12. Foundation Works for Regulator

12-1 Determining the foundation type

12-1-1 Concept and flow

Chapter 11,'Stability and Structural Calculation', shows the results of the examination of foundation works. The ground reaction force (actual stress of foundation) Figures calculated for each case are available. Each layer's bearing capacity was also assessed. The examination was conducted according to the flow chart in Figure 12-1.2. The common foundation type is shown in Figure 12-1.1.

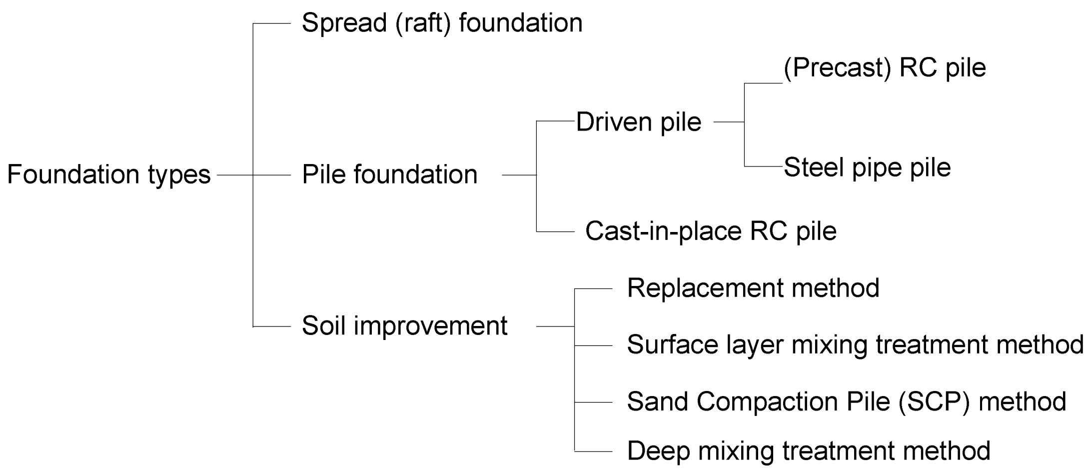


Figure12-1.1 Classification of foundation works

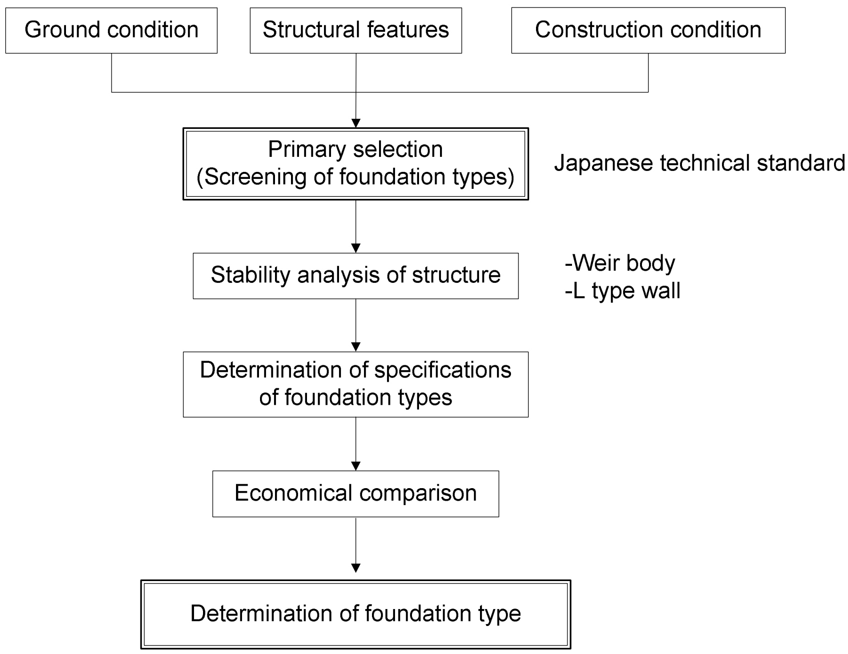


Figure12-1.2 Flowchart of foundation works

As for the bearing capacity of Terzaghi, the Egyptian code equation has a different applied co-efficient that gives a larger result than that of the Japanese equation. Under sand conditions, the results of the bearing capacity from the Egyptian code are almost seven times greater than the Japanese Figures. There is also a substantial difference in the general evaluation as a result of the difference in N value (refer to Appendix).

To overcome these great differences in results, the Egyptian consultant usually applies a settlement method in combination with the Terzaghi method stipulated in Egyptian code. The Bahr Yusef and Ibrahimia regulators bearing capacity results arrived at by the settlement method are almost the as those arrived at by the Japanese equation.

Accordingly, the bearing capacity should be evaluated by a combination of the Terzaghi formula in the Egyptian code and the settlement method, the latter being applied under sand layer conditions. This decision was approved by the expert panel meeting at the 19th TAC meeting.

12-1-2 Primary selection of foundation method

The bearing capacity of every regulator must be assessed using the ratio in Table 12-1.1.

(1) Bearing capacity

The equation for calculating bearing capacity should be consideration with eccentricity of acted load, which is in the basis of the modified Terzaghi method. The ultimate bearing capacity must take a safety ratio into account. Calculating bearing capacity takes the following into consideration:

Figure12-1.3 Locations of borehole for design

a) Allowable bearing capacity of foundation should be secured the following safety ratio against the ultimate bearing capacity considering the eccentricity of the load.

Table12-1.1 Safety ratio for bearing capacity (Egyptian code)

Normal	Seismic
2.5	1.8

b) Ultimate bearing capacity of the foundation using revised Terzaghi formula considering eccentricity of the load in the Egyptian code, is calculated as the followings:

$qu = c \cdot Nc \cdot \lambda c \cdot ic + \gamma 1 \cdot Df \cdot Nq \cdot \lambda q \cdot iq + \gamma 2 \cdot Be \cdot Nr \cdot \lambda r \cdot ir$

$qa = 1/n \cdot qu$

Where,

qu ; ultimate bearing capacity considering eccentricity of the load (kN/m^2)

qa ; allowable bearing capacity (kN/m^2)

n ; safety ratio (Table 12-1.2)

Nc ; $(Nq-1) / \tan\varphi$

Nq ; $e^{\pi \cdot \tan\phi} \cdot \tan^2(45+\phi/2)$

Nr ; $(Nq-1)\tan\varphi$

ic ; $iq-(1-iq)/(Nq-1)$

iq ; $\{1-0.7 \cdot (H*Fb/(V*Fb+A \cdot c \cdot \cot\phi))\}^3$

ir ; $\{1-(Hb/(Vb+A \cdot c \cdot \cot\phi))\}^3$

$\gamma 1$, $\gamma 2$; unit weight of ground below foundation load surface (kN/m^3)

*when foundation level is under groundwater level, apply submerged unit weight

λc, λr, λq ; refer to Table 12-1.2

Table12-1.2 Shape factor of the foundation (Egyptian code)

