4.4 Delivery Pressured Pipelines and Its' Appurtenant Structures

4.4.1 General Description and Condition

This section of "4.4" was mainly compiled on the structural design of the pipeline systems based on the "concept of basic design". Major items of the structural design are suitable thickness of steel pipes, analysis of pipe buckling and safety measures for thrust load and temperature stress of the pipe. Designing of appurtenant structures is one way surge tanks and related valves concerned.

Selection of pipe materials, optimum diameter and suitable number of pipe to be installed shall be referred to the "Basic Design Report" which was compiled as Volume Ⅰ-1.

(1) Pipe Specifications

- Pipe materials : Steel pipes
- Pipe diameter : 2,400 mm (inside diameter)
- Number of the pipe to be installed for each construction stages Stage I : 3 rows

(2) Hydraulic condition

Item	Description	Stage I
1. Design discharge		(cu.m/sec)
1.1. Pump discharge	-Three units operation -Two units operation -One unit operation	32.481 23.931 12.900
1.2. Pipe discharge per one row	-Three units operation -Two units operation -One unit operation	10.827 7.977 4.300
2.Water level		(m)
2.1.Suction sump	H.W.L. N.W.L. L.W.L.	10.70 9.90 8.80
2.2. Discharge tank	H.W.L. N.W.L. L.W.L.	92.90 (10.827cum/s) 92.68 (7.218cum/s) 92.43 (3.609cum/s)

4.4.2 Design of Typical Cross Section

(1) Location of O/M road

The location of O/M road shall be the center of both Stage I and Stage II pipeline location. The survey alignment entirely correspond to the centerline of O/M road except between IP.17 and IP.18 which was shifted to right side 25m because of cross sectional topography and elevation.

(2) Distance between centerline of O/M road and Stage I pipeline

Distance between centerline of O/M road and Stage I pipeline (which corresponds pipe center of 2nd row) is 25m or longer as shown typical cross section considering the width of pipe bedding, side slop of excavation and width of O/M road.

(3) Pipe stock yard

Pipe stock yard shall be allocated at opposite side of O/M road with 12m width. (Refer to Figure 2.3-1 typical cross section.)

(4) Slope of excavation and embankment

(a) Temporary slope of excavation and embankment
In view of safety the side slope during construction period, side slope both excavation and embankment shall be 1:2.0 considering to shear strength of soil and refer to stability analysis.

(b) Permanent slope of excavation and embankment
To ensure stability of slope, finishing slope of excavation and embankment shall be 1: 3.0 and within 3.0m of vertical height considering construction of stone pitching and refer to stability analysis.

(5) Distance between pipe centerline and toe of side slope

Horizontal distance at left side of pipe centerline to toe of side slope shall be 20m considering to construction of backfill of pipeline.

(6) Clear distance of pipes and quality of backfill on circumference of pipe

The quality of compacted backfill is significantly important to such kind of deflection pipe to design of deflection ratio and tensile stress of pipe.
Distance between pipe and pipe shall be taken enough to complete compaction with required quality of backfill by appropriate machinery. The compaction of sand, for saying SP material by Unified Soil Classification System (U.S.B.R.), is rather difficult because of uniformity of grain size. Such as vibrating roller (2 to 3 tons of weight) may be appropriate

to achieve compaction with subsidiary measure of vibrating plate compactor, tamper, rammer and combination with tamping at pipe surrounding.
Thus, distance between pipe and pipe for compaction may be 1.5m or more according to 1.0m occupied width of vibrating roller with 4.0m (2.45 + 1.5≒3.95) distance of pipe to pipe center.

(7) Protection of soil surface against wind erosion

The surface of soil above embedded pipe shall be protected against wind erosion by the laterite layer and crashed gravel pavement in reference to the experience of NSDO and economical point of view.

(8) Laterite bedding

It is very important to lay steel pipe on the consolidated bedding.
In order to meet such requirement, laterite soil bedding for proper foundation treatment is most suitable method for performance of backfill compaction.

4.4.3 Design of Steel Pipe Thickness

(1) Standard for design of steel pipe

As shown Basic Design Report, design standard of steel pipe is referred to JWWA (Japan Water Works Association), "Pipeline" Design Standard of MOAFFJ and Japan Water Steel Pipe Association, that these are primarily based on AWWA (American Water Works Association). Main conditions and methods of steel pipe design based on the above standards are as follows;

(a) External load; Load distribution modulus by Spangler
Vertical earth pressure by Marston
Live load 70 t truck, method by "Pipeline" design standard of MOAFFJ

(b) Calculation Method
JWWA Method is adopted to calculate and check both allowable tensile stress and deflection of steel pipe. The criteria of allowable tensile stress of the material (JIS STPY 400 equivalent to ASTM A283 or A285, A570 and A36) is 1,400kgf/cm^2 and allowable deflection to the diameter is 3 % for the internal mortar lining of the pipe.

(c) Modulus of soil reaction E'
The value of modulus of soil reaction (called E' value herein after) is one of the most important factor on design of pipe wall thickness. The average of E' value is listed in the Table 4.4-1 recommended by the JWWA (based on AWWA), and Table 4.4-2 recommended by the "Pipeline" MOAFFJ.

Table 4.4-1 Average Value of Modulus of Soil Reaction (E') by JWWA

Soil Type /Primary Pipe Zone Backfill Material (United Classification System)	E' for Degree of Compaction Bedding kgf/cm² Non Compaction	Slight <85% Proctor <40% Rel. den.	Moderate 85-95% Proctor 40-70% Rel. den..
Fine-grained soil (LL>50%) /Soils with medium to no high Plasticity CH, MH, CH-MH	Soils in this category require special engineering analysis to determine required density, moisture content, compactive effort.		
Fine-grained soils (LL>50%) /Soils with medium to no high Plasticity CL,ML,ML-CL,CL-CH, ML-MH, with less than 25% coarse-grained particles.	3.5	14	28
Fine-grained soils (LL<50%) /Soils with medium to no high Plasticity CL,ML,ML-CL,CL-CH, ML-MH, with more than 25% coarse-grained particles. Coarse-grained soils with fines/GM, GC, SM, SC containing more than 12% fines	7	28	70
Coarse-grained soils with little or no fines /GW, GP, SW, SP containing less than 12% fines	14	70	140
Crush rock			210

Table 4.4-2 Average Value of Modulus of Soil Reaction (E') by MOAFFJ unit; kgf/cm²

Construction method / Bedding material / Material of the original ground	Sheet pile construction: Sandy soils	Sheet pile construction: Gravelly soils	Non sheet pile construction: Sandy soils	Non sheet pile construction: Gravelly soils
Gravelly soils	35	50	45	60
Sandy soils	30	40	40	55
Clayey soils	25	35	30	40
Others	10	15	15	20

E' value of 48 kgf/cm² of this project shall be comprehensively determined by the following reasons;

(i) Material of the original ground soil is categorized SP. (poor grained sand)

(ii) E' value is generally affected by the degree of the compaction backfill, but SP material may not be compacted good result because of uniformity of the grain size.

(iii) It is referred to many field experiences of the MOAFFJ shown in the Table 4.4-2.

