4.3.2 Related Facilities

(1) Ventilation

1)Introduction

Before the discussions about alternative plans for the ventilation system, possibility to reuse the existing fans was confirmed as follows:

a. Based on the basic design of thickness of the new concrete lining (450m), 70 percent of the existing duct areas can be secured.

b. It has been confirmed by the fan-maker "Woods (UK)" that the existing fans can be reused with adjustment of fan's pitch angle from 23 /20 to 14 /12 and reduction of the wind volume to 70 percent of the existing fans. Summary of the above examination are as shown below

Item	Existing	After Rehabilitation	Remarks
Supply Duct	10.8m^2	7.8m^2	70%
Exhaust Duct	10.5m^2	7.6m^2	70%
Max.supply (8-fans)	616m^3/sec.	410m^3/sec.	
Max.supply (1-fan)	77m^3/sec.	51m^3/sec.	
Pressure	2,400 Pa	2,147 Pa	< 2,400 Pa

Exhaust fans will also be adjusted by a similar method.

c. Two specific graphs are attached hereinafter for future detailed examination:
Fig.4.3.52 shows the specific relation between Volume Flow and Fan Total Pressure.
Fig.4.3.53 shows the specific relation between Fan Pitch Angle and Fan pressure.

2) Selection of the Transverse Ventilation system

Detailed procedure to select the Transverse Ventilation System was described in the attached letter addressed to S.C.A. dated 11th October 1991, and the transverse system was accepted by S.C.A.. (Ref. Appendix-5) However,the followings are to be noted:

a. Air Volumes by Operation Levels
After Rehabilitation the total fan capacity (m^3/s) would be reduced to 70 percent as shown by levels in the following table:

Oeration Level	Existing Supply	Supply after Rehabilitation
7	616	410
6	504	335
5	338	225
4	244	162
3	118	78
2	62	41
1	0	0

Modification of the control system for the ventilation at the control room is not required, and the existing operation manual will be applied accordingly.

b. Duct Area after Rehabilitation

As already described, the duct areas after the Rehabilitation will have approximately 70 percent of the existing areas : 7.8 m^2 for air supply and 7.6 m^2 for exhaust.

c. Cost Data for the Comparison

In the letter, cost data for the vertical shaft and ceiling panels were shown, however, these preliminary costs did not include the overhead and preparation cost fully.

d. Existing Fans

As indicated by S.C.A. the possibility to continuously use the fans were discussed with the maker and it was confirmed that all fans (100%) will be reused after the Tunnel Rehabilitation with the adjustment of fans' pitch angle from 23°/20° to 14°/12°.

e. Effect of the Pilot Shaft in case of "Fire"

It is certain that the chimney effect will appear due to the incoming air flow with a velocity of clearly over 2m/sec. This chimney effect will act as an advantageous flow to quickly exhaust the smoke from the shaft only in case of occurrence of fire at around the middle zone of the Tunnel, and to allow people to escape out of the Tunnel. However, it may be rather difficult to distinguish the fire due to fresh air supply by the chimney effect . Therefore, this effect can not be said to be advantageous on the whole.

3) Recommendation on the Operation

The Team considers that S.C.A. should only operate the air supply fans in a similar way to the semi-transverse system for the following reasons:

a. The air conditions in the Tunnel could be maintained only to ensure an acceptable level of air supply to dilute the foul gas.
b. Saving of the operation cost could be achieved by reduction of electricity charge for about 50 percent.
c. Saving of the maintenance cost also could be achieved by reduction of the spare parts cost for the exhaust fans.

However, in case of emergency such as "Fire", the exhaust fans shall be operated.

(2) Structure of Ceiling

1) Function of Ceiling

The ceiling is designed to be used as an exhaust duct of transverse ventilation system.

2) Principal Features of Ceiling Structure

a. Component of Ceiling

The components of ceiling are illustrated below.

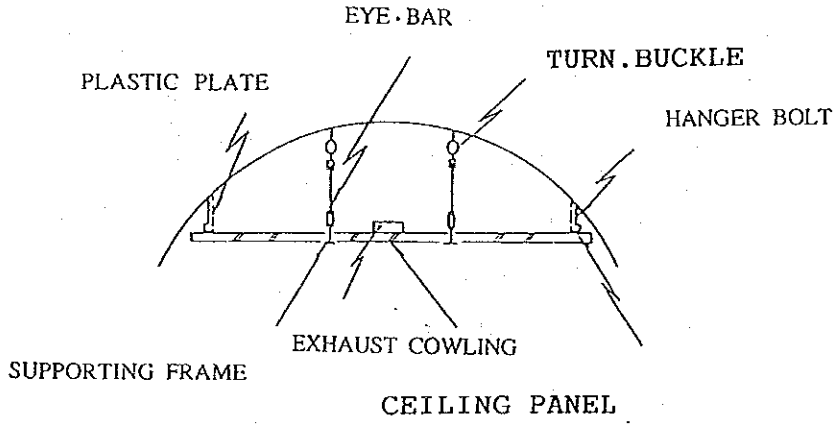


Fig.4.3.27 Components of Ceiling

b. Alternative for both hanger bolts

The way of supporting ceiling panels with hanger bolt shall be changed to a metal frame device because of the following reasons:

- The plastic laminated panel fitted on a segment to prevent exhaust air from leakage shall be eliminated for its combustibility.
- In order to widen the area of exhaust duct, smaller hanging device shall be used.

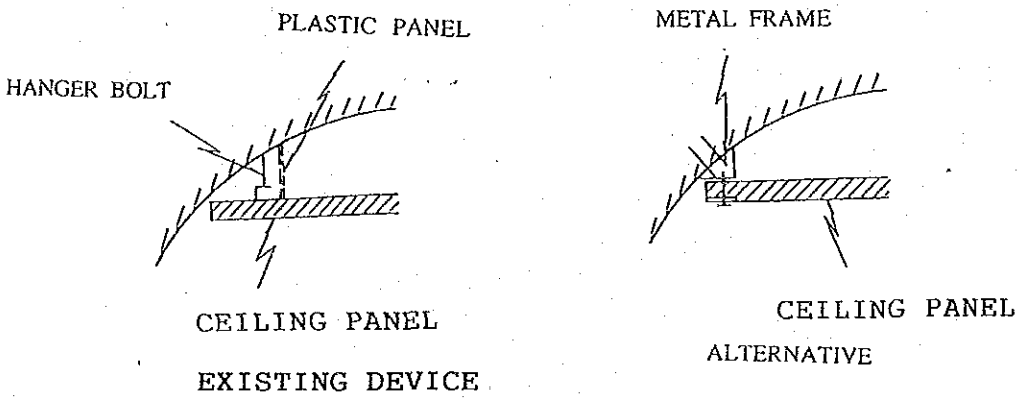


Fig.4.3.28 Alternative for Hanger Bolts

3) Arrangement of Ceiling Panel

The ceiling panel is installed 50 millimeters higher from the vertical clearance of 5 meters from the road surface to create a space for pavement overlay in the future.

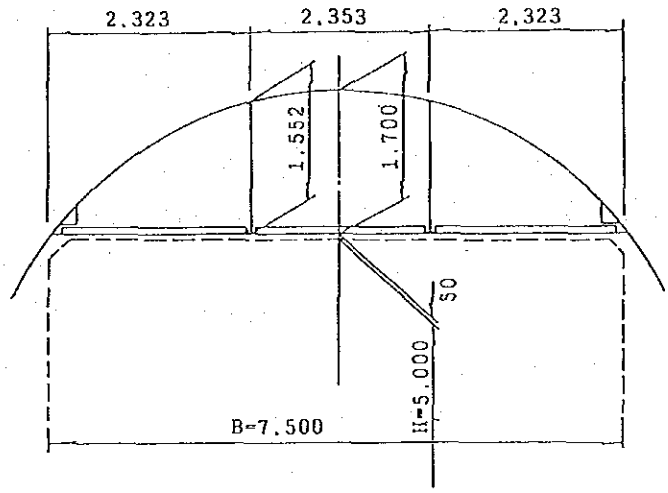


Fig.4.3.29 CEILING ARRANGEMENT

4) Details of structure

a. Structure members for ceiling

The following structures are designed for the ceiling:

- Concrete Lining (Reinforced Concrete-made)
- Ceiling Panel (Reinforced Concrete-

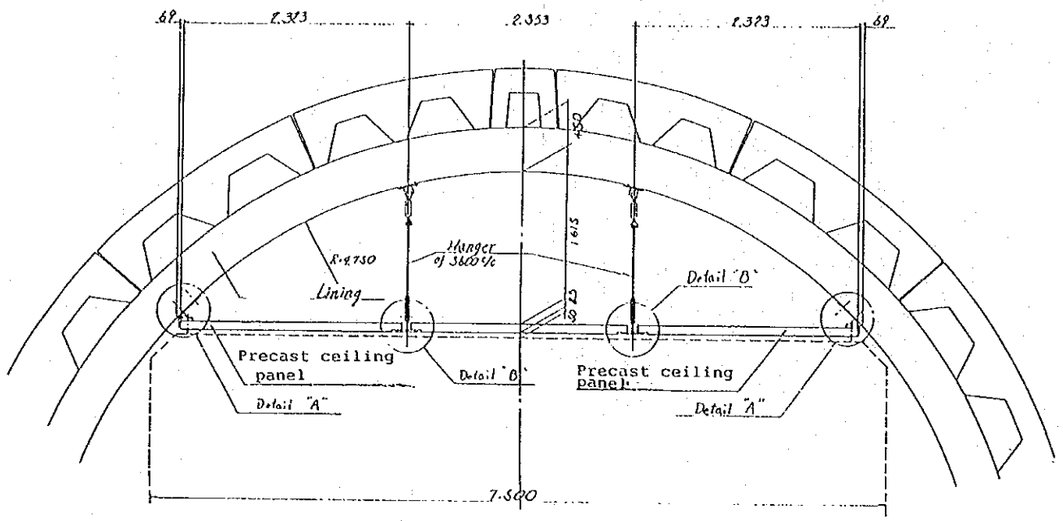
- Hanger (Steel Structure-made)
- Supporting Frame (Steel Structure-made)
- Duct Cowling (Steel Structure-made)

b. Inspection car

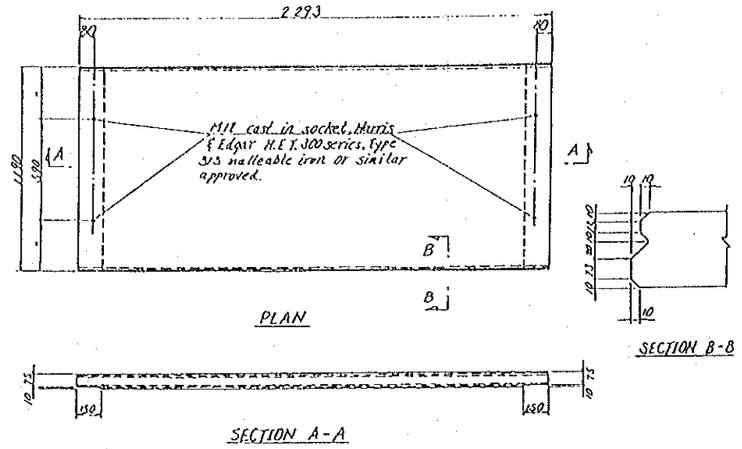
Thinking of the height of 1.6 meters between the ceiling and the new lining at the crown it may be too low to walk comfortably while doing inspection. Therefore, inspection cars moving along a rail are proposed to be furnished in the space of the center ceiling panel for inspector to pass above duct cowlings, if necessary.

5) Ceiling structure and arrangement

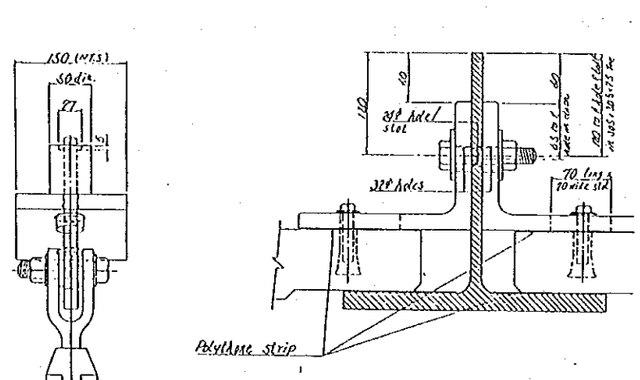
See Fig 4.3.30.



POSITION OF EAVS SUPPORTS AND HANGER

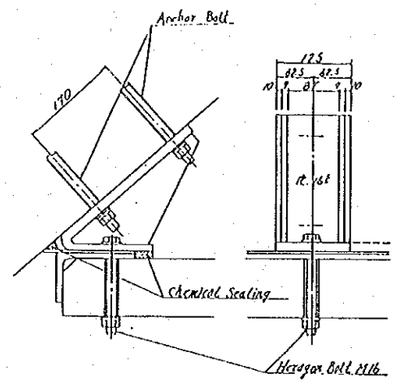


MIDDLE CEILING PRECAST CONCRET PANEL

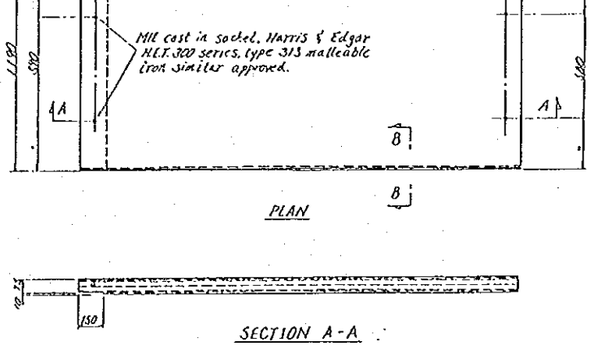


MIDDLE HANGER

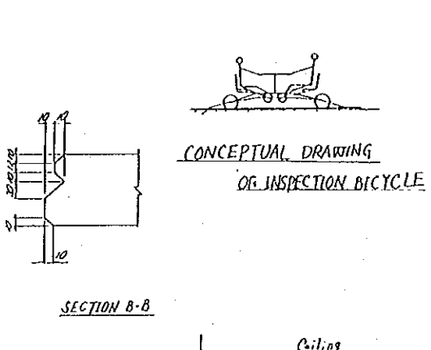
DETAIL OF EAVES FIXING
(Detail " B ")



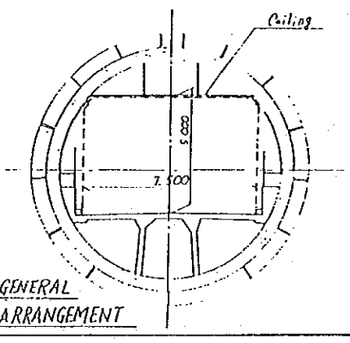
SUPPORTS (Detail "A")



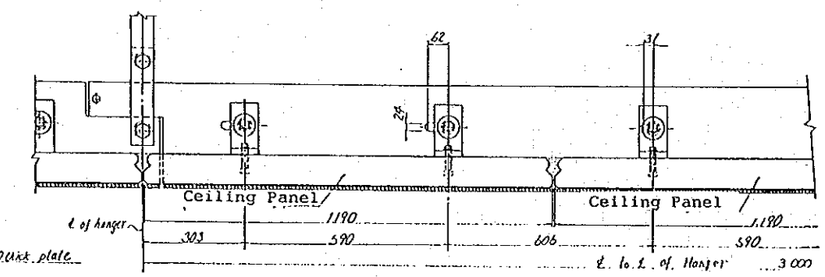
SIDE CEILING PRECAST CONCRET PANEL



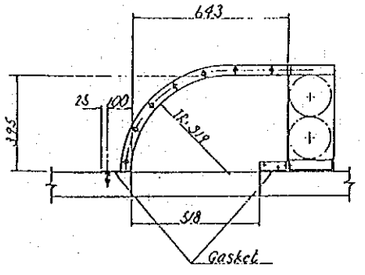
CONCEPTUAL DRAWING OF INSPECTION BICYCLE



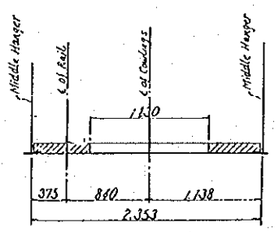
SCHEMATIC GENERAL ARRANGEMENT



ELEVATION ON MIDDLE HANGER



EXHAUST COWLINGS



POSITION OF RAILS AND COWLINGS

Note; The rail composed of single steel angle is set up for inspection bicycle running along it.

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CEILING STRUCTURE AND ARRANGEMENT					
Scale		Date		Review	
JICA					

Fig.4.3.30 CEILING

(3) Tunnel Lighting

1) Introduction

The existing tunnel lighting system is as follows :

a. Basic illumination
   2,076 nos of fluorescence lumps are installed continuously.
b. Entrance illumination
   420 nos of high pressure sodium lumps are installed.
c. Transformer
   10 nos of 30KVA, 3-phase(Φ) 3.3KV-380V are installed under the walkways.
d. Distributor panel
   20 nos of panels are installed on the lower wall.

In the Minutes of Discussion dated September 2, 1991, it was agreed that the existing fluorescent lamp would be reused after the Rehabilitation Works. However, the sodium illumination will be applied to the basic illumination due to the following reason :

After the Rehabilitation Works, it is physically impossible to re-install the 10 nos of transformers for the fluorescent lamps in the narrowed space under the walkways, while the sodium illumination system would only require 30 percent of the existing lamps which could use the supply of 380V electricity directly from the west side switch room.

2) Basic Illumination

Basic illumination is designed to maintain 8cd/m^2 which would be sufficient by providing low pressure sodium lamp (424 nos) every 8.0m on both sides.

3) Entrance Illumination

Transitional illumination from the tunnel portal(6,000cd/m^2) to tunnel light (8cd/m^2) is designed by using high pressure sodium lumps (334 nos) due to high efficiency of source of the lamp.

Details of the lighting fixture and sodium lamps are illastrated in Fig. 4.3.31 and 4.3.32.

4)Electricity Distribution System

The existing power supply system is summarized below :

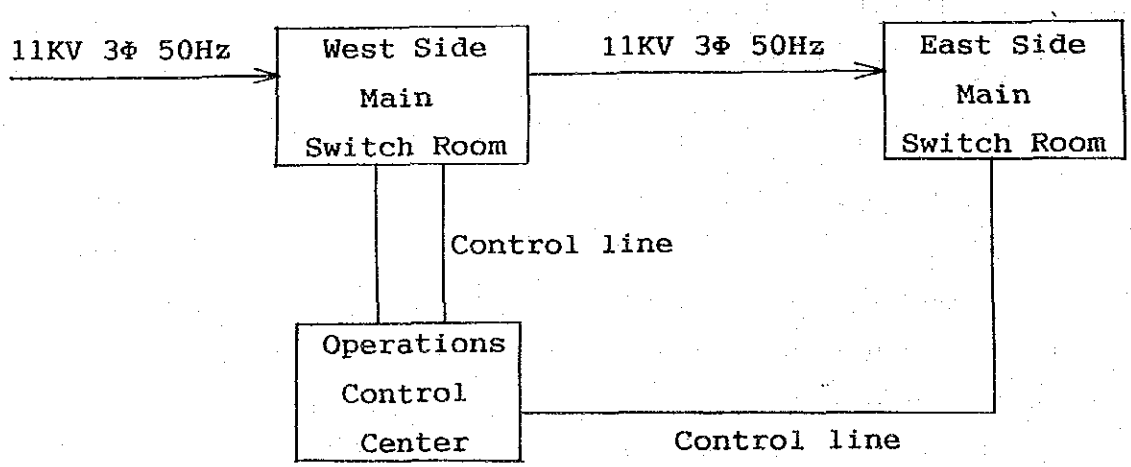


Fig.4.3.31 The Existing Power Supply System

New distribution panel for the tunnel lighting will be installed at the existing main switch rooms and electricity will be supplied with 380V 3Φ line. This system is illustrated in Fig. 4.3.33

4) Emergency/ Maintenance System

The existing un-interruptible power supply system will be maintained as it is so that whenever power will be off, the emergency batteries will start working immediately to supply power for a short time (about 5 minutes), and at the same time the emergency generators will be automatically switched on and begin to supply power within 5 minutes. This system accordingly can keep the tunnel lighting of the sodium lamp without any power stop, they are installed in the existing inverter rooms at both sides.

While maintenance work such as cleaning of light fixtures is being done, it is not required to switch off the power at main switch room, because the power can be disconnected if necessary, by each connector which will be installed at each sodium lamp respectively.

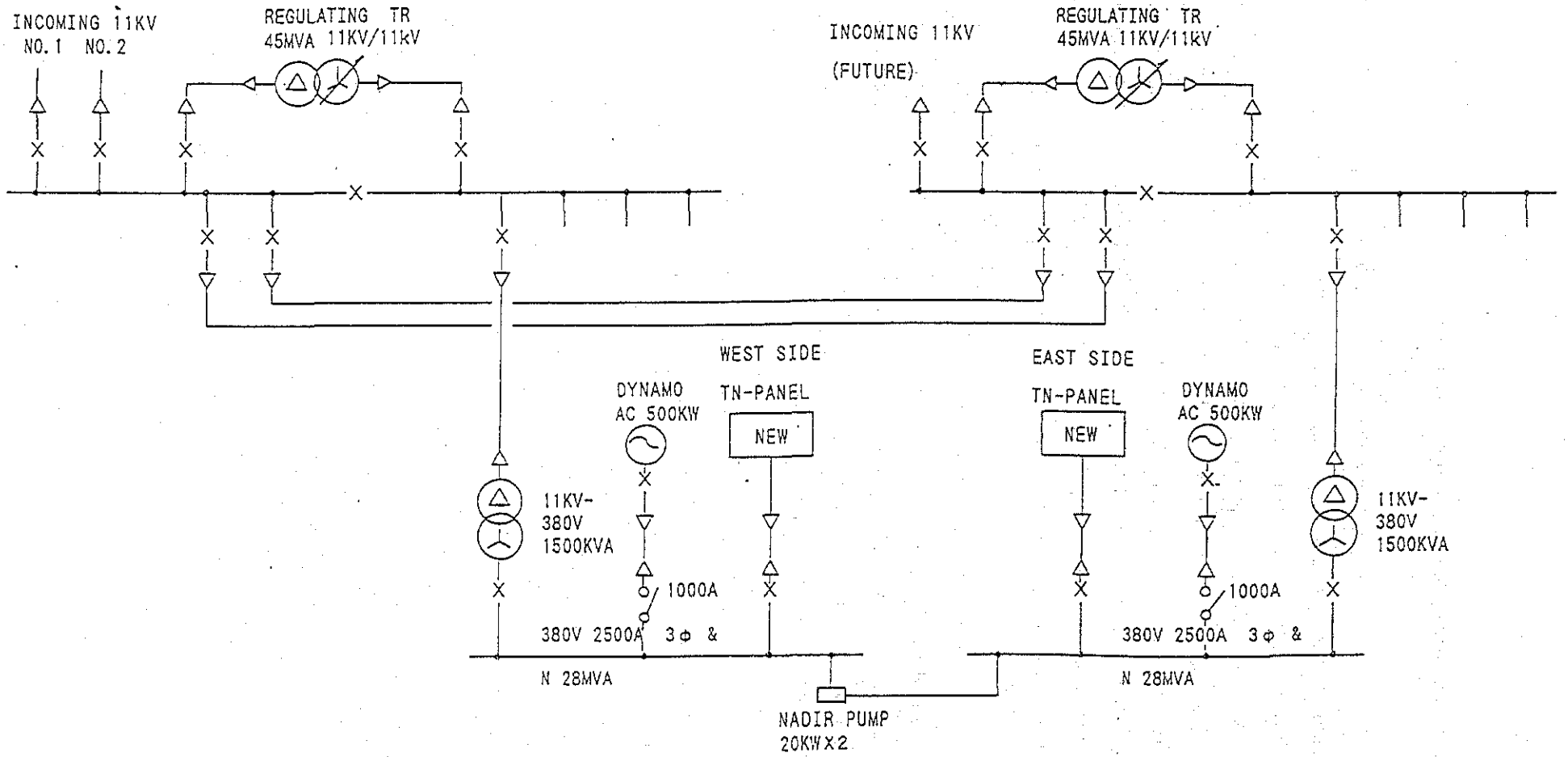
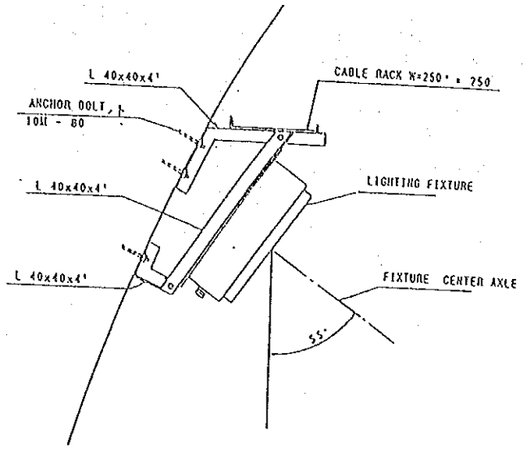
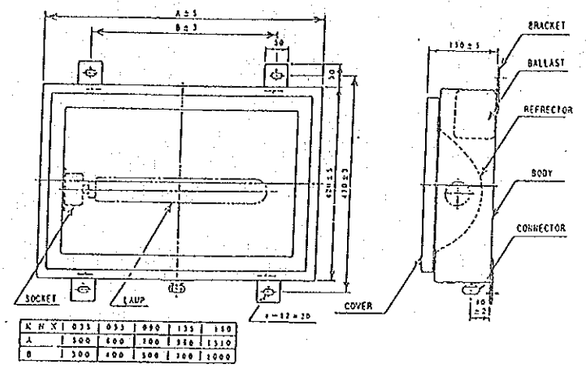


Fig.4.3.32 LAYOUT OF POWER DISTRIBUTION SYSTEM

INSTALLATION OF LIGHTING FIXTURE

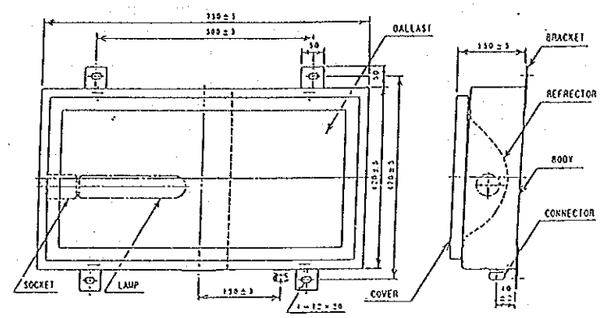


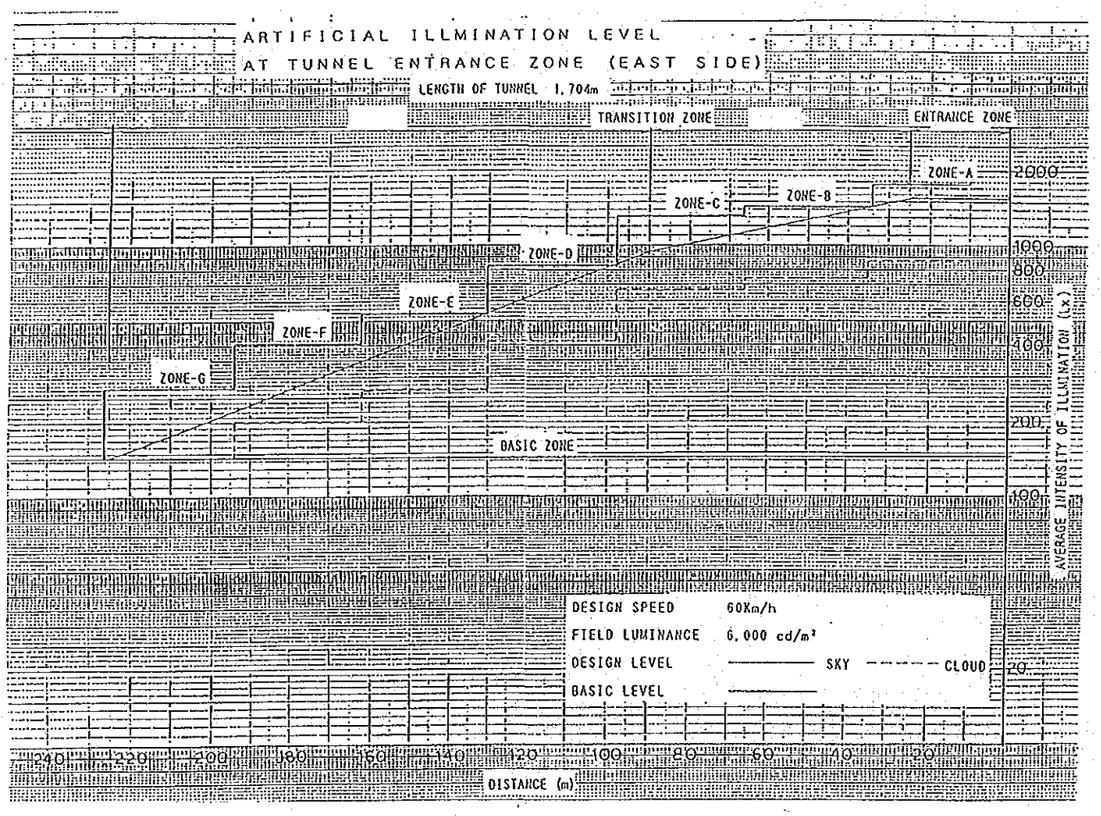
LOW PRESSURE SODIUM LAMP FIXTURE (mm)



N W N	035	055	090	135	180
A	500	600	800	1200	1510
B	300	400	500	700	1000

HIGH PRESSURE SODIUM LAMP FIXTURE (mm)





EAST SIDE ENTRANCE ILLMINATION FIXTURE LAYOUT

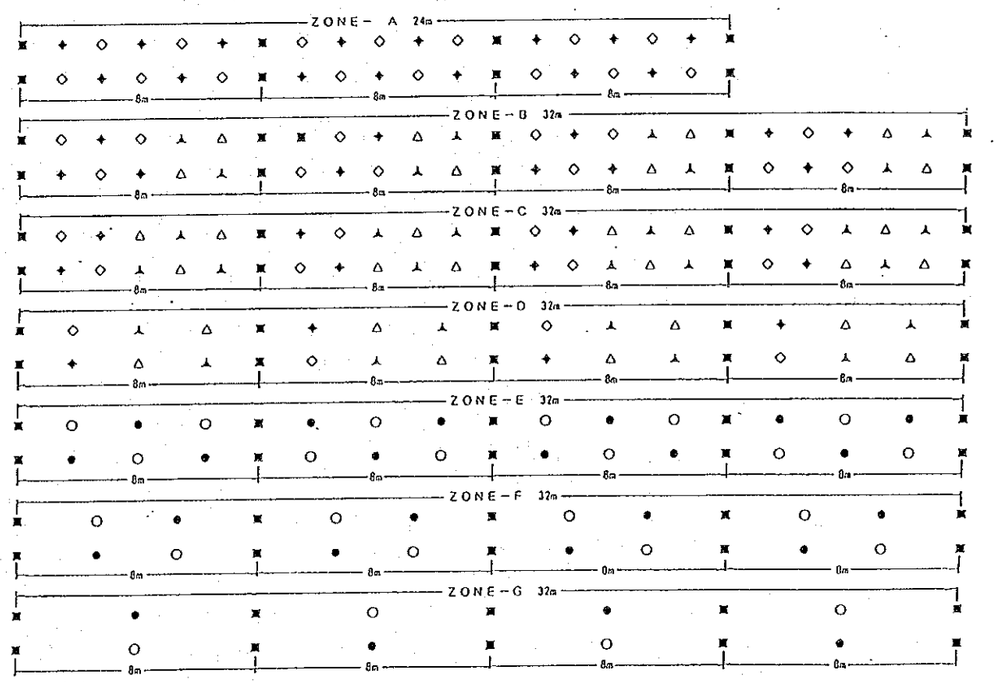


Fig.4.3.33 TUNNEL LIGHTING BY SODIUM LAMP

(4) Wall panel (Interior surface)

1) Purpose of Study

In this chapter, the following two items are to be studied :

a. Incombustibity of existing interior surfaces made of bakelite
b. Alternative to existing interior surfaces

2) Incombustibility of the Existing Interior Material

a. Classification of Incombustibility

Japan Building Structure Standards classify the panel material for building into three classes.

