A6.2.5 Comparison of Vertical Grades

(1) General

The Study Team studied the proposed vertical grades of the road crossing in this phase. The results of the comparison are shown in Table A6.2.3.

(2) Grades Studied

The Study Team compared six alternatives of vertical grades. These grades are shown below and refer Fig. A6.2.14 to Fig. A6.2.19.

- Alternative 1 : 3 %
- Alternative 2 : 4 %
- Alternative 3 : 5 %
- Alternative 4 : 2 % and 4 %
- Alternative 5 : 4 % with level sections in the middle of the approach viaducts
- Alternative 6 : Combination of 3 % and 4 %

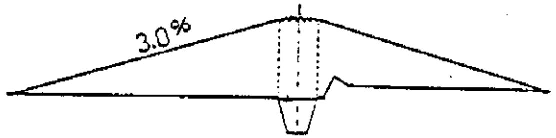
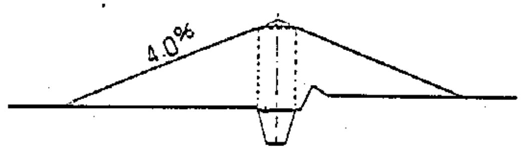
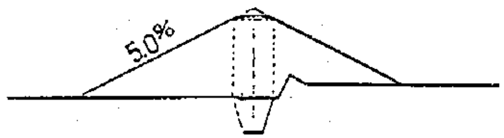
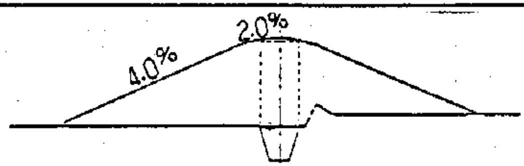
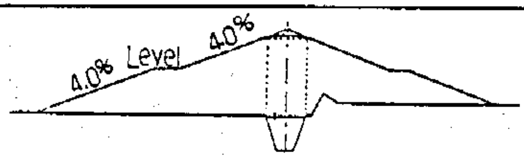
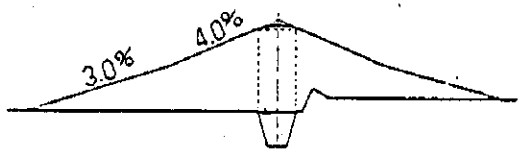
(3) Outline Descriptions of Alternatives

- Alternatives 1 to 3 show constant vertical grades of 3 %, 4% and 5% which is a normal type application.
- A shallower grade will be provided for the main bridge section in Alternative 4.
- A level section will be provided midway up the approach viaduct in order to reduce the strain on climbing vehicles and assist the traffic flow - Alternative 5.
- A shallower grade for the lower section and a steeper one for the upper section of the approach viaduct, which will decrease the average height of the approach viaduct in Alternative 6. The construction cost of the approach viaduct in this case will be lower than for an average vertical grade of 3.5%.

(4) Discussion

The information on the future traffic demand and construction cost of the structures is required to decide the optimum vertical grade of this road crossing. If the general condition of Egyptian vehicles is considered, a shallower grade would be preferable. The Study Team has selected a maximum vertical grade of 4.0% at present and the vertical grade of 4.0% or less will be selected for the road crossing the Canal based on the result of this study.

Table A6.2.3 Comparison of Vertical Grades

Alternative Vertical Grades	Profile	Bridge Length (m) Main Bridge	Bridge Length (m) Approach Viaducts	Bridge Length (m) Total	Comments	Bridge Area (m²) Main Bridge	Bridge Area (m²) Approach Viaducts	Bridge Area (m²) Total (Ratio)	Priority
Alternative 1 3.0%		670	3,860	4,530	The most preferable plan for traffic and to satisfy in the Egyptian request. However, the construction cost is the most expensive.	12,600	72,600	85,200 (1.22)	High
Alternative 2 4.0%		670	2,730	3,400	A compromising plan between Case 1 and Case 3. This vertical grade might not be acceptable for Egyptian vehicles.	12,600	52,300	63,900 (1.00)	High
Alternative 3 5.0%		670	2,050	2,720	This is the case where the maximum vertical grade is applied. The construction cost is the cheapest but it is not preferable for traffic.	12,600	38,500	51,100 (0.80)	Low
Alternative 4 2% + 4%		670	3,030	3,700	The shallower vertical grade is provided for the main bridge section. The bridge length is a little longer than that of Case 2.	12,600	56,600	68,200 (1.09)	Medium
Alternative 5 4% + Level		670	3,330	4,000	The level sections are positioned midway along the approach viaducts to improve speed and reduce gear changes.	12,600	58,800	71,400 (1.18)	Medium
Alternative 6 3% + 4%		670	3,255	3,925	The average vertical grade is 3.5 %. The average height and construction cost of the approach viaducts might be lower.	12,600	60,500	73100 (1.15)	Medium

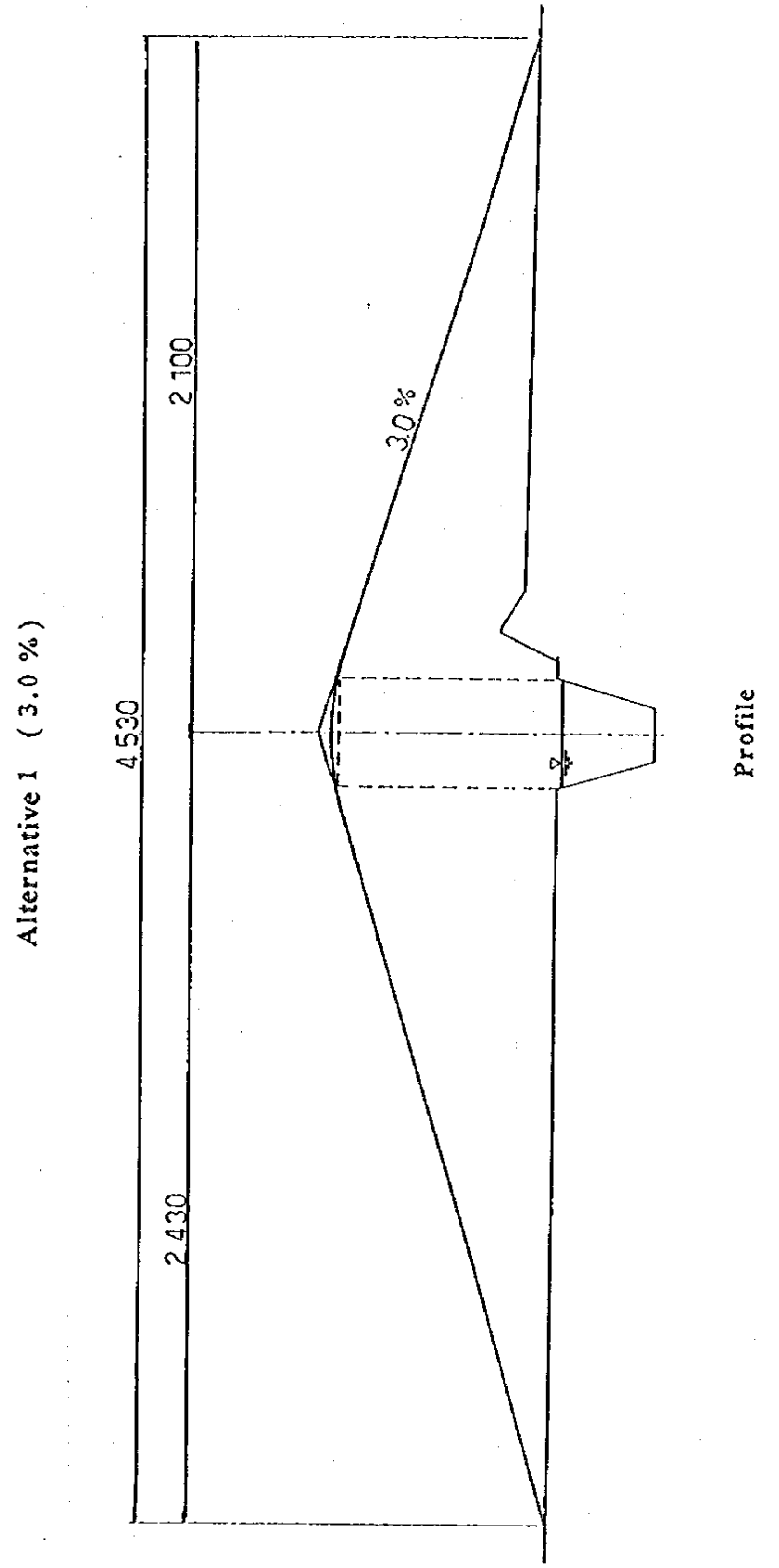


Fig. A6.2.14 Alternative Vertical Grade (1)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

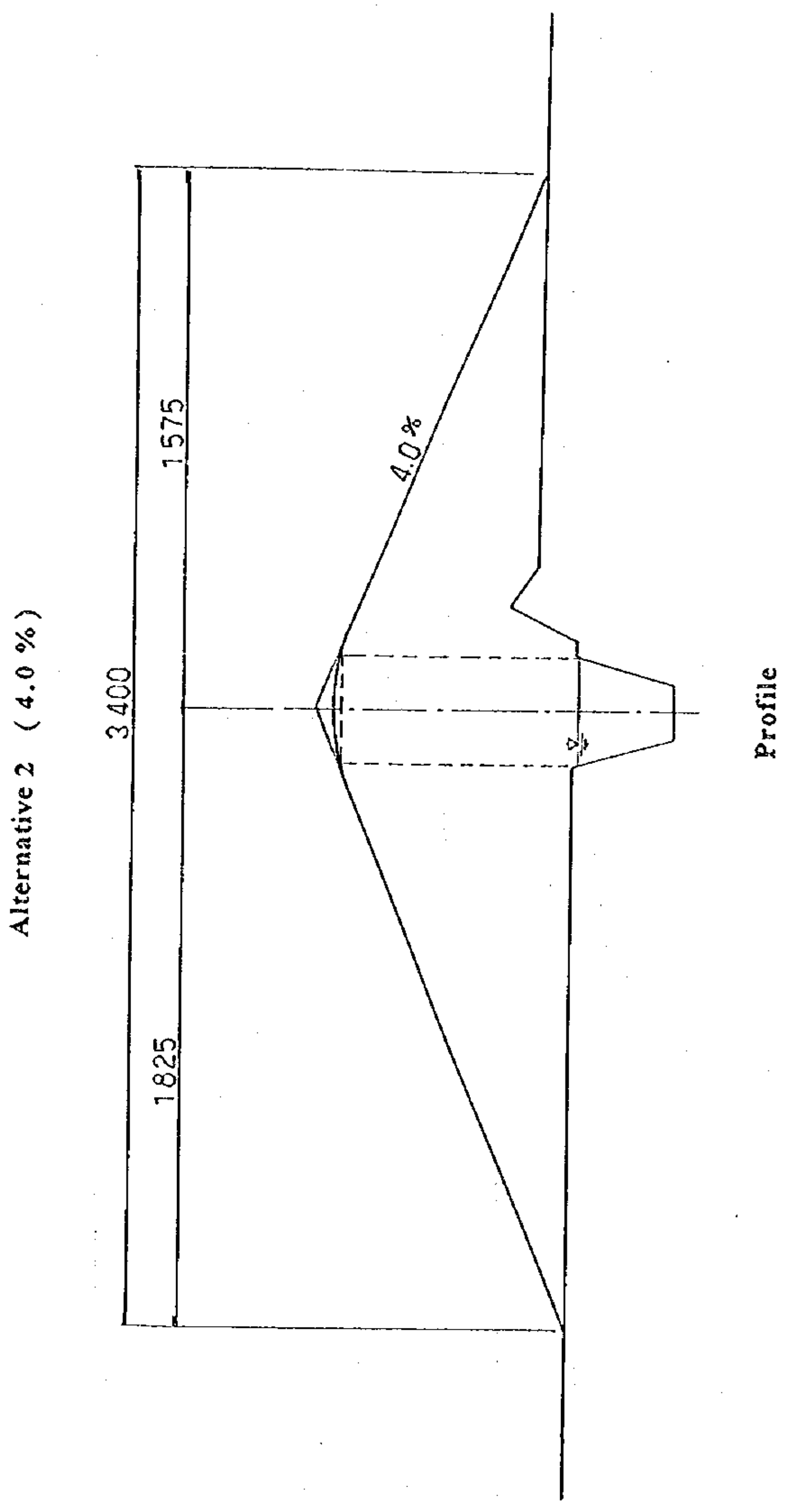


Fig.A6.2.15 Alternative Vertical Grade (2)

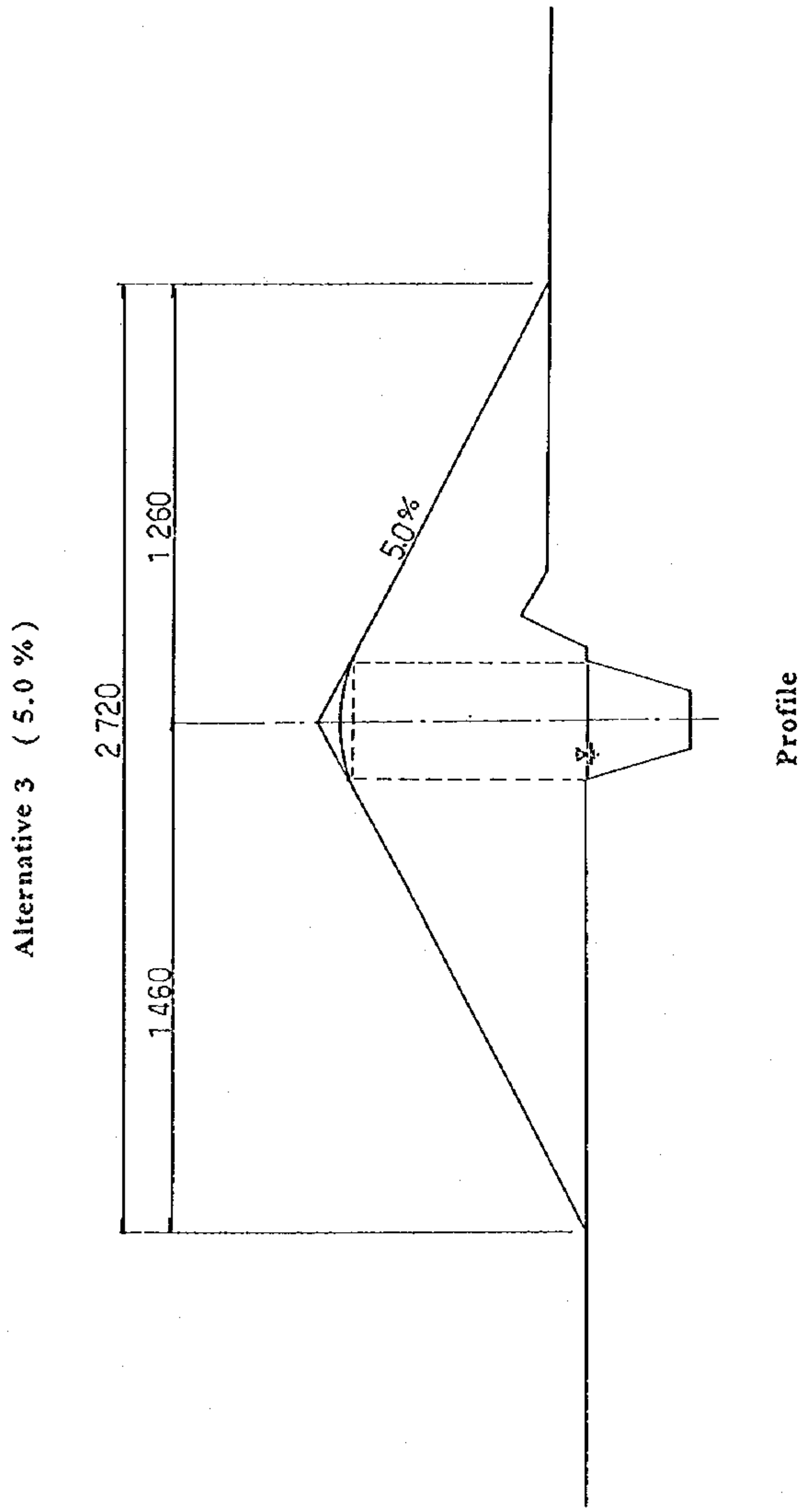


Fig. A6.2.16 Alternative Vertical Grade (3)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

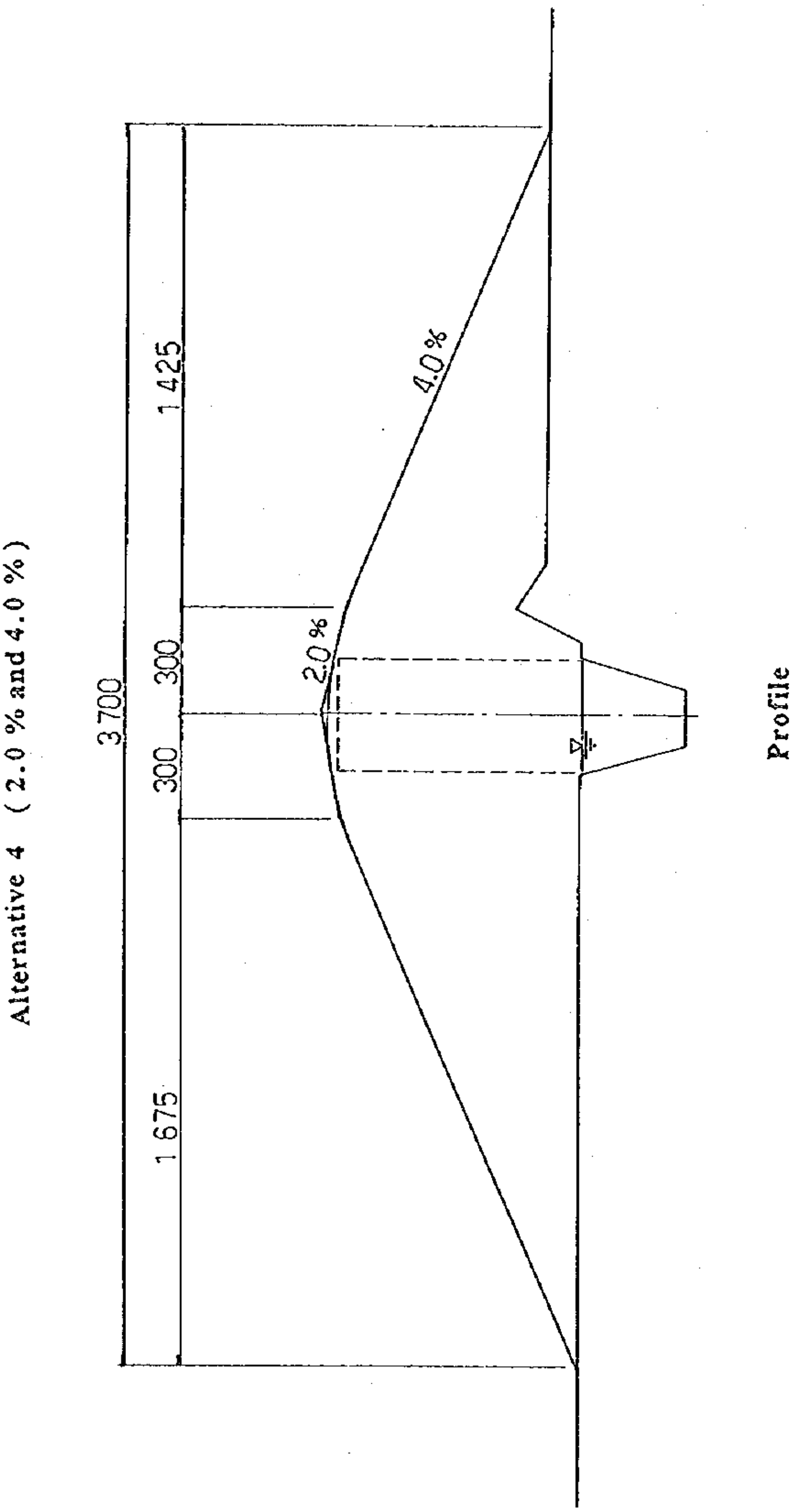


Fig. A6.2.17 Alternative Vertical Grade (4)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

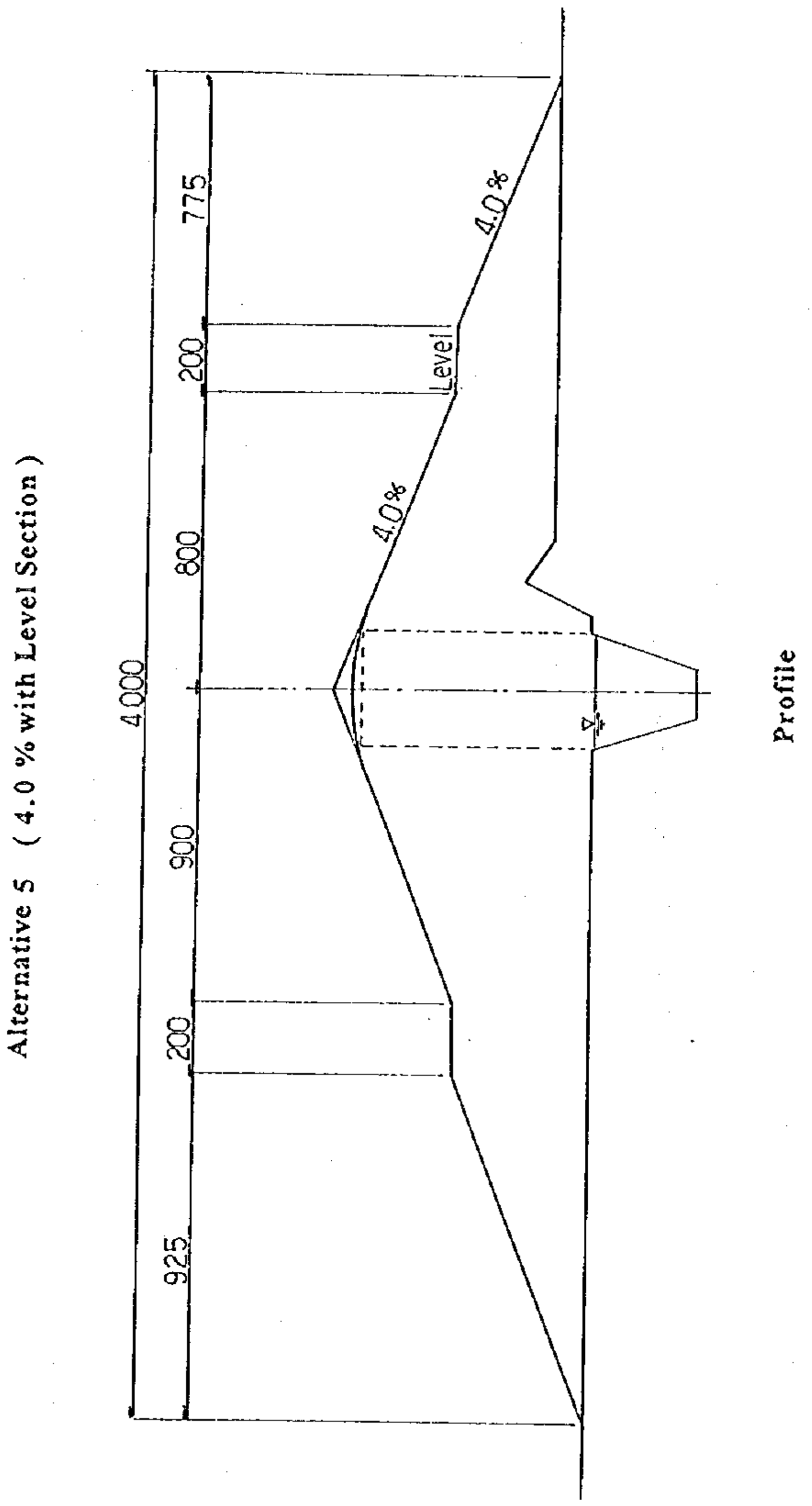


Fig. A6.2.18 Alternative Vertical Grade (5)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

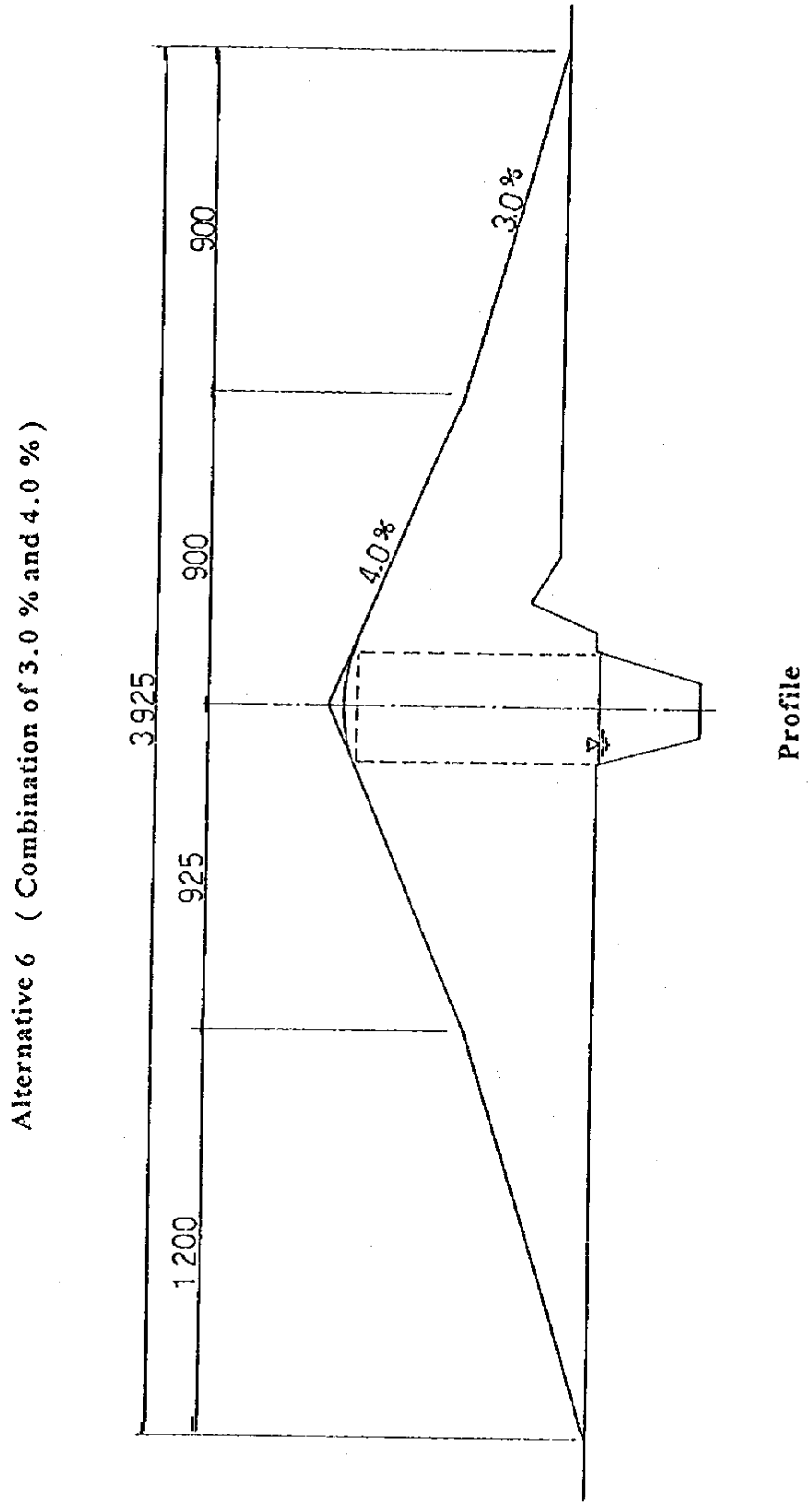


Fig. A6.2.19 Alternative Vertical Grade (6)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

A6.2.6 Study of Navigation Clearance

(1) Vertical Clearance

A vertical clearance of 70 m above H.H.W.L has been assumed.

(2) Horizontal Clearance

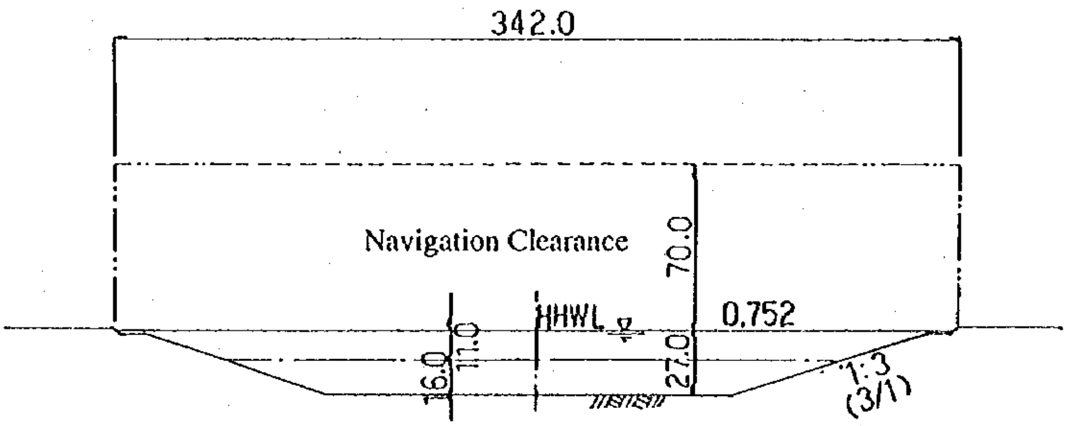
1) The horizontal navigation clearance to the south of km 60 will be;

a) B = 342 m (The width of the Suez Canal between the bank), or
b) B = 250 m (The width of the Suez Canal at a depth of 11 m below water level)

2) The horizontal navigation clearance to the north of km 60 will be;

a) B = 384 m (The width of the Suez Canal between the bank), or
b) B = 270 m (The width of the Suez Canal at a depth of 11 m below water level).

Note ; Suez Canal Authority defines that the width at 11 m below water level is the width of the navigation channel of the Suez Canal.

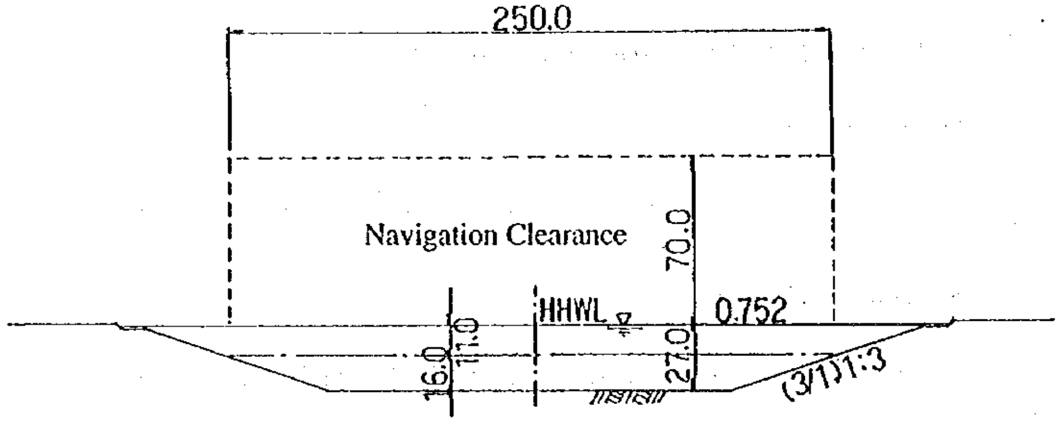


Case 1-a

Navigation Clearance to the South of km 60

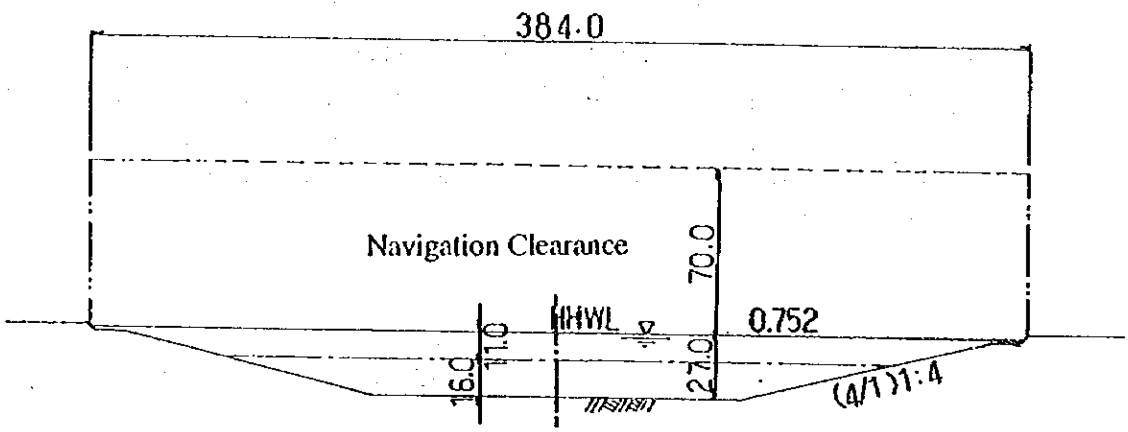
Fig. A6.2.20 Navigation Clearance (1)

Note : The depths and widths at the final stage of the Canal expansion plan are shown in Fig. A6.2.20 and Fig. A6.2.21.

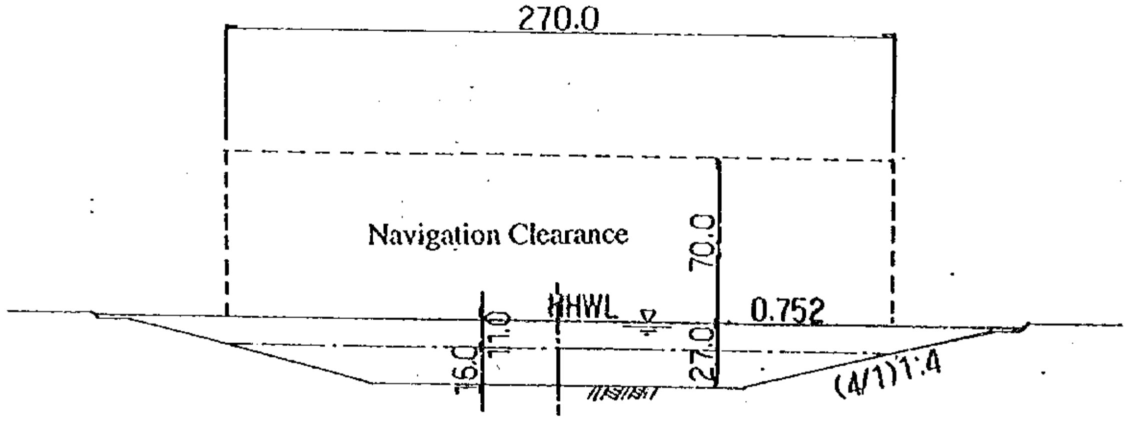


Case 2-b

Navigation Clearance to the South of km 60



Case 2-a



Case 2-b

Navigation Clearance to the North of km 60

Fig.A6.2.21 Navigation Clearance (2)

2) Length of Approach Sections Related to the Canal Width and Vertical Grade

The results of the study on the length of approach sections relative to the width of navigation clearances of the Suez Canal and the vertical grades of the approach sections are shown in Table A6.2.4.

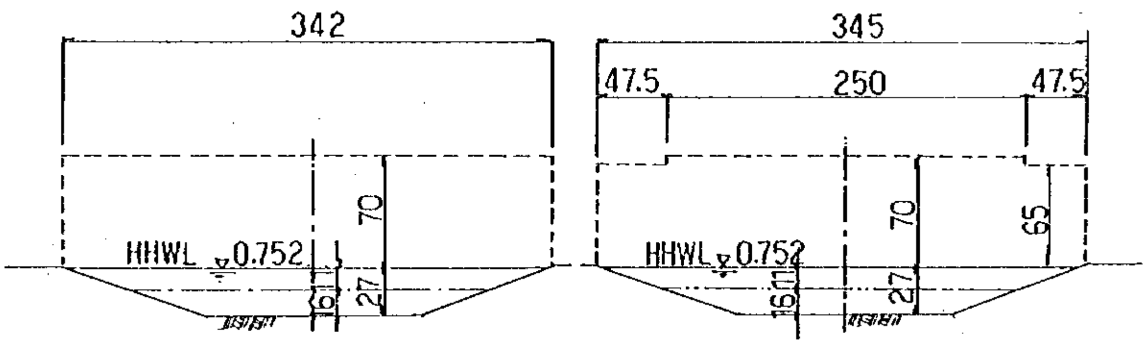
The number in the difference column of the table indicates the difference in length of the approach sections for either a 250 m or a 350 m navigation clearance width with 4.0 % and 3.3 % vertical grades.

Table A6.2.4 Comparison on Length of Approach Section

Vertical Grade (%)	Navigation Clearance (m)	Total Length of Approach Sections (m)	Difference (m)
4.0%	a) 70 m × 342 m	2 × 1,790 m	100 m
	b) 70 m × 250 m 65 m×2×47.5 m	2 × 1,740 m	
3.3%	a) 70 m × 342 m	2 × 2,170 m	100 m
	b) 70 m × 250 m 65 m × 2 × 47.5 m	2 × 2,120 m	

- From the comparison, the difference in length of the approach sections is 100 m for the selected widths.

This figure is equivalent to an area of about 2,000 m^2 in the area of road surface within the approach section.



