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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

GENERAL AUTHORITY FOR ROADS, BRIDGES AND LAND TRANSPORT
MINISTRY OF TRANSPORT AND COMMUNICATIONS
THE GOVERNMENT OF THE ARAB REPUBLIC OF EGYPT

THE DETAILED DESIGN STUDY
ON
THE PROJECT FOR CONSTRUCTION
OF
THE SUEZ CANAL BRIDGE
IN
EGYPT

FINAL REPORT

DETAILED DESIGN REPORT

JANUARY 1997

PACIFIC CONSULTANTS INTERNATIONAL
CHODAI CO., LTD.

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NOTE

The following exchange rate was adopted through this report :

US $ 1.00 = LE 3.4 (November 1996)

PREFACE

In response to a request from the Government of the Arab Republic of Egypt, the Government of Japan decided to conduct a Detailed Design Study on THE PROJECT FOR CONSTRUCTION OF THE SUEZ CANAL BRIDGE and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent a study team to the Republic of Egypt between October 1996 and January 1997. The study team was headed by Mr. Hiroyuki ENDO and composed of members of Pacific Consultants International and Chodai Co., LTD.

The team held discussions with the officials concerned of the Government of the Arab Republic of Egypt, and conducted field surveys at the area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Arab Republic of the Egypt for their close cooperation extended to the team.

January 1997

Kimio FUJITA
President
Japan International Cooperation Agency

January 1997

Mr. Kimio FUJITA
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

Letter of Transmittal

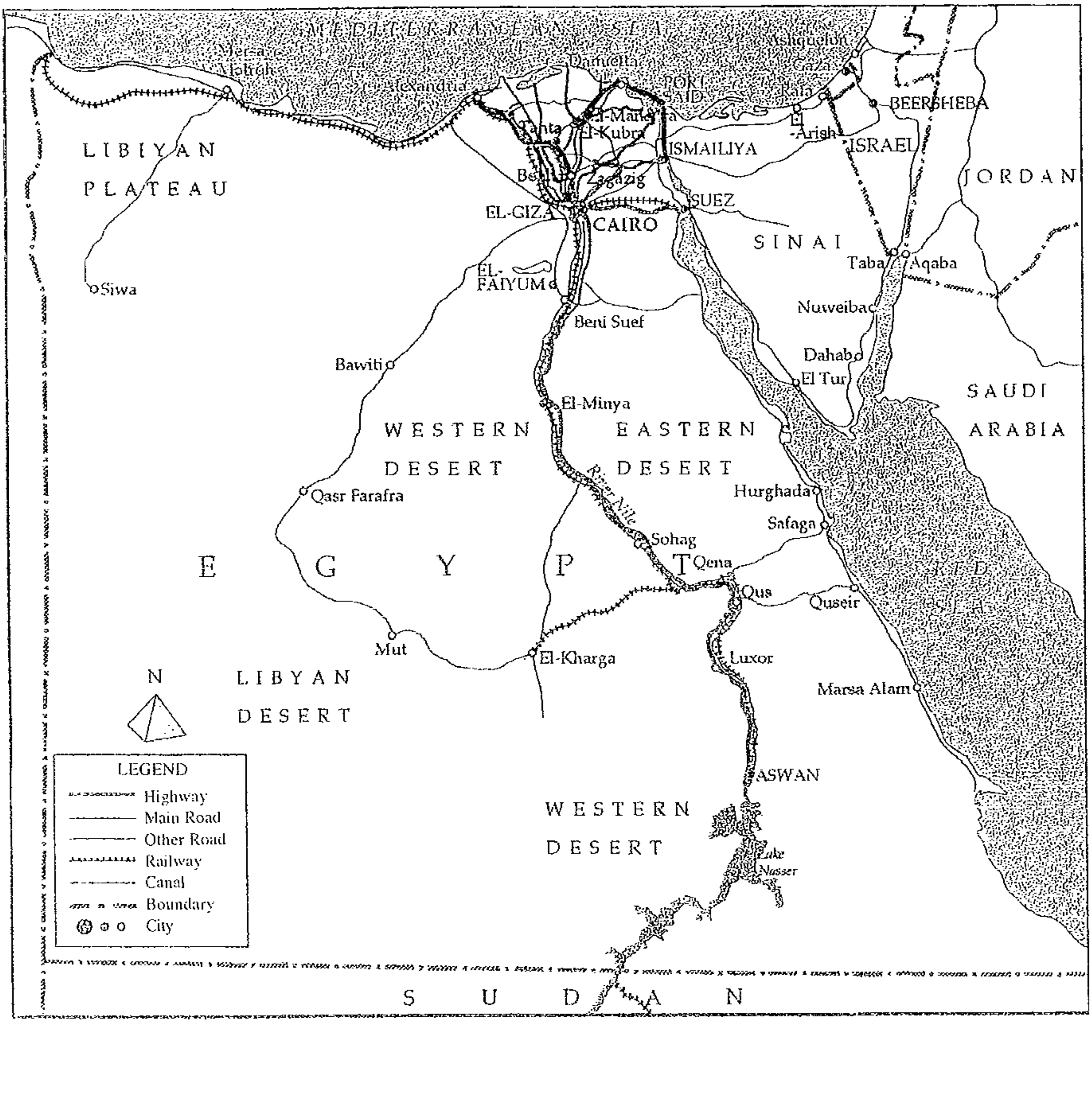
We are pleased to submit you the report on the Detailed Design Study on the Project for Construction of the Suez Canal Bridge in Egypt. The report contains the advice and suggestion of he authorities concerned of the Government of Japan and your Agency as well as the comments made by the Ministry of Transport and Communications, General Authority for Roads, Bridges and Land Transport and the authorities concerned in the Arab Republic of Egypt. The reports consist of six volumes, an Executive Summary, a Detailed Design Report, Design Calculation Reports, Prequalification Documents, Tender Documents and Priced Bill of Quantities. This report presents the Detailed design Study on the Project for Construction of the Suez Canal Bridge in Egypt.

The Sinai Peninsula occupies the North - Eastern quarter of Egypt, and is expected to become the important center of economy, culture and politics with the development of the Sinai Peninsula. We believe that this project will contribute greatly to upgrade the transport system across the area which is presently provided with Ahmed Hamdi Tunnel and six ferry systems crossing the Suez Canal.

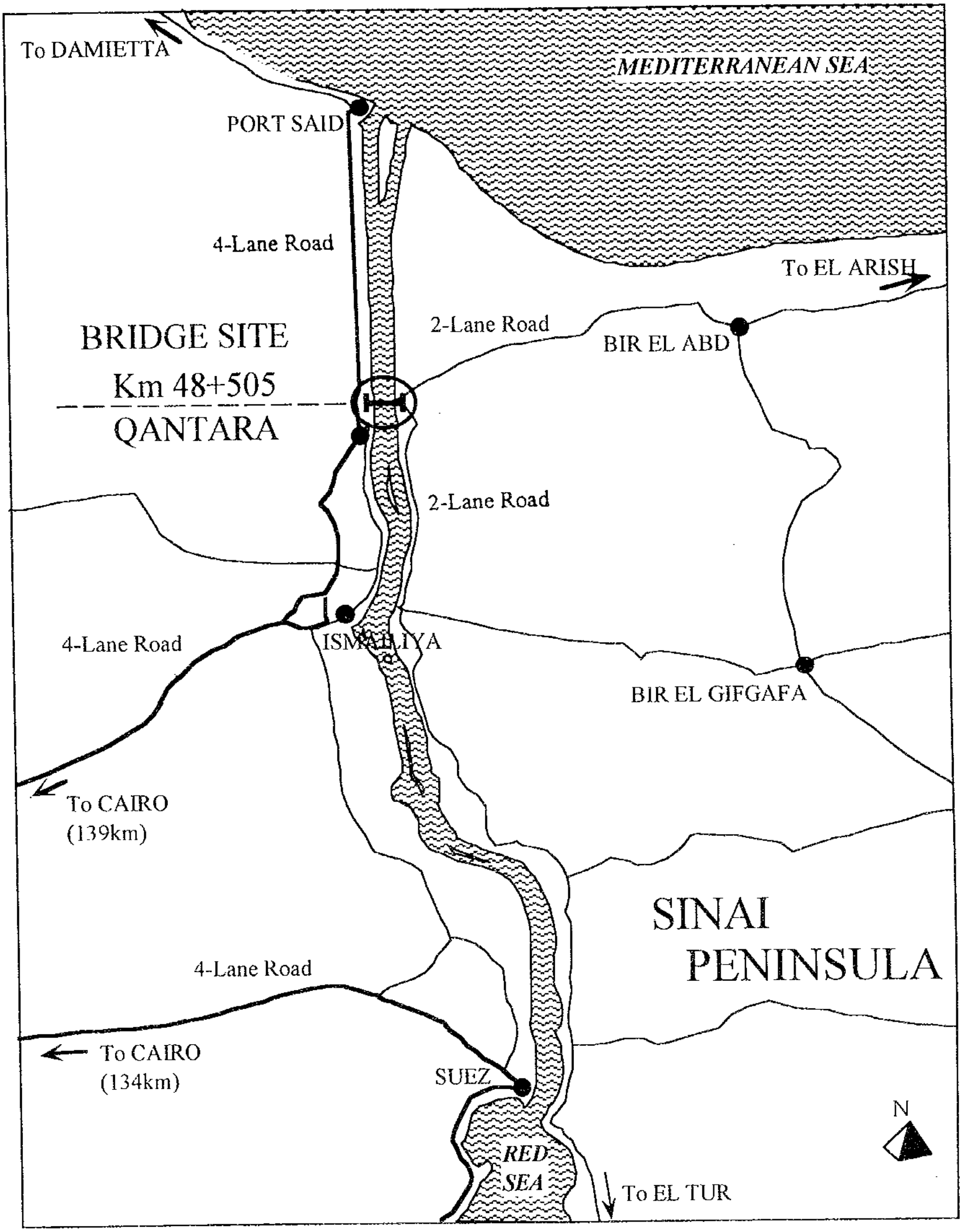
We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs, the Ministry of Construction and the Ministry of Transport. We also wish to express our deep gratitude to the Ministry of Transport and Communications and the Governmental Agencies concerned in the Arab Republic of Egypt, the Japanese Embassy at Egypt for the close cooperation and assistance extended to us during out study. We hope this report will contribute to construct a bridge crossing the Suez Canal at Qantara.

Very truly yours,

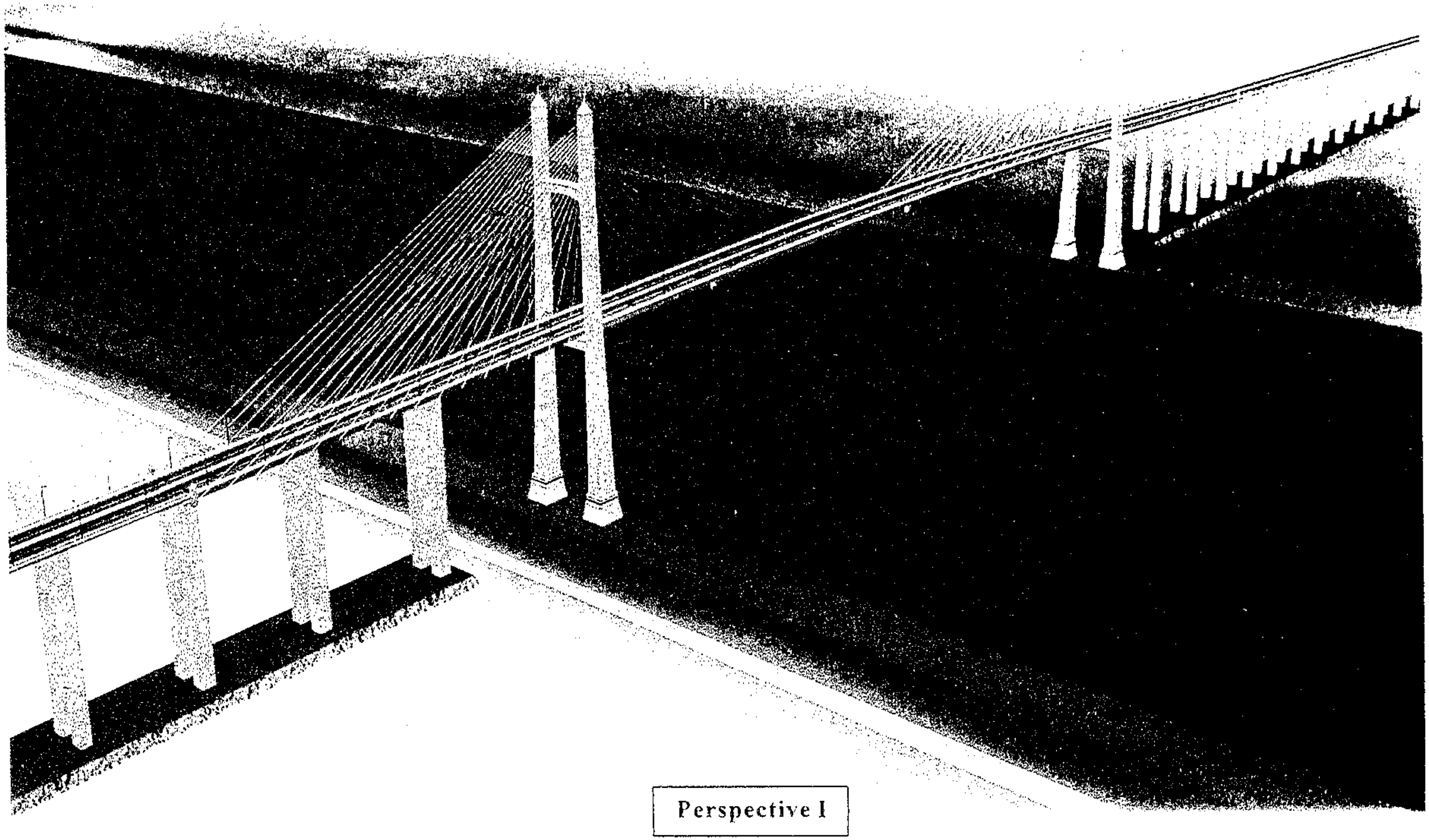
Mr. Hiroyuki ENDO
Team Leader
The Detailed Design Study on the
Project for Construction of the
Suez Canal Bridge in Egypt