Shape of foundation	Belt type	Square or Circle	Rectangle, ellipse, or oval
λq, λc	1.0	1.3	$1+0.3 \cdot (Be/Le)$
λr	1.0	0.7	$1-0.3 \cdot (Be/Le)$

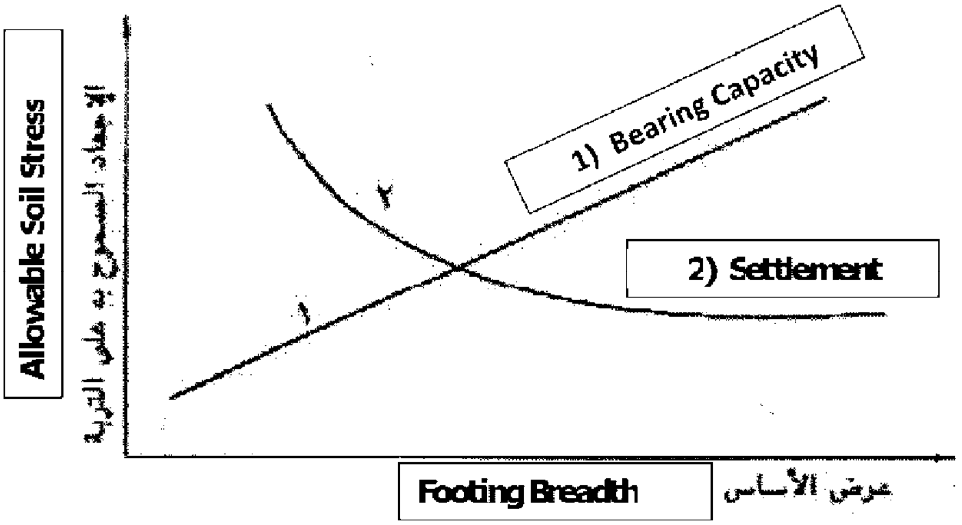
Be ; width of foundation for the effective loading considering eccentricity (m)

$Be = B - 2e$

c) Allowable bearing capacity of foundation by the settlement method under the Egyptian code, explained as follows.

1. DESIGN REQUIREMENTS IN THE EGYPTIAN CODE OF SOIL MECHANICS AND FOUNDATION

- The design of shallow foundation according to the Egyptian code for soil mechanics requires the determination of allowable bearing capacity and the settlement of soil separately and takes the safe soil stress from the two conditions.
- Often, in large dimension foundation, the settlement is the governing condition in the design.
- The following Figure shows the relation between the allowable stress of soil and breadth of footing for the bearing capacity and the settlement (Figure 3.3 in the Egyptian code).



شكل (٣-٢) العلاقة بين الإجهاد المسموح به وعرض الأساس

١) لمعامل أمان معين من فشل تربة الأساس

٢) لمقدار معين من الهبوط

Relation between Allowable Stress & Footing Breadth

2. ALLOWABLE TOTAL SETTLEMNT

Total settlement $\leq$ 100 150 mm (Clay Soil)

Total settlement $\leq$ 70 – 100 mm (Sandy Soil)

[The greatest values used for more stiff structures]

[clause 3.2.6.6.a]

Figure12-1.4 Concept of settlement by Egyptian code (1/2)

3. ALLOWABLE SOIL STRESS FOR BAHRYUSEF & IBRAHIMIA REGULATORS ACCORDING TO EGYPTIAN CODE

B. Total settlement (s)

[clause 3.4.5.4]

$$s = \sum \frac{\sigma}{E_s} \cdot h_z$$

where ,

s the total settlement (mm)

σ the stress at the mid-height of the layer (KN/m2)

h_z layer thickness (m)

E_s Modulus of elasticity (KN/m2)

E_s = (4-12) N_{SPT} (Kg/cm2)

E_s = 4 N_{SPT} ------------ for silt soil and sandy silt soil

E_s = 7 N_{SPT} ------------ for fine and medium sand

E_s = 10 N_{SPT} ------------ for coarse sand

E_s = 12 N_{SPT} ------------ for gravel and sandy gravel

[clause 3.4.3.3.b]

$$\sigma_z = \frac{q}{(1+z/B).(1+z/L)}$$

[clause 3.4.4.4.c.1]

Where B & L are the footing dimensions

Considering the allowable settlement = 70 mm and by applying the previous equations for settlement, the allowable soil stress will be:

Figure12-1.5 Concept of settlement by Egyptian code (2/2)

d) Result of the calculations

From the calculations, the bearing capacity of each regulator is shown in Table 12-1.3.

Table12-1.3 Summary of bearing capacity

Regulator name and related structure		By Revised Terzaghi formula Normal (kN/m^2)	By Revised Terzaghi formula Seismic (kN/m^2)	By Settlement method (normal) (kN/m^2)	Remarks
Bahr Yusef regulator	Regulator foundation (Br.No.BH-N2D)	267.2(Dir. F.A) 269.2(Dir. W.A)	300.0(Dir. F.A) 306.2(Dir. W.A)	**49.16** (applied)	Sand ground: N=6, φ=23°
	L type wall (H-N2C)	**19.3**(Dir. F.A) -(Dir. W.A) (applied)	**24.6**(Dir. F.A) -(Dir. W.A)	36.37	Sand ground: N=8, φ25°
Ibrahimia regulator	Regulator foundation (Br.No.BH-N3')	511.5(Dir. F.A) 512.8(Dir. W.A)	573.1(Dir. F.A) 585.5(Dir. W.A)	**91.48** (applied)	Sand ground: N=13, φ27°
	L type wall (Br.No.BH-N3)	**19.3**(Dir. F.A) - (Dir. W.A) (applied)	**24.6**(Dir. F.A) -(Dir. W.A)	80.69	Sand ground: N=9, φ25°
Badraman regulator	Badraman canal (Br.No.BH-A1 B)	**239.24**(Dir. F.A) **487.07**(Dir. W.A) (applied)	**317.39**(Dir. F.A) **652.91**(Dir. W.A)	— (Clay layer)	Silty clay: N=18, φ0°
	Diroutiah canal (Br.No.BH-A1 A)	**191.36**(Dir. F.A) **309.68**(Dir. W.A) (applied)	**251.30**(Dir. F.A) **417.04**(Dir. W.A)	— (Clay layer)	Silty clay: N=14, φ0°
Abo Gabal regulator	Both of Abo Gabal and Irad Delgaw canal (Br.No.BH-N5)	**383.69**(Dir. F.A) **415.24**(Dir. W.A) (applied)	**513.37**(Dir. F.A) **570.44**(Dir. W.A)	— (Clay layer)	Silty clay: N=25, φ0°
Sahelyia regulator (Br.No.BH-N6)		**223.25**(Dir. F.A) **317.02**(Dir. W.A) (applied)	**286.60**(Dir. F.A) **418.43**(Dir. W.A)	— (Clay layer)	Silty clay: N=16, φ0°

Note1:Safety measures from landslides and eccentricity are by far more over than targeted range which is available to evaluate the numerical equation. Therefore, the direct foundation cannot apply to L type wall.
Note2:"Dir. F. A." shows "Direction of Flow Axis", "Dir. W.A." shows "Direction of Wire Axis"

(2) Evaluation of bearing capacity

When compared with the ground reaction force (that is the result of examining the stability of the regulators in chapter 11 “Stability and Structural Calculation" and the calculated bearing capacity on Table 12-1.4 for each case), it seems that the large scale regulators of Bahr Yusef and Ibrahimia do not have adequate bearing capacity. Therefore, direct foundation cannot be used with the Bahr Yusef and Ibrahimia regulators.