Case a **Case b**

Fig. A6.2.22 Navigation Clearance for This Study

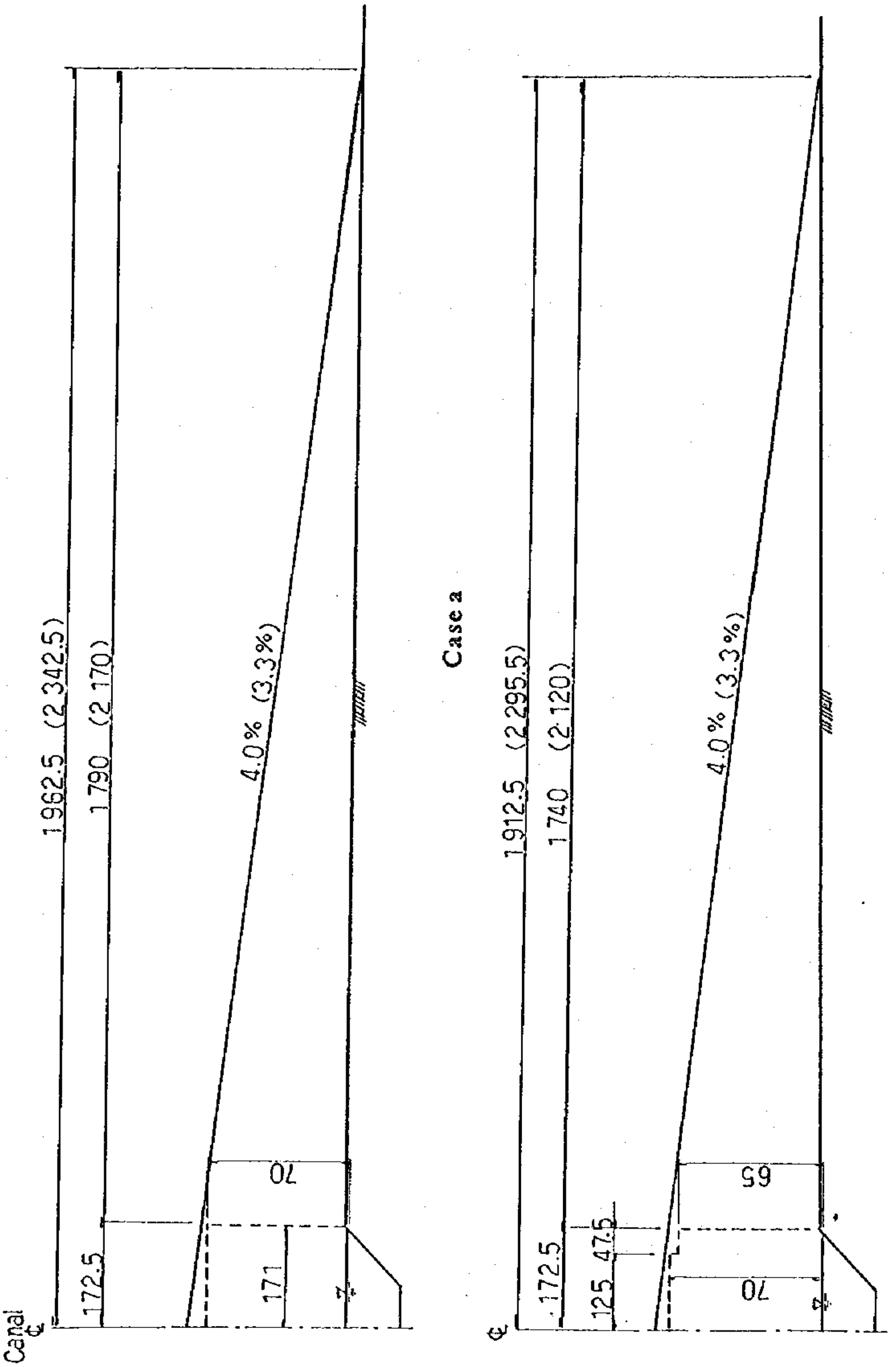


Fig. A6.2.23 **Comparison of Difference of Approach Section Length**

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

A6.2.7 Study of Ship Collision

7.1 Risk of Ship Collision

The risk of ship collision with the piers of the main bridge over the Suez Canal will be examined in this chapter.

(1) Study Parameters

1) Ship Characteristic Assumed for Study

The Study Team has selected a representative ship for this study taking into account the past records of the Suez Canal Authority (SCA).
The past records indicate that the average tonnage of ships was 22,000 DWT in 1993 and the major ship types of the Canal traffic were general cargoes and containers.
The maximum size ship recorded was a 560,000 DWT tanker, however, the frequency of tankers more than 100,000 DWT is very low. The increase in the average tonnage of the Canal traffic has leveled off in the past few years, therefore, it is unlikely the size of the ships will increase significantly in the future.
The risk of accidents involving large ships greater than 100,000 DWT is considered to be very low. Thus, a ship of 50,000 DWT which is a representative size among the Canal traffic, has been selected for this study, and is shown below in Fig. A6.2.24.

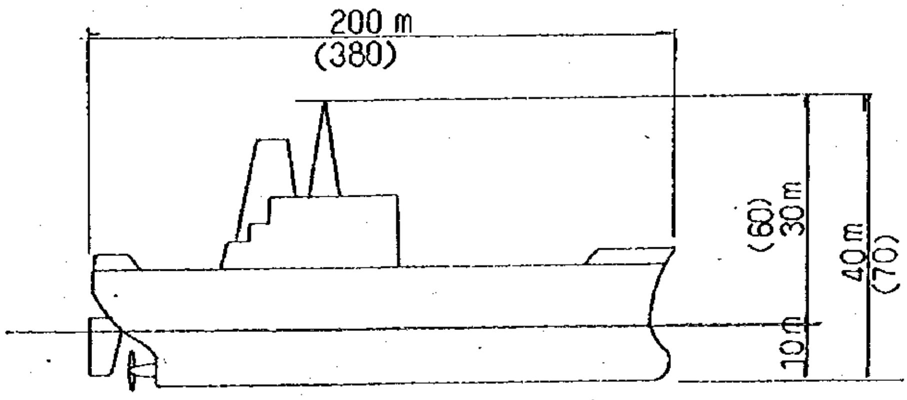


Fig. A6.2.24 Ship Dimensions Assumed

2) Study Parameters

The Study Team will examine the risk of ship collision with the piers of the main bridge using the following parameters;

- The bridge will cross at a point where the Canal is straight,
- The width of the Canal will be 342m or 384 m and the depth 27 m as at the final stage of the Canal improvement plan,
- The two cases of the size of the ship assumed for this study are 200 m length, 30 m width, 30 m height and 10 m transit draught (the Study Team proposal), and 380 m length, 58 m width, 60 m height and 10 m draught (the Egyptian requirement),
- The ships which pass through the Suez Canal are fully controlled and there is no possibility of weather related accidents, and
- The primary cause of accidents is assumed to be poor ship control or steering problems.

(2) Possible Causes of Ship Collisions

1) Events Leading to Ship Collision

The width of the Canal at the bridge location is considered to be approximately 350 m or 385 m with a navigation width of 250 m.

With a ship length of 200 m, the angle of collision is expected to be very small. Assuming the angle between the ship and rudder is 10° (The maximum angle between ship and rudder is usually 15°), when steering problems occur, the ship collision angle is anticipated to be about 15° .

Based on the ship size and Canal dimensions, a possible ship collision sequence could be as shown in Fig. A6.2.25.

2) Ship Rebound After Collision

There are two possible types of ship rebound following collision with the side slopes which may occur.

One is a sliding movement. A ship runs into the Canal bank and grounds on the bank. The inclination of the bank is 1/3 , thus, the ship leans towards and is deflected back into the Canal. (Type 1 in Fig. A6.2.26)

The other is a rotational movement. A ship hits the Canal bank and the bow of the ship penetrates it. The ship then stops and starts rotating around the bow. (Type 2 in Fig. A5.2.26)

These two types of ship rebound after hitting the Canal bank are shown in Fig. A6.2.26.

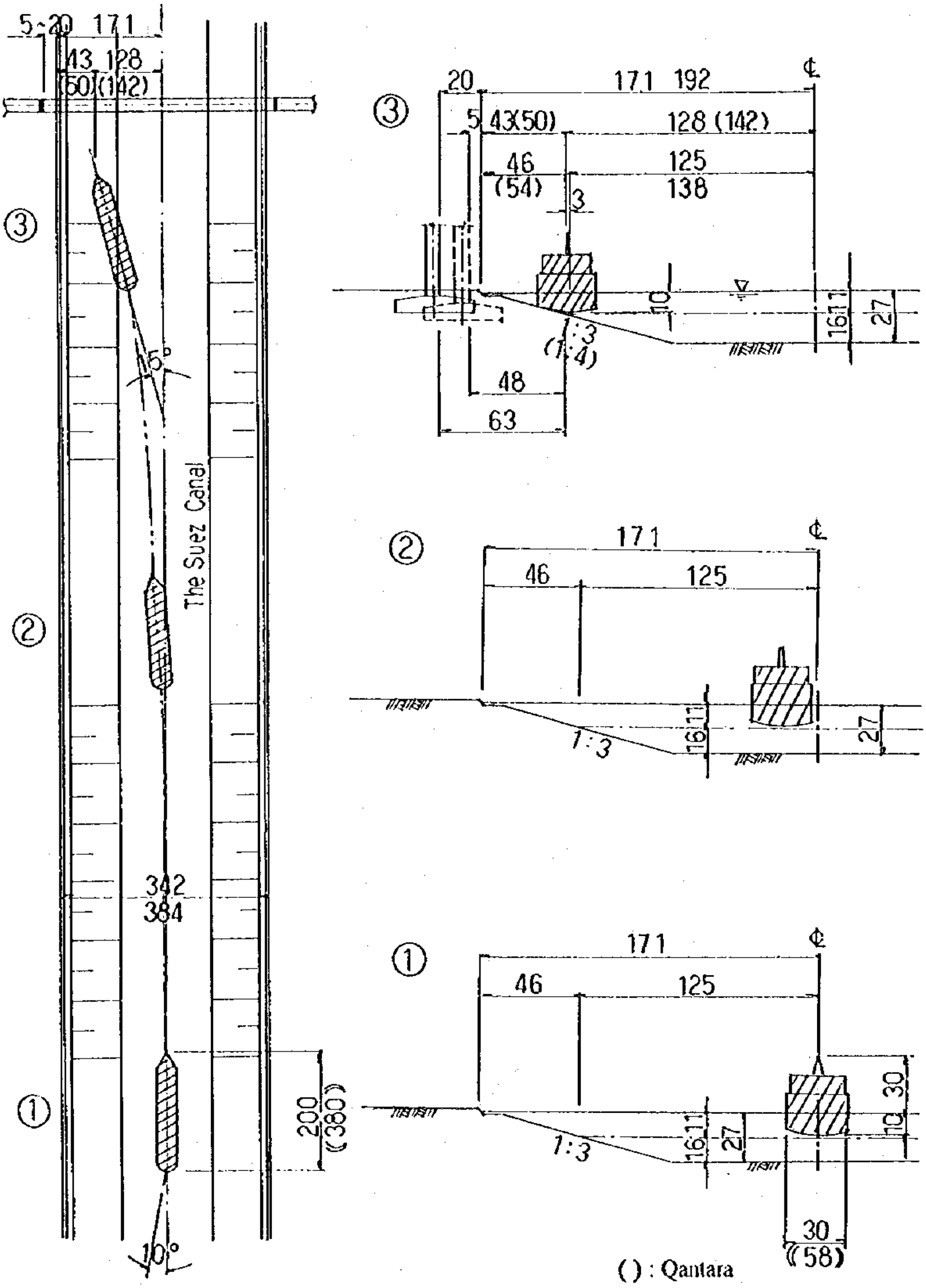
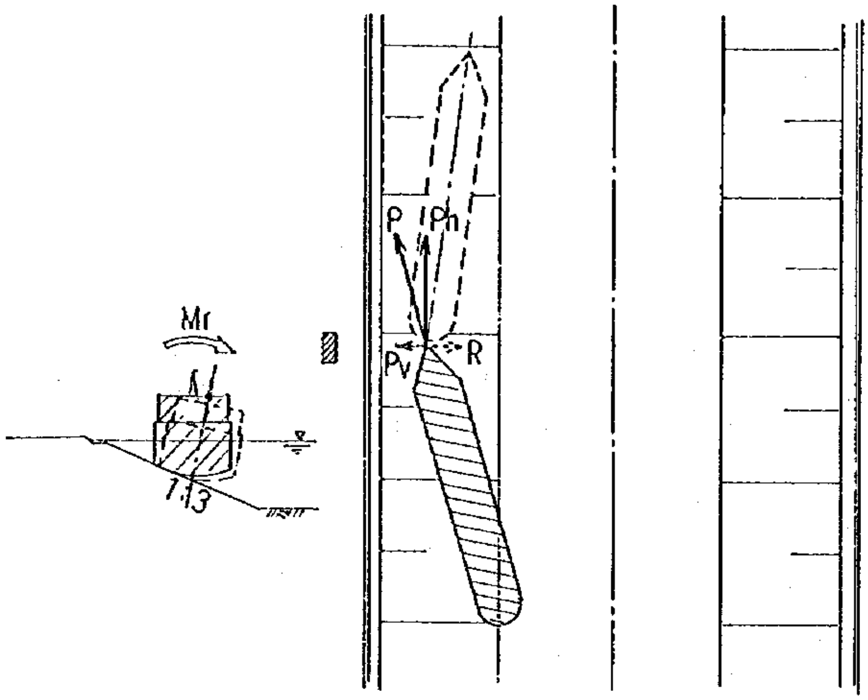
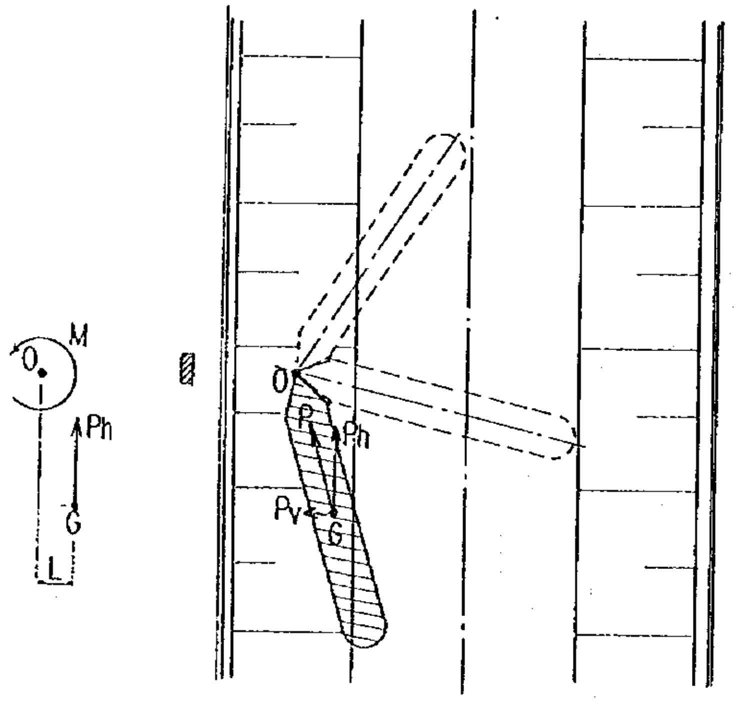


Fig. A6.2.25 Possible Sequence of Ship Collision

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL



Type 1



Type 2

Fig.A6.2.26 Types of Ship Collision

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

3) Anticipated Ship Collision Force

The force of the colliding ship acting on the pier of the bridge is understood to be relatively small and not to affect the pier seriously due to the following reasons;

- The shallow angle of collision and, hence the resultant force acting on the pier is relatively small.
- The majority of the collision force will act along the axis of the ship due to the small collision angle and sliding movement of the ship, and
- The collision force will be transferred into a moment force which is the force required to rotate the ship.

(3) Ship Collision Force

1) Calculation of Ship Collision Forces

Ship collision force will be calculated using the above parameters based on the formula of the design standards of Honshu Shikoku Bridge Authority and AASHTO.

Calculation of ship collision in shows on Pages A6 - 38 to A6 - 43.

2) Results of Calculations

a) Ship Collision Forces Based on the Honshu Shikoku Bridge Authority Standard

If the largest possible ship (560,000 t tanker) or medium size ship (200,000 t ship) collided with a pier of the bridge at normal navigation speed, the collision forces would be high, in the range of 31,000 t to 11,000 t.

However, the piers are assumed to be installed on the shore about 5 m to 20 m behind the shoulder of the Canal slope. Therefore, the ship collision force is expected to be greatly reduced due to the friction between the ship and the Canal bank. If the collision speed is assumed to be 1/10 of the normal navigation speed, the ship collision force would be correspondingly reduced to the smaller figure of 300 t to 100 t. (This Collision speed is assumed taking into consideration of the stopping distance of the assumed ship and the distance between the pier and the collision point)

Intrusion distances and impact force distributions of 500,000 t tanker and 200,000 t ship are calculated when ship collision speeds are 10 km/hr (two third of the normal navigation speed) and 14 km/hr (normal navigation speed) and the results of the calculation are shown in Paragraph 7.2.3 and Chapter 9.

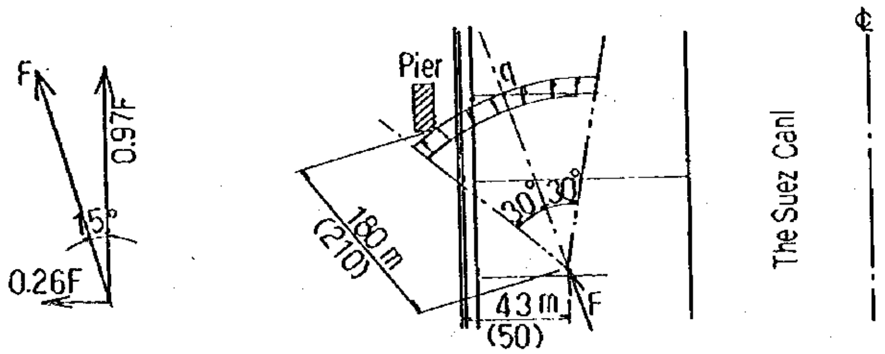
b) Ship Collision Force Based on AASHTO Standard

If the largest possible ship (560,000 t tanker) or medium size ship (200,000 t ship) collided with a pier of the bridge at normal navigation speed, the collision forces would be high in the range of 83,000 kips (38,000 t) to 50,000 kips (23,000 t).

If the collision speed is assumed to be 1/10 of the normal navigation speed, the ship collision force would be correspondingly reduced to the smaller figure of 8,400 kips (3,800 t) to 5,000 kips (2,300 t).

c) Summary

The ship collision forces calculated above are the forces acting along the axis of the ship. The resultant forces acting on the pier of the bridge will be relatively small due to the small collision angle.
The collision force on the Canal bank will be distributed and absorbed before the force reaches the pier by the soil mass of the bank.



( ) : Qantara

Fig. A6.2.27 Distribution of Ship Collision Force

(4) Discussion

1) Need to consider Ship Collision Force

The piers of the Canal crossing bridge are expected to be installed on the shore approximately 5 m to 20 m behind the shoulder of the Canal slope. Therefore, the possibility of ship collision with the pier is extremely low.

However, if the bridge is constructed over a vessel passing area and a pier is installed close to the navigation channel, the ship collision force is usually taken into account in the pier design. However, where a pier is installed on the shore or off shore shallows, the ship collision force is not generally considered in the design.

According to the past records of ship accidents in the Suez Canal, no serious accidents involving ships in straight sections of the Canal have occurred. The bridge is expected to be located in a straight section and, therefore, the ship collision forces will not be considered necessary for the pier design.

2) Ship Collision Force and Protective Measures

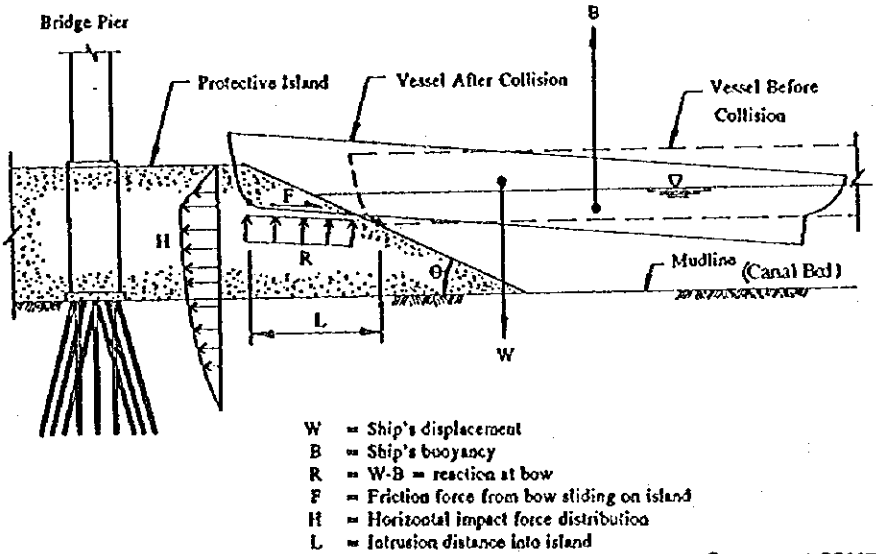
a) General

However, if in spite of the above conclusion, it is still considered necessary to design the piers to prevent collision forces, then, the size of the ship and collision speed selected to calculate these forces should be studied in detail and selected.

The use of shock absorbers or fenders should be considered as protective measures against ship collision in order to minimize the effect of the force on the piers.

b) Example of Protective Measures

One way of preventing ship collision is to provide protective islands. An example of a protective island is shown in Fig. A6.2.28.
The profile of the protective island is very similar to the bank of the Canal, and thus, the Canal bank itself can be assumed to be one of the protection measures against ship collision.
(Refer to 7.2.3 for intrusion distance and impact force distribution)



Source : ASSHTO

Fig. A6.2.28 Example of Protective Island

Refer to Chapter 9 for the additional study for intrusion distance and impact force

7.2. Ship Collision Force

7.2.1. Ship Collision Force : Case 1

Ship Collision force will be calculated based on the design standard for substructures of the Honshu - Shikoku Bridge Authority of Japan (HSBA).

- Substructure Design Standard 1980 The Honshu Shikoku Bridge Authority

(Refer to Fig. A6.2.29)

Ship Collision Forces

$$F = \frac{W \cdot V^2}{4 \cdot g \cdot D}$$

where ; F : Ship Collision Force (t)
D : Stopping Distance of Colliding Ship (m)
W : Weight of Colliding Ship (t)
V : Collision Speed (m/sec)
g : Acceleration of Gravity (9.8m/sec)

(1) Study Parameters

Ship collision force will be calculated using the following parameters.

1) Weight of Ship

W_1 = 560,000 t (Maximum weight vessel of the Suez Canal traffic)
W_2 = 200,000 t (Based on the design standard of the HSBA)

2) Stopping Distance D = 8 m (Based on the design standard of the HSBA)

(2) Collision Force

1) For the Maximum Size Vessel

a) For a Collision Speed of 15 km/hr

$$F = \frac{560{,}000 \times 4.2^2}{4 \times 9.8 \times 8} = 31{,}500 \text{ t}$$

$$V = 15 \times 1{,}000 / 3{,}600 = 4.2 \text{ m/sec}$$

b) For a Collision Speed of 5 km/hr

$$F = \frac{560{,}000 \times 1.4^2}{4 \times 9.8 \times 8} = 3{,}500 \ t$$

$$V = 5 \times 1{,}000/3{,}600 = 1.4 \ m/sec$$

c) For a Collision Speed of 3 km/hr

$$F = \frac{560{,}000 \times 0.83^2}{4 \times 9.8 \times 8} = 1{,}230 \ t$$

$$V = 3 \times 1{,}000/3{,}600 = 0.83 \ m/sec$$

d) For a Collision Speed of 1.5 km/hr

$$F = \frac{560{,}000 \times 0.42^2}{4 \times 9.8 \times 8} = 315 \ t$$

$$V = 1.5 \times 1{,}000/3{,}600 = 0.42 \ m/sec$$

2) For a Medium Size Vessel

a) For a Collision Speed of 15 km/hr

$$F = \frac{200{,}000 \times 4.2^2}{4 \times 9.8 \times 8} = 11{,}250 \ t$$

$$V = 15 \times 1{,}000/3{,}600 = 4.2 \ m/sec$$

b) For a Collision Speed of 5 km/hr

$$F = \frac{200{,}000 \times 1.4^2}{4 \times 9.8 \times 8} = 1{,}250 \ t$$

$$V = 5 \times 1{,}000/3{,}600 = 1.4 \ m/sec$$

c) For a Collision Speed of 3 km/hr

$$F = \frac{200{,}000 \times 0.83^2}{4 \times 9.8 \times 8} = 439 \ t$$

$$V = 3 \times 1{,}000/3{,}600 = 0.83 \ m/sec$$

d) For a Collision Speed of 1.5 km/hr

$$F = \frac{200{,}000 \times 0.42^2}{4 \times 9.8 \times 8} = 113 \ \text{t}$$

$$V = 1.5 \times 1{,}000 / 3{,}600 = 0.42 \ \text{m/sec}$$

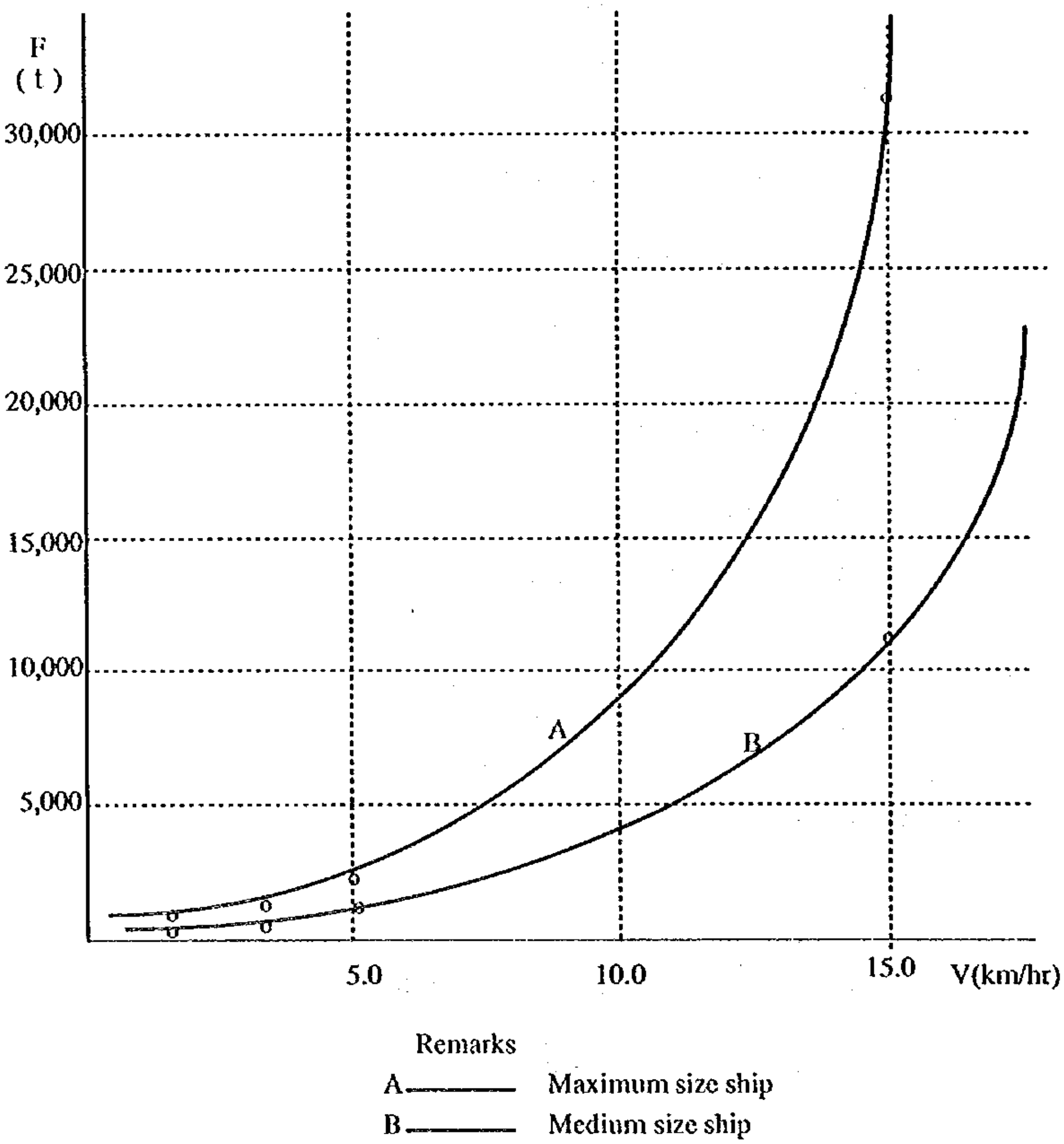


Fig. A6.2.29 Relationship between Collision Speed and Collision Force (1) HSBA Standard

7.2.2. Ship Collision Force : Case 2

Ship Collision force will be calculated based on the guide specification of AASHTO.

- Guide Specification and Commentary for Vessel Collision Design of Highway Bridge Volume 1: Final Report February 1991 AASHTO

Ship Collision Forces (Refer to Fig. A6.2.30)

$$Ps = 220(DWT)^{1/2} \frac{V}{27}$$

where ; Ps : Equivalent Static Ship Impact Force (kips) (1 kip = 1,000 lbs)
DWT : Deadweight Tonnage of Ship (tonnes)
V : Collision Speed (fps)

(1) Study Vessel

Ship collision force will be calculated under the following weight of vessels.

W_1 = 560,000 t (Maximum weight vessel of the Suez Canal traffic)
W_2 = 200,000 t (Tonnage of the 10% largest tankers)

- The 10% largest tanker among tankers of 10,000 DWT or more passed through the Suez Canal in 1994, that is, the 273rd largest tanker among 2,730 tankers.

(2) Collision Force

1) For the Maximum Size Vessel

a) For a Collision Speed of 15 km/hr

$$Ps = 220 \times 560{,}000^{1/2} \times \frac{13.67}{27} = 83{,}400 \text{ kips} = 38{,}000 \text{ t}$$

$$V = 15 \times 1{,}000 / (3{,}600 \times 0.3048) = 13.67 \text{ fps} = 4.18 \text{ m/sec}$$

b) For a Collision Speed of 5 km/hr

$$Ps = 220 \times 560{,}000^{1/2} \times \frac{4.56}{27} = 27{,}800 \text{ kips} = 12{,}600 \text{ t}$$

$$V = 5 \times 1{,}000 / (3{,}600 \times 0.3048) = 4.56 \text{ fps} = 1.39 \text{ m/sec}$$

c) For a Collision Speed of 3 km/hr

$$Ps = 220 \times 560{,}000^{1/2} \times \frac{2.73}{27} = 16{,}600 \text{ kips} = 7{,}500 \text{ t}$$

$$V = 3 \times 1{,}000 / (3{,}600 \times 0.3048) = 2.73 \text{ fps} = 0.83 \text{ m/sec}$$

d) For a Collision Speed of 1.5 km/hr

$$Ps = 220 \times 560{,}000^{1/2} \times \frac{1.37}{27} = 8{,}350 \text{ kips} = 3{,}800 \text{ t}$$

$$V = 1.5 \times 1{,}000 / (3{,}600 \times 0.3048) = 1.37 \text{ fps} = 0.42 \text{ m/sec}$$

2) For a Medium Size Vessel

a) For a Collision Speed of 15 km/hr

$$Ps = 220 \times 200{,}000^{1/2} \times \frac{13.67}{27} = 49{,}800 \text{ kips} = 22{,}600 \text{ t}$$

$$V = 15 \times 1{,}000 / (3{,}600 \times 0.3048) = 13.67 \text{ fps} = 4.17 \text{ m/sec}$$

b) For a Collision Speed of 5 km/hr

$$Ps = 220 \times 200{,}000^{1/2} \times \frac{4.56}{27} = 16{,}600 \text{ kips} = 7{,}500 \text{ t}$$

$$V = 5 \times 1{,}000 / (3{,}600 \times 0.3048) = 4.56 \text{ fps} = 1.39 \text{ m/sec}$$

c) For a Collision Speed of 3 km/hr

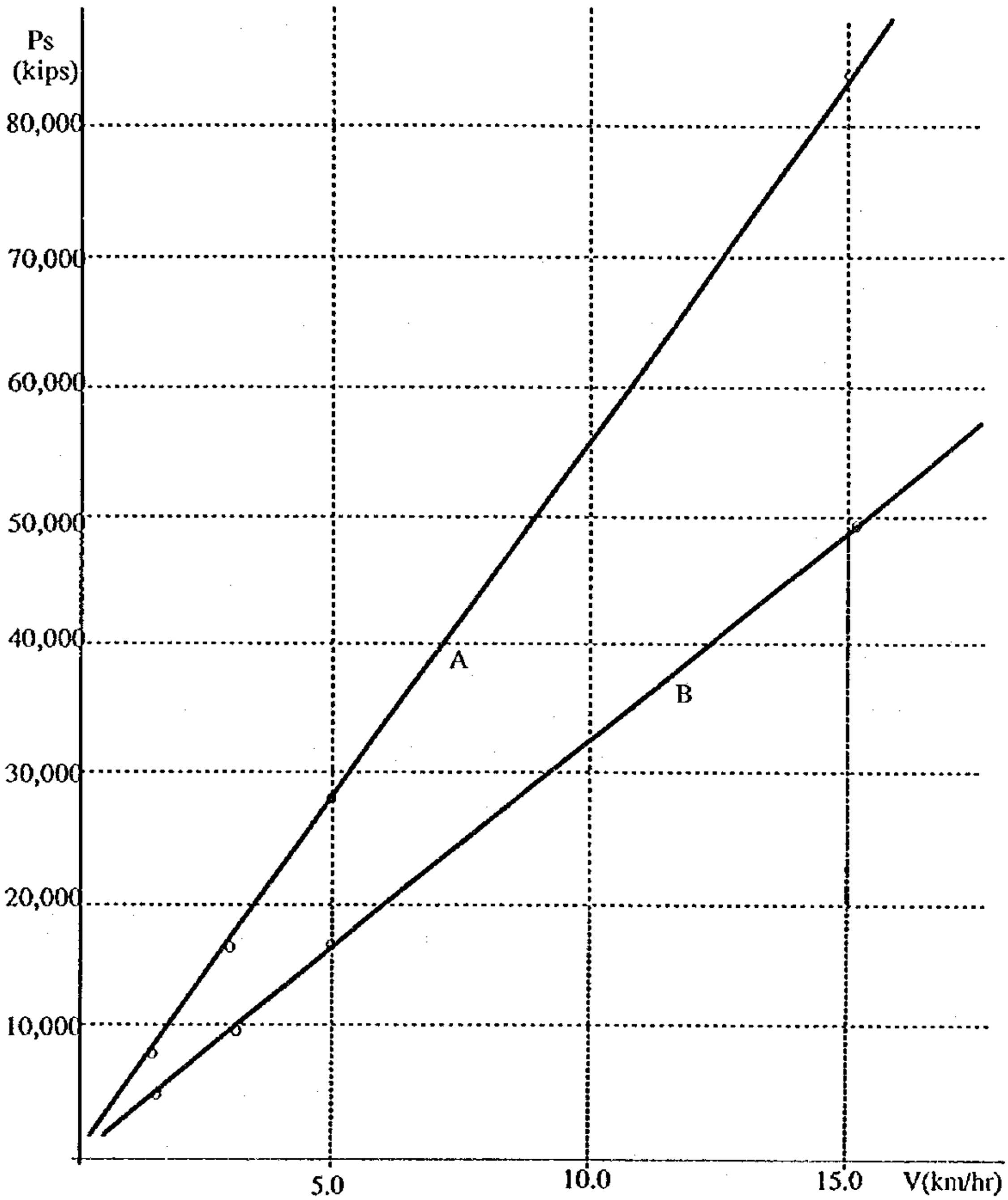
$$Ps = 220 \times 200{,}000^{1/2} \times \frac{2.73}{27} = 9{,}950 \text{ kips} = 4{,}500 \text{ t}$$

$$V = 3 \times 1{,}000 / (3{,}600 \times 0.3048) = 2.73 \text{ fps} = 0.83 \text{ m/sec}$$

d) For a Collision Speed of 1.5 km/hr

$$Ps = 220 \times 200{,}000^{1/2} \times \frac{1.37}{27} = 4{,}970 \text{ kips} = 2{,}260 \text{ t}$$

$$V = 1.5 \times 1{,}000 / (3{,}600 \times 0.3048) = 1.37 \text{ fps} = 0.42 \text{ m/sec}$$



Remarks

A ———— Maximum size ship

B ———— Medium size ship

Fig. A6.2.30 Relationship between Collision Speed and Collision Force (2)
(AASHTO Standard)

7.2.3 Intrusion Distance and Impact Force Distribution

Intrusion distance and impact force distribution have been calculated based on the following parameters assumed.

(1) Calculation Parameters

1) Ship Weight and Size

- Ship Weight : 200,000 DWT
- Ship size : 380 m length, 58 m width, 60 m height and 10 m transit draft
  (Average width under the surface of the sea is 52.63 m)

W = B → Average width = 200,000 / (380× 10.0) = 52.63 m

Where ; W : Deadweight Tonnage of Ship
B : Ship's Buoyancy

2) Ship Collision Forces

F = 15,000 t (33,000 kips)

Deadweight tonnage of ship : 200,000 t and Collision speed : 10 km/hr
Calculated based on the AASHTO Specification (Refer to Fig. A6.2.30)

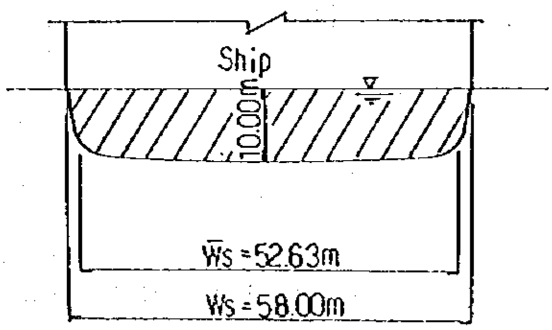
(2) Intrusion Distance

A intrusion distance has assumed that a collision ship stops when collision force and friction force between the collision ship and the surface of Canal bank.