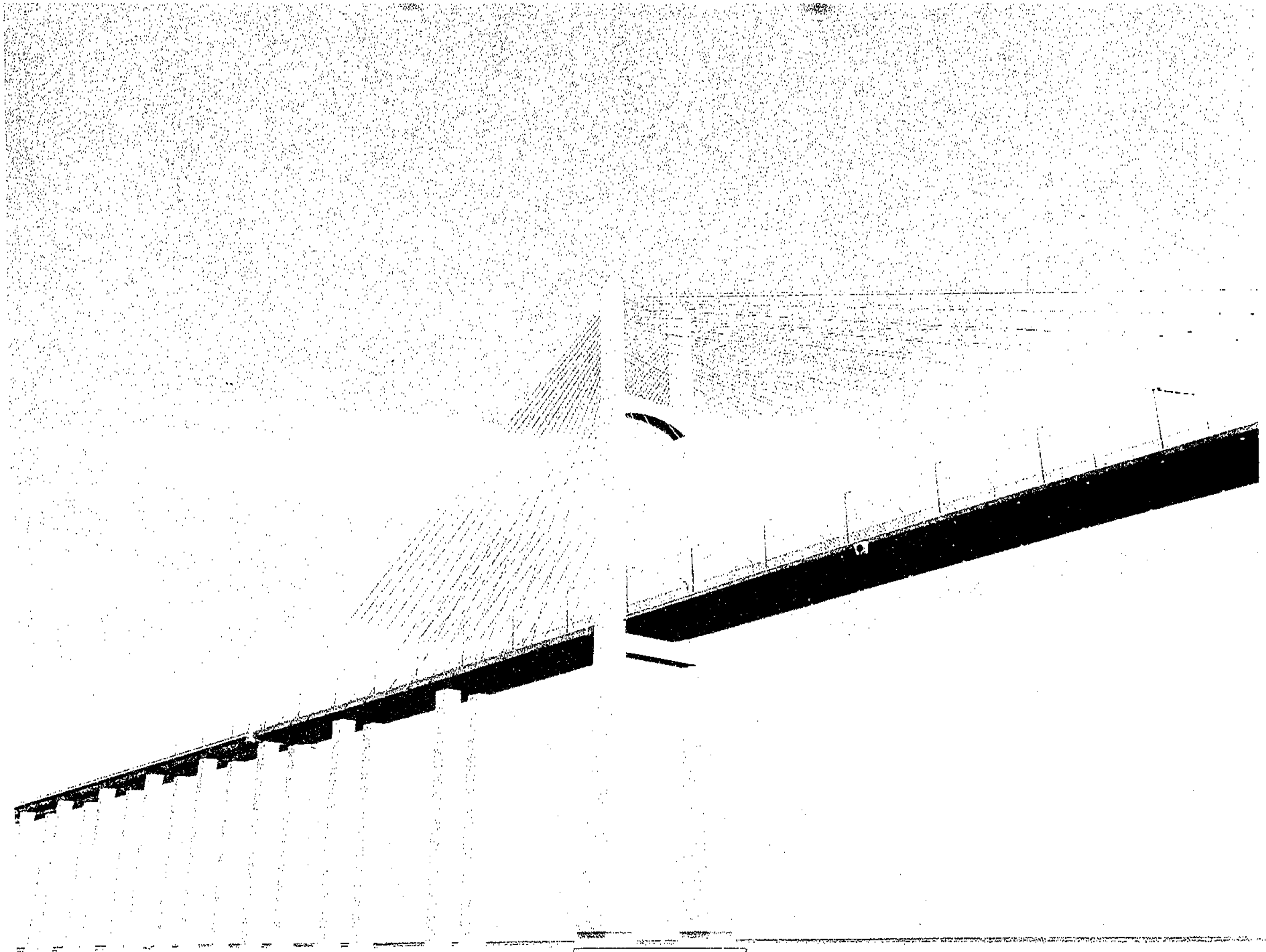
Project Location Map



Project Location Map



Perspective I



Perspective II

Abbreviations

A. Authorities and Agencies

AASHTO	:	American Association of State Highway and Transportation Officials
BS	:	British Standard
GARBLT	:	General Authority for Roads, Bridges and Land Transport
GOPP	:	General Organization for Physical Planning
JICA	:	Japan International Cooperation Agency
MOP	:	Ministry of Planning
MOS	:	Ministry of State
MOTC	:	Ministry of Transport and Communications
SCA	:	Suez Canal Authority
UNDP	:	United Nations Development Program
USAID	:	Unites States Agency for International Development

B. Other Abbreviations

A	:	Ampere
ave.	:	Average
A/P	:	Authorization to Pay
B	:	Breadth
Br	:	Bridge
cm	:	Centimeter
cm^2	:	Square Centimetre
CBR	:	California Bearing Ratio
H	:	Height
HP	:	Horse Power
kg	:	Kilogram
kg/cm^2	:	Kilogram per Square Centimetre
kgf/cm^2	:	Kilogram force per Square Centimetre
kgf/m^3	:	Kilogram force per Cubic metre (force)
kl	:	Kilolitre
km	:	Kilometre
km^2 or sq. km	:	Square Kilometre

km/h	:	Kilometre per Hour
kvA	:	Kilovolt-Ampere
kw	:	Kilowatt
l	:	Litre
LE	:	Egyptian Pound
Min.	:	Minimum
Max.	:	Maximum
m, M	:	Metre
m^2	:	SQ. M : Square Metre
m^3 or cu. m	:	Cubic Metre
min.	:	Minute
mm	:	Millimetre
mm^2	:	Square Millimetre
No.	:	Numbers
sub-str.	:	Substructure
sup-str.	:	Superstructure
t	:	Tonne
t/h	:	Tonne per Hour
t/m^2	:	Tonne per Square Metre
veh.	:	Vehicles
VpD or VPD	:	Vehicles per Day
W	:	Width
%	:	Percent
ø	:	Diametre
$	:	Dollar
¥	:	Yen

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CHAPTER 1

BASIC DESIGN POLICY FOR BRIDGES AND ROADS

CHAPTER 1 BASIC DESIGN POLICY FOR BRIDGES AND ROADS

1.1 Determination of Bridge Location and Bridge Type

In the Feasibility Study the following studies have been made.

(1) Crossing System

1) Future Traffic Demand

Three scenarios of socio-economic developments are considered in this study in order to analyze an appropriate crossing structure for the Suez Canal.
Future traffic demand can be estimated ranging from 6,000 to 33,000 vehicles per day at crossing locations.

2) Number of Lanes

It will be necessary to provide a four lane crossing structure at either Qantara, Ferdan or Ismailiya in 2017 in any socio-economic framework case.

3) How to Provide the Four Lane Crossing Structure

There are two possible methods available of providing a four lane crossing structure . One is to construct a four lane capacity crossing and the other is to construct one two-lane crossing initially, and at a later stage to construct another two-lane crossing at an adjacent location, in order to meet the traffic increase. This is the so- called staged construction method. Using the stage construction method, it should be noted that after completion of the second structure, it will be necessary to revert to a one way flow system on each structure. This is necessitated by the need to rationalize the crossing approach or access road layout, and to ensure a safe efficient and uninterrupted traffic flow pattern.

From the results of evaluation, it is preferable to construct one four lane crossing structure. If two- lane structures are selected, the second two lane crossing structure has to be opened up in 2009 under this condition.

(2) Alternative Structures

Alternative Structures (bridge/tunnel, location and physical configuration) have been compared and the best alternative (cable-stayed bridge with four lanes and 3.3% vertical grade) has been selected for the following reasons.

1) Bridges or Tunnels

From the viewpoint of economic viability, a bridge at the locations of Qantara, Ferdan or Ismailiya, or tunnel at the locations of Ferdan and Ismailiya can be demonstrated to be viable with respected to the Economic Internal Rate of Return of these alternatives.

The estimated costs of tunnels are much higher than the cost of bridge alternatives. Taking account of the massive anticipated financial expenditures for the Sinai Development in the coming two decades, it is essential to minimize expenditure on the infrastructures as far as possible.

Comparing the results of economic and financial factors between these two alternatives, it can be said that the bridge alternatives are more favorable than the tunnel alternatives.

2) Crossing Location

The four possible bridge location alternatives has been compared: Qantara, Ferdan, Ismailiya and Srabuiom, and the results of the comparison are as follows;

a. Traffic Flow and Sinai Development

Comparing the projected future traffic flows of these four locations, Qantara, Ferdan and Ismailiya are expected to have the greatest traffic volumes and to become the most important components of the arterial road network connecting Sinai and the main land Egypt. Expected traffic volume at Qantara, Ferdan and Ismailiya in the year 2017 are 28,800, 33,300 and 32,900 vehicles respectively.

b. Engineering Aspect

From the engineering aspect, no critical difference in engineering problems can be observed between these four alternative locations.

c. Financial Cost / Economic Evaluation

From the results of the EIRR, they rank in the following order of preference.

1. Ismailiya,
2. Ferdan,
3. Qantara, and
4. Srabuiom

d. Navigation Safety

Egyptian National Railway have decided that the new railway swing bridge to be constructed at Ismailiya, and consequently SCA has required that the road bridge be constructed at a different location . The new crossing bridge must be located at least t 3 Km away from the end of the curve of the channel and the new railway bridge, to ensure that there is sufficient stopping distance for the maximum sized vessels in transit on the Canal to avoid the risk of colliding with the bridges. This distance of 3 km, which is six to seven times the length of the maximum sized vessels (about 450m length), has been confirmed as reasonable by the Study Team.

Taking this constraint into consideration, only Qantara and Srabuiom will satisfy these navigation safety requirements.

e. Future Development of the Canal

SCA has a plan to construct second channel to by-pass the channel at Srabuiom in the near future and this will cause a considerable increase in the construction cost of the bridge at Srabuiom.

As the results of all these comparison , Qantara has been selected as the best crossing location because the navigation safety being the main factor dictating the selection of the crossing location.

3) Vertical Grade

When considering the forecast traffic volume for the target year of the plan, a vertical grade of 4% for the bridge would appear to suffice with reference to the international design standards. It should be noted, however, that many of the vehicles currently used in Egypt are overloaded and aged trucks and these vehicles will make up a large percentage of the vehicles crossing the bridge. These factors indicate that it is recommended to design vertical grade of 3.3% for the bridge. In addition, as the heavy vehicle ratio is about 20% of road crossing traffic, the effect on the environment around the crossing including noise and air pollution especially by heavy vehicles will be considerable and hence providing a vertical grade of 3.3% for the bridge should be considered.

(3) Best Alternative

Based on the above study, the following option has been recommended.

Crossing location	:	Qantara
Type of crossing structure	:	Bridge
Number of lanes	:	4 lanes
Vertical grade	:	3.3%

1.2 Selection of Structure Type

1.2.1 Main Bridge

(1) Bridge Type suitable for Main Bridge Superstructure

Steel Arch, Steel Truss, Suspension and Cable Stayed Bridges are all suitable structure for span length of 350 m to 400 m.

Therefore it is necessary to consider the technical and economical aspects and also the existing conditions of the proposed bridge location, such as geographical, topographical, environmental and the Canal navigation channel, as well as the procurement of materials, plant and equipment, safety of the construction works and the easy traffic flow and driving conditions, etc.

i) Steel Arch Bridge

A balanced steel arch bridge with a central elevated road surface would be suitable for the topographical conditions at the proposed bridge site. However when considering the navigation clearance of 70 m high x 384 m wide required, the proposed span length of this type of bridge will be much longer than 384 m, and is not economical.

ii) Steel Truss Bridge

A steel truss bridge with Gerber hinges could be considered, however this type is more expensive than other types for span lengths of around 400 m, and not pleasing in the aesthetic design. Therefore this type is not suitable.

iii) Suspension Bridge

Generally this type of bridge is considered economical for spans in excess of 600 m. It is also necessary to construct an anchorage structure to resist the horizontal force of the cables. Thus when also taking into account the existing geotechnical and topographical conditions at the proposed site, this type is not considered suitable.

iv) Cable Stayed Bridge

Cable stayed bridges have big advantages in their structural, economical and aesthetic characteristics, when compared to other types of bridges. With the development of anti-corrosion systems for the stay cables, the computer aided design, and the efficient construction techniques, cable stayed bridges have been built world-wide, and the span length has been steadily increasing.

After comparison of the above types of structures, the cable stayed bridge was selected as the most suitable type for the Main Bridge of Suez Canal Bridge.

(2) Type of Main Girder

For the type of main girder, the following 3 types have been compared.

i) Prestressed Concrete (PSC) box girder

The balanced cantilever erection system of pre-cast prestressed concrete segments has to be considered with the very limited construction time period available for this project. However the weight of 1 segment of 3 to 4 m length is approx. 100 ton, which is equivalent to the weight of a steel box girder of 9 to 10 m long. Therefore this type is not considered suitable by reason of the construction time available. In Japan the longest span of a PSC cable stayed bridge constructed so far, is 260 m, and almost all have been cast in-situ. The experience of pre-cast PSC cable stayed bridges in Japan is very limited, with only 2 or 3 constructed to date.

ii) Composite Steel and Concrete

When considering the limited construction time period available, a pre-cast concrete deck slab should be selected. However at present the experience of the cable stayed bridge of composite steel and pre-cast concrete deck for vehicle loads is very limited in the world and the relevant data, such as durability of the pre-cast concrete deck slab is also limited.

iii) Steel Box Girder

The steel box girder type has advantages of stability, when considering wind and seismic loadings. In addition the maintenance costs of repainting every 10 years are relatively insignificant, since the annual rainfall of 30 mm and the very low humidity will limit the effects of weathering. The weight of a steel box segment of 12 m length is around 120 ton, which is much lighter than the segment of PSC girder type. Taking all the above factors into account, when comparing these three types, the steel box girder has been selected.