Class A : incombustible material, ex. concrete, asbestos slate, steel structure etc.
Class B : quasi-incombustible material, e.g. cement plate containing wooden fiber, plaster board etc.
Class C : non flamable material, e.g. laminated wooden plate covered with flame-resistant coat, flame-resistant plastic plank etc.

The existing wall panel made of bakelite is generally considered as the category of Class C as classfied above, though it is less flame resistant than the other materials in this group.

b. Proper material for interior surface

Tunnel Design Standard and Guideline issued by NIHON DORO KODAN stipulates that only Class "A", incombustible material, can be used as tunnel interior material from the view point of preventing the spread of fire and harmful gas caused by traffic accident .
Judging from the above stipulation, the existing interior panels should be replaced by another material.

3) Alternative to the Existing Interior Material

There are three parts covered with the interior materials in the Tunnel that must be studied.

These include the underside surface of the ceiling, both side walls and the front of both walkways.

The underside of ceiling easily gets dirty with car smoke, and the dark color lessens the luminous intensity of the lamp. However there is no significant reason to cover the underside of ceiling with interior material due to the downward angle of lamp.
Therefore the latter two parts mentioned above will be examined herein.

a. Interior lining on both side walls

There are three kinds of typical interior materials actually employed in Japan :

Type 1. Silica acid calcium board (i.e., Asbestos slate)put together by baking with inorganic film
Type 2. Asbestos slate boarded with tile panel
Type 3. Asbestos slate boarded with painted steel

Those three materials passed the incombustible test according to the Japan Building Construction Standard.

In those Types, Asbestos slate with inorganic film on it is most recommendable, because it has a long record and has been employed widely in many places in Japan.

This type has been considered to satisfy the following necessary conditions well for tunnel interior use.

This material is not only fire-proof but also capable of holding clean, flexible in fitting on circular walls and more economical in comparison with other two types.

b. Interior lining on the precast concrete panel and steel plate attached to the carriageway side of the walkway

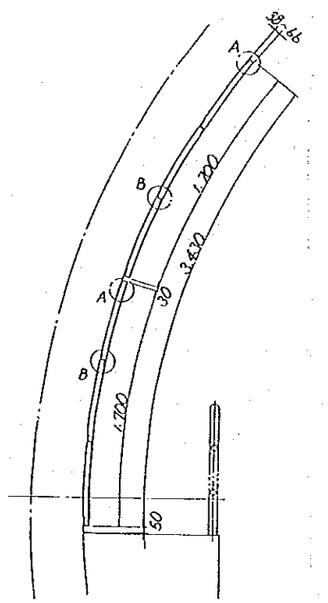
The paint coating system applied on the precast concrete panel and steel plate is examined as a substitute for interior plank because of its easy treatment.

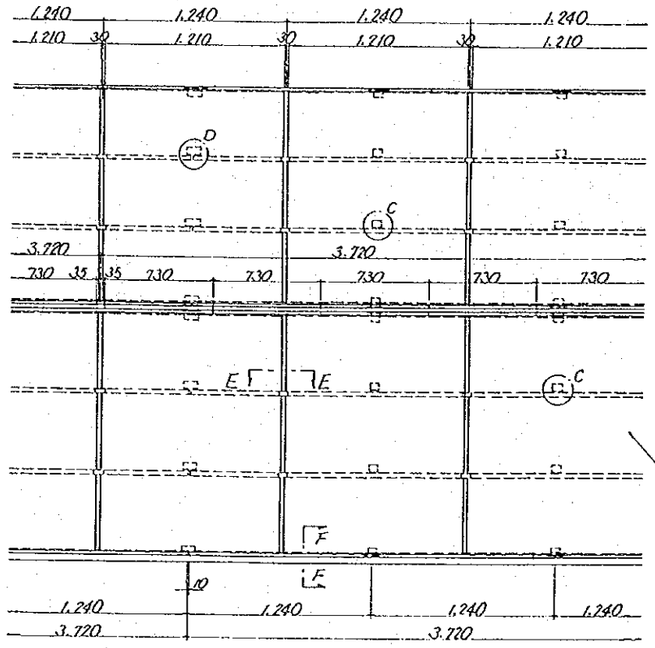
The fluorine coating system is selected as a representative one compared with other paint systems.

The result of the surface baking test of this material conducted in accordance with NIHON DORO KODAN Standard indicates that it belongs to the quasi-incombustible material which is generally unused as tunnel lining. However the volume of gas caused by burning organic paint should not give harmful effects on people due to it's minor volume.

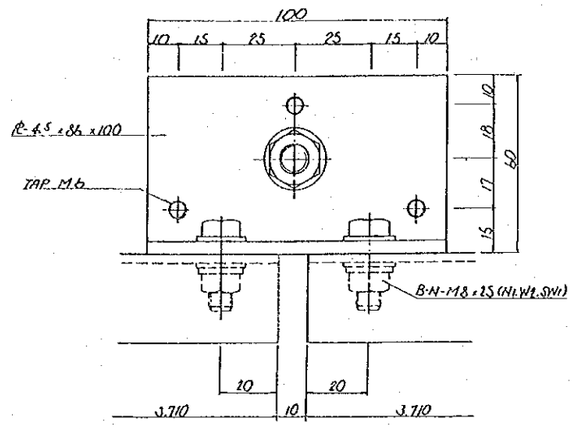
4) General Arrangement of Interior Panels

See Fig. 4.3.34



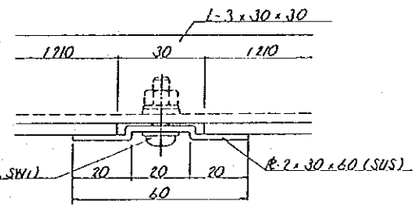


Standard Arrangement of Interior Panel

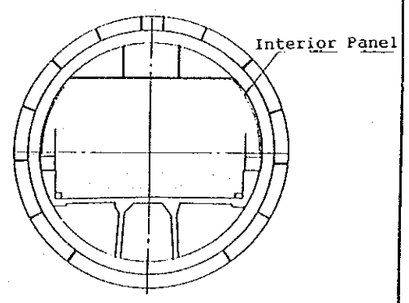


DETAIL Ⓓ (Scale 1:1)

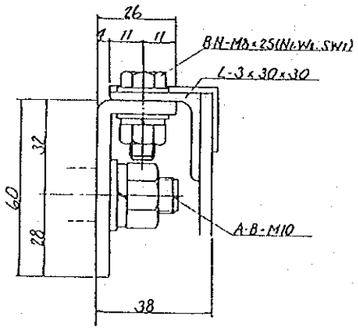
Silicic acid calcium
Panel with inorganic corting



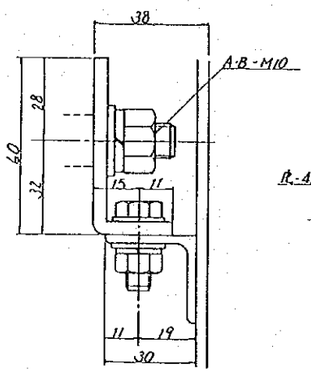
SECTION E-E (Scale 1:1)



SCHEMATIC GENERAL ARRANGEMENT



DETAIL Ⓐ (Scale 1:1)



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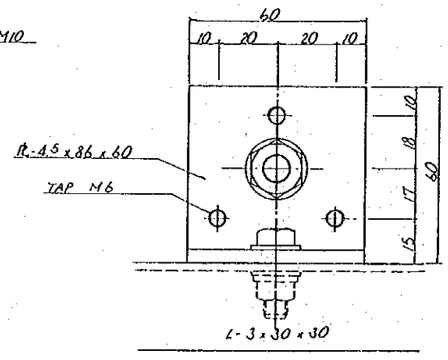

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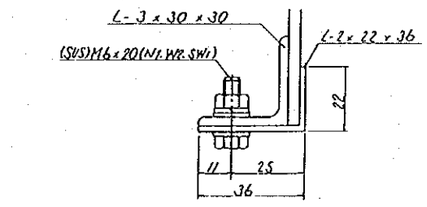

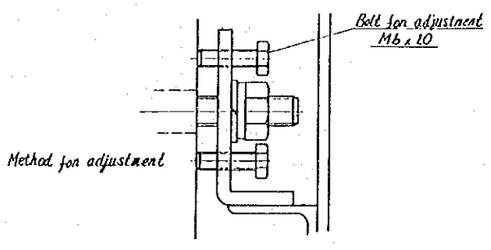

SECTION F-F (Scale 1:1)

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GENERAL ARRANGEMENT OF INTERIOR PLANK					
Scale		Date		Review	
JICA					

Fig.4.3.34 **WALL PANEL**

(5) Walkway

1) Objective of Study

The objective is to re-examine the main dimension and decide the skeleton of the walkway considering the size narrowed by new lining of the Rehabilitation Works.

2) Structure of the Existing Walkway

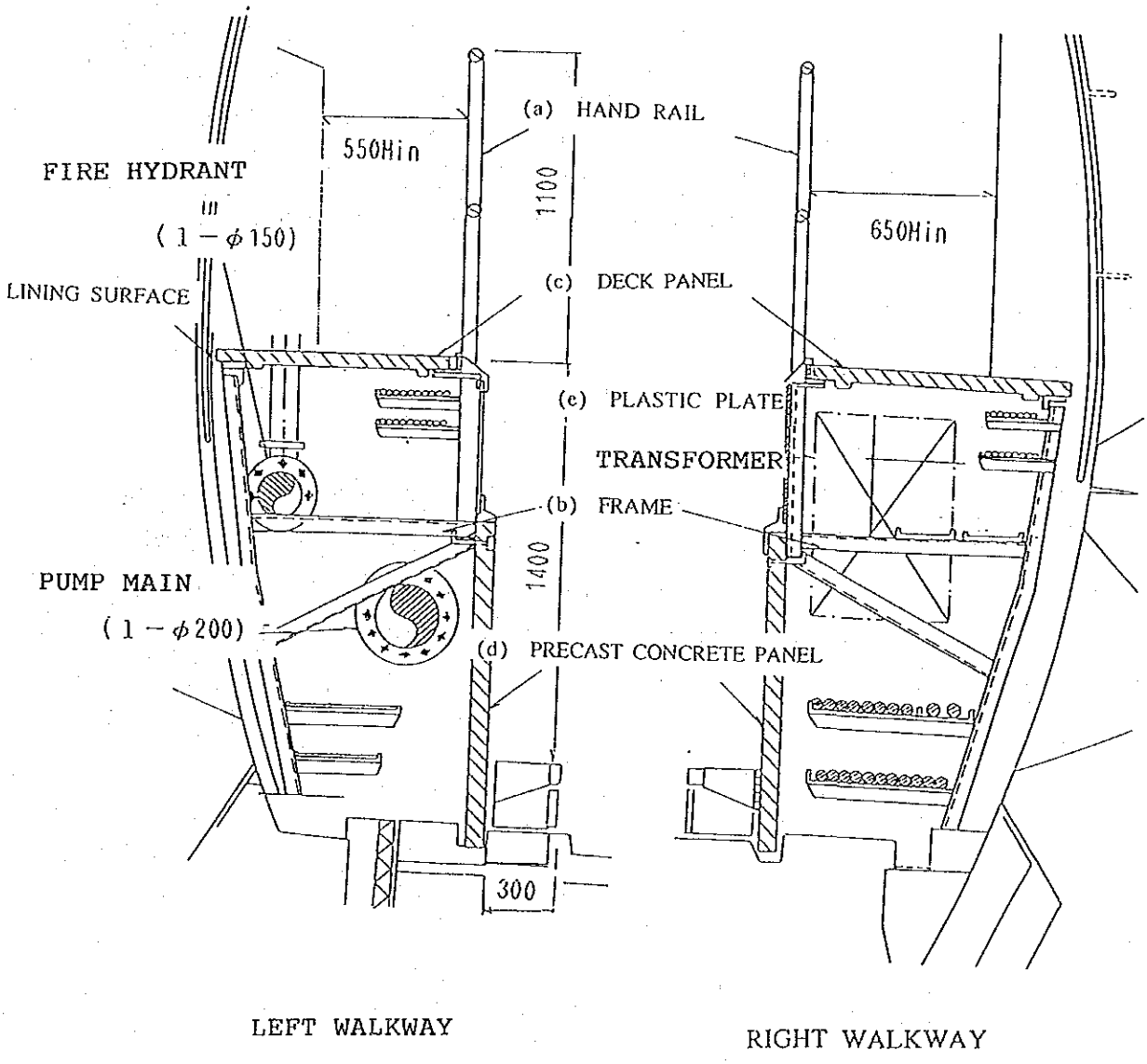


Fig.4.3.35 The Existing Walkway

The walkway is composed of several members as illustrated in above figure. Here we can describe the function of the main members from the view point of structural analysis.

- "(a)HANDRAIL" and "(c)DECK PANEL" are furnished for the safety of an inspector

- "(b)FRAME" supports not only self weight but also accessories such as power cables, telecommunication cables, fire hydrant and drain pipe etc.

- "(d)PRECAST CONCRETE PANEL" serves to prevent damage of accessories that may be caused by traffic accidents.

-"(e)PLASTIC PLATE" shall be alternated with a steel plate due to combustibity of the plastic plate.

3) Proposed Structure Form

a. Design Concept

This new structure is basically designed with the same intention as the existing walkway that gives an inspector convenience to look into accessories installed under the walkway by detaching the concrete deck panels or a precast concrete panel.

b. Alternative structure

Principal differences from existing walkways are as follows : (ref. Fig.4.3.36)

- The new lining of 450mm in depth is to reduce 299mm of the walkway width from 945mm to 646mm despite that part of the reduced of walkway width is absorbed with the space between lining surface and walkway and shifting a handrail by 75mm toward the carriageway.

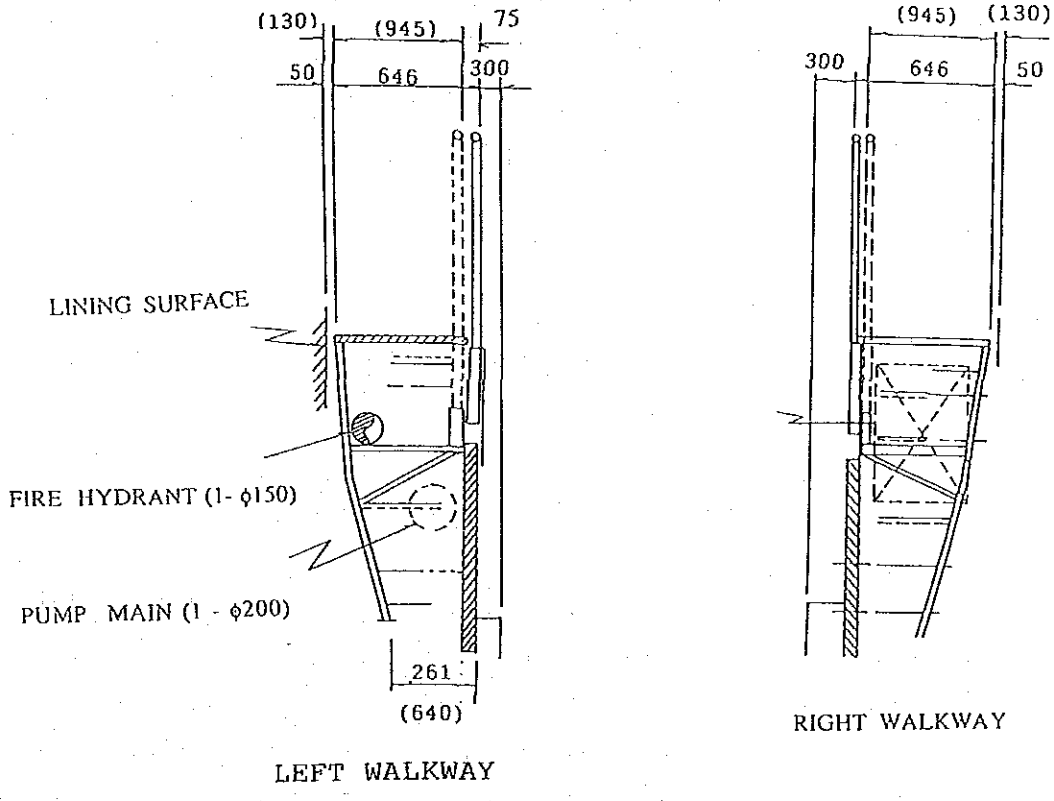


Fig.4.3.36. Proposed Walkways

- The pumping pipe must be transferred to the corner of the ventilation duct in order to create more space for the cable tray under the walkway.

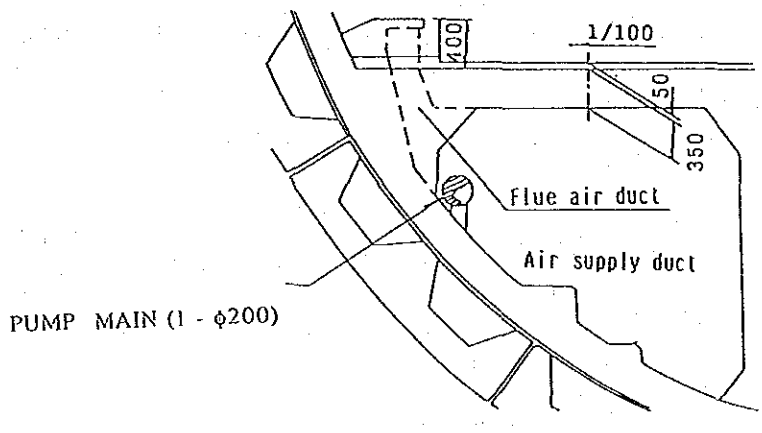
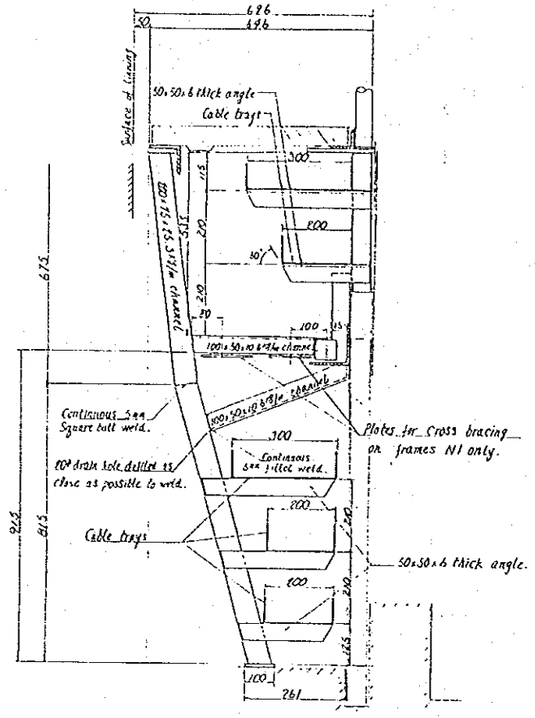


Fig.4.3.37 Location of Pumping Pipe

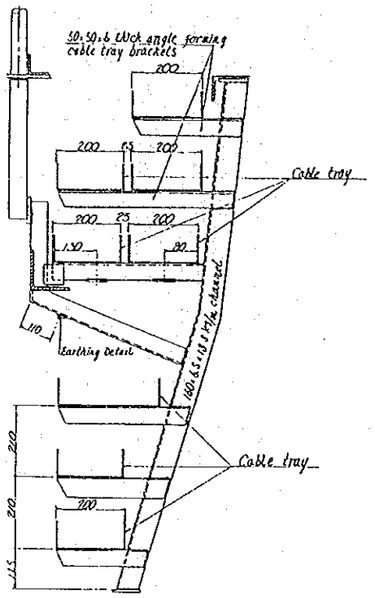
- In the right walkway, there is enough space to accommodate all cables because the existing electrical transformers are removed due to the change of power system for lightning. The arrangement of the Structural member is the same as the left side.

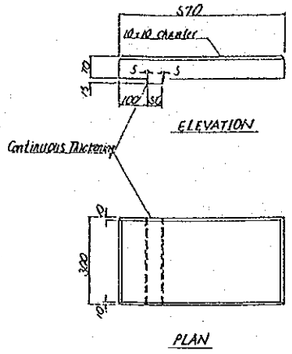
4) Tunnel Walkway

See Fig. 4.3.38

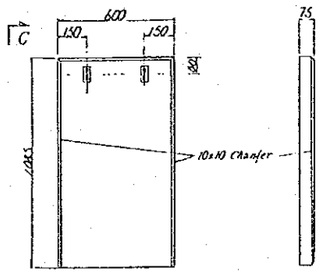


STANDARD WALKWAY FRAME

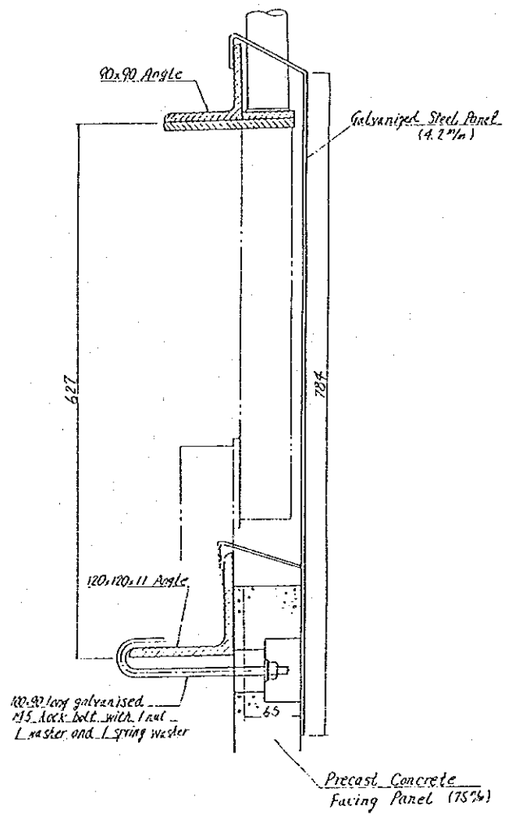




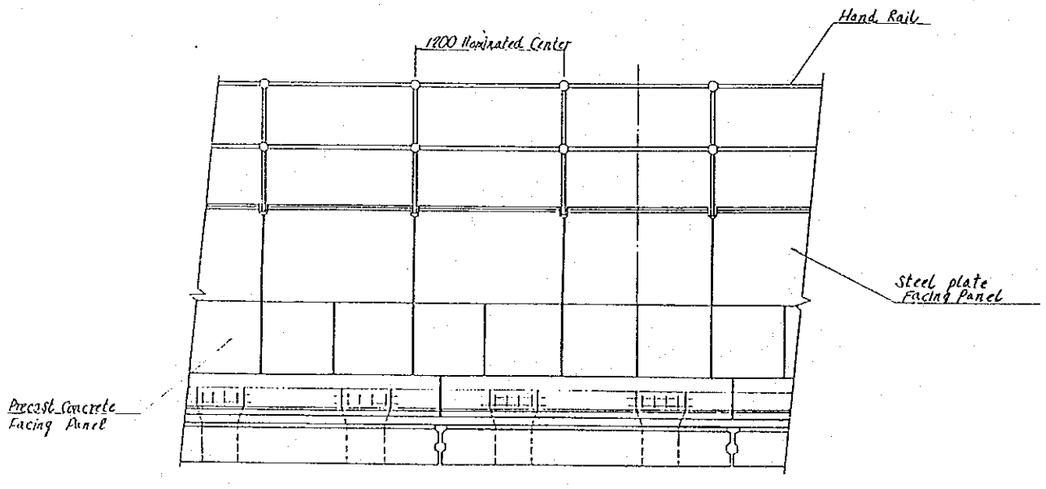
PRECAST CONCRETE FLOOR PANEL



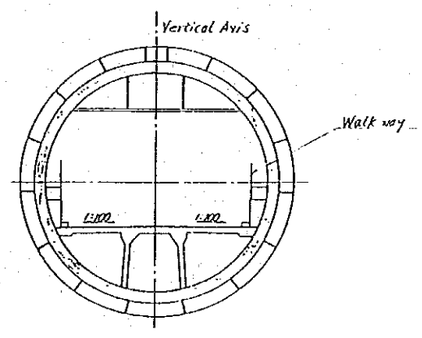
PRECAST CONCRETE FACING PANEL



STEEL PLATE FACING PANEL



WALKWAY GENERAL ARRANGEMENT



SCHEMATIC GENERAL ARRANGEMENT

AHAMED HAMDI TUNNEL					
TUNNEL WALKWAY					
Scale		Date		Review	
JICA					

Fig.4.3.38 **WALKWAY**

(6) Communication System

1) Emergency Telephone

37sets of the existing emergency telephone will be reused, however, steel works for installation will be required. The existing wires for telephone shall also be replaced by new wires because the change in location of the telephone equipment will result in a shortage of wire lengths.

2) Radio Telephone

A radio telephone line is located beneath the crown of the Tunnel. This line could be continuously used after the Rehabilitation Works because there is no branch connections. However, steel works for installation will be required.

3) CCTV Surveillance System

22 sets of Coaxial Cable Television Cameras are provided in the Tunnel, and 4 separate sets of cameras are provided outside the Tunnel. All of them will be reused after testing and adjustment, if required. However, the wires for the TV system will be replaced due to partial shortage of wire length. A total of 26 sets of TV monitors at the central control room will be reused.