1) Reaction at Bow

R = W - B = 200,000 - (380 - L) × 52.63 × 10.0 = 526.3 L

Where ; R : Reaction at Bow
W : Deadweight Tonnage of Ship
B : Ship's Buoyancy
L : Intrusion Distance into Bank



2) Intrusion Distance

F = R · tan (ϕ / 2)

Where ; ϕ : Coefficient f Internal Friction (ϕ = 40° ; N-Value = 40)

15,000 = 526.3 L × tan (40 / 2) = 191.56 L

L = 15,000 / 191.56 = 78.3 m

3) Horizontal Impact Force Distribution

H = 2F / (Ws·D)

Where ; H : Horizontal Impact Force Distribution

F : Ship Collision Force (F = 15,000 t)

Wx : Distribution Width

(Wx = Ws + 2X · tan (45 - ϕ / 2) = 58.0 + 0.9326X m)

Ws: Ship Width (Ws = 58.0 m)

D : Distribution Depth (X / (4 / tan 15°) + X · tan (45 - ϕ / 2))

X : Distance ahead from Bow of Ship

(Refer to Fig. A6.2.31)

a) At Point A (10 m ahead from Bow of Ship)

H = 2 × 15,000 / (67.33 × 5.56) = 82.59 t/m²

B = 67.33 m, D = 5.56 m

b) At Point B (20 m ahead from Bow of Ship)

H = 2 × 15,000 / (76.65 × 11.12) = 36.14 t/m²

B = 76.65 m, D = 11.12 m

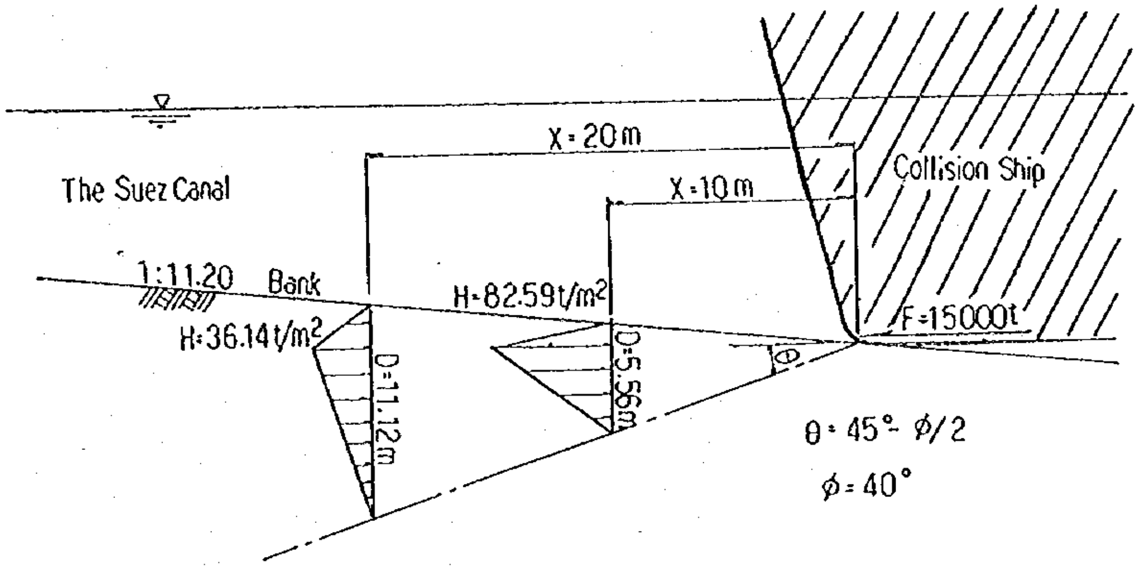


Fig. A6.2.31 Horizontal Impact Force Distribution

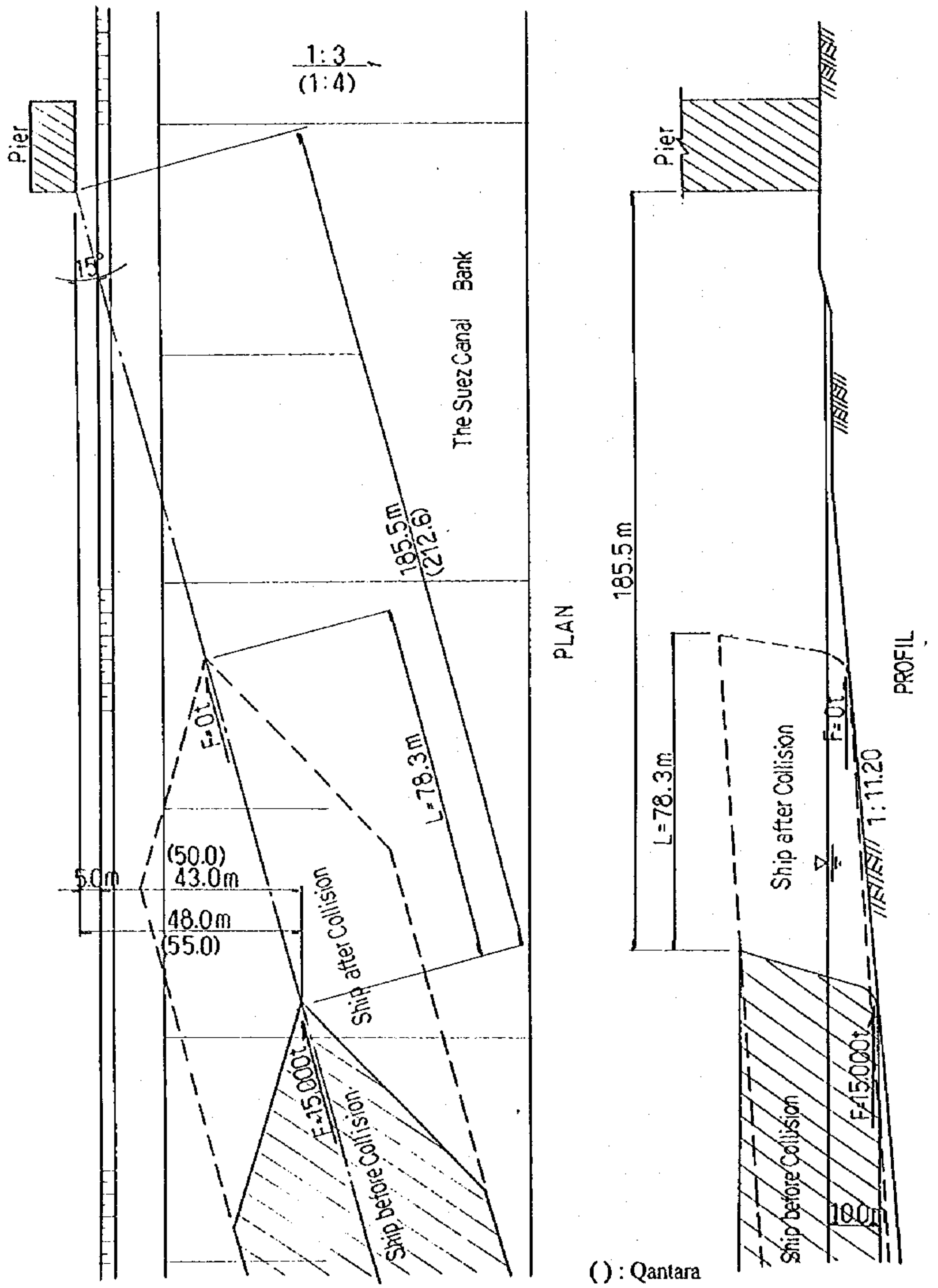


Fig. A6.2.32 Intrusion Distance into the Canal Bank

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

A6.2.8 Design Standards and Criteria for Tunnel

1. Tunnel Structure

(1) Design Speeds

In accordance with the Egyptian geometric design standards, the design speed of the divided Desert Road is 80 km/hr.

The Design speed is the maximum safe speed at which a vehicle can travel a specified section of roadway under normal conditions, governed by the design features of the roadway. The design speed is influenced principally by the topography, tunnel length and size, safety requirements, economic conditions, environmental factors, traffic volumes, functional classification of the roadway and location e.g. urban/rural, underwater. However, the design speed of the Canal underwater tunnel can be compared with examples of underwater road tunnels elsewhere in the world, as shown in Table A5.2.4.

A design speed of 60 km/hr is the normal speed in rural surroundings for underwater road tunnel.

However, the design speed of 60 km/hr has been selected for the Canal crossing underwater tunnel, for reasons of safety and security.

(2) Number of Road Lanes

In general, the number of lanes will be decide based upon the traffic demand forecast. Even if one lane in each direction (2 way) would be sufficient to accommodate the traffic demand, two lanes in each direction totaling four lanes would be preferable, for safety and security reasons.

(3) Lane Width and Shoulder

In principle the lane width will be decided in accordance with the Egyptian Standards. If the Egyptian standard is used for the canal road crossing, the useable lane width will be 3.65 m. However, a smaller lane width of 3.5 m based on the Japanese standard will be studied to reduce the construction cost of the Canal crossing structure. The rehabilitated Ahmed Hamdi Tunnel to the North of Suez has 3.75 m wide lanes in each direction. This includes a median strip of 0.40 m effectively reducing the usable lane width to 3.55 m in each direction.

The lane width in AASHTO is 3.65 m. The shoulder width with in the tunnel section needs to be reduced a minimum for economic reason. AASHTO recommends a 0.60 m width as the minimum and Japanese road standards suggest a 0.50 - 0.75 m width. The lane width in most European countries varies between 3.0 -3.5 m width with a total verge width of 1.0 - 1.5 m in the tunnel for inspection purposes.

Table A 6.2.5 Major Underwater Tunnels

Tunnel Name	Length m	Water Depth	Construct. Method	Traffic Lanes	Tun. Dimensions	Lane Width Traf. Speed	Grade %	Ventilation System
1 Kanmon Road Japan	3,461 (780)	15"	Shield	2 Way	∮ 11.4	7.5 m 40km/h	4.0	Transverse System
2 Tokyo 001 Japan	1,325 (1,035)	13	Immersed Tube	2 Lane X 2	8.8*37.4 H W	10.5 m 80km/h	4.0	Semi Transvers System
3 Tamariver Japan	2,170 (1,549)	13.9	Immersed Tube	3 Lane X 2	10*39.9 H W	10.5 m 80km/h	4.0	Supply & Exhaust
4 Oosakasouth Japan	2,200 (1,025)	14.7	Immersed Tube	2 Lane*2 + Railway	8.5*35.2 H W	7.0 m 60km/h	5.0	Semi Transverse System
5 Tokyo-Bay Japan	9,500	25	Shield Under Cons	2 Lane X 2	∮ 14.2	10.5 m 80km/h	4.0	Supply & Exhaust
6 HongKong East Hong Kong	1.860	16	Immersed Tube	2 Lane*2 + Railway	9.8*35.4 H W	7.5 m 60km/h	3.0	Semi Transverse System
7 Sydnyharbour Australia	2,280 (960)	16	Immersed Tube	2 Lane X 2	7.8*29.4 H W	7.5 m 60km/h	4.2	Semi Transverse System
8 Mersey TN U.K.	3,226 (1,586)	10	Shield	2 Lane X 2	∮ 14	8.4 m 40km/h	3.0	Semi Transverse System
9. Brooklyn Battery USA	2,780	15	Shield	2 Lane X 2	∮ 10	6.5 m 50-60km	4.0	Transverse System
10. Queen Mid Town USA	1,955	13	Shield	2 Lane X 2	∮ 10	6.4 m 60km/h	4.0	Transverse System
11. Much Henly USA	2,195 (1,646)	15 12	Immersed Tube	4 Lane X 2	10*24 X 2	7.0 m 60km/h	–	Transverse System
12. Chesapeake Bay. B-T USA	L=37km T1=1749m T2=1661m Br=19.6K	7,6 21	Immersed Tube	2 Way	11.3*11.3 H W	6.5 m 50-60km/h	4.0	Transverse System
13. Norde Lyon France	3,250 X 2	Under River	Shield Under Cons	2 Lane X 2	∮ 10.96	7.6 m 60km/h	4.0	Transverse System
14. Ahmed Hamdi A.R.Egypt	1,640 (400)	17	Shield Suez Canal	2 Way	∮ 12	7.5 m 40-50km	3.9	Transverse System
15. St. Clair Canada	1,840 (600)	10	Shield	Railway	∮ 9.2		2.0	Jet Fans
16. Channel TN UK/France	50,000 (30,000)	30	Shield	Railway	∮ 8.4		1.2	Supply and Exhaust

Source : JICA Study Team

Note ; Length(m) is the under water section

(4) Gradients of the Roadway

The gradients of the roadway are of primary importance, since in most cases they constitute a determining factor on the length of the tunnel, and hence its construction cost.

In general, attempts are made to select gradients which will not cause congestion through the excessive slowing down of heavy vehicles.

Gradients of up to 1 in 25 (4.0%) are considered acceptable for modern traffic and although it is sometimes necessary for practical purposes to exceed this, these steeper gradients should be kept as short as possible.

Examples of some long underwater tunnels are shown in Table A6.2.4, and an example of roadgrade effect on the tunnel length for the underwater canal tunnel is shown in Table A6.2.5.

Table A6.2.5 Gradient and Length of Suez Crossing Tunnels

Table A6.2.6 Tunnel and Approach Cutting Lengths

Location	Gradient	Tunnel (m)	Approach (m)	Total Length (m)	Remarks
Qantara	4%	1785.0	925.0	2710.0	GL=+2.5m
	3.3%	2119.0	1121.2	3240.2	
Ferdan	4%	1785.0	925.0	2710.0	GL=+2.5m
	3.3%	2119.0	1121.2	3240.2	
Ismailiya	4%	1910.0	925.0	2835.0	GL=+5.0m
	3.3%	2270.6	1121.2	3391.8	
Srabioum	4%	1910.0	925.0	2835.0	GL=+5.0m
	3.3%	2270.6	1121.2	3391.8	
Srabioum	4%	2318.0	925.0	3243.0	East Bank
Additional	3.3%	2678.6	1121.2	3799.8	extended

Note: Tunnel Length=Portal headwall to Portal headwall
Approaches includes ±40m of Portal Structure
* Distance of Center Line bypass channel from Center Line existing channel scaled at 408m

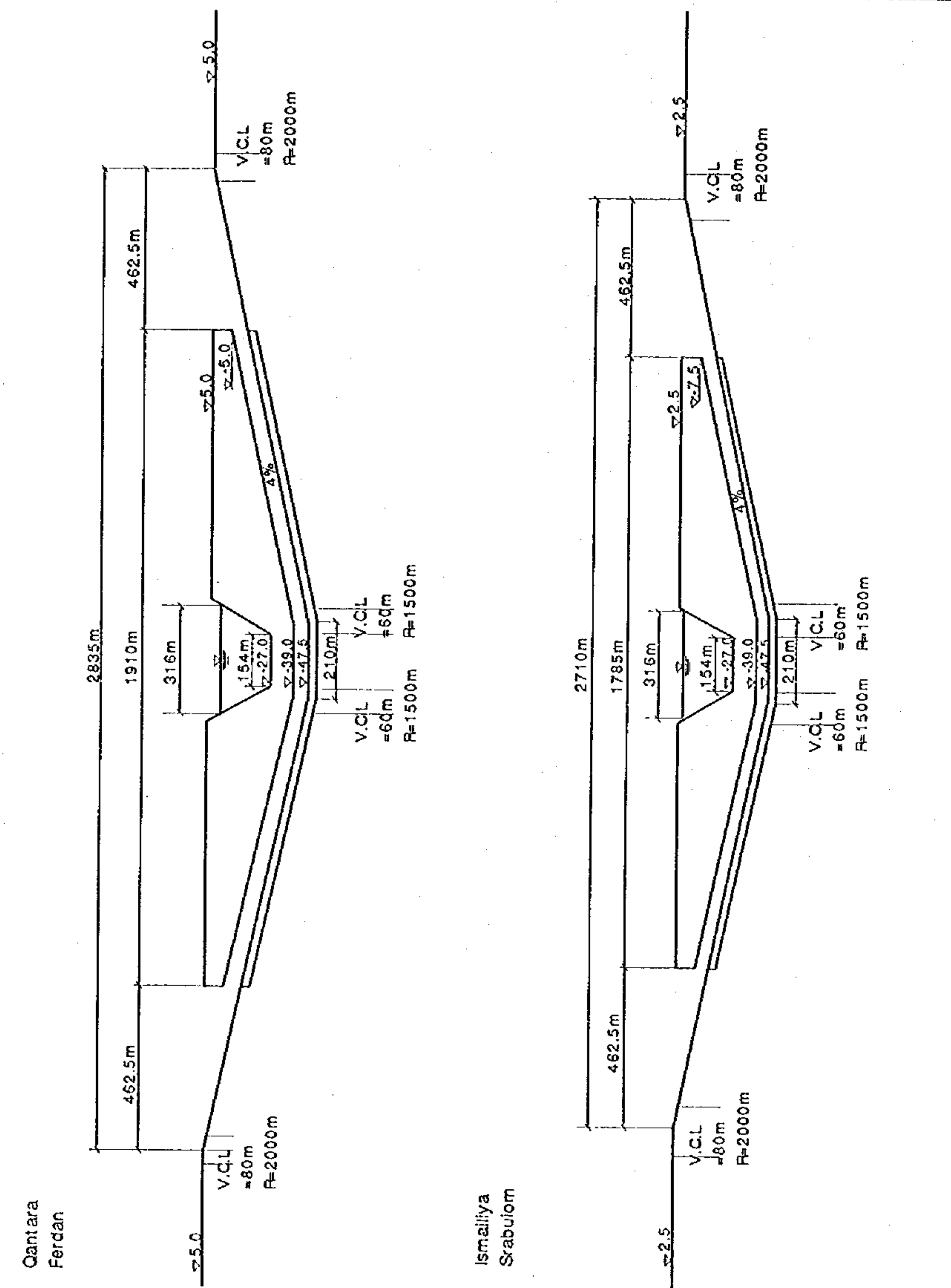


Fig. A6.2.33 Longitudinal Sections of Tunnel Options of 4 % Vertical Grade

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

2. Tunnel Facilities

(1) Facilities Required

1) Ventilation Facilities

Ventilation is one of the most important factors in the design of road tunnels. The point at which artificial ventilation becomes necessary depends upon a number of factors, including length, cross=section, and traffic density.

With the increase in the number of vehicles using roads, road networks including tunnels are rapidly being expanded and improved.

Also, it is essential to establish smooth, safe and comfortable traffic conditions. Exhaust fumes from the tunnels in particular are a major concern in respect to the protection of the natural environment, since they contain harmful and noxious substances like diesel soot and acid gases.

Thus, the environmental condition in road tunnels is now recognized as being of prime importance.

If the tunnel is short say (500 m), natural ventilation may suffice. An artificial ventilation system becomes necessary at a point dependent upon the length of the tunnel and the frequency of traffic.

The various types and features of tunnel ventilation systems are described in the following Table A6.2.6.

The most efficient ventilation systems rely upon a transverse ventilation system of blower and exhaust fans, operating through suitably spaced inlet and outlet shafts connected to the tunnel portals. This is the arrangement adopted in most road tunnels of any appreciable length.

But, a transverse ventilation system is the most expensive facility and initial and maintenance costs are high.

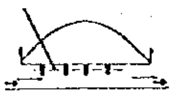
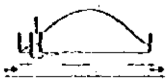
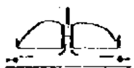
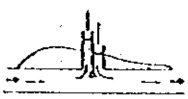
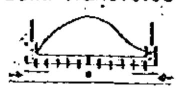
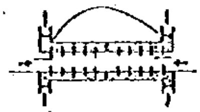
2) Tunnel Lighting Facilities

Tunnel lighting is a feature second only to efficient ventilation in the functional requirement of road tunnels, and involves a number of special requirements.

The reflective background is of the utmost importance in achieving a satisfactory effect, thus the surface finish of tunnel lining should be selected with special consideration of this.

The efficiency of any tunnel lighting system depends to a considerable degree upon the luminance of the walls.

Table A6.2.7 Ventilation System

SYSTEM	TYPE	FEATURES
LONGITUDINAL VENTILATION SYSTEM	Jet-Emitting Fan (Booster Fan) Jet-emitting fans 	1. Low initial cost. 2. Applicable to existing tunnels. 3. Bi-directional ventilation is available by reversing the fans. Booster fans are used only for uni-directional ventilation. 4. When many fans are installed, fine control according to traffic density can be attained by changing the number of running fans. 5. Since the air flows along the tunnel, the pressure loss is low and duct is not necessary, so the cross-sectional area of tunnel is smaller. 6. The velocity of air flow is constant and the pollutant concentration is the highest at the air stream exit.
	Saccardo 	1. Easy maintenance, because the fans are installed near the portals. 2. In comparison with jet-emitting fan system, countermeasures against noise near the portals are easier. 3. Since the air flows along the tunnel, the pressure loss is low and duct is not necessary, so the cross-sectional area of tunnel is smaller. 4. The velocity of air flow is constant and the pollutant concentration is the highest at the air stream exit.
	Exhaust at the Vertical Shaft 	1. No environmental problem at tunnel portals, since exhaust gas is not discharged there. 2. Since the air flows along the tunnel, the pressure loss is low and duct is not necessary, so the cross-sectional area of tunnel is smaller. 3. The air flow direction reverses at the vertical shaft and the pollutant concentration is highest there. 4. Unbalanced ventilation may occur due to natural wind and the change in directions of traffic density, so jet-emitting fans are also used in common.
	Supply and Exhaust at the Vertical shaft 	1. Generally applied to uni-directional traffic. The traffic piston effect can be utilized effectively. 2. By increasing the number of vertical shafts, the length of tunnel can be increased infinitely. 3. Since the air flows along the tunnel, the pressure loss is low and duct is not necessary, so the cross-sectional area of tunnel is smaller. 4. The velocity of air flow is constant and the pollutant concentration is the highest at the vertical shaft on the air stream exit.
SEMI-TRANSVERSE VENTILATION SYSTEM	Forced Semi-Transverse 	1. Air duct is furnished within the tunnel and fresh air is supplied through equally spaced slits. 2. The effect of natural wind is minimal. 3. The air flow direction reverses at the tunnel center, its velocity is highest at the portals, and the pollutant concentration is uniform.
	Induced Semi-Transverse 	1. Air duct is furnished within the tunnel and exhaust gas is discharged through equally spaced slits. 2. No environmental problems at the tunnel portals, since contaminated gas is exhausted through the portals. 3. The air flow direction reverses at the tunnel center, its velocity is highest at the portals, and the pollutant concentration is the highest at the center.
TRANSVERSE VENTILATION SYSTEM		1. Since supply and exhaust ducts and supply and exhaust fans are necessary, initial and maintenance costs are high. 2. The air velocity along the tunnel is nil and the pollutant concentration is uniform. 3. In the event of fire, smoke can be exhausted effectively.

Maintenance and lamp replacement can as a rule only be carried out in a busy tunnel at night when the traffic is at its minimum.

a) Composition and Scale of Tunnel Lighting

The tunnel lighting facilities consist of the following items. See Fig. A6.2.34.

b) Basic Lighting

This is the main tunnel lighting throughout the inner section of the tunnel, and provides the necessary level of lighting to maintain safe operating conditions within the tunnel. It is normally supplemented by emergency lighting in the event of power failures.

c) Entrance Lighting

During daytime,, as drivers travelling on an open road enter a tunnel with their eyes used to the bright light, so the inside of the tunnel looks relatively dark and they cannot identify objects in the tunnel. After entering the tunnel, drivers need some time for their eyes to adapt to the lower luminance of the tunnel.

Entrance lighting is the system installed in the entrance zone as supplementary lighting to overcome theses visual problems at the transition from bright to lower luminance levels.

Artificial lighting is the normal method employed for providing entrance lighting, but there are some cases where natural light controlled by louvers or sunshines is used.

The design standard of external luminance is as shown in Table A 6.2.7.

d) Luminous Source

The luminous source for the majority of tunnel lighting is low pressure sodium lamps (N.L) which meet the lighting requirements in the presence of traffic dust and fumes, and are economical.

4) Emergency Facilities

a) General

Traffic signalling and emergency equipment are also important items in road tunnels. Tunnels are provided with emergency equipment to suit the tunnel classification (length of tunnel and traffic volume) with a view to giving maximum warning to drivers of problems and to minimize the occurrence od accidents and security of traffic.

b) Control System for Emergency Facilities

Emergency systems are designed so that all the available facilities and functions are integrated to provide an efficient and rapid response to traffic accidents in the tunnel. An accident in the tunnel is generally reported by emergency telephones and push button equipment or CCTV monitoring. Fire is automatically reported by fire detectors.

Notification of an emergency is received first by the switchboard of the central control and is then transmitted to the administration office in charge. The schematic layout of a typical tunnel control system is shown below in Fig. A5.2.35.

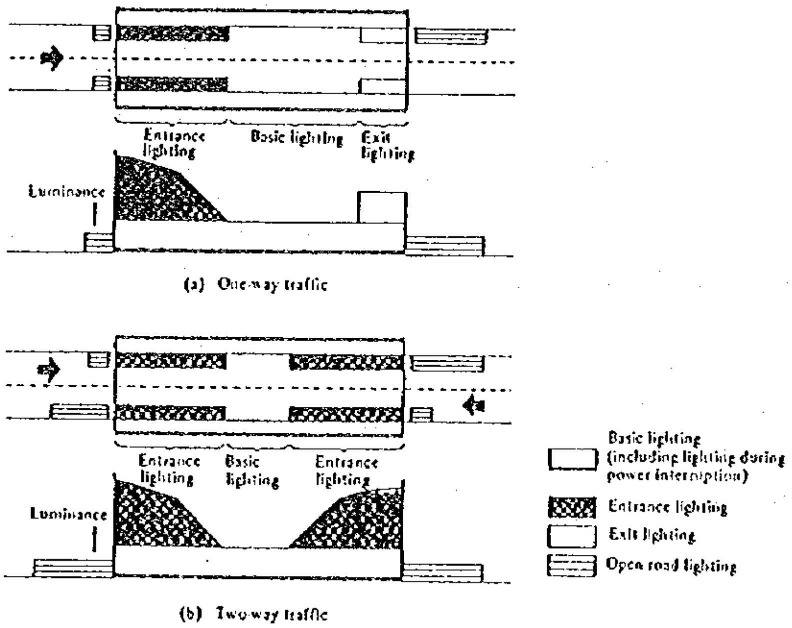


Fig. A6.5.34 Schematic Layout of Tunnel Lighting

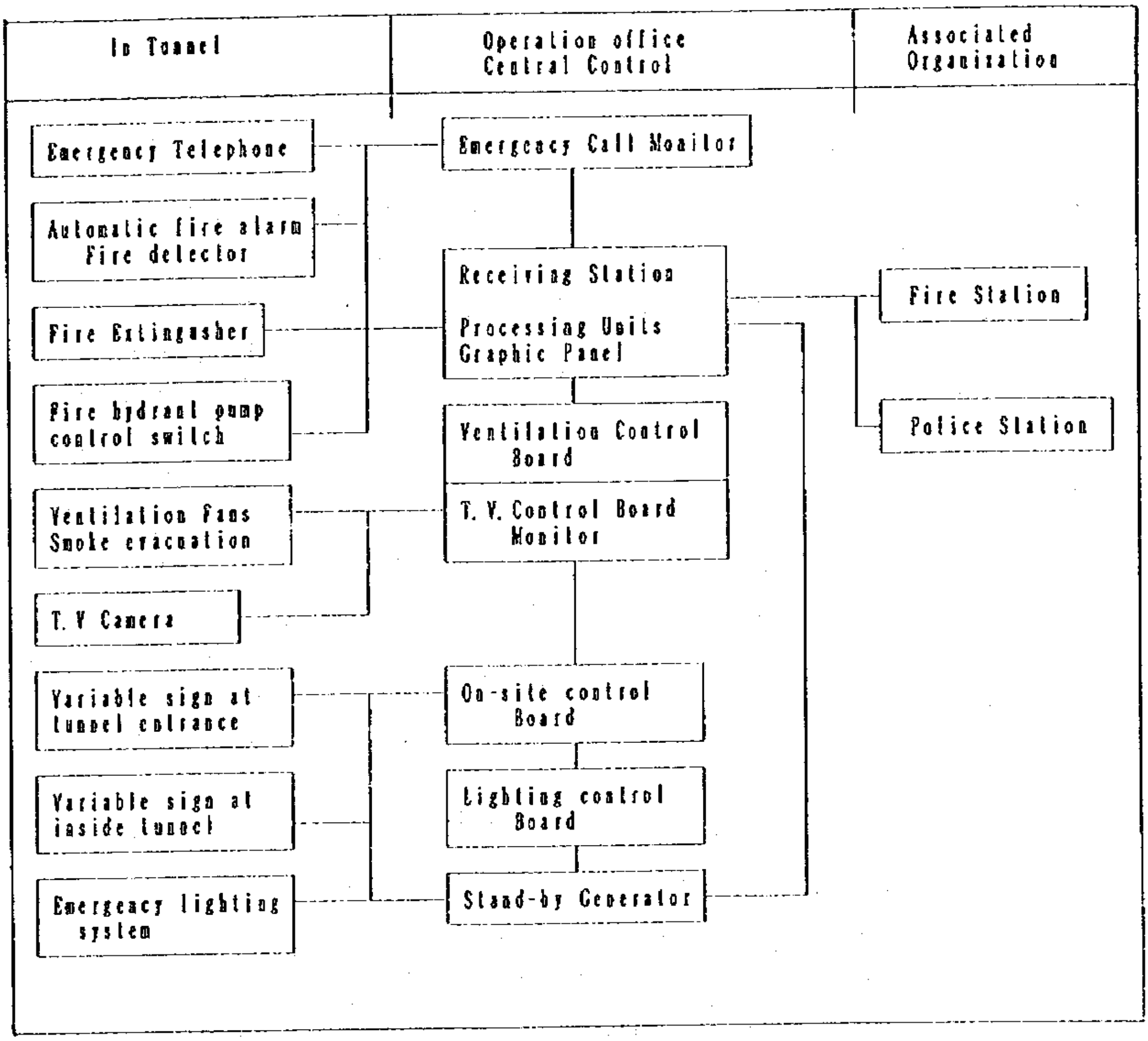


Fig. A6.5.35 Typical Tunnel Control System

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Table A 6.2.8 External Luminance for Tunnel Entrance

Category	Estimated External Luminance cd/m2	Conditiond outside tunnel / Potal Area
A	6,000	1) High luminance areas, such as the sky or sea, which occupy more than 50% of the entire field of a driver's vision. 2) The tunnel entrance to be located in open terrain, with the entrance facing south. 3) High Luminance to be expected near the tunnel entrance.
B	4,000	1) High luminance areas, such as the sky or sea, which occupy more than 25% of the entire field of a driver's vision. 2) The tunnel entrance to be located in fairly open terrain, with the entrance facing southwest by at leasst 45 degrees. 3) Tunnel to be located in normal hilly terrain or in urban areas.
C	3,000	1) High luminance areas, such as the sky or sea, which are not present in the field of view to any considerable degree. 2) The tunnel entrance to be located in a hilly area with steep hills or forests. 3) The tunnel entrance in Urban areas, and where no direct sunrays fall on the entrance through out the year.

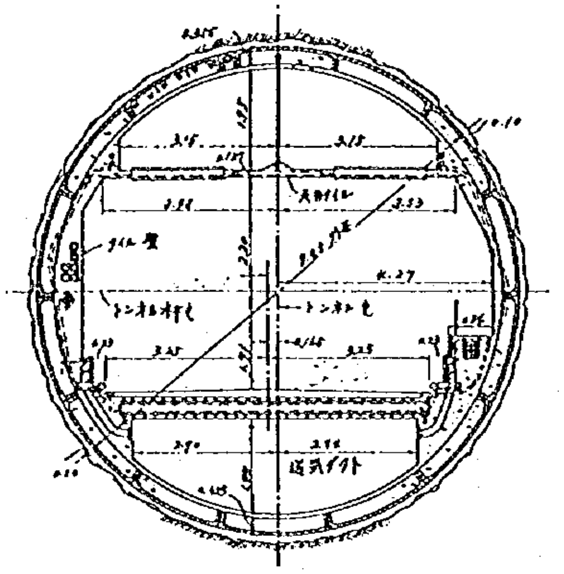
Source : JICA Study Team

NOTE: 1) "Road Lighting" of CIE Tunnel Entrance Lighting
The International Lighting Association.
2) Design Standard of Ministry of Construction, Japan.
3) Design Standard of the Japan Highway Public Corporation.