(3) Bridge Length and Span Length of the Main Bridge

i) Bridge Length

With the requirements of the navigation clearance of 384 m wide x 70 m high, the vertical grade of 3.3 % and limit on embankment height at the abutments, (20 m on east bank and 10 m on west bank), a bridge length of 730 m was decided, as shown in the General View of the Bridge.

ii) Center Span Length

A minimum distance of 10 m was required from the crest of the Canal bank to the center of each pylon, and therefore the center span length was decided as (10 + 384 + 10)=404 m.

(4) Pylon Type for the Main Bridge

For economical reasons a reinforced concrete structure was selected, and further analysis determined that a H shape pylon was the most suitable.
The pylon shape will influence the aesthetic form of the cable stayed bridge, and therefore it is very important to select the most appropriate type. Generally H and A shapes are commonly employed, and there is no significant difference in their ability to withstand seismic and wind loads.
From the case of construction aspect the H shape has advantages, since construction of the H shape pylon is simple, and the arrangement and prestressing of the stay cables is easier than that for the A shape.
The pylons will be a major land mark in the region and a monument to the Project. The H shaped pylon will reflect the image of the Ancient Obelisk of Egypt and is thus considered the most appropriate for this prestigious structure.

(5) Foundation Type for the Main Bridge

Generally in Egypt caisson foundations and cast in situ bored pile foundations are commonly used. However bored pile foundations require very large pile caps and to avoid disturbance to the Canal bank a much longer span than 404 m, would be required. The caisson foundation could also possibly disturb the soil around the foundations. Finally it was decided to select the concrete diaphragm wall type foundation particularly, since Egypt has some experience of this type of foundation and the plant and equipment required are available in Egypt.

1.2.2 Approach Bridges and Approach Roads

(1) Approach Bridges Superstructure

The vertical grade is 3.3 %, which will result in the bridge pier height varying from 10 m to 70 m. The span length and pier height have to be taken into account, when determining the most suitable bridge structure.
The following types have been considered.

i) Steel plate girder
ii) Steel box girder
iii) PC box girder

For an economical span length of 40 m to 60 m and a pier height of approx. 60 m, these three types have similar construction cost. However when considering the maintenance costs, the PSC box girder is the most economic and has been selected as the most suitable type of superstructure. With the comparatively high piers, continuous rigid frame structures with monolithic connections between box girders and piers will be employed, and for the lower piers, continuous girders with bridge bearings.

(2) Approach Bridges Substructure

Cast in situ bored piles and rectangular reinforced concrete piers have been selected.

(3) Approach Embankments and Approach Roads

Embankments of 20 m max. height on the East Bank and 10 m max. height on the West Bank have been selected, since in the desert on the East Bank there is no restriction on Land acquisition, whilst on the West Bank there are restrictions in the land available due to the built up and agricultural area crossed by the road.

The gradient of the side of the embankments will be 2:1 (H:V), and the surface of the slope is to be protected against erosion.

1.3 Aesthetic Considerations

1.3.1 General

For the aesthetic design of the main bridge, three types of examination have been carried out.

1) Scale model,
2) Computer graphic simulation, and
3) Perspective drawings

Using these, the shape of the main pylons, auxiliary piers, deck girder etc. have been studied.

The shape of main pylon has been designed to reflect the image of the Obelisk when viewed from the Canal and it will also mark the new entrance into Egypt. When viewed from the road, the main pylons are located at the entrance between Africa and Sinai Peninsula, and the upper transverse beam and the two vertical columns form a gateway.

The main deck girder is a very slim trapezoidal box shape and has good aesthetic lives when viewed from every angle.

The piers are simple rectangular columns and no specific surface finish has been provided as this would detract from the beauty of the pylons.

1.3.2 Scale Model

A 1/500 scale model of the Main Bridge including some spans of the approach bridges has been manufactured and several views of this model are shown in Photo 1.1.

1.3.3 Computer Graphic Simulation

Based on the Project plan, a simulation video film was prepared. The proposed main bridge profile was examined from three (3) different views, the Canal and the proposed road. These views are shown on Photo Nos.1.2 to 1.5 herein.

1.3.4 Perspective Drawings

Two perspective drawings of birds eye view and the Canal side view were prepared. These views are shown in Photos 1.6 and 1.7 herein.