(7) Traffic Safety Facilities

1) Carbon Monoxide Analyzer (CO Monitor)

There are 8 CO monitors: 5 sets are installed on the side wall of the Tunnel and 3 sets in the exhaust duct. They can be continuously reused (after the Rehabilitation Works) with necessary steel works for installation after testing and adjustment of the function. However, wires of cables for these monitors will be replaced.

2) Visibility Monitor (VI Monitor)

There are 5 sets of VI monitors installed on the wall of the Tunnel which are equipped with transceiver/receiver and control point, they can be reused (after the Rehabilitation Works) with necessary steel works for installation after testing and adjustment of the function. However, the wires for these monitors will also be replaced.

3) Fire fighting Equipment

There are 18 sets of fire hydrant and fire extinguisher. They will be reused (after the Rehabilitation Works) with minor repair of the metal doors of the hydrant's protective covering. Water supply pipe system for fire hydrants will be reused after polishing the rusted areas of the joints and replacing the gaskets. The control cable for alarms will be newly replaced due to partial shortage of cable length.

4) Control Wiring System

There is a large number of control wires on cable racks under the walk way for the purpose of remote supervisory control at the control center in the west side. These control wires will be replaced with new ones after examination of each wire, and the cable racks will also be replaced with new hot-dip galvanized steel racks.

5) Power Supply Cable to East Side Main Switch Room

There are 2-11 KV distribution cables, one is in the service duct and the other is a spare one on the cable rack of the north side . They will be reinstalled together within the service duct by being hung by hooks on the wall.

(8) Pipes

The basic design concept of pipe is to replace the existing pipes with new ones of the same or superior quality. Therefore the following will be taken into consideration;

1) The contract document has revealed that the existing pump main (1- Φ200) and exhaust pipe (1- Φ150) are designed in accordance with Cast Iron Pipe Class k9 in BS Standard which is considered just equivalent to Iron Class 3 in Japanese Industrial Standard (JIS).

   Japanese products will be used for the following reasons;

   a. Easy procurement.
   b. There are long history of use in Japan.
   c. Japanese contractor has extensive experience in treating them.

2) A vinyl chloride pipe is the most suitable drainage piep substitute, because a drainage pipe does not require so much strength as steel and moreover a vinyl pipe is rust-proof.

3) The inner lining and outer coating, for preventing steel corrosion, shall have properties equivalent to or superior than those of existing pipes.

4) The pressure test after the installation of pipes shall be conducted with the same pressure magnitude as was for existing pipes .

4.3.3 Fresh Water Supply Pipeline

The Fresh water supply pipelines are to be moved out of Through Service Duct in the Tunnel and installed partly on land and partly at the bottom of Suez Canal as has been stated in "4.2.3. Fresh Water Supply Pipeline."

The fresh water supply pipeline route is shown in Fig.4.3.39. Some explanations are stated as follows:

- The starting point is the west valve chamber, being the same as the existing tunnel route.
- The new lines are to be directed to the east through agricultural land running over the Sweet Water Canal by the pipe beam bridges and cross Suez Canal by the bottom pull method. Then, they will be laid on land through sand desert toward south/east until they reach the east valve chamber which is the ending point.

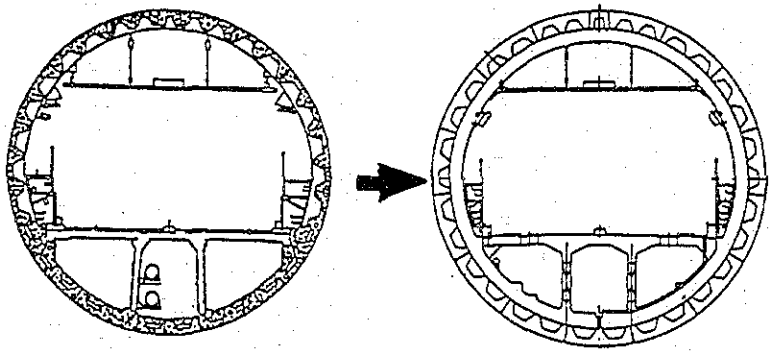
The basic design criteria of the fresh water supply pipelines are as follows:

pipe diameter : 500mm NID-- 2 lines
working pressure : 8 bar(kg/cm^2)
test pressure : 12 bar(kg/cm^2)
pipeline length (each)in plane:

- Cast iron pipe on land*	2,497m	-2 lines:	4,494m
- Steel pipe crossing Suez Canal	420m	-2 lines:	840m
- Steel pipe crossing Sweet Water Canal	33m	-2 lines:	66m
- Total	2,950m	-2 lines:	5,900m

* For the 2nd line, the existing cast iron pipes in the Tunnel are to be dismantled from the Tunnel and reused.

The contents of the pipes/lengths are shown in Fig 4.3.40.



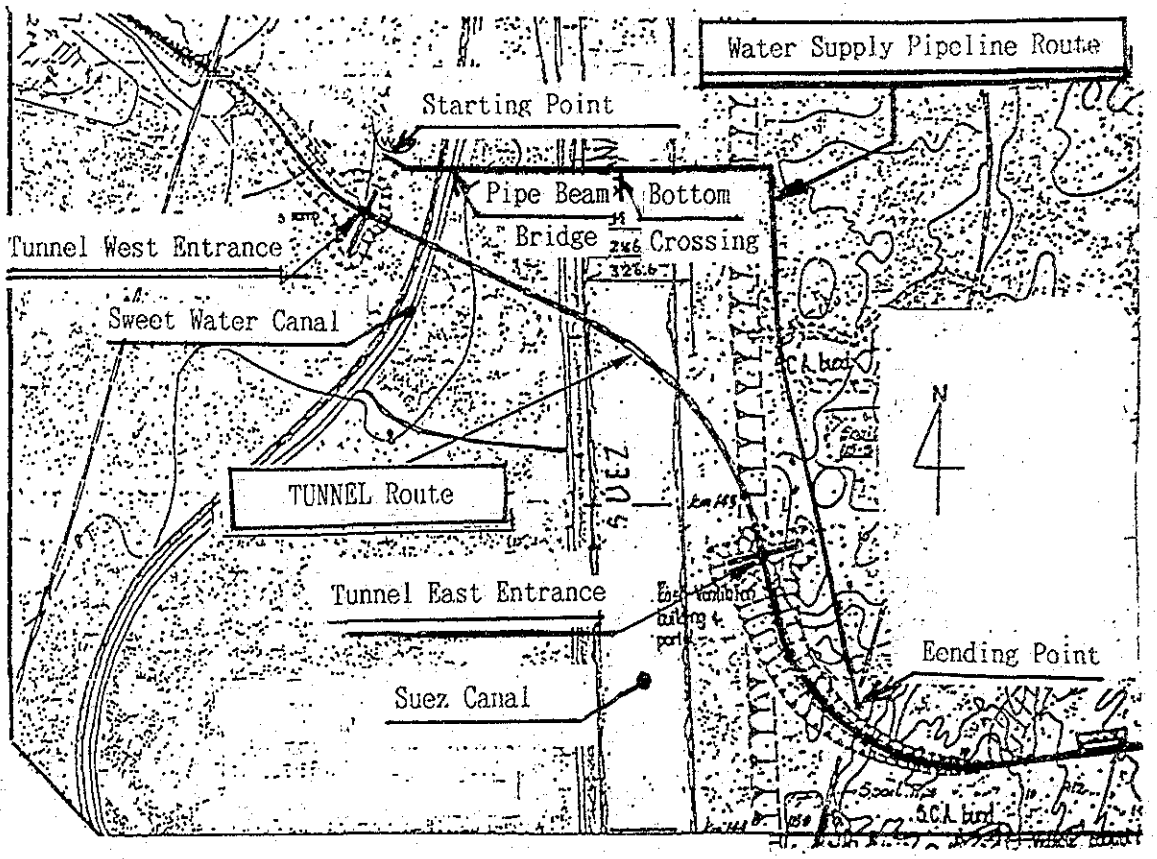
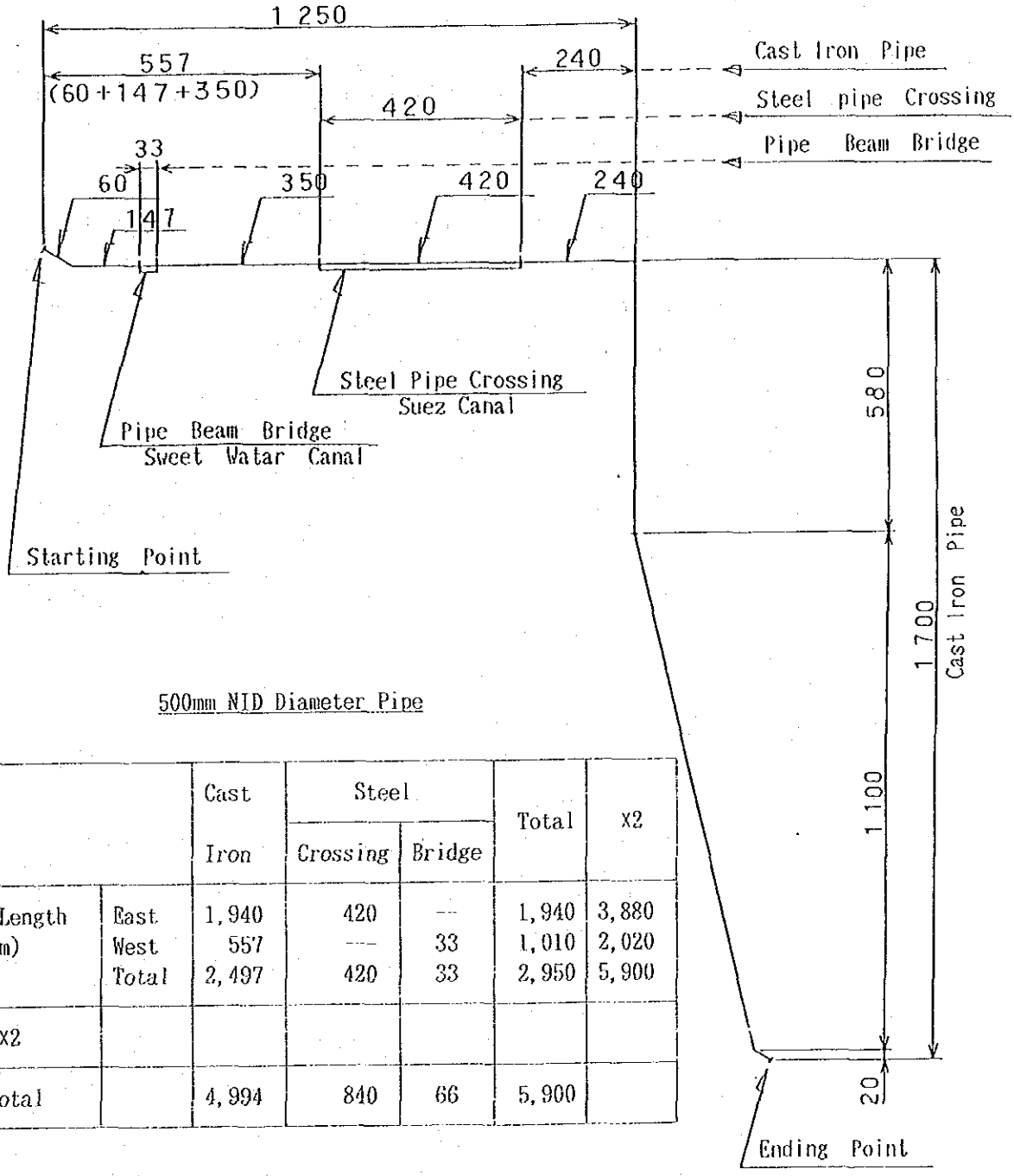


Fig.4.3.39 Fresh Water Pipeline to be Dismantled and Installed on Land and under the Canal



500mm NID Diameter Pipe

		Cast Iron	Steel		Total	X2
			Crossing	Bridge		
Plane Length (m)	East	1,940	420	---	1,940	3,880
	West	557	---	33	1,010	2,020
	Total	2,497	420	33	2,950	5,900
X2						
Total		4,994	840	66	5,900	

Fig.4.3.40 Pipeline Route and Contents

Note: Fresh Water Supply Pipeline Route shall be finalized at the Detail Design Stage.
(ref. Appendix-11, (4) Route Study : Soultion (1) & (2))

(1) Cast Iron Pipes

1) Cast iron pipes of 2,497m in length are to be used for the on land portion include:

a. 557m through agricultural land from the west valve chamber to the west coast of Suez Canal
b. 1940m from the east coat of Suez Canal to the east valve chamber through sand desert

2) The reasons for the application of cast iron pipes rather than steel pipes for the above on land portion are as follows:

a. The existing pipes in the Tunnel are cast iron pipes.
b. Compared with steel pipes, cast iron pipes have advantages in that no special techniques, skilled workers/ engineers and equipment are needed for welding connection, non-destructive inspection of welding connection and field corrosion painting for welding connection portions as required for steel pipes.
c. There is no big difference in the future maintenance/ inspection.

3) In recent twenty years, ductile cast iron pipes have already become popular in the world because of their strength and ductility. The existing pipes in the Tunnel are also ductile cast iron pipes.
In Japan, there are JIS standards namely JIS G 5526: Ductile Iron Pipes and JIS G 5527: Ductile Iron Fittings of 1974. These standards have been revised 3 times already and adjusted to ISO 2531 Ductile iron pipes, fittings and accessories for pressure pipelines.

In U.K., there is BS (British Standand)4772. -- The pipes in the Tunnel have been produced by this BS 4772. In U.S.A., there is AWWA (American Water Works Association) C151. The pipes in Attaka Stock Yard of S.C.A. are based on this AWWA C151.
These pipes by different standards are possible to be connected by special collar and/or flanged spigot.

4) Among JIS G 5526: Ductile Iron Pipes, there are 11 types of ductile cast iron pipes classified by their difference in connection methods such as K-type and T-type.

For your reference, these types are listed in Table 4.3.7 and Fig. 4.3.41 as a general description of the different types of connection.

Table4.3.7 Type of Ductile Iron Pipes and Diameter

Type	Diameter (mm)	
	Pipes	Fittings
A	75－ 350	75－ 350
K	75－2600	75－2600
KF	300－ 900	300－ 900
S	500－2600	500－2600
SII	100－ 450	100－ 450
U	700－2600	700－2600
UF	700－2600	700－2600
US	700－2600	700－2600
T	75－2000	75－ 250
PI	300－1350	300－1100
PII	300－1350	75－2600

Fig.4.3.41(1/2) Types of Ductile Iron Pipes

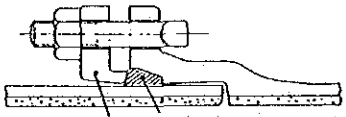
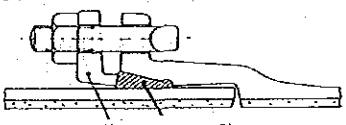
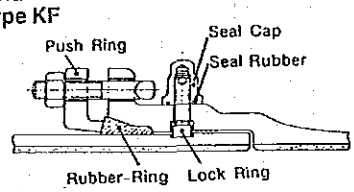
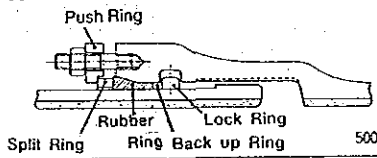
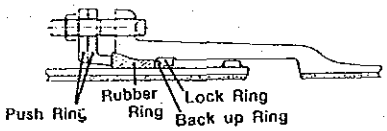
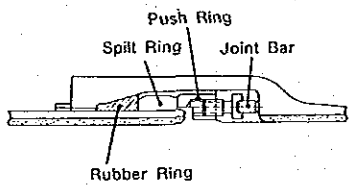
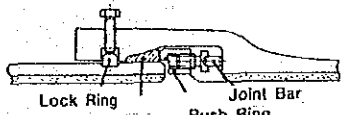
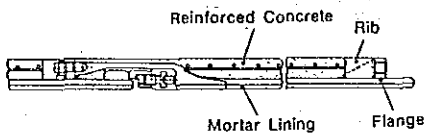
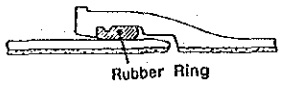
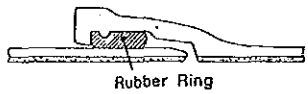
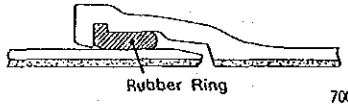
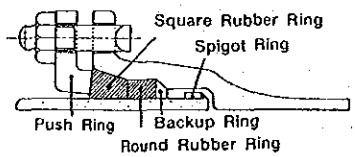
	Features	Uses
Type A  75㎜~350㎜	Easily workable, elastic and flexible	Waterworks and sewage systems, agricultural and industrial water, sea water, mud, ash, low pressure gas, etc.
Type K  75㎜~2,600㎜	Because of rubber's high compressibility, it excells in air-tightness and withstands high pressure. In regard to workability, flexibility and elasticity, it is equivalent to type A.	Waterworks and sewage systems, power stations, industrial and agricultural water, sea water, mud, ash, etc.
Type KF  300㎜~900㎜	Excellent in preventing separation where stress works to pull pipes apart, such as in curved pipe sections.	Waterworks and sewage systems, industrial and agricultural water, mud, ash, etc.
Type S for earthquake-proof  500㎜~2,600㎜	Made of elastic and extremely flexible, based on the earthquake-proof principle, the joint has a receptacle which is finally caught by the spigot so that it firmly resists pull-out forces.	Duct lines which require vibration resistance.
Type SII  100~450㎜	Made of elastic and extremely flexible based on the earthquake-proof principle, the joint has a spigot which is finally caught by the receptacle so that it firmly resists pull-out forces.	Same as type S.
Type U  700㎜~2,600㎜	Because jointing work can be done from inside the pipe, this pipe can be used easily even in tunnels, narrow ditches, etc. It is equivalent to type K in workability and elasticity. It can also be used as a pipe in high pressure systems if the outside is made of concrete.	Waterworks and sewage systems, industrial and agricultural water, sea water for power stations, high pressure systems, etc.

Fig.4.3.41(2/2) Types of Ductile Iron Pipes

	Features	Uses
Type UF  700㎜~2,600㎜	It prevents U-shaped pipes from slipping apart and is used in curved pipe sections. When provided with concrete, it can also be used in high pressure systems.	Same as type U.
Type U for driving method  700㎜~2,600㎜	Ferroconcrete is used to coat type U and type UF ductile pipes (inside-jointed). The outside diameter of the receptacle section is equal to that of the pipe body section. By bolting the receptacle together with the flange welded to the spigot, thrust is transmitted and thrust bending is prevented.	Waterworks and sewage systems, industrial and agricultural water, etc.
Type T  75㎜~250㎜  300㎜~600㎜  700㎜~2,000㎜	Only a rubber ring is attached, and jointing work can be done very easily. In respect to water-tightness, it is equivalent to type A.	Waterworks and service water equipment, agricultural and industrial water etc.
Type TM for gas supply  100㎜~300㎜	Round and square rubber rings are almost completely bound between the backup ring and the push ring. Also, the spigot is kept from hitting against the round rubber ring even when pull-out force is applied to the joint. Therefore, a strong resistance to slipping is obtained.	Gas supply.

5) Type

For 500mm NID Ductile Cast Iron Pipes, T-type (TYTON-type) is to be applied for straight pipes. The reasons for using T-type are the following:

a. The existing pipe is TYTON-type.
b. In Japan, there are 11 types as shown in Table 4.3.39 and Fig. 4.3.61, but overseas, T-type is the most widely used.
c. Maintenance is comparatively easy due to less parts being used. While T-type is selected for straight pipes, the fittings for K-type are to be chosen such as bend, collar, flanged spigot, flanged socket and level invert tee with flanged branch, because T-type fittings are available only for pipes of up to 250mm NID in diameter as shown in Table 4.3.7.

6)Conditions for Installalion

- Burial Depth 1m
  (under the road: more than 1.5m)
- Polyetylene sleeve (PVC sleeve) shall be applied on the pipelines throughout the whole length for protection against salt deterioration.

(2) Pipelines Crossing Suez Canal

1) Design Criteria

The Design Criteria for the fresh water supply pipeline crossing under the Canal starting from 590m away from the west valve chamber are as follows:

Diameter: 500mm NID
Laying Length: 480m -- 2 lines
Maximum Water Depth*: -27.0m (planned)
(at present: -20.5m
at phase 2: -24.0m)
Burial Depth : 2.0m
Maximum Density of Salt: 2.4%(24g/1,000g)
Maximum Tidal Range* : 1.9-2.0m
Distance between Pipelines: 4-5m,depending on the laying method(Dredging bottom width:10.0m)

* Please refer to the attached materials in Appendix-13.

2) Planning and Design of River-crossing and/or Submarine Pipelaying Operations

The planning and design stage of river-crossing and/or submarine pipelaying operations begins with the study of basic project elements such as transport/discharge conditions and surveys for pipeline route selection.

Steel pipe specifications are determined in accordance with basic pipelaying conditions, while the pipelaying method is determined on the basis of the selected pipeline route and environmental conditions in the project area. When the conditions for submarine pipeline maintenance are defined, pipe specifications are finalized and the execution method is determined on the basis of a detailed pipeline design.

A total cost estimation is then made with reference to the work schedule, and this, of course, includes the costs for materials, pipelaying and so on.

Fig. 4.3.42 shows the planning and design flow for a submarine pipelaying operation. Each planning and design stage is later described in details.

3) Steel Pipe Design

For general pipeline installation on land, different types of pipes such as steel, cast iron, PCY, hume, and asbestos-cement are available for choice depending on the purpose of use. For submarine pipelines to be laid on the sea bed and to be exposed to severe underwater conditions including heavy external forces imposed by, for example, vessel anchors, the usual practice is to use steel pipes. This is because steel pipe has high strength and adequate elasticity, is reliable in quality and available in many different sizes and types.

Recent improvements in anti-corrosion coating/lining methods and cathodic protection technology have upgraded the corrosion resistance of steel pipes to the same level as other types of corrosion-resistant pipes. The high product reliability of steel pipes can be seen from the growing demand for their use in many submarine pipeline installation plans for transportation of clean water, sewage water, irrigation water, and industrial water. Generally, small and medium diameter pipes specified in JIS G 3454 (STPG) and large diameter pipes JIS G 3457 (STPY) are the most widely used types in submarine pipeline plans.

For the present project, the following steel pipe has been designed to be adopted

JIS G 3453 (STPG) Sch 30

(size) 509.0φ x 12.7mm

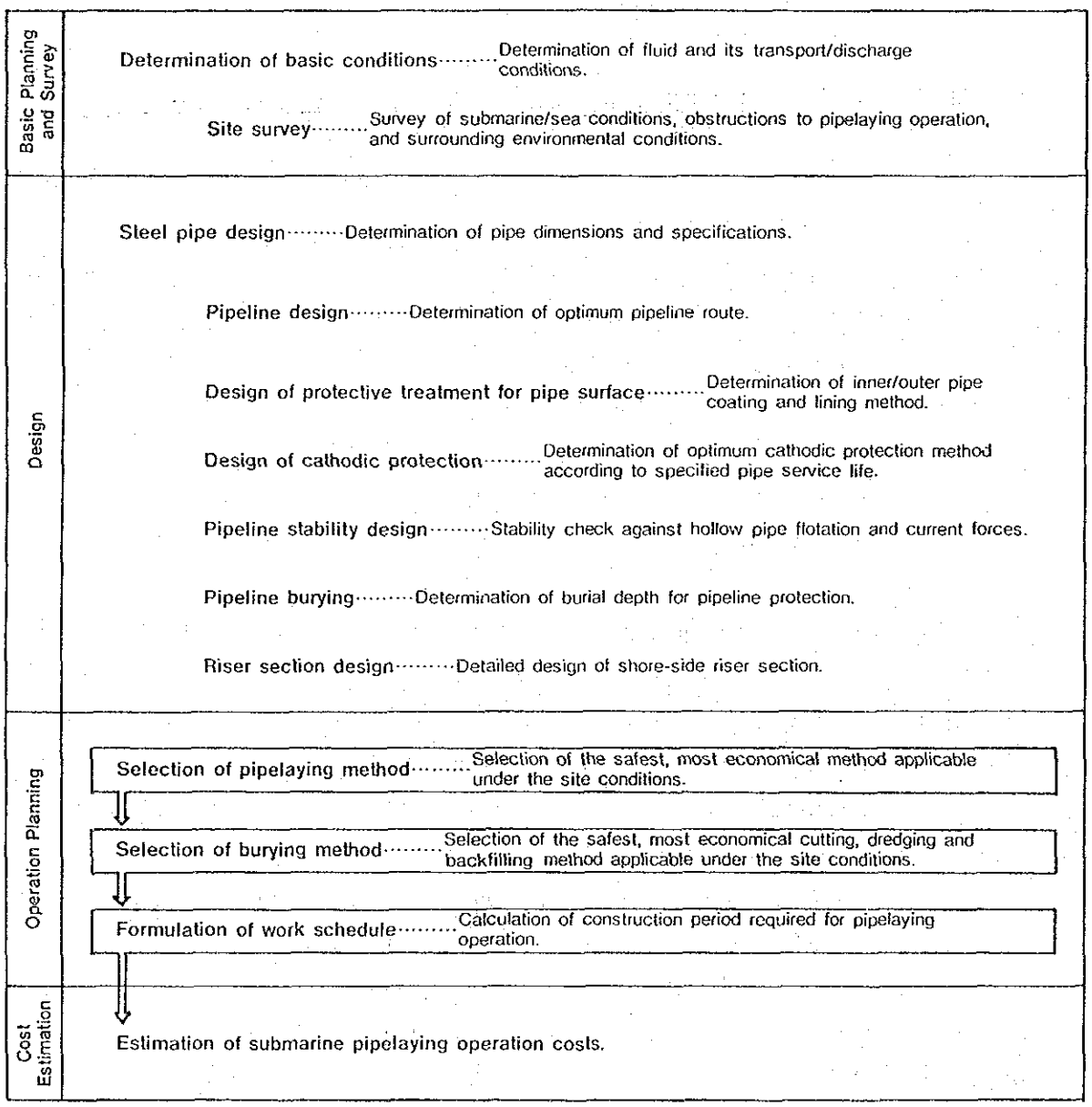
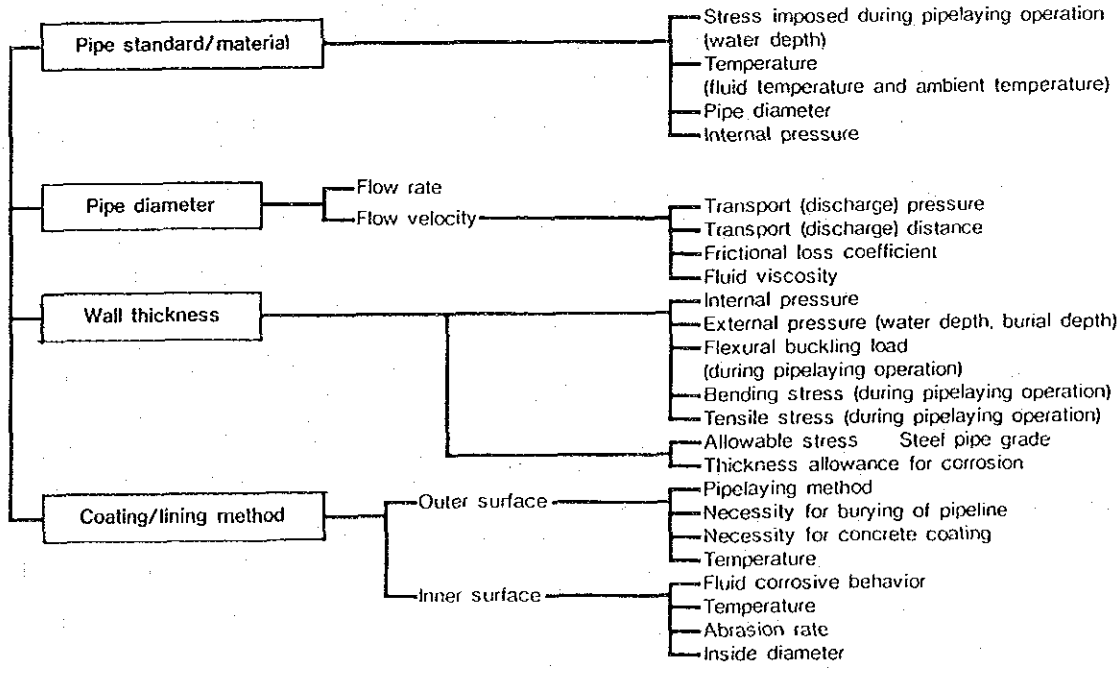


Fig.4.3.42 Planning & Design of Submarine Pipelaying Operation

The standard, material, diameter, wall thickness and coating/lining method of steel pipes used in submarine pipelaying operations are determined in accordance with the conditions shown below. The pipe diameter is usually decided by the designed transport volume and the discharge pump capacity. The pipe wall thickness is to be fixed at a value that makes the pipe strong enough to ensure a smooth and safe pipelaying operation. The wall thickness thus determined gives the pipeline a strength large enough to withstand all external forces and service conditions, except when the working pressure is very high.