(iv) The 20% of E' value of the Table 4.4-2 can be adjusted by the wide excavation of pipe installation by the following equation.

$$\alpha a = \left[1 + \frac{0.1 \times (Bc - Bs)}{100}\right] \leq 1.2$$

$$E' = \alpha a \times E'o = 1.2 \times 40 = 48 \text{ kgf/cm}^2$$

where; αa; coefficient of correction

Bc; design excavation width (mean) at pipe center; 23.6m/3=7.87m=787cm

Bs; standard excavation width at pipe center; 390cm ("Pipeline" design standard of MOAFFJ)

(2) Determination of pipe wall thickness

The final decision of pipe wall thickness is 22mm at the following conditions and calculation result of steel pipe thickness;

- The maximum earth cover above top of pipe is 5m.
- Live load at top of soil is loaded by the 70 t truck.
- Modulus of soil reaction is 48 kgf/cm^2.
- Allowable tensile stress of steel pipe is 1,400 kgf/cm^2 and allowable deflection ratio is 3.0 % for internal pipe coating with mortar lining.

Calculation of steel pipe thickness is summarized in case 1m to 5m earth cover to the following table, and calculation of detail procedures are shown in Appendix C.4.4-1.
In the Table 4.4-3, the figures of upper and lower indicate deflection ratio (%) and bending stresses (kgf/cm^3) for diameter 2,400mm, respectively.

Table.4.4-3 Required Pipe Thickness by Earth Cover

H(m) \ t	15	16	19	22
1.0	1.9% 1386 O.K.	1.9% 1297 O.K.	1.7% 1111 O.K.	1.6% 977 O.K.
2.0	1.9% 1360 O.K.	1.8% 1273 O.K.	1.7% 1090 O.K.	1.5% 958 O.K.
3.0	2.0% 1470 OUT!	2.0% 1377 O.K.	1.8% 1179 O.K.	1.7% 1037 O.K.
4.0	2.4 1708 OUT!	2.3% 1599 OUT!	2.1% 1369 O.K.	1.9% 1204 O.K.
5.0	2.7% 1959 OUT!	2.7% 1835 OUT!	2.5% 1571 OUT!	2.2% 1382 O.K.

Notes : Hatched thickness is minimum required thickness for each earth cover.

4.4.4 Analysis of Pipe Buckling (Durability of Steel Pipe against Negative Pressure)

In order to check the durability of steel pipe against negative pressure during occasion of the water hammer phenomenon, following analysis are examined to check safety of steel pipes. The following equation shall be applied to check the safety of steel pipe for allowable vacuum pressure. The formula is referred to AWWA manual chapter 6.

$$\gamma_w \cdot h_w + R_w \cdot W_c / D + P_v \leqq q_a$$

where, h_w : Height of water above pipe (*in*) $h_w = 0$

γ_w : Specific weight of water (0.0361 *lb/cu.in*)

P_v : Internal vacuum pressure (*psi*)

= atmospheric pressure less absolute pressure inside pipe (*psi*)

W_c : Vertical soil and live load on pipe per unit length (*lb/in*)

D : Diameter of pipe 94.5 *in*

$Wc / D = (0.786 + 0.071)\ kgf/cm^2 = 0.857 \times 1 / (0.456 / 2.54^2)$

Vertical load of soil and live load

$\therefore\ Wc / D = 12.2\ lb/in^2$

q_a : Allowable buckling pressure (*psi*)

$q_a = (1 / F_s) \cdot (32\ R_w \cdot B' \cdot E' \cdot EI / D^3)^{1/2}$

where, F_s : Design factor $= 2.5$ for $(h/D) \geqq 2$

$= 3.0$ for $(h/D) < 2$

where, h : Height of ground surface above top of pipe (*in*)

$\therefore\ F_s = 3.0$ $h/D = 1.0m / 2.4m = 0.42 < 2$

R_w : Water buoyancy factor $= 1 - 0.33\ (h_w/h)$, $0 \leqq h_w \leqq h$

$h_w = 0$ then $R_w = 1$

B' : Empirical coefficient of elastic support $B' = 1/(1 + 4\ e^{-0.065H})$

where, H : Height of fill above pipe (*ft*)

(Refer to ANSI/AWWA C950-81)

$H = 1.0m / 0.303 = 3.0\ ft$

$\therefore\ B' = 1 / (1 + 4\ e^{-0.065 \cdot H}) = 0.237$ for H=1.0m

$E' = 48\ kgf/cm^2 = 48 \times 1 / (0.456 / 2.54^2) \fallingdotseq 680\ psi$

$E = 2{,}100{,}000\ kgf/cm^2 = 2{,}100{,}000 \times 1 / (0.456 / 2.54^2)$

$\therefore\ E = 3.00 \times 10^7\ psi$

$I = 1.0 \times (2.2/2.54)^3 / 12 = 0.0541\ in^4/in$

$\therefore\ q_a = (1/3.0) \times (32 \times 1.0 \times 0.237 \times 680 \times 3.00 \times 10^7 \times 0.054 / 94.5^3)^{1/2}$

$= 24.9\ (psi) = 1.74\ (kgf/cm^2)$

then, $P_v \leqq q_a - (\gamma_w \cdot h_w + R_w \cdot W_c / D)$

$= 24.9 - (0 + 1.0 * 12.2) = 12.7\ lb/in^2$

$\therefore\ P_v \leqq$ 0.89(earth cover 1m) kgf/cm²

As the result of above calculation, steel pipeline with 22mm thickness and 1.0m earth cover may have durability within the vacuum pressure of 0.89 kgf/cm² (approx. 9 m of minus pressure).

4.4.5 Safety Measures for Temperature Stress and Thrust Load

The restriction force of steel pipeline embedded in soil is functioned and certain length of pipe has resistance against temperature load and against thrust load due to the water pressure and velocity in pipe.
The required length against temperature load and thrust load are estimated at anticipated condition.

(1) Required length of pipeline against temperature load

Condition of estimation;
Maximum values of temperature variation in the year round in pipeline will be 20℃ which is considered variation of the temperature of water in pipe and variation of buried pipe temperature is almost negligible.