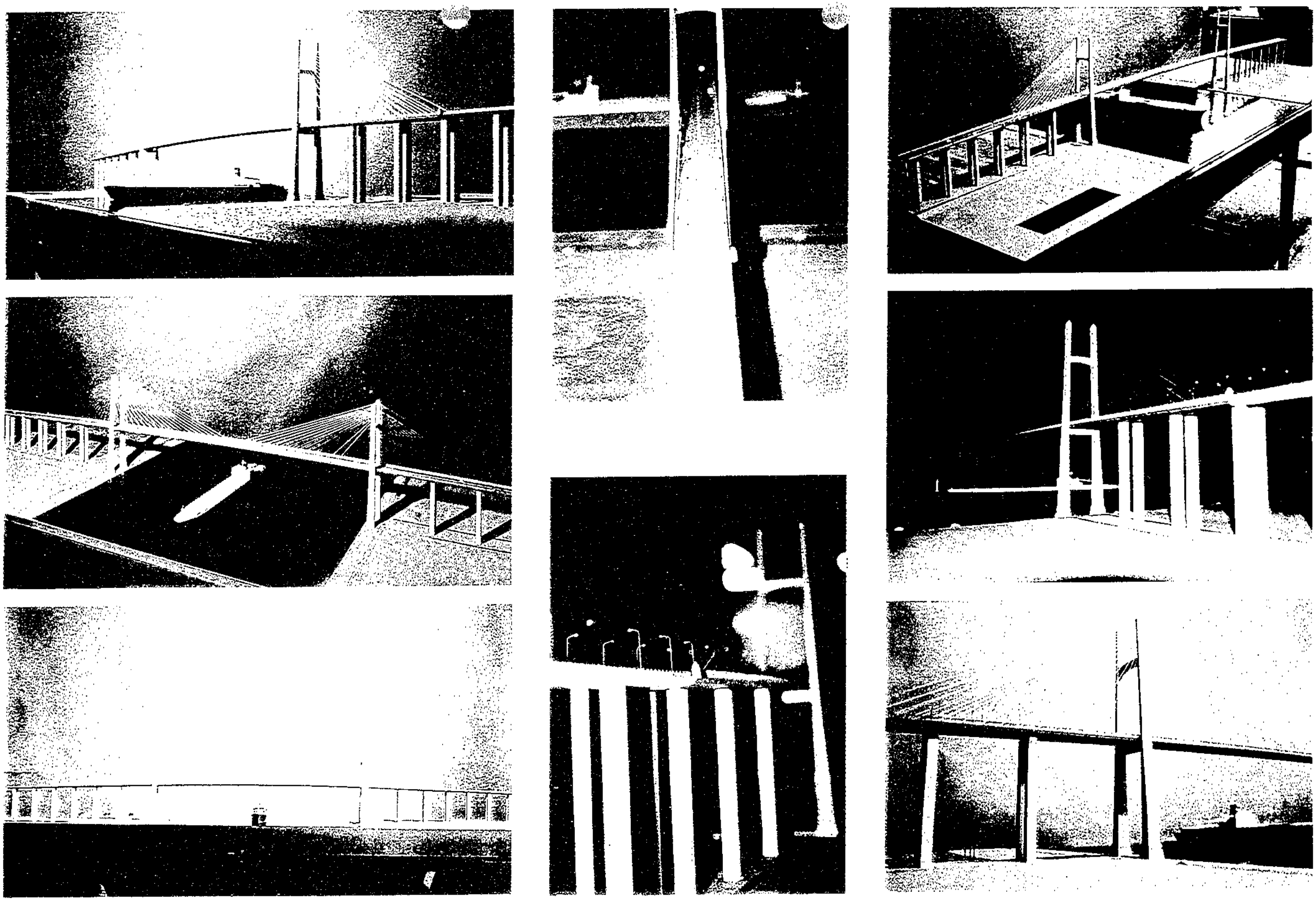


Photo 1.1 Scale Model

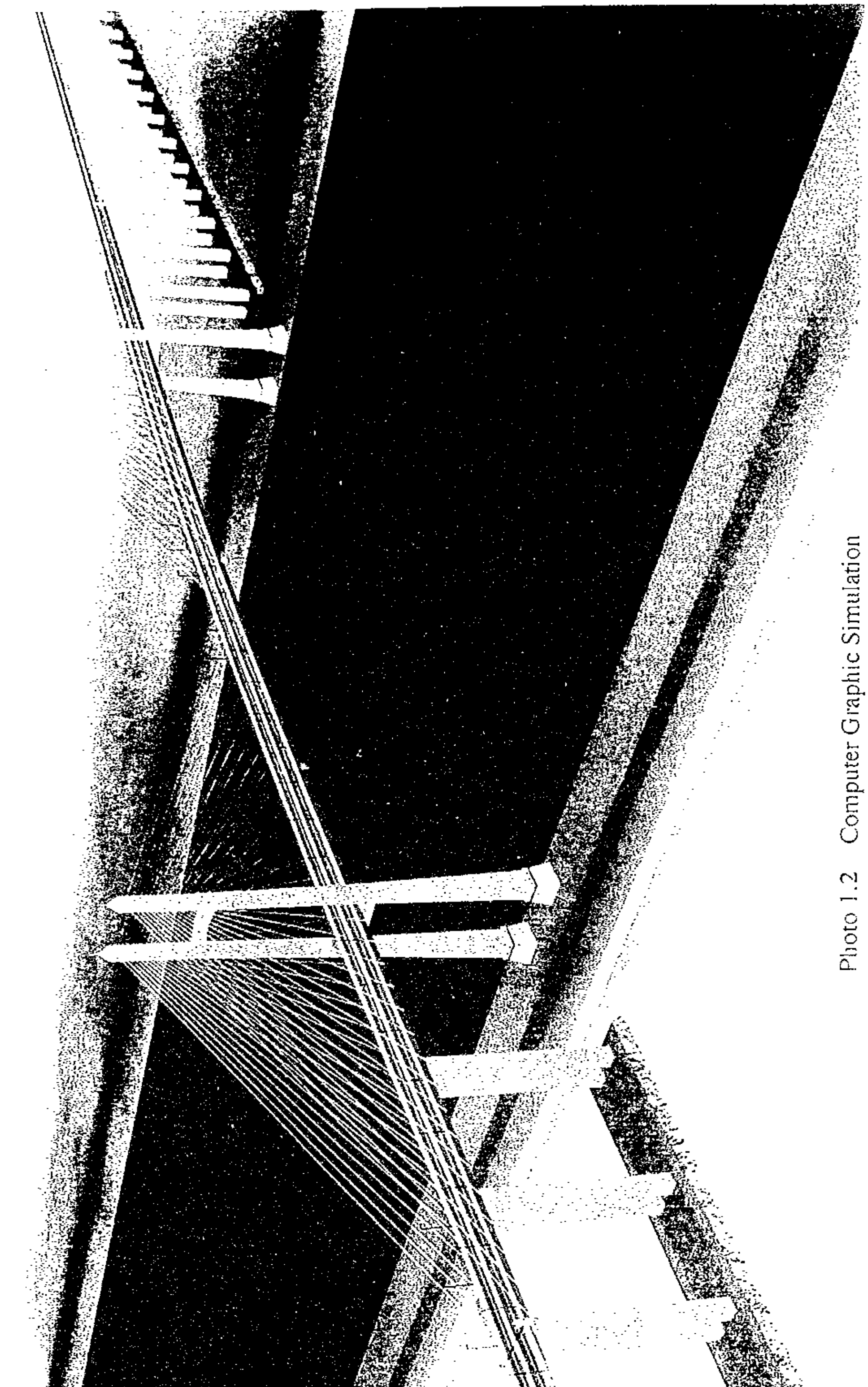


Photo 1.2 Computer Graphic Simulation

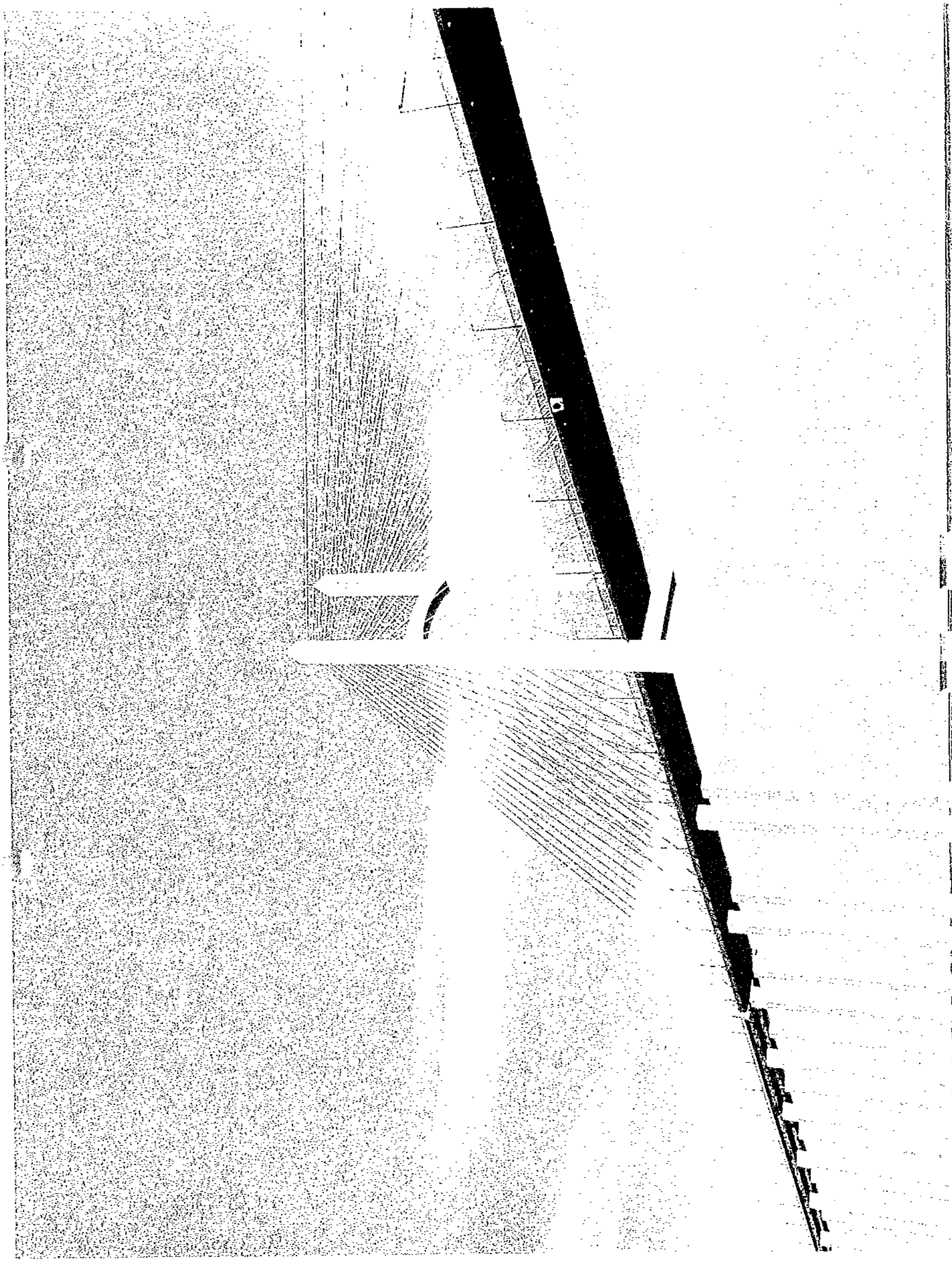


Photo 1.3 Computer Graphic Simulation

Photo 1.4 Computer Graphic Simulation

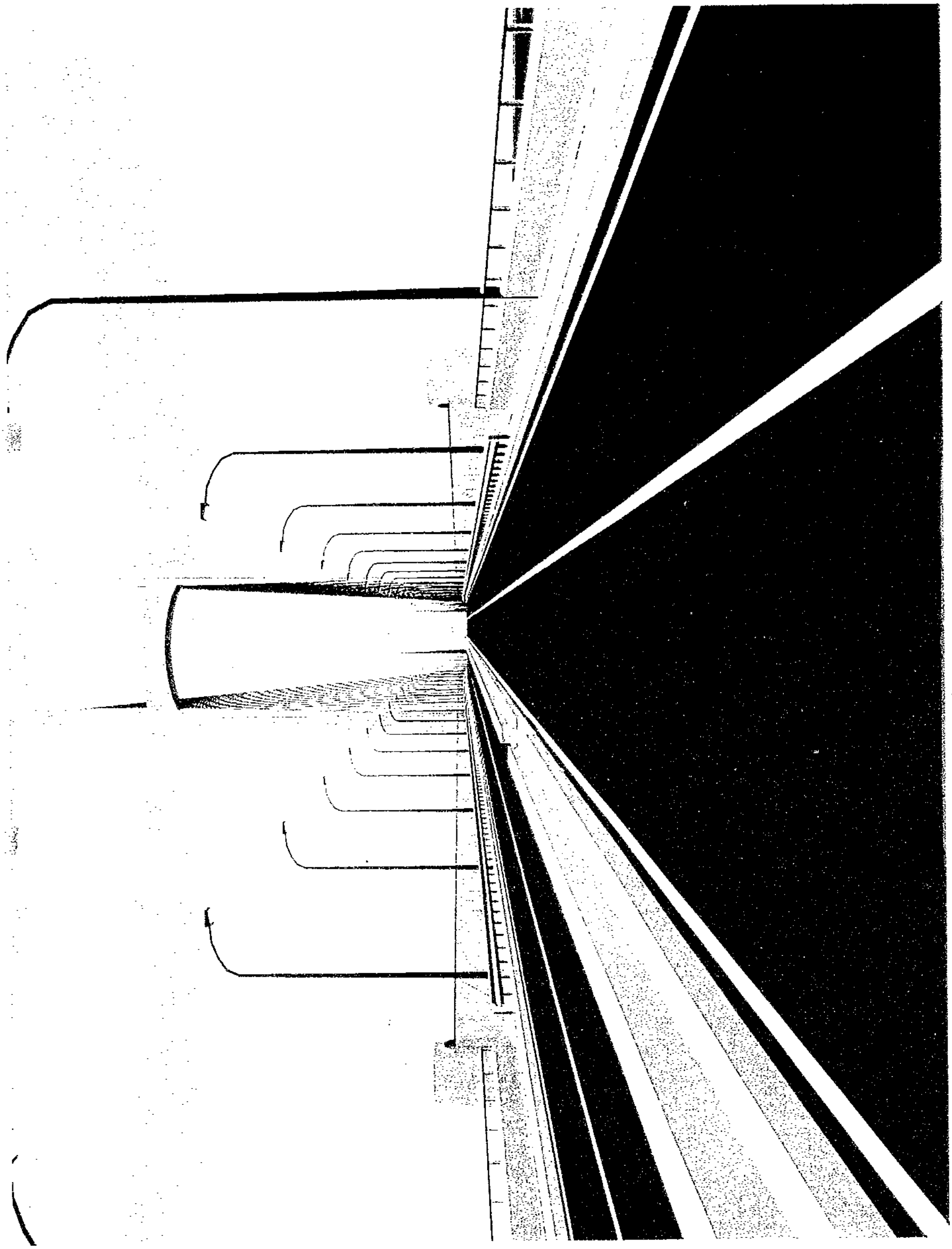


Photo 1.5 Computer Graphic Simulation

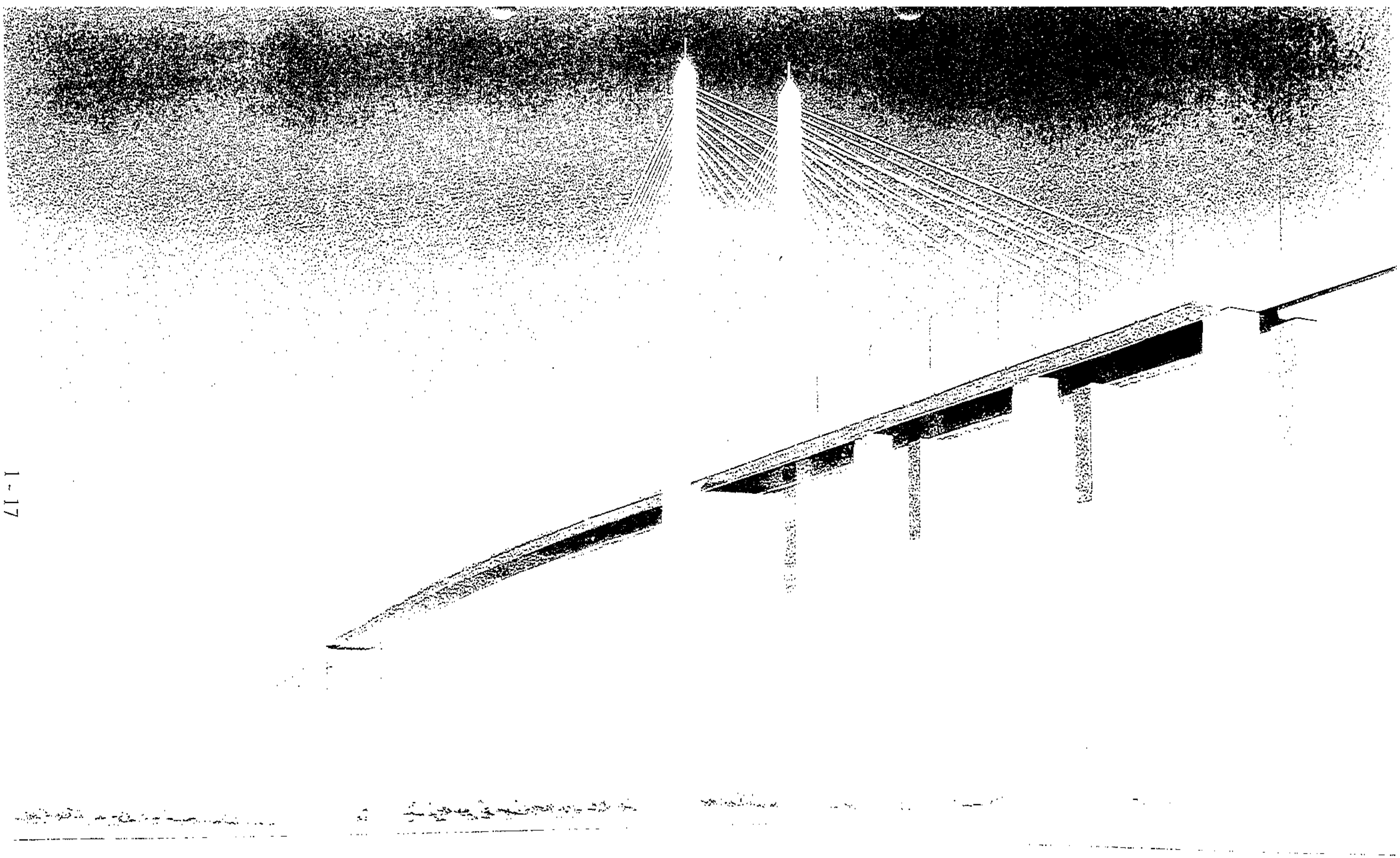


Photo 1.6 Perspective **Suez Canal Bridge**

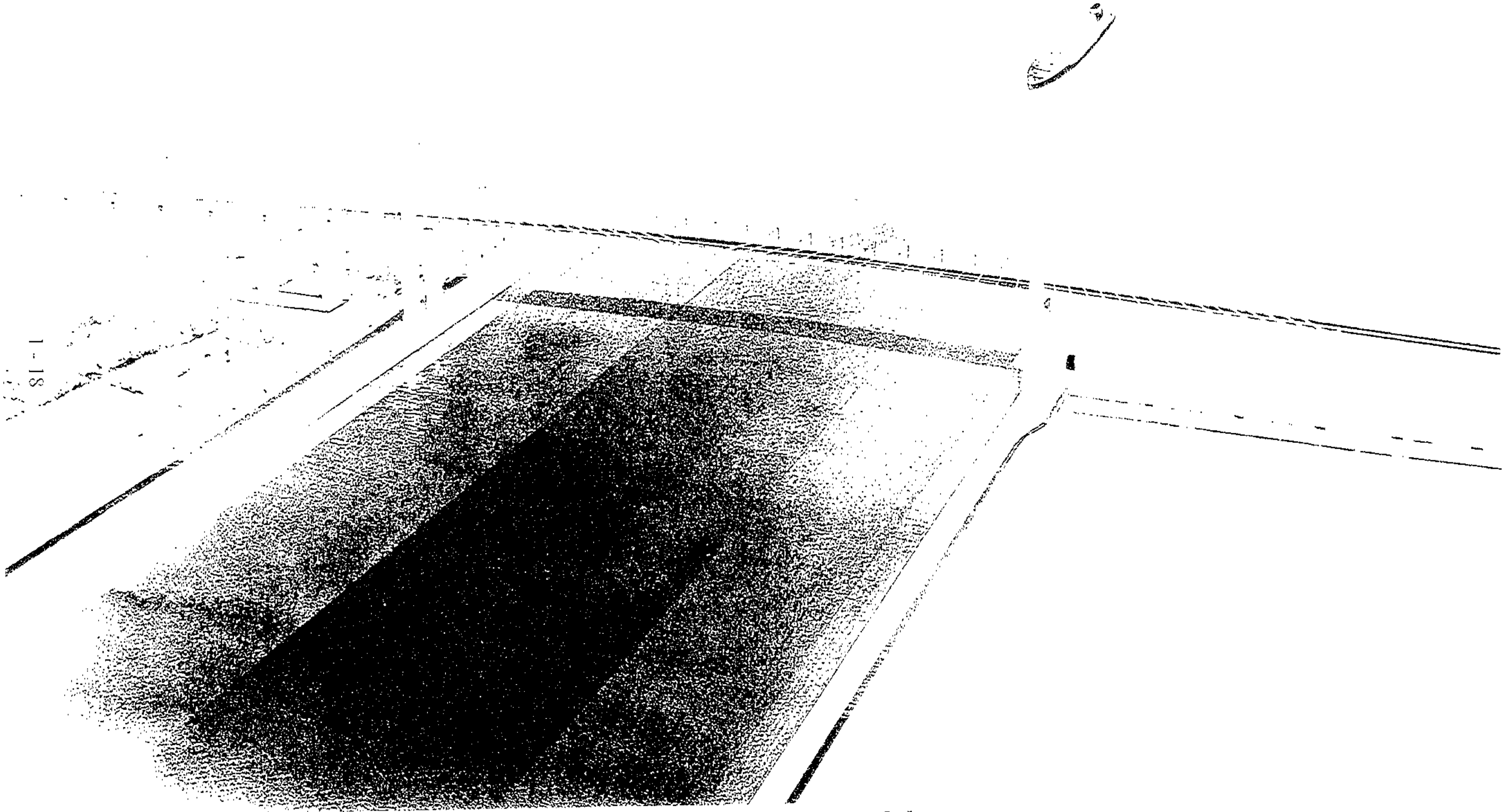


Photo 1.7 Perspective **Suez Canal Bridge**

CHAPTER 2

DESIGN STANDARDS AND SPECIFICATIONS

CHAPTER 2 DESIGN STANDARDS AND SPECIFICATIONS

2.1 Geometric Design

2.1.1 General Description

The geometric design of the road crossing over the Suez Canal has been carried out based on Egyptian standards taking into consideration the local conditions.