Accordingly, the ground reaction force (actual stress of foundation) found by examining the stability of the Bahr Yusef and Ibrahimia regulators is around 136kN/m^2.In order to ensure a bearing capacity against 136kN/m^2 (by backward calculation method), the necessary bearing capacity should be N=18 calculated at141kN/m^2N=18 layers are observed as follows.

・Bahr Yusef : 10m below (EL27.5m) from the bottom of designed apron (EL37.5m)

・Ibrahimia : 4m below (EL33.5m) from the bottom of designed apron (EL37.5m)

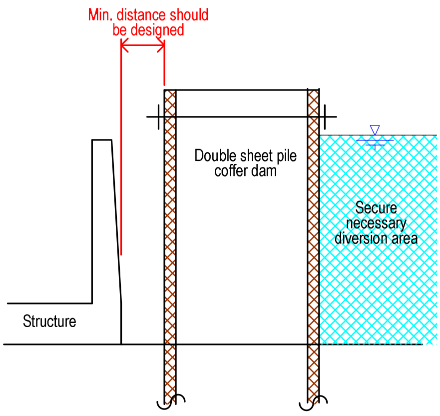


Figure12-1.6 Relation between double sheet pile and structure

The L type protection walls shortly downstream of Bahr Yusef and Ibrahimia regulator cannot use the direct foundation. These walls types are not designed with the footing slab behind the wall because of the marginal limitation of double sheet pile cofferdam (Figure 12-1.6). Therefore, the footing slab must be designed at the front of the wall, which means the resisted vertical force is by far smaller than the horizontal force due to earth and water pressure, so it overloads the landslide, eccentricity capacity, and bearing capacity. Accordingly, **L-type protection walls cannot use direct foundation.**

The small scale Badraman, Abo Gabal, and Sahelyia regulators have a clay layer around the bottom of the apron with a high N value, and sufficient bearing capacity. Hence **direct foundation should be applied to the small scale regulators.**

A comparison between the ground reaction force (actual stress of foundation) and the allowable bearing capacity is shown on Table 12-1.4.

Table12-1.4 Result of the examination of bearing capacity

Normal condition

		Geological conditions	Max. actual stress by stability exam. (kN/m2)		Min. bearing capacity (kN/m2)	Judgment (OK or NG)	N value	Remarks
Bahr Yusef	Regulator	sand	144.84	>	49.16	NG	6	
	L type wall	sand	68.53	>	19.3	NG	8	
Ibrahimia	Regulator	sand	144.82	>	91.48	NG	13	
	L type wall	sand	68.52	>	19.3	NG	9	
Badraman	Badraman regulator	clay	107.27	≦	239.24	**OK**	18	Raft foundation
	Diroutiah. regulator	clay	101.56	≦	191.36	**OK**	14	Raft foundation
Abo Gabal	Regulator	clay	106.47	≦	383.69	**OK**	25	Raft foundation
Sahelyia	Regulator	clay	141.89	≦	223.25	**OK**	16	Raft foundation

Seismic condition

		Geological conditions	Max. actual stress by stability exam. (kN/m2)		Min. bearing capacity (kN/m2)	Judgment (OK or NG)	N value	Remarks
Bahr Yusef	Regulator	sand	133.15	>	68.28 note)	NG	6	
	L type wall	sand	82.84	>	24.6	NG	8	
Ibrahimia	Regulator	sand	144.82	>	127.06 note)	NG	13	
	L type wall	sand	82.84	>	24.6	NG	9	
Badraman	Badraman regulator	clay	107.14	≦	317.39	**OK**	18	Raft foundation
	Diroutiah regulator	clay	95.86	≦	251.30	**OK**	14	Raft foundation
Abo Gabal	Regulator	clay	111.44	≦	513.37	**OK**	25	Raft foundation
Sahelyia	Regulator	clay	153.67	≦	286.60	**OK**	16	Raft foundation

Note: Seismic bearing capacity is assumed by normal bearing capacity to be as follows:

$68.28 kN/m^2 = 49.16\ kN/m^2 \times 2.5/1.8$, $127.06 kN/m^2 = 91.48\ kN/m^2 \times 2.5/1.8$

