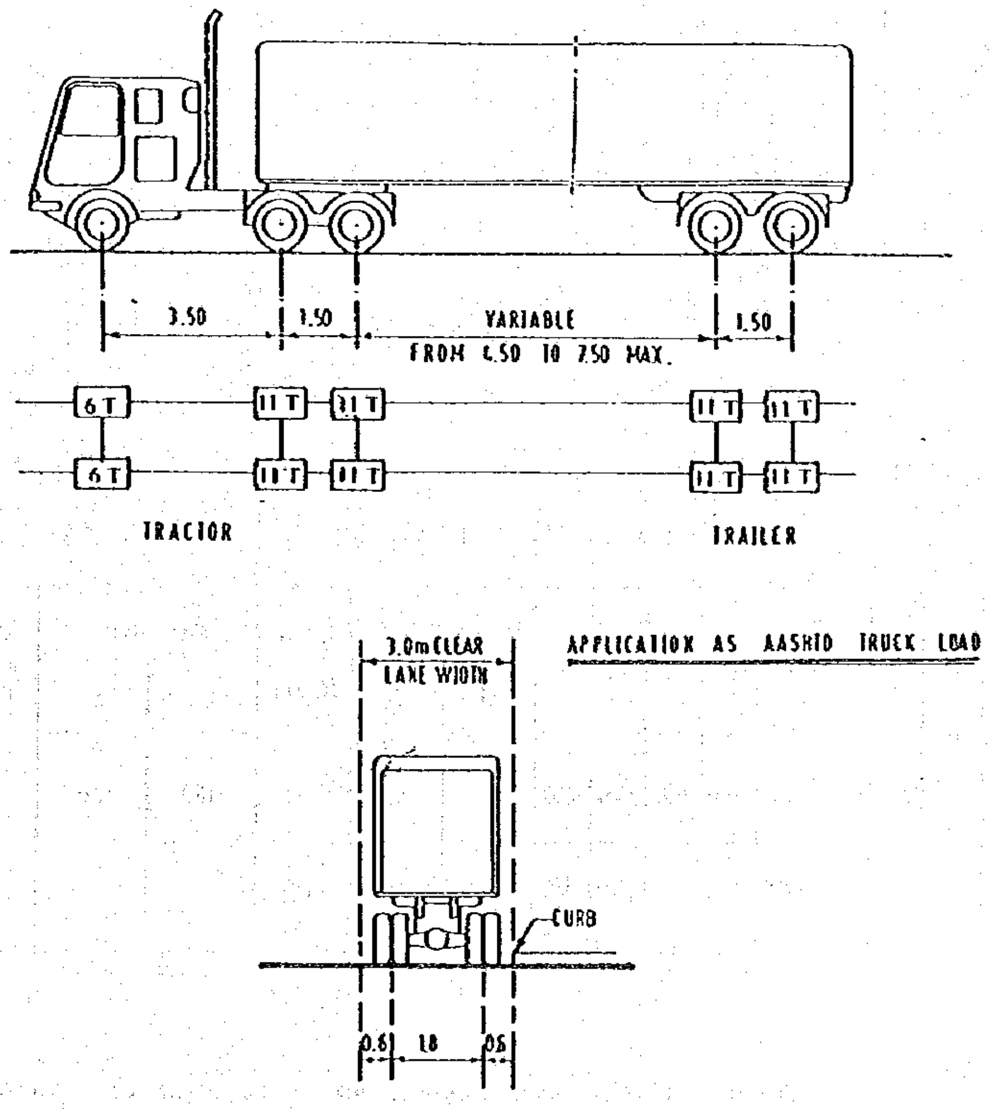
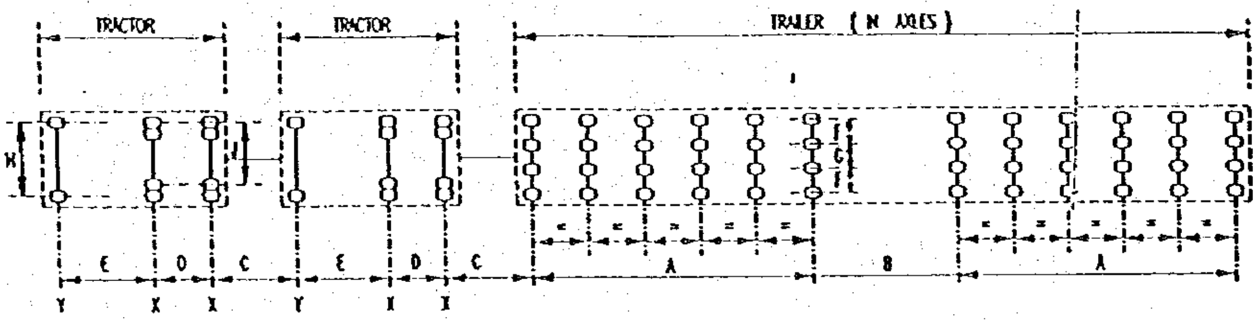


Figure 3.25: Special Truck Type A (Oman)



VEHICLE TYPE	DIMENSIONS (mm)									TRAILER			TRACTOR		
	A	B	C	D	E	F	G	H	J	NO. OF AXLES (N)	SELF WEIGHT (Tonne)	PAYLOAD (Tonne)	AXLE LOAD X	AXLE LOAD Y	TOTAL WEIGHT (Tonne)
B 1	8000	13650	5500	1600	4400	1020	900	2700	1850	12	90	310	18.3	10.0	46.6
B 2	10670	0	4775	1500	6250	1020	900	2700	1850	15	50	210	9	6	24.0

APPLICATION:
MAY BE PLACED ANYWHERE WITHIN TWO LANES, NO OTHER TRAFFIC SHALL OCCUPY THE TWO LANES FOR THE LENGTH OF THE TRUCK PLUS 20m AHEAD AND 20m BEHIND.
TRACTORS MAY BOTH PULL (AS SHOWN) OR ONE PULL AND ONE PUSH

Figure 3.26: Special Truck Type B (Oman)

Results of this comparative study is summarized in Figure 3.27. In the Feasibility study, the comparative analysis on live load was carried out for a typical 2 lane road section with an effective width of 7.5 m. In this D/D study, the comparative analysis is carried out for a 2 lane road section with an effective width of 10.7 m inclusive of shoulders. This is almost equivalent to a 3 lane road section. Variations can be expected depending on the differences in road width under considerations. As in the F/S study, the design live load applied in Oman is higher than the Japan TL25 standards.

Comparing the bending moments of Japan TL25 standards for 15m width and span length 20 to 40m, with those of other countries, it has about the same values as those of the British UK or French BS Standards, while it is about 1.3 to 1.6 times higher than those for the American HS standards. Only those of Holland and Sweden are 1.1 to 1.2 times higher than the Japanese TL25 standards. For similar span lengths, the live load applied in Oman is relatively high compared to those of other countries.

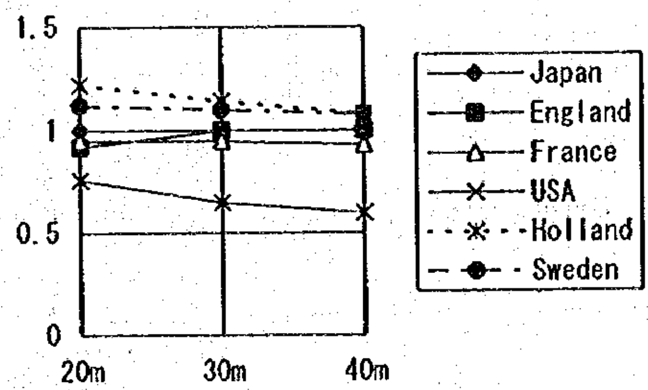


Figure 3.27: Comparative Analysis of Bending Moments by Various Standards

Based on the above comparative study, it is concluded that the live load as specified in the revised 1994 Oman Highway Design Manual is sufficient and safe. This requirement will be applied for the design of flyover structures in this study.