As shown Figure 4.4-1 "Expansion/contraction",(so called exp./contr.), and temperature stress of steel pipeline embedded in soil, variation of longitudinal length of exp./contr. in pipeline will be occurred within the zone of exp./contr., and variation of longitudinal length of exp./contr. of pipeline at zone of restriction is never occurred due to the restriction force between earth pressure and friction load of the pipe surface.
Temperature stress at zone of restriction will be estimated by the following equation.
The detailed discussion for this are presented here and the result of calculation shows that tensile stress caused by increased temperature 20℃ is only 504 kgf/cm^2 (axial tensile stress at pipe distance longer than 50.5 in case earth cover 1.0m to 17.9m in case 5m earth cover from free end)

The temperature stress to act in the pipe by restricting pipe from the exp./ contr. can be estimated as following equation :

$$\sigma_t = E \cdot \alpha \cdot T$$

where; σ_t : Temperature stress (kgf/cm^2)
E : Young's modulus for steel (2.1×10^6 (kgf/cm^2))
α : Liner expansion modulus for steel (1.2×10^{-5}/℃)
T : Value of annual temperature variation (20℃)

And the length of exp./contr. to meet restriction force will be estimated by the following equations;

$$L_2 = \frac{P_t}{\tau} = \frac{A_S \cdot E \cdot \alpha \cdot T}{\tau}$$

$$\tau = \mu \cdot w \cdot H_O \cdot \pi \cdot D_C$$

where; L_2: Required length to meet restriction force with exp./contr. (cm)
P_t : exp./contr. force (kgf) (= As · σ_1)
τ : Restriction force (kgf)
μ : Friction factor between soil and pipe surface 0.5 in general
w : Unit weight of soil 0.0018 (kgf/cm^3)

H_O: Height of ground surface above pipe center(Di/2+earth cover)

in case 1m earth cover, H_O=120+100=220cm

in case 5m earth cover H_O=120+500=620cm

D_c : Outside diameter of pipe 244(240+2.2x2)cm

Di : Inside diameter of pipe 240 cm

As : Real sectional area of steel pipe 〔$\pi/4(D_c^2-D_i^2)=3.14/4(244^2-240^2)$

=1,520 cm^2

And also the value of longitudinal length of exp./contr. and axial tensile stress can be calculated the following equations;

$\Delta l = L_2 \cdot \alpha \cdot T/2$ (cm)

$\sigma_t = 2.1\times10^6\times1.2\times10^{-5}\times20 = 504$ kgf/cm^2 < 1,400 kgf/cm^2

(α_t valve is within allowable tensile stress)

Restriction force

$\tau = 0.5\times0.0018\times(220\sim620)\times3.14\times244 = 151.7\sim427.5$ kgf/cm^2

Therefore, length for restriction force (L_2) and exp./contr.(Δl) is

$L_2 = 1{,}520\times504/(151.7\sim427.5) = 5{,}050\sim1{,}792$cm = 50.5m$\sim$17.9m, and

$\Delta l = (5050\sim1790)\times1.2\times10^{-5}\times20/2 = 0.61\sim0.22$ cm

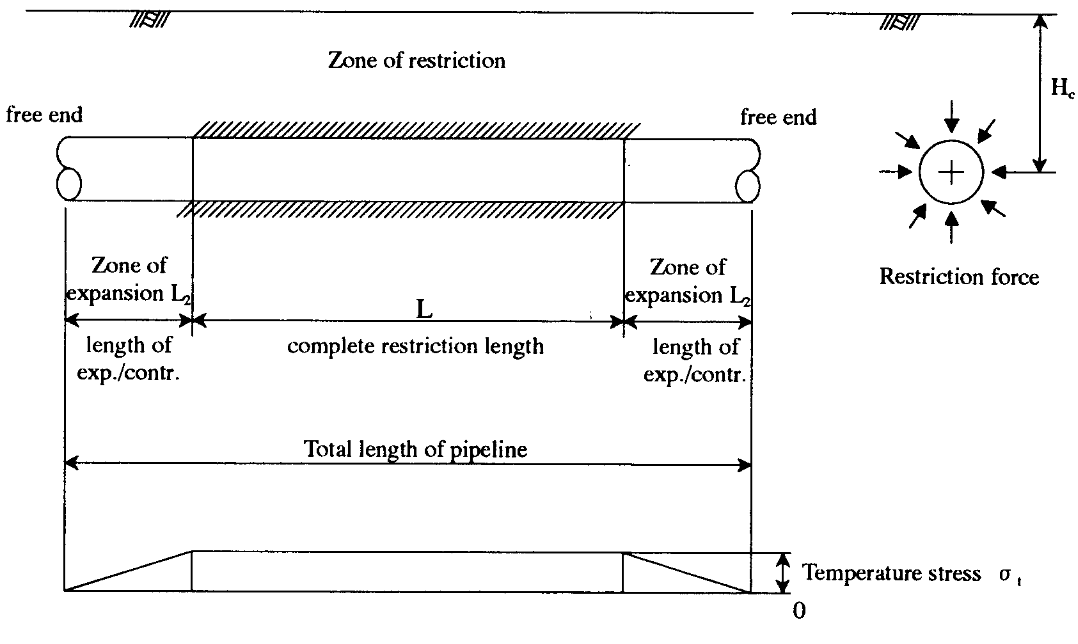

Figure 4.4-1 Exp./Contr. of Temperature Stress of Embedded of Steel Pipeline

(2) Required length for thrust load and restriction force

As shown Appendix C.4.4-2, if there is structurally continuous length more than 21.3m of steel pipeline without any joint in case 1m earth cover, no thrust block is requested. it is generally accepted in the steel pipeline without provision of any thrust block as a common knowledge.

(3) Necessary and unnecessary of Flexible Pipe Joint

(a) The purpose of flexible pipe joint

The purposes of provision of flexible pipe joint are to be safe against stresses caused by expansion & contraction, temperature, unequal settlement and others. Further in case connection with valves and other appurtenant structures, flexible pipe joint may be needed to safe its flange bolts of the valves and other facilities caused by expansion & contraction of temperature and welding stresses.

However, steel pipe has strong enough such stresses, flexible pipe joint may only be needed to protect valve and appurtenant structures.

(b) Unnecessary of flexible pipe joint

As shown above section (1) and (a), flexible pipe joint may not be necessary in the steel pipeline and estimations of pipe settlement and stress shown in Appendix C.4.4-3 are also indicated unnecessary of flexible pipe joint.

4.4.6 Protection against Corrosion of Steel Pipes

(1) General Description

Protection measures for corrosion of steel pipes shall be considered the following points to supply the water safety to beneficial area and to maintain and to prolong its life as well conditions of interior and external surface of steel pipes.

- -Lining and Coating the internal surface of the steel pipes
- -Coating and wrapping the external surface of the steel pipes
- -Protection against chemical erosion by electrical measures
- -Protection against c/s (between concrete and soil) macro-cell corrosion

There are many countermeasures for protection against corrosion of steel pipes as mentioned the above. In this study, selection and discussion of protection method shall be concentrated the items only easy applicable methods taking into account the actual field conditions which were obtained from the field surveys and geological investigations.

(2) General Information for the Study on Protection against Corrosion

a) Water quality

According to the information collected from NSDO Kantara office, salinity contents of irrigation water can be summarized as follows;

Sample site	TDS	Sampling month
Upstream of PS. No.2	776	Jul.98
	1,694	Jan.98
Downstream of PS. No.3	1,752	Jul.98
	3,974	Jan.98
Upstream of Suez Siphon	1,351	Mar.99

Note; TDS; Total Dissolved Solid of Salinity, ppm

b) Electric resistivity test

According to the geological soil test, electric soil resistivity at proposed site of the pipeline ranges as follows;

Resistivity (Ω-cm)	Percent (%)
Below 2,000	10
2,000~3,000	30
3,000~4,000	30
4,000~5,000	30

(3) Property of the Chemical Erosions

There are many factors influenced to the chemical erosion shown as follows;

Factors of the water (pH, oxygen solved in water and others), sea water, atmosphere and the soil (resistivity, moisture contents, pH, electricity, composition and others)

Among the factors, resistivity and pH of the soil are the most influence factors for pipe erosion.