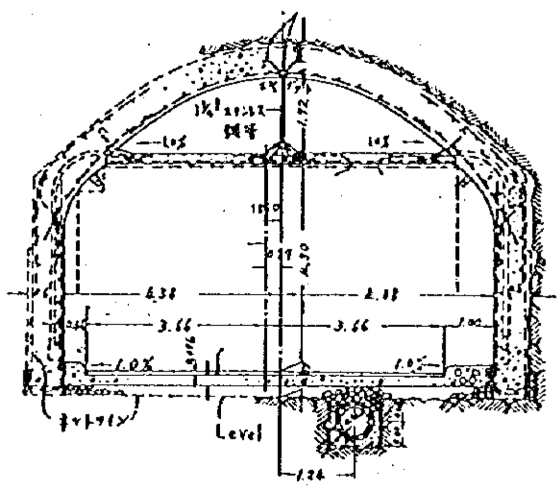
3. Tunnel Cross Section

Table A6.2.9 Tunnel Cross Section (Traffic Clearance)

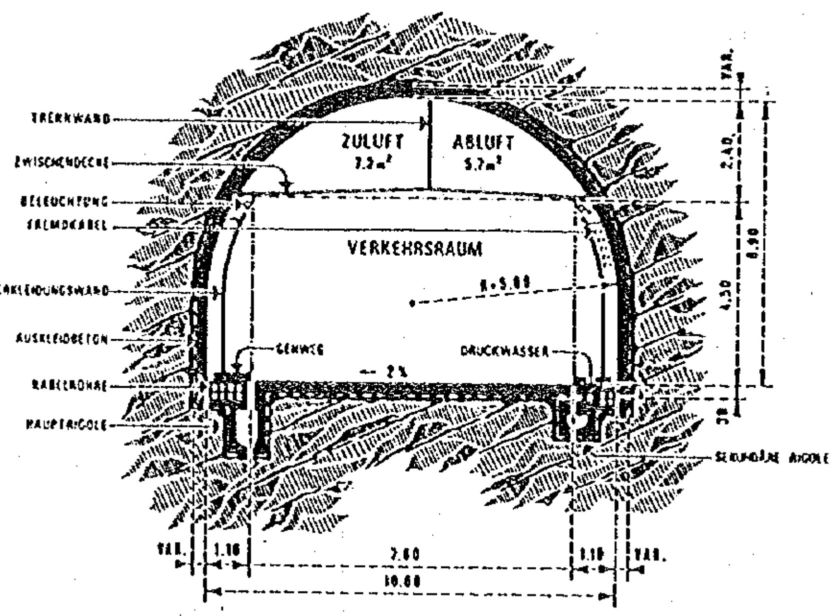
No	Tunnel Name	Country	Length (m)	Const. Method	Road Width (m)	Clearance Height (m)	Shoulder (m)
1	Brooklyn-Battery	U. S. A N. Y	2, 780	Shield	6. 50 (2 WAY)	4. 20	0. 23
2	Boqueron	VENEZU-ELA	1, 800	Rock	7. 32 (2 WAY)	4. 30	1. 00 Inspect.
3	Gotthard	SWITZER-LAND	16, 321	Rock	7. 80 (2 WAY)	4. 50	1. 10 Inspect.
4	Holland	U. S. A	2, 600 * 2	Shield	7. 50 (2 Lane)	4. 50	(1. 00) Inspct.
5	Kanmon	JAPAN	3, 461	Shield	7. 50 (2 WAY)	4. 50	0. 25
6	Norde Lyon (Under-Const.)	FRANCE	3, 250 * 2	T. B. M	7. 60 (2 Lane)	4. 50	0. 30
7	Mersey	U. K	3, 226	Shield	10. 97 (3 Lane)	4. 50	0. 30
8	Mont Blanc	FRANCE -ITALY	11, 600	Rock	7. 00 (2 Way)	4. 50	(0. 796) Inspect.
9	Seelisberg	SWITZER -LAND	9, 292 * 2	Rock	7. 50 (2 Lane)	4. 50	(1. 37) Inspect.
10	Squirrel Hill	U. S. A	1, 288	Rock	7. 32 (2 Way)	4. 32	(0. 84) Inspect.
11	Tokyo No. 1 Fairway	JAPAN	1, 325	Immersed Tube	10. 50 (3 Lane)	4. 60	0. 50
12	Velsen	HOLLAND	768	Immersed Tube	7. 00 (2 Way)	4. 50	(1. 00) Inspect.
13	Webster Street	U. S. A	1, 065	Shield	7. 32 (2 Way)	4. 50	0. 30
14	Wawona	U. S. A	1, 289	Rock	7. 32 (2 Way)	4. 50	(0. 90) Inspect.
15	Wagenburg	GERMANY	824	Rock	7. 50 (2 Way)	4. 50	0. 40
16	Ahmed Hamdi	EGYPT	1, 640	Shield	7. 50 (2 Way)	5. 00	0. 25



1. BROOKLYN-BATTERY TUNNEL
(U. S. A)



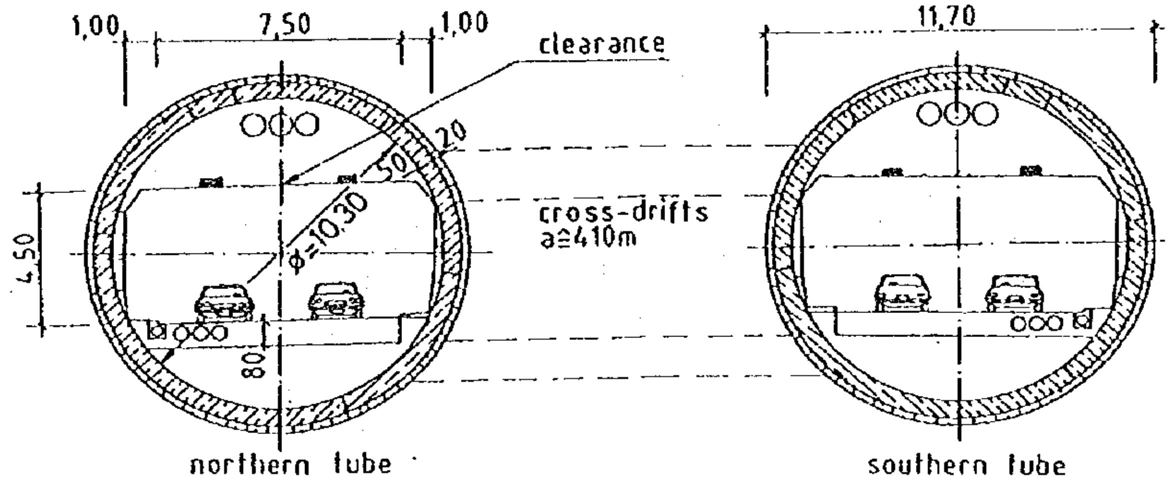
2. BOQUERON TUNNEL
(VENEZUELA)



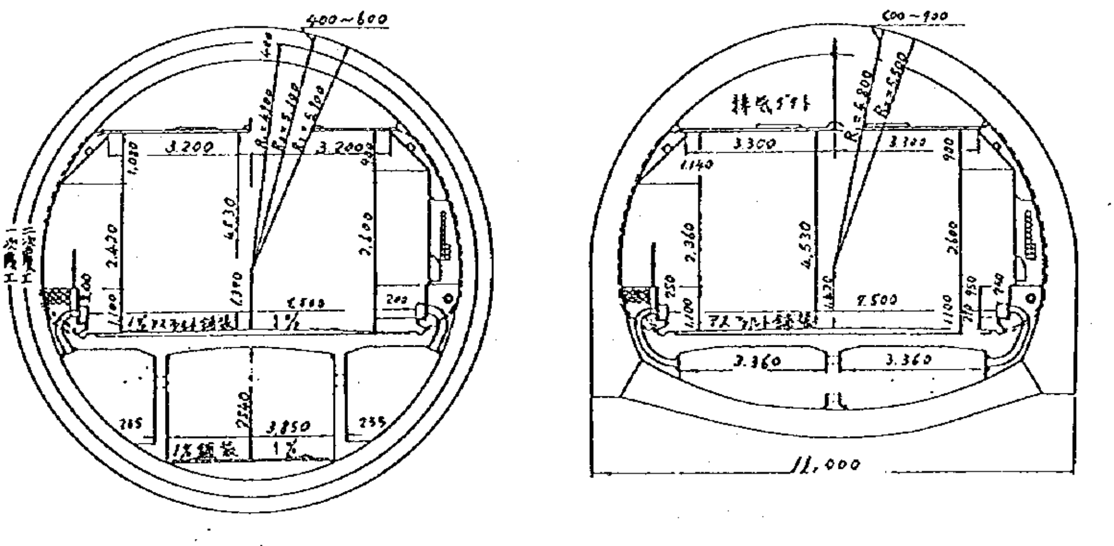
3. GOTTHARD TUNNEL
(SWITZERLAND)

Fig. A6.2.36 Tunnel Cross Section 1

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL



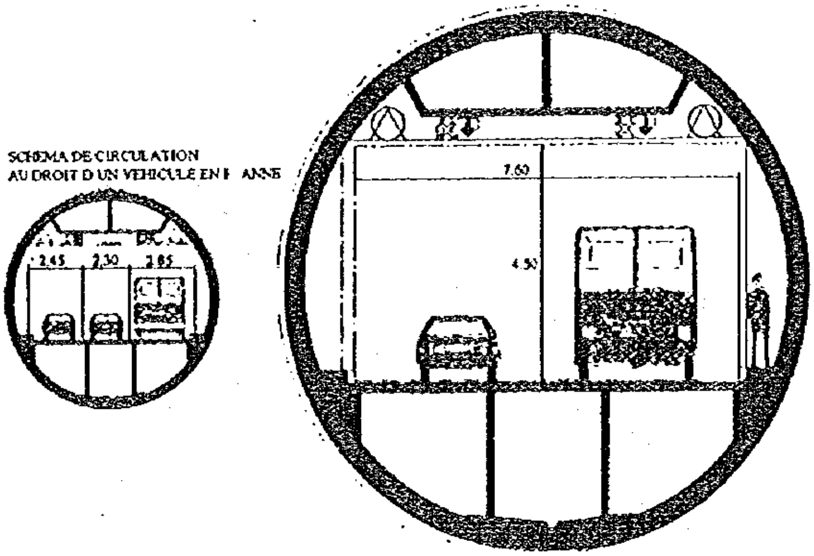
4. HOLLAND TUNNEL
(U. S. A)



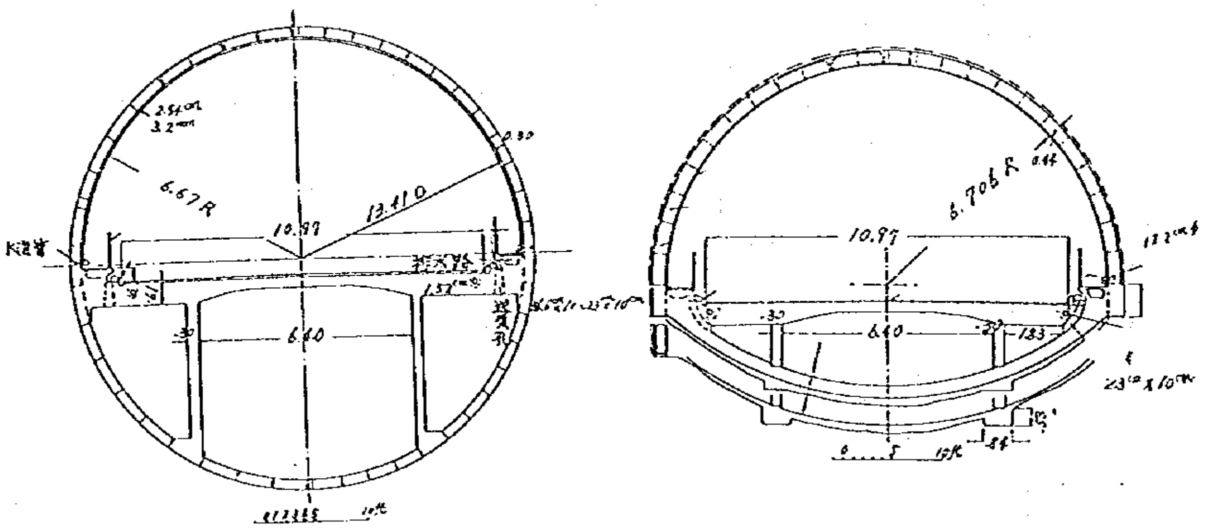
5. KANMON TUNNEL
(JAPAN)

Fig. A6.2.37 Tunnel Cross Section 2

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL



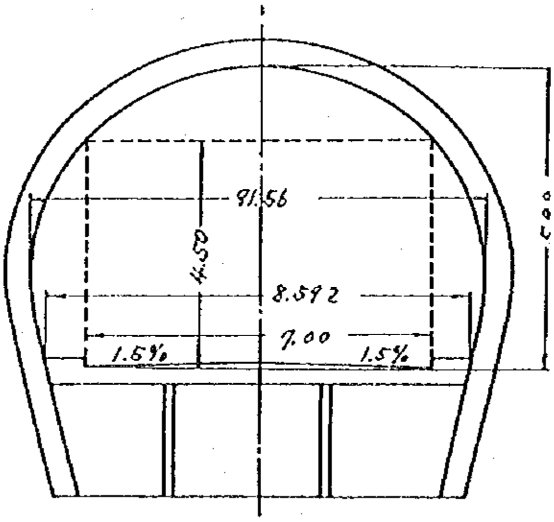
6. NORDE LYON TUNNEL
(FRANCE)



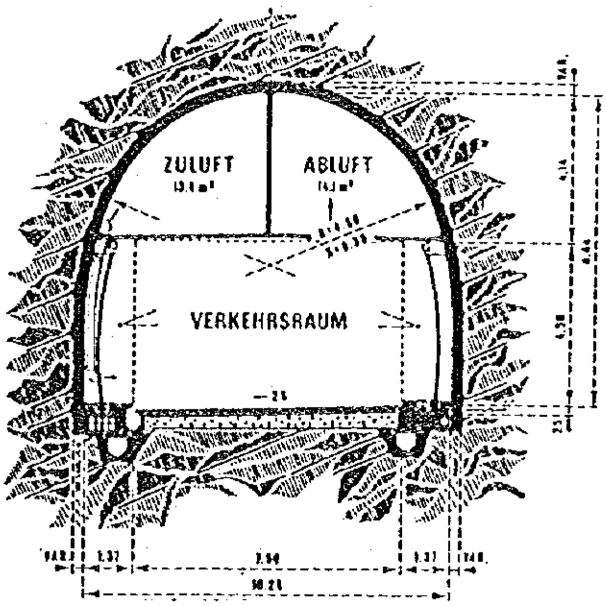
7. MERSEY TUNNEL
(U. K)

Fig A6.2.38 Tunnel Cross Section 3

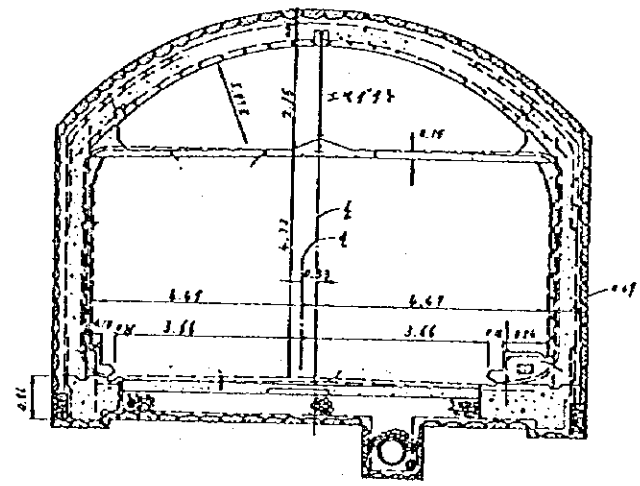
THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL



8. MOUT BLANC TUNNEL
(FRANCE-ITALY)



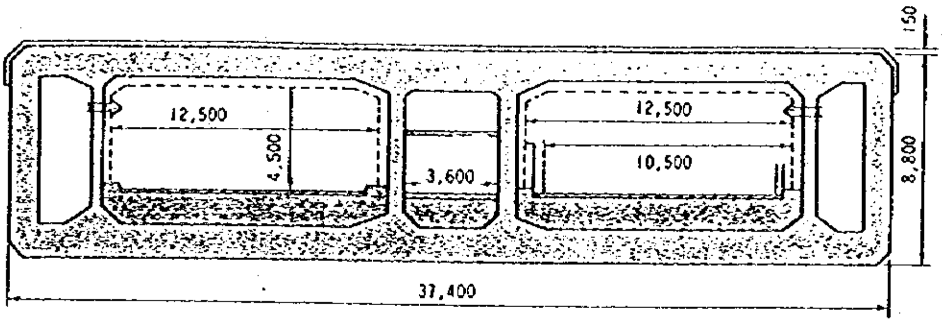
9. SEELISBERG TUNNEL
(SWITZERLAND)



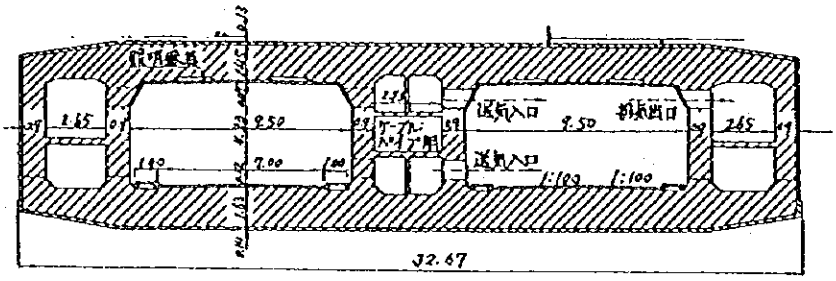
10. SQUIRREL HILL TUNNEL
(U. S. A)

Fig. A6.2.39 Tunnel Cross Section 4

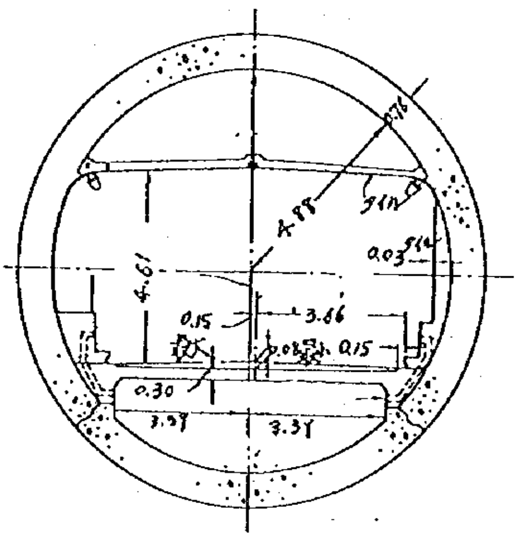
THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL



11. TOKYO NO. 1 FAIRWAY TUNNEL
(JAPAN)



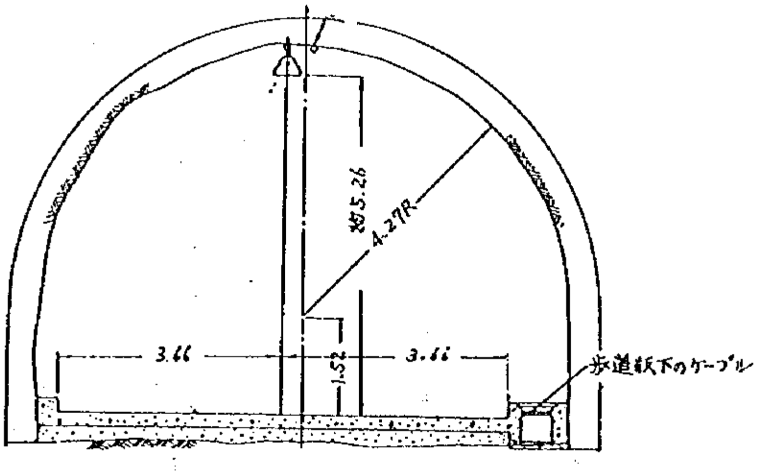
12. VELSEN TUNNEL
(HOLLAND)



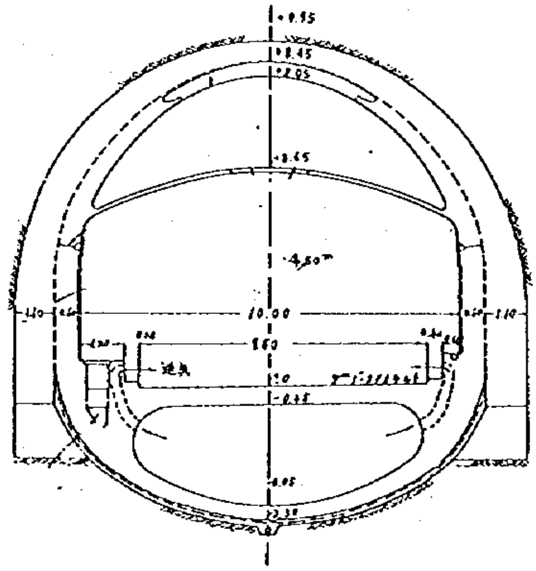
13. WEBSTER STREET TUNNEL
(U. S. A)

Fig. A6.2.40 Tunnel Cross Section 5

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL



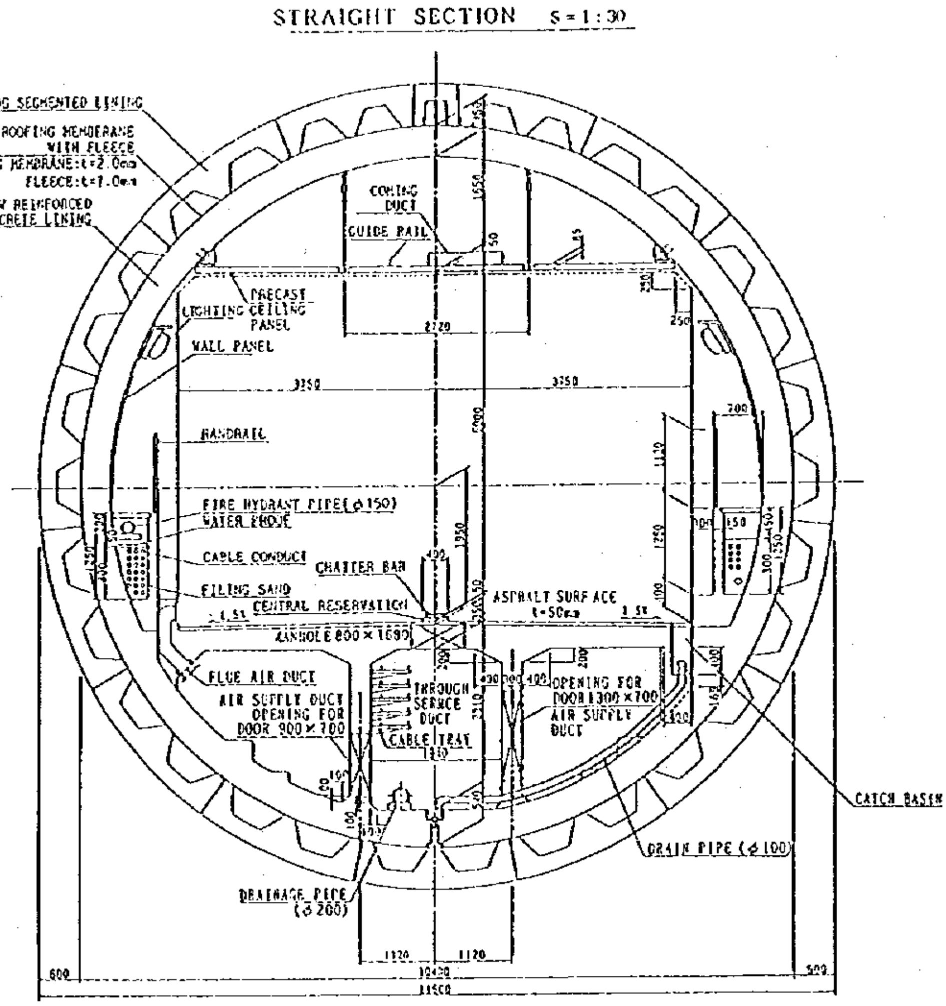
14. WAWONA TUNNEL
(U. S. A)



15. WAGENBURG TUNNEL
(GERMANY)

Fig. A6.2.41 Tunnel Cross Section 6

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

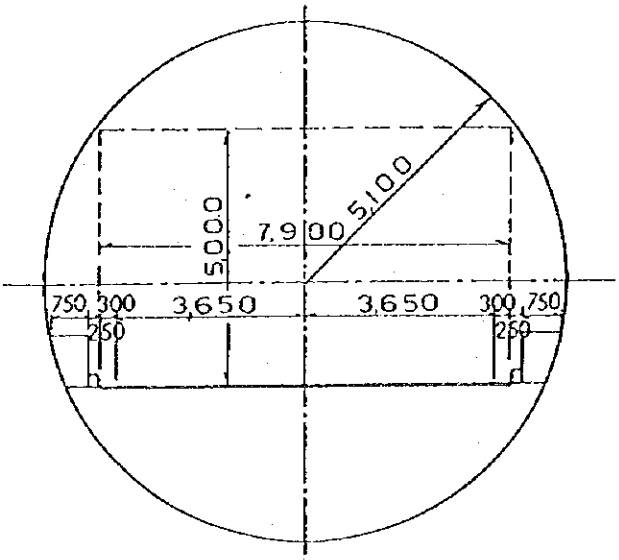


Typical Section of Tunnel After
Rehabilitation works of Canal

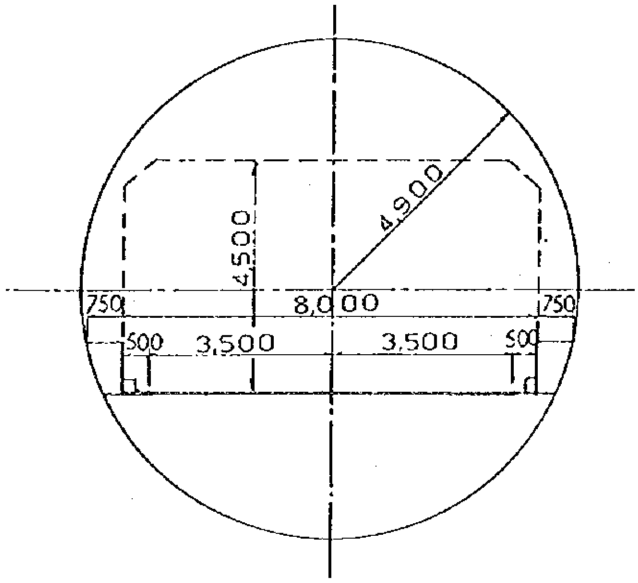
16. AHMED HAMDI TUNNEL
(EGYPT)

Fig. A6.2.42 Tunnel Cross Section 7

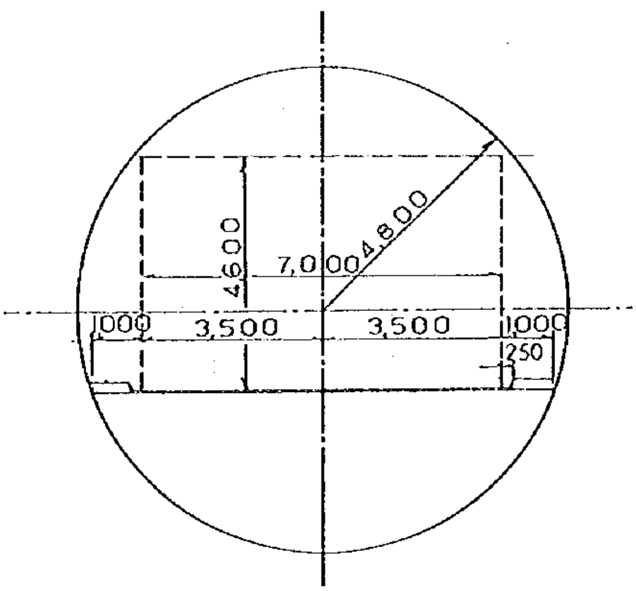
THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL



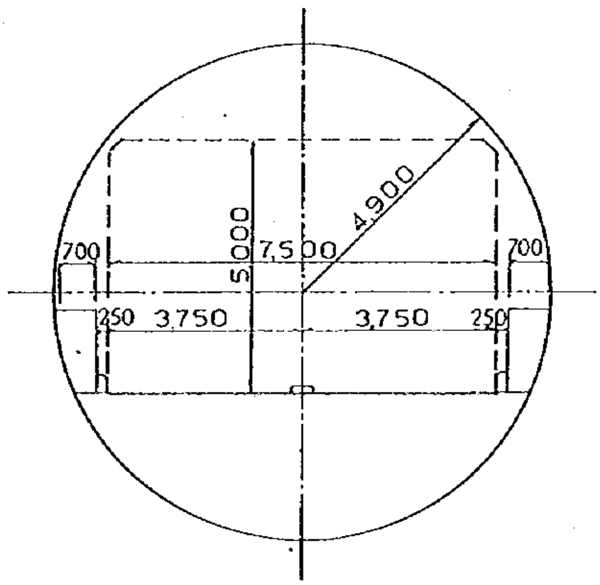
AASHTO STANDARDS



JAPANESE STANDARDS



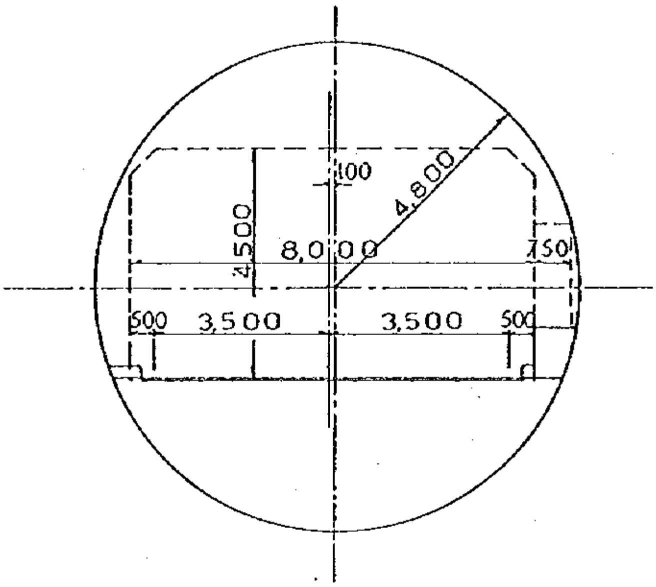
EUROPEAN STANDARDS



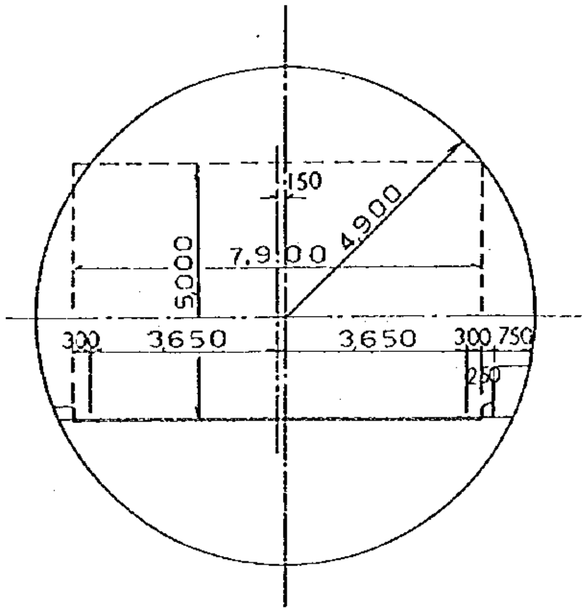
EGYPTIAN STANDARDS
(A. H. Tunnel)

Fig. A6.2.43 Tunnel Dimensions with Walkway Both Sides

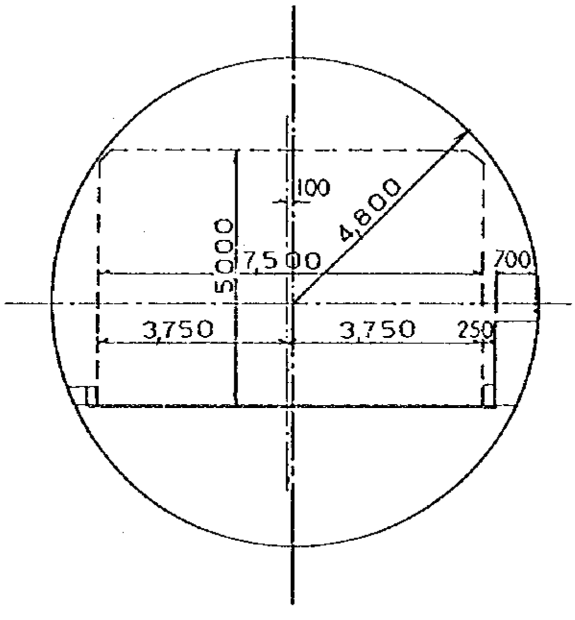
THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL



JAPANESE STANDARDS



AASHTO STANDARDS



EGYPTIAN STANDARDS
(A. H. Tunnel)

Fig. A6.2.44 Tunnel Dimensions with Walkway One Side

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

A6.3 Physical Conditions

A6.3.1 Seismic Historical Records

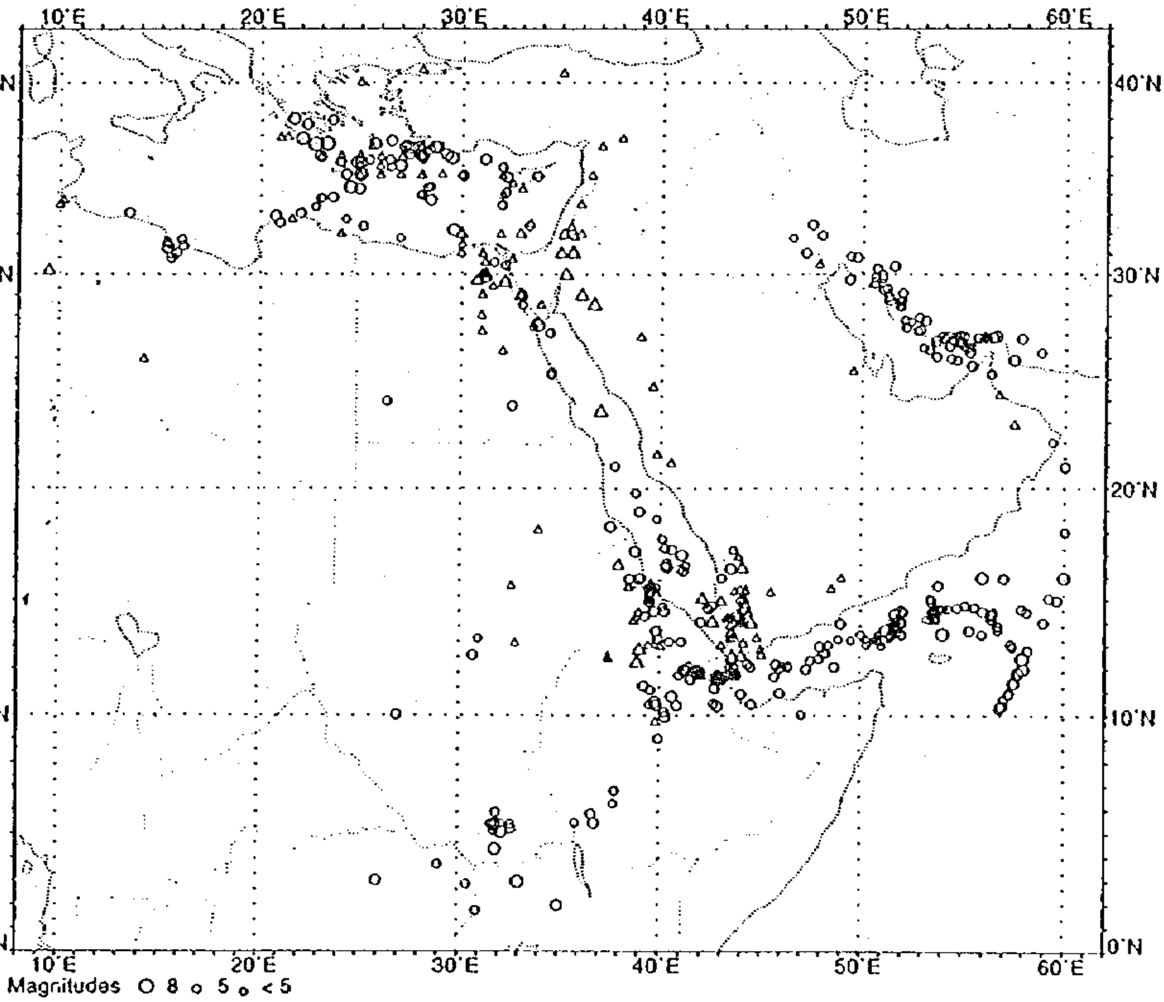


Fig.A6.3.1 Seismic of Egypt, Arabia and Red Sea

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

A6.3.2 Topographic and Geological Conditions

(1) Topography

1) Qantara Km 48+500

West Bank - there is a low embankment alongside the Canal of approximately 3 m height, upon which the Port Said/ Ismailiya railway and the canalside road run. Inland of this the ground falls away to a low lying wet area, and then rises gently to an elevation of 2-2.6 m where cultivated land exists. There is a military area about 1 km from the canal bank, south of the centreline. The main Port Said/Ismailiya divided highway runs in a NE/SW direction about 1.2 km from the canal bank and immediately beyond the military area.

East Bank - there is a more extensive embankment present here, up to 9 m high with a peak at 16 m. This then drops away to form a plateau, parallel with the canal at 6-8 m in height, 400 m from the canal bank. This then falls away to a very low lying area where there is standing water. The ground is sandy with no cultivation.

2) Ferdan Km 65+300

West Bank - there is a steep sided embankment rising to 9 m height alongside the canal. This extends for about 100 m from where it falls away to the north-south divided road, at elevation 4.0 m. Inland of this, on the centreline, there is a military fortification rising to 22 m in height. To the north of this, however, the embankment and surrounding ground is much lower.

Inland there is a fish farm area and cultivated low lying land extending to 1 km from the Canal Bank. Beyond this the terrain is very low lying swamp and marshlands, with water lying over large areas.

East Bank - the canal bank rises to about 14 m height and is of an even and symmetrical profile, with occasional higher mounds, together with a large man made gully. From 200 m inland the ground level falls away to about 2 m and apart from one or two small ridges is relatively flat, level, and featureless desert, with an elevation of 2-3 m.

3) Ismailiya Km 69+500

West Bank - there is a steep sided double ridged embankment at this location, extending for approximately 200 m inland. The ground then falls away sharply to a depression, beyond which the main canalside divided road is located. Inland of this at a similar elevation runs the single track Ismailiya/Port Said railway. The ground is gently undulating inland of this, falling away to an elevation of about 8 m, which is generally maintained. To the north of the centreline it is predominantly cultivated land, whilst to the south it is sand, until the line of a main drain/irrigation ditch some 1.5 km from the Canal. The developing industrial zone is located just to the south of this location.

East Bank - there is a steep embankment rising to 23 m alongside the canal. This slopes gently away inland, until an elevation of about 11 m is attained 1 km from the canal. This plateau dips to the north where a lake has formed. The ground then rises gently up to the main Suez/Qantara highway which is located about 2.3 km from the canal at a mean elevation of 16 m. The terrain is principally desert in this area.

4) Srabuiom Km 90+000

West Bank - the embankment slopes gently away from the canal, to a height of about 9.5 m and then falls gradually away inland, to undulate between 6 and 10 m elevation. The canalside road runs just behind the embankment, with a principal connecting road branching off this to the Cairo/Port Said highway.

There is a mixture of cultivated land and undeveloped land with several high (22-23 m) fortifications in the area.

Mango tree plantations are well established about 1.5 km inland from the Canal.

East Bank - there is a wide, level shelf alongside the canal, which then rises steeply to form an embankment about 19 m high, in the form of a plateau running up to 500 m inland. This then drops away sharply to form undulating desert with an elevation of generally 12 to 16 m.

There are two gullies formed through the Canal embankment, to the north and the south of the Survey Centreline.

(2) Geological Conditions

1) Qantara Km 48+500. Two boreholes B-1 and B-2 were drilled at this location. Borehole B-1, on the West Bank, was drilled to a depth of 35 m (-33.37 m datum level) in the front face of the canal embankment. This revealed a virtually continuous strata of fine to medium dense sands, with traces of silt. There was a 2 m band of silty clay identified at depth of 30 m (-28.77 m datum level) and standing water at -0.72 m datum level.

Borehole B-2, on the East Bank was drilled to a depth of 50 m (-43.7 m datum level) in the middle of the canal embankment. This revealed a predominantly dense sandy strata with several bands of silty clay, particularly at the bottom of the borehole (-36 to -44 m below datum). Standing water was recorded at +3.50 m above datum.

2) Ismailiya Km 69+500 - A total of seven boreholes were drilled along the location centreline, four on the West Bank and three on the East Bank.

The borehole B-3 in the canal embankment was drilled to 50 m depth (-40.5 below datum) whilst the remainder C-1 to C-3 were drilled to 35 m depth (-26 to -27 m below datum).

The strata revealed is predominantly dense fine to medium sands, interspersed with layers of clay and silty material. A thin layer of sandstone (20 cm) was identified in BH B-3 at - 27.5 m datum level, and occasional gravel and cobbles were also recorded in this and BH C-1. Standing water was recorded at or about datum level in all boreholes.

The borehole B-4 in the canal embankment was drilled to 50 m depth (-37.0 m below datum) whilst the others, C-4 and C-5 were drilled to 35 m depth (-24 and -21 m b.d.) respectively.

The two boreholes nearer to the canal revealed a consistent strata of dense fine to medium sand, with some silt and gravel, and a thin sandstone layer within clay/silt near the base of BH B-4. The BH C-5 mainly indicated similar sand strata, but it is more interspersed with layers of clays and silts.

The standing water was recorded in all boreholes as a little above datum level.

3) Srabuiom Km 90+00 - Two boreholes B-5 and B-6 were drilled at this location, both in the front slope of the canal embankment. Borehole B-5 on the West Bank was drilled to 35 m depth (-26 m b.d.) This revealed dense fine to medium sands to -15 m b.d. with layers of silty clay, sands and a layer of claystone beneath. The standing water was recorded at -1 m b.d. Borehole B-6 on the East Bank was drilled to 50 m depth (-46 b.d.) and revealed considerable layering of the strata to -28 b.d. The layers consisted of dense sands, silty clays, sandstone, siltstone and some cemented sand. Below this level there is a 13 m layer of dense sand, beneath which highly fractured limestone interbedded with layers of sand was identified. This material had a poor percentage recovery and an RQD rating of zero. Standing water was recorded just above and below the canal datum.