In addition, the loading by the HS(20)x 2 standards is the highest for the overall bridge design. The maximum moment will vary depending on the type of structure being designed and therefore the maximum loading where applicable will be selected for the respective design structure in this study.

In accordance with the Omani design standards, the relationship between bending moment and shearing force for each span of 20 m to 35 m is shown in Figures 3.28 and 3.29.

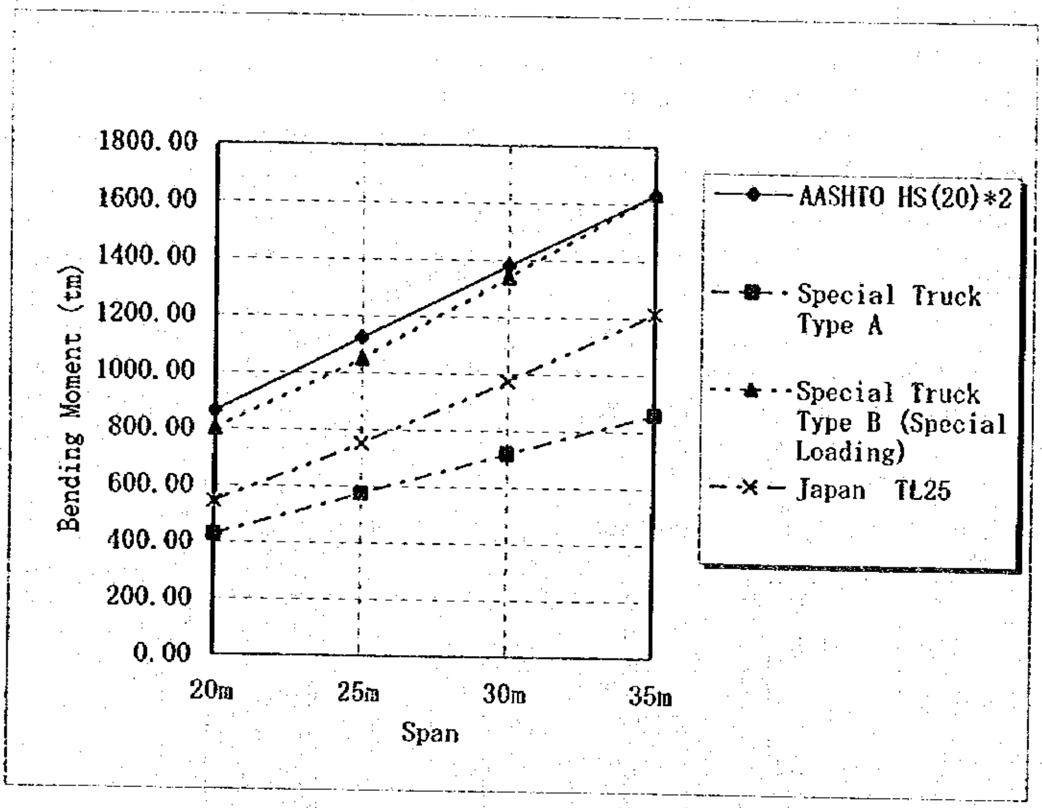


Figure 3.28: Comparison of Bending Moments

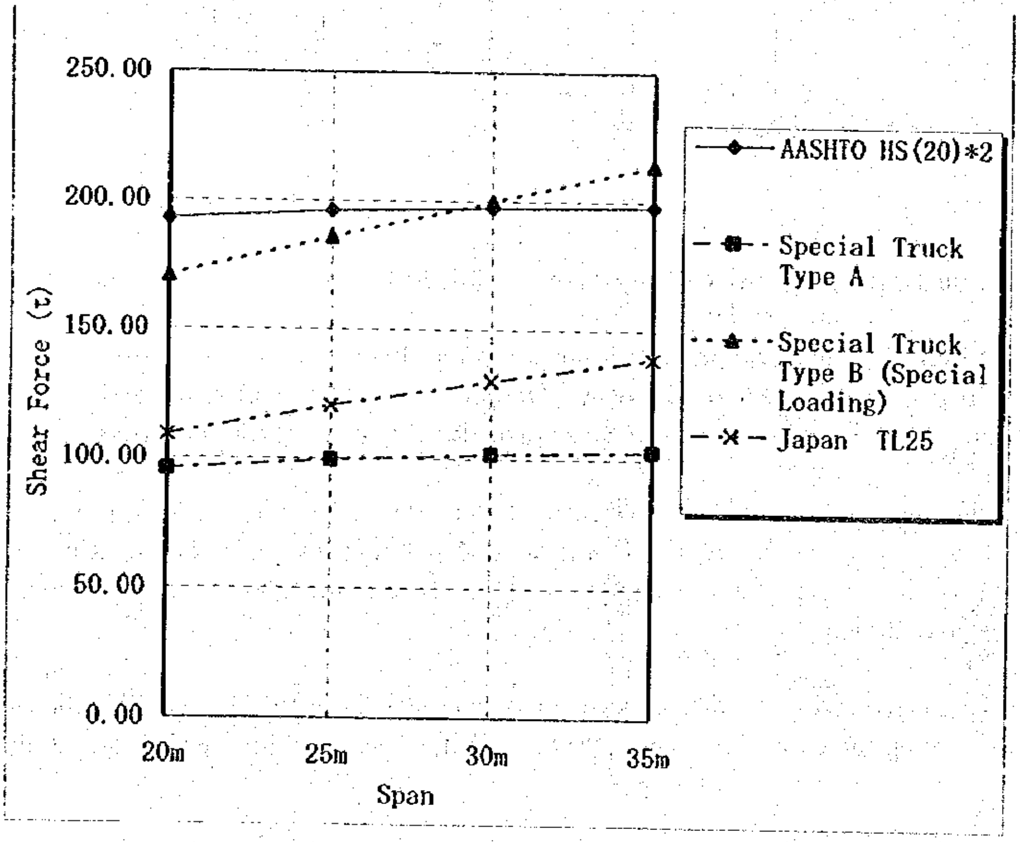


Figure 3.29: Comparison of Shearing Force

3.3 Design Conditions of Pedestrian Underpasses

3.3.1 Structural Types

The proposed pedestrian underpass is structurally comprised of basically a box tunnel under the Batinah Highway and two approach staircases with canopies to be provided at both ends of the tunnel.

The general layout of the pedestrian underpass is shown in Figure 3.30. Location of the proposed pedestrian underpasses has already been discussed in section 2.3.

(1) Box Tunnel

Structural Type : Cast-in-place reinforced concrete 1 span box culvert with a light well at around the center of culvert.
A light well in the highway median will be provided to avoid the need for daytime artificial illumination.

Dimension : Box tunnel length will be determined along with the alignment criteria prescribed in section (2) below.
Box internal size: Internal height = 3.0m
Internal width will be determined in accordance with the following table.