Design of Pipe Specifications

4) Pipeline Route Design

Pipelaying work accounts for a very large proportion of the total cost of submarine pipeline installation. In the pipeline route design, therefore, it is necessary to pay careful attention to the conditions listed below as well as to the ease of pipeline installation so as to minimize the cost of pipelaying operations.

a. Conditions for Pipeline Route Selection

This is for pipelines that cross the Canal by way of a right angle.

Attention is to be paid to the following conditions in route selection:

water depth: It is desirable that the water depth should be as shallow as possible in so far as it permits easy navigation of the work vessels.

Sea bottom slope: The sea bottom should have a smooth and flat surface.

Submarine geology: Places covered with rocky layers should be avoided as far as possible.

Littoral drift: Places with violent changes in sea bed configuration should be avoided as far as possible.

Sea conditions: Places favored with calm current and wave conditions should be selected.

Submarine obstructions: All obstructions such as dangerous objects, concrete blocks, sunken vessels, scrap metal, and existing pipelines, cables and other structures should be avoided as far as possible.

Marine traffic and fairways: Places on heavy marine traffic routes and busy fairways should be avoided as far as possible.

Environmental conditions: Consideration should be given to the pipe yard (A long pipe fabrication yard on land aligned with the pipeline route is required for bottom-pull pipelaying operations) and to the riser sections.

Allowable radius of curvature in curved line design: The pipeline should be laid in a straight line whenever feasible. If it has to be laid in a curved line to avoid a submarine obstruction or for any other reason, the curved line should be given a large radius and the use of bend pipes should be minimized.

b. Longitudinal Pipeline Alignment

Attention is to be paid to the following items:

Bottom slope: It is desirable that the sea bottom on which the pipeline is to be laid has a mild slope. In places with depressions produced by past dredging operation or places near the shores where the water depth changes abruptly, the sea bottom condition is generally not uniform and the varying bottom slope often imposes undue stress on the pipeline. When it is impossible to avoid such places, the pipeline route should be dredged or filled in advance to provide a mild longitudinal slope, which will maintain the pipeline within its elastic range.

Minimum burial depth: In most submarine pipelaying operations, pipeline is buried beneath the sea bed to be protected against damages due to external forces imposed by waves, vessel anchorage, and seine boat fishing operations. The longitudinal pipeline alignment needs to be designed to meet the burial depth requirements determined on the basis of such external forces. If the burial depth should be changed in any section of the route, such change should be made on a gradual basis so as to hold the pipeline within the allowable radius of curvature.

Littoral drift and scouring: In places where phenomena like littoral drift and scouring are prone to occur owing to wave and current forces, the pipeline should be buried at a depth that is away from the influences of such phenomena.

Fairway dredging: If the pipeline route crosses any existing or planned fairways, the burial depth should be determined by taking into account the existing fairways or the future fairway dredging plans.

5) Design of Anti-Corrosion Coating/Lining of Steel Pipes

Steel pipes without surface protection treatment corrode as time passes. It is reported that corrosion progresses at a rate of 0.5mm/year in river water, 0.12mm/year in sea water and 0.02mm/year on the sea bed, though naturally these rates may vary depending on the actual surrounding conditions. To protect steel pipes against corrosion, some suitable anti-corrosion surface treatment is applied. Broad classifications of this type of treatment include galvanization, bituminous coating, synthetic resin lining, and cement mortar lining. The coating/lining method is to be determined in accordance with the place of use, as shown in the following Table 4.3.8.

The coating/Lining methods are as follows:

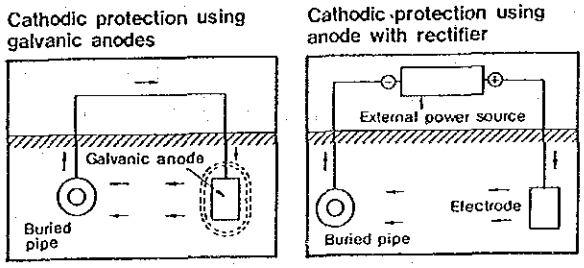
internal coating: tar epoxy 0.5mm(500 1/1000mm)
external coating: polyethylene 2.5mm

6) Cathodic Protection for Submarine Pipelines

To guard against corrosion, submarine pipelines are given two types of protection: an external anti-corrosion coating and cathodic protection. Cathodic protection itself can be divided into two types or methods: the power-impressed method in which power is supplied from an outside source, and the galvanic anode method in which power is obtained by making use of the potential difference between the anode and iron. In determining which method to use, the decision should be made in accordance with environmental conditions because each method has its own advantages and disadvantages as shown below.

Fig.4.3.43 is the selection and design process of cathodic protection for submanine pipelines.

Aluminum sacrificial anode bracelet has been adopted for the basic design.



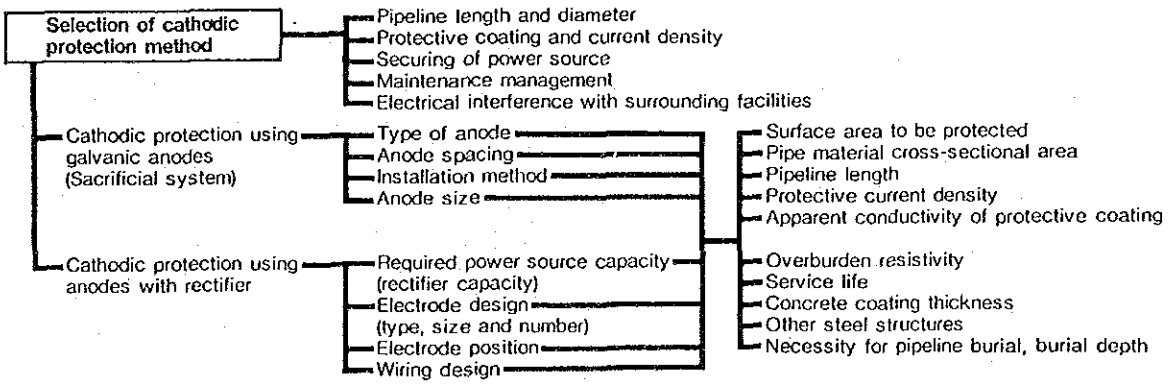
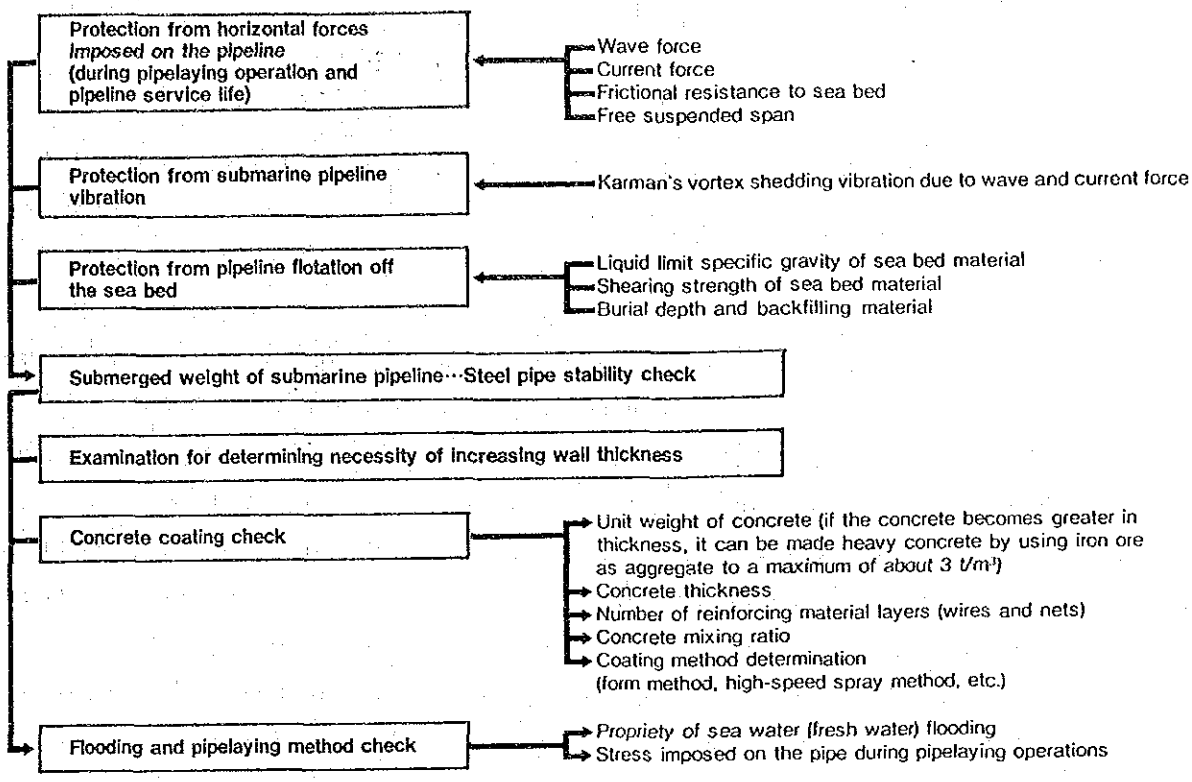


Fig.4.3.43 Design Procedures for Different Cathodic Protection Mehtods

7) Stability Design of Submarine Pipelines

There should be no flotation of submarine pipelines off the sea bed, and they should not be carried away by current or other external forces during or after completion of pipelaying operations. The pipeline stability design is intended to check and satisfy this important condition. Steel pipes with a diameter of more than 400mm generally float when they are empty, and steel pipes with a diameter of 300-400mm are not stable enough for submarine piping because their submerged weight is insufficient. In sea areas where current velocity is high, steel pipes are prone to be driven along the sea bed surface, so that their minimum submerged weight must be proportionate to the outside diameter. Submerged weight is determined by the pipe diameter, current and wave forces, and sea bottom conditions. If the pipe's empty weight is lighter then its required submerged weight, various compensation measures are taken. Specifically, the wall thickness is intentionally increased if the pipe has a medium or small diameter, or the outer surface is coated with concrete if the pipe diameter is large. Also,the pipe can be flooded with sea water and submerged to the sea bed, as is occasionally practiced in shallow waters using the natural flooding method.

For the present project, a concrete coat of 50mm for the steel pipes has been designed.



Design Procedures for Stability of Submarine Pipelines

Table 4.3.8 Anti-Corrosion Coating/Lining Method in Different Enviromental Conditions

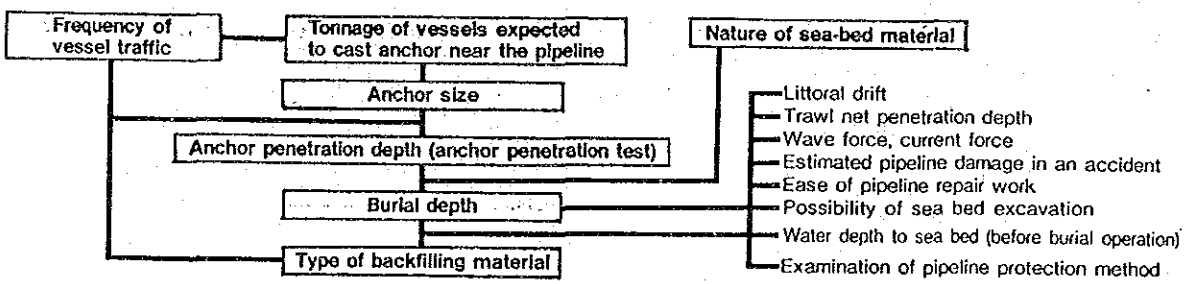
Type of anti-corrosion treatment and environmental condition			Coating/lining method
Internal anti-corrosion treatment		Fresh water or sea water	1. Coal-tar enamel coating 2. Zinc-rich paint coating + Tar epoxy resin coating 3. Tar epoxy coating 4. VLP (polyvinyl chloride lining) 5. FLP (polyethylene powder lining) 6. Mortar lining 7. Galvanizing 8. Almer (aluminum plating)
External anti-corrosion treatment	Piping on land	Places exposed to limited corrosive action	1. Rust-preventive oil paint coating + Synthetic resin paint top coating 2. Synthetic oil paint coating + Synthetic resin paint top coating 3. Galvanizing
		Places exposed to heavy corrosive action, as observed in highly humid districts, coastal areas and industrial zones	1. Zinc-rich paint coating + Chlorinated rubber varnish coating 2. Tar epoxy resin coating + (Non-bleeding type) { Chlorinated rubber varnish top coating (tinting) / Synthetic paint top coating (silver) }
	Under-ground piping	Places exposed to limited corrosive action	1. Polyethylene coating 2. Asphalt, vinylon cloth covering (single layer) 3. Galvanizing
		Places exposed to relatively heavy corrosive action	1. Polyethylene coating 2. Asphalt, glass cloth covering (two layers) 3. Asphalt, vinylon cloth covering (two layers)
	Submarine piping	*Fresh water*	1. Polyethylene coating 2. Coal-tar enamel, glass cloth covering (two layers) 3. Asphalt, vinylon cloth covering (two layers) 4. Tar epoxy resin coating
		Sea water	1. Polyethylene coating 2. Coal-tar enamel, glass cloth covering (two/three layers) 3. Zinc-rich paint coating + Tar epoxy resin coating 4. Tar epoxy resin coating

8) Burial Design of Submarine Pipelines

Submarine pipelines laid on the surface of the sea bed and consequently left without protection are vulnerable to the influences of wave and current forces. A number of accidents recorded in overseas countries offer ample evidence of the danger presented by such unprotected pipelines. Burial operations are also necessary in order to protect the pipeline against damage caused by the anchoring of vessels, since there exists the possibility that an anchor is cast right on the pipeline, or even caught by it if a moored vessel is carried away by strong winds. In an instance of this type reported some time ago, a pipeline was dragged a number of kilometers away from its original position.

Burial of the pipeline is required if all these problems are to be prevented, and it is generally the practice to bury it at a depth of from one to four meters beneath the sea bed surface.

In case of Suez Canal, since water pipelines' crossing point located 142km from Port Said is in a fairway and the fairway is within the anchoring prohibition zone, the pipelines are buried 1-2m beneath the surface.



Procedures for Burial Design of Submarine Pipelines

9) Selection of Pipelaying Method

There are three major submarine pipelaying methods: the lay barge method, the floating (towing) method, and the bottom pull method. To select the safest and the most economical one for a specific job, conditions of pipeline, environment and work vessel must first be taken into consideration.

A concept description of pipelaying method is provided in the following Fig. 4.3.44. Besides, a comparison of different pipelaying methods is demonstrated in Table 4.3.8. Within this scale of choices, which are explicitly explained respectively, the most safe and economical selection of the bottom pull method has been adopted here for this project.

Table 4.3.8 Comparison of Three Pipelaying Methods

	Bottom-pull method	Floating method	Lay barge method
1. Method	Long pipes prefabricated at the onshore pipe yard are pulled on the sea bed with wire ropes connected to towing winches on the winch pontoon (fixed in the same position) or on the opposite shore.	Long pipes prefabricated on land or at sea are floated and towed to the installation site, then laid on the sea bed by means of welding them to the already submerged pipe section, the end of which is hoisted by cranes and floats. In the towing method, pipes are welded at the pipe yard and successively towed to the installation site.	Each single pipe is welded to the already submerged pipe section on the lay barge, which moves forward after each pipe is welded and submerged.
2. Pipe yard	A pipe yard aligned with the pipeline route is required. It should have sufficient work space and facilities for fabricating and towing long pipes, and should also have pipe launching facilities.	A pipe yard with sufficient work space and facilities for fabricating, launching and towing long pipes is required, but it need not be aligned with the pipeline route. In the towing method, a pipe yard aligned with the pipeline route is required.	A pipe storage yard is required, but no onshore pipe fabrication facilities are necessary.
3. Environmental conditions	Relatively free from the influences of environmental conditions excluding sea bed conditions, and high in adaptability to changes in climatic conditions. Suspension of pipelaying operation is possible.	Requires relatively mild weather conditions because of low adaptability to sudden climatic changes. Suspension of pipelaying operation is possible but not easy.	Virtually free from the influences of surrounding conditions, and high in adaptability to changes in climatic conditions. Suspension of pipelaying operation is possible.
4. Pipelaying facilities	Large-capacity towing facilities are required.	Welding pontoons are necessary, but no other special facilities are required. Welding operation at sea calls for a large number of work vessels.	A specially equipped lay barge is required, but not many work vessels of other types are necessary.
5. Pipe weight adjustment	The sumberged pipe weight is reduced to minimize the frictional resistance to the sea bed and towing force. Floats are also used occassionally for pipe weight adjustment.	The submerged pipe weight is adjusted for smooth, natural pipe sagging and bending from the sea surface to the sea bed. Floats are also used for this purpose.	The submerged pipe weight is adjusted for smooth, natural pipe sagging and bending from the lay barge to the sea bed. Stingers are used for this purpose.
6. Application range	• Applicable to pipelaying operations under favorable pipe yard and submarine conditions, as well as to offshore construction projects of a considerably large scale • Not suited to complex pipeline installation of very large-scale offshore construction work. • Applicable in adverse marine conditions (wind, waves, tidal currents). • Suited to pipeline installation within a fairway, especially in areas with heavy marine traffic.	• Highly economical when applied in small-scale pipelaying operations • Applicable to complex pipeline installation • Suitable for pipelaying operation areas favored with mild marine conditions. • If rough weather frequently occurs, the safety of pipelaying operations can be assured by selecting a suitable (fair) work day, since the pipeline is laid by the cyclic repetition of the same procedures. • Ease of securing a large number of work vessels should be ensured.	• Suited to installation of a relatively long submarine pipeline. • Not suitable for complex pipeline installation.

Selection of pipelying method

Criteria for selection

- Pipeline length and size
- Longitudinal pipeline alignment
- Pipe yard conditions
- Ease of securing pipelaying machinery and equipment
- Climatic and marine conditions
- Marine traffic and fairway conditions
- Fishing operations
- Shore-side riser section arrangement

Classification of pipelaying methods

- Lay barge method
- Floating method
- Towing method (continuous towing)
- Bottom-pull method

● Lay barge method
Each single pipe is welded to the submarine pipeline on the lay barge, which moves forward after each pipe is welded and submerged.

● *Floating method*
Long pipes prefabricated on land or at sea are floated and towed to the installation site, then laid on the sea bed by means of welding them to the already submerged pipe section, the end of which is hoisted by cranes and floats. In the towing method, pipes are welded at the pipe yard and successively towed to the installation site.

● Bottom-pull method
Long pipes prefabricated at the on-shore pipe yard are pulled on the sea bed with wire ropes connected to towing winches on the winch pontoon (fixed in the same position) or on the opposite shore.

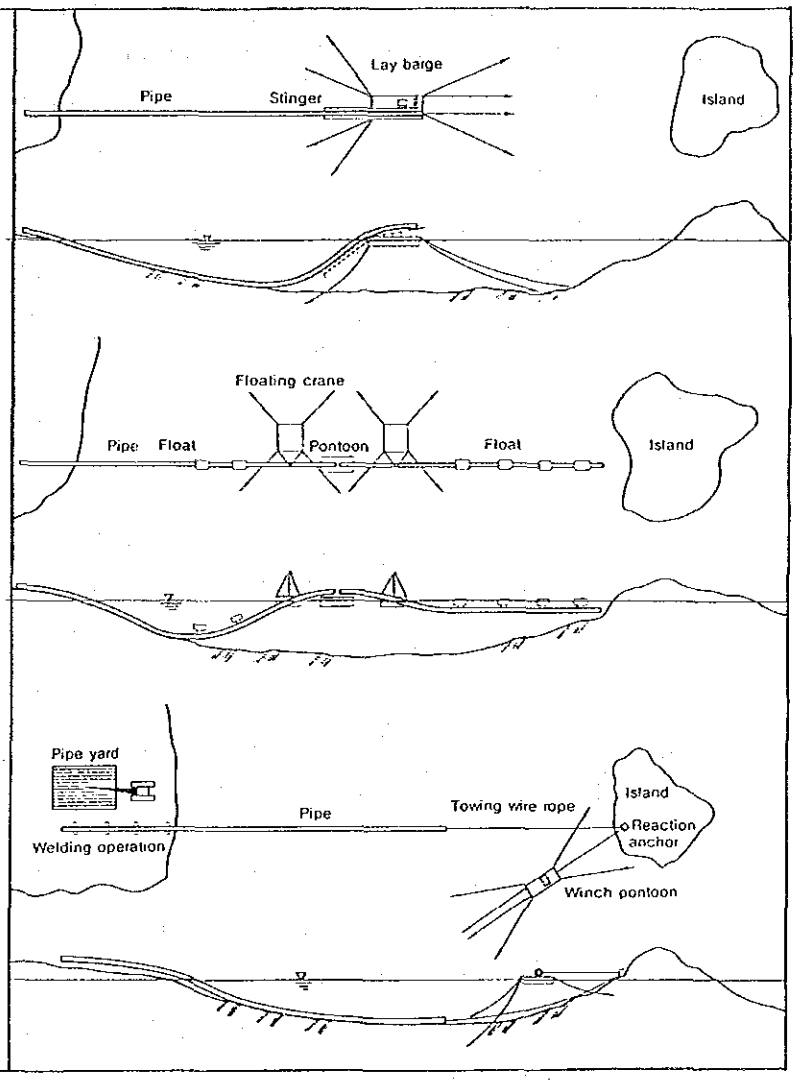


Fig.4.3.44 A Conceptual Description of Pipelaying Methods

10) Cross Section of Pipelaying

The cross section of pipelines crossing under Suez Canal is shown in Fig. 4.3.45.

Long pipes prefabricated at the east bank prefabrication pipe yard are pulled on to the Canal bed with ropes connected to the 15 ton towing winches on the opposite west shore.

11) Design Output

The design output for pipelines Crossing Suez Canal is as follows:

Diameter	: 500mm NID
Laying Length	: 480m* --- 2 lines
Steel Pipe	: JIS G3454 Sch 30 508.0φ X 12.7 (Dia. X W.T)mm
Maximum Water Depth	: -27.0m (planned)
(at Present : -20.5m,	at phase 2: -24.0m)
Burial Depth	: 1~2.0m *
Distance between Pipelines	: 4~5m*,depending on the laying method
Painting/Lining	
- Internal Coating	: Tar Epoxy 0.5mm
- External coating	: Polyethylene 2.5mm
Cathodic Protection	: Aluminum sacrificial anode bracelet
Concrete Weight Coat	: 50mm
Pipelaying Method	: Bottom Pull Method

Note for * : to be finalized at the Detail Design.

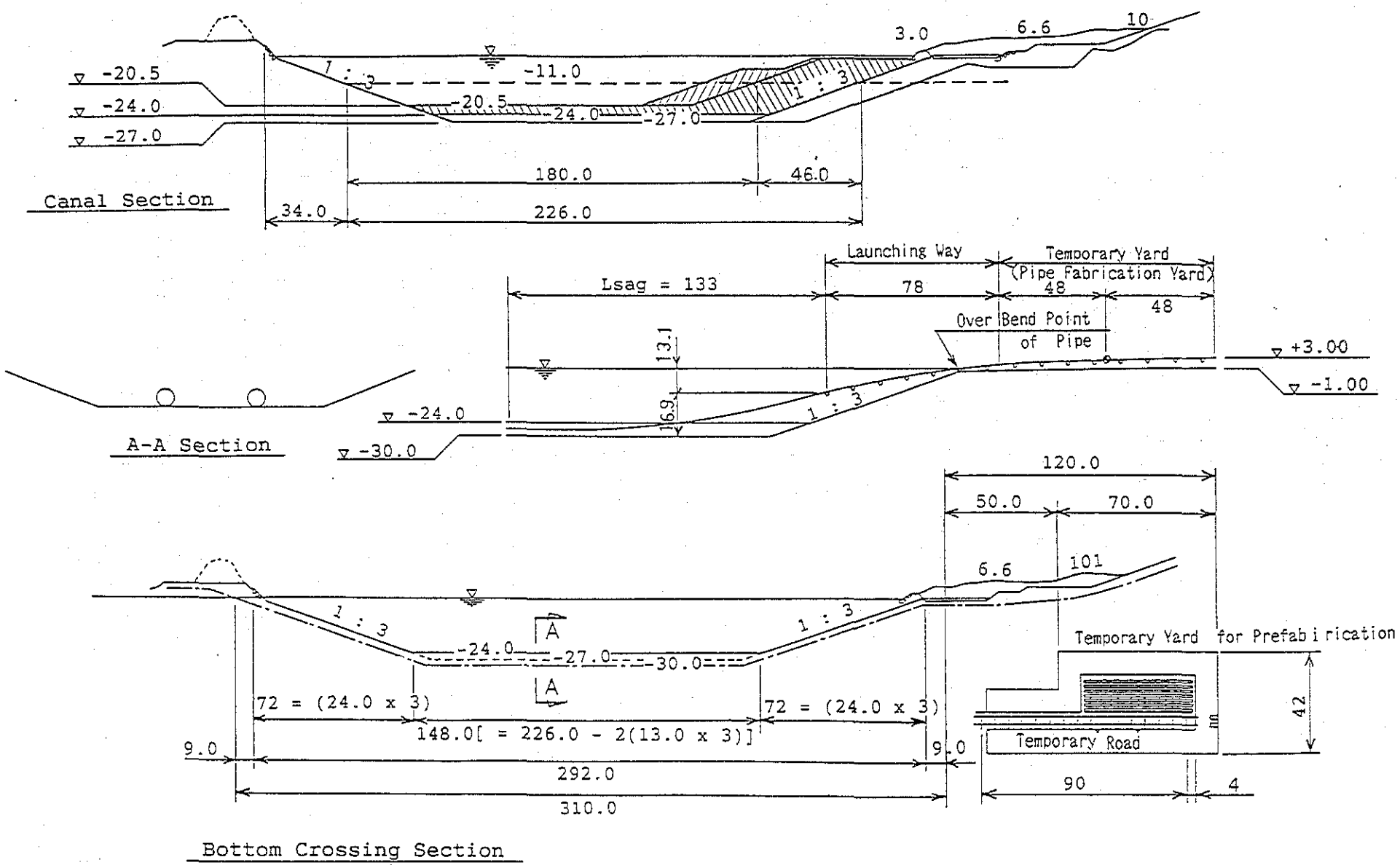


Fig.4.3.45 Suez Canal Section and Pipelines Crossing Under the Canal

(3) Pipe Beam Bridge

1) Design Criteria

Location: approximately 210m east of the starting point-the east valve chamber.
Purpose : Crossing the Sweet Water Canal
Diameter: 500mm NID 2-lines.
Crossing span length: 27.0m

2) Type of Pipe Beam Bridge

It is an economical way to use Pipe Beam Bridges for river crossing purpose and usually steel pipe material is adopted for these bridges. (ref. WSP 007-88)

There are 3 main types of pipe beam bridges
- Simple pipe beam
- Armed Pipe Beam
- Arched pipe beam bridge

a. Simple Pipe Beam
 - It is the most simple and economical type in respect to installation and operation/maintenance.
 - However, this type has span length limit in the diameter and the wall thickness as shown in Fig. 4.3.46 and 4.3.47.

b. Armed Pipe Beam
 - There are many kinds of armed pipe beams such as flanged beam, beam with truss and with suspension wires.

c. Arched Pipe Beam
 - Steel pipes shall be prefabricated and installed very carefully as designed.

3) Selection of Pipe Beam Bridge Type(s)

The following type of steel pipe with diameter of 500mm NID is selected for pipe beam bridge, based on the conditions stated "4.3.3(1) Cast Iron Pipe" and "4.3.3(2) Pipelines Crossing Suez Canal"

Steel Pipe: by JIS G 3453 Carbon Steel Pipes for Pressure piping, STPG Sch 30
Diameter x Wall Thickness: 508.0ϕ x 12.7 mm

a. Simple Pipe Beam type with the span length of up to approximately 18m can be used but it is not applicable for the span length of 27m without an additional arm or a support pier.
b. The cost for Armed Pipe even with the most simple T-type flange is too high for the span of 27m (compared with the ratio of 27m vs 18m simple pipe beam type).
c. Arched Pipe Beam can be applicable to the span length of up to 35m and it is also the most economical selection for 27m span length.
The conclusion is that " Arched Pipe Beam Bridge" is probably a suitable selection.