A6.3.3 Borehole Logs

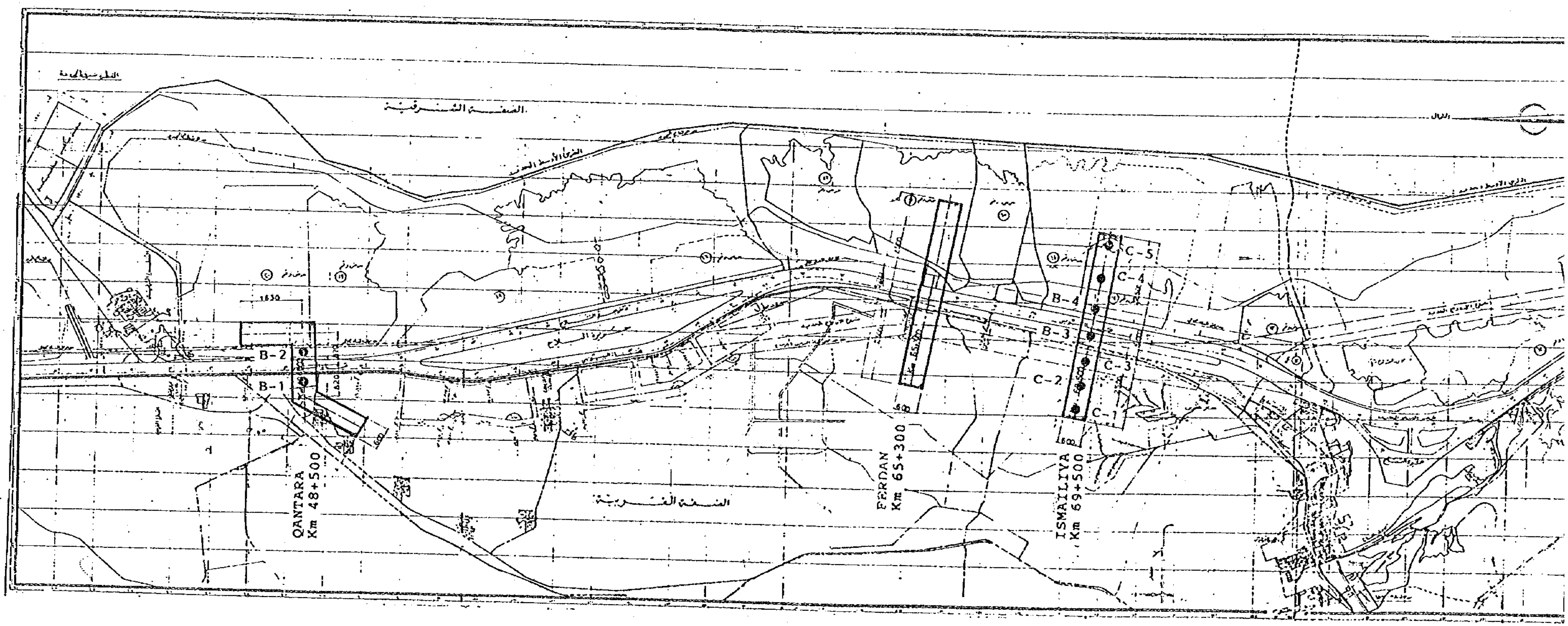


Fig. A6.3.2 Location Map of Proposed Sites for Field Su

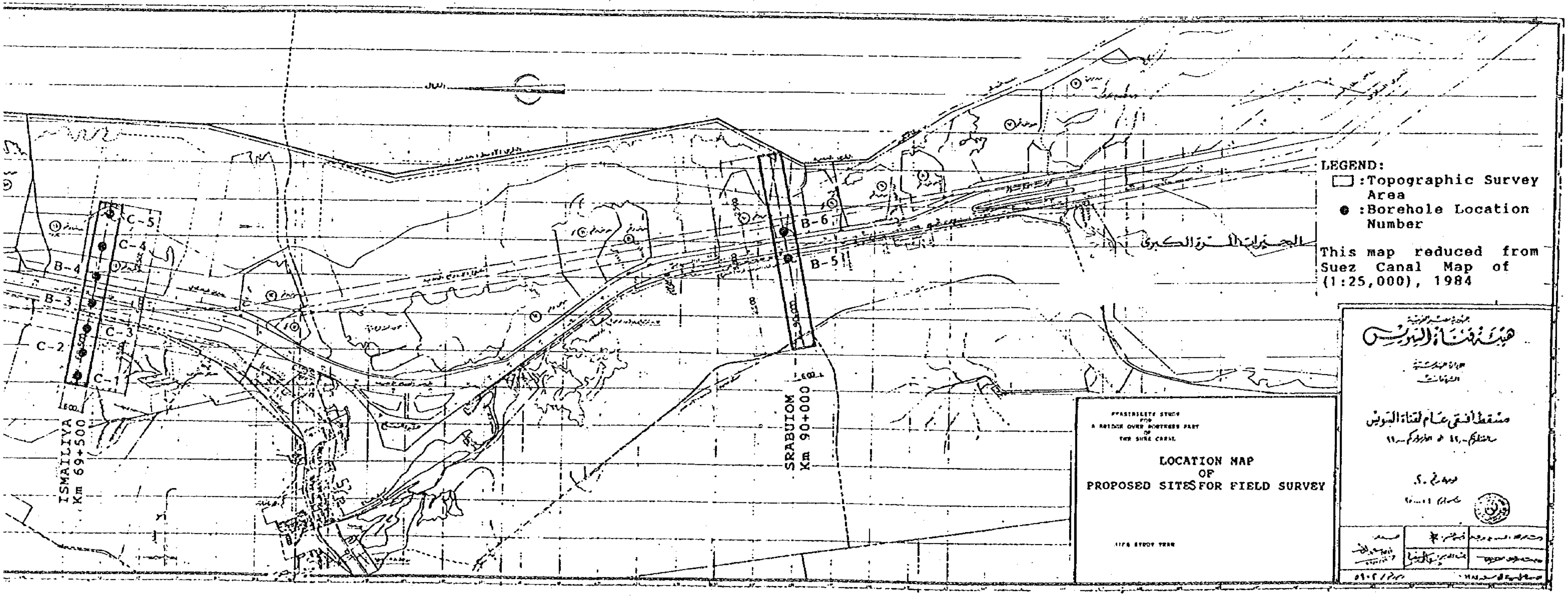


Fig. A6.3.2 Location Map of Proposed Sites for Field Survey

CROSSING STRUTURE OVER SUEZ CANAL

Kantara - West Bank Km 48+500

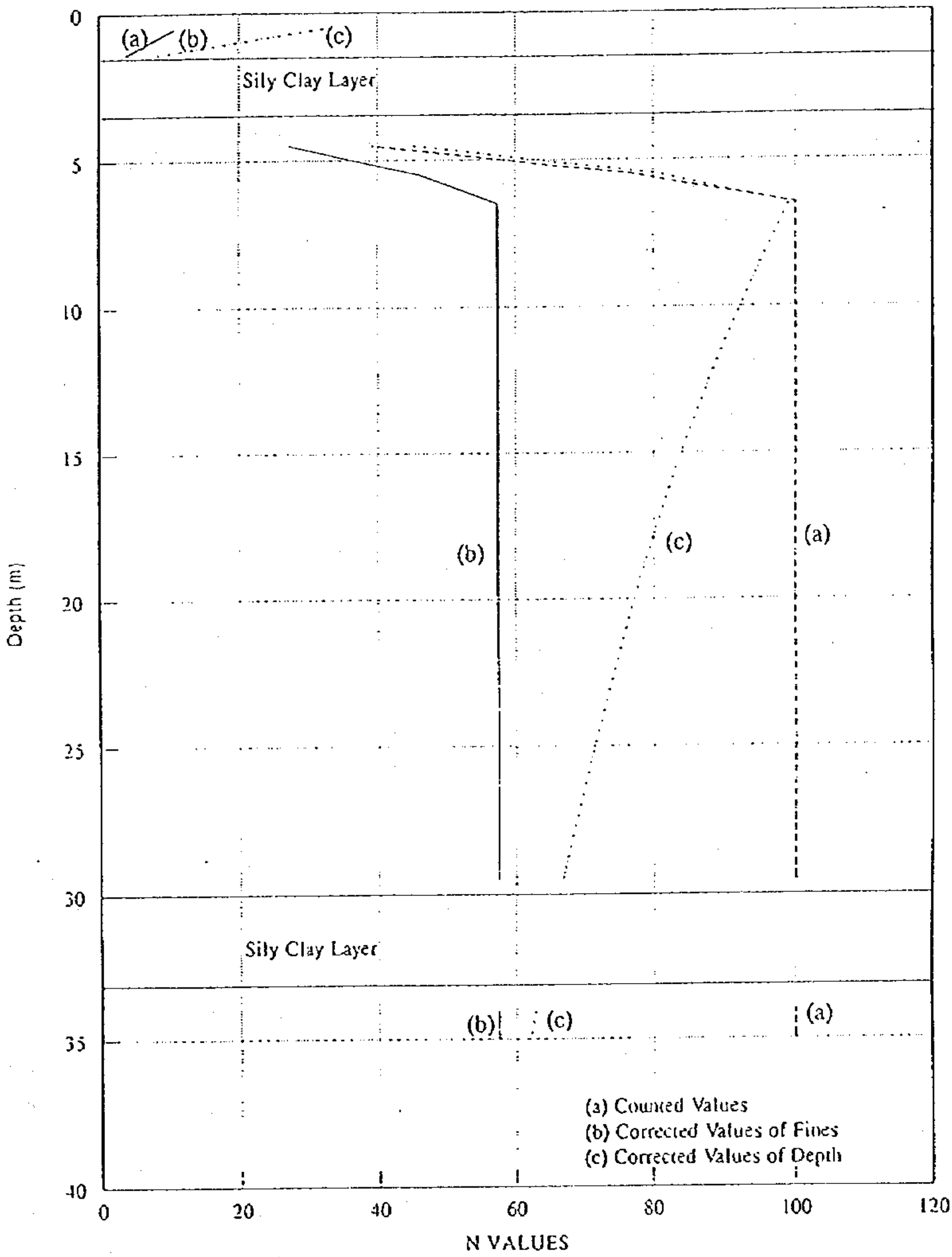


Fig. A6.3.3 Borehole Log No. B-1, (1)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

BOREHOLE NO. (B-1)

PROJECT:	Crossing Structure Over Suez Canal	DRILLING FLUID	Bentonite	DATE START:	22/12/1995
LOCATION:	Kantara - West Bank km 48 + 500	DRILLER	Karam	DATE END :	30/12/1995
CLIENT:	Jica Study Team	RIG TYPE	Acker	G. L :	1.63 m
		WEATHER	Warm	F.W.D Inside BH =	2.35 m
				N :	902530
				E :	740718

Depth (m)	Sample Depth (m)	Legend	SOIL DESCRIPTION	USCS	Layer End (m)	S.P.T	q_u (kg/cm2)	w_n %	W_L %	W_P %	γ_b (t/m3)	Recovery (%)	R.Q.D.(%)	Test Indication
			SAND, FINE TO MEDIUM, TRACES OF SILT, TRACES OF CEMENTED SAND, CALCAREOUS, YELLOW			11						95	-	
1					1.45	3						99	-	
2		G.W	CLAY, SILTY, SOME SAND POCKETS, TRACES OF BROKEN SHELLS, CALCAREOUS, LIGHT GREY		2.50	4						98	-	
3			(and sand)				1.4	43			1.73			
					3.25	27						92	-	
4			SAND, FINE TO MEDIUM, TRACES OF SILT, SLIGHTLY CALCAREOUS, YELLOWISH GREY		4.50	39						86	-	
5			(with some silt)			77						87	-	
6			(becomes medium to fine)		6.00	82/27cm						90	-	
7						85/25cm						80	-	
8				SP				16						●
						87/25cm						82	-	
9						90/24cm						78	-	
10						50/13cm (2nd Penetration)						89	-	
11						50/12cm (2nd Penetration)						00	-	
12						50/8cm (2nd Penetration)						87	-	
13						50/9cm (2nd Penetration)						00	-	
14						50/10cm (2nd Penetration)						83	-	
15						50/10cm (2nd Penetration)						90	-	
16					16.50	50/11cm (2nd Penetration)						86	-	
17						50/14cm (1st Penetration)						85	-	
18			(becomes poor graded, traces of fine gravel)			50/13cm (1st Penetration)						90	-	
19				SP	19.00			13						●
						50/11cm (1st Penetration)						89	-	
20			(becomes with some silt)		20.00									

REMARKS

Fig. A6.3.4 Borehole Log No. B-1, (2)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

BOREHOLE NO. (B-1)Contin.

PROJECT: Crossing Structure Over Suez Canal	DRILLING FLUID Bentonite	DATE START: 22/12/1995	
LOCATION: Kantara - West Bank km 48+500	DRILLER Karam	DATE END : 30/12/1995	
CLIENT: Jica Study Team	RIG TYPE Acker	G. L : 1.63 m	
	WEATHER Warm	F.W.D Inside BH = 2.35 m	
		N : 902530	
		E : 740718	

Depth (m)	Sample Depth (m)	Legend	SOIL DESCRIPTION	USCS	Layer End (m)	S.P.T	q_u (kg/cm2)	W_n (%)	W_L (%)	W_p (%)	γ_b (t/m3)	Recovery (%)	R.Q.D.(%)	Test Indication
			SAND, FINE TO MEDIUM, SOME SILT, GREYISH YELLOW			50/12cm (2nd Penetration)						65	-	
21					21.50	50/10cm (2nd Penetration)						87	-	
22			(medium to fine)			50/11cm (1st Penetration)						90	-	
23			← (becomes with traces of silt)		23.50	50/13cm (1st Penetration)						83	-	
24					24.50	50/14cm (2nd Penetration)						00	-	
25			← (becomes medium to fine, traces of silt)			50/12cm (2nd Penetration)						8[illegible]	-	
26				SP-SM	26.50	50/13cm (1st Penetration)						87	-	●
27						50/10cm (1st Penetration)						83	-	
28			← (becomes fine, light grey)			50/9cm (1st Penetration)						00	-	
29						50/11cm (1st Penetration)						76	-	
30			← (becomes with some clay lumps, light grey)		30.00									
31			CLAY, SILTY, SOME FINE SAND POCKETS, TRACES OF IRON OXIDES, YELLOWISH GREY				>5	24			1.96			
						50/13cm (2nd Penetration)						98	-	
32				CV			>5	18	83	30	2.04			
33					33.00	90/27cm						95	-	
34			SAND, FINE TO MEDIUM, SOME SILT, TRACES OF CLAY, YELLOWISH GREY	SM	34.00	90/28cm						92	-	●
35			← (becomes and clay, traces of iron oxides)		35.00									
			END OF BORING 35.00 m											

REMARKS

The term "lumps" denotes accumulations of size 1-4 cm

Fig. A6.3.5 Borehole Log No. B-1, (3)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

BOREHOLE NO. (B-2)

PROJECT:	Crossing Structure Over Suez Canal	DRILLING FLUID	Bentonite	DATE START:	1/1/1996
LOCATION:	Kantara - East Bank km 48+500	DRILLER	Karam	DATE END :	3/1/1996
CLIENT:	Jica Study Team	RIG TYPE	Acker	G. L :	6.30 m
		WEATHER	Warm	F.W.D Inside BH =	2.80 m
				N :	902555
				E :	741122

Depth (m)	Sample Depth (m)	Legend	SOIL DESCRIPTION	USCS	Layer End (m)	S.P.T	q_u	W_n	W_L	W_p	γ_t	Recovery (%)	R.Q.D.(%)	Test Indication
							kg/cm2	%	%	%	t/m3			
1			SAND, MEDIUM TO FINE, TRACES OF SILT, TRACES OF FINE GRAVEL, CALCAREOUS, LIGHT YELLOW			38						94	-	
2						22						91	-	
3		G.W				45						91	-	
4				SP-SM		46		15				79	-	●
5						41						80	-	
6						13						00	-	
7					7.00	13						00	-	
8			CLAY, SILTY TRACES OF FINE SAND, TRACES OF BROKEN SHELLS, CALCAREOUS, LIGHT GREY			10	1.7					100	-	
9					8.70	47						94	-	
10			SAND, FINE TO MEDIUM, TRACES OF SILT, YELLOWISH GREY		10.00	51						89	-	
11			(medium to fine, calcareous, yellow)			94/18cm						90	-	
12						97/24cm		16				88	-	
13					13.00	50/13cm (2nd Penetration)						00	-	
14			(becomes with some silt)		13.50	79						82	-	
15						50/11cm (2nd Penetration)						86	-	
16						50/10cm (2nd Penetration)						80	-	
17						50/14cm (2nd Penetration)						89	-	
18						50/10cm (2nd Penetration)						90	-	
19						50/13cm (1st Penetration)						80	-	
20					20.00	50/12cm (1st Penetration)						81	-	

REMARKS

Fig. A6.3.6 Borehole Log No. B-2, (1)

BOREHOLE NO. (B-2)Contin.

PROJECT:	Crossing Structure Over Suez Canal	DRILLING FLUID	Bentonite	DATE START:	1/1/1996
LOCATION:	Kantara - East Bank km 48+500	DRILLER	Karam	DATE END :	3/1/1996
CLIENT:	Jica Study Team	RIG TYPE	Acker	G. L :	6.30 m
		WEATHER	Warm	F.W.D Inside BH = 2.80 m	
				N :	902555
				E :	741122

Depth (m)	Sample Depth (m)	Legend	SOIL DESCRIPTION	USCS	Layer End (m)	S.P.T	q_u (kg/cm²)	w_n %	W_L %	W_p %	γ_b (t/m³)	Recovery (%)	R.Q.D.(%)	Test Indication
			SAND, POOR GRADED, TRACES OF SILT, YELLOWISH GREY			50/9cm (1st Penetration)						83	-	
21						50/7cm (1st Penetration)						81	-	
22						50/7cm (1st Penetration)						85	-	
23			← (medium to fine)			50/9cm (1st Penetration)						85	-	
24						50/10cm (1st Penetration)						78	-	
25						50/9cm (1st Penetration)						81	-	
26					26.00	50/6cm (1st Penetration)						00	-	
27						50/6cm (1st Penetration)						00	-	
28						50/5cm (1st Penetration)						87	-	
29						50/5cm (1st Penetration)						00	-	
30						50/5cm (1st Penetration)						00	-	
31					31.50	4								
32			← @100cm CLAY, SILTY, TRACES OF FINE SAND, DARK GREY, VERY SOFT		32.50	50/5cm (1st Penetration)						90	-	
33						50/5cm (1st Penetration)		15				87	-	
34				SP-SM	34.50	50/7cm (1st Penetration)						80	-	●
35						50/5cm (1st Penetration)						86	-	
36			← (becomes medium to fine, with traces of clay lumps, yellow)			50/5cm (1st Penetration)						78	-	
37						50/6cm (1st Penetration)						90	-	
38					38.00	50/5cm (1st Penetration)						91	-	
39			← (becomes yellow)	SP-SM		50/6cm (1st Penetration)						82	-	●
40														

REMARKS

The term "lumps" denotes accumulations of size 1-4 cm

Fig. A6.3.7 Borehole Log No. B-2, (2)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

BOREHOLE NO. (B-2)Contin.

PROJECT: Crossing Structure Over Suez Canal
LOCATION: Kantara - East Bank km 48 + 500
CLIENT: Jica Study Team

DRILLING FLUID Bentonite
DRILLER Karam
RIG TYPE Acker
WEATHER Warm

DATE START: 1/1/1996
DATE END : 3/1/1996
G. L : 6.30 m
F.W.D Inside BH = 2.80 m
N : 902555
E : 741122

Depth (m)	Sample Depth (m)	Legend	SOIL DESCRIPTION	USCS	Layer End (m)	S.P.T	q_p kg/cm2	w_n %	W_L %	W_p %	γ_b t/m3	Recovery (%)	R.Q.D.(%)	Test Indication
41			SAND, POOR GRADED, TRACES OF SILT, TRACES OF FINE GRAVEL, SLIGHTLY CALCAREOUS, YELLOW			50/6cm (1st Penetration)						87	-	
42						50/5cm (1st Penetration)						90	-	
43					42.50	96/25cm						97	-	
			CLAY AND SILT, YELLOWISH GREY											
44			← (with some fine sand, some calcareous material, highly calcareous)			99/27cm >5						80	-	
45					44.50									
			← (becomes light brow)		45.50		>5	35			1.90			
46			← @100cm SAND, POOR GRADED, SOME SILT, SOME CLAY, HIGHLY CALCAREOUS, LIGHT GREY			98/25cm						00	-	
47					46.50									
			← (becomes sandy)		47.50			23			1.98			
48														
49			← (with some fine sand, light brown, more silt)											
50					50.00		>5							
			END OF BORING 50.00 m											

REMARKS

Fig. A6.3.8 Borehole Log No. B-2, (3)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

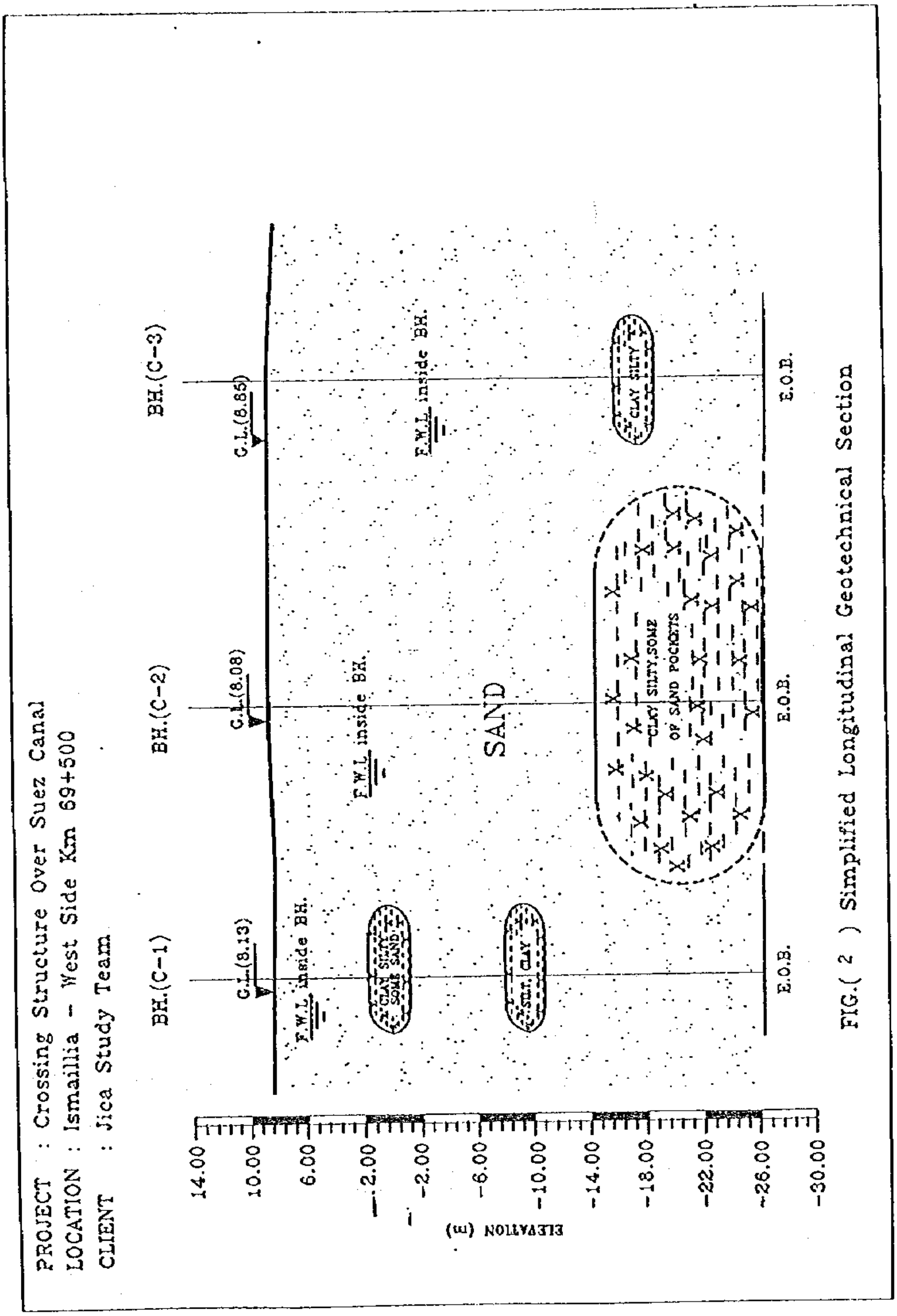


Fig. A6.3.9 **Simplified Longitudinal Geometrical Section (West Bank)**

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

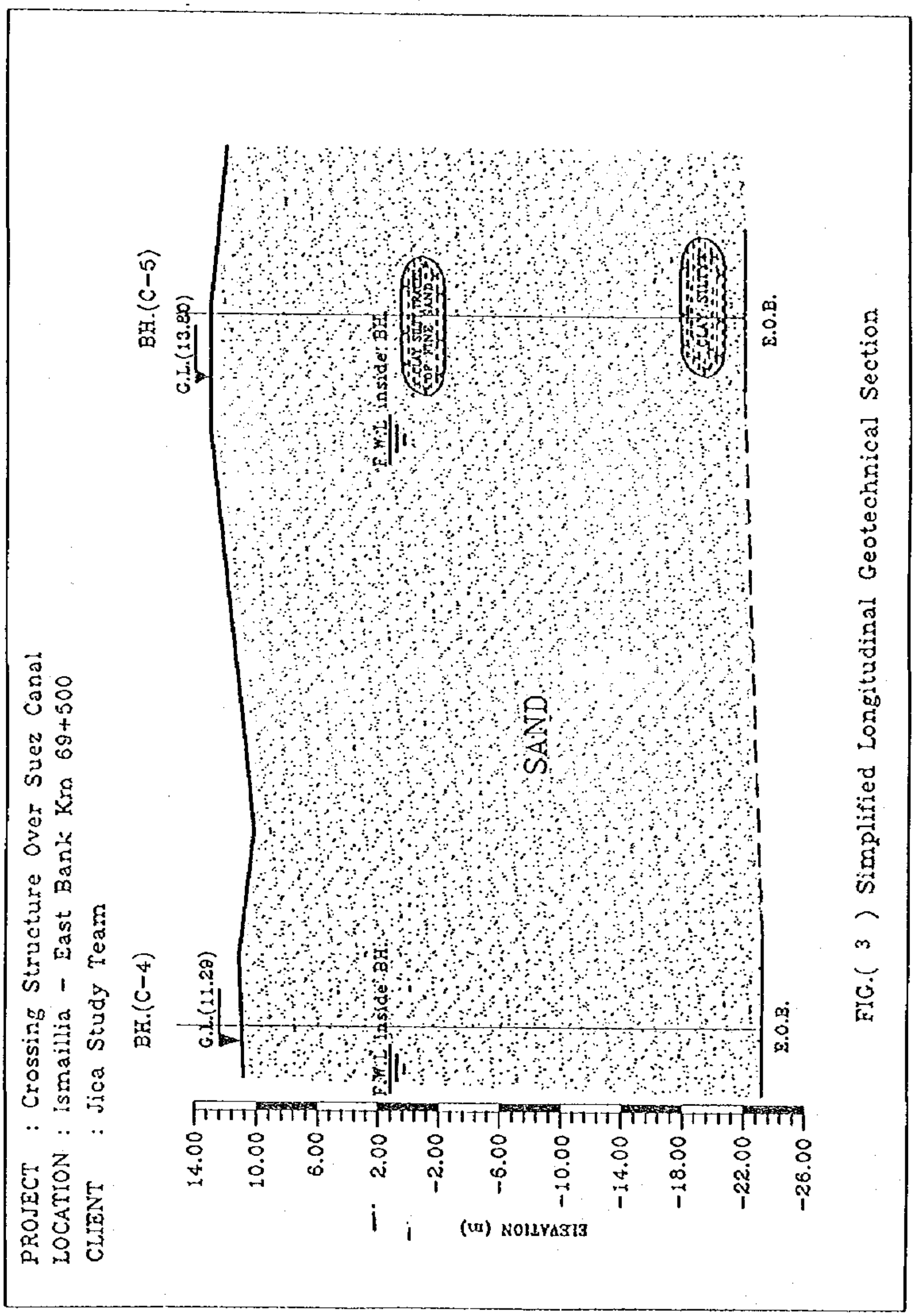


Fig. A6.3.10 **Simplified Longitudinal Geometrical Section (East Bank)**

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

A6.4 Status of Highway Construction

Table A6.4.1 List of Recently Constructed Bridges over the River Nile and Others (1)

Name (Location)	Client (Contractor)	Completed	Bridger Features
1. Giza Bridge (Giza)	Cairo Governorate (Arab Contractors)	1971	- Prestressed Concrete - Length 4TOM, width 34.60m
2. 6th of October (Cairo)	Cairo Governorate (Arab Contractors)	1979	- Prestressed Concrete (Main Spans) - Overall Length 12.5km, main span 115m
3. El-Abbasia Flyover (Cairo)	Min. of Development (El-Nasr General)	1983	- Precast Prestressed Concrete - Length 1,000m, 4-lanes
4. 15th May Bridge (Cairo)	Cairo Governorate (Arab Contractors)	1985	- Prestressed Concrete Box - Length 2.5km
5. Beni Suef Bridge (Beni Suef)	Min. of Transport (Arab Contractor)	1985	- Prestressed Concrete - Length 1,086m, width 21m
6. El-Dokki Flyover (Giza)	Min. of Housing & Reconstruction (El-Nasr General)	1985	- Steel Flyover - Length 700m, width 15m
7. El-Azhar Elevated Road (Cairo)	Cairo Governorate (Arab Contractors)	1985	- Weathering Steel + RC - Length 1,200m, width 13.6 m
8. Airport Bridge (Cairo)	Cairo Governorate (Arab Contractors)	1986	- Prestressed Concrete - Length 1,180m, width 21m
9. Zamalek Bridge (Zamalek-Cairo)	Cairo Governorate (Arab Contractors)	1986	- Prestressed Concrete - Length 1,000m, width 16.60m
10. Tharwat Flyover (Giza)	Min. of Housing & Reconstruction (El-Nasr General)	1986	- Steel - Length 504m

Table A6.4.2 List of Recently Constructed Bridges Over the River Nile and Others (2)

Name (Location)	Client (Contractor)	Completed	Bridger Features
11. Autostrad Bridges (Cairo)	Min. of Development (El-Nasr General)	1987	- Precast PSC + Steel-concrete composite
12. Damietta Bridges (Damietta)	Min. of Development (El-Nasr General)	1988	- Prestressed precast beams spanning 25-32m
13. Road El-Farag Bridge (Cairo)	Cairo Governorate (Arab Contractors)	1992	- 3-Span PSC - Main Span Length 130m
14. Luxor Bridge (Luxor)	Min. of Transportation & Communication (El-Nasr General)	1993	- Prestressed Concrete Box Girders - Length 900m, width 22m
15. Faraskour Bridge (Faraskour)	Min. of Transport (Nile General Co. for Roads & Bridges)		- 19 Spans Prestressed Concrete
16. El-Warrak Bridge (Giza)	Min. of Construction & Communities		- PSC Girders - Length 2.0km, width 42.0m
17. Al-Mansura Bridge (Manosura)	Min. of Transport (Nile General Co. for Roads & Bridges)	1995	- PSC Girans - Length 1080m, width 20.0m

Source JICA Study Team

A6.5 Tunnel Crossing

A6.5.1 Tunnel Structure

(1) Tunneling Methods

1) NATM for Tunnel Construction

This system has been widely used in Europe for road and railway tunnels, generally in cohesive or weak rock type ground conditions.

It is a method whereby the ground deformation and type is constantly monitored during excavation and construction and relies on the arch formed to mobilize and distribute the ground stresses around it.

Excavation is done in stages with rapid application of ground support, normally a combination of steel arches, rockbolts or dowels, reinforcement mesh and shotcrete. This is known as the primary support lining. The excavation is carried out using conventional equipment e.g. backhoes, roadheaders, excavators and hand trimming, and whilst not achieving rapid progress, typically 10-15m per week, has the advantage over shield driven (TBM) methods that there is no delay waiting for TBM manufacture nor the cost of this specialist equipment. It is generally more economic for short length tunnels, up to approximately 1km of drive.

A secondary, normally in situ concrete lining, is also required to achieve a fully structural long term structure, incorporating a waterproofing and drainage layer membrane.

This method is not suitable where variable ground conditions and a high water table are present. These conditions would require ground stabilization methods and probably dewatering e.g. chemical treatment, compressed air or deep wellpoint pumping.

Recent experiences in Germany and U.K. have demonstrated the sensitivity of this method to variable ground conditions e.g. tunnel collapses in Munich and at London Heathrow airport.

A typical excavation sequence and section of this type of tunnel is shown in Fig. A6.5.1.

2) Full Faced Mechanical TBM for Tunnel Construction

This type of TBM is used in rock strata and stable cohesive soft ground conditions, preferably above the water table level.

A powerful rotating cutter head equipped with suitable cutting tools bores into the ground and the excavated material is fed by mechanical methods onto a conveyor belt for disposal by dumptruck or rail car outside the tunnel.

In soft ground conditions, the tunnel is normally formed with precast concrete segmental linings either bolted together, or if very stable ground conditions apply, by expansion against the ground.

The TBM is propelled forward through the ground by means of shove rams which push off the previously constructed segmental tunnel lining. This type of tunnel construction achieves high rates of progress up to 100m per week with experienced crews at the diameter required (11.5m) for the Suez Crossing.

If poor ground conditions or water bearing soils are encountered, however this type of TBM will not operate satisfactorily as it provides very little face support. Either ground treatment or compressed air are required, both of which add considerable cost and reduce the progress rates.

In water bearing sands and gravels the loss of compressed air through the ground would be extremely high and with the risk of a blow out beneath the Canal would not be a suitable method.

A typical full face Mechanical TBM is shown in Fig. A6.5.1.

3) Earth Pressure Balance TBM for Tunnel Construction

These machines are normally full face type, but incorporate a heavy duty sealed bulkhead to the rear of the cutterhead and employ a screw conveyer system to remove the excavated spoil from the cutterhead chamber.

The bulkhead enables the front of the machine to be pressurized, using the excavated material as the medium for this purpose. This pressure is calculated from the soil characteristics and depth to act as a support mechanism to the excavated face. The rate of extraction by the screw conveyor is adjusted to balance the rate of TBM advance and hence a steady pressure is maintained on the face.

This type of machine is most commonly used in very soft or weak cohesive soils or in poor mixed soil conditions.

Bolted precast concrete segmental lining is normally used for this type of tunneling and the lining must be grouted with a cement based mortar to ensure long term stability and load distribution by the lining.

This type of TBM is less suitable for non-cohesive sand and gravel in water bearing ground as face pressure control is difficult to achieve and high wear is probable to the screw conveyor system. All other characteristics are similar to the full face mechanical TBM described above.

A typical EPBTBM is shown in Fig. A6.5.2.

4) Slurry TBM for Tunnel Construction

These machines are also normally full face type and incorporate a heavy duty sealed bulkhead.

This bulkhead enables the front section of the TBM to be pressurized, but in this case the pressurizing medium is bentonite or polymer fluid.

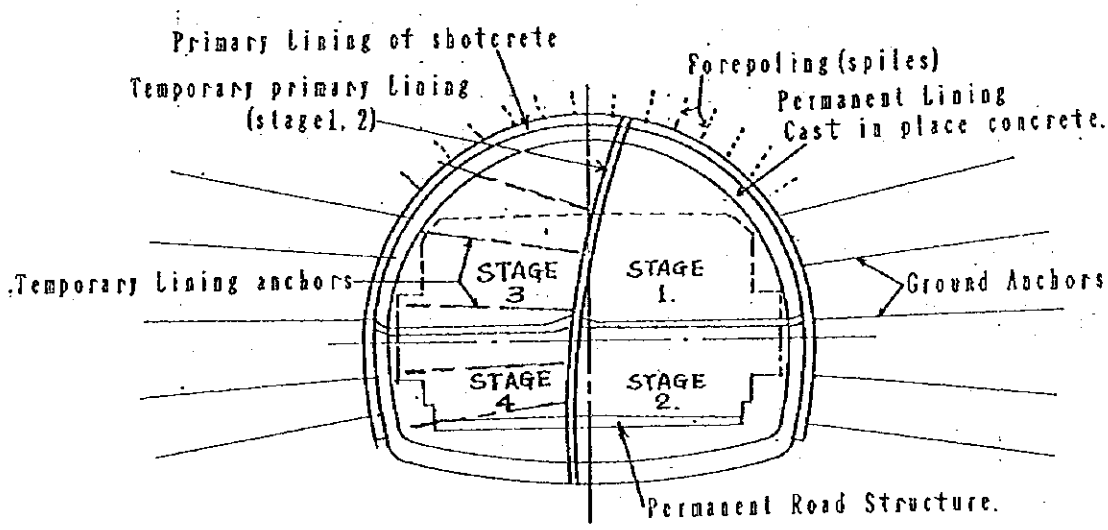
This is circulated through large diameter pipes (250-300mm ϕ), and in addition to providing the necessary face support is also used to transport the excavated material out of the tunnel.

The material is then separated from the bentonite in a separating plant consisting of screens, cyclones and if required, filter presses and the cleaned bentonite is re-circulated into the system.

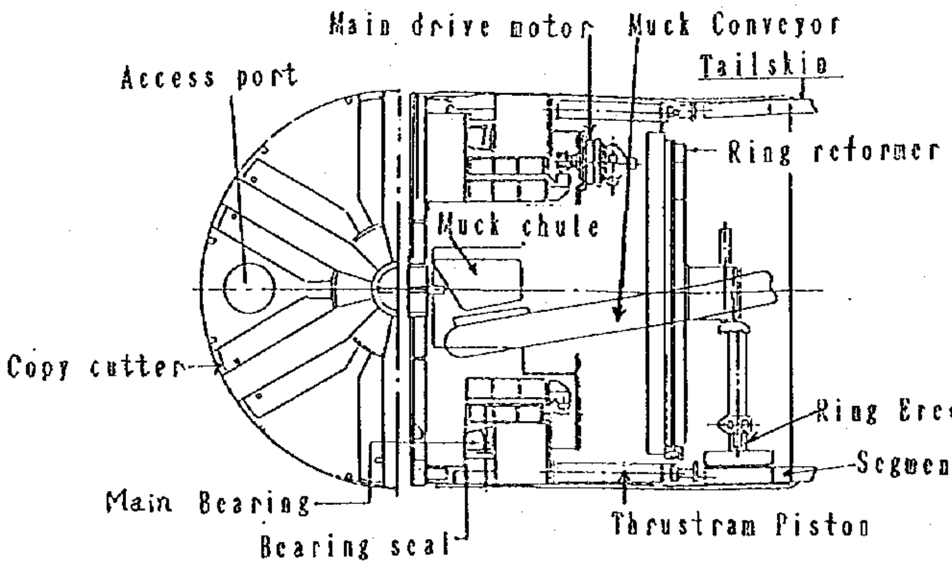
These type of machines are normally used in unstable water bearing non-cohesive soils e.g. sands and gravels. If used in the mixed unstable soils the finer materials (clays and silts) tend to block up the separation plant, which in turn causes delays and cost to the tunneling operation and possibly breakdown of the equipment.