Box Length	Minimum internal size (including finishes)		Minimum structual size (excluding finishes)	
	Height	Width	Height	Width
<23m	2.3m	3.0m	2.4m	3.3m
23m and longer	2.6m	3.3m	2.7m	3.6m

Pavement : Material - Granolithic screed
Gradient - i = 1.00% (cross section)
Thickness - max.=100mm

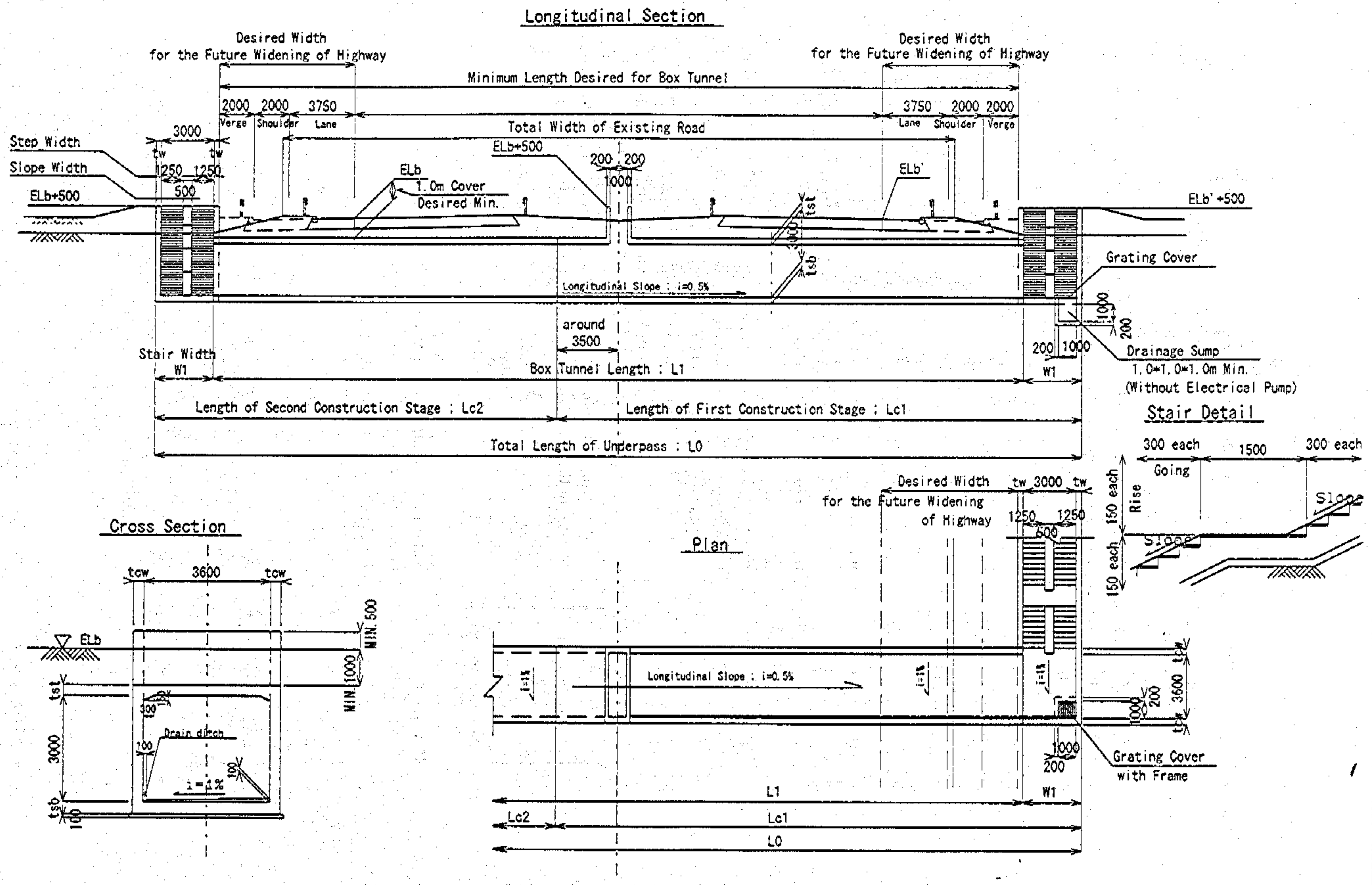


Figure 3.30 General Layout of Pedetrian Underpass

(2) Approach Staircase

Details of approach staircase are shown in Figures 3.30 and 3.31 . The entrance/exist staircases can either be one directional towards Muscat or Aqr or two directional approaches. The decision of providing which type of approach is based on results of field investigation and survey on pedestrian behavior on site. The types of approach to provide at both ends of the underpass at each of the 12 locations are proposed and shown in Table 3.11.

Structural Type	:	Cast-in-place reinforced concrete structure stair with slope in the middle
Dimension	:	Internal width = 3.0m Stair dimension - Rise = 150mm - Tread = 300mm Slope gradient = 50% Slope surface will be equal to the nose of stairs.
Hand Rail	:	For aged and physically handicapped pedestrians and children, handrail will be provided on both sides of the stair cases. Shape of the handrail will have circular or rounded cross-section for better grips.

(3) Canopy above Staircases

Entrance canopies will be provided over approach staircases to reduce the effects of wind or rain. The canopy not only serves as a guard but also as an entrance gate to the pedestrian underpass. Therefore, the canopy will be designed with aesthetic considerations. Aesthetic design of the structures is discussed in section 3.5.

Structural Type	:	Cast-in-place reinforced concrete structure
Clearance	:	Minimum clearance at entrance will be 2.70m in height.