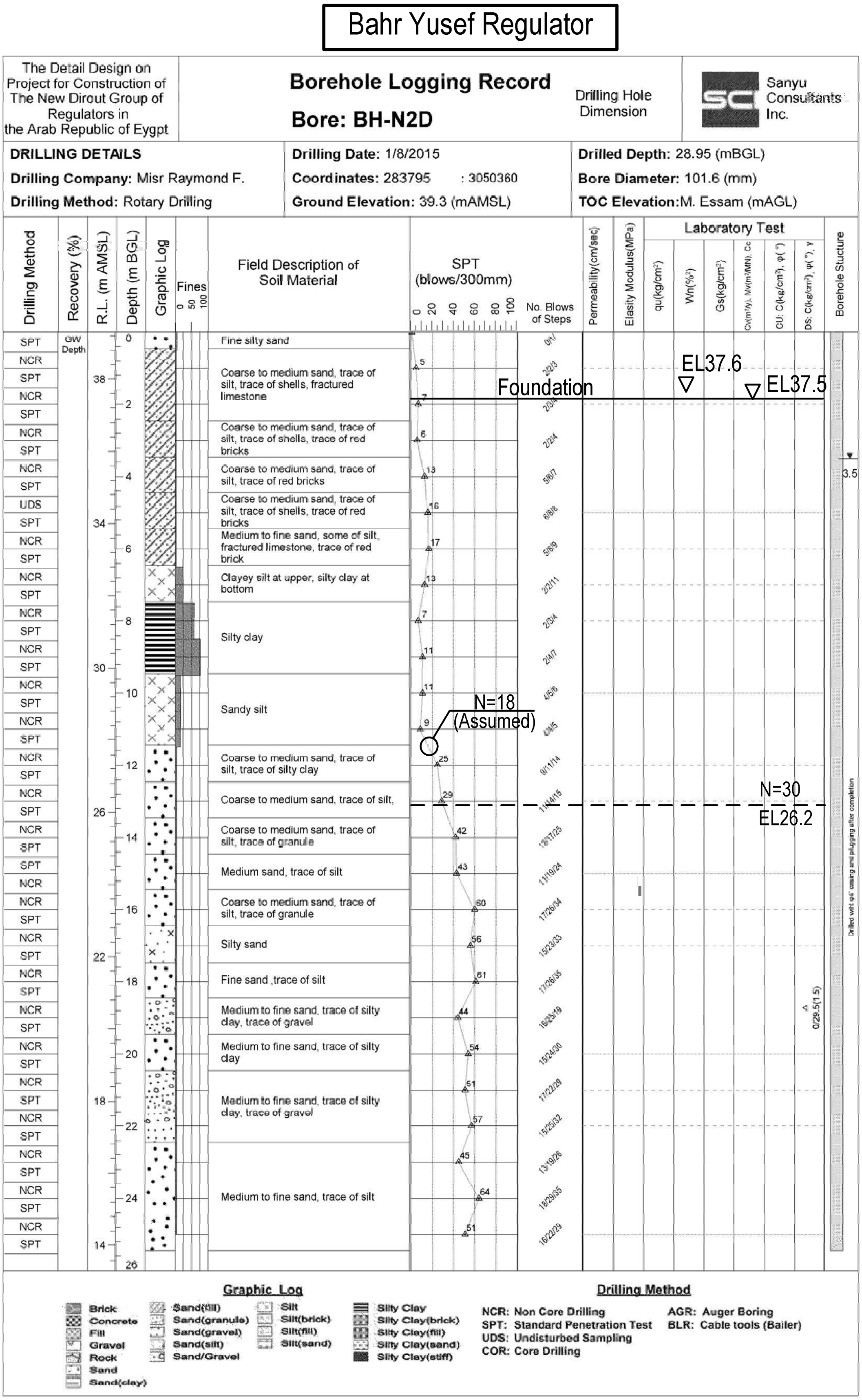


Figure12-1.7 Br No. BH-2D Bahr Yusef regulator

Bahr Yusef L type wall

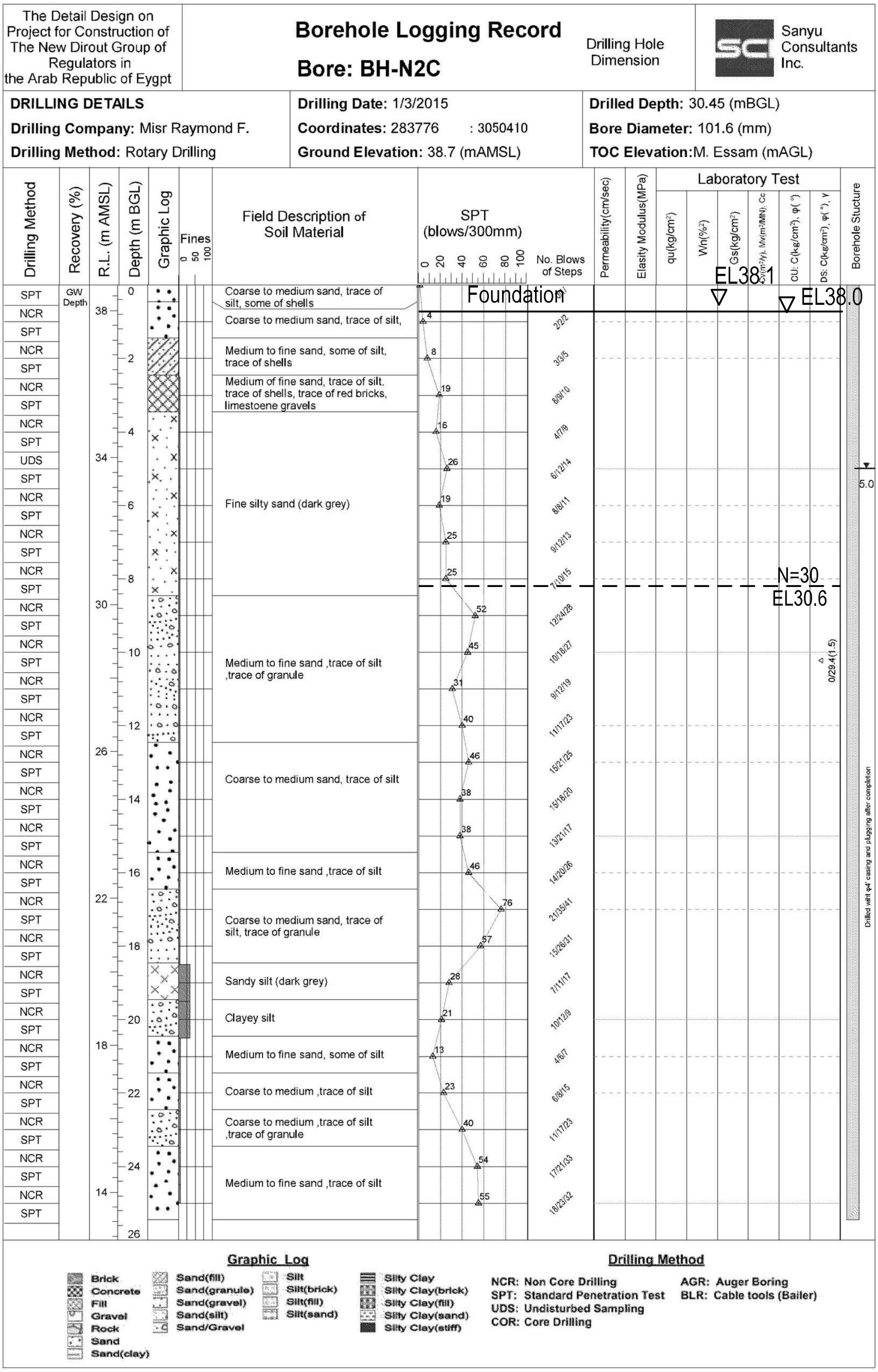


Figure12-1.8 Br No. BH-N2C Bahr Yusef regulator (L type wall)