Although pH of the soil is ranged 6 to 7.6 by the soil investigation, that corrosive soil is ranged to less than 4. Then the most influenced factor to chemical erosion is the electric resistivity.

Corrosiveness of soil classified by the electric resistivity is shown in the following table by source of the Japan Water Steel Pipe Association.

Relations between corrosiveness of soil and electric resistivity **(unit; Ω-cm)**

Corrosiveness	much more	more	medium	less	seldom
electric resistivity	<900	900 to 2,300	2,300 to 5,000	5,000 to 10,000	>10,000

The electric resistivity of the soil is investigated 1,000 to 5,000 Ω-cm, then the soil of the site is ranged to corrosiveness of more to medium.

In Japan, recently macro-cell erosion has frequently pointed out to the operating steel pipeline, and macro-cell phenomena is explained that macro-cell erosion of c/s from concrete (anode zone) to soil (cathode zone) will be occurred and it has been sometime violently progressed at the connection of concrete and soil. It is recognized that special attention is needed.

(4) Countermeasures of the Steel Pipe Corrosion and Cathodic Protection System

In general, coating, lining and/or painting are commonly used internal and external of the pipeline, furthermore for safety and prolong its life, electrical protection methods such as cathodic impressed current system for high electric resistivity of soil and galvanic anode system for low electric resistivity of soil will be used for the protection against chemical erosion.

In the case of the Project, cathodic impressed current system (so called cathodic protection system herein after) will be applied according to the large scale protection and soil electric resistivity.

Cathodic protection system with asphalt vinylon cloth coating shall be introduced in this Project by the following reasons;

(a) Soil corrosiveness is ranged more to medium.

(b) Countermeasure against macro-cell corrosion shall be requested to take account of the circumference of concrete structure along the pipeline.

(c) There are two way to ensure and prolong it's life, one is the construction of high quality and high cost of external coating except cathodic protection system, the other is the construction of medium or low cost of external coating combination with cathodic protection system.
The construction cost of the former is more expensive than the construction and maintenance cost of the latter as shown in the following table, and the former is not completely safe against corrosion because of inevitable deterioration and frayed spot of the coating.
Then, the latter shall be recommendable to the Project, and the external coating will be the most ordinary and economical way of asphalt vinylon cloth coating as shown in the Table 4.4-5 and cathodic protection system has effectiveness not only soil electrical corrosion but also macro-cell corrosion.

Comparison table of high quality coating and low cost coating with cathodic p.s.

Expense for high quality and high cost coating except cathodic protection system	Expense for low cost coating and cathodin protection system
Construction cost of Polyurethane coating 2, 500 $^{LE/m}$ × 3 × 9,400^{m} = 70.50 ^{millionLE} Maintenance cost neglect Total 70.50 $^{m.\ LE}$	Construction cost of Asphalt vinylon cloth coating 800 $^{LE/m}$ × 3 × 9,400^{m} = 22.56 ^{millionLE} Maintenance cost 20^{years} × 50,000 $^{LE/(L.S.)}$ = 1.00 〃 Total 23.56 $^{m.\ LE}$

Note: Maintenance cost is for 20 years

(5) Coating Method of Interior Surface of the Pipeline

As shown Table 4.4.-4, mortar lining will be determined for interior surface of the steel pipeline. To consider constant smoothness of interior surface for long period, mortar lining is the most recommendable method by many experiences in the world. The mortar lining will be constructed as a lump-sum construction at the site in place with good performance, although in case of coating by the other material it would be anxious about the interior surface damaged by the labors at the time of welding and other works.
Thickness of the mortar lining shall be equal to more 12.7 mm in accordance with AWWA Standard, then the proposed lining thickness will be determined 13 mm with allowance of +3 mm.
Construction of mortar (cement-mortar) lining is carried out by the adequate machinery that is illustrated Figure 4.4-2 for an example.
The construction method, machinery, schedule and others of the mortar lining will be discussed in the construction planning.

Table 4.4-4 Comparison table on coating method of interior surface

Item	Coal-tar Epoxy	Liquid epoxy Resin	Mortar
Technical characteristics			
Thickness of coating (mm)	0.5	0.5	13.0
Water Imperviousness	○	○	○
Durability	○	○	◎
Influence on water quality	△	○	○
Versus Alkalinity	○	○	◎
Cost Economy (LE /liner meter in the factory)	1,900	2,400	1,100
Conclusion	○	○	◎

Note; ◎; Most suitable, ○; Suitable, △; Influence

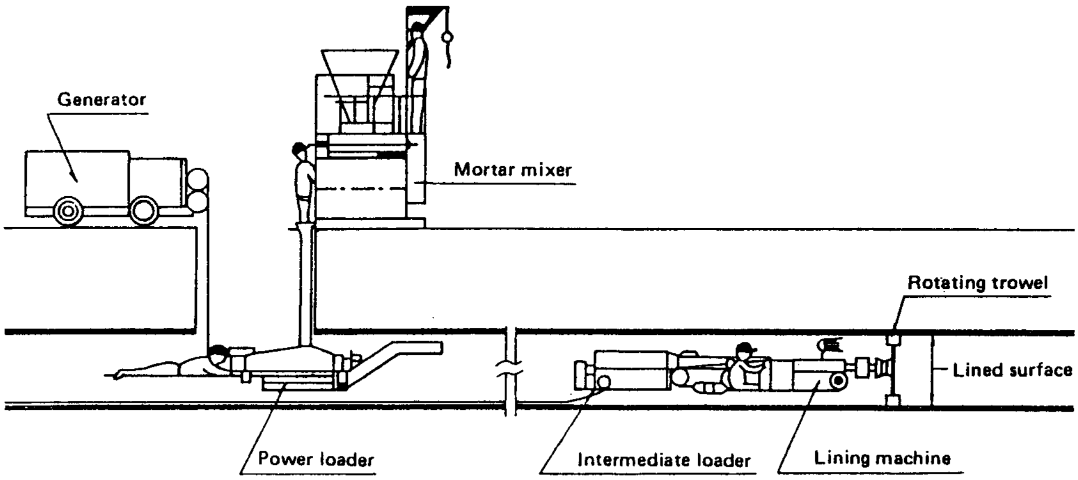

Figure 4.4-2 Machinery of Mortar Lining

(6) Coating Method of External Surface

External coating method of asphalt vinylon cloth may be satisfied to this pipeline on the assumption with electrical protection method as stated above. There are many experiences in the world to use asphalt vinylon cloth coating. The idea of the design on cathodic protection system is determined with no relations between the kinds of coating method and electrical protection method. There are two ways to design cathodic protection system, one is to design taking account of the kinds of coating method and the other is to design without consideration of coating methods. For the design of this project, the latter will be suitable to ignore the kinds of coating methods and to design a maximum degree of electric current, that lead to more economical way considered with coating cost and electric protection method. Then the coating method may be the cheapest and it is shown in the following table.