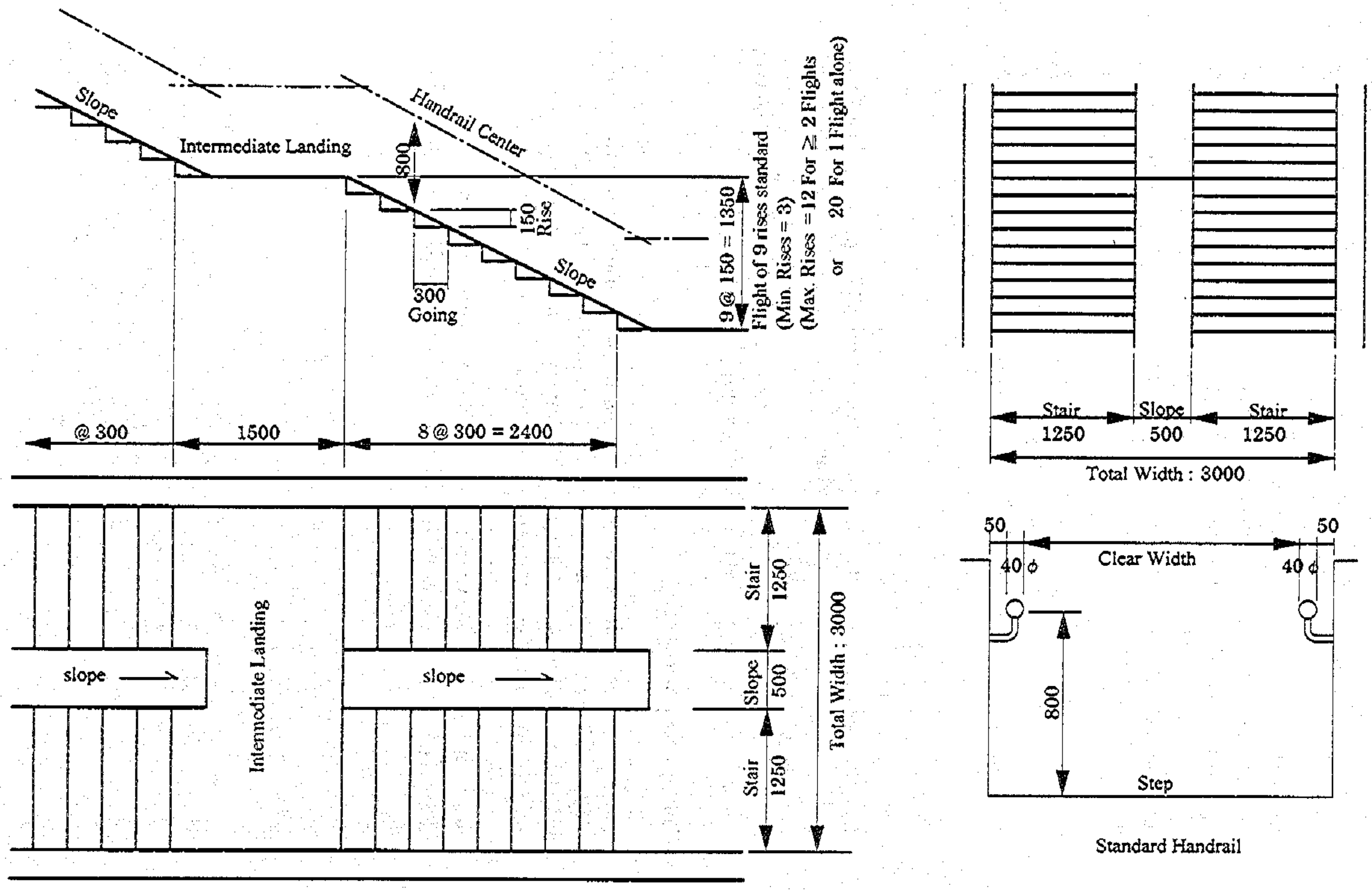
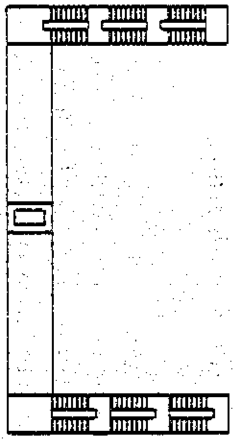
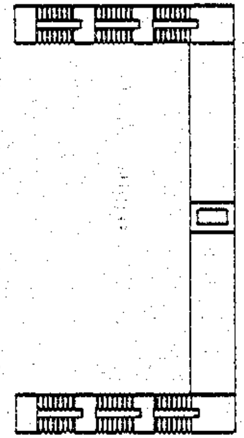
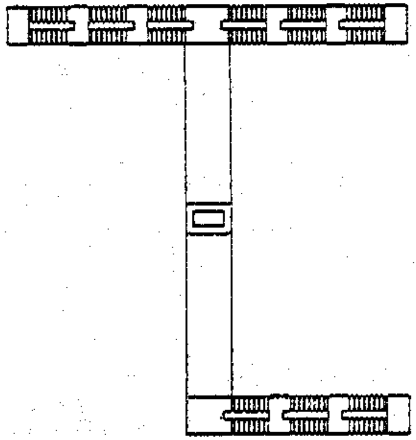
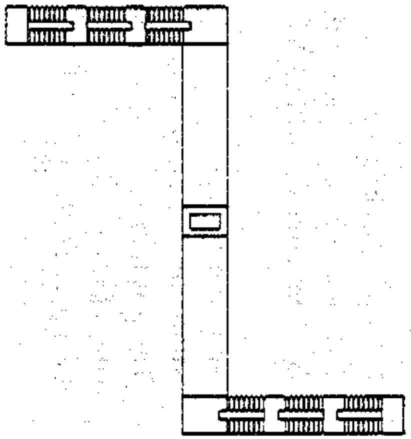
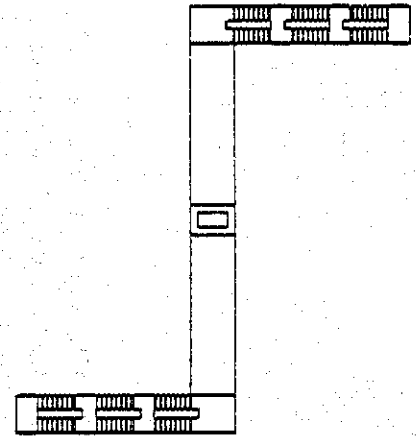
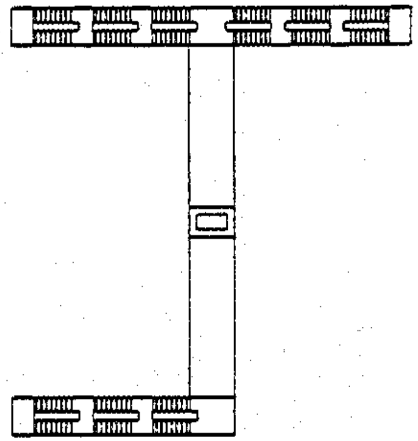


Figure 3.31 DESIGN CONDITIONS OF APPROACH STAIRCASE

Table 3.11 TYPES OF PEDESTRIAN UNDERPASSES

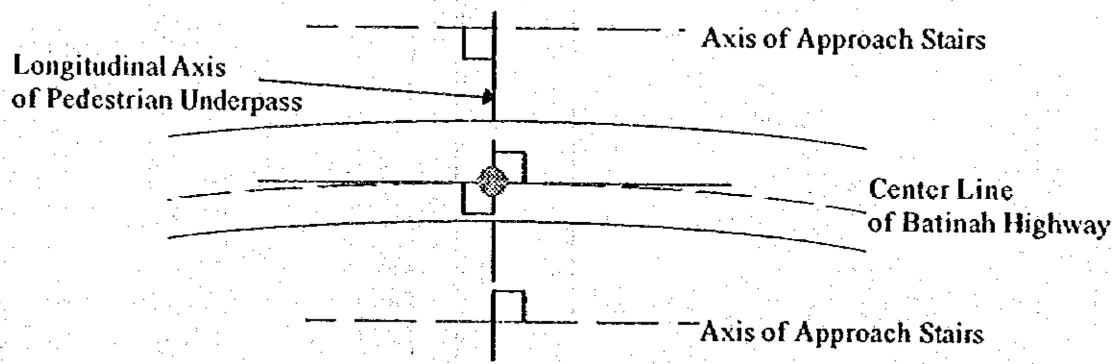
	Aqr ←		→ Muscat
Type			
Location	P-2 : Al Billah P-11 : Liwa P-9 : Majaz A'Sughra	P-4 : Al Qarat	P-6 : A'Suweiq
	Aqr ←		→ Muscat
Type			
Location	P-1 : Barka P-8 : Qarih	P- 7 : Al Khadra P-12 : Asrar Bani Sa'd P-10 : Khor A'Siyabi	P-3 : A'Tareef P-5 : A'Tharmad

3.3.2 Criteria For Alignment

(1) Criteria for the Horizontal Alignment of Pedestrian Underpasses

The pedestrian underpass at each of the locations will be horizontally aligned to satisfy the following conditions:

- The longitudinal axis of the box tunnel crossing the Batinah Highway will be set up in perpendicular to the center line of highway.
- Approach staircases will be planned perpendicular to the longitudinal axis of the box tunnel.



- Distance from the outer curb of the existing highway to the edge of the approach stair wall will be 7.75 m or more in anticipation of future widening of the Batinah Highway, for an additional traffic lane. (See Figure 3.30)

(2) Criteria of Vertical Alignment of Pedestrian Underpass

Criteria to determine the elevation of the pedestrian underpasses will be as follows : (See Figure 3.30)

- Longitudinal Gradient
  The longitudinal gradient of the box tunnel will be 0.50%.
  Gradient direction will be decided after considering the drain direction.

- Minimum Cover
  Minimum ground cover above the upper slab of the box tunnel will be 1.000m.
  The position where this specification is to be applied determined will be the outer edge of the outer traffic lane of highway where the road surface is the closest to the upper slab of the tunnel. (See Elb in Figure 3.30)

- Light Well Height
  The light well opening in the median will not be less than 0.500m above the ground level.

- Entrance Height
  The height of the entrance will be raised to 0.500m or more than the pavement level of the outer edge of the outer traffic lane. (See Elb, Elb' in Figure 3.30) This recommended height of the entrance will be examined in consideration with landscaping design around the entrance.

3.4 Traffic Capacity and Number of Lanes

3.4.1 Traffic Capacity

(1) General

The calculation of traffic capacity for the proposed flyovers and other facilities basically follows the Highway Capacity Manual (HCM), prepared by DGR in 1994.