2.1.2 Design Standards and Specifications to be Applied

The following Egyptian standards issued by GARBLT, have been used for the design of the road crossing over the Suez Canal where possible. Other standards such as American, Japanese and European standards have been used to supplement the Egyptian standards when required.

- Highway Geometric Design Standard (English)
- Geometric Design of Roads; 1994 (Arabic)

The following standards have been used to supplement the Egyptian standards for the geometric design of the road crossing;

- "Geometric Design of Highways and Streets" AASHTO (USA)
- "Geometric Design Standard" Japan Road Association (Japan), and
- "British Standard" British Standard Institution (Britain).

2.1.3 Design Criteria

(1) Road Classification and Design Speed

1) Road Classification

The proposed road crossing for the Suez Canal is to be classified as a Primary Desert Road corresponding to the Cairo - Ismailiya - Port Said Road.

The road crossing over the Canal is to be connected directly into the Cairo - Ismailiya - Port Said Desert Road on the west side of the Canal and the Suez - Qantara road (New Central Road) on the east side. These roads are classified as Primary Flat Desert Roads.

The approach sections of the road crossing over the Canal are considered to be very long and steep. (About 2 km of length for each side and 3.3 % of vertical grade).

2) Design Speed

In accordance with the Egyptian standards, the design speed of a Primary Rolling Desert Road is 80 km/hr. Hence, the design speed of the Canal crossing road is 80 km/hr.

(2) Design Geometry

1) General

As a rule, the Egyptian standards have been used for the geometric design of the road crossing. However, the geometric design criteria of other countries have been used for some of the design to complement the Egyptian standards.

2) Vertical Grade

According to the Egyptian standards, the maximum vertical grade is 5.0 % for a design speed of 80 km/hr.

However, a gentler vertical grade is more preferable for smooth traffic operation and a vertical grade of more than 4.0 % is not considered to be suitable for the existing types of Egyptian vehicles, based on observations of traffic movement on the Cairo fly overs.

The vertical grade for the road crossing over the Suez Canal has been examined and a vertical grade of 3.3% has been selected based on the results of the studies and discussions with GARBLT.

(3) Cross Section

1) Number of Lanes

In general, the number of lanes selected will be based on the traffic demand and other related factors.

A 4 lane crossing, 2 lanes for each direction, has been selected taking into consideration the future traffic volume crossing the Suez Canal.

2) Lane Width

The lane width has been studied and determined taking into consideration the Egyptian and other standards.

The lane width based on the Egyptian standards is the widest, however this width also includes for shoulders and hard strips on structure sections. The carriageway width which incorporates traffic lanes, shoulders and hard strips is the widest in AASHTO standards.

The lane width of 3.65 m based on the international recognized AASHTO standards would be applicable for the road crossing the Canal.

3) Shoulder

The shoulder serves as an emergency parking strip and its width must allow lateral clearance between stationary and passing vehicles.

According to the AASHTO standard, the minimum width of shoulder is 0.6 m. Hence, a shoulder width of 0.60 m has been provided for the main and approach bridges for economical construction.

A shoulder width of 1.25 m for the approach earthwork sections and 2.25 m for the access roads has been provided based on the Japanese and Egyptian standards.

Shoulder width is shown in Fig. 2.1.1.

4) Median

A median should be provided for a road with two lanes of traffic in one direction. A median width of 1.5 m has been provided on the bridge and approach embankments.

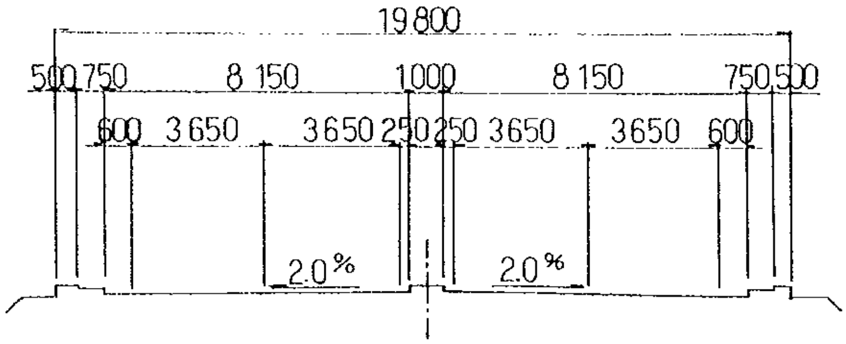
A median width of 3.0 m for the access roads has been provided in accordance with the Egyptian standards.

(4) Design Criteria

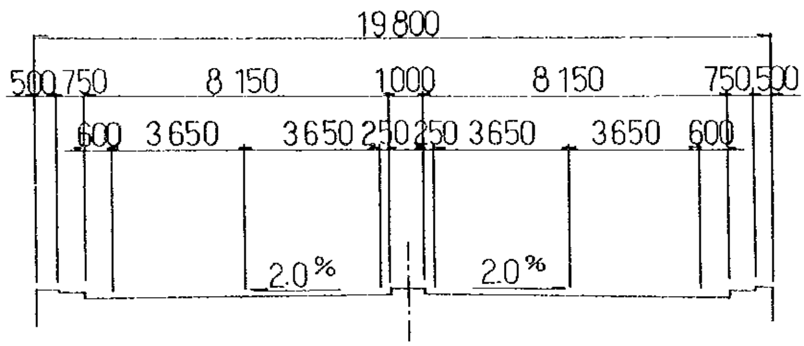
The criteria proposed for the geometric design of the road crossing over the Canal are summarized in Table 2.1.1.

(5) Navigation Clearance

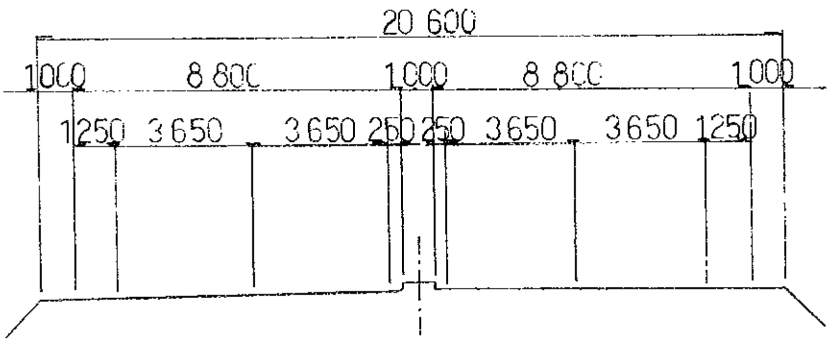
A horizontal clearance of 384 m and a vertical clearance of 70 m above H.H.W.L of the Suez Canal at Qantara have been used for the design of the road crossing over the Canal. This navigation clearance is shown in Fig. 2.1.2.



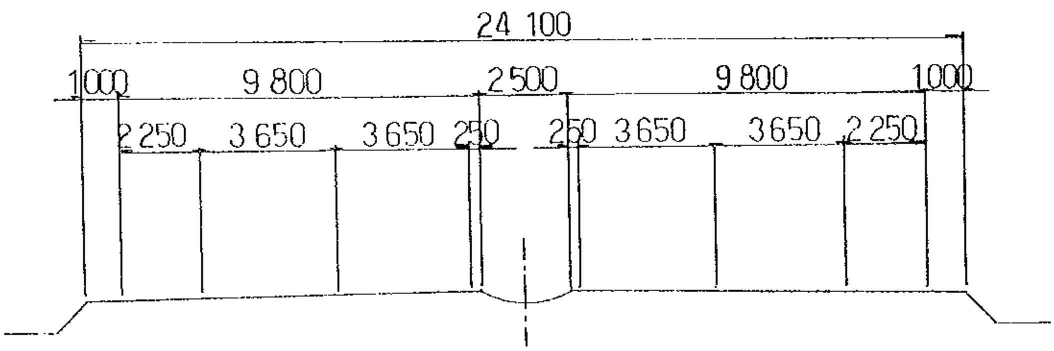
Main Bridge



Approach Viaduct



Approach Embankment



Access Road

Fig. 2.1.1	**Cross Sections of Canal Bridge and Road (4 Lane Road)**	*THE DETAILED DESIGN STUDY ON THE PROJECT FOR CONSTRUCTION OF THE SUEZ CANAL BRIDGE*

Table 2.1.1 Geometric Design Criteria

Item	Unit	Figure	Remarks
Design Speed	km/hr	80	Primary Rolling Desert Road
Lane Width	m	3.65	
Shoulder Widths for ;			
1) Bridge or Tunnel Section : 4 Lanes	m	0.60	
2) Earthwork Section : Elevated	m	1.25	Approach Road
3) Earthwork Section : Level	m	2.25	Access Road
Hard Strip Width	m	0.25	
Median Width	m	1.50	
Crossfall	%	2.0	
Maximum Superelevation	%	6.0	
Maximum Vertical Grade	%	3.3	Rolling Desert Road
Minimum Stopping Sight Distance	m	105	
Minimum Passing Sight Distance	m	140	
Minimum Horizontal Curve Radius	m	250	
Minimum Horizontal Curve Radius without Transition Curve	m	2,000	
Minimum Vertical Curve Radius for ;			
1) Crest Curve	m	3,000	
2) Sag Curve	m	2,000	
Nose Taper	m	12.3	
Taper Length	m	150	

Source : Study Team

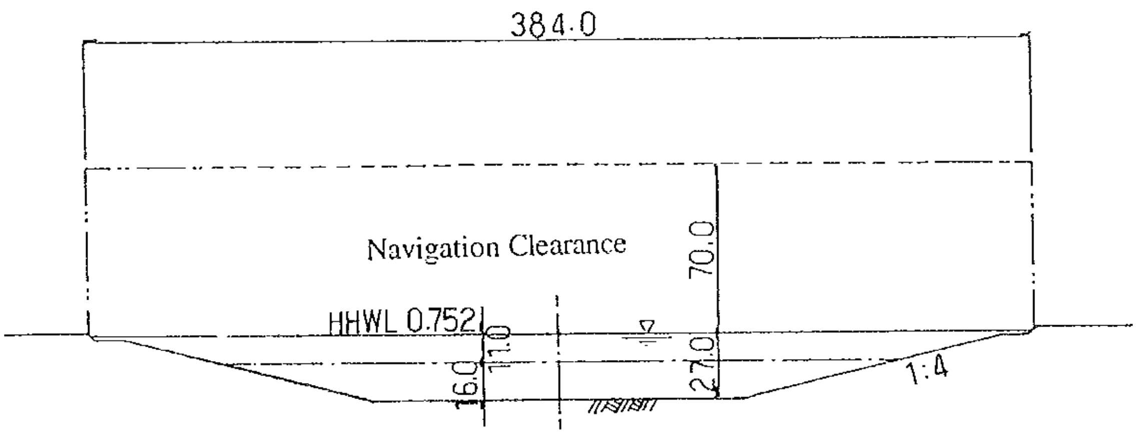


Fig. 2.1.2 Navigation Clearance at Qantara

(6) Structural Clearance

1) Road Clearance

A vertical structural clearance of 5.5 m and a horizontal structural clearance of the carriageway width based on the Egyptian standards will be used for the bridge.

2) Construction Gauge of Railways

The railway construction gauge of the proposed Canal bridge crossing of the Ismailiya - Port Said Railway, will be allowed for in the design. The headroom of the railway appears to be 5.5 m based on the Egyptian standards as shown in Fig. 2.1.3 below.

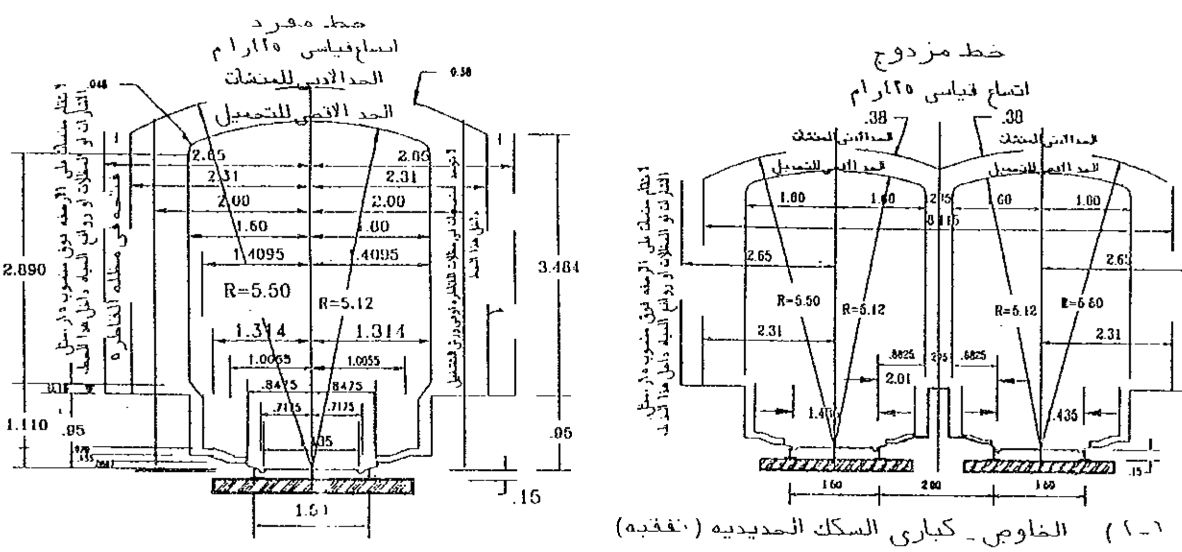


Fig. 2.1.3 Construction Gauge of Railway

2.2 Main Bridge

2.2.1 General Description

(1) Superstructure

The superstructure of the main bridge shall be a cable stayed type with one steel box girder carrying the four lanes of traffic. The bridge has a 404 meters long main span bridging the entire width of the Canal (384 meters in future expansion plan).
The two side spans are 163 meters long each, subdivided into three smaller spans by pendulum supports on reinforced concrete piers.