4) Design Output

The design output for Arched Pipe Beam is as follows:

Diameter -- 500mm NID --2 lines

Steel Pipe-- JIS G 3454 sch 30

508.0ϕ x 12.7 (Dia x W.T) mm

Span Length --27.0m

Bridge Design Length --33.0m (approximately)

Bridge Actual Length --35.0m (approximately)

Arch Height (center to center) -- 4.0m (approximately)

Painting/Lining

Internal : Tar Epoxy

External : Epoxy/Polyethylene

Burial Depth at the ends : 1.0m

Concrete Anchors at both ends: approximately 30m^3 x 2sets of Air Valves at the top of Arch(each)

The outline of the Arched Pipe Beam Bridge is to be shown in Fig. 4.3.48.

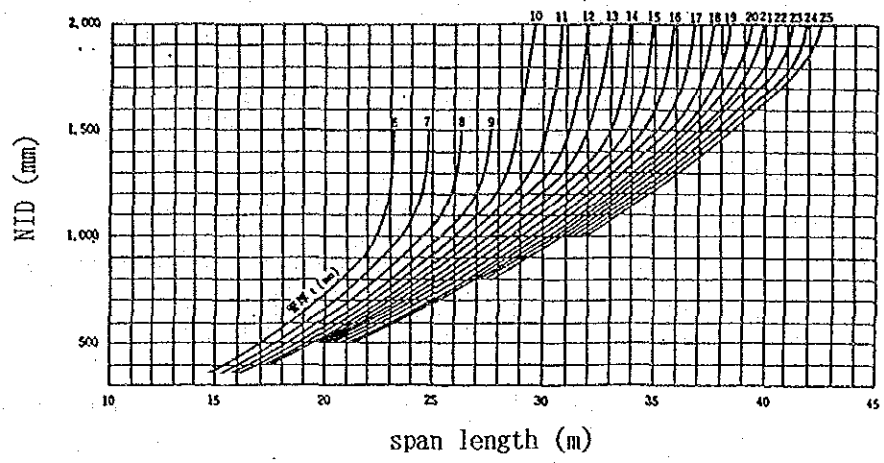


Fig.4.3.46 Maximum Allowable Span Length for Simple Pipe Beam

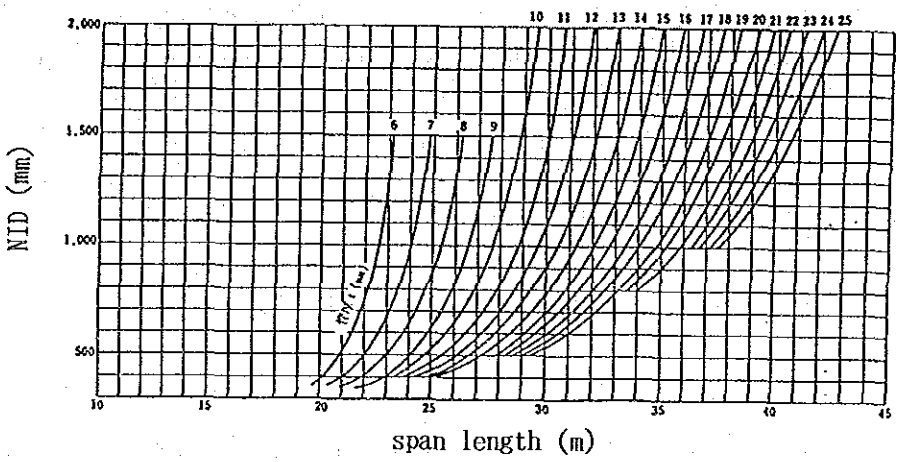


Fig.4.3.47 Maximum Allowable Span Length for Fixed/Free Supported Pipe Beam

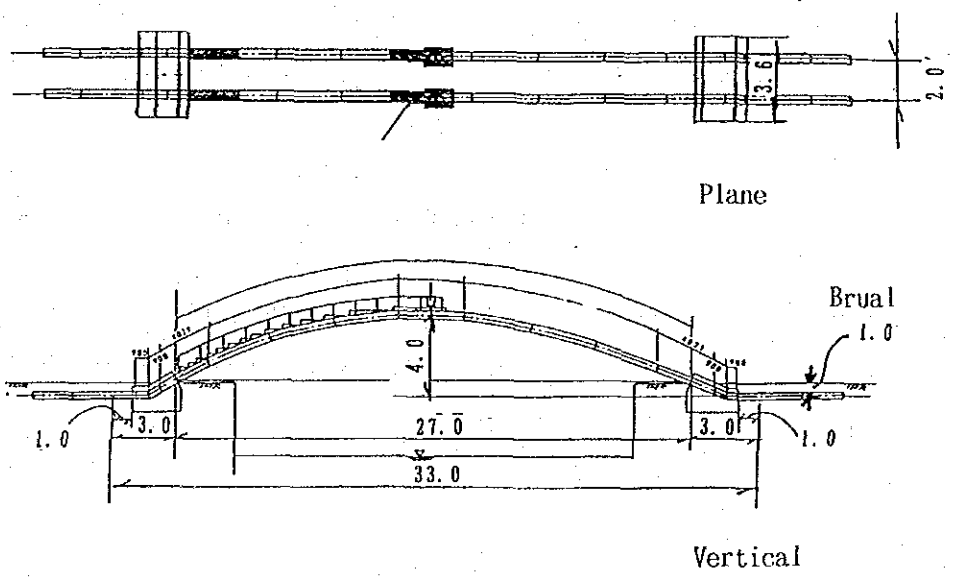


Fig.4.3.48 50mm NID Arched Pipe Beam Bridge

Reference Standards

1) Japan Society of Civil Engineers : Standards Specifica tionssor Tunnel (Shield), 1990

2) Sir William Halcrow & Partners Ltd, Osmac Joint Venture : GEOTECHNICAL REPORT, March 1977

3) Herbert H. Einstein, M.ASCE and Charles W.Schwartz, A.M.ASCE : "Simplified Analysis for Tunnel Support" Journal of the Geotechnical Engineering Division, April 1979, pp.498-518

4) Nihon Doro Kodan : Manual for Design and Construction, 1987

5) Japan Road Association : Design Guidelines for Common Duct, 1986

6) Japan Ports and Harbors Association : Technical Standards for Port and Harbor Facilities in Japan, 1980

7) Japanese Industrial Standard (JIS)
- A series : Civil Engineering
- G series : Ferrous Materials and Metallugy
- R series : Ceramic Industry
- Z series : Test Methods Common to Metallic Materials

(Japanese Standards Association,1957-90)

8)Japan Steel Water Pipe Association Standard (WSP)

(Japanese Water Pipe Association,1988)

CHAPTER 5

OUTLINE OF CONSTRUCTION PLAN

Chapter 5 Outline of Construction Plan

5.1 Construction Conditions

Since the whole part of the Tunnel segment has been suffering serious damage, the structural soundness of the Tunnel is rapidly approaching the limit of ultimate strength judging from the results of our field survey our experience .

Immediate execution of the proper Rehabilitation Works should be carried out as quickly as possible.

For this purpose, the Construction policies shall be :

Early Start
Shortening of Work Schedule
Cost Optimum
Safety First

Based on the above policies, the construction plan is to adopt the most practical and advanced construction method to meet completion target in the schedule.

Furthermore, in consideration of the importance of this Tunnel from social and economic points of view in the area, to keep the existing function of the Tunnel as much as possible is definitely required.

5.1.1 Construction Conditions

The following construction conditions have been settled through negotiations with S.C.A. :

(1) The traffic restrictions during the Rehabilitation Works are to be as follows:

1) One lane traffic
2) The speed limit of 20 km/h; Further restriction is to be applied to large vehicles.

3) The traffic is to be stopped between 8:00 pm through 6:00 am. During the period of special work such as the assembling/dismantling/moving works for Centles and Sliding Forms, the traffic is to be stopped the whole day(s) according to schedule of construction. The period of traffic stoppage should not exceed one month during the Rehabilitation Works. Each stoppage period should last 4 days to the maximum.

(2) The Works is to be carried out by 3 shifts (24 hours per day).

(3) A minimum of one line of the fresh water supply pipelines shall be kept in operation at a time.

(4) Electrical power cable and communication telephone cable shall be temporarily removed from the Tunnel for the execution of the Rehabilitation Works except for those necessary for the Works.

5.1.2 Construction Plan

As stated above, the policies for our construction plan are:

- Early Start
- Shortening of Work Schedule Optimum
- Cost Optimum
- Safety First

Some detailed explanaitons of the plan based on those policies are given below.

(1) Early Start

For the installation of the fresh water supply pipe-lines, the Canal dredging for the portion crossing the bottom of the Canal and the excavation/earthing for the on land portion are to be directly carried out by S.C.A. in advance.

(2) Shortening of Work Schedule

- The Rehabilitation Works area especially for Road Deck is to be divided into 4 sections in the whole Tunnel length. Because the most critical pass in the work schedule is the concreting for the Road Deck. And by this 4 parallel work application, the critrical pass can be imiproved drastically.

  The follosings are to be considered:

  - Centle working efficiency
  - Parallel concreting and concrete curing
  - Material flow in and out
  - *Traffic restriction*

Through this analysis with Schedule vs Cost optimum, it has been concluded approximately 400m - 4 sections.

- Concreting steps are to be minimized especially for the portion of the lower lining and road deck.

- By moving the fresh water supply pipelines out of the Tunnel to the outside, the working efficiency in the Tunnel especially for the portion of the lower lining and road deck is to be remarkably improved.

- The Works is to be carried out by 3 shifts (24 hours per day).

- All centles and concrete forms are to be operated by automatic motor driven wheel/rail system.

(3) Cost Optimum

- Cost optimum is related to Schedule Optimum which is to be achieved through shortening of work schedule including Early Start.

- The amoung of site work should be increased as much as possible.

- The followings are to be adopted for effective construction .
  - The existing Ventilation System, especially fans, will be reused as much as possible.
  - The existing Lightening System will be used until the crown concrete lining work starts and will be replaced after the Rehabilitation Works.

(4) Safety First

- Safety First shall be one of the most important principles in this Rehabilitation Works.
  Special safety rules and responsible organizations shall be established in advance.

  Safety of the following people and equipment must be taken care of:

  -1) Personnel in charge of the Works and the traffic through the Tunnel
  -2) The traffic passengers through the Tunnel
  -3) Engineering consultants in charge of supervision and the contractors
  -4) Prorperty belonging to S.C.A.

- A traffic control system for traffic safety dincluding necessary signals/guide plates and traffic control/patrolman is to be established. This is because of the traffic in the Tunnel will be complicated by the movement of the one lane/(lane) route throughout the working period and of 4-work sections . Also, this system is definitely required for the safety of the personnel who are involved in the Rehabilitation Works.

- Ventilation System during the Rehabilitation Works is also one of the important safety control items. Consideration for setting up temporary fans and CO gas level are to be included.

- For fire emergency, portable fire extinguisher shall be adopted in addition to the existing fire engines.

5.2. Construction Method

5.2.1. Construction Sequence

The construction Sequence is designed in consideration of:

(1) "5.1.2 Construction Plan" (as stated above) and
(2) the followings:

1) The Rehabilitation Works of Upper Half Section will commence after completion of the Lower Half Section.
2) Construction materials such as waterproofing sheet, steel bar and concrete, shall be transported during non-traffic period (night time), as there is no space to store materials at the site.
3) Erections of scaffold and sliding form and demolition of the existing road deck shall be executed while traffic is stopped.
4) The form for concrete shall be prefabricated and should be moveable as much as possible.
5) Concrete which is used for lining and road deck shall be specially designed to meet the requirement.
   The required concrete strength is:
   150kgf/cm^2 for releasing the form for the road deck and
   270kgf/cm^2 for opening to the traffic.
6) The attached construction sequence Fig.5.2.1 is based on the portable form for the road deck being released 5 days after casting concrete and the portable centle for the arch concrete being shifted in 2 day cycles.

The construction sequence, which is based on the most optimum study as stated in the following section "5.2.2. Construction Method", is shown in Fig. 5.2.1.

Concerning the fresh water supply pipelines, the followings shall be note:

The fresh water supply pipelines located in the Tunnel at present shall be moved out from the Tunnel in view of safety, economy, working convenience of the Rehabilitation Works and future maintenance. The route is to be partly on land and partly crossing the bottom of Suez Canal.

One new pipeline is to be installed first and filled with water.
After the start of water supply operation of the 1st line , the existing pipes in the Tunnel shall be dismantled and installed as the 2nd line after being checked and selected for reuse.

5.2.2. Construction Method

A construction method as mechanically automatic as possible has been conceived based on consideration of:

Early Start
Shortening of Work Schedule
Cost Optimum
Safety First

The actual plan for the construction method is shown in Fig. 5.2.2, FIg.5.2.3, and Fig.5.2.4.

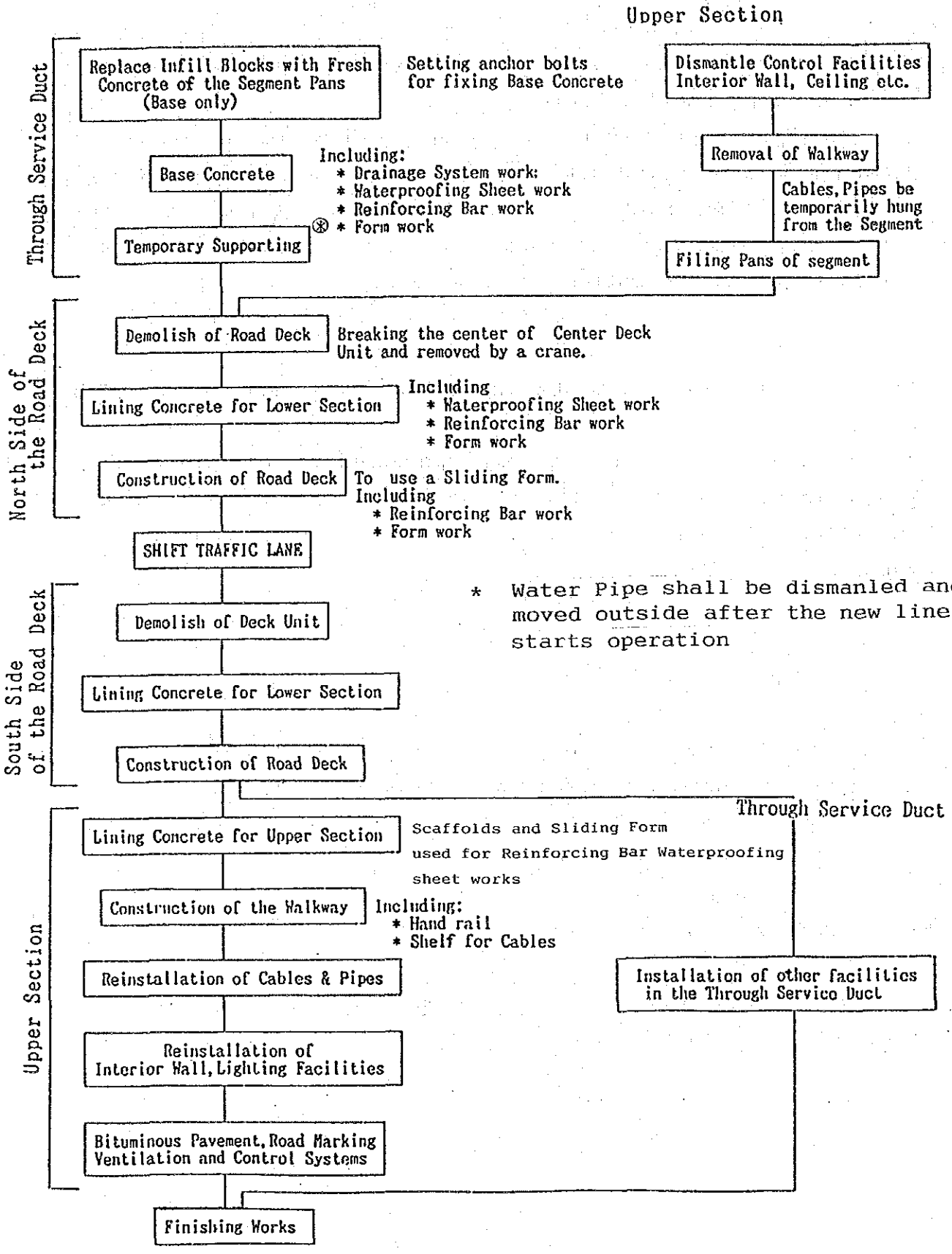
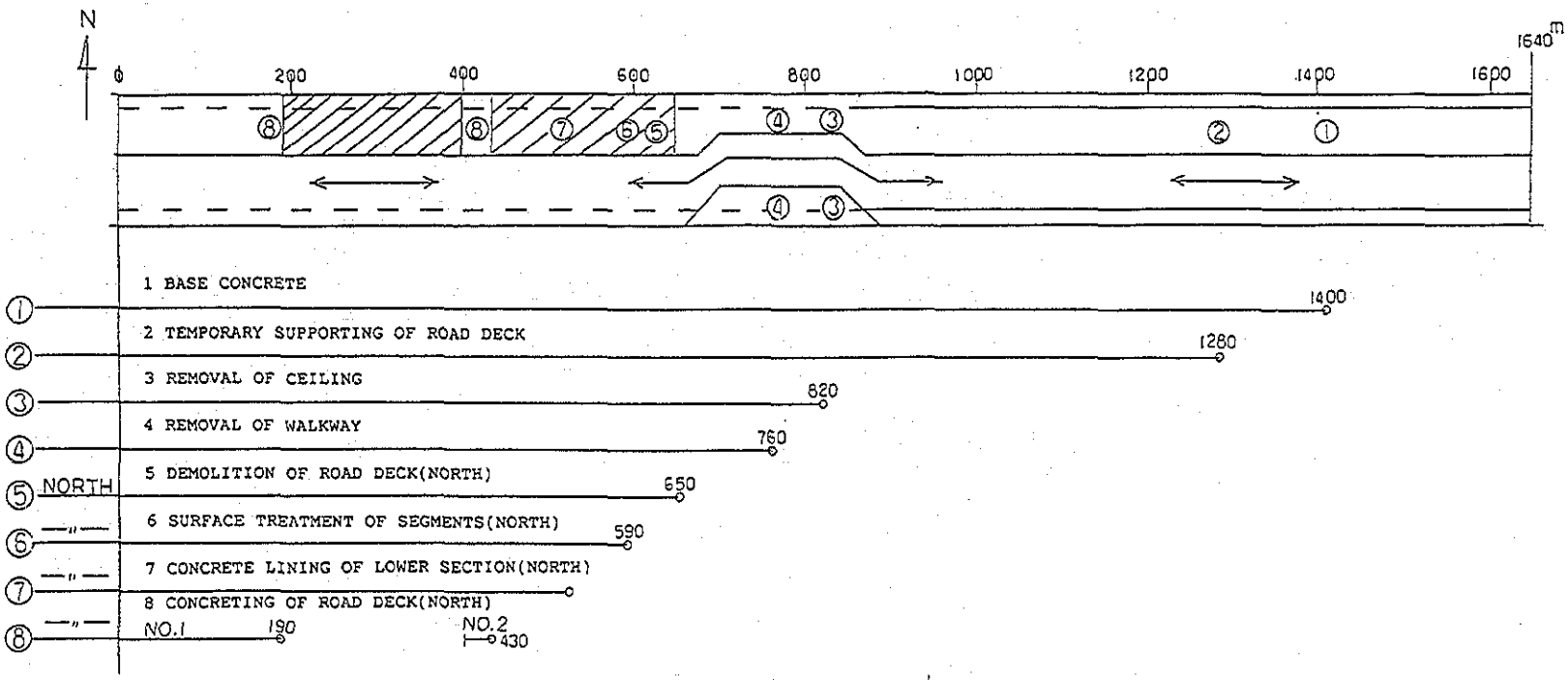
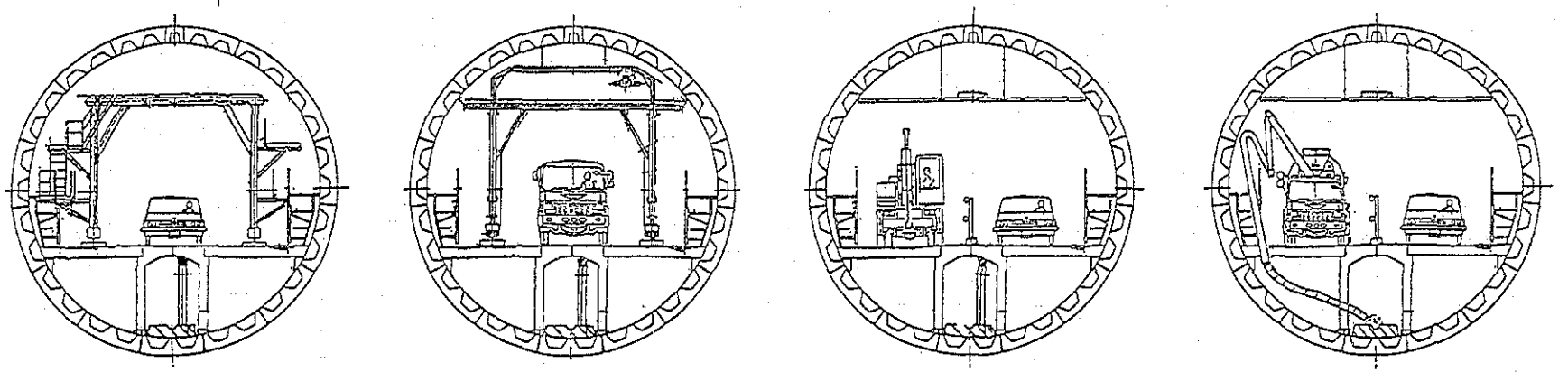


Fig. 5.2.1 Construction Sequence





④ REMOVAL OF WALKWAY ③ REMOVAL OF CEILING ② TEMPORARY SUPPORTING OF ROAD DECK ① BASE CONCRETE

Fig. 5. 2. 2 PROSPECTIVE VIEW
on the 12th Month After Commencement of the Works

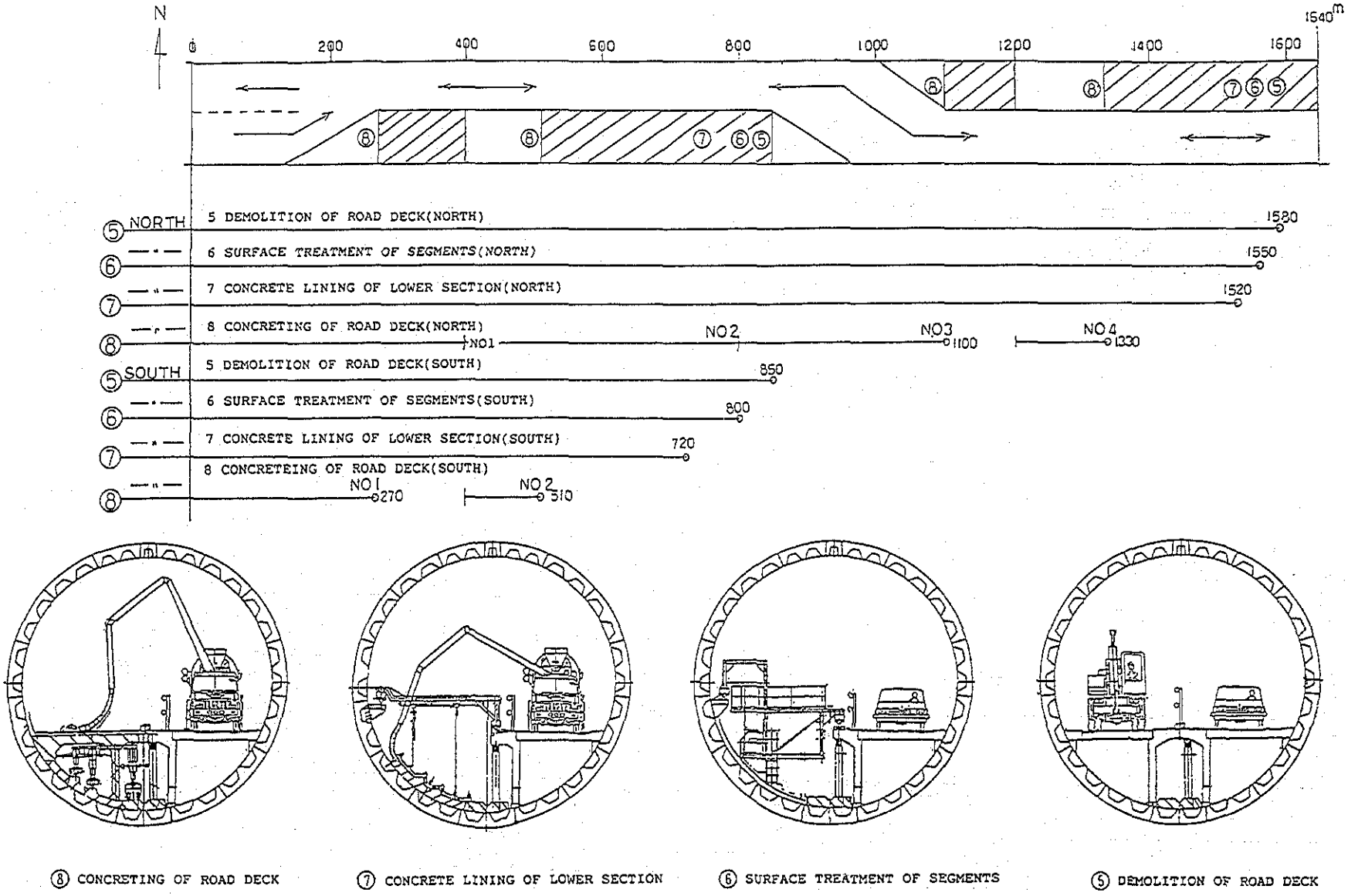


Fig. 5. 2. 3 PROSPECTIVE VIEW

on the 20th Month After Commencement of the Works

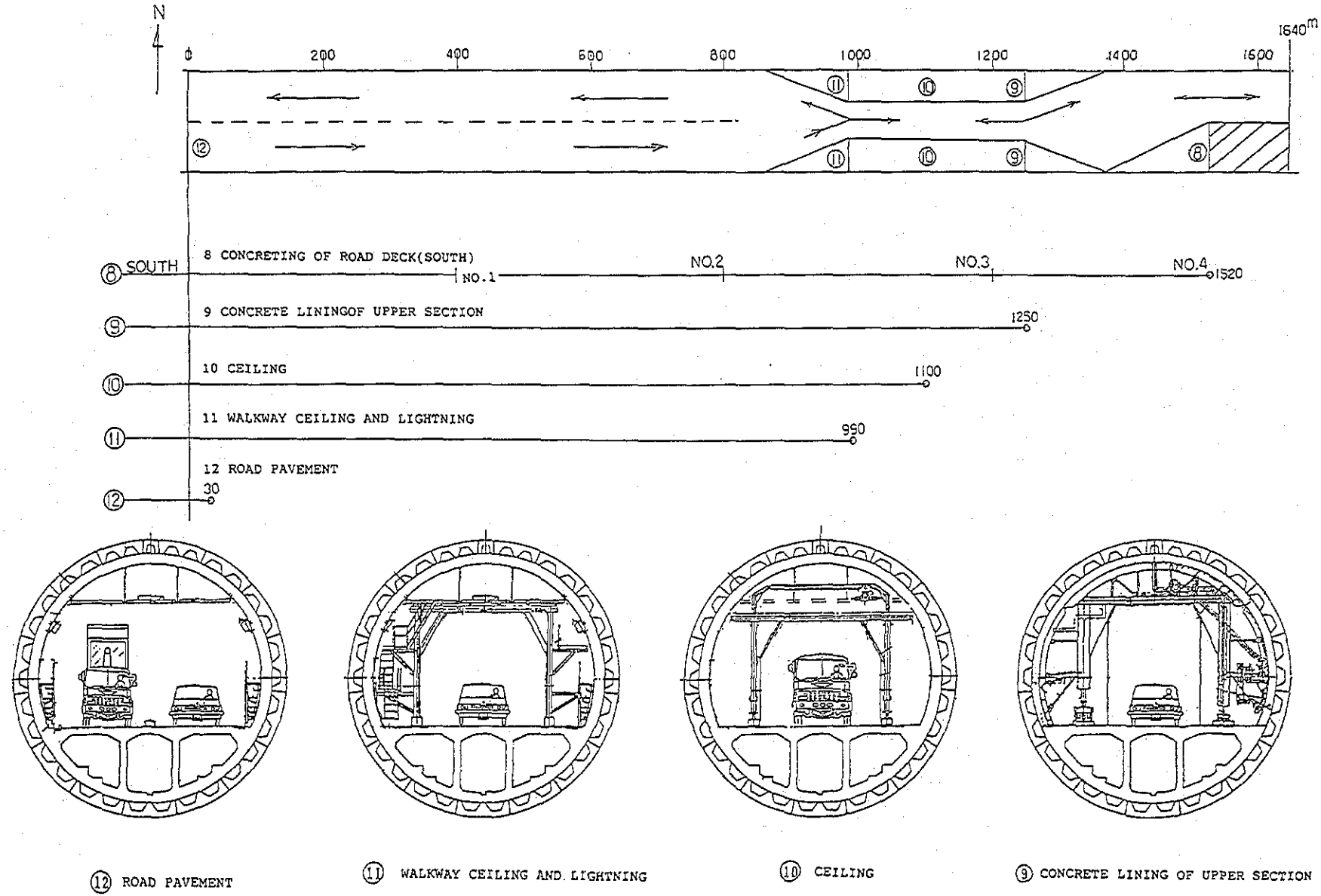


Fig. 5.2.4 PROSPECTIVE VIEW
on the 30th Month After Commencement of the Works

5.3 Procurement Plan of Materials

5.3.1 Procurement Plan of Materials for Structure

(1) Materials and equipment procured from Japan

The material and equipment which are considered to be difficult to obtain in Egypt or more expensive than in Japan, will be purchased Japan.