(2) Multilane Road

a) Analysis Method

The traffic capacity is given by the following formulas:

$$SFi = MSFi*N*Fw*Fhv*Fe*Fp \quad (1)$$

$$= Cj*(v/c)i*N*Fw*Fhv*Fe*Fp$$

Where,

SFi = Service flow rate for service level 'i' under common condition of road and traffic (veh/hr)
Cj = Traffic capacity for design speed j under ideal conditions; Basic capacity (pcu/hr/lane)
(v/c)i = Maximum rate between traffic flow volume and traffic capacity under service level ' i ' ; Coefficient of service level
MSFi = Maximum service flow rate for service level i under ideal condition (pcu/hr/lane)
N = Numbers of lane
Fw = Coefficient of lane width and lateral clearance
Fhv. = Coefficient of heavy vehicle computed by:

Fhv = 1/(1+Pt(Et-1))*

where,

Pt = Rate of heavy vehicle
Et = Passenger car equivalent

Fe = Coefficient of road classification
Fp = Coefficient of driver population

$$DDHV = A\ ADT*K*D/PHF \quad (2)$$

Where,

DDHV	=	Directional design hour volume (veh/hr)
AADT	=	Annual average daily traffic at target year (veh/hr)
K	=	Design hour volume rate
D	=	Directional distribution rate (May not be applicable to capacity analysis of multilane road)
PHF	=	Peak-hour factor

The following formula is derived from the above two formula (1) and (2).

AADT = SFi*PHF/(K*D).................................. (3)

b) Traffic Capacity

The traffic capacity of proposed highway and crossroad is shown in Table 3.12 using the above computation methods and formulae.

Table 3.12 Analysis of Traffic Capacity for Multilane Road

Item	Unit	Highway	Highway	Crossroad	Crossroad
Design Speed	km/hr	120	120	80	80
Type of Terrain		Level	Level	Level	Level
Type of Road		Divided	Divided	Divided	Divided
Road Location		Rural	Rural	Rural	Suburban
No.of Lane		2+2=4	2+2=4	2+2=4	2+2=4
Width of Lane	m	3.75	3.75	3.5	3.65
Outer Clearance	m	2.0	2.0	1.0	1.0
Inner Clearance	m	1.2	1.2	1.0	0.6
Rate of Heavy Vehicle	%	10.0	10.0	10.0	10.0
Passenger Car Equivalent		1.7	1.7	1.7	1.7
Basic Capacity	pcu/hr/lane	2,000	2,000	1,900	1,900
Service Level		B*	C	C*	D*
Coefficient of Service Level		0.54	0.71	0.6	0.76
Max.Service Flow Rate	pcu/hr/lane	1,100	1,400	1,150	1,450
Coefficient of Lateral Clearance		0.99	0.99	0.94	0.97
Coefficient of Heavy Vehcile		0.93	0.93	0.93	0.93
Coefficient of Road Classification		1.0	1.0	1.0	0.90
Coefficient of Driver Population		1.0	1.0	1.0	1.0
Service Flow Rate	veh/hr/lane	1,000	1,300	1,000	1,150
Design Hour Volume Rate		0.08	0.08	0.08	0.08
Directional Distribution Rate		-	-	-	-
Peak-Hour Factor		0.92	0.94	0.94	0.95
Daily Traffic Capacity	veh/d/lane	11,500	15,500	12,000	13,500
Daily Traffic Capacity(4-lane)	veh/d	46,000	62,000	48,000	54,000

Note : The service level with (*) is recommended in the Government's standard.

(3) Ramp

The analysis method is same as the multilane road discussed above, and the traffic capacity is shown in Table 3.13.

Table 3.13 Analysis of Traffic Capacity for Ramp

Item	Unit	Ramp	Ramp	Ramp
Design Speed	km/hr	80	60	60
Type of Terrain		Level	Level	Level
Type of Road		Divided	Divided	Divided
Road Location		Rural	Rural	Rural
No.of Lane		1	2	1
Width of Lane	m	5.0	3.65	5.0
Outer Clearance	m	2.0	1.0	2.0
Inner Clearance	m	1.0	1.0	1.0
Rate of Heavy Vehicle	%	10.0	10.0	10.0
Passenger Car Equivalent		1.7	1.7	1.7
Basic Capacity	pcu/hr/lane	-	-	-
Service Level		B*	C*	C*
Coefficient of Service Level		-	-	-
Max.Service Flow Rate	pcu/hr/lane	900	1,000	1,100
Coefficient of Lateral Clearance		0.99	0.97	0.99
Coefficient of Heavy Vehcile		0.93	0.93	0.93
Coefficient of Road Classification		1.0	1.0	1.0
Coefficient of Driver Population		1.0	1.0	1.0
Service Flow Rate	veh/hr/lane	850	900	1,000
Design Hour Volume Rate		0.08	0.08	0.08
Directional Distribution Rate		-	-	-
Peak-Hour Factor		0.92	0.94	0.94
Daily Traffic Capacity	veh/d/lane	10,000	10,500	12,000
Daily Traffic Capacity(1or2-lane)	veh/d	10,000	21,000	12,000

Notes : 1.A basic capacity and a coefficient of service are not indicated in HCM.
2.A max.service flow rate of 2-lane is a 1.9 times in the case of 1-lane.
3.The service level with (*) is recommended in the Government's standard.

(4) Two - Lane Road

a) Analysis Method

The traffic capacity is given by the following formulas;

$$SFi = 2{,}800*(V/C)i*Fd*Fw*Fhv \quad \text{..........................} \quad (4)$$

Where,

SFi,(V/C)i,Fw and Fhv are as mentioned in the formula (1)
Fd = Coefficient of traffic directional distribution

DHV = AADT*K/PHF.. (5)

Where,

AADTK and PHF are as mentioned in the formula (2)

DHV = Design hour volume (veh/hr)

The following formula is derived from the above formula (4) and (5).

AADT = SFi*PHF/K... (6)

b) Traffic Capacity

The traffic capacity of a two-lane road is computed and shown in Table 3.14.

Table 3.14 Analysis of Traffic Capacity for Two-Lane Road

Item	Unit	Crossroad	Crossroad	Crossroad
Design Speed	km/hr	80/60	80/60	80/60
Type of Terrain		Level	Level	Level
No.of Lane		1+1=2	1+1=2	1+1=2
Width of Lane	m	3.65	3.65	3.65
Outer Clearance	m	1.0	1.0	1.0
Inner Clearance	m	0.0	0.0	0.0
Rate of Heavy Vehicle	%	10.0	10.0	10.0
Passenger Car Equivalent		2.2	2.2	2.0
Directional Distribution Rate	%	60/40	60/40	60/40
Basic Capacity	pcu/hr/2-lane	2,800	2,800	2,800
Service Level		C*	D*	E
Coefficient of Service Level		0.43	0.64	1.00
Percent No Passing Zones	%	0	0	0
Max.Service Flow Rate	pcu/hr/2-lane	1,200	1,800	2,800
Coefficient of Lateral Clearance		0.81	0.81	0.93
Coefficient of Heavy Vehcile		0.89	0.89	0.91
Coefficient of Directional Distribution		0.94	0.94	0.94
Service Flow Rate	veh/hr/2-lane	800	1,200	2,250
Design Hour Volume Rate		0.08	0.08	0.08
Peak-Hour Factor		0.94	0.95	1.00
Daily Traffic Capacity	veh/d/2-lane	9,400	14,300	28,000

Note : The service level with (*) is recommended in the Government's standards.

3.4.2 Number of Lanes

The number of lanes is determined from the traffic demand forecast and traffic capacity. The number of lanes for each classified road is shown in Tables 3.15 to Table 3.17.

Table 3.15 Number of Lanes Proposed for Highway

No.of R/A	Name of R/A	Number of Lane	Min.service Level
R/A-2	A'Naseem Garden	2 + 2 = 4	C
R/A-3	Barka	2 + 2 = 4	C
R/A-5	Al Muladdah	2 + 2 = 4	B
R/A-8	Al Khaburah	2 + 2 = 4	B
R/A-10	Saham	2 + 2 = 4	B
R/A-12	Sohar	2 + 2 = 4	B
R/A-14	Falaj Al Qabail	2 + 2 = 4	B
R/A-18	Aqr	2 + 2 = 4	B

Note : A highway with 6-lanes is necessary to keep a service level B. However,the existing highway can fulfill the function under a service level C.