The tunnel lining and grouting requirements are similar to those required for the EPBTBM described in 3) above.

A typical Full Face Slurry TBM is shown in Fig. A6.5.2.

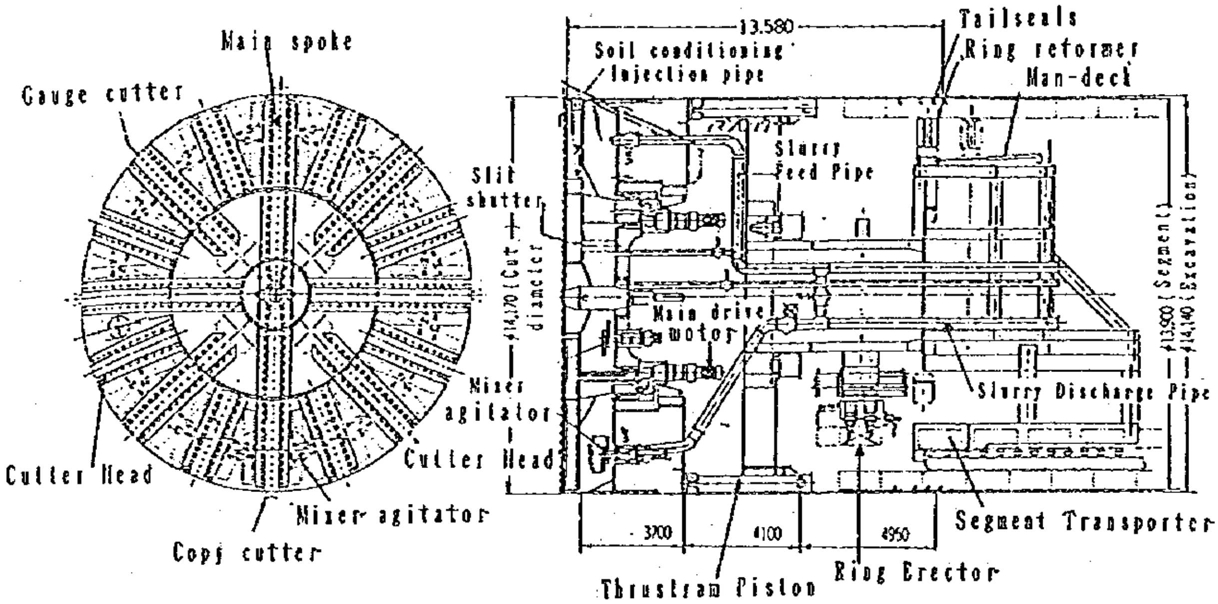


TYPICAL NATM TUNNEL

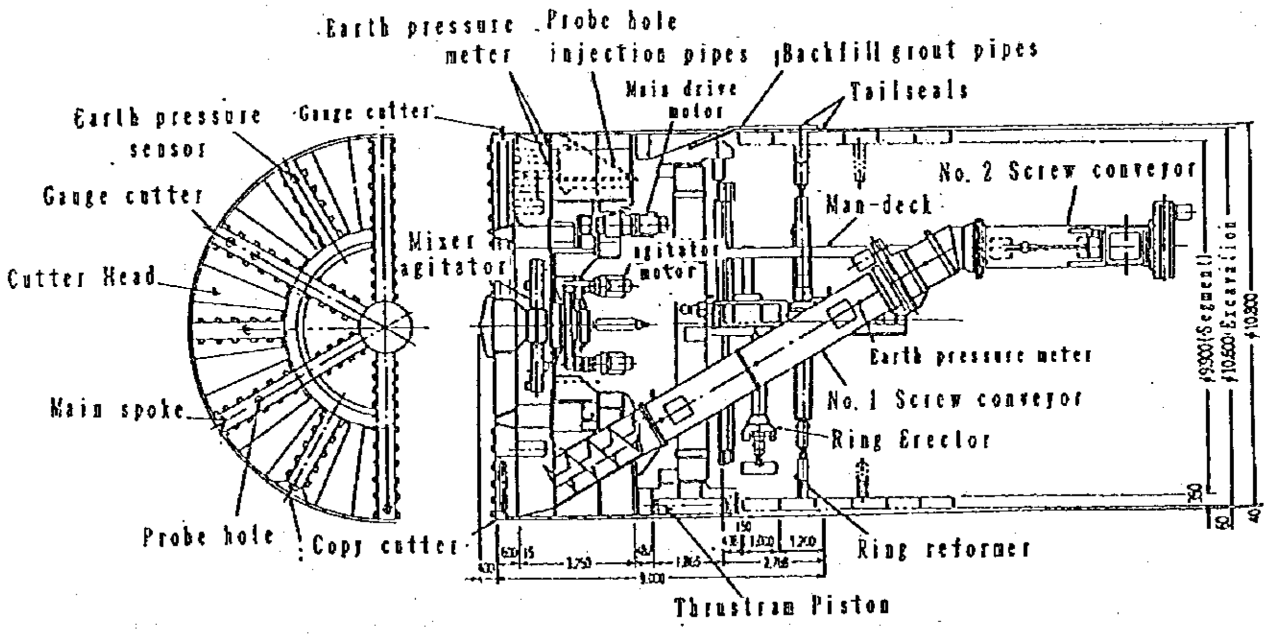


FULL FACE MECHANICAL TBM.

Fig. A6.5.1	Typical NATM Tunnel and Full Face Mechanical TBM	*THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL*



SLURRY SHIELD TBM.



EARTH PRESSURE BALANCED SHIELD TBM.

Fig. A6.5.2 Slurry Shield TBM and Earth Pressure Balanced Shield TBM

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

A6.5.2 Construction Sequence of Tunnel

(1) Construction Sequence

1) The principal activities to construct the tunnel and approach (access) roads will be undertaken in the following sequence.

- a Prepare Site area and Establish Temporary facilities
- b Commence Portal pile construction
- c Commence dewatering and approach excavation
- d Excavate Portal Structure installing wall restraints as required.
- e Construct temporary access road to Portals
- f Construct Portal sumps and TBM Base Slabs
- g Ground Treat Portal Headwall Areas
- i Receive, assemble and test TBM + equipment
- h Construct thrust block structure for TBM Drive No.1
- j Launch TBM and construct primary lining No.1 tunnel
- k construct thrust block structure for TBM Drive No.2
- l Remove TBM from No.1 tunnel and prepare for No.2 tunnel
- m Construct secondary lining and walkway in No.1 tunnel
- n Launch TBM construct primary lining No.2 Tunnel
- o Remove TBM from No.2 tunnel dismantle and dispose and Repeat e) above
- p Construct permanent portal structures and access roads throughout
- q Install all permanent facilities and controls and commission
- r Demobilize and clear site.

2) Some of these activities will be concurrent, but it is to be noted that the main site should be established on the West Bank initially, with a secondary site for construction of the East Bank Portal and approaches following this. The construction of No.2 tunnel will also be undertaken from the East Bank and hence adequate facilities, storage areas and cross canal transport (launch) will be required to service these activities.

(2) Construction Methods-Principal Activities

1) Approach Cuttings

Initial surface preparation either by general excavation to +5.0 m above datum or filling to +2.5 m above datum, dependant upon existing ground levels will be carried out over the whole area of the portal and approach cutting, prior to main excavation and portal piling commencing. Deep well dewatering will then be installed and operated throughout the approach area, prior to main excavation commencing. Excavation will then commence using backhoes and front loaders (3 machines envisaged) with tipper trucks hauling the material to dump site. The slopes will be formed by the backhoes as excavation proceeds, and if water persists, well point dewatering will also be installed.

As the excavation progresses into the deeper section the sub-base for the access roads can be laid and this will assist the haul trucks climbing out of the cutting. The excavation will cease at the portal structure where a 10% gradient ramp will be formed, from formation level to the ground level, within the portal piled structure. This will be removed during the staged excavation of the portal. As completed areas of the cutting slopes become available, weep drains and stonepitching will be placed. Upon completion of the excavation of the slope the drains and road base will be constructed. These activities will commence on the West Bank and transfer to the East Bank upon completion to suit the overall phasing of the contract.

2) Portal Structure

Timely completion of this structure on the West Bank is essential to avoid delays to the commencement of tunnelling. The portal structure consists of interlocking (secant) piles formed by large diameter drilling rigs together with steel H beams in selected piles. To achieve the required output of 4 piles per day two such rigs will be employed. The drilling, working on a 6 day single shift basis, should be completed within 5 months.

Staged excavation will then commence, which will be dependent upon waling and ground anchor installation at each level. Two shift working is envisaged for these activities, using backhoe excavators.

This will continue until the formation level is reached for the TBM base slab. This will then be cast in reinforced concrete and the main sump constructed. Following this the thrust block structure incorporating tunnel rings and a heavy reinforced concrete surrounding structure will be constructed some 10-12 m from the headwall. Concurrent with this, and prior to TBM delivery the headwall piles at the tunnel eye will be trimmed and a double seal system installed, to permit the TBM to penetrate and operate under slurry pressure. Ground treatment of a block of ground on the tunnel side of the headwall, to prevent ground loss during commencement and completion of the two tunnels respectively will then be undertaken. These activities will commence on the West Bank, and as each activity is completed the operation will transfer to the East Bank. This will achieve the most economic and efficient construction method.

3) Tunnel Construction

The TBM will be delivered to the job site in dismantled sections by trucks.

The trucks will deliver the main components (e.g. cutter head, main shell, tailskin etc) directly to the TBM assembly point at the portal face. These will be offloaded in the required sequence and assembled on the TBM cradle, of steel rails, previously constructed with the base slab.

In parallel with the TBM assembly, all ancillary trailing gear and the Bentonite Separation Plant will be prepared and connected to the TBM pumps. After successful testing of the TBM functions, the machine will be propelled forward by the shove rams, acting on the thrust block structure, to engage and penetrate the portal headwall. Great care will need to be taken during this activity to ensure accurate alignment is maintained, and that these is no ground loss through the headwall. As the TBM advances, a complete ring will be built after each 1.2 m advance.

Once the TBM has fully entered the ground, the rings built will be concreted into the headwall, to provide a permanent seal. The TBM can then operate in full slurry mode with all functions operating normally.

The typical ring build cycle involves advancing the machine during excavation, at which time continuous grouting of the annulus formed, between the erected lining and the excavated diameter, will be undertaken, using a suitable mortar mix. This will be pumped via the tailskin pipes and subject to full monitoring to ensure correct flow, pressure and volume is achieved. Upon completion of the excavation cycle, the TBM will halt and the lining ring will be erected, segment by segment, until the key segment is fully secured.

These operations will be carried out around the clock working probably for 6 days a week. An average rate of 200 m/month of tunnel construction has been chosen, based upon experience and progress of other similar projects, and this is considered a conservative and achievable rate.

When the TBM reaches the far portal headwall (East Side), the ground treatment system will have been completed, and a pattern of relieving holes 2 m deep should be drilled from the outside face around the break out perimeter. This will ensure a clean break through of the TBM and minimize any problems. After break through the TBM will be partially dismantled, refurbished as necessary, and re-assembled at the East Portal. The TBM launch and tunnel construction of No.2 tunnel would be a repeat of the above description. It is to be noted however that the slurry separation plant, segment storage, associated equipment and materials would need to be transferred to the East Bank prior to tunnel construction re-commencing.

4) Secondary Lining and Road Deck construction.

These activities will commence in the No.1 tunnel following removal of the TBM and backup.

A careful survey to confirm alignment will be necessary and the tunnel will be thoroughly cleaned and any repairs carried out prior to further work commencing.

These activities will involve 4 stages of work phased one after the other and will be probably undertaken working in a West to East direction for both tunnels.

These 4 stages comprise:

i) Invert - Fix geotextile and pvc membrane up to road deck level and protect invert with a 10 cm layer of mortar. Place reinforcement, side forms and concrete 12 m long bays.

ii) Lower side walls - Place reinforcement and erect steel sideforms. Concrete 12 m long bays, - 2 sides.

iii) Road Deck - handle and instal central deck sections and side slabs to suit length of concreted tunnel.

iv) Fix geotextile and pvc membrane to remainder of tunnel arch profile, in lengths to suit. Place and fit reinforcement to arch (This is only necessary in central 400 m section of tunnel where affects of Canal deepening will be felt). Place and align rails for hinged steel travelling arch shutter and place and fix shutter. Place concrete in 12 m long bays.

This sequence will be continuous until No.1 tunnel is completed where upon the same cycle will be repeated in No.2 tunnel.

An average completion rate of 100 m of tunnel per month has been determined for these activities based on past experience. The low point tunnel sump will be constructed during this period, but prior to secondary lining concrete reaching the location.

The side walks will also be constructed after the tunnel arch is completed and will involve the placing of some dowels into the secondary lining, fixing of reinforcement, steel formwork (20 m bay lengths) and concreting both sides of the tunnel simultaneously.

2 Lanes Steel Box Girder Alternatives (L=353m) General View S=1:1500

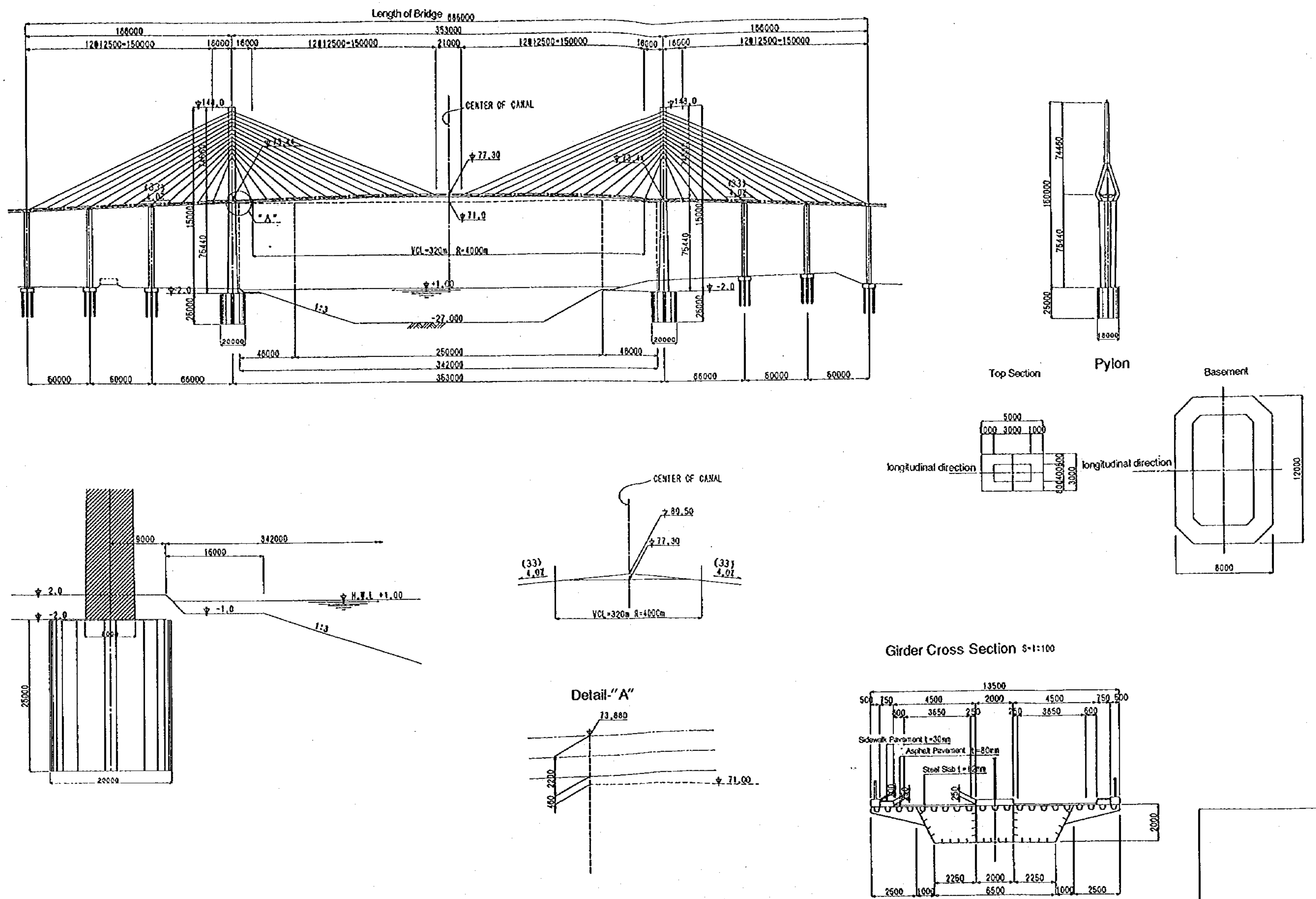
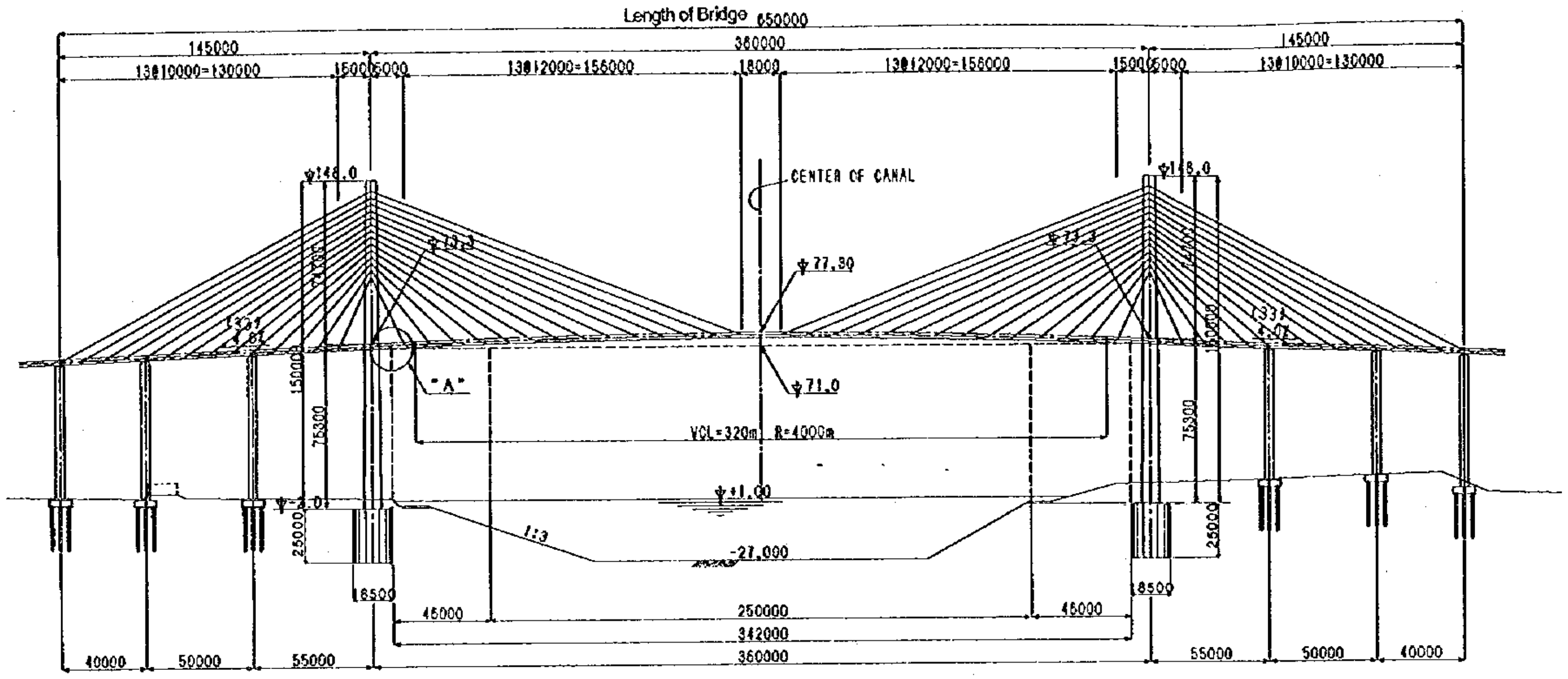
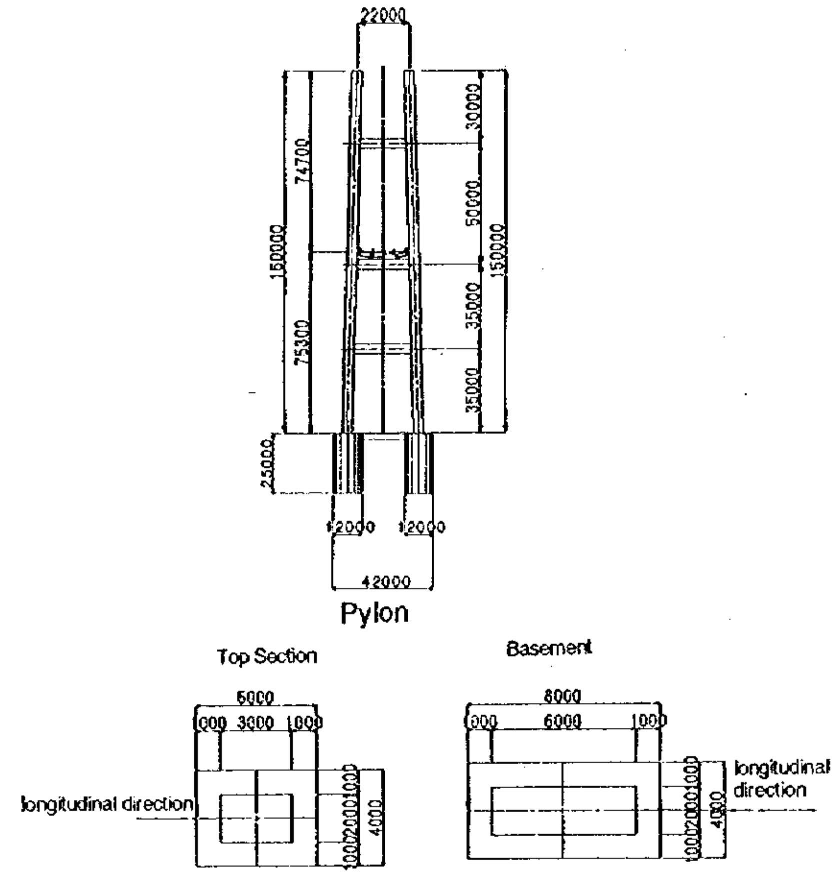
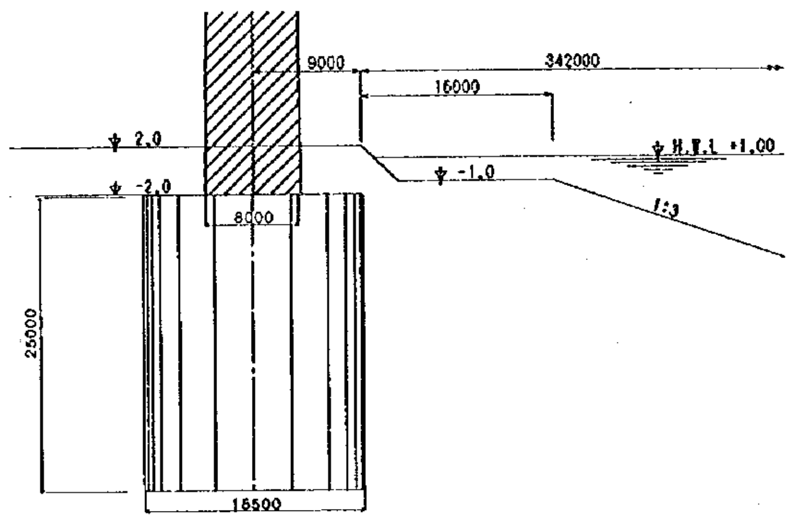


Fig A6.6.1 General View (2 Lane Steel Box Girder Alternative L=353m)

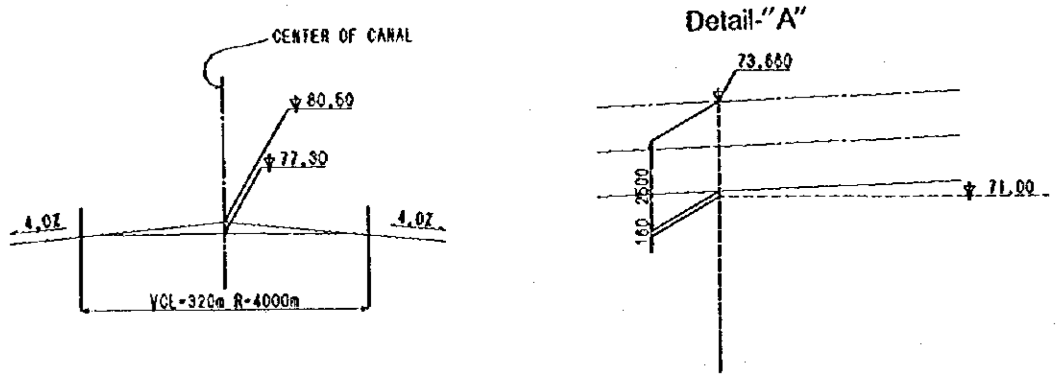
Steel Box Girder Alternative (L=360m) General View S=1:1500







Detail-"A"



Girder Cross Section S=1:100

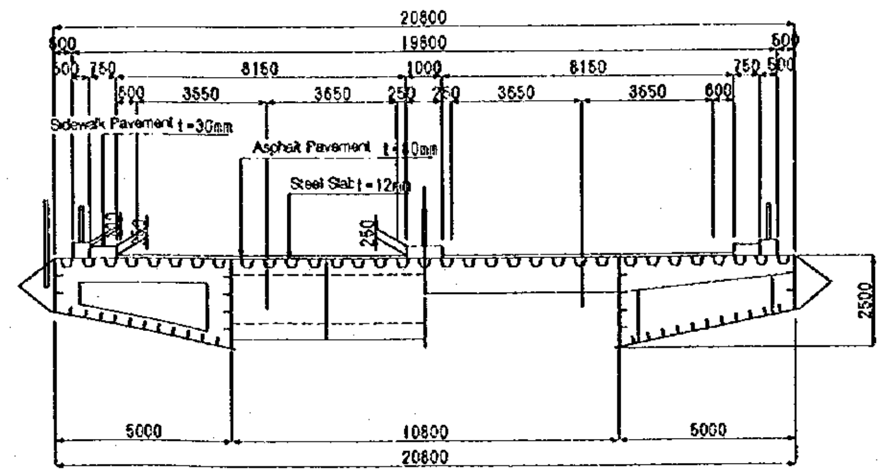


Fig A6.6.2 General View (Steel Box Girder Alternative : L=360m)

Steel Box Girder Alternative (L=404m) General View S=1:1500

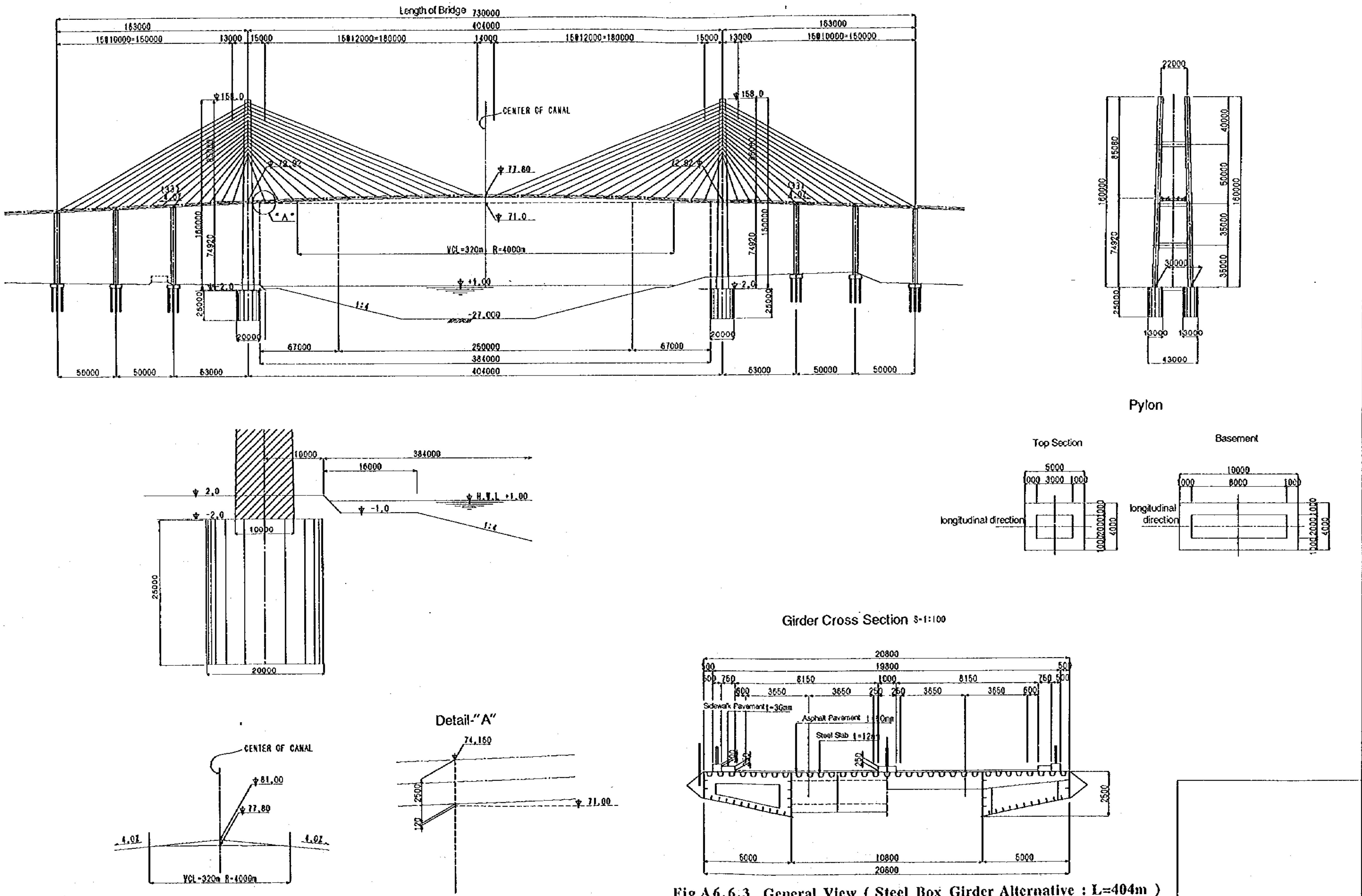
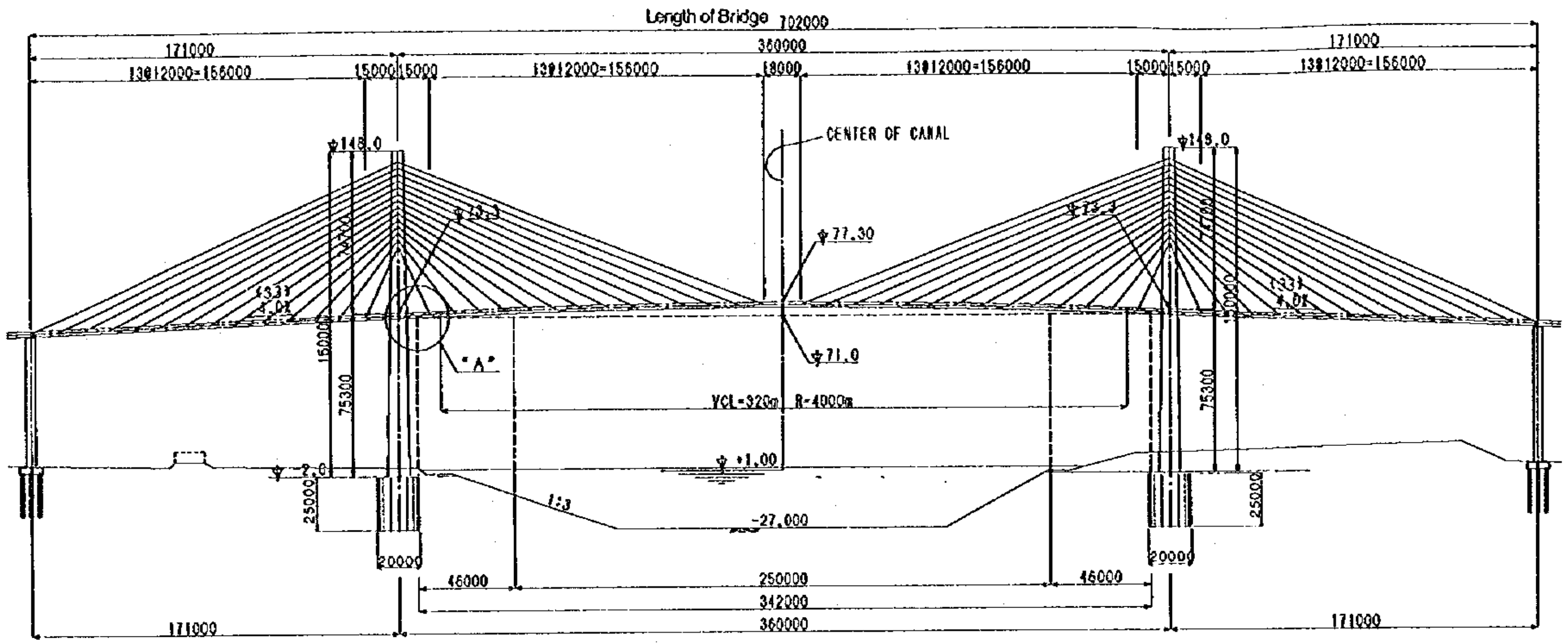
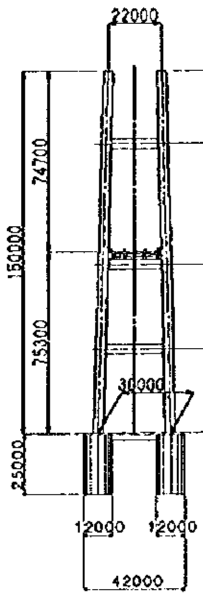


Fig A6.6.3 General View (Steel Box Girder Alternative : L=404m)

Steel-Concrete Composite Girder Alternative (L=360m) General View S=1:1500

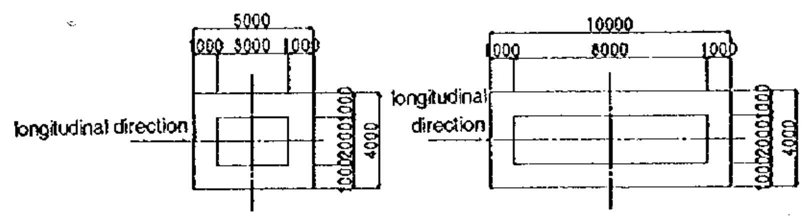


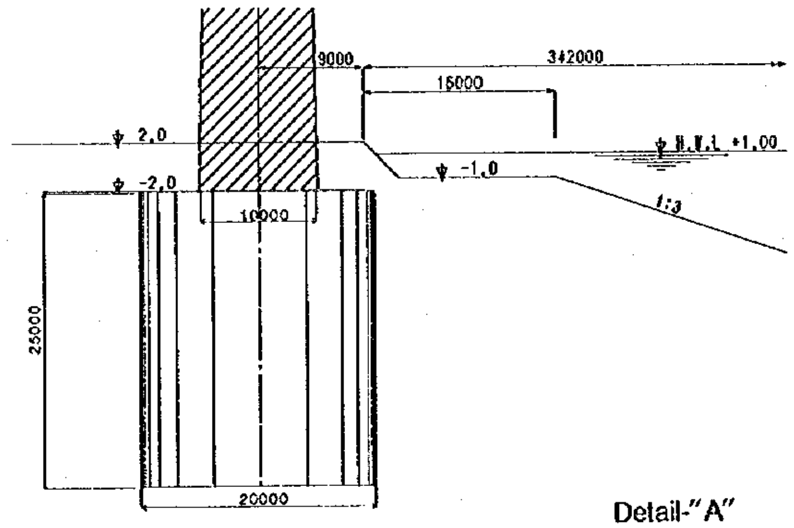


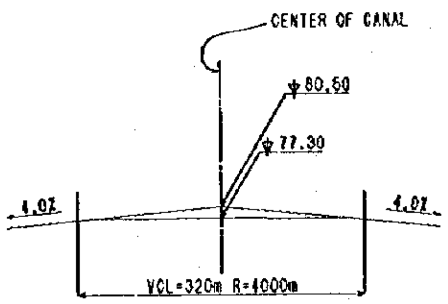
Pylon

Top Section

Basement







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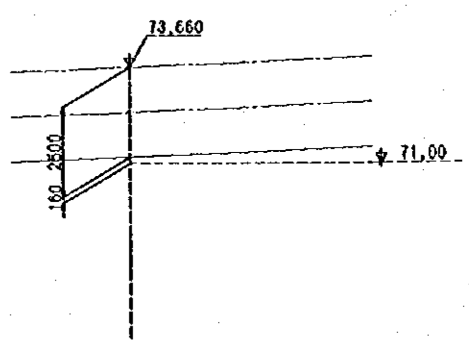