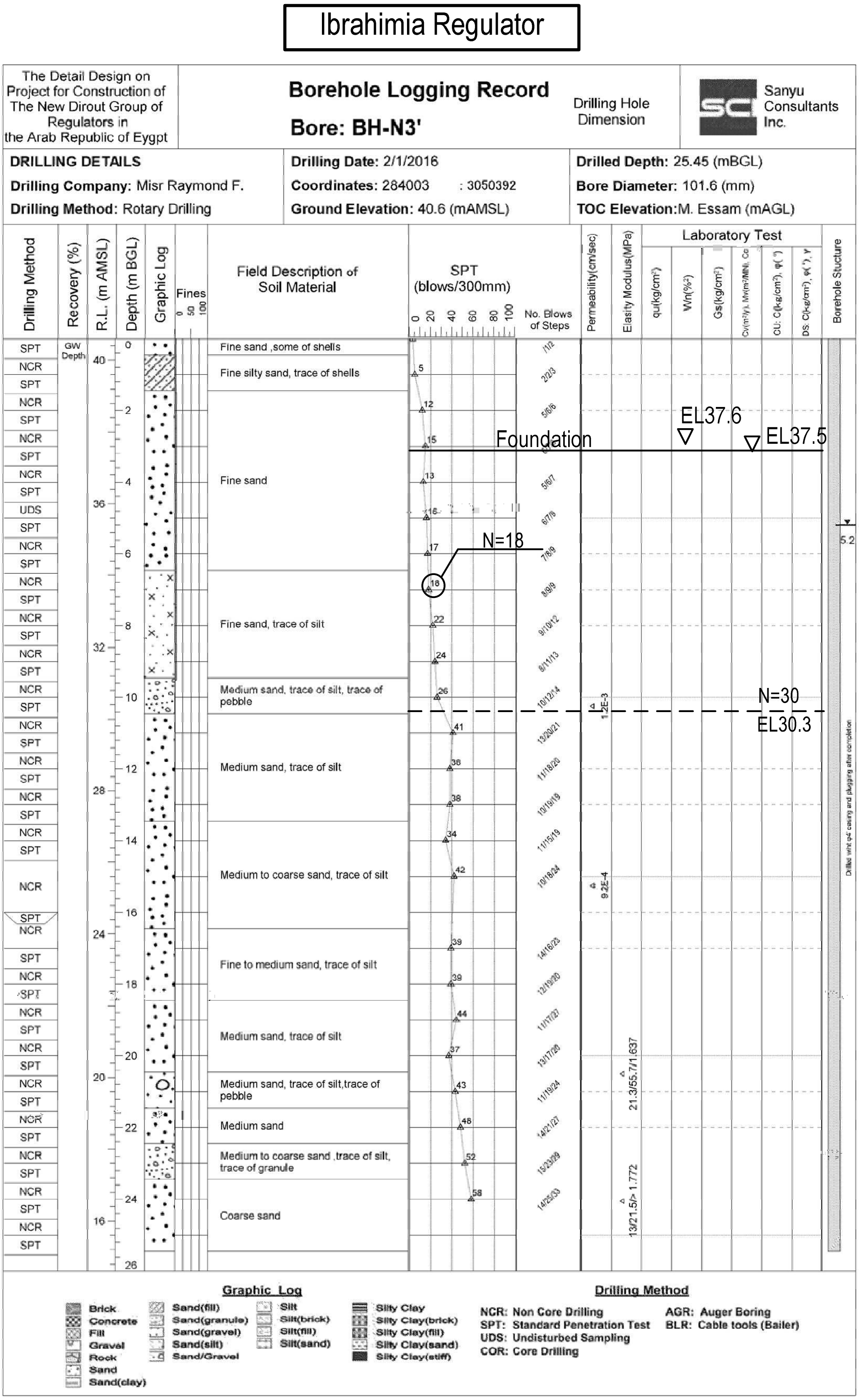


Figure12-1.9 Br No. BH-N3' Ibrahimia regulator

Ibrahimia L type wall

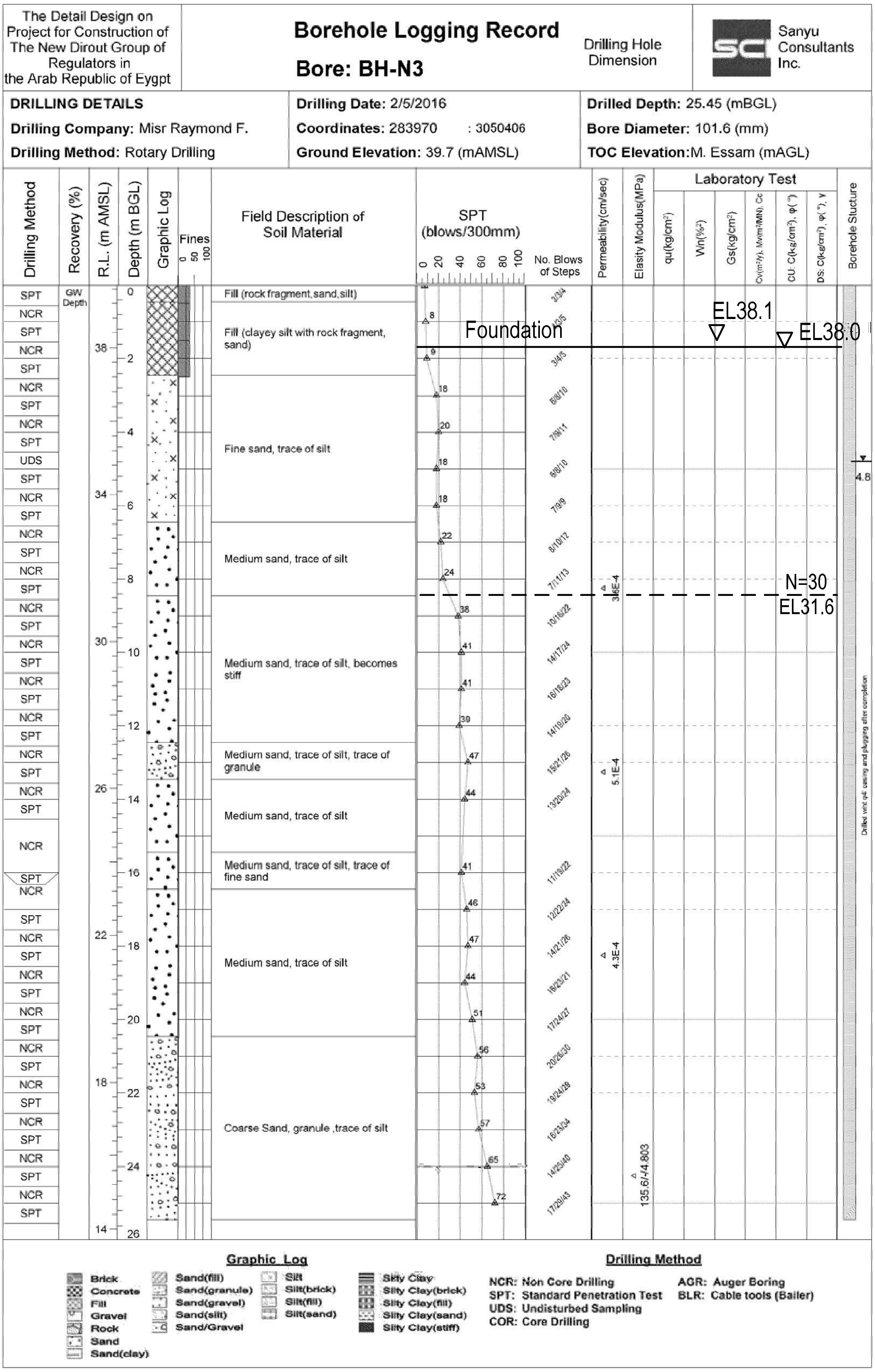


Figure12-1.10 Br No. BH-N3 Ibrahimia regulator (L type wall)