Table 3.16 Number of Lanes Proposed for Cross Roads

No.of R/A	Name of R/A	Seaside Road		Inland Road	
		Number of Lane	Min.Service Level	Number of Lane	Min.Service Level
R/A-2	A'Naseem Garden	1 + 1 = 2	C	1 + 1 = 2	C
R/A-3	Barka	2 + 2 = 4	C	2 + 2 = 4	C
R/A-5	Al Muladdah	1 + 1 = 2	C	2 + 2 = 4	C
R/A-8	Al Khaburah	1 + 1 = 2	C	2 + 2 = 4	C
R/A-10	Saham	2 + 2 = 4	C	2 + 2 = 4	C
R/A-12	Sohar	2 + 2 = 4	C	2 + 2 = 4	D
R/A-14	Falaj Al Qabail	1 + 1 = 2	C	1 + 1 = 2	C
R/A-18	Aqr	-	-	-	-

Note : The seaside crossroad at Sohar R/A is located in the suburban of Sohar City. Therefore, the road is planned under a service level D.

Table 3.17 Number of Lanes Proposed for Rampways

No.of R/A	Name of R/A	Muscat-Side		Aqr-Side	
		Number of Lane	Min.Service Level	Number of Lane	Min.Service Level
R/A-2	A'Naseem Garden	D 1 M 1	C	D 1 M 1	C
R/A-3	Barka	D 2 M 2	C	D 1 M 1	C
R/A-5	Al Muladdah	D 1 M 1	C	D 1 M 1	C
R/A-8	Al Khaburah	D 1 M 1	C	D 1 M 1	C
R/A-10	Saham	D 1 M 1	C	D 1 M 1	C
R/A-12	Sohar	D 1 M 1	C	D 1 M 1	C
R/A-14	Falaj Al Qabail	D 1 M 1	C	D 1 M 1	C
R/A-18	Aqr	D 1 M 1	B	D 1 M 1	B

Notes : 1.The ramp at Aqr R/A keeps a service level B, because the ramp is classified into a primary road.
2.D and M indicates Diverge and Merge respectively.

3.5 Aesthetic Considerations for Flyovers and Pedestrian Underpasses

Landscape and urban design procedure in cities and regional areas of Sultanate of Oman has been achieved greatly in advance recent two decades. Reflecting of this background, general urban design scheme has been developed and harmonized in architectural building forms, color and texture, and public open spaces also in good landscaping quality with plenty of plants. These landscape feature is quite significant in comparing to other cities of Arabian counties. Also reflecting these urban design features, existing flyover facilities have seen in high quality of design .

Roundabouts in the Batinah highway have been implemented significant monuments with landscaping, and they become symbols for each local districts. So that planed flyovers for these Roundabouts shall be recognized quite essential in their design development.

3.5.1 Flyovers and Roundabouts

Roundabouts in the Batinah highway are managed either by Ministry of Regional Municipalities and Environment or Muscat Municipality depending on their locations. Both the Ministry and Muscat Municipality have been achieved implementation and management for their Roundabout monuments with landscaping.

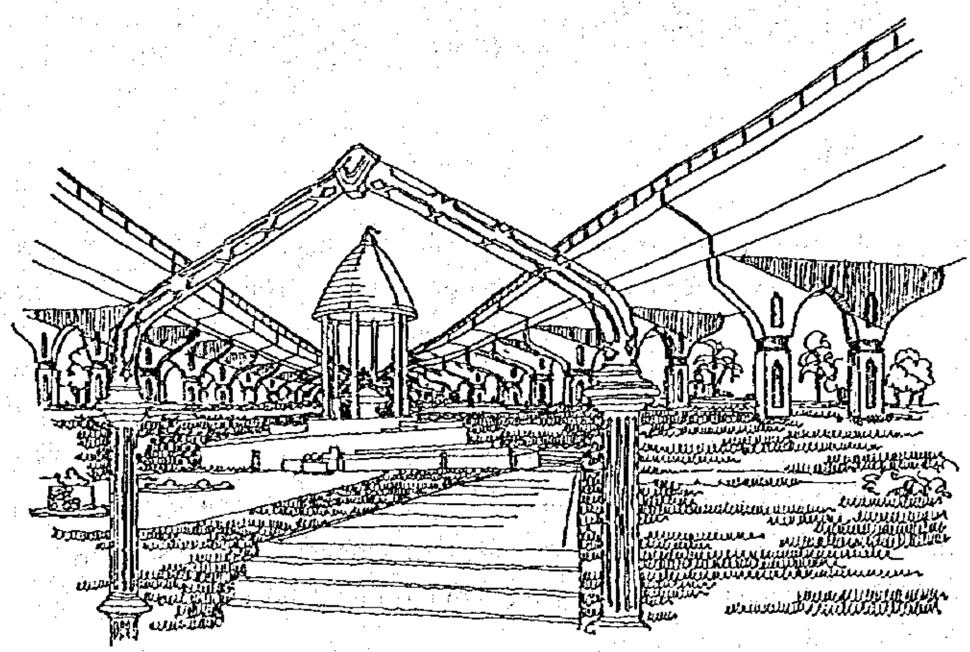
This Study is aimed aesthetic flyover design in accordance with situation of existing and future scheme of Roundabout monuments.

(1) A' Naseem Garden Roundabout

A new monument has been constructed recently at one of the study roundabouts, namely A'Naseem Garden R/A. The elevated central monumental structure which forms a design concept of gazebo style on the spiral terrace is well presented using sharp contrasts achieved by the green turfed lawn and flowering plants. The proposed flyover at this roundabout shall be designed so as not to affect this newly completed monument while at the same time to complement the symbolic elements of the monument.

The proposed Type B flyover has ample central space in between the bridge sections to accommodate the monument thus forming a unified landscape composition. Type B flyover is therefore proposed for this roundabout. An image of proposed flyover shall be a white slender bridge structure spanning over the green turfed ground. Double column piers are proposed for the central section to create some scenic focus.

To further enhance and compliment the monument and it's surrounding garden landscape, it is recommended that the alignment of the flyover be designed in achieving and oval shape to create more unity with the new monument at this roundabout.

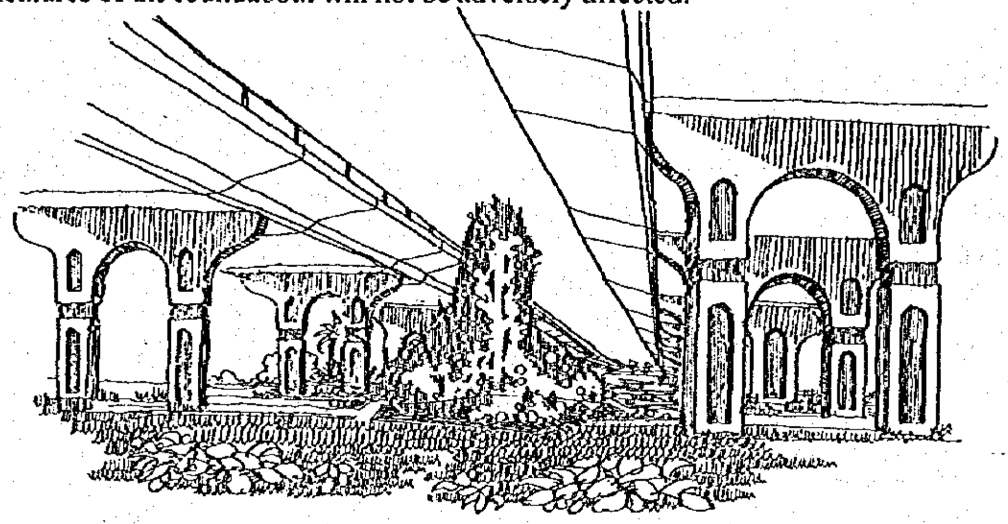


A'NASEEM GARDEN Roundabout

(2) Barka Roundabout

Type A flyover is recommended for the roundabout with the bridge section spanning over the center of the roundabout. The existing water fountain in the center of the roundabout can still be seen through the intervals of the piers, retaining it as the symbol of the roundabout. To achieve this effect, double column piers are recommended with design to harmonize with the water fountain for the central section, and most of other piers will be of single column type.