Table 4.4-5 Comparison table on coating method of external surface

Item	Asphalt Vinylon cloth (coating)/ (wrapping)	Coal-tar Epoxy (coating) / Glass-cloth (wrapping)	Polyurethane coating
Technical character			
Thickness (mm)	3.5	3.5	3.0
Adhesive	○	○	◎
Durability	□	○	◎
Corrosiveness	○	◎	◎
Cost Economy (LE /liner meter in the factory)	800	1,600	2,500
Conclusion	◎	○	△

Note; ◎; Finest, ○; Fine, □; fair △; Inferior

(7) Design of Cathodic Protection Method

Design calculation result is summarized in the following table and detail calculation prosedures are shown in Appendix C.4.4-4.

Impressed current system for underground piping

Service of facility	Water Pipeline
Protective Current Requirement	213A
Transformer-rectifier 50V×50A	6units
Quantity of High Silicon Iron Anode	96pcs
Width of Groundbed	70m/groundbed
Diameter of anode	0.16m
Depth of bore hole	Approx. 6.3m

Proposed source of electricity for the cathodic protection system shall obviously be from the auxiliary at No.7 Pumping Stasion, as the result of comparative study of power source indicating the table below.

Comparison study on power source from substation or solar generation

Items	Substation supply	Solar cell generation
Construction Cost	Cost for cable Steel tape armor cable (4-cv cable 66-V 70 mm^2) 9,400m×10LE=950,000 LE Labor installation 500m×200LE=100,000LE Total 1,050,000LE	Cost for Solar generation and battery Solar cell 300,000 LE Controller 100,000 Battery 200,000×10=2,000,000 (300AH×4sets 3 year life cycle Then 10 times renewal for 30 years) Sub-total 2,400,000/unit Total 14,400,000LE
Conclusion	◎	

4.4.7 Design of Appurtenant Structures

(1) Design of Surge Tank

(a) Construction material of the surge tank

To decrease water hammer pressure, two places of one way surge tank system are adopted for this pipeline. Construction material of the surge tank shall be designed with the aspect of endurance, free of maintenance and economical. Concrete type is more advantageous than metal type.

(b) Dimensions of surge tanks

No 1 Surge Tank (KM 110+300)

Design items	Computer estimation	Designed
Section area	60m^2	5.0×15.0 = 75m^2
Initial water level	56m	56m
Elevation of pipe center	50m	50m
Low water level	52m	52m
Capacity	240m^3	75 m^2×4m = 300m^3
Designed /Computer estimation	—	300 /240 = 1.25
Dia. & No.of connection pipe	ϕ1.5m×2 sets	ϕ1.5m×2 sets

No 2 Surge Tank (KM 114+700)

Design items	Computer estimation	Designed
Section area	5m^2	2.8×4.0 = 11.2m^2
Initial water level	68m	68m
Elevation of pipe center	64m	64m
Low water level	66m	66m
Capacity	10m^3	11.2 m^2×2m = 22.4m^3
Designed /Computer estimation	—	22.4 /10= 2.24
Dia. & No.of connection pipe	ϕ0.7m×2 sets	ϕ0.7m×2 sets

Notes; (1) Designed /Computer estimation of capacity shall be larger than 1.2 for allowance of estimation.
(2) Design of Section area at No 2 Surge Tank is designated by the allocation of structures.

(c) Arrangement of equipment

Major equipment for the surge tank is listed as follows;

(i) Check valve

When the main pipeline will be the state of vacuum at down surge of water hammer phenomena, water from surge tank shall be flown in to pipeline through check valve. Two sets of check valve of swing type shall be mounted for the safety.

(ii) Butterfly valve

For maintain of surge tank and check valve, butterfly valve shall be mounted between check valve and main pipeline. Butterfly valve is better than stop valve because of easy operation. Even butterfly valve at turning by manual operation at opening or closing, times of turning 550 for ϕ1,500mm and 120 for ϕ700mm may be needed. There is some alternation to take bring portable handle driven by generator of gasoline, which is provided for maintenance work.

(iii) Float valve

Float valves will be functioned to keep full water level of the surge tank and size of the valve may be small to be full within several hours. Two sets of float valves for one unit of surge tank will be needed for safety and also strainer to clean water mounted with two sets of stop valves at front and back side of the strainer will be needed to keep function well. Moreover a by-pass pipeline and one set of stop valve for the time of the float valve damaged may be needed to confirm safety.

(iv) Other equipment

Spill way pipe, drain water pipeline for emptying the surge tank and connection pipe of surge tanks each other, drainage ditch, manhole, air vent, ladder rung, and other necessary equipment shall be needed.

(d) Structural design of surge tank

Structural design of surge tank No,1 and No,2 are consist of the following items and these are all arranged in Appendix C.4.4-5.

(i) Pipe wall thickness

Dia. 1.50m (surge tank No,1) and Dia. 0.7m (surge tank No,2)

(ii) Reinforced concrete

- Water tank (surge tank No,1 and No,2)
- Valve chamber (surge tank No,1 and No,2)

(2) Design of Blow Off

Blow off is to drain water from the pipeline for maintenance works such as inspection and repair of pipe inside, and its location is at lowest elevation of the pipeline. Four blow off (beginning of pipeline, blow off No,1~No,3) are proposed and its diameter is determined to ϕ400mm and time to drain water entirely from pipeline is estimated approximately 7 hours as shown Appendix C.4.4-6 (1). It is reasonable because of within working time a day.

Structural designs of blow off are consist of the following calculations shown in Appendix C.4.4-6.

- Pipe wall thickness of drain pipe
- Structural calculation of reinforced concrete at valve chamber

(3) Design of Air Valve

(a) Purpose and nominal diameter of air valve

The purpose of air valve is to exhaust air from pipeline, to keep flow capacity and to prevent air hammer phenomena. Another purpose is to breathe air when the pipeline will be drained water for maintenance works.

The diameter of air valve is determined to exhaust air as correspond to discharge when the

pipeline is filled by water at beginning of pump operation.
Diameter will be determined 200mm as calculated in Appendix C.4.4-7.

(b) Interval and location of air valve
The location of air valve shall be determined at adequate places which air will be left without transport such as place immediate downstream of an up-slope and place immediate upstream of a down-slope of pipeline. Even places at flat slope of pipeline, it is requested to provide air valve at each 600 to 700m intervals that will be recommended 1.5 times of standard distance (400m in general) because of both economical and adequate operation stated in 2.6.7 Study on beginning and end of pump operation.

(c) Structural design of air valve chamber
Structural design of air chamber to calculate reinforced concrete and safety against thrust force are shown in Appendix C.4.4-7.

4.4.8 Construction of Pipeline

(1) Method of Pipe Construction

In general, the pipeline dia.0.8m and wall thickness of pipe 12mm or less may be laid on continuous installation welded at out of excavated trench. In case of this Project pipeline dia.2.40m, it shall be lowered and laid on the excavated trench each by each a piece of pipe by crane 40 to 50 ton of lifting capacity. If the pipeline dia.2.40m would be laid on continuous installation, the significant capacity of crane would be needed and thus is not economical way of installation.