The cross section of the main steel box girder has 2.5 meters depth and 19.8 meters width. At both ends of the girder, a stay cable from the main pylon will be fixed through a steel pipe.

(2) Stay Cable

The Stay cable will be a prestressing strand type cable and anchored to the top of the concrete pylon and to both sides of the steel box girders at their ends.

(3) Pylon

The two pylons will be of the reinforced concrete H shape type with total height of 152.5 meters above top of foundation level (maximum elevation 160 meters with top cap and lightning conductor and obstruction lights). The pylon has two transverse beams at the level of 67.5 m and 122.5 m.

The pylon column will be a hollow section varying in size from bottom to top of the pylon. The column base will be a solid reinforced concrete structure of 10 x 11 meters maximum with.

(4) Piers

Three piers for each side span will be reinforced concrete type.
Their heights are about 65 to 62 meters on the west side and 63 to 60 meters on the east side. Twin columns on single pile cap will be designed for each pier. The cross section of the column will be hollow and 4.5 x 4.5 meters square.

(5) Pylon Foundations

The pylons of the main bridge will be supported on rectangular concrete diaphragm wall foundations, with one foundation under each leg of the pylon. The dimension of each diaphragm wall, will be 14 x 12 meters rectangular in plan, with a depth of 30.5 meters.

(6) Pier Foundation

The piers for the side spans will be supported on pile foundations. The piles will be cast-in-situ concrete 1.5 meters in diameter and 15 meters in length.

2.2.2 Design Standards and Specifications to be Applied

(1) Design Method

The "Allowable Stress Design" method will be used for the design works in accordance with the Japanese Code. The "Limit State Design" method will be used to check the structural safety factor under ultimate and serviceability limit state with the British Standards BS5400. The stability of the foundation under various loading conditions will be checked using the Japanese Standards.

(2) Codes and Standards

The following codes and standards will be used in the design;

1) Japanese Standard Specifications for Highway Bridges, Feb. 1994, Japan Road Association
2) Egyptian Standard Specifications for Construction Materials
3) British Standards, 5400, Part 1 to 10, 1988
4) Egyptian Code for Loads and Forces in Construction
5) BD (Bridge Design) 37/88, Loads for Highway Bridges (Egypt)

(3) Loadings and Materials

The bridge structure will be designed for all allowable dead, live, wind, temperature, earthquake loads, ... etc., as given below. The appropriate load combinations to be used are described below.

1) Design Loads

a) Dead load: (D)
The dead load consists of the weights of the structure and permanent utilities supported on the bridge.

b) Prestressing: (PS)
Prestressing of the stay cable.

c) Shrinkage of Concrete: (SH)
+- 15 x 10^{-5} for the pylon shaft.

d) Creep of Concrete: (CR)
Based on the Japanese Standard Specification, estimate the creep value supposing 50% of relative humidity taking into consideration the member dimension.

e) Live (Vehicle) Load: (L)
The Egyptian standard load, according to Egyptian Code for Loads and Forces in Construction is applied. 60 tons of trailer truck loading is used.

f) Impact Load: (I)
Based on the Egyptian Code for Loads and Forces in Construction

g) Temperature Change: (T)
Maximum effect on each section is applied from the following temperature conditions;
for whole structure:
steel girder/stay cable: +- 30 degrees
concrete structure: +- 20 degrees

for temperature difference within member:
steel girder : +- 15 degrees (top and bottom flange)
main pylon : +- 5 degrees

h) Wind Force: (W)

Basic wind force is taken as 200 kg/m^2 at 0 to 10 m above ground level, with a linear height adjustment as below;

h = 100 m: 250 kg/m^2
h = 200 m: 350 kg/m^2

i) Wind Force with Live Load: (WL)

Half of wind force (W) will be applied with live load condition.

j) Seismic Load: (EQ)

The seismic load will be calculated using modified acceleration response spectrum defined in Japanese Standard Specification, with a ground acceleration of 125 gals. However, this modified acceleration shall not be less than 100 gals.

k) Foundation Settlement: (SD)

1.5 cm differential foundation settlement between two neighboring pier foundations or 2.5 cm differential pylon foundation settlement will be applied and the maximum effect allowed for in the design.

l) Breaking Cables: (C1 or C2)

Two cases will be applied: either one cable or two cables broken.

m) Ship Collision: (CO)

n) Construction Error: (EO)

For pylon, pylon top displacement of 15 cm

o) Replacement of Bearings

Any one bearing replacement, 1 cm lift up at bearing position

2) Load Combinations

The following combinations will be applied;

a) D + PS + CR + SH (= AA)	: r = 1.00
b) AA + EO + SD	: r = 1.00
c) AA + L + I + EO + SD	: r = 1.00

d) AA + L + I + EO + SD + T : r = 1.15
e) AA + EO + SD + W : r = 1.25
for foundation stability : r = 1.50
f) AA + L + I + SD + WL : r = 1.25
g) AA + EO + SD + T + W : r = 1.35
h) AA + L + I + EO + SD + T + WL : r = 1.35
i) AA + EO + SD + EQ : r = 1.50
j) AA + L + I + EO + SD + CO : r = 1.50
k) AA + L + I + EO + SD + C1 : r = 1.15
l) AA + 0.1*(L + I) + EO + SD + C2 : r = 1.50
m) AA + L + I + EO + SD + RR : r = 1.00
Where r: rate of increase

3) Materials

Following principal materials have been used;

a) Concrete

The concrete design strengths to be used for diaphragm wall, pile, pylon, pier and medium are as below;

for diaphragm wall : f'c = 240 kg/cm^2
(cement content not less than 400 kg/m^3)
for wall top : f'c = 300 kg/cm^2
for pile : f'c = 240 kg/cm^2
(cement content not less than 400 kg/m^3)
for pile cap : f'c = 240 kg/cm^2

for pier column : f'c = 240 kg/cm^2
for pylon : f'c = 300 kg/cm^2
f'c = 350 kg/cm^2,
cable anchorage zone only
for median : f'c = 210 kg/cm^2

b) Reinforcing Bar

The steel reinforcement used for concrete structures will be grade ST24/35 (ST35) or ST36/52 (ST52) satisfying the Egyptian Standard Specifications (or British Standards) or equivalent.

c) Structural Steel

The structural steel used for the main steel box girder will be grade SS400, SM490, SM490Y or SM520 satisfying the Japanese Standard Specifications or equivalent.

d) Stay Cable

Freyssinet strand (H15) or equivalent.

e) Bearing

For the bearings between the steel deck girder and auxiliary piers, a Pendel type bearing will be designed to resist the uplift forces of the deck girder due to loading. For the bearings on the pylons, steel-rubber hybrid type bearing will be employed to allow the large longitudinal displacement of the deck girder.

2.3 Approach Bridges

2.3.1 General Description

The Detailed Design of the Suez Canal approach bridges will be basically carried out in accordance with the " The Egyptian Code for Design and Execution of Reinforced Concrete Structures (Arab Republic of Egypt)" (hereinafter referred to as "Egyptian Code") as the prime design standard for loading. The actual design works for the Suez Canal approach bridges are to be carried out in Japan. Although the principal loading concept is in accordance with the Egyptian Code, various detailed calculation methods will be based on the Japanese specification as listed in 2.3.2 below.

2.3.2 Design Standards and Specifications to be Applied

The following Standards will be used for this detailed design study.

【Arab Republic of Egypt】

[Ministry of Construction, New communities, Housing and Public Utilities]

- The Egyptian Code for Design and Execution of Reinforced Concrete Structures (1989)

【United Kingdom of Great Britain and Northern Island】

[British Standard Institution]

- BS 5400 : Steel, concrete and composite bridges
  - Part 1: General Statement
  - Part 2: Specification for loads
  - Part 3: Code of practice for design of steel bridges
  - Part 4: Code of practice for design of concrete bridges
  - Part 5: Code of practice for design of composite bridges
  - Part 6: Specification for materials and workmanship, steel
  - Part 7: Specification for materials and workmanship, concrete, reinforcement and prestressing tendons
  - Part 8: Recommendations for materials and workmanship, concrete, reinforcement and prestressing tendons
  - Part 9: Code of practice for bearings
  - Part 10: Code of practice for fatigue

【The United States of America】

[American Association of State Highway and Transportation Officials]

- Standard Specifications for Highway Bridges (Fifteenth Edition 1992)
- Standard Specifications for Transportation Materials and Methods of Sampling and Testing
  - Part I
  - Part II

[American Concrete Institute]

(hereinafter referred to as "ACI")

- Building Code Requirements for Reinforced Concrete (ACI 318-83)

【Japan】

[Japan Road Association]

- Road Structure Ordinance
- Specifications for Highway Bridges (February, 1994)
  - Part Ⅰ Common
  - Part Ⅱ Superstructure (Steel Bridges)
  - Part Ⅲ Superstructure (Concrete Bridges)
  - Part Ⅳ Substructure
  - Part Ⅴ Seismic Design
- Design Guideline for Concrete Highway Bridges (February, 1994)
- Construction Guideline for Concrete Highway Bridges (February, 1994)
- Guideline for Road Design and Works
- Guideline for Drainage Design of Roads

[Japan Highway Public Corporation]

- Design Standard for Highway and Bridges (February, 1994)
  - Part Ⅰ
  - Part Ⅱ
  - Part Ⅲ
  - Part Ⅳ
  - Part Ⅴ

2.3.3 Design Criteria for Approach Bridges

(1) Design Loads

(a) Types of Load

Structures will be designed to carry the loads and forces shown in the following table.

Table 2.3.1 Types of Loading

Classification	Types of load
Principal load (P)	1. Dead load (D) 2. Live load (L) 3. Impact (I) 4. Prestressing force (PS) 5. Effect of creep of concrete (CR) 6. Effect of shrinkage of concrete (SH) 7. Earth pressure (E) 8. Hydraulic pressure (HP) 9. Buoyancy or Uplift (B)
Secondary load (S)	10. Wind load (W) 11. Thermal effect (T) 12. Earthquake (EQ)
Particular loads to be regarded as Principal loads (PP)	13. Effect of ground movement (GD) 14. Effect of settlement of supports (SD) 15. Centrifugal force (CF)
Particular loads (PA)	16. Longitudinal force (LF) 17. Temporary load during erection (ER)

(b) Dead load (D)

The following unit weights of materials are to be used in computing the dead load.

Table 2.3.2 Dead Loads

Types of Dead Load	Unit Weight (kgf/m^3)	Types of Dead Load	Unit Weight (kgf/m^3)
Steel or cast steel	7850	Asphalt pavement	2300
Cast iron	7250	Bituminous material	1100
Aluminum alloys	2800	Compacted sand, earth and gravel	1900
Timber(treated or untreated)	800	Loose sand, earth, and gravel	1800
Concrete(plain)	2350	Underground water	1000
Concrete(reinforced or prestressed)	2500		
Cement mortar	2150		

(c) Live load (L)

The following vehicle loadings will be considered for this detailed design.

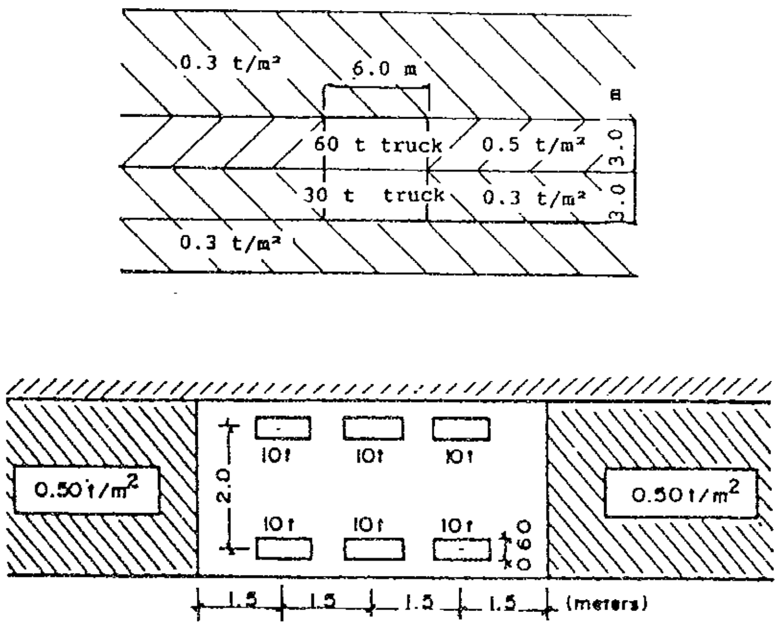


Fig. 2.3.1 Vehicle Loads

(d) Impact (I)

Impact Formula ; $I = 0.4 - 0.008 \times L$

in where

I = impact factor ;

L = length in meters of the portion of the span that is loaded to produce the maximum stress in the structural member.

(e) Side Maintenance Walkway Loading

Girders, sidewalk floors, stringers and their immediate supports will be designed for a live load of 500 kgf/m^2 on the sidewalk area. And this load intensity will be also applied on the median of the bridges.

(f) Thermal Effect (T)

i) The base temperature for the design calculation will be as follows:

	Temperature
Base temperature ------------------------	+20℃

ii) Range of Temperature for Structural Design

Rise and fall in temperature of the structures will be considered as a change between the base temperature and the range of temperature.

For Concrete Structures

	Temperature Rise	Temperature Fall
General concrete structures ----------------------	+20 ℃	−20 ℃

The sectional force due to the difference of temperature between deck slab and other members will be calculated with assumption that the temperature distribution in deck slab and other members is respectively uniform and the relative difference of temperature between them is 5 ℃.