The existing flowering plants and small shrubs where the piers are to be located shall be transplanted within the roundabout and close to the perimeter so that the original landscape features of the roundabout will not be adversely affected.



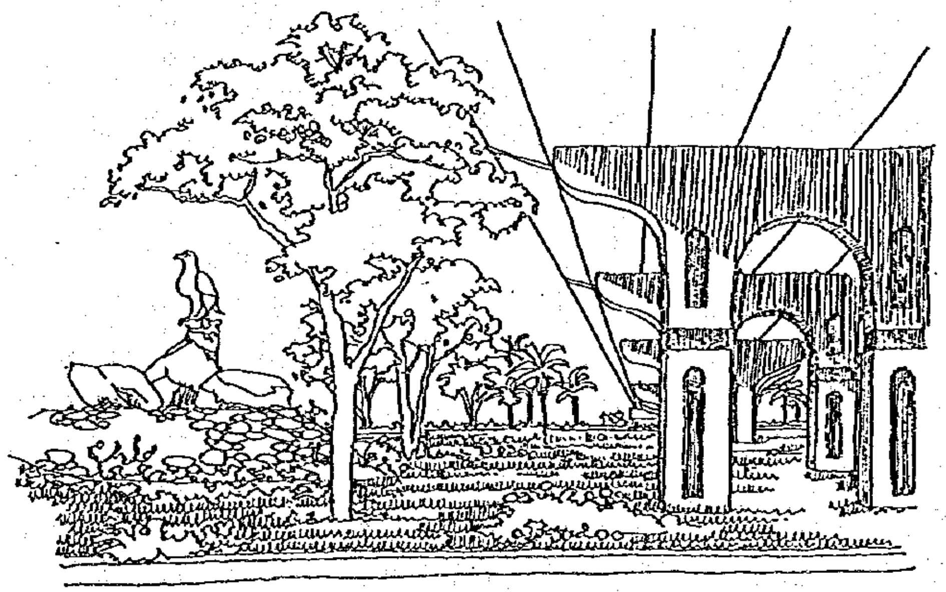
BARKA Roundabout

(3) Al Muladdah Roundabout

The current landscape focus of this roundabout is a pair of falcons statues raised on pedestals located at both side of the access roadway. This junction is currently being improved to become a roundabout. Any monument or landscaping design at this roundabout has not been planned yet by the Ministry of Regional Municipality and Environment.

The Type A flyover is recommended for this roundabout with double column piers at the central section as the focus element and single column pies at other sections. The flyover silhouette so create can become the symbol of this roundabout.

Since there is little planting at the roundabout at present, a new landscape work can be organized to complement the flyover structures. The original falcon statues can be relocated to the perimeter of the new roundabout as a landmark for this location. New planting shall include low trees, shrubs and ground cover plants composed to form garden images.



AL MULADDAH Roundabout

(4) Khaburah Roundabout

The existing landscaping at this roundabout is comprised of colorful flowering plants at the center of the roundabout. This scenic landscaping can be easily be observed from intervals of the bridge piers.

Some symbolic large crowned trees are recommended to be planted in addition to the existing landscaping at the center of the roundabout to achieve visual enrichment. Double column piers at the central section are recommended to with landscaping composition harmoniously incorporated with the structures. Single column piers are applied to other sections.

(5) Saham Roundabout

The existing landscape elements consists of two low hill mounds planted with shrubs and low trees. The proposed type A flyover at this roundabout shall span over the mounds in the center of the roundabout. Some of the plantings where the piers are to be located will therefore be transplanted. To maintain the existing visual appearance of the hilly grove atmosphere, the shrubs, trees and ground cover plants affected by the proposed flyover shall be transplanted to a new arrangement within the roundabout.

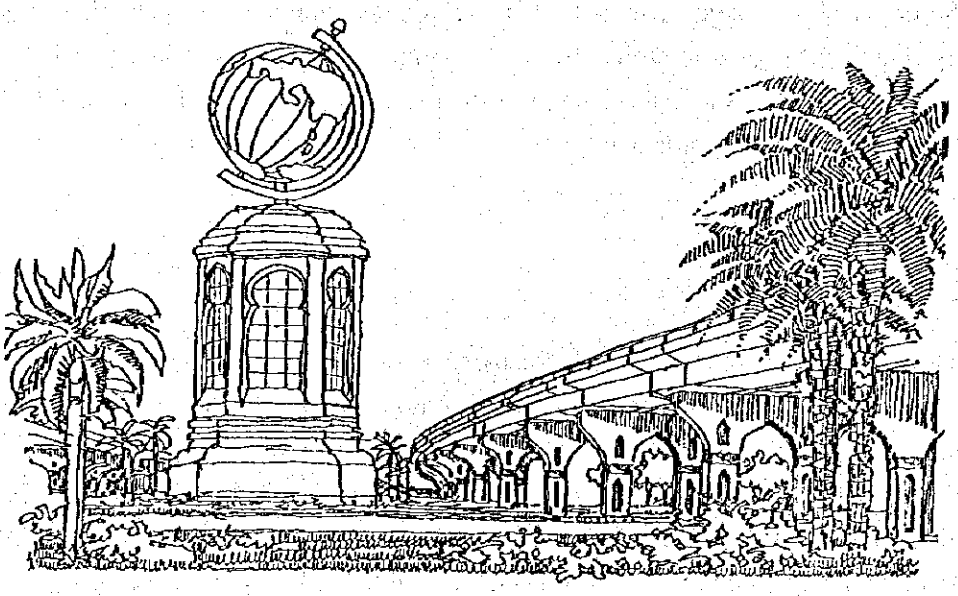
The new landscape appearance would maintain a sense of continuation of groves. Thus, the entire image of the flyover is one that passes through foliage grove. Single column piers are recommended for the other sections with emphasis to achieve visual continuity of the original landscape scenery.

(6) Sohar Roundabout

A new monument is now under the construction at this roundabout by the Muscat Municipality. The new monument will be an approximately 30 meter high Islamic symbolic tower intended to be the new landmark of Sohar.

This new monument, by virtue of it's size and height will become a very strong element in the overall landscape at this roundabout. This monument shall be visible to the road users who can utilize it as a landmark to ascertain their arrival in Sohar. To others in the vicinity of the roundabout, it is an important symbol of beauty. Type B flyover is therefore recommended.

With this type of structure, design of the flyover piers become an important consideration. The piers should be utilized as a component to harmonize with elements from the monument and to intigrate the proposed monument design features. Double column piers are applied for this roundabout in consideration of it's structural stability and design form integration to the new monument.



SOHAR Roundabout

(7) Falaj Al Qabail Roundabout

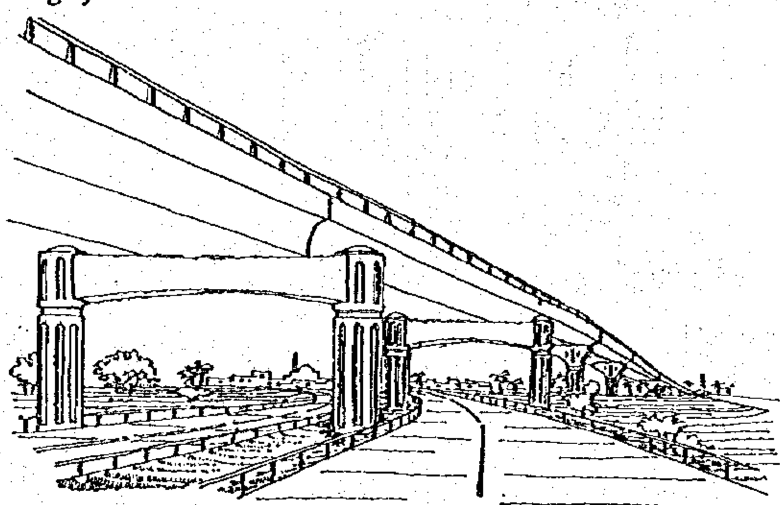
The present landscape of the roundabout is of rock hill composition with waterfall arrangement and wild animal sculptures. The Muscat Municipality is considering a modification of this monument into something more substantial as a future development scheme, but so far there is no specific proposal yet.