(2) Clearance for Pipe outside Welding and Inspection

Outside clearance at joints of pipe may be increased to take up the correct posture for welding and inspection. Recommendable dimensions of clearance may be of 0.80m distance from outside of pipe and 1.0m width as illustrated Figure 4.4-3. Ii is requested to be stabilized foundation of the pipeline and to ensure the safety of all persons working in the trench.

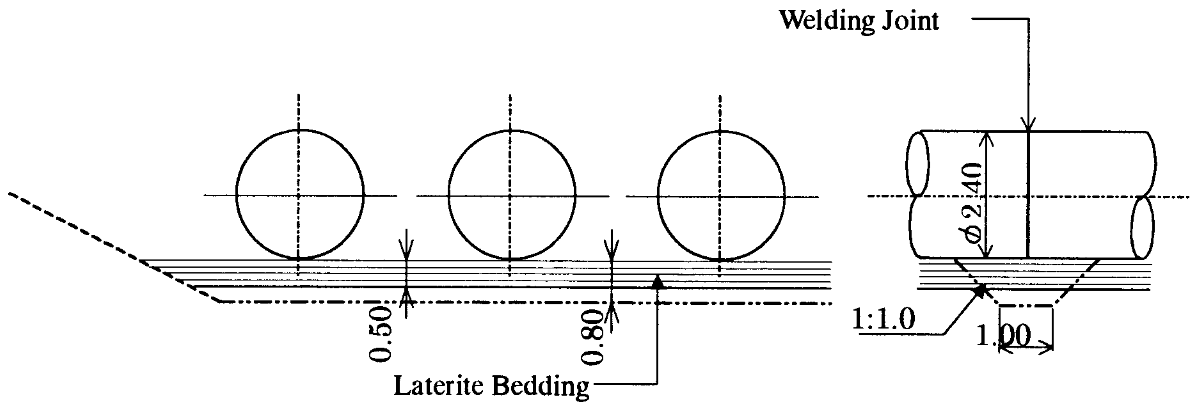

Figure 4.4-3 Recommendable Clearance for Joint Welding

(3) Method of Joint Welding

Steel pipe shall be requested to achieve good quality of joint welding as a matter of great concern. There are in general, two method to weld pipe joint, one is ordinary way to weld at both inside and outside pipe (double V welding), and the other is the method inside welding only with backing plate as shown Figure 4.4-4.

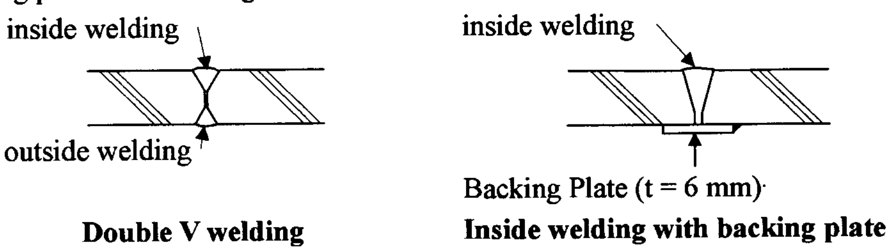

Figure 4.4-4 Joint Welding Method

The comparison of characteristics of two joint welding methods are tabulated as follows:
And the method of inside welding only with backing plate is more recommendable for the Project primarily considered with the high quality of welding and high speed of construction, but the method of double V welding will not be denial.

Method of joint welding	Double V welding	Inside welding only with backing plate
Method of welding	Submerged arc welding	Electro gas arc welding Electro slag arc welding
Possibility of automatic welding	Inside :Possible Outside : Impossible	High possibility of automatic welding with high technology
Quality of welding	Depend on the workmanship of the welder	Constant and high quality
Required accuracy	Required normal precision	Required more precision for manufacturing and installation
Time for joint welding	Approx. 20 hr/joint/a welder	Approx. 7 hr/joint/a welder

Note: Cost of two methods may be difference from the condition of the country, in case of Japan, inside welding with backing plate is rather cheaper than double V welding method.

(4) Pipe specials, Fittings and Others

Pipeline needs various kinds of specials and fittings, such as bends, blow off pipe, flanges, cover of man-hole pipe, air valve devices, flexible joints and others.
These shall be manufactured for compliance with the Standard as specified in the Technical Specifications and Drawings.
The thickness of steel pipe for these specials, fittings and other pipes shall be as shown in the Drawings. And details for reinforcement and others shall be designed based on 12 bars to 2 bars of inner water pressure in accordance with the longitudinal profile (Appendix C.4.4-2, Figure 1:Prpopsed Design Pressure by each block) and adequate out side loads.

4.5 Spillway

(1) Retaining Wall

The walls of spillway inlet are designed as a retaining wall. The computations of the retaining wall are divided into two separate steps: (1) stability analysis and (2) structural design. The computations of the retaining wall and other reinforced concrete structures composed of spillway system are shown in Appendix C.4.5-1. Necessary reinforcements of the retaining wall at BP+15m are shown on Figure 4.5-1.

(2) Flume

The discharge canals of the spillway outlet channel are designed as a flume and the computations of flumes are shown in Appendix C.4.5-2 and necessary reinforcements of the flume sections are shown on Figure 4.5-2.

(3)Riprap Cannal

Velocity of water, water depth, local conditions, etc. should be considered in determining thickness of riprap. The designed riprap canal has a low velocity of 0.947 m/sec and a deep water depth of 2.95 m. In general, the thickness of riprap protection will be 0.30m(12-inch) to 0.45m(18-inch) think where the water depth Is 2.1-3.0m(7-10 feet) as recommended by the USBR. In considering the above and that the canal foundation Is loose, the thickness of the riprap is decided to be 0.40m.