These are:

- Water proofing Sheet: ECB (Ethylene Co-polymer Bituminous)
- Fleece: Polypropylene
- Steel manholes on road deck
- Steel gate doors at deck

(2) Materials and equipment procured from Egypt

- Cement: Portland Cement
- Aggregate
- Reinforcing steel bars

(3) Materials and equipment procured from EC

- N/A

These will be minor changes in the above mentioned category depending on the result of the field survey in the detail design stage.

5.3.2 Procurement Plan of Materials for Facilities

(1) Materials and equipment to be procured from Japan

The materials and equipment which are considered to be difficult to obtain in Egypt or more expensive than in Japan, will be purchased in Japan.

These are:

-Forgings; Turnbuckle and Bolt

-Pipe system; Pumping main and Exhaust pipe at Nadir sump tank

-Wall panel; Silica acid Calcium panel for interior facing

-Shaped steel and plate; Walk ways and ceiling hanger

-Wires; Control system

-Equipment; Tunnel lighting system

(2) Materials and fabricated menbers to be procured from Egypt

- Cement: Portland Cement
- Aggregate
- Reinforcing steel bar

The same as materials for the Tunnel structure

(3) Materials and equipment to be procured from EC

The materials and equipment which are considered difficult to be replaced with alternatives because of technical reasons with existing qrupment and facilitied shal be procured from original makers.

These are:

- Communication cables: for TV camera, CO/V1 monitors

- Space parts: for TV camera, CO/VI monitors if necessary

There will be minor changes in the above mentioned category depending on the results of the field survey in the detail design stage.

5.3.3 Procurement Plan of Materials for Water Supply Pipelines

(1) Materials and equipment procured from Japan

The materials and eequipment which are considered to be difficult to obtain in Egypt, and more expensive than in Japan or for which no actual record of public service in Egypt, will be purchased in Japan.

- Ductile cast iron pipes: On land pipeline
- Ductile cast iron fittings: On land pipeline
- Steel pipes: Cross section of pipelines crossing under Suez Canal and crossing over Sweet Water Canal
- Aluminum sacrificial anode: for steel pipes crossing under Suez Canal

(2) Materials and equipment procured from Egypt

- Cement: Portland Cement
- Aggregate
- Reinforcing steel bars

(3) Materials and equipment procured from EC

- N/A

There will be minor changes in the above mentioned category depending on the results of the field survey in the detail design stage.

5.4 Temporary Facilities

Temporary Facilities are as follows:

1) Concrete Plants
2) Fabrication Yards for precast concrete panels
3) Portable Centles for concreting
4) Scaffolding Wheels for Works
5) Electric Facilities
6) Water Supply
7) Ventilation during the Rehabilitation Works
8) Tunnel Lighting during the Rehabilitation Works
9) Fabrication Yard for Bottom Pull Pipelines Crossing Suez Canal
10) Safety Facilities
11) Warehouse
12) Test Equipment
13) Others

(1) Concrete Plants

The Batcher Plants for concreting with the capacity of $60m^3/hr$ will be installed. This makes it possible to finish one concreting every 2.5 hours for Crown Portion of $95m^3$.

It includes:
(1) 2 - 50ton Cement Silos
(2) 3 - Aggregate Bins
(3) 1 - Mixing Equipment

(2) Fabrication Yards for Precast Concrete Panels - Ceiling Panels

- for 4920 panels - 12 panels/day
- 5 days cycle including curing/releasing
- The yard layout is as in Fig 5.4.1.

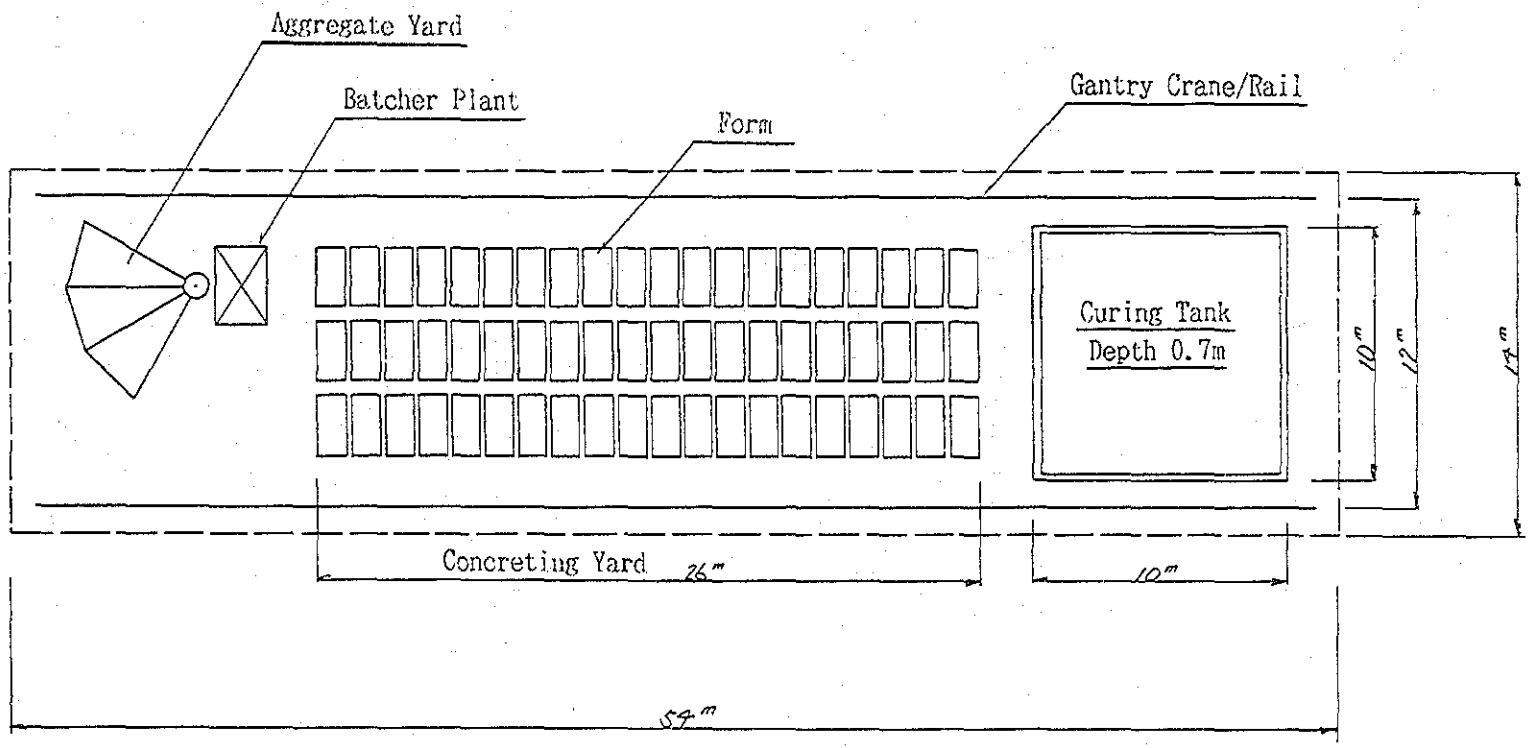


Fig.5.4.1 Fabrication Yards for Precasting Concrete Panels

(3) Portable Centles for Concreting

Motor driven wheel/rail Centles for concreting are to be prepared/used as:

Centles for Invert, Road Deck and Crown are shown in Fig.5.4.2.

(4) Scaffolding Wheels for the Works

Scaffolding Wheels have been designed as follows for keeping one traffic lane open and for the execution of the complicated and continuous work in the narrow tunnel:

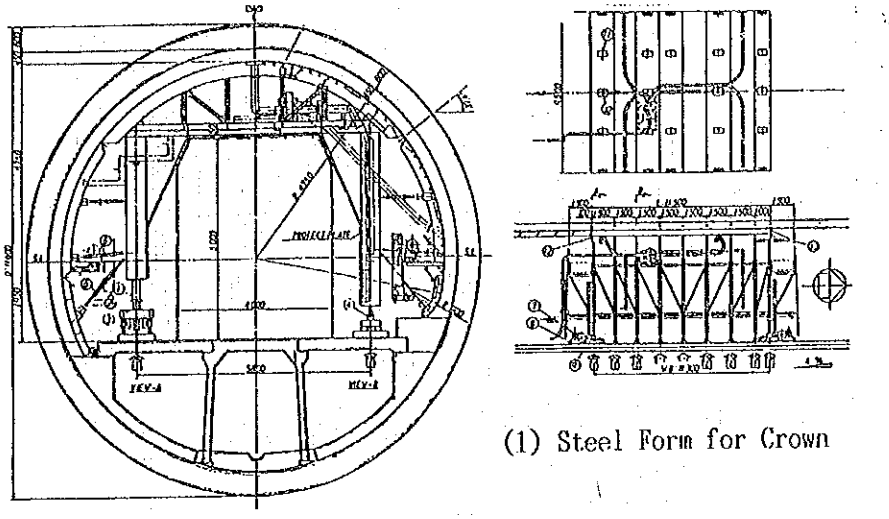
- Ceiling Panels Dismantle/Installation Fig.5.4.3.
- Interrior Installation Fig.5.4.4.
- Waterproofing Sheet Installation Fig.5.4.5.

(5) Electric Facilities

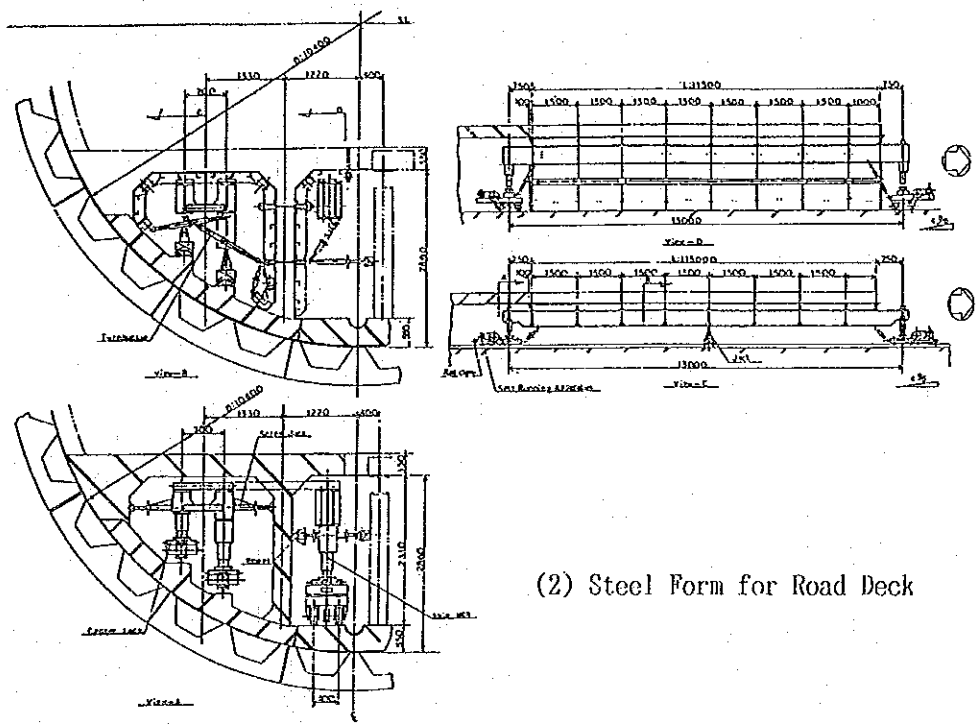
1) 380V / 220V, 500 KVA in Temporary Yard
It is assumed that the above Power Sources are to be delivered by S.C.A. from her Transformer Station for:

- Concrete Plant
- Maintenance Factory
- Carpenter/Reinforcing Steel Bar Plant
- Offices
- Outdoors

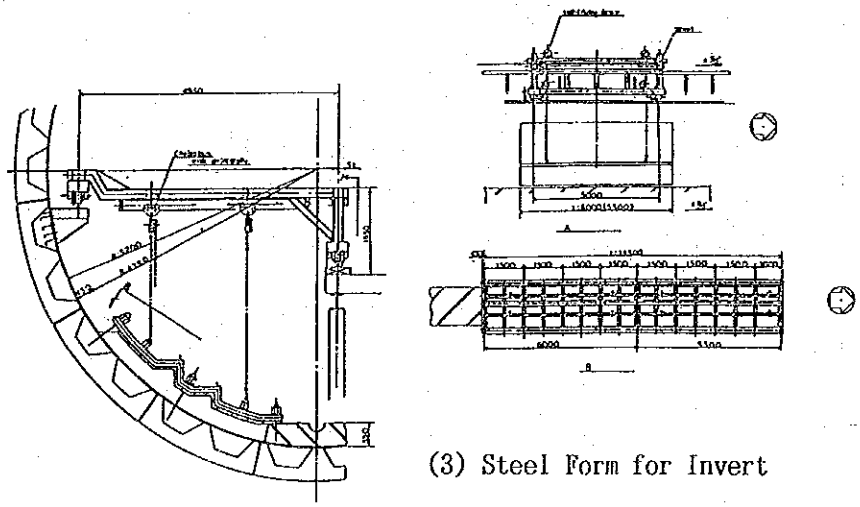
2) 400V / 200V for Fabrication Yards for precast concrete panels
11 KV will be provided by S.C.A. and it is to be changed down to 400V / 200V for:



(1) Steel Form for Crown



(2) Steel Form for Road Deck



(3) Steel Form for Invert

Fig. 5.4.2 Portable Centles for Concreting

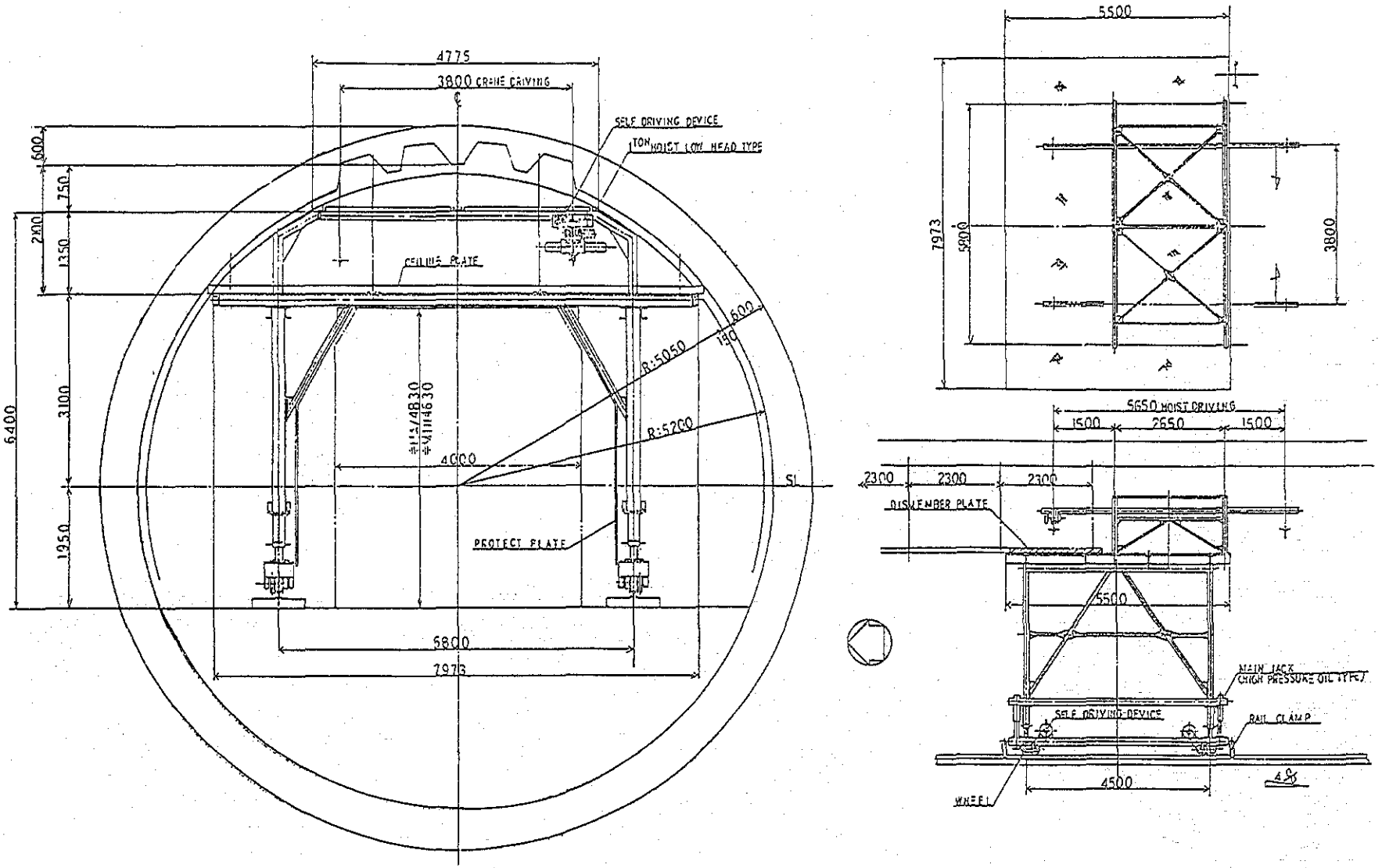


Fig.5.4.3 Scaffolding Wheels for Dismantlement/Installation of Ceiling Panels

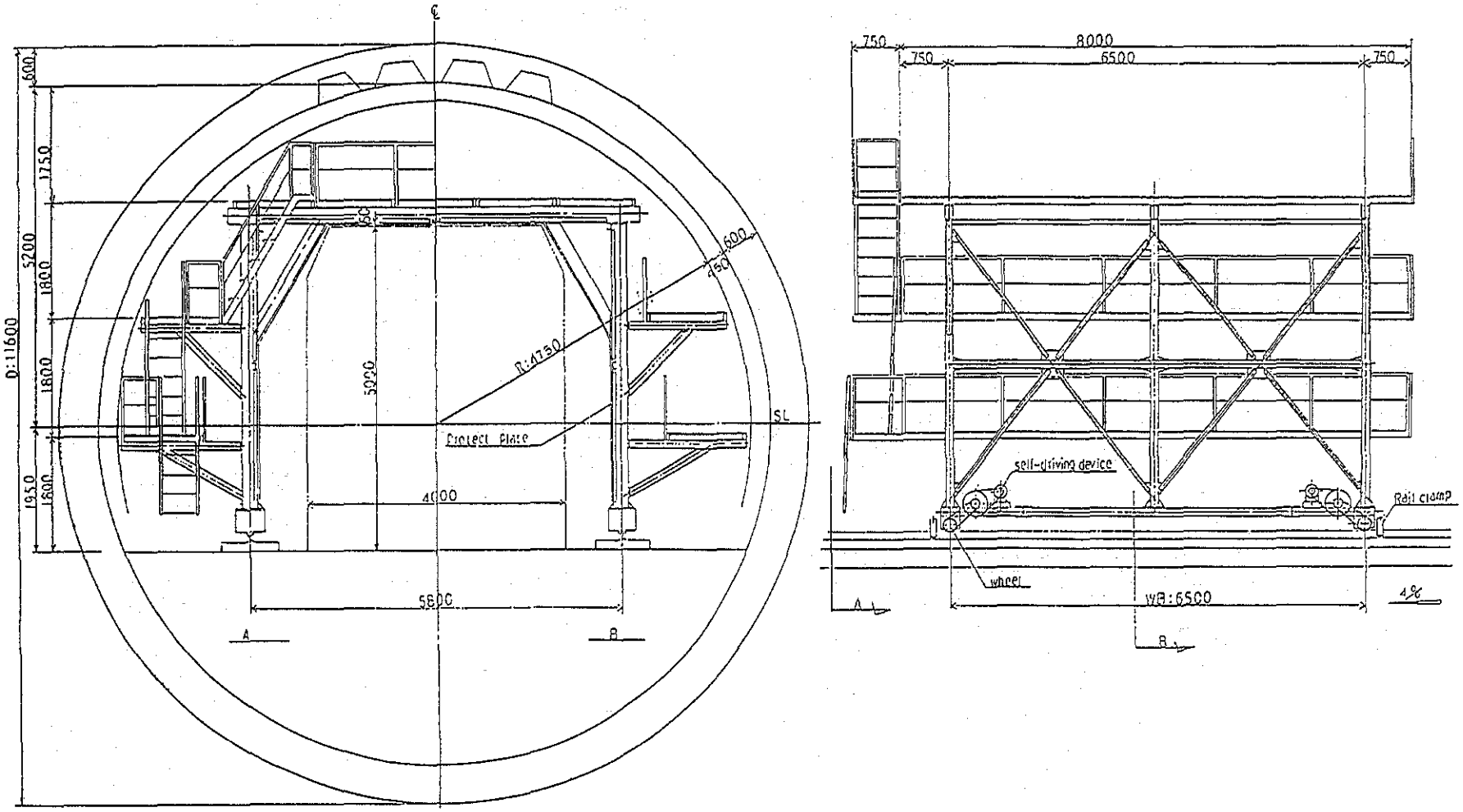


Fig. 5.4.4 Scaffolding Wheels for Interior Installation

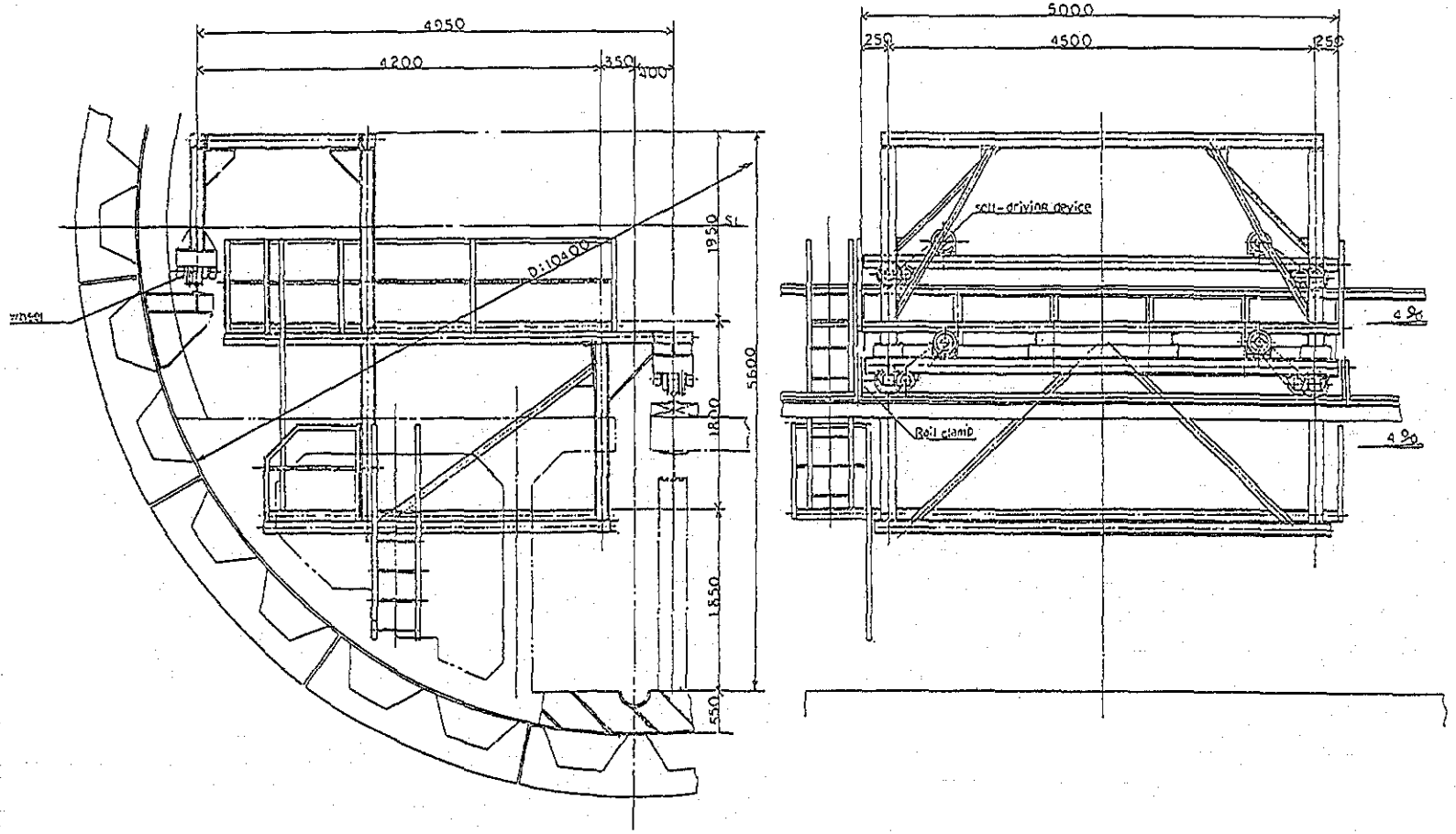


Fig.5.4.5 Scaffolding Wheels for Waterproofing Sheet Installation

- Concrete Plant
- Gantry Crane
- Welding Machines
- Water Pumps
- Lighting

3) 11KV Cables in the Tunnel

There are two 11KV 350Hz cables in the Tunnel. The one in the service duct shall be maintained during the Rehabilitation Works for supply of power from the west to east main switch room, and the other under the north walkway will be removed during the Works.

(6) Water Supply/ Drain Facilities

In the temporary yard, 80mm NID steel pipeline and 50mm NID vinyl chloride pipeline will be installed.
Water in the Tunnel for the Works will be delivered by tank trucks.
The drainage system in the temporary yard will be gutter with 300mm NID steel pipes crossing the road.
The drainage system in the Tunnel is to adopt 200mm NID vinyl chloride pipeline.

(7) Ventilation during the Rehabilitation Works

Considering health of workers in the Tunnel, CO gas shall be controled under 50 PPM.
According to the analysis and calculation, the minimum air supply volume will be 90m/sec.

(8) Tunnel Lighting during the Rehabilitation Works

The existing lighting system will be continuously used for the Rehabilitation Works.

(9) Fabrication Yard for Bottom Pull Pipelines Crossing Suez Canal

Fabrication yard is to be set up on the east bank of the Canal as shown in Fig. 5.4.6.
Long Pipes are to be weld connected/inspected/fieldcoated in this yard as:
$(12 + 12 + 12 + 12)^{m} = 48^{m}$
These long pipes prefabricated at this fabrication yard are pulled onto the Canal bed with wire ropes connected to 15ton towing winches located on the opposite west bank.

(10) Safety Facilities

• Safety First shall be one of the most important principles in this Rehabilitation Works.
Special safety rules shall be settled and responsible organizations shall be established and authorized in advance.

Safety of the following people and equipment must be taken care of:

1) Personnel in charge of the Works and the traffic through the Tunnel
2) The traffic passengers through the Tunnel
3) Engineering consultants in charge of supervision and the contractors
4) Property belonging to S.C.A.