Location of roadside facilities and it's condition at this roundabout are rather critical for widening a space of service access road if type B flyover will be projected. Therefore Type A flyover is recommended for reducing environmental impacts on lands acquisition and facilities compensation to community, and major concept of the original monument of roundabout will be maximum preserved and rearranged it's layout by the time of new monument development coming. Future new monument development in this roundabout will be recommended symmetrically allocated at both side of flyover type A. For type A flyover, double column piers are recommended for the all sections.

(8) Aqr Roundabout

The existing roundabout landscape at Aqr Roundabout consists of terraced garden with flowering plants. The proposed grade separation will comprise of an at grade by-pass from Batinah Highway to Route No.5, and two single lane ramp bridges over the by-pass. This is therefore a special type compared to the other locations.

Aqr roundabout is located at the gateway to Oman from the neighboring country of U.A.E. Therefore the proposed special structure will be provided to create some impressive landmarks to identify this important location. The portable rigid frame pier with longer cross beam can be designed for the sections where the rampway passes over the highway, and T-wall piers for other sections. Columns of these piers can also be enhanced in their appearance using symbolic elements.



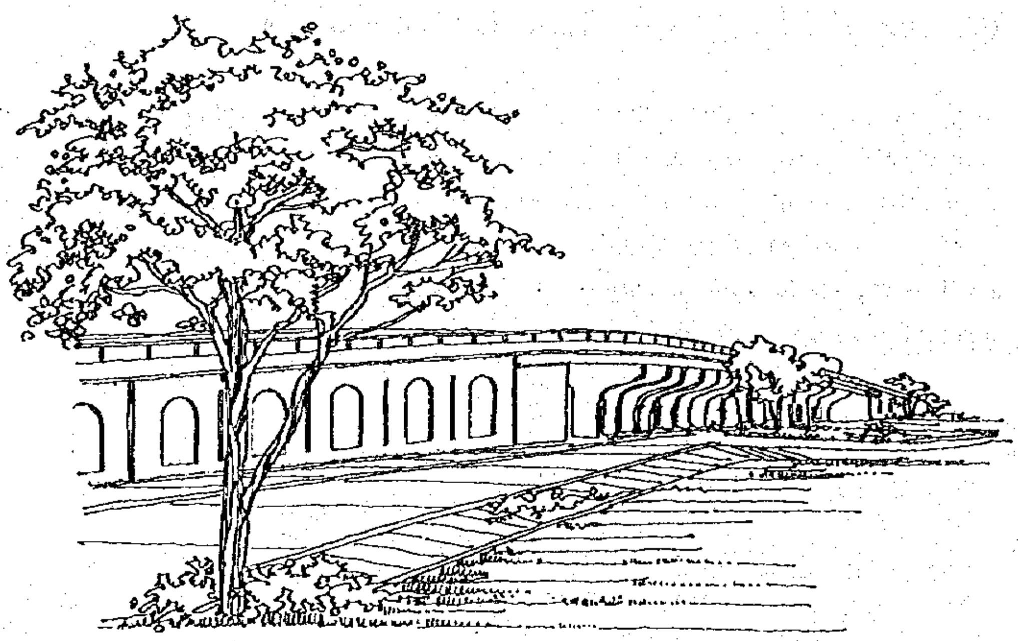
AQR Roundabout

3.5.2 Retaining wall

Retaining walls are proposed up to 300 m in length and 6.5 m in height at abatement on both ends of the flyovers. The retaining wall will therefore have a triangle side elevation with a 3 % slope. Although up right solid wall may look strong with a sense of stability, some engraves on the wall can produce a continuity effect on the retaining wall.

Simplified Islamic arch form, for instance can be introduced on the surface of the walls, and slender form can produce a continuous repetitive design display light and shadows on the solid wall.

The abutment are 6.5 m high and without the introduction of the engraves, it becomes a very strong element in contrast with other column piers and girders. The engravings will therefore help to blend the retaining wall into the overall bridge structural design.



RETAINING WALL

3.5.3 Pedestrian Underpasses

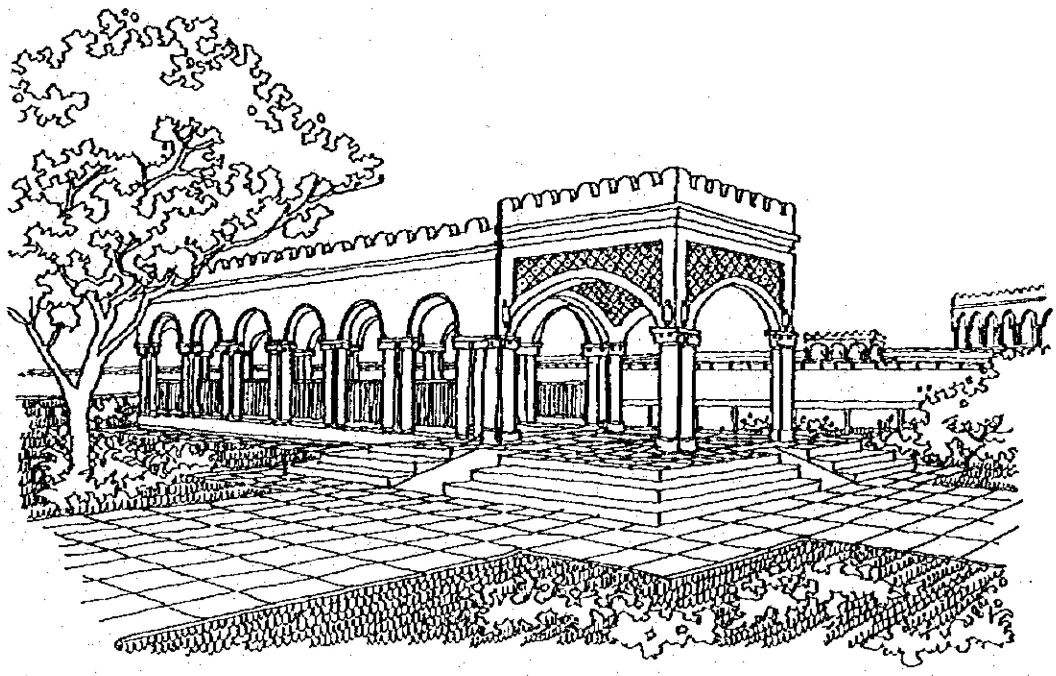
Pedestrian underpasses are proposed at 12 critical locations along the Batinah highway. Facility leading to the entrance/exit points of the underpass are therefore important elements to be considered in the design. These facilities should have some distinct and attractive appearance to encourage people in the surrounding areas to use the pedestrian underpass. Major design aspects are discussed below:

(1) Entrance Identification

Identification of the entrance to the underpass become the major design element. The entrance should therefore be designed with distinctive appearance to encourage pedestrians using the underpass facility. A clean silhouette design is most preferred.

(2) Community Amicable Appearance

The pedestrian underpass should be treated as a daily usage facility and part of the overall town scape element, such as Islamic arches, domes and other geometrical design. The wall openings of the canopy structure become an important element to incorporate such concept. A well proportioned Islamic arch type opening at appropriate intervals is proposed. Therefore the entrance facility requires a design manner with community amicable appearance.



PEDESTRIAN UNDERPASS

(3) Attractive Space

The surrounding space near the entrance is also quite important to create the correct atmosphere. When the space the entrance to the underpass has attractive features to encourage people to use them, the space would eventually become a converging or gathering point for the local people to mix, relax or rest. Such a behavior would encourage the usage of the underpass.

Small plaza with terraced space and canopy will be provided at the entrance front. Attractive pavement, street furniture and shade providing landscape objects are recommended.