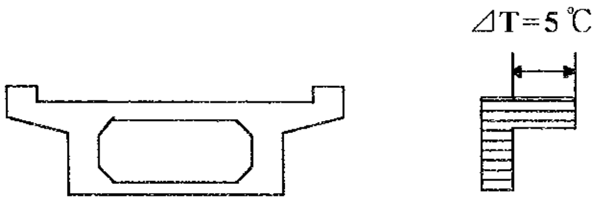


Fig. 2.3.2 Assumed temperature difference

iii) Coefficients of Thermal Expansion

The coefficients of thermal expansion will be as follows:

Classification	Coefficient of Thermal Expansion
Reinforcing Bar and Concrete of Concrete Structure	10×10^{-6} /℃
Steel and Concrete of Composite Girder	12×10^{-6} /℃

iv) For the calculation of the amount of movement at movable bearing supports.

The range of temperature for the calculation of the amount of movement at movable bearing supports is given as follows:

Type of Bridges	Range of Temperature
Prestressed or reinforced concrete bridge	±0℃～+40℃

v) The thermal effect for underwater or underground structures will not be considered.

(g) Effect of Creep (CR) and Shrinkage (SH) of Concrete

The effect of creep and shrinkage of concrete to be considered in designing concrete members will be as follows:

i) The strain due to creep of concrete will be calculated by the following formula:

$$\varepsilon_{CC} = \frac{\sigma_C}{E_C}\phi$$

where

ε cc = strain due to creep of concrete;

σ c = stress of concrete due to sustained load (kgf/cm^2);

Ec = Young's modulus of concrete (kgf/cm^2);

ϕ = creep coefficient of concrete.

ii) For the calculation of the prestress loss and the statically indeterminate force, the creep coefficient of concrete given in the following table will be used as standard value :

Age of concrete when sustained (days) load is applied.		4～7	14	28	90	365
Creep coefficient	For using high-early-strength Portland cement	2.6	2.3	2.0	1.7	1.2
	For using normal Portland cement	2.8	2.5	2.2	1.9	1.4

iii) When the prestress loss is calculated, the shrinkage strain of concrete will be as given in the table below:

Age of concrete when prestress is introduced (days)	4～7	28	90	365
Shrinkage strain	20×10^{-5}	18×10^{-5}	16×10^{-5}	12×10^{-5}

(h) Temporary load and Force during Erection (ER)

For any stage of construction, the study on the effects of the weight of members and equipment, wind and earthquake will be carried out talking into consideration the construction method and the structural conditions during construction.

(i) Earthquake (EQ) : Seismic load

Acceleration at ground level is to be 125 gal for the detailed design of the Suez Canal Bridge. Design coefficient for approach bridges in the static analysis is listed in Table 2.3.3 ,with consideration that the higher pier will have the longer period of structural vibration.

Table 2.3.3 Design Seismic Coefficients for Approach Bridges

Classification	Design Seismic Coefficient : Kh
Elevation > 40 m	0.125
Elevation < 40 m	0.156

(j) Effect of settlement of support (SD)

Magnitude of settlement of support to be considered for approach bridges is 15 mm. This settlement is considered as relative difference between piers and design analysis will be carried out as follows;

- Give 15 mm settlement to each pier in the framing model as a unit case.
- Pick up the maximum sectional force of each member from combination of above cases.

(2) Combinations of Loads and Rate of Increase

The following table represents various combinations of loads and forces to which a structure may be subjected. Each component of the structure, or the foundation on which it rests, will be designed to withstand safely all loading combinations of these forces that are applicable to the particular site or type.

However, secondary loads and particular loads to be regarded as principal loads will be taken into account. Basic allowable stresses specified in (4) of this section will be increased by multiplying the rates given in Table 2.3.4.

Table 2.3.4 Combinations of Loads and Rate of Increase

Application	Combinations of loads	Rate of increase
For Superstructures	1. P+PP	1.00
	2. P+PP+T	1.15
	3. P+PP+W	1.25
	4. P+PP+T+W	1.35
	5. P+PP+LF	1.25
	6. P(without live loads and impact)+EQ	1.50
	7. W	1.20
	8. In case considering ER	1.25
For Substructures	1. P+PP	1.00
	2. P+PP+T	1.15
	3. P+PP+W	1.25
	4. P+PP+T+W	1.35
	5. P+PP+LF	1.25
	6. P(without live loads and impact)+EQ	1.50
	7. In case considering ER	1.25

where

P = Principal load
PP = Particular load to be regarded as principal load
T = Thermal Force
W = Wind load
LF = Longitudinal force
EQ = Earthquake
ER = Temporary load during erection

(3) Specified Design Strength of Structural Concrete

The following specified design strength will be used for the detailed design of approach bridges. This strength is based on the test using the cylindrical specimen.

	Specified Design Strength (kgf/cm^2) (Strength at 28 days)
Superstructure (Girder, Cross beam)	350
Substructure (Pier, Abutment, Pile cap)	240
Foundation (Pile)	300

(4) Allowable Stresses

(a) Allowable stresses of reinforcing bars

Table 2.3.5 Allowable Stresses of Reinforcing Bars (unit : kgf/cm^2)

<table>
<tr><th colspan="3">Classification \ Reinforcing Bars</th><th>ST37</th><th>ST52</th></tr>
<tr><td rowspan="5">Tensile Stress</td><td rowspan="3">Cases ignoring effect of collision force or earthquake force in the combinations of loads</td><td>1)Ordinary members</td><td>1200</td><td>1800</td></tr>
<tr><td>2)Floor slab</td><td>1200</td><td>1400</td></tr>
<tr><td>3)Members underwater or below ground water level.</td><td>1200</td><td>1600</td></tr>
<tr><td colspan="2">4) Basic allowable stresses in cases including effect of collision or earthquake force in the combinations of loads.</td><td>1200</td><td>1800</td></tr>
<tr><td colspan="2">5) For the calculation of lap joint or anchoring length of reinforcing bars.</td><td>1200</td><td>1800</td></tr>
<tr><td colspan="3">6) Compressive Stress</td><td>1200</td><td>1800</td></tr>
</table>

(b) Allowable Stresses of Reinforced Concrete

a. For members cast in dry condition (above water table level).

Table 2.3.6 Allowable Stresses of Reinforced Concrete

(Unit : kgf/cm^2)

Types of Stress	Concrete Class	240
Compressive Stress	Flexural compressive stress	80
	Axial compressive stress	65
Shear Stress	In case shearing is resisted only by concrete	3.9
	In case shearing is resisted by both concrete and diagonal tension reinforcement	17
	Punching shear stress	9.0
Bond Stress	With round bar	8.0
	With deformed bar	16

The allowable bearing stress of reinforced concrete will be as follows:

$$\sigma_{ba} = \left(0.25+0.05\frac{Ac}{Ab}\right)\sigma ck$$

where

σ_{ba} = Allowable bearing stress of reinforced concrete (kgf/cm^2) ($\leqq 0.5\,\sigma ck$)
Ac = Total area of reinforced concrete in case of local loading (cm^2)
Ab = Locally loaded area (cm^2)
σck = Specified compressive strength of reinforced concrete (kgf/cm^2)

b. For cast-in-place concrete piles constructed underwater

Table 2.3.7 Allowable Stresses of Cast-in-place Concrete Piles Constructed Underwater

(unit : kgf/cm^2)

	Designation compressive strength of concrete	300
	Specified compressive strength of underwater concrete	240
Compressive Stress	Flexural stress	80
	Axial compressive stress	65
Shear Stress	In case shearing is resisted only by concrete	3.9
	In case shearing is resisted by both concrete and diagonal tension reinforcement	17
Bond Stress	With deformed bar	12

(c) Allowable Stresses of Plain Concrete

Table 2.3.8 Allowable Stresses of Plain Concrete

Type of Stress	Allowable Stress
Compressive stress	$\frac{\sigma ck}{4} \leqq 55$
Flexural tensile stress	$\frac{\sigma tk}{7} \leqq 3$
Bearing stress	$0.3\,\sigma ck \leqq 60$

Where

σ ck = Specified compressive strength of concrete

σ tk = Specified tensile strength of concrete prescribed in JIS A 1113

(d) Allowable Stresses of Prestressed Concrete

a. Allowable Compressive Stresses of Prestressed Concrete

Table 2.3.9 Allowable Compressive Stresses of Prestressed Concrete

(Unit : kgf/cm^2)

Concrete Class			350
Immediately after prestressing	Flexural compressive stress	(1) Rectangular section	150
		(2) T shaped or Box section	140
	(3) Axial compressive stress		110
Other Conditions	Flexural compressive stress	(4) Rectangular section	120
		(5) T shaped or Box section	110
	(6)Axial compressive stress		85

b. Allowable Tensile Stresses of Prestressed Concrete

Table 2.3.10 Allowable Tensile Stresses of Prestressed Concrete

(Unit : kgf/cm^2)

Type of Stress \ Concrete Class			350
Flexural Tensile Stress	(1) For Immediately after prestressing		12
	(2) For the loading principal loads except live load and impact		0
	Principal load or Particular load to be regarded as principal load	(4) For floor slab	0
		(5) For other conditions	0
(6) Axial tensile stress			0

c. Allowable Diagonal Tensile Stresses of Prestressed Concrete

Table 2.3.11 Allowable Diagonal Tensile Stresses of Prestressed Concrete

(Unit : kgf/cm^2)

Conditions \ Concrete class	350
(1) With consideration for only shear force or only torsional moment	8
(2) With consideration for both shear force and torsional moment	11

d. Allowable Bond Stresses of Prestressed Concrete

Table 2.3.12 Allowable Bond Stresses of Prestressed Concrete

(unit : kgf/cm^2)

Conditions \ Concrete class	350
(1) With round bar	9
(2) With deformed bar	18

e. Allowable Stresses of Tendons

Allowable stresses of tendons for Freyssinet Prestressing Method authorized by Japan Society of Civil Engineering are listed in Table 2.3.13.

Table 2.3.13 Tendons for Freyssinet Method

(Standard Specification for Freyssinet Method by Japan Society of Civil Engineering)

Diameter & Composition of Tendons	Area	Unit Weight	Ultimate Strength (σ_{pu}) & Ultimate Load		Yield Strength (σ_{py}) & Yield Load		Allowable Tensile Stress (σ_{pa}): Initial Prestressing, $\sigma_{pa} \leqq 0.80\ \sigma_{pu}$ or $\leqq 0.90\ \sigma_{py}$		Allowable Tensile Stress (σ_{pa}): Immediately after Prestressing, $\sigma_{pa} \leqq 0.70\ \sigma_{pu}$ or $\leqq 0.85\ \sigma_{py}$		Allowable Tensile Stress (σ_{pa}): At Service Load, $\sigma_{pa} \leqq 0.60\ \sigma_{pu}$ or $\leqq 0.75\ \sigma_{py}$		Designation of Materials
mm	mm²	Kgf/m	kgf/mm²	kgf	kgf/MM	kgf	kgf/mm²	kgf	kgf/mm²	kgf	kgf/mm²	kgf	
ϕ 5	19.64	0.154	175	3450	155	3050	140	2745	123	2415	105	2070	SWPR1
12 ϕ 5	235.68	1.848		41400		36600		32940		28980		24840	SWPR1
ϕ 7	38.48	0.302	165	6350	145	5600	131	5040	116	4445	99	3810	SWPR1
12 ϕ 7	461.76	3.624		76200		67200		60480		53340		45720	SWPR1
ϕ 8	50.27	0.395	160	8050	140	7050	126	6345	112	5635	96	4830	SWPR1
12 ϕ 8	603.24	4.740		96600		84600		76140		67620		57960	SWPR1
T12.4	92.90	0.729	175	16300	150	13900	135	12510	123	11410	105	9780	SWPR7A
12T12.4	1114.80	8.748		195600		166800		150120		136920		117360	SWPR7A
T12.7	98.71	0.774	190	18700	160	15900	144	14310	133	13090	114	11220	SWPR7B
12T12.7	1184.52	9.288		224400		190800		171720		157080		134640	SWPR7B
T15.2	138.70	1.101	190	26600	160	22600	144	20340	133	18620	114	15960	SWPR7B
12T15.2	1664.40	13.212		319200		271200		244080		223440		191520	SWPR7B
1T12.7	98.71	0.774	190	18700	160	15900	144	14310	133	13090	114	11220	SWPR7B
1T15.2	138.70	1.101	190	26600	160	22600	144	20340	133	18620	114	15960	SWPR7B
1T15.2	138.70	1.101	175	24500	150	20800	135	18720	123	17150	105	14700	SWPR7A
1T17.8	208.40	1.652	190	39500	160	33600	144	30240	133	27650	114	23700	SWPR19
1T19.3	243.70	1.931	190	46000	160	39500	144	35550	133	32200	114	27600	SWPR19
1T20.3	270.90	2.149	185	50500	160	43000	144	38700	130	35350	111	30300	SWPR19
1T21.8	312.90	2.482	185	58400	160	50500	144	45450	130	40880	111	35040	SWPR19

2.4 Approach Roads and Access Roads

2.4.1 General Description

The design of the approach roads and access roads of the road crossing over the Suez Canal will be carried out based on Egyptian standards and taking into consideration the local conditions.

2.4.2 Design Standards and Specifications to be Applied

The following Egyptian standards issued by GARBLT, have been used for the design of the road crossing over the Suez Canal where possible. Other standards such as American, Japanese and European standards have been used to supplement the Egyptian standards when required.

- Highway Geometric Design Standard (English)
- Geometric Design of Roads; 1994 (Arabic)

The following standards have been used to supplement the Egyptian standards for the geometric design of the road crossing;

- "Geometric Design of Highway and Streets"	AASHTO (USA)
- "Geometric Design Standard"	Japan Road Association (Japan), and
- "British Standard"	British Standard Institution (Britain).

2.4.3 Design Criteria

(1) Approach Roads

1) General

The approach roads are the structures connecting the approach bridges to the access roads. The approach embankments are expected to be on high embankments.