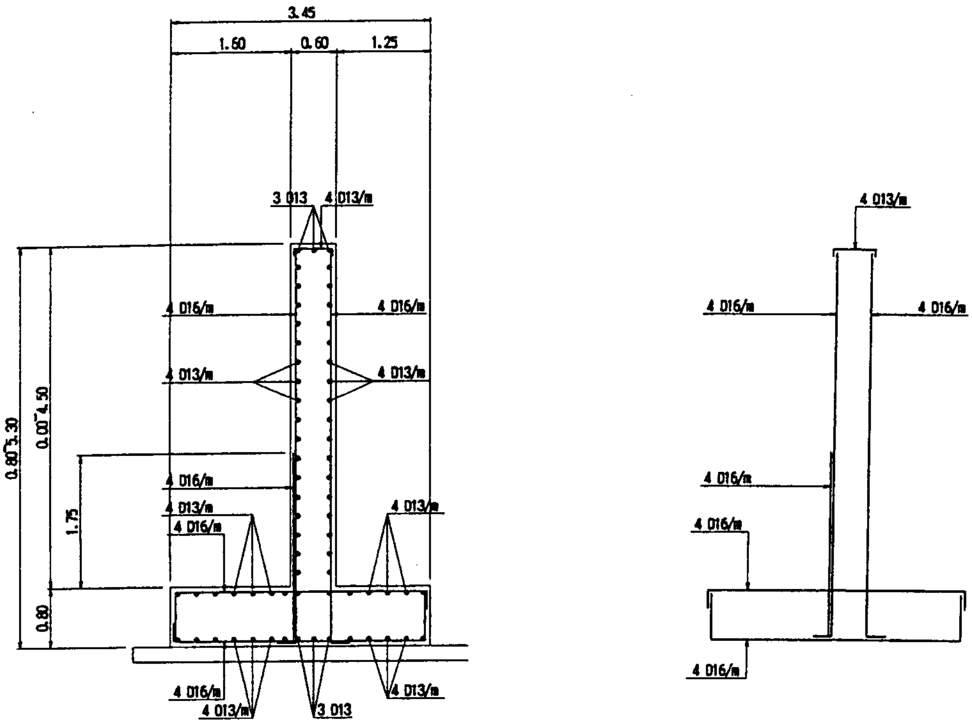

Figure 4.5-1 Section of Retaining Wall at BP+15m

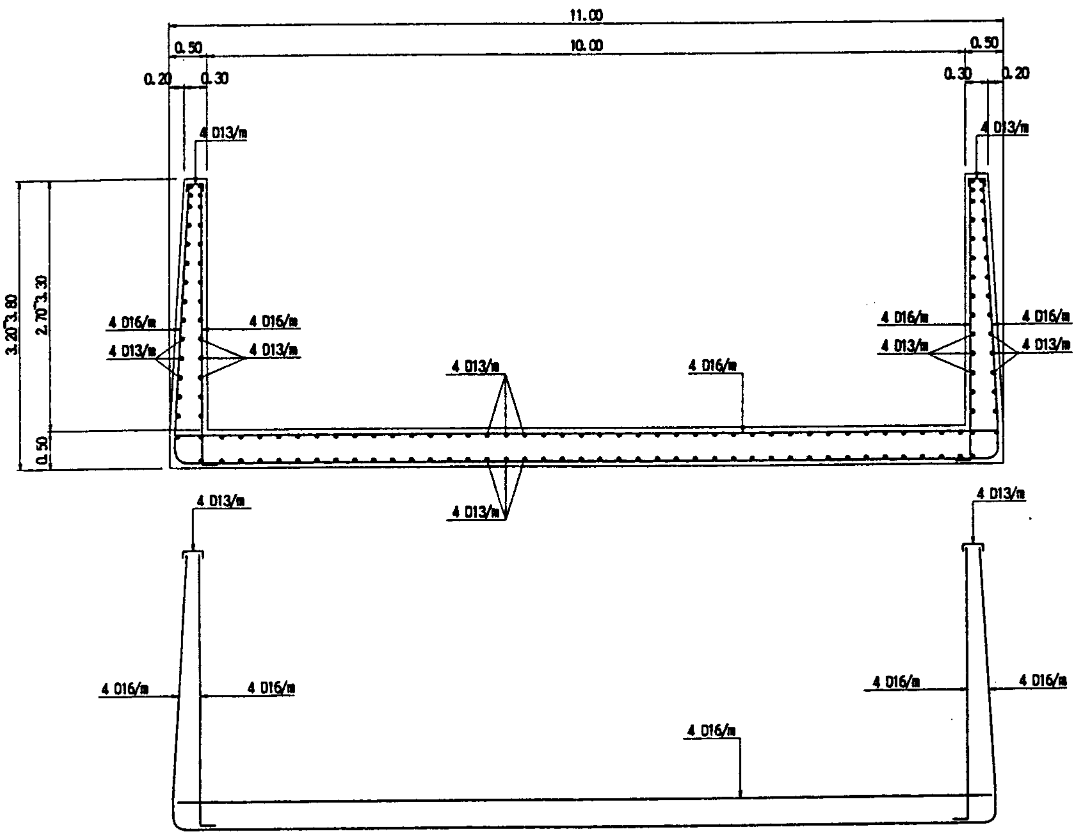

Figure 4.5-2 Section of Flume

4.6 Sand Settling Basin

The sand settling basin consists of the main structure with the retaining walls of seven types, the gate section with two types and O/M bridge section with two types. These structures further divided into the following types.

• Main structure	-----------------	Retaining walls of Inverted T-shape type (Type W 1 to Type W 6) Retaining wall of Gravity type (Type W 7)
• Gate section	-------------------	Gate section of Box type rahmen structure Block out section of Box type rahmen structure
• O/M bridge	-----------------	Superstructure of Cast-in place concrete T beam spans Infrastructure of 2 sell flume

(1) Main Structure

(a) Side-wall Type of Main Structure

The designed of side-wall type of the sand settling basin shall be selected taking into account structural stability, foundation conditions, easy construction and economy. According to the Interim Report (2), the side-wall type of the sand settling basin was proposed inverted T-shape type of the height: 6.70m (lower section) and slope protection of the height: 4.50m (upper section). The following possible three types alternatives of side-wall, however, was studied as summarized in the Table 4.6-1.

The result of the comparison study was that Inverted T-shape type of the height: 8.90m (lower section) with slope protection of the height: 2.5m (upper section) is suitable, because this type is structural safety, no leakage of water, normal construction and most economy.

The main structure consists of the retaining walls of Inverted T-shape type and Gravity type.

The walls and footing slabs of the Inverted T-shape walls are supported by cantilevers to securestability against earth pressure and soil reaction.

(b) Structural Analysis of Main Structure

The structural analyses of the retaining wall are divided into two separate steps: (1) stability analysis and (2) structural design. The structural analyses of the retaining wall are carried out as shown in Appendix C.4.6-1 and necessary reinforcements are shown on Figure 4.6-1.

Table 4.6-1 Alternatives of Side Wall Type of Sand Settling Basin

Type	Inverted T-Shape (1)	Inverted T-Shape (2)	Counterfort Wall
Dimensions	Wall: Height: 6.70 m Width(B): 4.70 m Slope: Height: 4.50 m Length: 10.06 m	Wall: Height: 8.90 m Width(B): 5.80 m Slope: Height: 2.50 m Length: 5.59 m	Wall: Height: 11.50 m Width(B): 10.60 m Slope: Height: – Length: –
Structural Stability	Against overturning e = 0.50m < B/6 = 0.78m Against sliding Fs = 1.54 > Fa = 1.50 Against bearing capacity R=19.14tf/m²<Ra=22.66tf/m²	Against overturning e = 0.66m < B/6 = 0.97m Against sliding Fs = 1.62 > Fa = 1.50 Against bearing capacity R=26.67tf/m²<Ra=27.90tf/m²	Against overturning e = 0.94m < B/6 = 1.77m Against sliding Fs = 1.51 > Fa = 1.50 Against bearing capacity R=12.19tf/m²<Ra=38.88 tf/m²
Structural Safety	• Reinforced concrete lining of upper section will occur differential settlement. • Leakage of water will beeasy occurred at the part of settlement of the berm.	• Plain concrete lining may be sunk at a part of berm. • Leakage of water will not occur.	• This type is most safety.
Construction	Normal	Normal	Complicated
Economy (1,000 LE)	(LE 9,845 x 226.5m) 2,230 (1.12)	(LE 8,758 x 226.5m) 1,984 (1.00)	(LE 18,060 x 226.5m) 4,091 (2.06)