Badraman Regulator (Badraman canal)

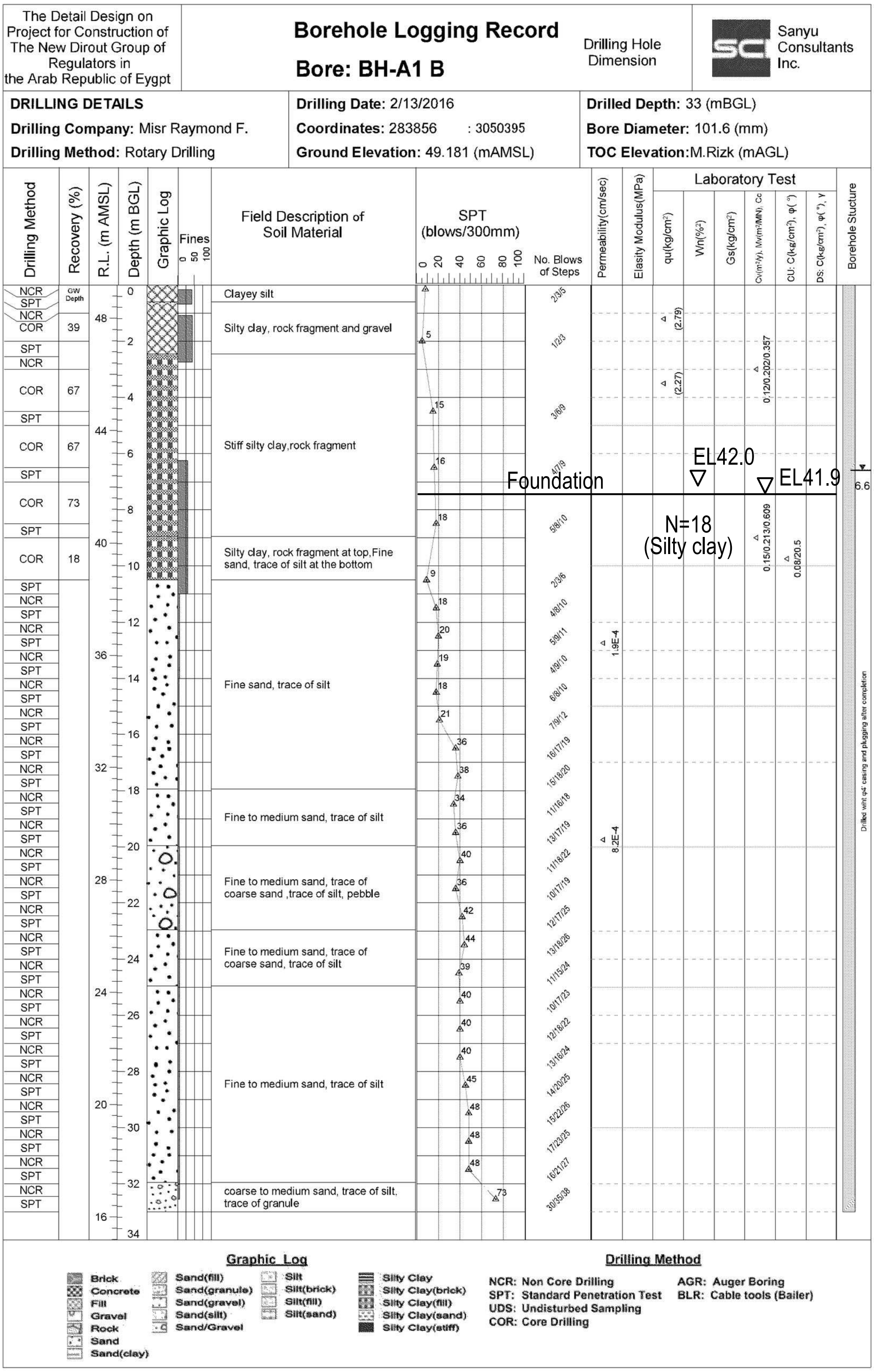


Figure12-1.11 Br No. BH-A1B Badraman regulator (Badraman canal)

Badraman Regulator (Diroutiah canal)