The height of the embankments depends upon the soil condition of the site and the economics of construction, taking into consideration the cost of the acquisition of the farm land. The farm land in the Project sites has been developed for many years and it is not economical to acquire this established farm land for the huge area required. (For example for a 10 to 15 m high embankment, between 60 m and 75 m width of farm land will be acquired). On the East Bank side (Sinai Side), a high embankment will be examined based solely on the geological conditions, whilst on the West Bank Side, a low embankment of about 10 m height has been examined, to minimize land use at the site. (Refer to Fig. 2.4.1)

2) Material

As a principle, the approach embankments will be built using local sand from around the Canal road crossing site. However, using high quality materials from a quarry is considered to be required to maintain the stability of the approach embankments, because the approach embankment will be high. (Refer to Paragraph 4.3.2)

The sand to be used for the approach embankments will be selected at an early stage of construction.

3) Maximum Height

The height of the approach embankments considerably affects the construction cost of the Canal crossing bridge. The higher the embankment is constructed, the lower will be the cost of the bridge structure. However, the height of embankments is limited as they can become unstable. In addition, high embankments will detract from the aesthetics of the Canal crossing bridge.

The maximum height of the embankments have been selected taking account of stability of the embankments and land acquisition area. A maximum height has been determined, as shown below.

- For the East Bank side : 20 m based on the stability of the embankments.
- For the West Bank side : 10 m to minimize land use.

4) Side Slope

In accordance with the Egyptian standards, the maximum slope of an embankment whose height is more than 3.0 m is 3:2 (horizontal: vertical).
The slope of the approach embankment has been selected as 2:1 in order to maintain stability of the embankment taking into consideration the strength of the soil used for the embankments. (Refer to Fig. 2.4.1)

The inclination of the approach embankment slopes has been studied and determined based on the result of the stability calculation of the embankment in Chapter 4. Slope protection for the approach embankments has been also studied in Chapter 4.

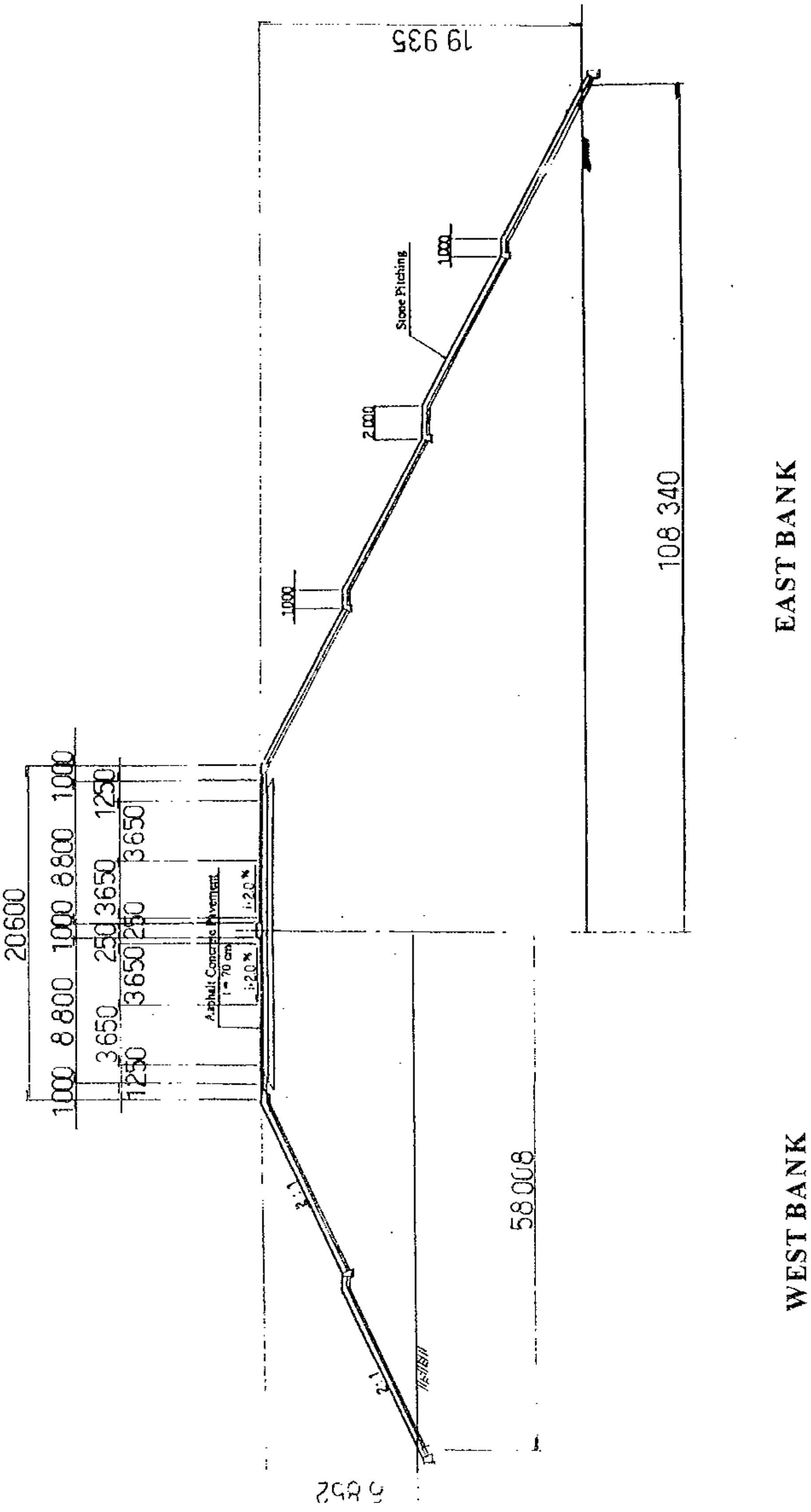


Fig. 2.4.1	**Standard Cross Section of Approach Embankments**

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(2) Access Roads

1) General

The access roads are the roads which connect the Canal crossing bridge to the existing road network. The access roads are expected to be on low embankments.

Access roads providing the connection between the crossing and the existing arterial road network are:

- West Bank (Main Land) : Cairo - Ismailiya - Port Said Road
- East Bank (Sinai Side) : New Central Road

2) Material

The embankment of the access roads will be built using local sand from around the Canal road crossing site. The sand to be used for the embankments will be selected at an early stage of construction.

3) Height

The access road structure will be formed on low embankments about 1.5 m above the ground, except in low swampy areas where a more substantial embankment will be required. Concrete pipe or culvert structures will be required for crossing the irrigation canals in the cultivated areas and the height of the access road will be decided taking into account these crossing structures.

The height of the access roads above the surrounding land will be approximately 2.0 m to 3.0 m to match the height of the Flat Desert Road and to provide the space for the crossing structures.

4) Side Slope

The Egyptian standards recommend an embankment slope of 2:1 (horizontal: vertical) where the height is 2.0 m to 3.0 m and 3:2 for the height more than 3.0 m.

The slope of the embankment of the access road has been determined as 2:1 in order to maintain stability of the embankment. (Refer to Fig. 2.4.2)

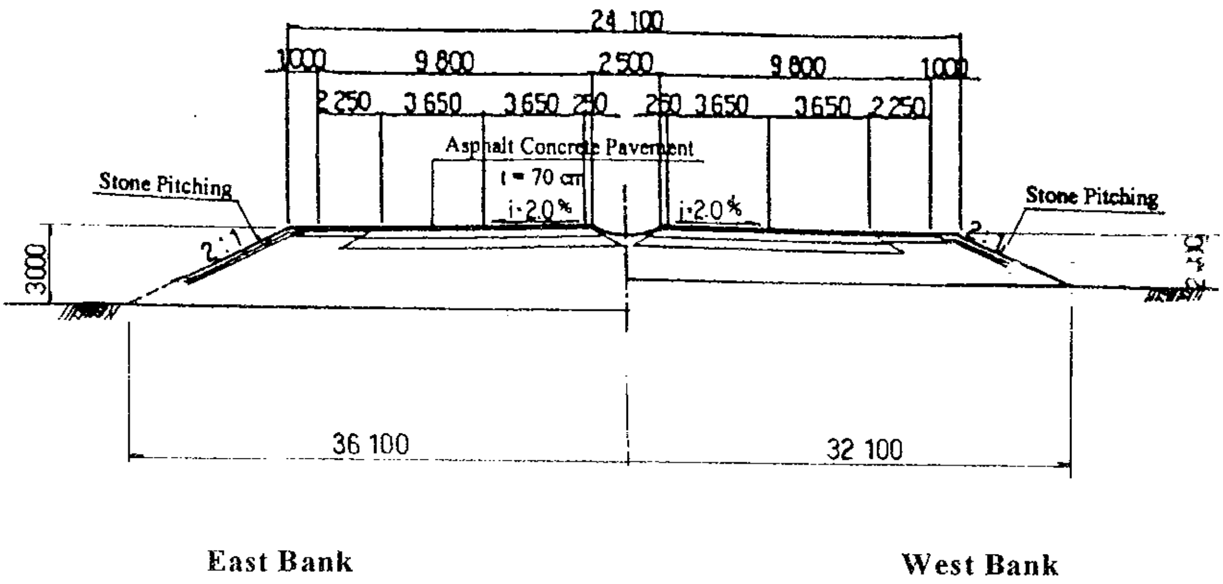


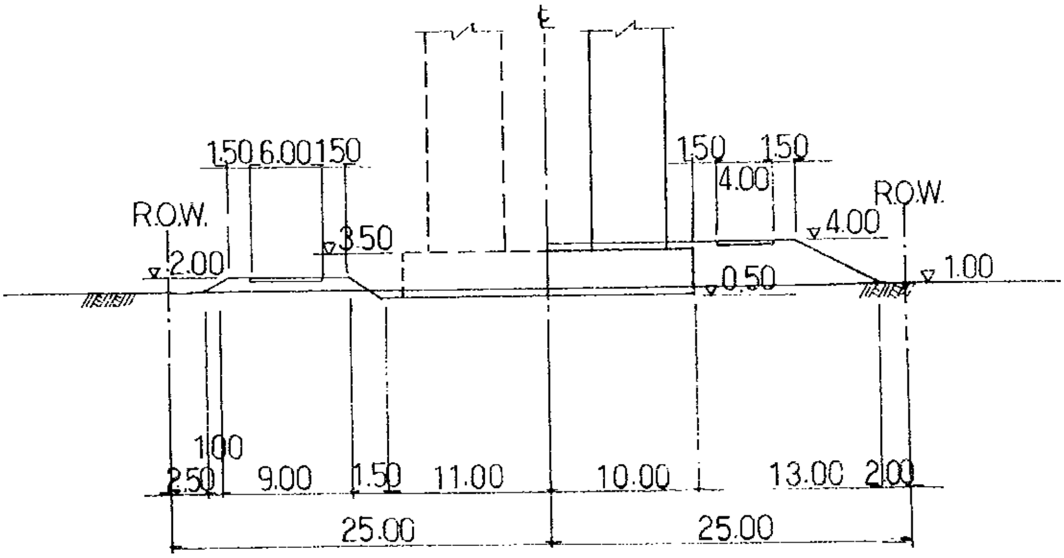
Fig. 2.4.2 Standard Cross Section of Access Roads

(3) Right-of-Way (R.O.W)

The right-of-way required for the road crossing the Suez Canal is shown in Fig. 2.4.3.

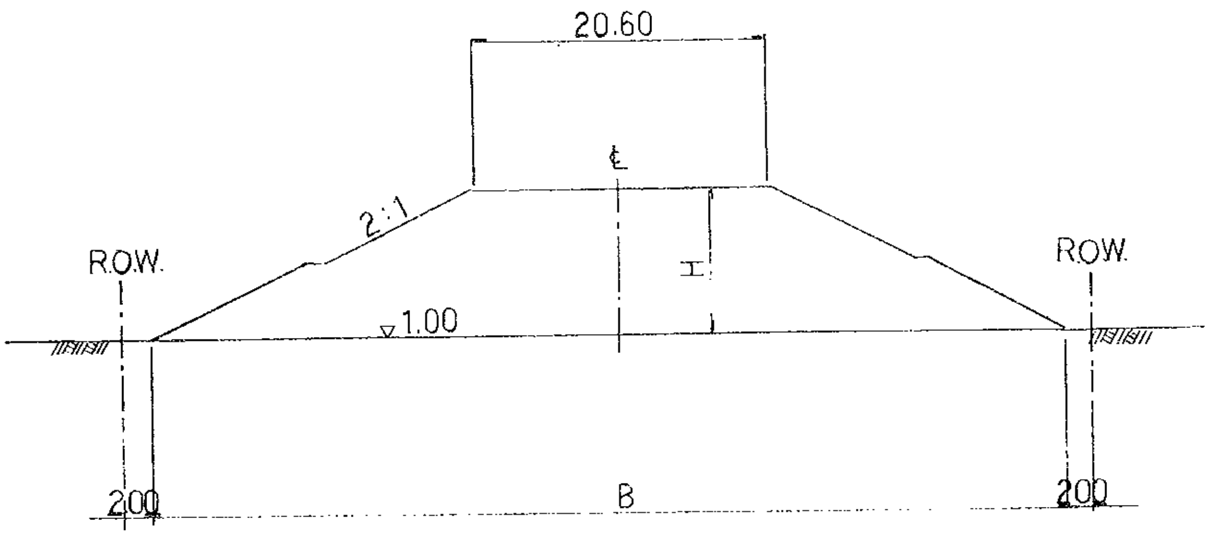
2.5 Results of Technical Discussions

The results of technical discussion to determine the design criteria for the Sue Canal bridge are shown in ANNEX - 2.



During Construction **After Completion**

Approach Viaduct



During Construction **After Completion**

Approach Embankment and Access Road

Fig. 2.4.3 Right-of-Way (R.O.W)