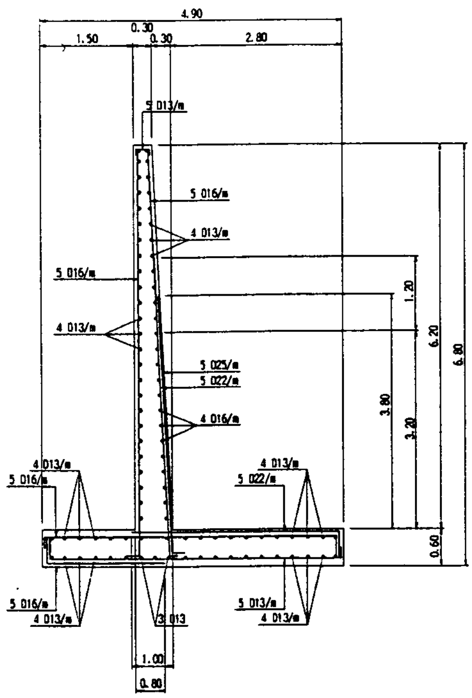

Figure 4.6-1 Arrangement of Reinforcement for Retaining Wall (W 1)

(2) Gate Sections

The structural analysis of the gate sections shall be made by box type rahmen structure with two (2) sells composed of upper plates, bottom plates, side walls and middle wall. In this paragraph, the results of two (2) analyses are shown for the gate and block out sections.

(a) Cases of Analysis

The structural analysis shall be made in the following two (2) cases.

Case	Combination of Loads
• Case 1: Filled in 1 sell box by water	Dead weight, earth pressure, internal water pressure, gate weight, hoist weight, crowd load, live load, ground reaction
• Case 2: Empty in box	Dead weight, earth pressure, gate weight, hoist weight, crowd load, live load, ground reaction

(b) Structural Analysis of Gate Section

The structural analysis of the gate sections are concluded as shown in Appendix C.4.6-2 and necessary reinforcements are shown on Figure 4.6-2.

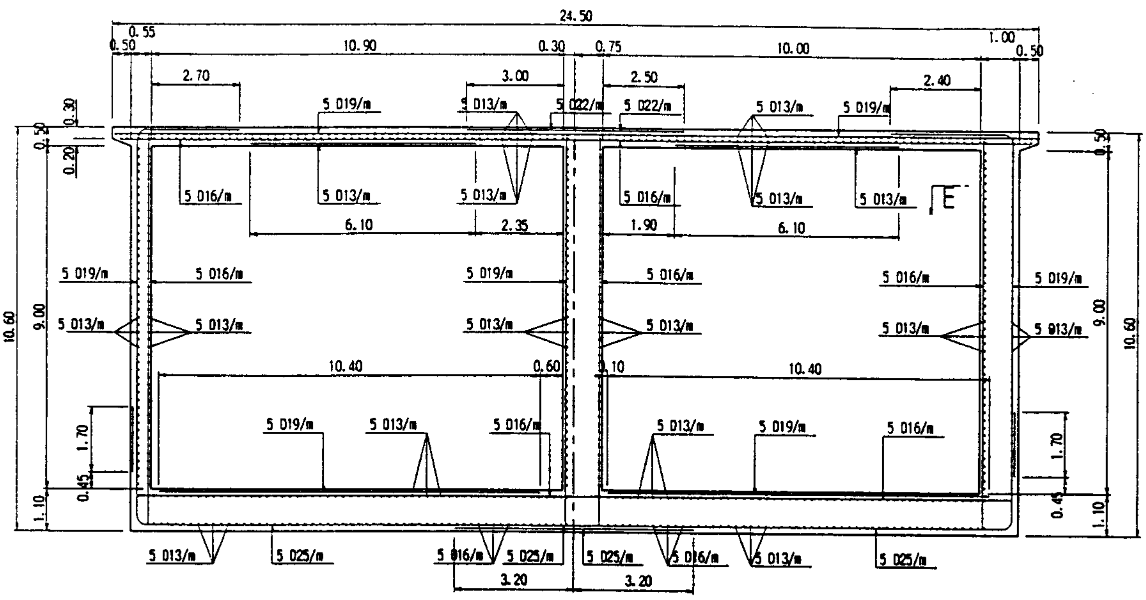

Figure 4.6-2 Arrangement of Reinforcement for Gate Section

(3) O/M Bridge

(a) Superstructure

The O/M bridge of cast-in place concrete T beam has total width of 14 m composed of side walks (2m x 2 lanes) and a roadway of 10 m as shown on Figure 4.2-3.

The structural analysis was carried out following the Egyptian code of practice, 1994 as shown in the design standard and the result is shown in Appendix C.4.1-1.

(b) Infrastructure

The infrastructure of O/M bridge is designed as a flume with 2 sell and the structural analysis is carried out as shown in Appendix C.4.6-3 and necessary reinforcements are shown on Figure 4.6-3.

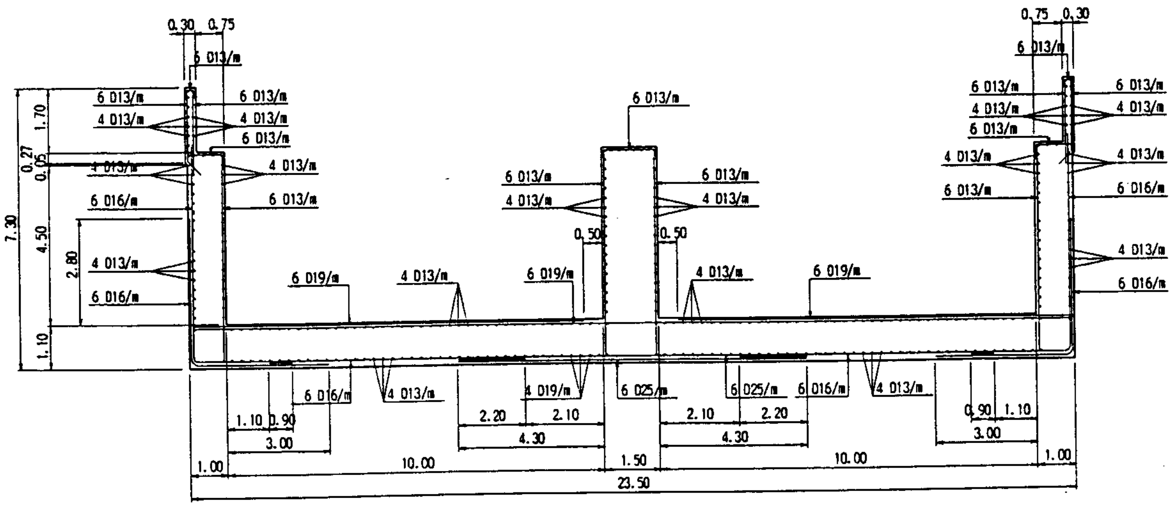

Figure 4.6-3 Arrangement of Reinforcement for Infrastructure of O/M Bridge