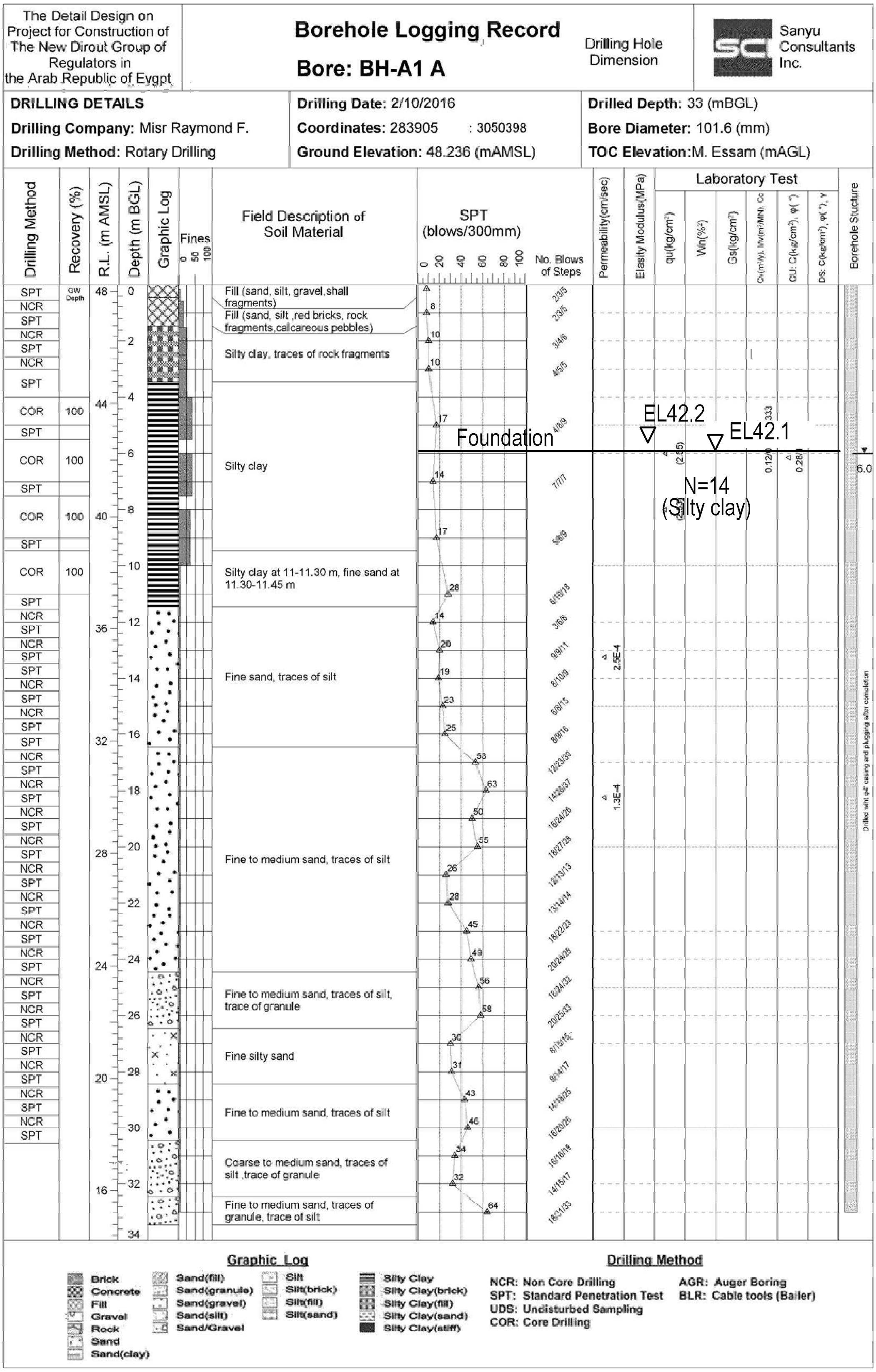


Figure12-1.12 Br No. BH-A1A Badraman regulator (Diroutiah canal)