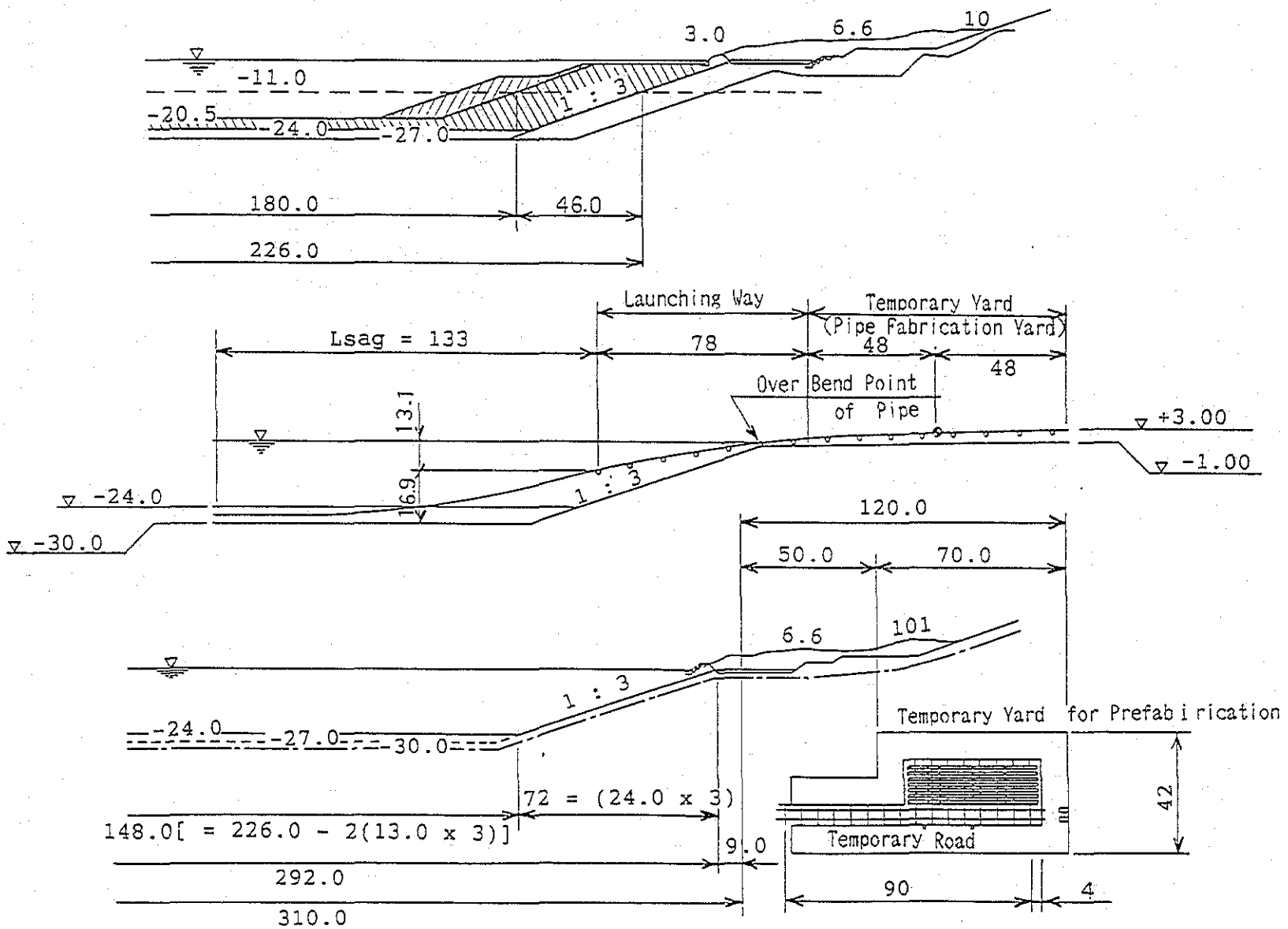


Fig.5.4.6 Temporary Yard for Prefabirication of Suez Canal Bottom Crossing Pipes (4X12m=48m)

1) Traffic control

• To ensure traffic safety, a traffic control system includigning necessary signals/guide plates and traffic control/patrolman is to be established. Because of the traffic in the Tunnel being complicated from time to time by one-lane traffic and the separation of 4-work sections, the traffic lane and the Works area are to be separatod by steel plate walls.

• The followings are the construction conditions based on the discussions with S.C.A.
The traffic restrictions during the Rehabilitation Works are to be as follows:

(1) One lane traffic.
(2) The speed limit is to be 20 Km/h. Further restriction is to be applied to large vehicles.
(3) The traffic is to be stopped between 8:00 pm through 6:00 am. During the period of special work such as the assembling/dismantling/moving works for Centles and Sliding Forms, the traffic is to be stopped the whole day(s) according to the schedule of construction. The period of traffic stoppage should not exceed one month during the Rehabilitation Works. Each stoppage may continue 4 days to the maximum.

Therefore, the concreting work and the main materials to be carried into/out of the Tunnel are to be done at night.

2) Ventilation System during the Rehabilitation Works is also one of the most important safety control facilities. Considerations for setting up temporary fans and lowering CO gas level are to be included.

3) In case of fire emergency, portable fire extinguisher is to be adopted in addition to the existing fire engines.

4) Emergency

An ambulance car shall stand by in case there is an accident. Special agreement/arrangement with S.C.A. for hospitals in case of emergency shall be established in advance.

(11) Warehouse

It is scheduled to install the following temporary buildings/houses.

- Office for Consultant Supervisors
- Office for Contractor
- Lodging for Workers
- Warehouse for Cement
- Warehouse for other materials
- Plant for Reinforcing Steel Bar
- Plant for Carpenters
- Machine Shop
- Test Plant

(12) Test Equipment

For the quality control of concrete, the following Test Equipment shall be installed at site:

- Aggregate Test Equipment
- Concrete Equipment

(13) Others

For carrying/transport of materials/equipment between the Tunnel and the temporary yards, the followings are to be considered:
For Dismantlement and Reinstallation of:

- Cables
- Lighting Equipment
- Interrior Panels and others
- Water Supply Pipes 500mm NID
- Fire Hydrant Pipes
- Drain/Drainage Pipes
- Others

For Dismantlement only:

- Concrete
- Reinforcing Steel Bars
- Waterproofing Sheet
- Metal Frames from Cable Duct
- Precast Concrete Panels

5.5 Supervisory Service

5.5.1 Organization of Supervisory Service by the Consulting Engineers

Supervisory Service by the Consulting Engineers consists of supervision of progress of works, workmanship and quality of works, inspection of works executed by Contractor, issuance of certificates in accordance with the general conditions, technical specifications and drawings for the construction of the Rehabilitation Works of the Tunnel, and coordination between S.C.A. and Contractor, in order to complete the Works as per schedule specified on the Contract.

The important points for the above Supervisory Service by the Consulting Engineers are stated below:

(1) It is important to supervise over workmanship and quality of works executed by Contractor, so that the Tunnel can be put in use safely for a long time after the Rehabilitation Works is completed.

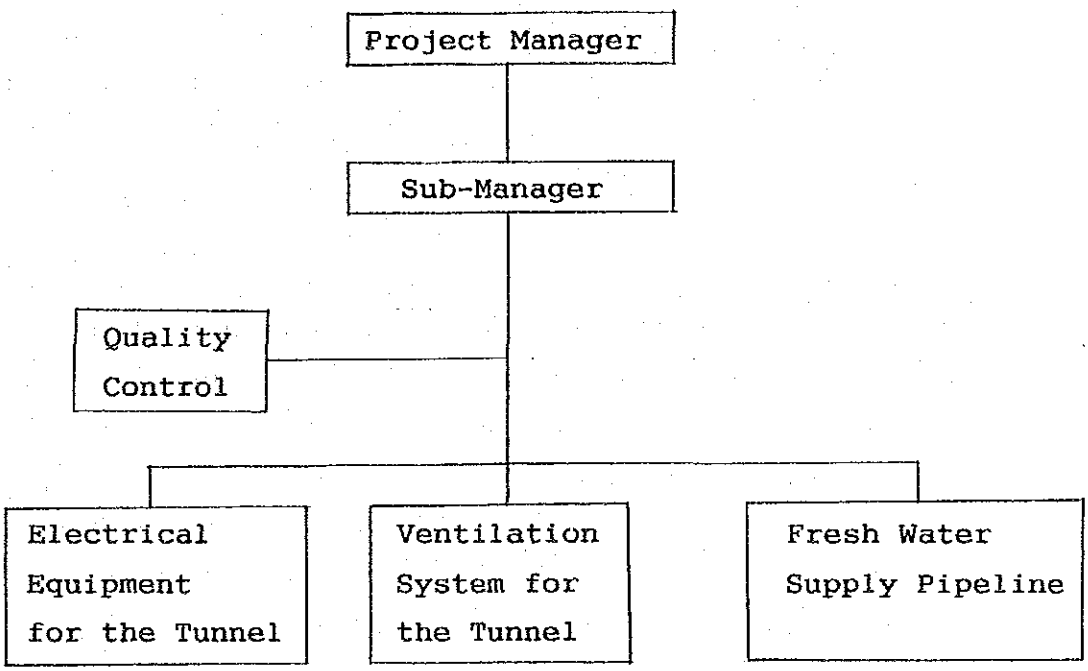
Meanwhile, it is absolutely necessary to check and analyze the chemical composition of water, aggregate and sand for construction use before commencement of the Works in order to prevent deterioration of reinforced concrete structure due to improper chemical composition in water and construction materials. Concrete quality control facilities at site shall be prepared by Contractor for this purpose. The laboratory facilities owned by S.C.A. could also be used .

(2) The existing facilities and equipment of the Tunnel are intended to be partially re-used.
Therefore, it is important to give a special care each time when these facilities and equipments are temporarily removed for maintenance, inspection or installation.

(3) The Rehabilitation of the Tunnel is intended to be executed under the condition that 1 lane of traffic is basically kept open day and night during the full period of construction.
Therefore, it is extremely important to pay an attention to the safety of traffic during the full period of construction.

The organization chart of Supervisory Service by the Consulting Engineer is shown in Fig. 5.5.1

The Organization Chart of Supervisory Service



(Note) The Site Office for Supervisory Service shall be set up in the Contractor's office on the work-site.

Fig.5.5.1 The Organization Chart of Supervisory Service

5.5.2. The Roles of Engineers for Supervisory Service

(1) Project Manager

Project Manager shall coordinate the overall Supervisory Service, which consists of coordination between S.C.A. and Contractor, inspection of works executed by Contractor and supervision of progress of works on the whole.

(2) Sub-Manager

Sub-Manager shall assist Project Manager in the overall Supervisory Service, which consists mainly of supervision of the Rehabilitation Works of tunnel structure such as removal of Road Deck, installation of fleece and water-proofing sheet, setting of Anchor, reinforced concrete work of the lower part and upper part of the Tunnel, installation of Road Deck, Curb Centerline for traffic, Drainage work, and supervision of removal of Fresh Water Pipelines' Cast Iron Pipes, removal and rebuilding of walkway, removal, manufacturing and installation of ceiling, piping work and removal of Cables.

(3) Engineer for Quality Control

The Engineers assigned for quality control shall supervise the tests conducted by Contractor for selection of an appropriate material for reinforced concrete structure and give necessary advices to the Contractor on the design of combination of concrete material.

(4) Engineer for Electrical Equipment for the Tunnel

The Engineers assigned for electrical equipment shall supervise removal and setting of Cables under the Pedestrian deck, removal of each equipment for Lighting, Firefighting, Cable for Wireless Telephone, Industrial Television Camera and the apparatus for measurement of visibility, and CO gas, temporary cables for lighting and ventilation for the construction works, installation of Lighting Equipment and Control Panel in the Control-center, and overhaul and setting of Control Equipment for Ventilation system.

(5) Engineer for Ventilation System of the Tunnel

The Engineers assigned for ventilaiton system shall supervise resetting work of Fans and Slottle for Ventilation.

(6) Engineer for Fresh Water Supply Pipeline

The Engineer assigned for the fresh water supplyu pipelines shall supervise installation work of pipelines on land and on the bottom of the Canal, and pipe Beam Bridge, be involved in testing of Water Pressure, and assist Sub. Manager in his supervision of removal of Fresh Water Pipelines, as necessary.

5.5.3 Time Schedule for Supervisory Service by the Consulting Engineer

Time Schedule for Supervisory Service by the Consulting Engineer is shown in Fig.5.5.1.

5.6. Scope of Work

The Scope of Work for the Rehabilitation Works is as follows:

5.6.1. Tunnel Structure

The Rehabilitation Works for the whole length (1650m) of the Tunnel shall be implemented by the method of reinforced concrete lining after applying waterproofing sheet on the existing concrete segments including the road deck.

After the Rehabilitation Works, the Tunnel shall be maintained through regular inspection and slight partial rehabilitation works only.

The rehabilitation design for the Tunnel shall allow future widening, deepening and doubling projects of the Suez Canal.

5.6.2. Related Facilities

As a basic policy, the road system and the related facilities after being rehabilitated shall recover their former function.
The possibility of reuse of materials and equipment has been studied according to the technical engineers' points of view which is shown in Table 1 in the Summary (The details are in "4.1. Field Survey").
The followings are some special notes.

(1) Ventilation System

- Transverse System
- Ceiling Panels: The ceiling panels (material only) are to be the scope of work by S.C.A.

(2) Special Telephone Cables

- The existing special telephone cables in the Tunnel shall be removed before commencement of the Rehabilitation Works.

(3) Wall Panels

- The existing wall panel material is not fireproof and therefore is to be replaced by a safer one: Silica acid Calcium board.

5.6.3. Fresh Water Supply Pipeline

Permanent Fresh Water Supply Pipelines (two lines) shall be installed outside of the Tunnel crossing the bottom of Suez Canal in order to secure the water supply to the Peninsula of Sinai and to facilitate the Rehabilitation Works. The followings are to be specially noted.

(1) Installation Sequence

One pipeline is to be installed first as a priority of this Rehabilitation Works and filled with water. After the commencement of the water supply operation of the 1st line, the existing pipes in the Tunnel shall be dismantled and installed as the 2nd line after being checked and selected for reuse.

(2) Canal Dredging

The Canal dredging for the pipeline crossing the Canal is to be carried out by S.C.A. in advance.

(3) Excavation/earthing

The excavation/earthing for the on land portion is to be carried out by S.C.A. in advance.

(4) Ductile Cast Iron Pipe 500mm NID

The ductile cast iron pipe 500mm NID of 500m in length is to be supplied by S.C.A. (from its stock). This type of pipe is to be used again for the 2nd pipeline when necessary.

5.6.4. Others

For the execution of the Rehabilitation Works, the following shall to be defined as the scope of work to be carried out by S.C.A:

Setting up and installation of:

1) Temporary yard for work
2) Access road for work
3) Ware house for material and equipment
4) Water supply for work
5) Electric power supply for work
6) Telecommunication service (telephone and telefax) for work

5.7. Schedule of Construction

The Schedule of Construction is shown in:
Table 5.7.1. (Bar Chart)
Table 5.7.2 (with Tunnel Length).

Table 5.7.1 Schedule of the Rehabilitaion Works

Item	Detail Design (Month) / Constraction (Month)
1. Detail Design	
2. Rehabilitation Works	
Preparation	
Site Preparation	
Water Pipeline	
Crossing Suez Canal	
Ductile Cast Iron Pipe	
Lining	
Base	
① Under Deck (North)	
② Under Deck (South)	
③ Crown	
Road Deck	
Dismantle (North)	
Dismantle (South)	
Concreting (North)	
Concreting (South)	
Facilities Dismantle	
Facilities Installation	
Walkway, Panels Dismantle	
Walkway, Panels Installation	

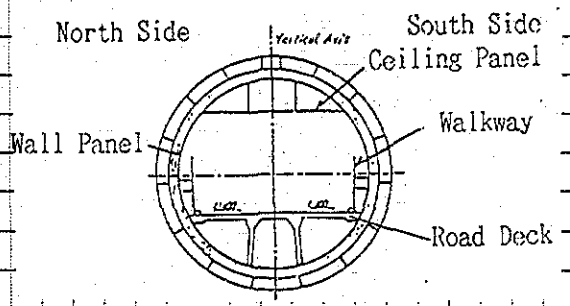
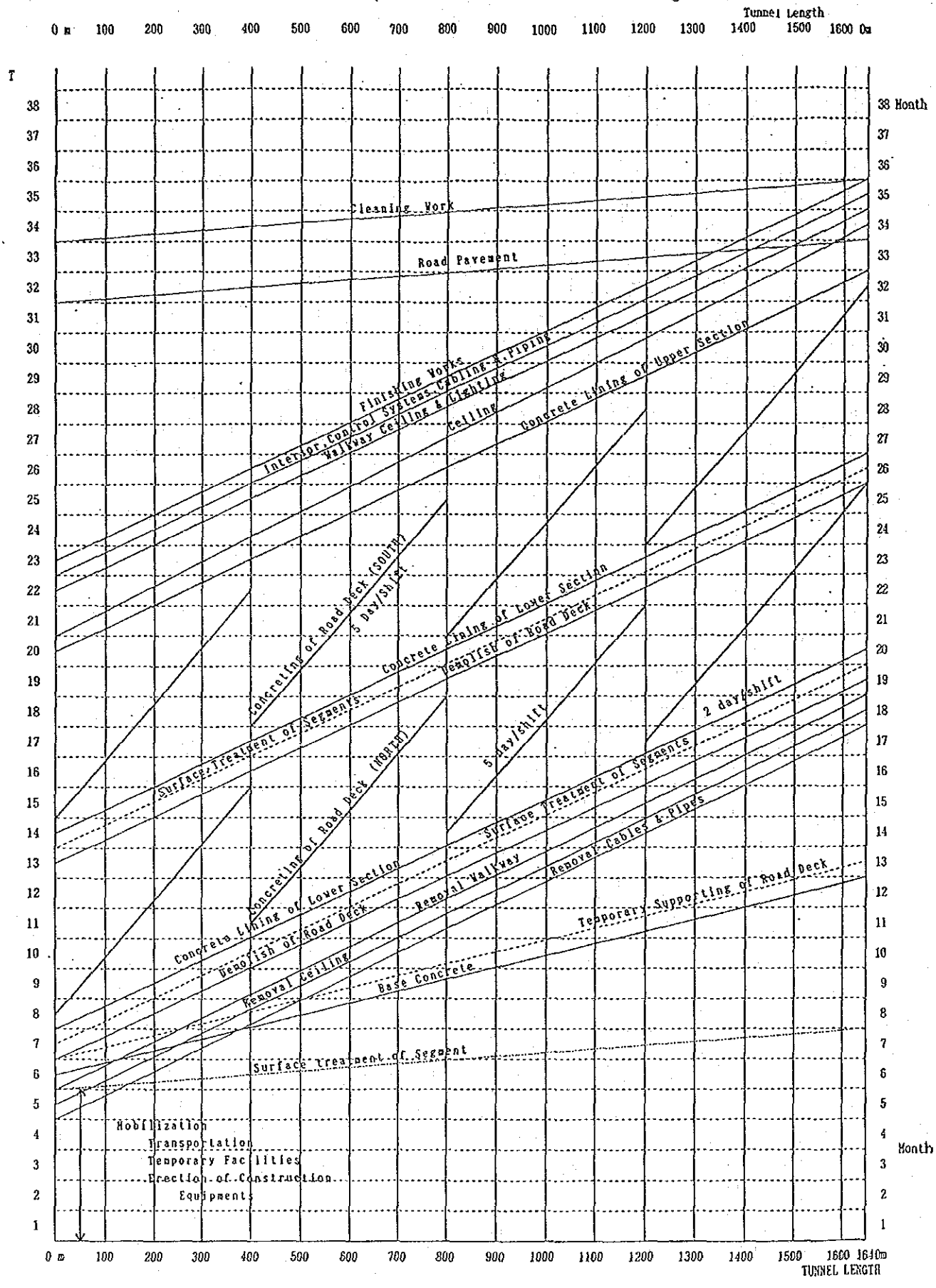


Table 5.7.2 Schedule of Construction (with Tunnel Length)



CHAPTER 6

OUTLINE OF MAINTENANCE METHOD OF THE TUNNEL AFTER LTS REOPENING

Chapter 6 Outline of Method of Maintenance of the Tunnel after its Reopening

Maintenance of the Tunnel is very important for the safety of traffic in the Tunnel.

In case the same deterioration of the Tunnel occurs again after the Rehabilitation Works is completed, it would be impossible to repair it.

Main points for Maintenance consist of Tunnel structure of Tunnel Lining (reinforced concrete Lining), Road Deck and Drainage System, and Related facilities such as Ventilation and Lightning system.

6.1 Maintenance of Tunnel Structure

6.1.1 Tunnel Structure

(1) Tunnel Lining (reinforced concrete Lining) of the tunnel structure is the most important for the Tunnel, which provides the Road Limit required for the traffic in the Tunnel and prevents the leakage of salty water into the inside of the Tunnel.

The Tunnel is categorized as a drainage type tunnel, the outside of which is covered with waterproofing sheet and fleece to cope with the leakage of salty water from the outside of the Tunnel.

Therefore, the following points are important for Maintenance of the Tunnel.

1) The tunnel structure should be regularly checked by the visual method every year.

2) It is necessary to check and grasp even a minute progress of deterioration of the Tunnel such as deformation of the tunnel structure and cracks in reinforced

concrete lining, and to keep the records of the progress of such deterioration, because such deterioration of the tunnel structure usually goes on very slowly and is apt to be overlooked.
It is desirable to perform a regular checking of the tunnel structure in details, especially in the course of the Expansion Project of Suez Canal.

3) In case leakage of salty water is unfortunately found, it is absolutely necessary to take a measure to stop such leakage of salty water as soon as possible and keep on checking continuously.

4) Frequency of a regular checking of the tunnel structure should be performed every year. However, it is necessary to perform a regular checking strictly in compliance with the plan of safety-checking of the tunnel structure in the course of Expansion Project of Suez Canal.

5) It is necessary to keep records and photographs of the deteriorated situation of the Tunnel such as deformation of the tunnel structure, cracks in reinforced concrete lining and leakage of salty water in details and turn it into a routine work.
Especially, in order to check changes in physical effects on the tunnel structure due to the Expansion Project of Suez Canal for the comparison purpose, it is necessary to grasp the deformation of the tunnel structure and cracks in reinforced concrete lining immediately after the Rehabilitation Works is completed.

6) In case deterioration of the tunnel structure is found, it is urgently necesary to perform a detailed investigation and discussion with engineers concerned to take proper steps for repairing purpose.

7) Items for checking of tunnel structure are stated below :

a. Situation and progress of cracks in the tunnel structure

b. Situation of the deformation of the tunnel structure

c. Situation, location and quantity of the leakage of salty water

Fig.6.1.1 is a flow chart showing maintenance and checking of a tunnel structure.

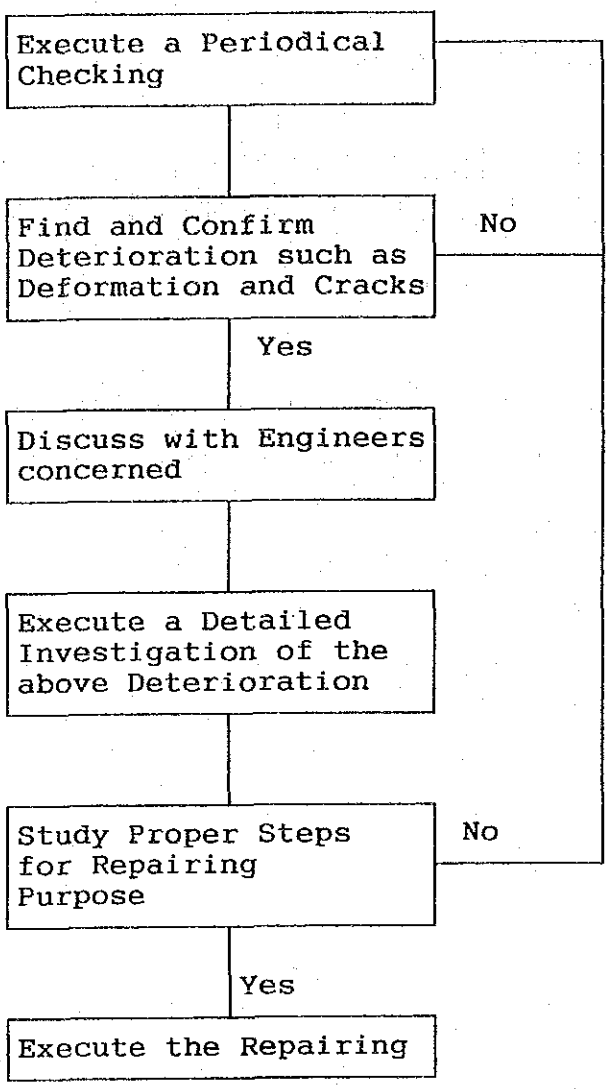


Fig.6.1.1 Flow Chart of Checking of Tunnel Structure

(2) Road Deck and Supporting Wall

Road decks are structural parts that directly bear dynamic loads by vehicles passing through the Tunnel and therefore, are apt to be damaged and deteriorated quickly.

In addition, deteriorated Road decks are very difficult and expensive to repair.

For the above reasons, it is essential to perform a periodical checking of Road decks in order to find out damaged points, and take necessary (and sufficient) steps as soon as possible.

In the structural design of Road decks in this Report, full consideration is given to the durability of Road decks to resist salty water, but the possibility of appearance of cracks due to dynamic loads by frequently passing vehicles should be carefully checked.

The main points to be checked are stated below :

1) Cracks of Road decks should be checked by the visual checking method.
   Items for checking are the direction, width, length, intervals, location, density of cracks and progress of cracking, and other chemicals.

2) Checking of cracks should be performed at least every six months, but checking the progress of cracks should be performed at least every three monthes.

3) In case the width of cracks is found to be more than 0.3mm, necessary steps should be studied and discussed in accordance with the flow chart in Fig. 6.1.1.
   Repairing work of cracks is to fill cracks with epoxy resin.

4) Supporting Walls should be checked simultaneously with Road decks at least every year.

(3) Drainage System

In case the underground water is leaked into the tunnel structure, it is drained through fleece into the drain gutter set at the bottom of the tunnel structure and collected into the Nadir sump in the deepest point of the Tunnel, and drained to the outside of the Tunnel there from by pumping.

The main points to be checked are stated below :-

1) It is necessary to clean down the drain gutter at the bottom of the tunnel structure from time to time, because crystallized saline is apt to occur in the above drain gutter, which could possibly be one of the causes for deterioration of drain gutter.

2) Cleaning of the drain gutter should be performed at least every three months.

3) In order to get rid of the above crystallized saline, it is necessary to prepare a handy instrument for cleaning.

4) Pumping equipment at the Nadir sump should be checked every month, and overhauled every two years.

5) Inflow of rain water and leakage of salty water into the Tunnel should be checked carefully.

6.1.2 Number of Personnel for Maintenance

Number of personnel required for maintenance of the tunnel structure are stated as follows :-

- In the course of Expansion Project of Suez Canal, two civil engineers are needed.
- After the above Project is completed, one civil engineer is enough for maintenance of the tunnel structure.

Two workers are enough for cleaning drain gutter.

Repairing work of cracks is to fill cracks with epoxy resin.

6.1.3 A View on the Maintenance Work by S.C.A.

(1) The traffic speed limit of 20Km/h which was suggested by Task Team in 1990 verballly is now being enforced.
This is effective for prevention of accident by the road deck deterioration.

(2) Concerning the drainage system, the ground water from the segment joints at the ceiling top to be guided to the side wall up to the invert is essential.

(3) The removal of the crystallized chrolide from the concrete(segment) surface is not recommendable, because this removes the surface (skin) layer and at the same time moves the covering concrete and as a result gives cotinuous supply of oxygen to the reinforcing steel bar.

(4) Concerning the Ventilation System, almost all covering boards at both sides of the ceiling have been removed and so the Transverse Ventilation effect is not expected. Instead, it is under the Semi-transverse Ventilation condition.

The following two actions shall be carried out before the commencement of the Rehabilitaion Works.

1) Leaked water is to be guided and collected into Nadir sump tank.

2) The repairing criteria, the repairing method and the strength check method on the base concrete portions at the feet of Road Deck Support Walls must be settled first.

The actual procedures of the above are as stated belosw.

A. Procedure for Leaked Water to be Guided and Collected into Nadir Sump Tank

1)Purpose

The tunnel deterioration is now going on by way of penatration of leaked water containing high density of salt into numerous places.

To stop this salty deterioraion as much as possible by the minimum cost and to keep the tunnel's structure strength until the commencement of the Rehabilitation Works, it is very essential that the leaked water to be guided and collected into Nadir sump tank.

It shall be also noted that this leaking water collecting method is only for temporary application before the actual commencement of the Rehabilitaion works, but not for permanent repair and/or improvement application.

2) Places/locations of leaking water

Places where leaking water appears can be categorized into the following four:

-segment joints
-grouting holes
-bolt connecting holes of segment joint
-segment concrete bodies (through the concrete's deteriorated and cracked areas)

The fourth location "leaking water through segment concrete body" in the above is not within the scope of this leaking water treatment, because it is so much complicated to apply any leaking water treatment and there is so far no practical/effective measures to deal with this kind of leakage.