Girder Cross Section S=1:100

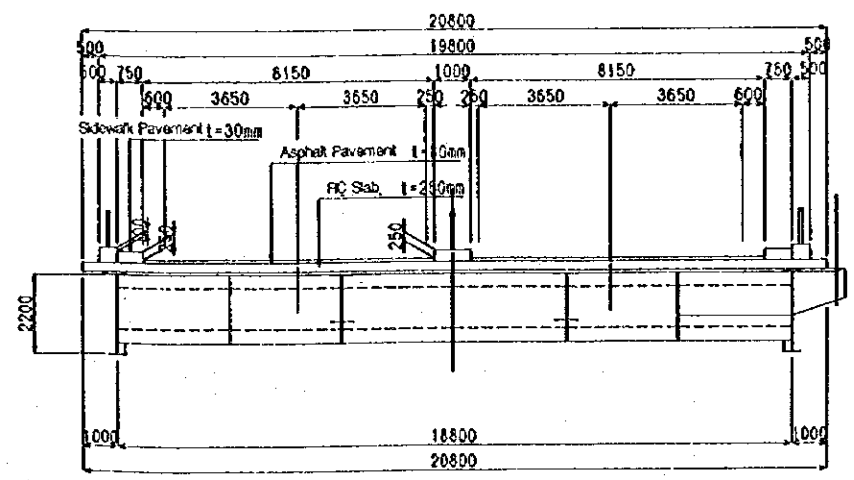
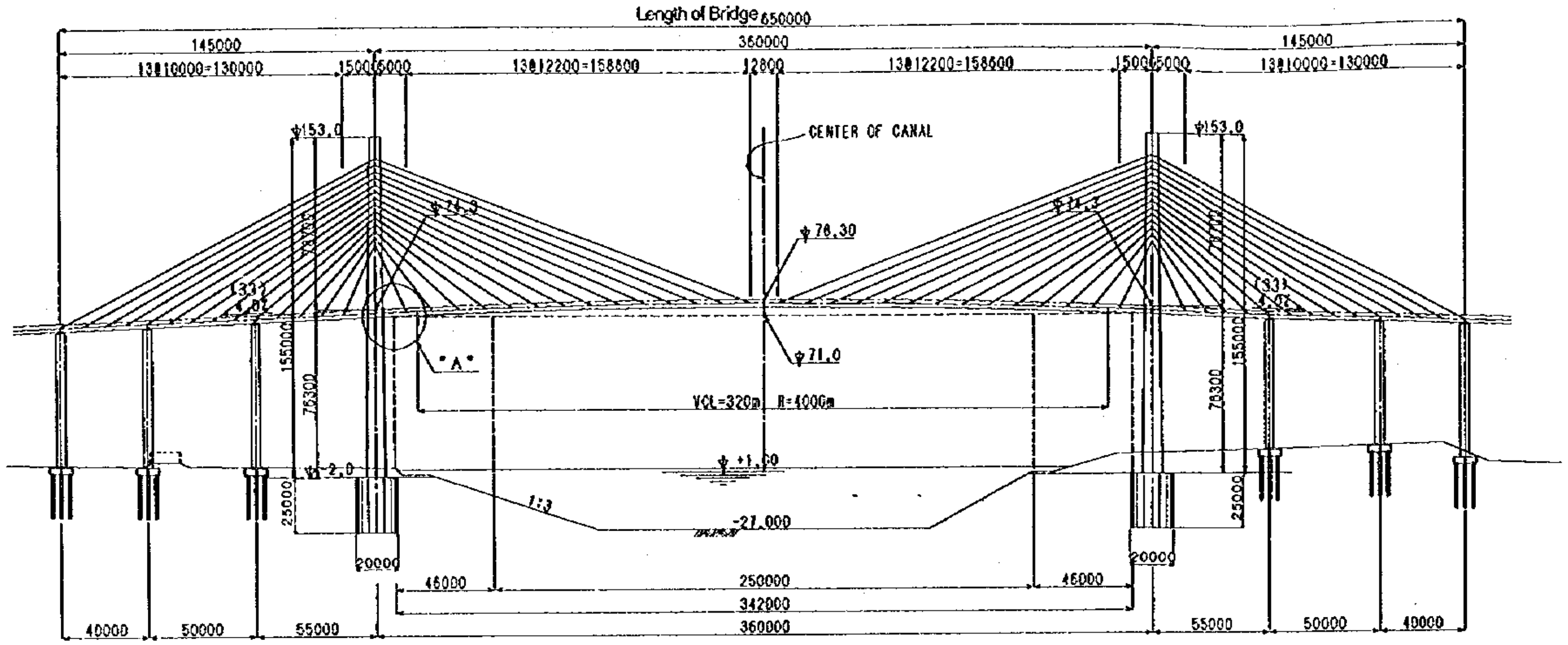
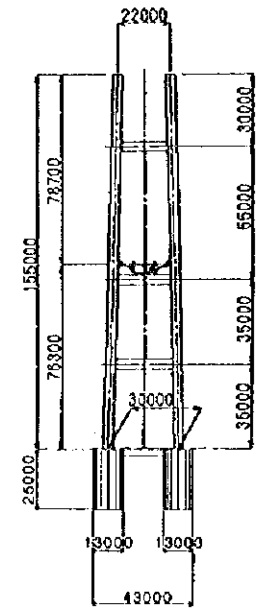


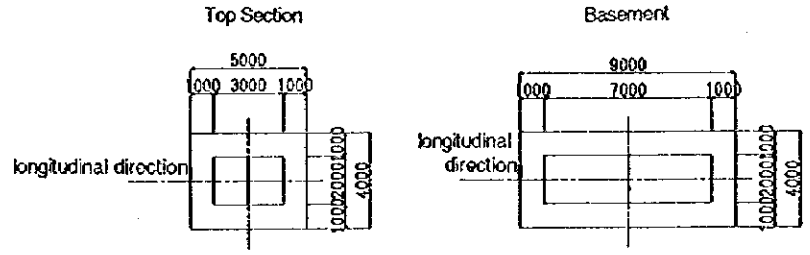
Fig A6.6.4 General View (Steel- Concrete Composite Girder Alternative : L=360m)

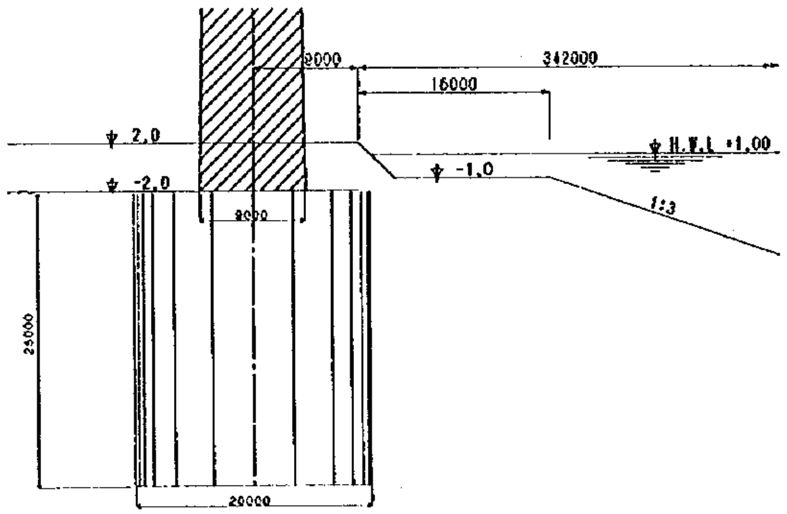
Prestressed Concrete Girder Alternative (L=360m) General View S=1:1500



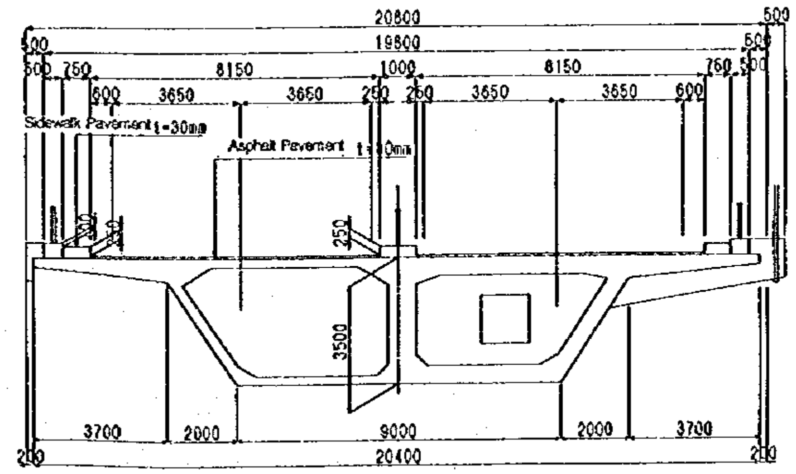


Pylon





Girder Cross Section S=1:100



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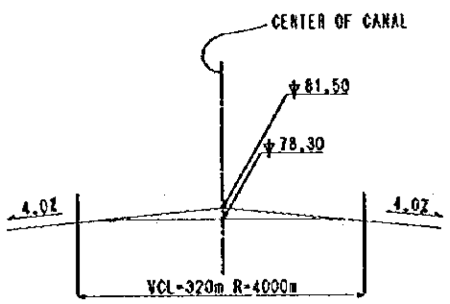


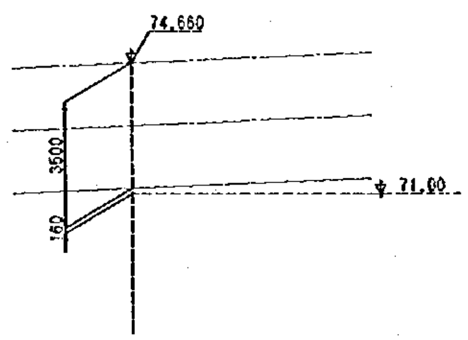


Fig A6.6.5 General View (Prestressed Concrete Girder Alternative : L=360m)

A. 6.7 Additional Scheme at Srabuiom

(1) General

The option would be required to ensure that the East Bank Tunnel Portal and approaches were suitably located to allow for construction of the future Deversoir Bypass Channel. This requirement would increase the tunnel length between the portals by approximately 400 meters but would not affect the approach cuttings. The East Bank access connecting road would be similarly shorted. The general tunnel route alignment would remain as for the single canal crossing at Srabuiom.

(2) Construction Schedule

Assuming that the additional length of the tunnels are constructed at the same rate as the standard schemes the schedule time is increased as follows for the 4 % gradient crossing.

1) Primary and Secondary Lining

Additional Time = + 8 months
Tunnel Opens after = 67 months

2) Primary Lining only

Additional Time = + 4 months
Tunnel Opens after = 46 months

(3) Construction Cost

As indicated in Table 6.6.2 (Summary of Tunnel Costs), the additional scheme is the most expensive of the tunnel options, and would not represent an economic solution

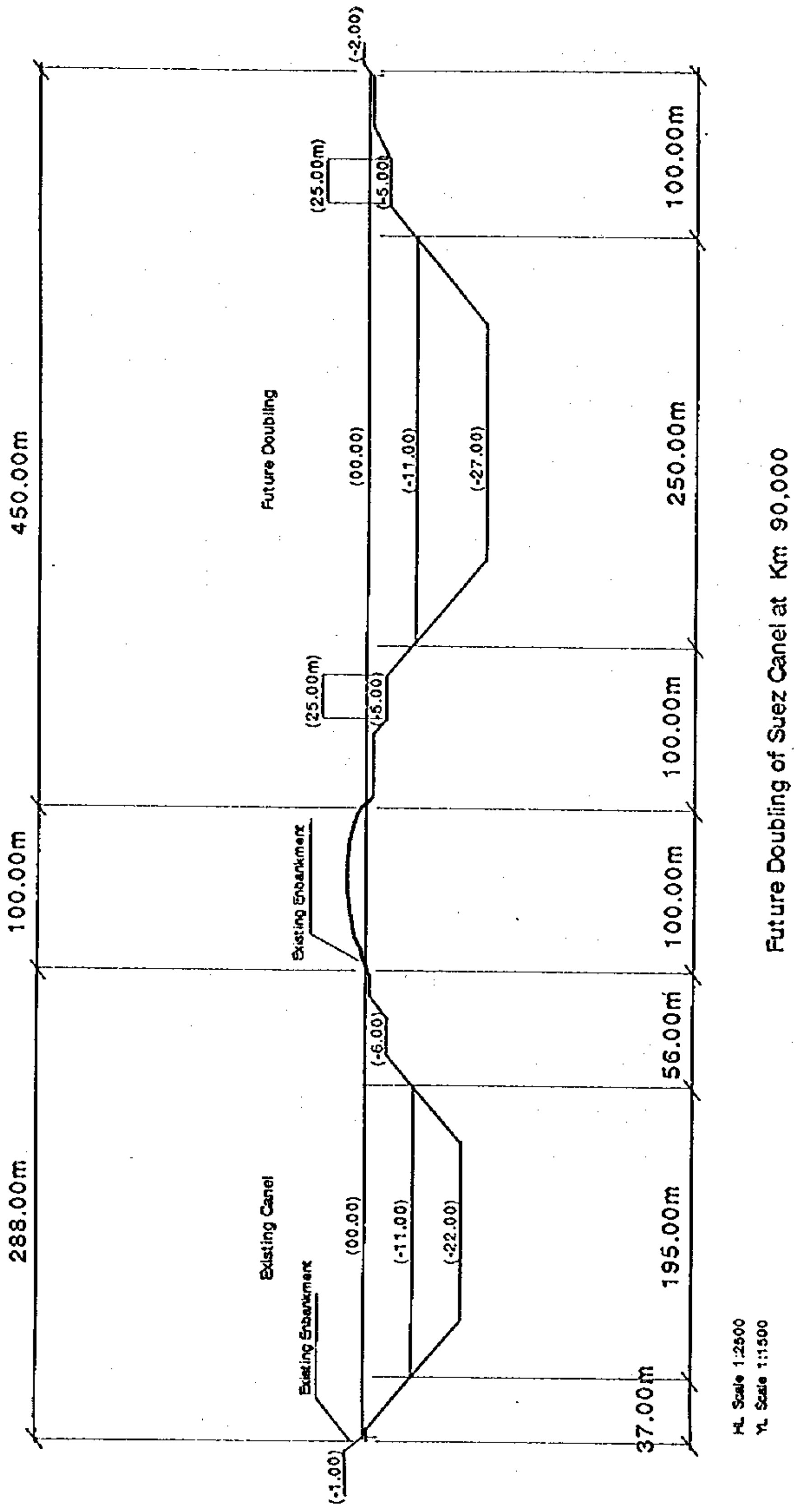


Fig. A6.7.1 Future Doubling of Suez Canal

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

Schematic General View of Bridge at Srabuiom

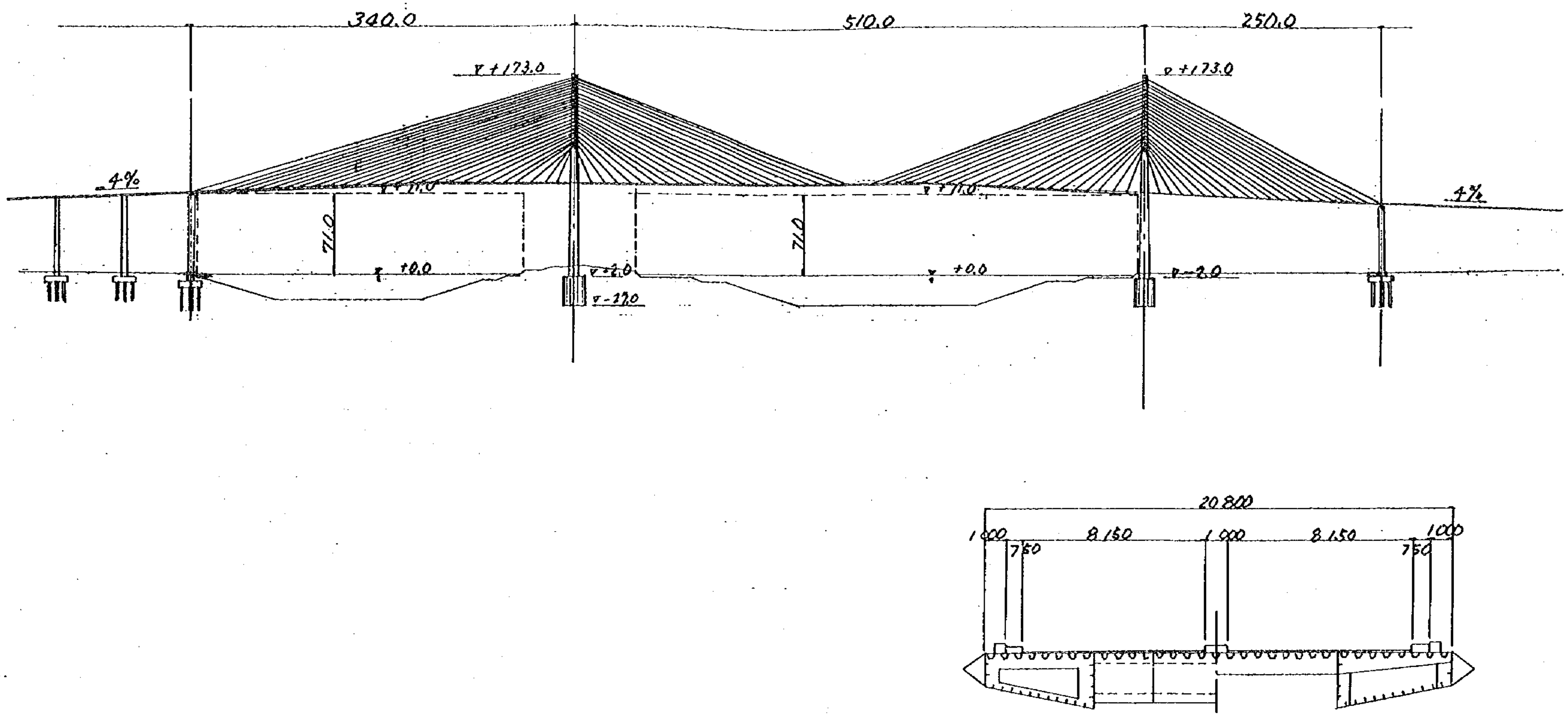


Fig. A6.7.2	Schematic General View of Bridge at Srabuiom	*THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL*

Chapter 7 Evaluation of Alternatives

A 7.1 Evaluation of structure Alternatives

Table 7.1.1 Yearly Allocation of Construction Costs

(4% of V.Grade, Financial Price) Unit: US$ 1,000

Bridge		Quantra	Ferdan	Ismailiya	Srabuion
Total Cost	%	123,400	117,800	105,200	104,200
1st Year	0.02	2,468	2,356	2,104	2,084
2nd Year	0.24	29,616	28,272	25,248	25,008
3rd Year	0.35	43,190	41,230	36,820	36,470
4th Year	0.33	40,722	38,874	34,716	34,386
5th Year	0.06	7,404	7,068	6,312	6,252

Tunnel		Quantra	Ferdan	Ismailiya	Srabuion
Total Cost	%	209,200	209,800	220,600	217,800
1st Year	0.02	4,184	4,196	4,412	4,356
2nd Year	0.18	37,656	37,764	39,708	39,204
3rd Year	0.20	41,840	41,960	44,120	43,560
4th Year	0.21	43,932	44,058	46,326	45,738
5th Year	0.21	43,932	44,058	46,326	45,738
6th Year	0.18	37,656	37,764	39,708	39,204

(3.3% o V.Grade, Financial Price) Unit: US$ 1,000

Bridge		Quantra	Ferdan	Ismailiya	Srabuion
Total Cos	%	138,900	134,400	119,500	118,500
1st Year	0.02	2,778	2,688	2,390	2,370
2nd Year	0.24	33,336	32,256	28,680	28,440
3rd Year	0.35	48,615	47,040	41,825	41,475
4th Year	0.33	45,837	44,352	39,435	39,105
5th Year	0.06	8,334	8,064	7,170	7,110

Tunnel		Quantra	Ferdan	Ismailiya	Srabuion
Total Cos	%	227,000	227,700	242,400	239,800
1st Year	0.02	4,540	4,554	4,848	4,796
2nd Year	0.18	40,860	40,986	43,632	43,164
3rd Year	0.20	45,400	45,540	48,480	47,960
4th Year	0.21	47,670	47,817	50,904	50,358
5th Year	0.21	47,670	47,817	50,904	50,358
6th Year	0.18	40,860	40,986	43,632	43,164

Table 7.1.2 Maintenance and Repairing Unit Cost of Canal Crossing Facilities

1. Bridge Maintenance		
	Bridge	Road
Periodic Cost	Every 10 Years Repainting 2.3 Million US$ Inspection 0.2 Million US$	Every 7 Yers 0.7 Million US$
Routine		25,000 US$/Km

2. Tunnel Routine Maintenance						
Location	Qantara	Ferdan	Ismailiya	Surabuiom		
Cost(Case 4 Lanes)	1.51	1.51	1.62	1.62	1.91	MillionUS$

Table 7.1.3 Comparison of Discounted Present Value of Financial Costs

(4 Lanes, 3.3% Vertical Grade)

Unit: US$ 1000

	Year	Construction and Maintemance Costs								Discount	Discounted Construction and Maintenance Costs							
		Bridge				Tunnel					Bridge				Tunnel			
		Qantara	Ferdan	Ismaili	Srabuiom	Qantara	Ferdan	Ismaili	Srabuiom	14.00%	Qantara	Ferdan	Ismaili	Srabuiom	Qantara	Ferdan	Ismaili	Srabuiom
1	1996	0	0	0	0	0	0	0	0	0.877	0	0	0	0	0	0	0	0
2	1997	2,778	2,688	2,390	2,370	4,540	4,554	4,848	4796	0.769	2,138	2,068	1,839	1,824	3,493	3,504	3,730	3,690
3	1998	33,336	32,256	28,680	28,440	40,860	40,986	43,632	43164	0.675	22,501	21,772	19,358	19,196	27,579	27,664	29,450	29,134
4	1999	48,615	47,040	41,825	41,475	45,400	45,540	48,480	47960	0.592	28,784	27,851	24,764	24,557	26,880	26,963	28,704	28,396
5	2000	45,837	44,352	39,435	39,105	47,670	47,817	50,904	50358	0.519	23,806	23,035	20,481	20,310	24,758	24,835	26,438	26,154
6	2001	8,334	8,064	7,170	7,110	47,670	47,817	50,904	50358	0.456	3,797	3,674	3,267	3,239	21,713	21,785	23,191	22,942
7	2002	255	273	283	78	40,860	40,986	43,632	43164	0.400	102	109	113	31	16,329	16,380	17,437	17,250
8	2003	255	273	283	78	1,500	1,510	1,620	1,470	0.351	89	96	99	27	526	529	568	515
9	2004	255	273	283	78	1,500	1,510	1,620	1,470	0.308	78	84	87	24	461	464	498	452
10	2005	255	273	283	78	1,500	1,510	1,620	1,470	0.270	69	74	76	21	405	407	437	397
11	2006	255	273	283	78	1,500	1,510	1,620	1,470	0.237	60	64	67	18	355	357	383	348
12	2007	255	273	283	78	1,500	1,510	1,620	1,470	0.208	53	57	59	16	311	313	336	305
13	2008	955	973	983	778	1,500	1,510	1,620	1,470	0.182	174	177	179	142	273	275	295	268
14	2009	255	273	283	78	1,500	1,510	1,620	1,470	0.160	41	44	45	12	240	241	259	235
15	2010	255	273	283	78	1,500	1,510	1,620	1,470	0.140	36	38	40	11	210	212	227	206
16	2011	2,555	2,573	2,583	2,378	1,500	1,510	1,620	1,470	0.123	314	316	317	292	184	186	199	181
17	2012	255	273	283	78	1,500	1,510	1,620	1,470	0.108	27	29	30	8	162	163	175	158
18	2013	255	273	283	78	1,500	1,510	1,620	1,470	0.095	24	26	27	7	142	143	153	139
19	2014	255	273	283	78	1,500	1,510	1,620	1,470	0.083	21	23	23	6	124	125	134	122
20	2015	955	973	983	778	1,500	1,510	1,620	1,470	0.073	69	71	71	57	109	110	118	107
21	2016	255	273	283	78	1,500	1,510	1,620	1,470	0.064	16	17	18	5	96	96	103	94
22	2017	255	273	283	78	1,500	1,510	1,620	1,470	0.056	14	15	16	4	84	85	91	82
23	2018	255	273	283	78	1,500	1,510	1,620	1,470	0.049	13	13	14	4	74	74	80	72
24	2019	255	273	283	78	1,500	1,510	1,620	1,470	0.043	11	12	12	3	65	65	70	63
25	2020	255	273	283	78	1,500	1,510	1,620	1,470	0.038	10	10	11	3	57	57	61	56
26	2021	2,555	2,573	2,583	2,378	1,500	1,510	1,620	1,470	0.033	85	85	86	79	50	50	54	49
27	2022	955	973	983	778	1,500	1,510	1,620	1,470	0.029	28	28	29	23	44	44	47	43
28	2023	255	273	283	78	1,500	1,510	1,620	1,470	0.026	7	7	7	2	38	39	41	37
29	2024	255	273	283	78	1,500	1,510	1,620	1,470	0.022	6	6	6	2	34	34	36	33
30	2025	255	273	283	78	1,500	1,510	1,620	1,470	0.020	5	5	6	2	29	30	32	29
31	2026	255	273	283	78	1,500	1,510	1,620	1,470	0.017	4	5	5	1	26	26	28	25
32	2027	255	273	283	78	1,500	1,510	1,620	1,470	0.015	4	4	4	1	23	23	24	22
Total		152,230	148,188	133,548	127,218	264,500	265,450	282,900	276,550		82,386	79,816	71,155	69,927	124,878	125,278	133,401	131,605

Table 7.1.4 Conversion to Economic Cost from Financial Cost

4 lanes, 3.3 Vertical Grade, Tunnel and Bridge Unit: US$ 1,000

lternative & Work	Investment Costs In Market Prices	Foreign Portion	Local Portion					Overall Conversion Factor	Investment Costs in Economic Prices
			Tradable Goods	Non-tradal Goods	Skilled Labor	Unskilled Labor	Transfer (Tax)		
		1.000	1.000	0.97	0.98	0.27	0		
Qntara Tunnel									
Tunnel &	166,173	48%	4%	3%	24%	16%	5%	78%	129,200
Access Rc	10,927	16%	5%	3%	43%	28%	5%	69%	7,497
Indirect/	35,400	80%	3%	3%	5%	4%	5%	87%	30,759
Engineeri	14,200	87%			8%		5%	90%	12,757
Land Acqu	300			100%				97%	291
Total	227,000								180,504
Ferdan Tunnel									
Tunnel &	166,173	48%	4%	3%	24%	16%	5%	78%	129,200
Access Rc	11,427	16%	5%	3%	43%	28%	5%	69%	7,840
Indirect/	35,500	80%	3%	3%	5%	4%	5%	87%	30,846
Engineeri	14,200	87%			8%		5%	90%	12,757
Land Acqu	400			100%				97%	388
Total	227,700								181,031
IsmailiyaTunnel									
Tunnel &	174,414	48%	4%	3%	24%	16%	5%	78%	135,607
Access Rc	14,686	16%	5%	3%	43%	28%	5%	69%	10,076
Indirect/	37,800	80%	3%	3%	5%	4%	5%	87%	32,844
Engineeri	15,100	87%			8%		5%	90%	13,566
Land Acqu	400			100%				97%	388
Total	242,400								192,481
Srabuiom Tunnel									
Tunnel &	174,414	48%	4%	3%	24%	16%	5%	78%	135,607
Access Rc	12,886	16%	5%	3%	43%	28%	5%	69%	8,841
Indirect/	37,500	80%	3%	3%	5%	4%	5%	87%	32,584
Engineeri	14,900	87%			8%		5%	90%	13,386
Land Acqu	100			100%				97%	97
Total	239,800								190,515
Qntara Bridge									
Main&Acce	102,816	73%	5%	3%	8%	6%	5%	85%	87,774
Access Rc	3,784	26%	9%	4%	34%	22%	5%	73%	2,768
Indirect/	21,300	28%	40%	18%	5%	4%	5%	86%	18,412
Engineeri	10,700	87%			8%		5%	90%	9,613
Land Acqu	300			100%				97%	291
Total	138,900							86%	118,857
Ferdan Bridge									
Main&Acce	99,365	73%	5%	3%	8%	6%	5%	85%	84,828
Access Rc	3,735	26%	9%	4%	34%	22%	5%	73%	2,732
Indirect/	20,600	28%	40%	18%	5%	4%	5%	86%	17,807
Engineeri	10,300	87%			8%		5%	90%	9,254
Land Acqu	400			100%				97%	388
Total	134,400							86%	115,008
IsmailiyaBridge									
Main&Acce	87,822	73%	5%	3%	8%	6%	5%	85%	74,974
Access Rc	3,778	26%	9%	4%	34%	22%	5%	73%	2,763
Indirect/	18,300	28%	40%	18%	5%	4%	5%	86%	15,819
Engineeri	9,200	87%			8%		5%	90%	8,265
Land Acqu	400			100%				97%	388
Total	119,500							86%	102,209
Srabuiom Bridge									
Main&Acce	89,845	73%	5%	3%	8%	6%	5%	85%	76,701
Access Rc	1,455	26%	9%	4%	34%	22%	5%	73%	1,064
Indirect/	18,000	28%	40%	18%	5%	4%	5%	86%	15,559
Engineeri	9,100	87%			8%		5%	90%	8,175
Land Acqu	100			100%				97%	97
Total	118,500							86%	101,597

Table 7.1.5 Yearly Allocation of Construction Costs

4%, Ecomonic Price Unit: US$ 1,000

Bridge		Quantra	Ferdan	Ismailiya	Srabuion
Total Cost	%	105,575	100,760	89,905	89,202
1st Year	0.02	2,112	2,015	1,798	1,784
2nd Year	0.24	25,338	24,182	21,577	21,408
3rd Year	0.35	36,951	35,266	31,467	31,221
4th Year	0.33	34,840	33,251	29,669	29,437
5th Year	0.06	6,335	6,046	5,394	5,352
Tunnel		Quantra	Ferdan	Ismailiya	Srabuion
Total Cost	%	166,298	166,756	175,120	172,998
1st Year	0.02	3,326	3,335	3,502	3,460
2nd Year	0.18	29,934	30,016	31,522	31,140
3rd Year	0.20	33,260	33,351	35,024	34,600
4th Year	0.21	34,923	35,019	36,775	36,330
5th Year	0.21	34,923	35,019	36,775	36,330
6th Year	0.18	29,934	30,016	31,522	31,140

Table 7.1.6 Comparison of Discounted Present Value of Economic Costs

(4 Lanes, 3.3% Vertical Grade, Bridge and Tunnel) Unit: US$ 1000

	Year	Construction and Maintenance Costs								Discount	Discounted Construction and Maintenance Costs							
		Bridge				Tunnel					Bridge				Tunnel			
		Qantara	Ferdan	Ismailiy	Srabuiom	Qantara	Ferdan	Ismailiy	Srabuiom	12.00%	Qantara	Ferdan	Ismaili	Srabuiom	Qantara	Ferdan	Ismailiy	Srabuiom
1	1996	0	0	0	0	0	0	0	0	0.893	0	0	0	0	0	0	0	0
2	1997	2,377	2,300	2,044	2,032	3,610	3,621	3,850	3,810	0.797	1,895	1,834	1,630	1,620	2,878	2,886	3,069	3,038
3	1998	28,526	27,602	24,530	24,383	32,491	32,586	34,647	34,293	0.712	20,304	19,647	17,460	17,356	23,126	23,194	24,661	24,409
4	1999	41,600	40,253	35,773	35,559	36,101	36,206	38,496	38,103	0.636	26,438	25,581	22,734	22,598	22,943	23,010	24,465	24,215
5	2000	39,223	37,953	33,729	33,527	37,906	38,017	40,421	40,008	0.567	22,256	21,535	19,139	19,024	21,509	21,572	22,936	22,702
6	2001	7,131	6,900	6,133	6,096	37,906	38,017	40,421	40,008	0.507	3,613	3,496	3,107	3,088	19,204	19,260	20,479	20,269
7	2002	214	229	237	65	32,491	32,586	34,647	34,293	0.452	97	104	107	29	14,697	14,740	15,672	15,512
8	2003	214	229	237	65	1,260	1,268	1,361	1,235	0.404	87	92	96	26	509	512	550	499
9	2004	214	229	237	65	1,260	1,268	1,361	1,235	0.361	77	83	86	23	454	457	491	445
10	2005	214	229	237	65	1,260	1,268	1,361	1,235	0.322	69	74	76	21	406	408	438	398
11	2006	214	229	237	65	1,260	1,268	1,361	1,235	0.287	62	66	68	19	362	365	391	355
12	2007	214	229	237	65	1,260	1,268	1,361	1,235	0.257	55	59	61	17	323	326	349	317
13	2008	802	817	825	653	1,260	1,268	1,361	1,235	0.229	184	187	189	150	289	291	312	283
14	2009	214	229	237	65	1,260	1,268	1,361	1,235	0.205	44	47	48	13	258	260	278	253
15	2010	214	229	237	65	1,260	1,268	1,361	1,235	0.183	39	42	43	12	230	232	249	226
16	2011	2,146	2,161	2,169	1,997	1,260	1,268	1,361	1,235	0.163	350	352	354	326	206	207	222	201
17	2012	214	229	237	65	1,260	1,268	1,361	1,235	0.146	31	33	35	9	184	185	198	180
18	2013	214	229	237	65	1,260	1,268	1,361	1,235	0.130	28	30	31	8	164	165	177	161
19	2014	214	229	237	65	1,260	1,268	1,361	1,235	0.116	25	27	28	8	146	147	158	143
20	2015	802	817	825	653	1,260	1,268	1,361	1,235	0.104	83	85	86	68	131	131	141	128
21	2016	214	229	237	65	1,260	1,268	1,361	1,235	0.093	20	21	22	6	117	117	126	114
22	2017	214	229	237	65	1,260	1,268	1,361	1,235	0.083	18	19	20	5	104	105	112	102
23	2018	214	229	237	65	1,260	1,268	1,361	1,235	0.074	16	17	17	5	93	94	100	91
24	2019	214	229	237	65	1,260	1,268	1,361	1,235	0.066	14	15	16	4	83	84	90	81
25	2020	214	229	237	65	1,260	1,268	1,361	1,235	0.059	13	13	14	4	74	75	80	73
26	2021	2,146	2,161	2,169	1,997	1,260	1,268	1,361	1,235	0.053	113	113	114	105	66	67	71	65
27	2022	802	817	825	653	1,260	1,268	1,361	1,235	0.047	38	38	39	31	59	59	64	58
28	2023	214	229	237	65	1,260	1,268	1,361	1,235	0.042	9	10	10	3	53	53	57	52
29	2024	214	229	237	65	1,260	1,268	1,361	1,235	0.037	8	9	9	2	47	47	51	46
30	2025	214	229	237	65	1,260	1,268	1,361	1,235	0.033	7	8	8	2	42	42	45	41
31	2026	214	229	237	65	1,260	1,268	1,361	1,235	0.030	6	7	7	2	38	38	41	37
32	2027	214	229	237	65	1,260	1,268	1,361	1,235	0.027	6	6	6	2	34	34	36	33
Total		130,050	126,591	114,001	108,916	212,004	212,741	226,501	221,385		76,002	73,649	65,659	64,586	108,827	109,162	116,109	114,526

Table 7.1.7 Data Sheet for Vehicle Operating Cost Calculation

Unit : LE

Items	Passenger Car	Peugeot	Pick-up-car (Seats)	Medium Bus (Seats)	Large Bus (Seats)	Super Dx. Bus (Air Condition)	M. Truck (8 Ton)	H. Truck (15 Ton)	SemiTrailer (25 Ton)	Truk-Trailer (20 Ton)	Trai-Trailer (30 Ton)	TrailerWagon (25 Ton)
Vehicle Price(excl. Tyres)Fin-L.E.	39,000.00	95,150.00	47,575.00	220,000.00	395,000.00	1,350,000.00	119,350.00	169,400.00	218,000.00	182,520.00	218,000.00	42,160.00
Vehicle Price(excl. Tyres)Econ-L.E.	35,450.00	86,500.00	38,360.00	200,000.00	311,000.00	1,000,000.00	108,500.00	154,000.00	168,990.00	152,100.00	168,990.00	34,980.00
Vehicle Life-Years	13.00	7.00	13.00	10.00	10.00	10.00	16.00	12.00	11.00	13.00	12.00	11.00
Vehicle Life Km	234,000.00	588,000.00	390,000.00	1,000,000.00	1,000,000.00	1,000,000.00	880,000.00	600,000.00	715,000.00	845,000.00	780,000.00	715,000.00
Vehicle Annual Km	18,000.00	84,000.00	30,000.00	100,000.00	100,000.00	100,000.00	55,000.00	50,000.00	65,000.00	65,000.00	65,000.00	65,000.00
Vehicle Life Operating Hours	7,800.00	11,760.00	7,800.00	20,000.00	20,000.00	20,000.00	17,600.00	12,000.00	14,300.00	16,900.00	15,600.00	11,000.00
Vehicle Annual Operating Hours	600.00	1,680.00	600.00	2,000.00	2,000.00	2,000.00	1,100.00	1,000.00	1,300.00	1,300.00	1,300.00	1,000.00
Fuel Price Fin-L.E./Liter	0.920	0.920	0.580	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
Fuel Price Econ-L.E./Liter	0.967	0.967	0.748	0.624	0.624	0.624	0.624	0.624	0.624	0.624	0.624	0.624
Fuel Consumption -Liter/Km	0.080	0.090	0.110	0.173	0.235	0.350	0.165	0.279	0.589	0.391	0.713	0.270
Tyre Unit Price Fin-L.E./Price	119.75	159.50	162.50	211.50	291.00	426.37	561.75	658.25	754.75	682.50	526.25	608.00
Tyre Unit Price Econ-L.E/Price	131.73	175.45	178.75	232.65	320.10	469.01	617.93	724.08	830.23	750.75	578.88	668.80
Number of Tyres	4.00	4.00	4.00	6.00	6.00	6.00	6.00	10.00	14.00	14.00	18.00	14.00
Tyre Life -Km	30,000.00	40,000.00	30,000.00	65,000.00	65,000.00	65,000.00	55,000.00	55,000.00	65,000.00	65,000.00	65,000.00	55,000.00
Lubricants Price Fin-L.E./Liter	3.344	3.080	3.080	3.080	3.080	3.080	3.080	3.080	3.080	3.080	3.080	3.080
Lubricants Price Econ-L.E./Liter	3.040	2.800	2.800	2.800	2.800	2.800	2.800	2.800	2.800	2.800	2.800	2.800
Lubri. Oil Consmption-Liter/1000km	2.83	3.40	3.97	6.95	10.67	15.38	5.00	9.45	12.73	9.45	12.73	9.45
Maintenance Spares/Year-%	10.00	10.00	11.00	14.00	11.00	7.00	9.00	7.00	7.00	8.00	7.00	7.00
Maintenance Labor-Hour/1000km	2.00	2.50	3.00	15.00	15.00	15.00	12.00	15.00	15.00	15.00	15.00	15.00
Maintenance Labor Cost Fin-L.E./Hou	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
Maintenance Labor Cost Econ-L.E./Ho	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
Depreciation.Distance Related-%	50.00	50.00	70.00	85.00	85.00	85.00	70.00	70.00	70.00	70.00	70.00	70.00
Depreciation Time Related-%	50.00	50.00	30.00	15.00	15.00	15.00	30.00	30.00	30.00	30.00	30.00	30.00
Opportunity Cost of Capital-%	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Real Rate of Interest of Capital-%	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Overhead Cost /Annum Fin-L.E	219.62	848.59	643.91	23,024.44	30,734.39	67,869.82	14,407.62	22,810.68	33,974.44	23,681.23	34,185.71	10,039.33
Overhead Cost /Annum Econ-L.E	219.62	848.59	643.91	23,024.44	30,734.39	67,869.82	12,500.78	18,876.64	32,822.93	23,717.40	33,420.57	10,434.64
Registration Fee(License)/Annum-L.E	66.00	84.00	96.00	380.00	440.00	198.00	506.00	930.00	494.00	585.00	1,001.00	60.00
Registration Fee(Insurance)/Annum-L	24.00	50.40	48.00	120.00	180.00	120.00	132.00	220.00	338.00	130.00	221.00	0.00
Crew-Number(Driver)	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
Crew-Number(Assistant)	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
Crew Unit Cost Fin-L.E./Hour	0.00	3.66	10.25	4.68	5.71	8.52	11.18	12.30	12.84	10.81	12.84	2.64
Crew Unit Cost Econ-L.E./Hour	0.00	3.66	10.25	4.68	5.71	8.52	11.18	12.30	12.84	10.81	12.84	2.64
Registration Fee(Insurance)												