3) Basic approach to water guiding and measures

Leaking water appeared from the upper half of the Tunnel (higher than the road deck) shall be stopped as much as possible inside the Tunnel, and then be guided to the lower half (lower than the road deck) and then to the outside.

This is the basic approach for minimizing the wet surface of the inside tunnel structure caused by the salty leaked water.

For the above approach, the following mesures are required:

- -To stop the leaked water found in the upper half of the Tunnel inside the Tunnel.
- -To guide the leaked water found in the lower half of the Tunnel through/by using of grouting hole etc. and collect the water into the Tunnel inside.
- -The guided water shall be collected in the water gutter at the bottom of the Fresh Air Duct, which is connected to Nadir sump tank.

Leaked water in the Through Service Duct is not within the scope for this leaking water treatment, because there is so far no practical/effective measures for this.

The following Fig.6.1.2 shows how the leaked water is to be guided.

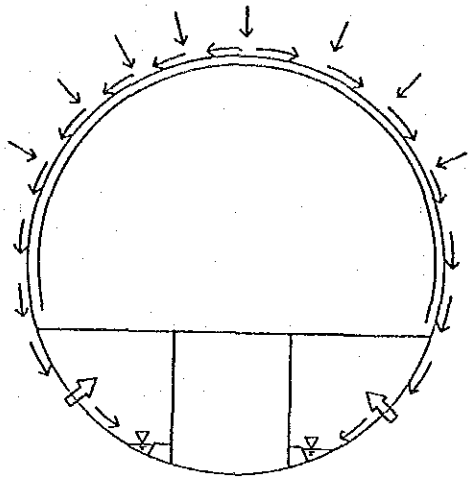


Fig.6.1.2 Leaking Water Guiding System

4) How to stop leaking water

The measures for stopping the leaking water vary depending on the locations of leaking water. The procedures for stopping leaking water at different leaking locations are suggested below:

a. Segment Joints

There are couple of situations in which leaking water appears at segment joints:

a-1. In case of healthy joint
- gap size of joint open
- size of high/low

a-2. In case of deteriorated joint
- gap size of joint open
- size of high/low

However, the basic procedures for stopping leaking water will be the same in both of the above situations a-1 and a-2, which can be listed as below.
- To nominate the joint locations where water leaking is found out.
- To clean the joints.
- To fill in the joint gaps with fiber such as 1-3 layers of flax rope(s) as demonstrated in the following figures.
- To apply the follow-up jet cement mortar onto the fiber as shown in Fib.6.1.3.

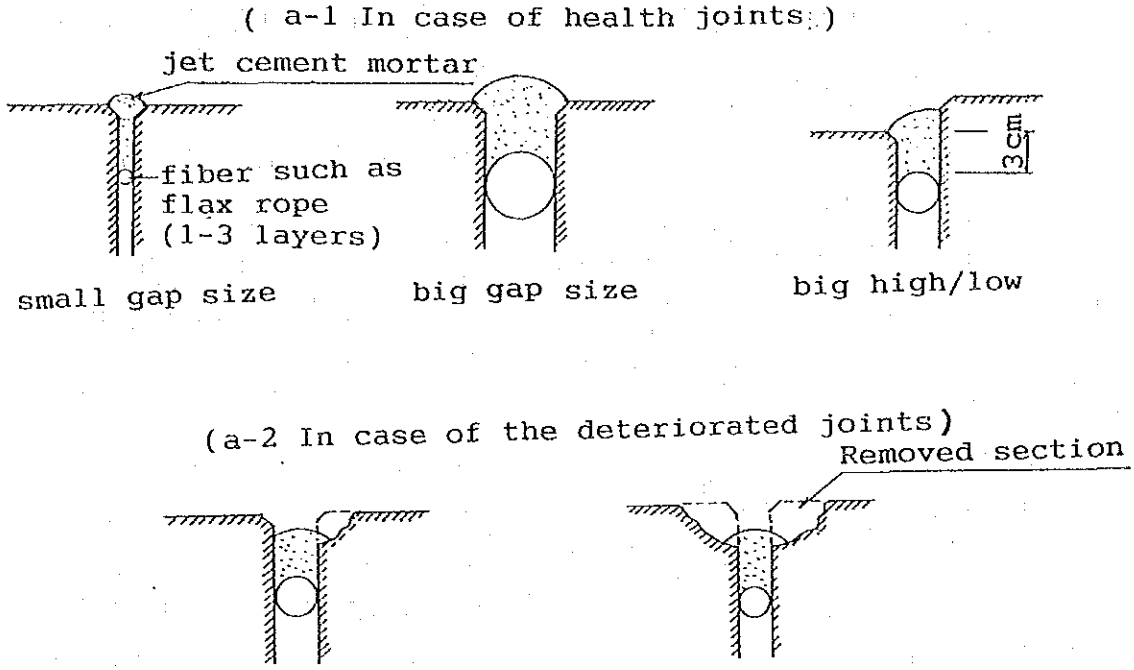


Fig. 6.1.3 Stopping Leaking Water at Segment Joints

b. Grouting Holes

There are the following two water leaking situations at grouting holes.

b-1. In case of cement milk in grouting hole

b-2. In case of no cement milk in grouting hole

However, the basic procedures for stopping leaking water will be the same in both situation of the above b-1 and b-2, which are shown below and in Fig.6.1.4.

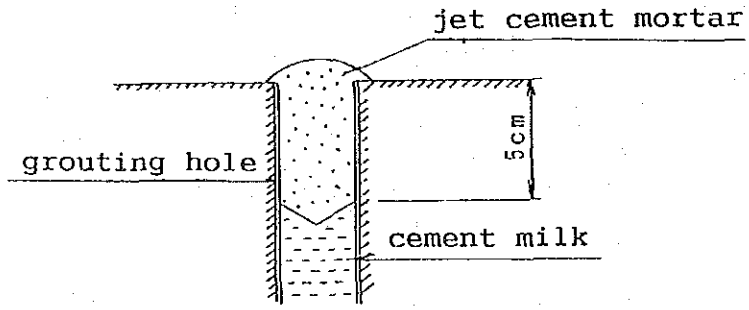
-To nominate the grouting holes where water leaking is found out,

-To remove the grouting caps,

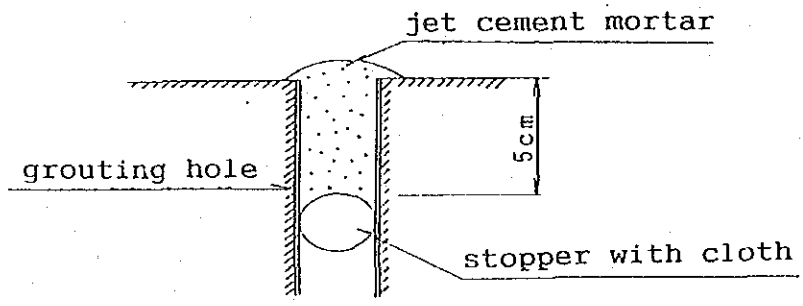
-To clean the inside of the grouting holes until the depth of approx. 5cm by using a drill of 5cm in diameter as shown,

-To pack the stopper with cloth as in the figures (in case of no cement milk in grouting holes only),

-To apply the follow-up jet cement mortar onto the cloth.



(b-1 In case of cement milk in grouting hole)



(b-2. In case of no cement milk in grouting hole)

Fig. 6.1.4 Stopping Leaking Water at Grouting Holes

C. Bolt Connecting Holes at Segment Joints

There are the following two cases, (Ref. Fig.6.1.5.) and therefore two counter mesurers are recommended here.

c-1. In case of segment joint bolt and nut being possible to be removed, "rubber bolt packing " can be inserted under the bolt cap and nut, and thus stop the leaking water.

c-2. In case of segment joint bolt and nut being impossible to be removed, "liquid swelling material" with pressure is to be inserted instead of "rubber bolt packing", so as to stop the leaking water.

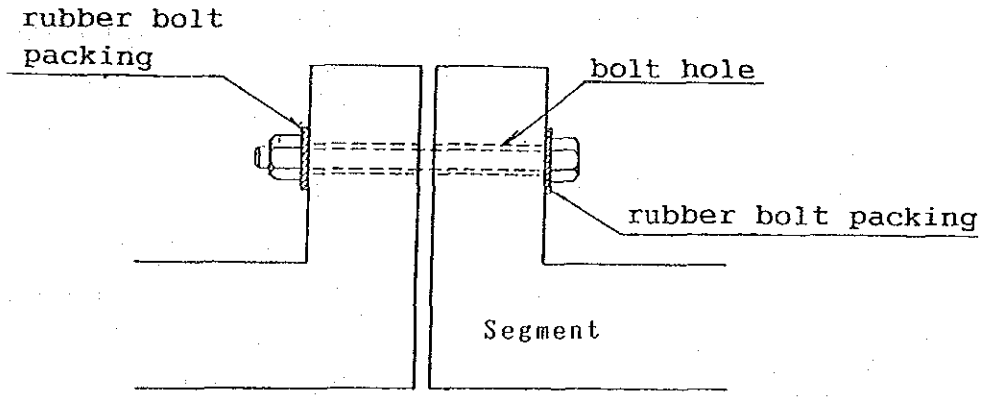


Fig. 6.1.5 Stopping Leaking Water at Segment Bolt Connecting Holes

5) How to guide and collect the leaking water

The procedures for "guiding and collecting the leaked water" at "segment joints" and "grouting holes" are stated as below.

a. Segment Joints

To stop leaking water through segment joint located at the tunnel top (on the ceiling), it is essential to guide/collect the leaked water through the segment joints located in the Fresh Air Duct.

There are two methods to be considered as shown below and Fig. 6.1.6. The first is better than the second because of low cost.

The work procedure for (b) is as follows:

-To nominate the segment joints from where leaking water appears so much.
-To clean the segment joints 2-3cm to the depth of the gutter and then guide the leaked water into the gutter.

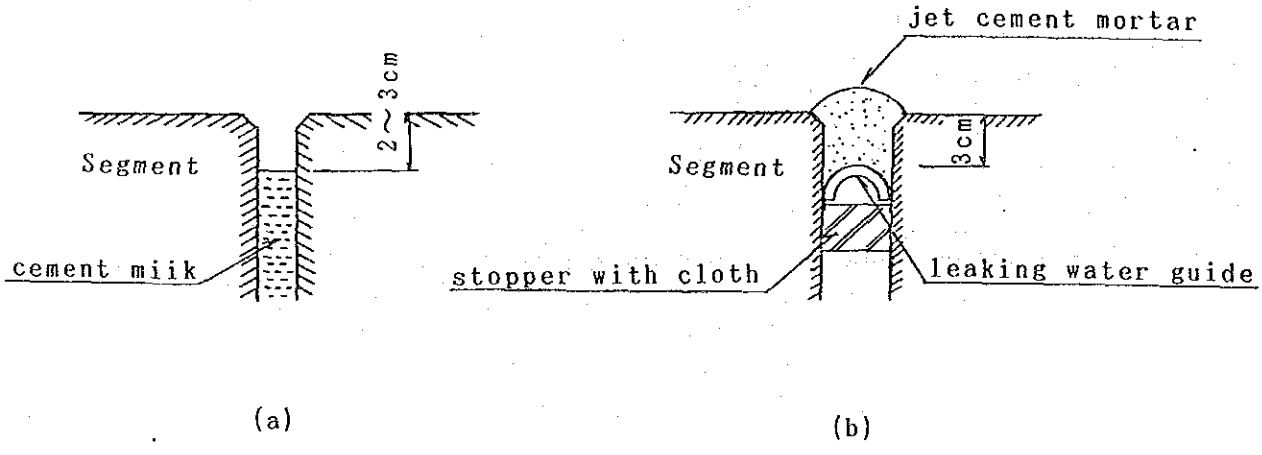


Fig.6.1.6 Guiding of Leaking Water at Segment Joints

b. Grouting Hole

When nominating the locations for guiding leaked water, places with the biggest leaking volume should be treated as the first priority. And in case of the volume of leaked water from grouting holes being small, the procedures for stopping the leaking water described in section "4) b" priviously should be followed.

At the locations where leaked water is to be treated, these measures should be taken.

-To enlarge the grouting holes by core cutter as shown in Fig.6.1.7.

-To insert "the leaking water guiding hose" and then fill jet cement mortar in position as shown in Fig.6.1.7.

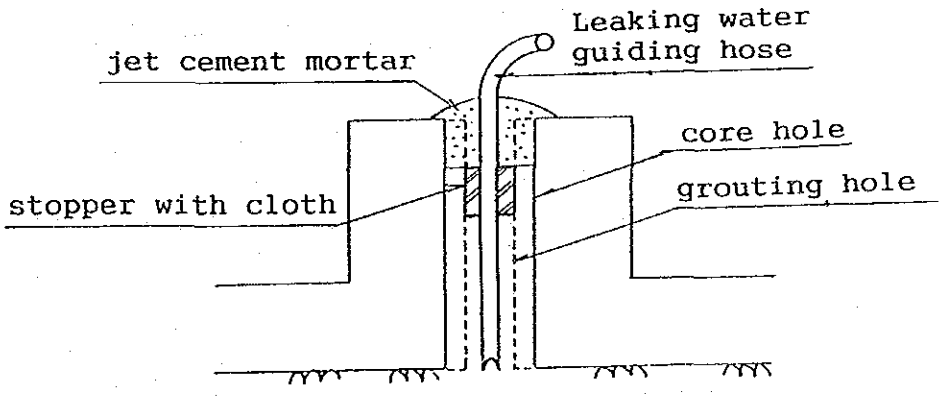


Fig. 6.1.7 Guiding Leaking Water at Grouting Holes

C. Collecting Water

The intentionally guided water through "the leaking water guiding hose" shall come to the water gutter at the bottom of Fresh Air Duct on both sides at the feet of the support walls and be collected into the Nadir sump tank as shown in Fig.6.1.8 below.

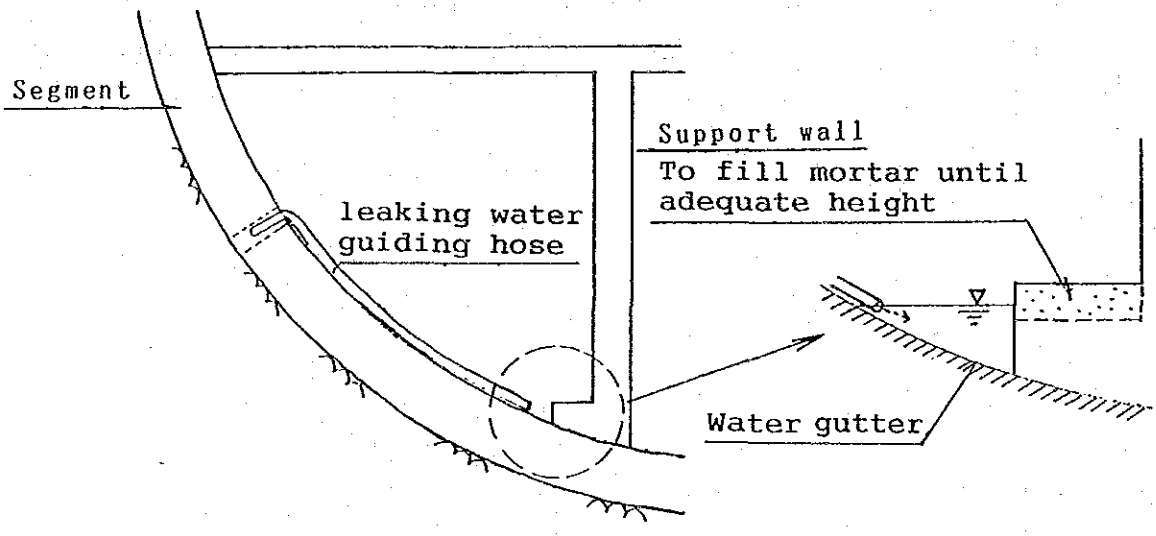


Fig. 6.1.8 A General View of Water Collection Process

(B) Procedure and Repairing Method for the Base Concrete Portions at the foot of Road Support Wall

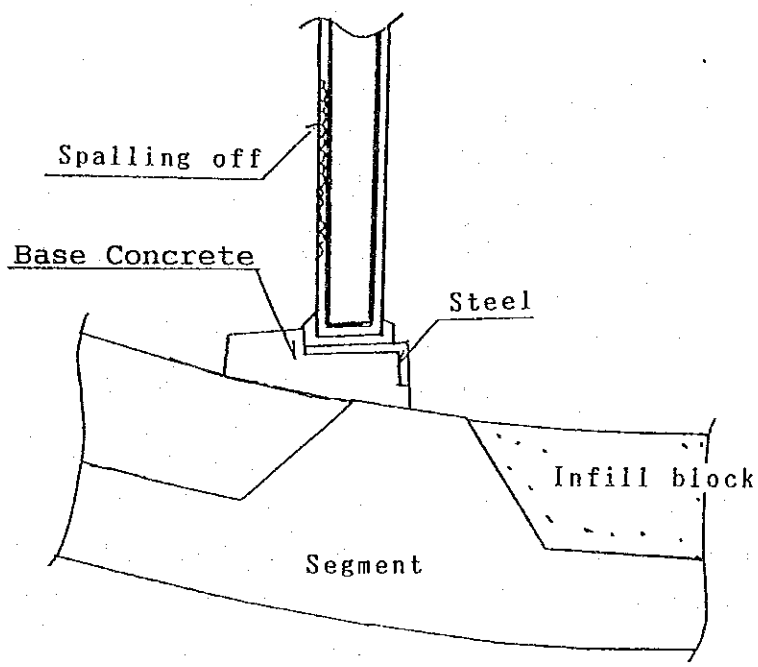


Fig.6.1.9. A General View of Support Wall Bases

A general view of Support Wall Base Concrete portion has been shown as in the above Fig.6.1.9.

1) Deterioration Reason

The deterioration reason of the base concrete portions at the feet of road support walls are summarized as bellows:

a. The leaking water from:
   -the segment joints
   -the grouting holes of the segment
   -the bolt connecting holes of segment joint in the Fresh Air Ducts

b. The leaking water from the segment joints in the upper half of the Tunnel comming into the Fresh Air Ducts through

- The drain pipe(s)
- The surface of the Road Deck and/or the boundary between pavement and road deck.

C. The drying by the Fresh Air

d. The inclusion of salty brought into the base concrete by the leaked water and the possibility of increase in water/cement ratio

The leaked water due to the reasons of above "a" and "b" is collected at the bottom of Fresh Air Duct and penetrates into the base concrete portions. And as a result of the capillary action of the Leaked salty water, the base concrete at the feet of road support walls deteriorates easily.

2) Repairing Criteria

The repairing criteria including the method for checking concrete strength are shown in the followig flow chart (ref. Fig.6.1.10.)

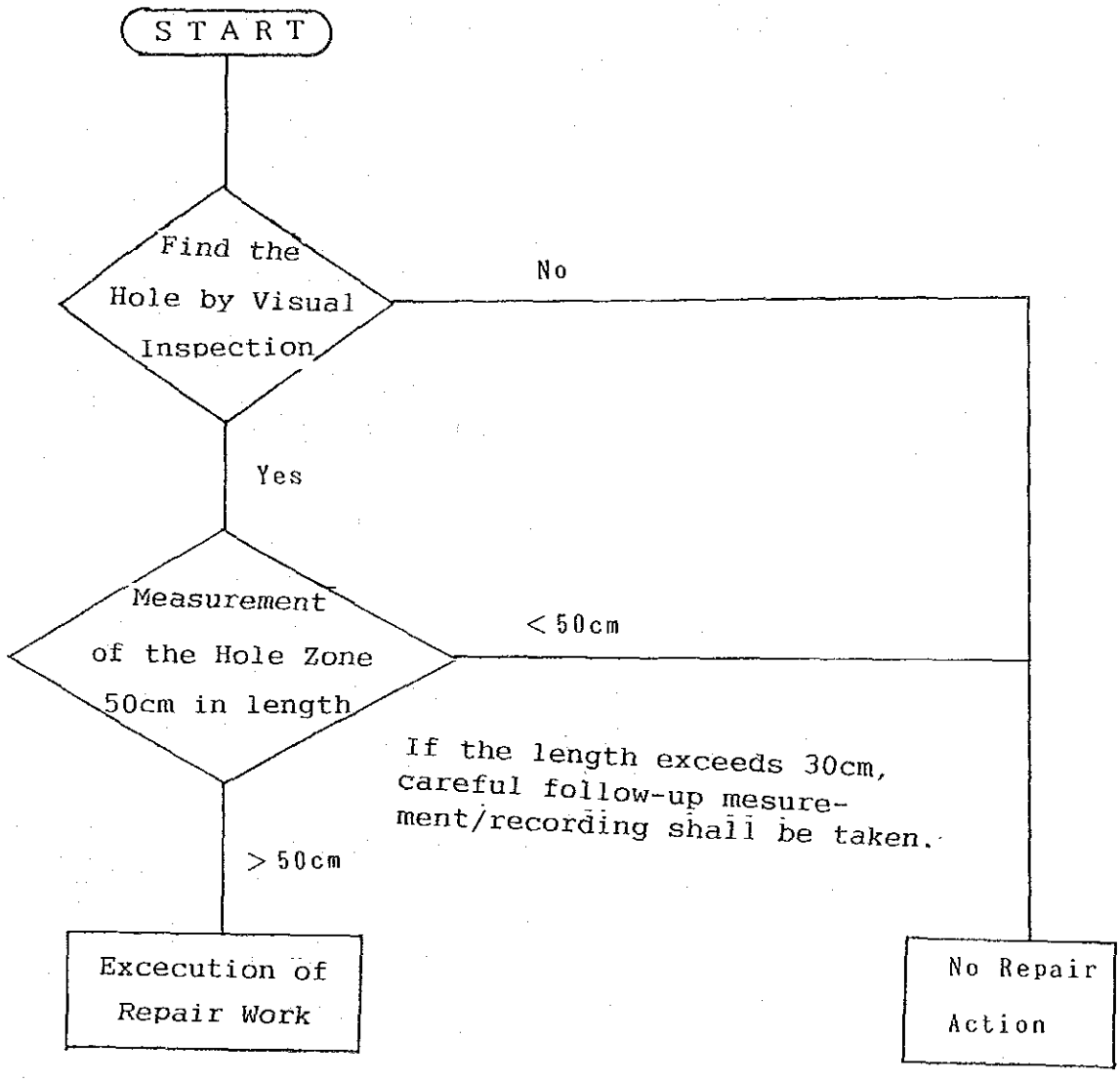


Fig.6.1.10 A General View of Support Wall Bases

3)Repairing Method

When the execution of the repairing work has been authorized as in the above "2) Repairing Criteria", the repairing shall be carried out as follows: (ref. Fig.6.1.11)

- To remove the porous concrete portion.
- To fill the jet cement mortar from the fresh air duct side as shown in the future.

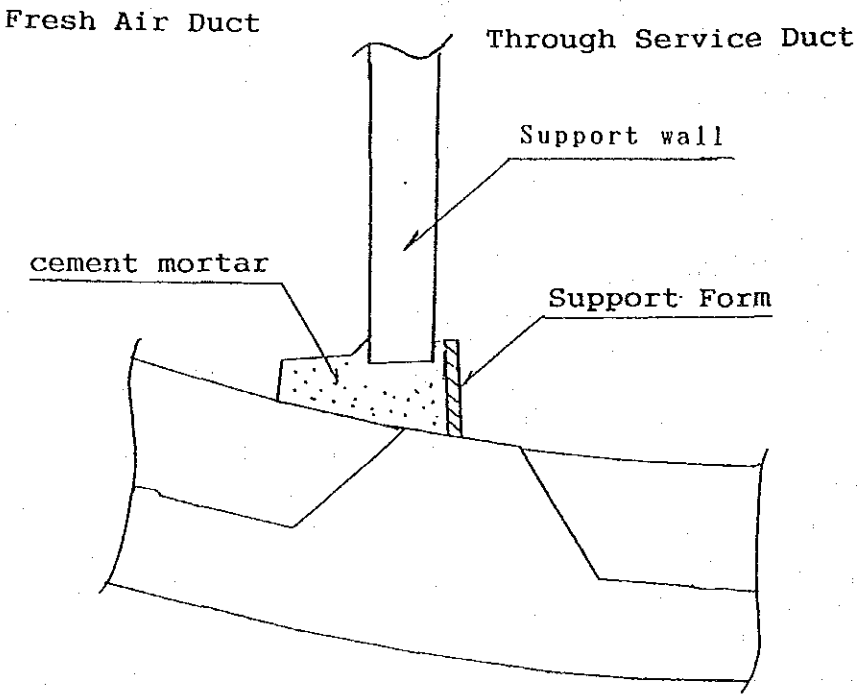


Fig.6.1.11. A General View of Porous Concrete Replacement by Mortar

6.2 Maintenance of Related Facilities

(1) Ventilation System

1) Maintenance of fans can be done based on the existing manual. No more cleaning works will be required in the narrow exhaust duct because salty water will be prevented to come out by a waterproofing sheet over the new cast-in-situ concrete of 450mm in thickness.

2) Local concentration of gas may occur at the east side of Nadir sump tank due to the curved alignment in vertical and horizontal directions. This local foul gas can be diluted by fresh air supplied from the adjustable outlet of flue air duct.

3) Daily control of air condition in the Tunnel will be monitored by the CO/VI monitors. As a maintenance service, wiping of lenses of these monitor equipment will be periodically required.

4) The following methods for cost saving in operation are recommended :

   a. Semi-transverse operation except in emergency cases
   b. Stoppage of ventilation during night when traffic are scarce

(2) Tunnel Lighting

There is no space between the lamps and the horizontal clearance, therefore lamps are likely to be destroyed by vehicles frequently, which may require storage and replacement of spare lamps accordingly.

(3) Duct Below Walkways

The structure of walkway is designed similar to the existing one which will simplify inspection works on wirings.

However, the width of walkway will be narrowed from 945mm to 646mm, which does not allow passage of especially at the north side of walking where the fire hydrants is located on the walkways, therefore, ladders will be provided.

(4) Other Facilities

The Tunnel Wall panel interior facing will be finished with silica acid calcium panel. Periodical cleaning works will be required once a year to ensure the lighting effect of the Tunnel at minimum.

Inspedtion on the installed pipes shall be made periodically to check the pointing condition and water leakage, etc.

CHAPTER 7

EVALUATION OF THE PROJECT AND CONCLUSION

Chapter 7 Project Evaluation and Conclusion

The summary of the evaluation and the conclusion of the Basic Design Study for the Rehabilitation Works for Ahmed Hamdi Tunnel is as follows:

(1) The Structural Strength of the Tunnel has been rapidly approaching the limit of ultimate strength and it is already in a difficult situation of keeping the soundnesss of the Tunnel in vew of structural mechanics without reinforcement. Immediate execution of the Rehabilitaion Works shall be carried out as quickly as possible.

(2) By full adoption of the updated new tunnel technology, it is possible that the tunnel structure does not undergo such deterioration again.

With the high technology and management level of S.C.A., the Authority is surely able to execute the maintenance control method which has been proposed in this Basic Design Study after the completion of the Rehabilitaion Works.

(3) Concerning the road facilities, though walkways become narrow, it is possible to install cables and pipings there. As for the Ventilation system, the existing one can be adopted and the present size and level can possibly be kept after the Rehabilitaion Works.

(4) In the process of implementing the Five Year Social and Economic Development Program in Egypt and in order to achieve the National Objectives which aim at economic development in both West and East bank zone of Suez Canal and the Peninsula of Sinai, the role of the Tunnel is vitally important because it is the sole route of surface transportation connecting the Mainland of Egypt with the Peninsula of Sinai.

At present, the traffic speed is restricted within 20km/h for the sake of traffic safety and only one lane operation can be kept open for maintenance work when required. AS a result of this, the traffic capacity shall be severely reduced temporarily. However, it is possible to recover the Tunnel's soundness completely without any reduction of its road function as it was designed originally. Therefore, the Rehabilitaion Works shall be carried out as soon as possible.

(5) After the completion of the Rehabilitaion Works, immediate execution of the Canal Expansion Project will be possible.

It can not only meet the international need for the Canal's marine transit of huge-sized vessels, but also enable S.C.A. to increase the transit revenue for the national economy of Egypt.

(6) S.C.A. is spending 1,400,000 Egyptian Pounds annually on average for maintenance/survey of the Tunnel. After the Rehabilitaion Works, this huge cost can be drastically reduced.

(7) In consideration of the expected economic and social effect as the result of this Rehabilitation Works, this project can be appraised as highly appropriate for Grant Aid, and it may serve as a very good example of Japan's contribution to development of friendly relationship between Egypt and Japan.