Table 7.1.8 Average Time Value by Vehicle Type by Crossing Points

	Qantara	Ferdan	No. 6	Srabuiom	Shatt	A. H	Vehicle Hour Value
	%	%	%	%	%	%	LE
P. Car	26. 24	7. 10	34. 29	14. 42	5. 12	21. 84	3. 708
Taxi	18. 46	1. 35	10. 16	1. 24	0. 00	10. 90	11. 561
m. bus	4. 34	2. 70	11. 22	2. 69	1. 40	11. 72	18. 105
pick up	33. 48	9. 12	33. 02	48. 30	6. 06	14. 61	15. 677
l. bus	2. 41	4. 39	3. 39	0. 00	0. 00	9. 39	43. 033
l. truk	12. 66	2. 20	3. 17	4. 53	2. 80	12. 07	27. 331
h. truk	0. 00	72. 14	0. 00	18. 95	82. 46	19. 40	34. 948
tractor	0. 12	0. 00	0. 21	2. 61	0. 00	0. 00	31. 899
oters	2. 29	1. 00	4. 54	7. 26	2. 16	0. 07	5. 706
	100. 00	100. 00	100. 00	100. 00	100. 00	100. 00	
	Average Time Value by Vehicle Type By Section					LE/h	
P. Car	0. 973	0. 192	0. 929	0. 390	0. 139	0. 591	
Taxi	2. 134	0. 156	1. 175	0. 143	0. 000	1. 260	
m. bus	0. 786	0. 489	2. 031	0. 487	0. 253	2. 122	
pick up	5. 249	1. 430	5. 177	7. 572	0. 950	2. 290	
l. bus	1. 037	1. 889	1. 459	0. 000	0. 000	4. 041	
l. truk	3. 460	0. 601	0. 866	1. 238	0. 765	3. 299	
h. truk	0. 000	25. 211	0. 000	6. 623	28. 818	6. 780	
tractor	0. 038	0. 000	0. 067	0. 833	0. 000	0. 000	
oters	0. 131	0. 057	0. 259	0. 414	0. 123	0. 004	
	13. 808	30. 026	11. 962	17. 700	31. 049	20. 387	

Table 7.1.9 Component of Vehicle & Trip Purpose

% of Vehicle for Pas.	Qantara	Ferdan	No. 6	Srabuiom	Shatt	A. H
	%	%	%	%	%	%
P. Car	26. 24	7. 10	34. 29	14. 42	5. 12	21. 84
Taxi	18. 46	1. 35	10. 16	1. 24	0. 00	10. 90
m. bus	4. 34	2. 70	11. 22	2. 69	1. 40	11. 72
pick up	33. 48	9. 12	33. 02	48. 30	6. 06	14. 61
l. bus	2. 41	4. 39	3. 39	0. 00	0. 00	9. 39
	84. 93	24. 66	92. 08	66. 65	12. 58	68. 46
Vehicle Component	%	%	%	%	%	%
P. Car	0. 31	0. 29	0. 37	0. 22	0. 41	0. 32
Taxi	0. 22	0. 05	0. 11	0. 02	0. 00	0. 16
Bus	0. 47	0. 66	0. 52	0. 77	0. 59	0. 52
	100%	100%	100%	100%	100%	100%

Trip Purpose						
To Work	51%	18%	41%	8%	16%	26%
Business	14%	52%	19%	58%	43%	45%
Others	36%	30%	40%	34%	41%	30%
	100%	100%	100%	100%	100%	100%
Productivity of Time	0. 65	0. 71	0. 60	0. 66	0. 59	0. 70

Chapter 9 Design Criteria for Preliminary Design

CHAPTER 9 DESIGN REQUIREMENTS

A9.1 Additional Study of Ship Collision

9.1.1 Ship Collision Force

Ship Collision force will be calculated based on the guide specification of AASHTO.

- Guide Specification and Commentary for Vessel Collision Design of Highway Bridge Volume 1: Final Report February 1991 AASHTO

Ship Collision Forces

$$Ps = 220\,(DWT)^{1/2}\,\frac{V}{27}$$

where; Ps : Equivalent Static Ship Impact Force (kips) (1 kip = 1,000 lbs)
DWT : Deadweight Tonnage of Ship (tonnes)
V : Collision Speed (fps)

(1) Study Vessel

W = 500,000 t (Maximum size vessel of the Suez Canal traffic)

(2) For a Collision Speed

V = 14 km/hr

(3) Collision Force

$$Ps = 220 \times 500{,}000^{1/2} \times \frac{13.67}{27} = 83{,}400 \text{ kips} = 38{,}000 \text{ t}$$

$$V = 14 \times 1{,}000 / (3{,}600 \times 0.3048) = 13.67 \text{ fps} = 4.18 \text{ m/sec}$$

Note : 500,000 DWT tanker in full load condition is used for this study. Weight of this tanker in ballast is about 200,000 t and the result of ship collision study in this case may be similar to that of 200,000 DWT ship. (Refer to Paragraph 7.2.3)

9.1.2 Intrusion Distance and Impact Force Distribution

Intrusion distance and impact force distribution have been calculated based on the following parameters assumed.

(1) Calculation Parameters

1) Ship Weight and Size

- Ship Weight : 500,000 DWT
- Ship size : 380 m length, 60 m width, 60 m height and 23 m draft
  (Average width under the surface of the sea is 57.21 m)

W = B → Average width = 500,000 / (380×23.0) = 57.21 m

Where ; W : Deadweight Tonnage of Ship
B : Ship's Buoyancy

2) Ship Collision Forces

F = 38,000 t (83,400 kips)

Deadweight tonnage of ship : 500,000 t and Collision speed : 14 km/hr
Calculated based on the AASHTO Specification (Refer to A9.1.1)

(2) Intrusion Distance

A intrusion distance has assumed that a collision ship stops when collision force and friction force between the collision ship and the surface of Canal bank.

1) Reaction at Bow

$R = W - B = 500{,}000 - (380 - L) \times 57.21 \times 23.0 = 572.1\,L$

Where ; R : Reaction at Bow
W : Deadweight Tonnage of Ship
B : Ship's Buoyancy
L : Intrusion Distance into Bank

2) Intrusion Distance

$F = R \cdot \tan(\phi / 2)$

Where ; ϕ : Coefficient f Internal Friction ($\phi = 40^\circ$; N-Value = 40)

$38,000 = 572.1\ L \times \tan(40/2) = 208.23\ L$

$L = 38,000 / 208.23 = 182.5$ m

3) Horizontal Impact Force Distribution

$H = 2F / (Ws \cdot D)$

Where ; H : Horizontal Impact Force Distribution

F : Ship Collision Force (F = 38,000 t)

Wx : Distribution Width

($Wx = Ws + 2X \cdot \tan(45 - \phi/2) = 60.0 + 0.9326X$ m)

Ws: Ship Width (Ws = 60.0 m)

D : Distribution Depth ($X / (4 / \tan 15^\circ) + X \cdot \tan(45 - \phi/2)$)

X : Distance ahead from Bow of Ship

(Refer to Fig. A9.1.1)

a) At Point A (10 m ahead from Bow of Ship)

$H = 2 \times 38,000 / (69.33 \times 5.33) = 205.67$ t/m²

B = 69.33 m, D = 5.33 m

b) At Point B (20 m ahead from Bow of Ship)

$H = 2 \times 38,000 / (78.65 \times 10.67) = 90.56$ t/m²

B = 78.65 m, D = 10.67 m

c) At Point B (20 m ahead from Bow of Ship)

$H = 2 \times 38,000 / (106.63 \times 26.66) = 26.73$ t/m²

B = 106.63 m, D = 26.66 m

(3) Discussion

As the results of this study, a collision ship is considered to spot before the pier of the bridge crossing the Canal and the distribution force of the ship collision at the pier is expected to be very small because the distance between the collision ship and the pier is very large.

Therefore, ship collision force is not big enough to effect the pier and not necessary to be considered the pier design.

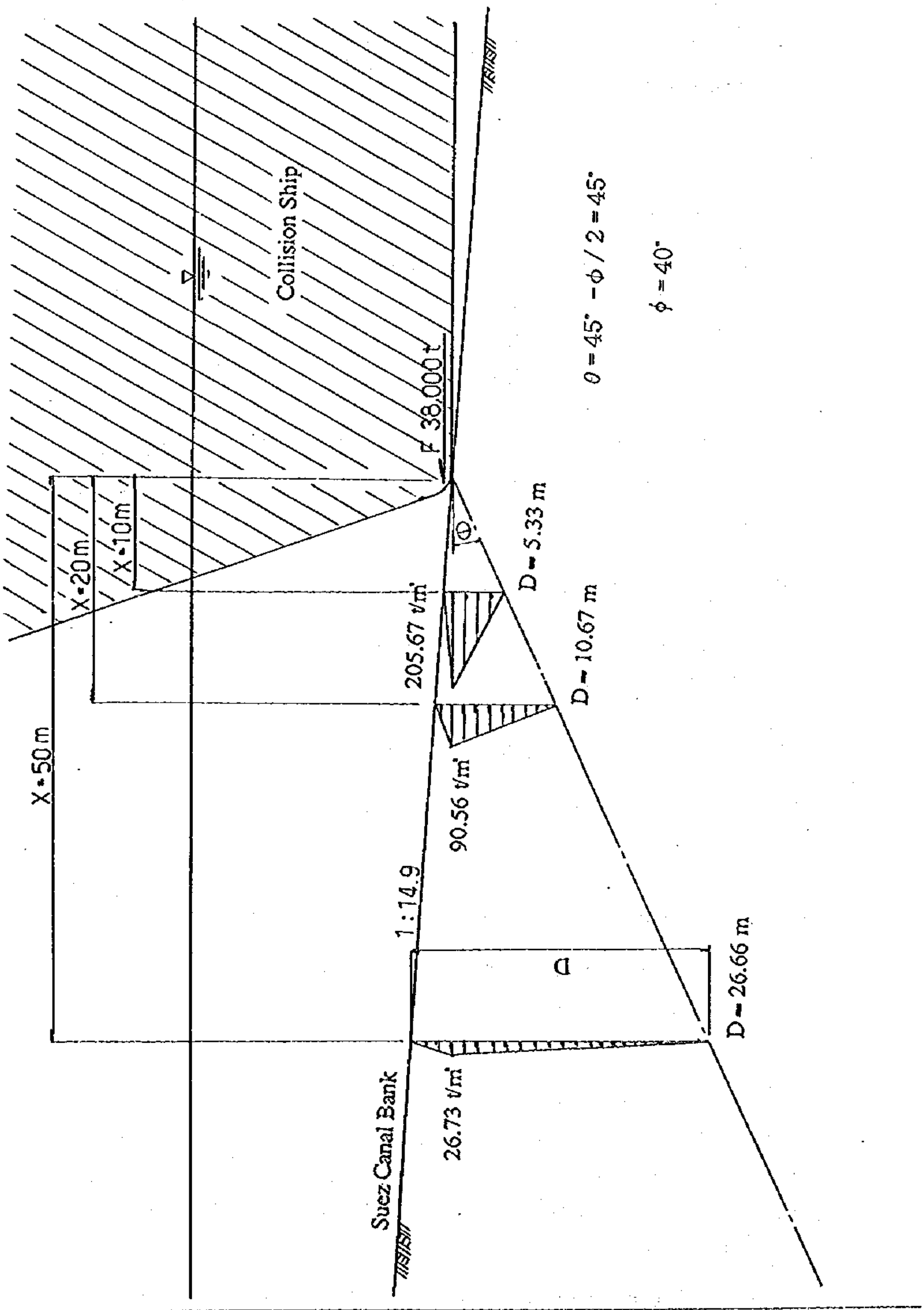


Fig. A9.1.1 Horizontal Impact Force Distribution

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

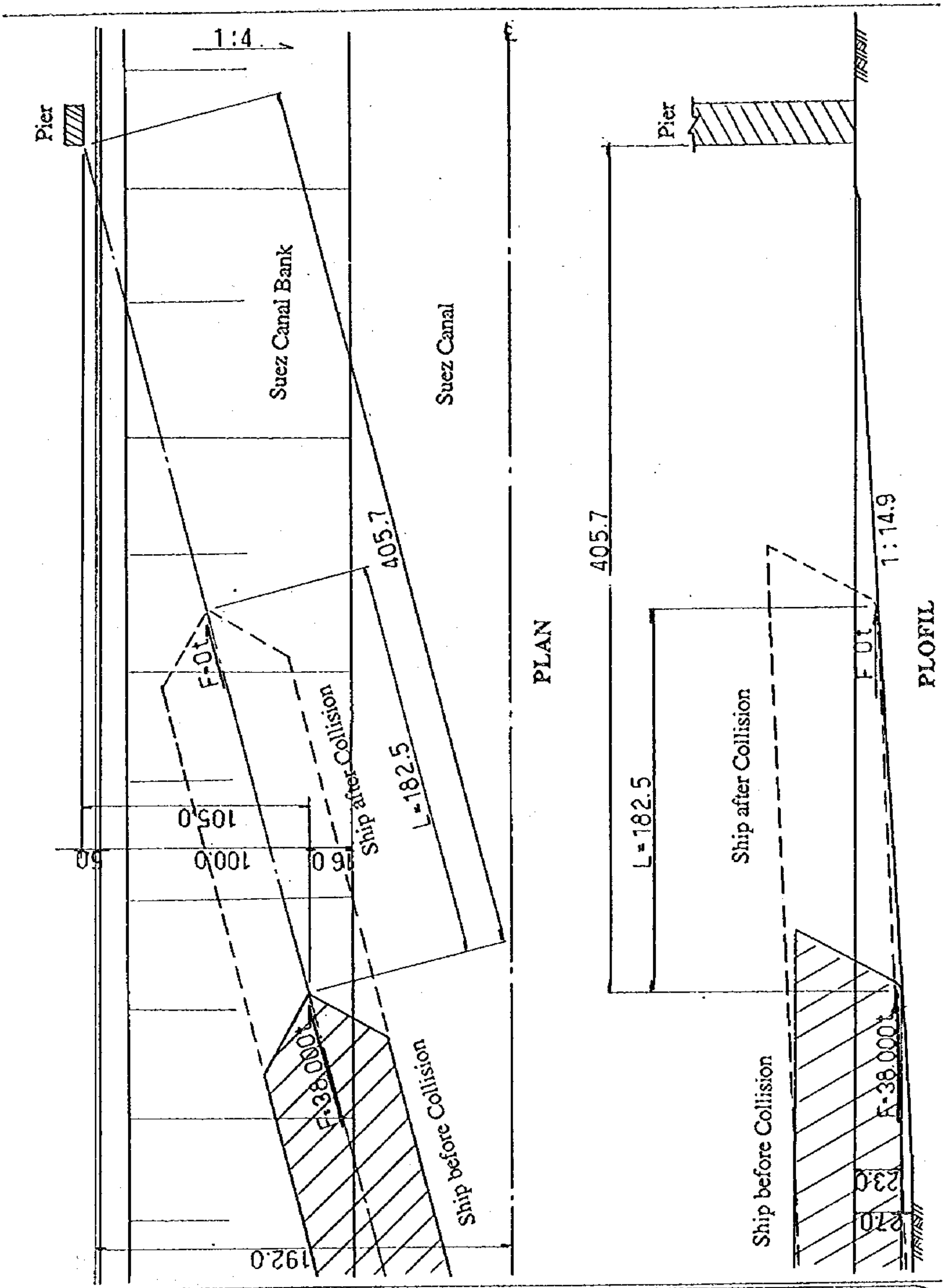


Fig. A9.1.2 Intrusion Distance into the Canal Bank

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

Chapter 10 Geometric Design

CHAPTER 10 GEOMETRIC DESIGN

A10.1 Horizontal and Vertical Alignment

A10.1.1 Connecting Road

(1) General

As a principle, the road crossing the Suez Canal connects onto Cairo - Iamailiya - Port Said Road on the West Bank and New Central Road on the East Bank. However, if the road crossing is connected onto the Cairo - Iamailiya - Port Said Road directly on the West Bank, the road crossing is anticipated to cause some problems.

Thus, the way of connecting onto Cairo - Iamailiya - Port Said Road is studied in this section in order to decide the way of connecting on the West Bank.

(2) Alternatives

The following 4 alternatives of the ways of connecting onto Cairo - Iamailiya - Port Said Road were compared.

- Alternative 1 : Connecting onto Cairo - Iamailiya - Port Said Road indirectly through Abou Souwer - Qantara Road
- Alternative 2 : Connecting onto Cairo - Iamailiya - Port Said Road directly at the south of Abou Souwer - Qantara Road
- Alternative 3 : Connecting onto Cairo - Iamailiya - Port Said Road directly at the north of Abou Souwer - Qantara Road
- Alternative 4 : Connecting onto Cairo - Iamailiya - Port Said Road directly at Abou Souwer - Qantara Road

(3) Discussion

The results of the comparison are shown in Table A10.1.1. As a result of the study, Alternative 3 is considered to be the best alternative for the following reasons.

- The construction cost of the road crossing is the cheapest among the above alternatives.
- These are no additional intersections or T-junctions other than the T-junction which connects the road crossing onto Cairo - Iamailiya - Port Said Road.
- Improvement of existing roads is not necessary.

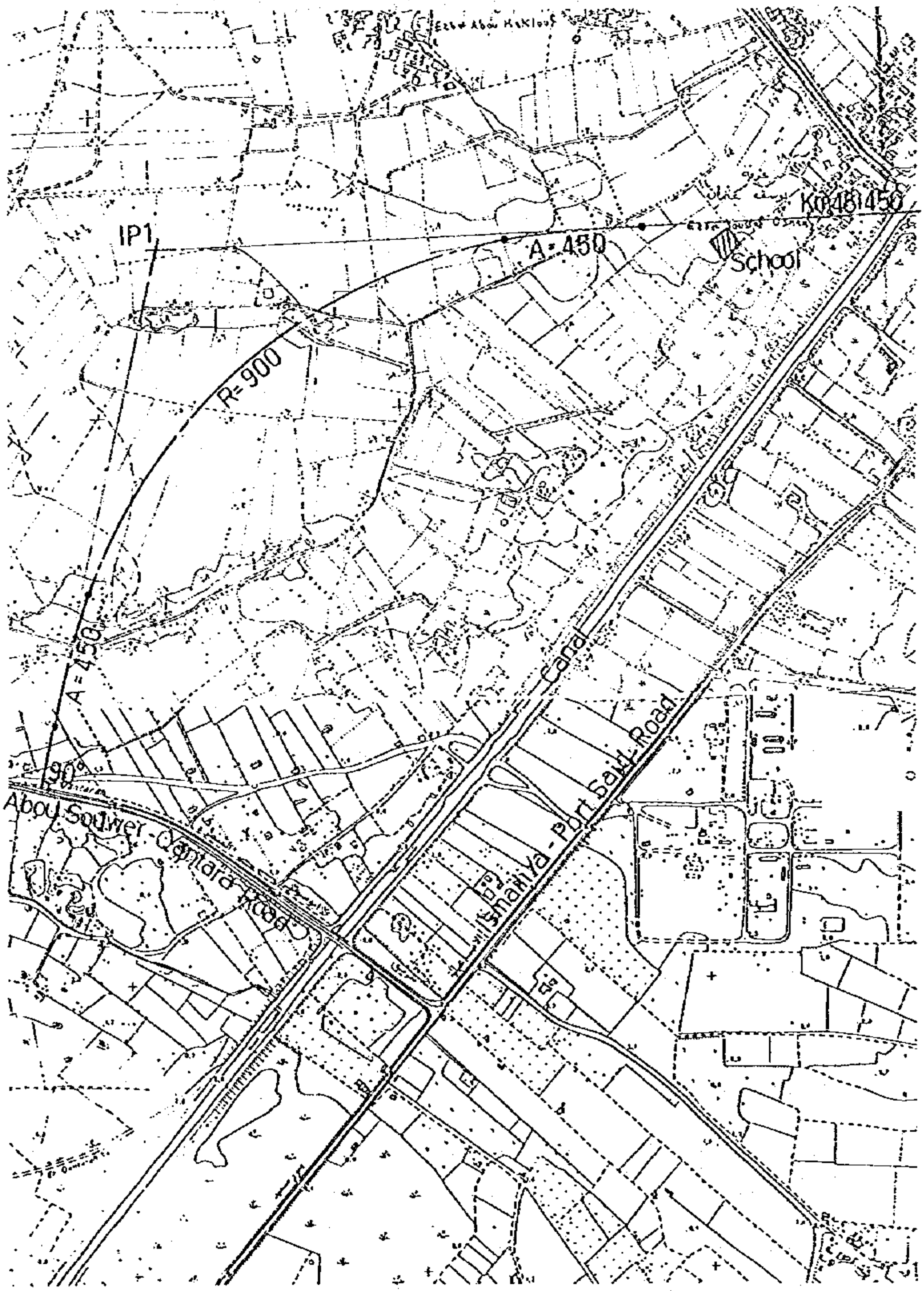


Fig. A10.1.1 Alternative Connecting Road (1)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

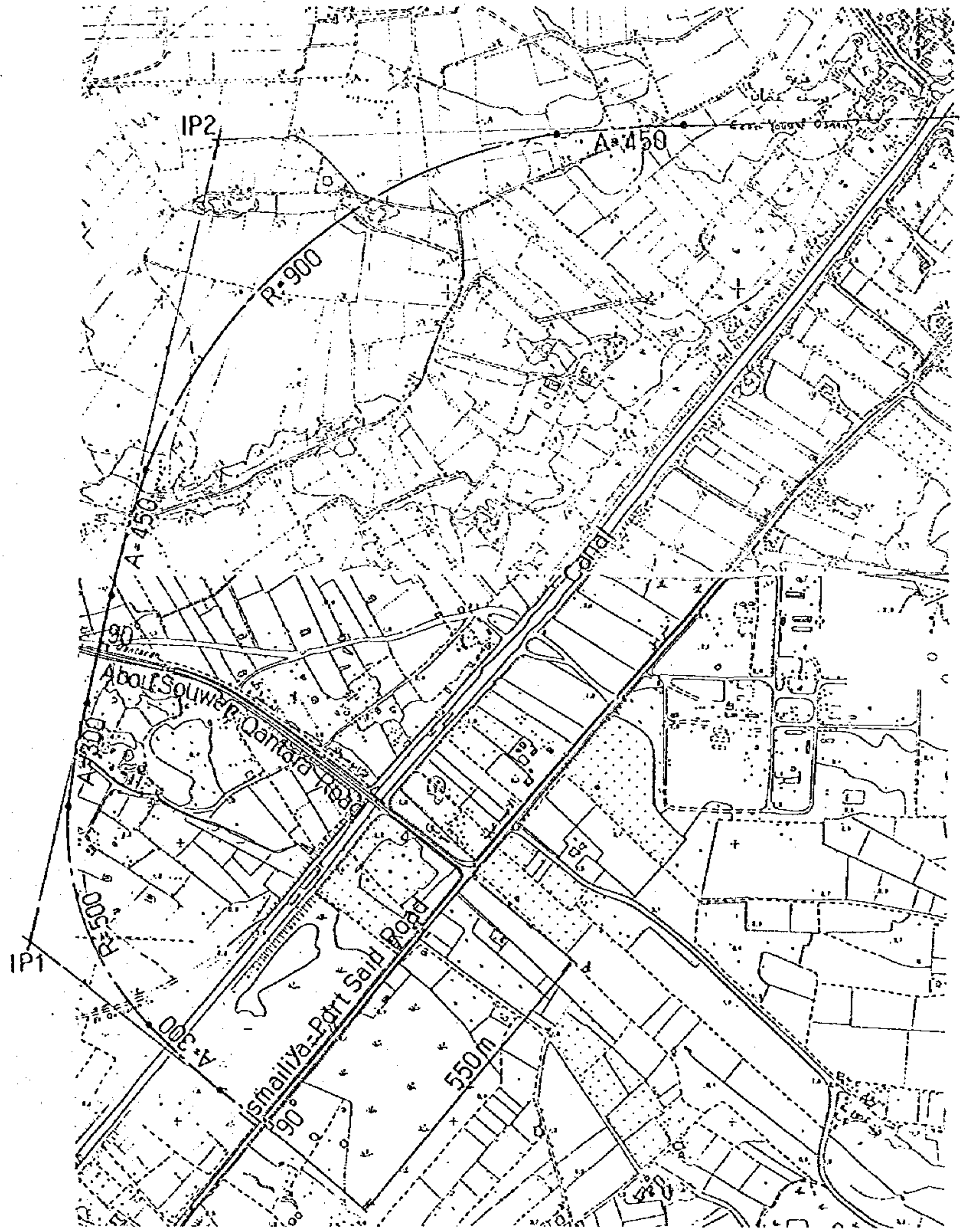


Fig. A10.1.2 Alternative Connecting Road (2)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

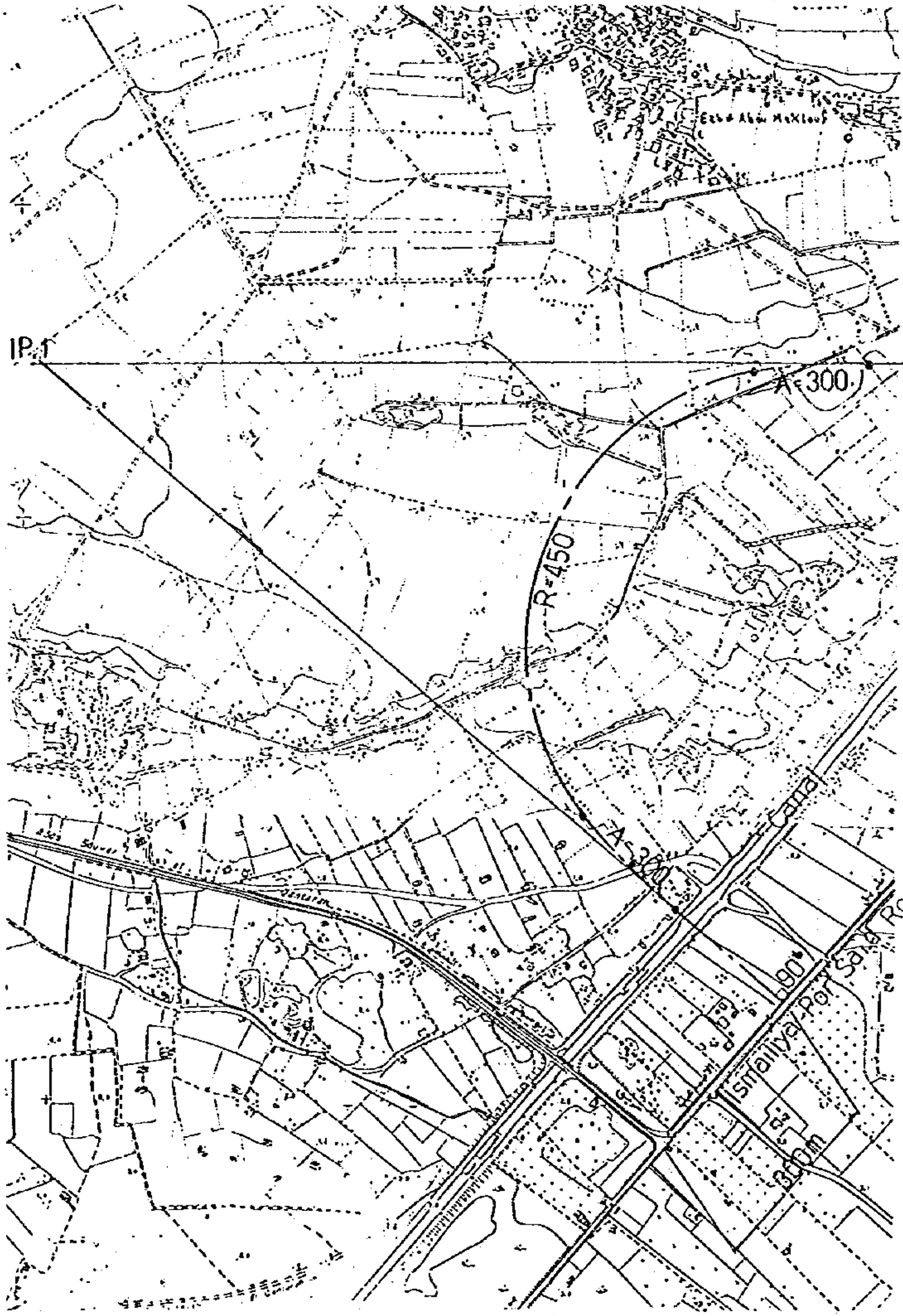


Fig. A10.1.3 Alternative Connecting Road (3)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

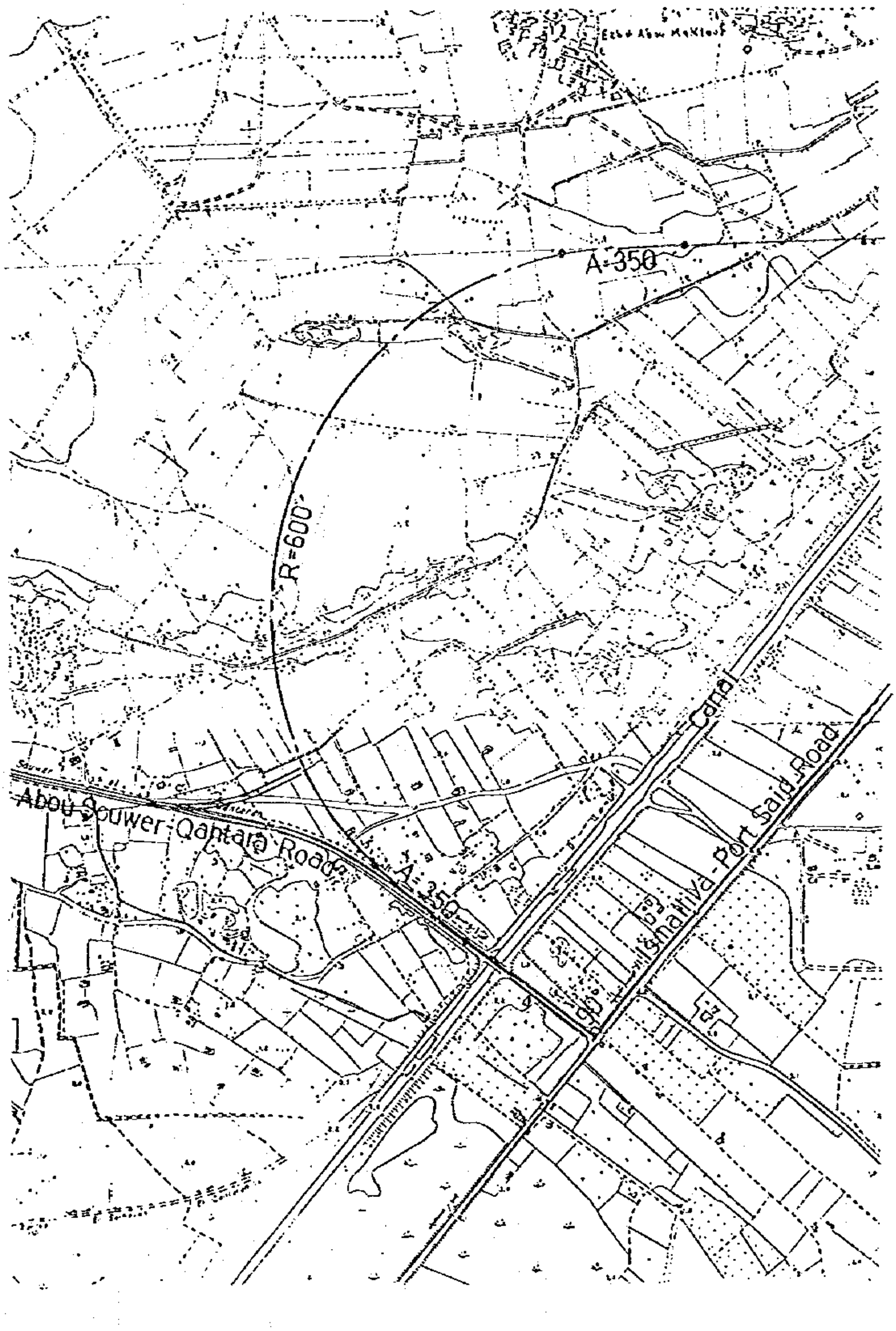
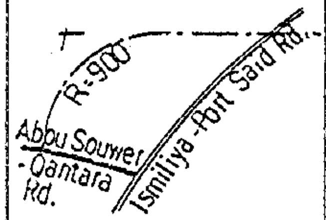
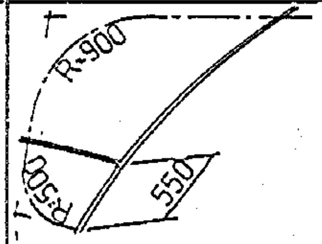
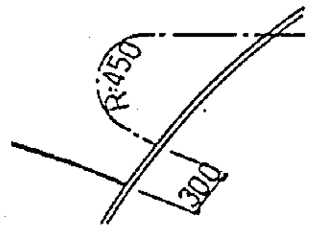
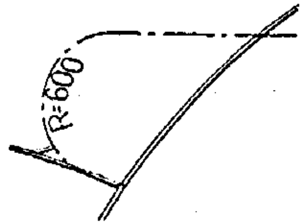


Fig. A10.1.4 Alternative Connecting Road (4)

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

Table A10.1.1 Comparison of Connecting Roads

Alternatives	Horizontal Alignment	Length of Road (m)	Comments	Evaluating							Priority
				Horizont. Align.	Inter Angle	T-Junction	Grade Crossing	Inter-sections	Improve-ment	Const. Cost	
Alternative 1 Abou Souwer - Qantara Road		Newly-build 3,750 Improvement 750 Total 4,500	The road crossing the Canal will be connected onto Abou Souwer - Qantara Road. Abou Souwer - Qabtara Road between the two T junc ions will be expanded from 2 lanes to 4 lanes.	Excellent 900m	Excellent 105°	Inferior (Two T-junctions)	Excellent (No grade crossing)	Excellent (1 iInter-section)	Excellent	Low (2 lane bridge)	Medium
Alternative 2 Ismailiya - Port Said Road 1		Newly-build 4,800 Improvement 0 Total 4,800	The road crossing the Canal will be connected onto Ismailiya - Port Said Road after the grade crossing with Abou Souwer Road at the south of this road.	Good 900m + 500m	Excellent 105° + 115°	Superior (One T-junction)	Poor (1 grade crossing)	Good (Distance between two inter-secsions : 550m)	Good	Highest (4 lane bridge)	Low
Alternative 3 Ismailiya - Port Said Road 2		Newly-build 3,650 Improvement 0 Total 3,650	The road crossing the Canal will be connected onto Ismailiya - Port Said Road at the north of Abou Souwer - Qantara Road.	Good 500m	Medium 40°	Superior (One T-junction)	Excellent (No grade crossing)	Good (Distance between two inter-secsions : 300m)	Medium	Lowest (4 lane bridge)	High
Alternative 4 Ismailiya - Port Said Road 3		Newly-build 4,050 Improvement 400 Total 4,450	The road crossing the Canal will be connected onto Ismailiya - Port Said Road at the T junction between Ismailiya - Port Said Road and Abou Souwer Road.	Good 600m	Medium 40°	Poor (One of two T-junctions is located in a curve section)	Excellent (No grade crossing)	Excellent (1 inter-section)	Medium	Low (2 lane bridge)	Medium

Source : JICA Study Team