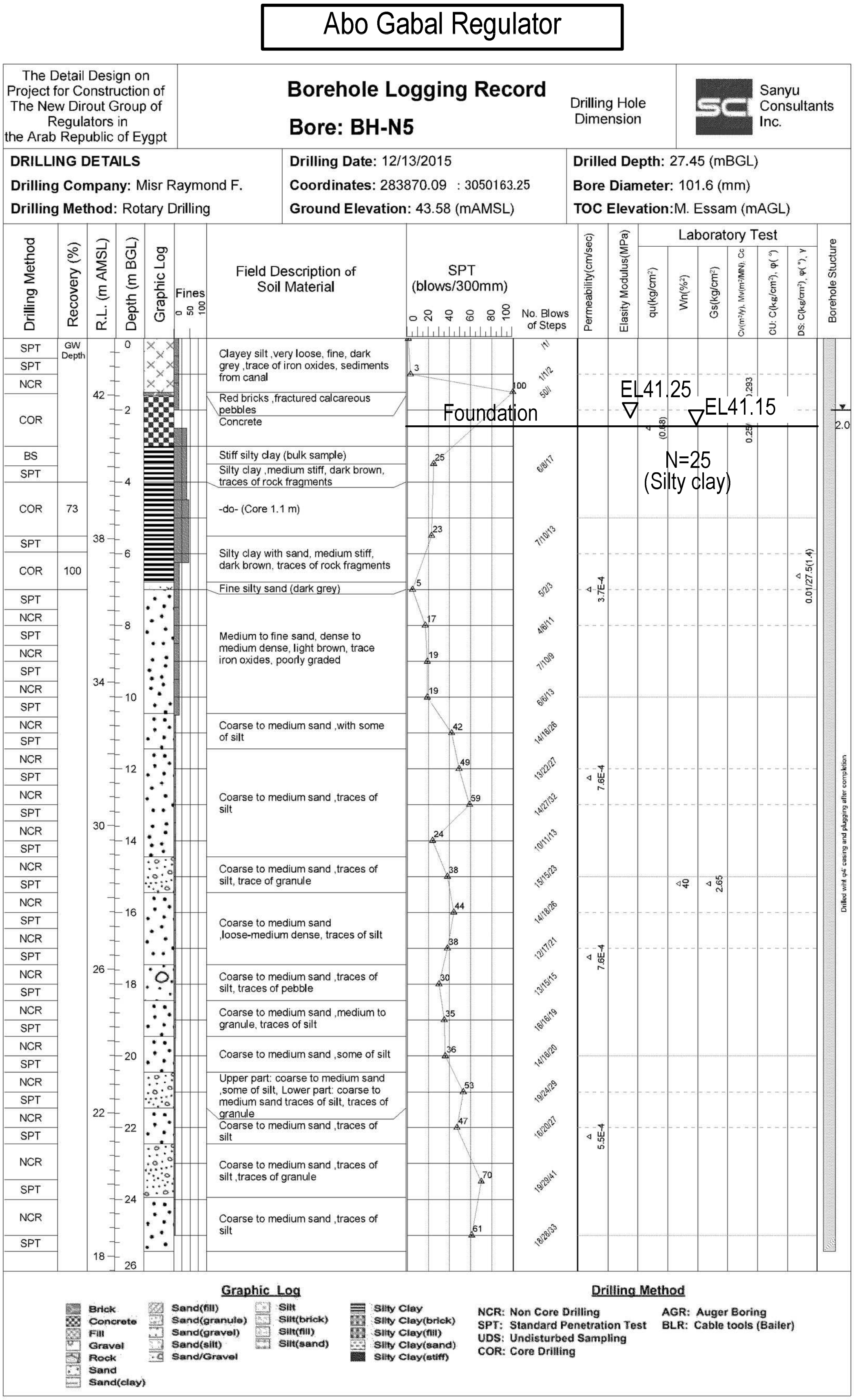


Figure12-1.13 Br No. BH-N5 Abo Gabal regulator

Sahelyia Regulator

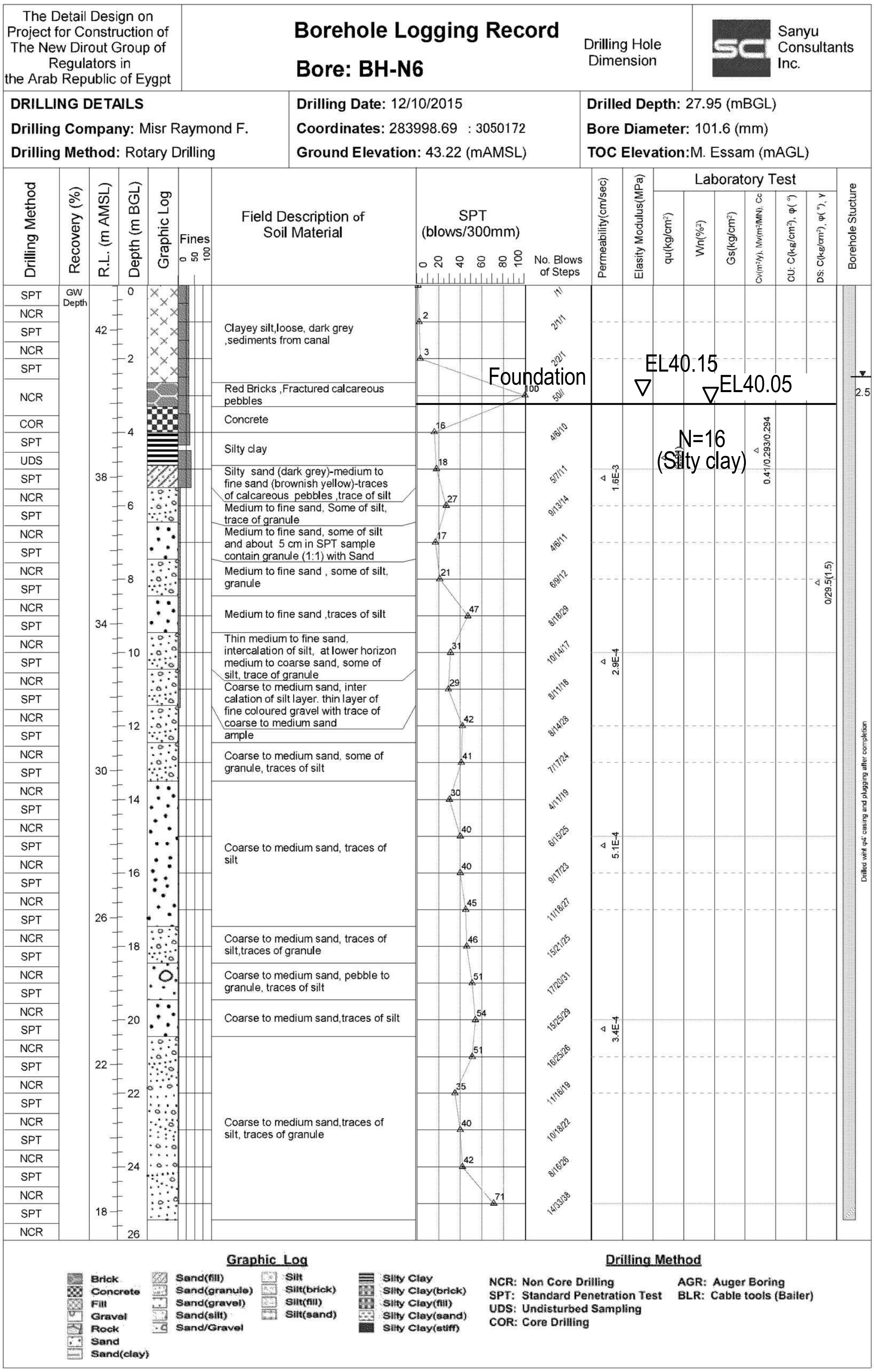


Figure12-1.14 Br No. BH-N6 Sahelyia regulator

(3) Results of primary selection of foundation

The large scale regulators of Bahr Yusef and Ibrahimia regulators which cannot take raft foundations must consider other foundation methods such as, soil improvement method, and pile foundation method. The conditions of the soil improvement method are shown in Table 12-1.5, and the evaluation of the available soil method is shown in Table 12-1.6. As a result of the evaluation, the soil improvement method selected for application is the ‘deep mixing treatment method. The conditions of the pile foundation method are the steel pipe pile, and cast-in-place RC pile shown in Tables12-1.7 and 12-1.8.

However, the Egyptian side strongly requested that the pre-casting concrete pile method be considered, as it is one of typical pile method in Egypt. In the response to their request, the pre-casting RC pile should be included in the methods evaluated.

Accordingly, the selected pile foundation and soil improvement methods for the final consideration were shown as follows.

Targeted foundation method after primary selection

- ✓ Soil improvement method: Deep mixing treatment method
- ✓ Pile foundation method: Steel pipe pile, cast-in-place RC pile, pre-casting RC pile

Table12-1.5 Site conditions related to foundation treatment works

condition for selection \ Target facility		Bahr-Yusef Reg.		Ibrahimia Reg.	
		Weir Body	Downstream Apron L-shaped Retaining Wall	Weir Body	Downstream Apron L-shaped Retaining Wall
Ground condition	Soil property and layer thickness	・Approx. 4.0m downward from the foundation level: Medium to Coarse Sand ・Further 6.0m downward: Silty Clay (BH-N2D) *Those layers consist of the mixture of the construction waste and canal deposit, which makes a large variety in the property of the soil. Therefore, bearing layer has significant difference in its depth place by place.		・Approx. 5.0m downward from the foundation level: Fine sand and Silty Fine Sand (BH-N3')	
	Intermediate layer	Upper layer: Permeable Lower layer: Impermeable	Supposed to be the mixture of permeable and impermeable layers	Sand (Permeable) Layer	
	Bearing layer	Sand (Permeable) Layer		Sand (Permeable) Layer	
Impact on bank(e.g. differential settlement,etc.)		–	–	–	–
Construction condition	Construction depth	Approx. 11.0m		Approx. 7.0m	
	Construction period	It must be completed in the restricted time (relatively short period)		It must be completed in the restricted time (relatively short period)	
	Many past construction case examples	–	–	–	–
	Restricted work area	Double sheet pile method restricts the work space for the construction		Double sheet pile method restricts the work space for the construction	
	Poor trafficability	Low Workability due to the soft clay layer (N-value≦5) in some area on the foundation level (such as BH-N2')		–	–
Environmental condition	Low vibration, low noise	–	–	It is necessary to take measures against the vibration considering the railway and bank protection work with more than 10m height on the right bank.	
	Impact on groundwater	–	–	–	–
	Impact on adjacent structures	–	–	There is the railway and bank protection work with more than 10m height on the right bank	
	Deformation prevention of surrounding ground	–	–	There is the railway and bank protection work with more than 10m height on the right bank	
Advantage of the method		To strengthen the bearing capacity aruond the foundation		To strengthen the bearing capacity aruond the foundation	
Economy		Economic superior method is required for the selection		Economic superior method is required for the selection	

Table12-1.6 Available soil improvement method and its evaluation

Selection condition			Soil improvement method	Replacement method	Surface layer mixing treatment method	SCP method	Deep mixing treatment method	Bahr-Yusef Reg.								Bahr-Yusef Reg.							
								Weir body				L type wall				Weir body				L type wall			
								Replacement method	Surface layer mixing treatment method	SCP method	Deep mixing treatment method	Replacement method	Surface layer mixing treatment method	SCP method	Deep mixing treatment method	Replacement method	Surface layer mixing treatment method	SCP method	Deep mixing treatment method	Replacement method	Surface layer mixing treatment method	SCP method	Deep mixing treatment method
Ground condition	Soil property and layer thickness	Sandy soil	10m or less	△	○	○	△	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0
			10m or more	×	×	○	△																
		Cohesive soil	10m or less	○	○	△	○	1	1	0	1	1	1	0	1								
			10m or more	×	×	△	○																
		Humus soil	3m or less	○	○	×	△																
			3m or more	×	×	△	△																
	Intermediate layer	Permeable layer exists		-	-	-	△				0				0				0				0
		Impermeable layer exists		-	-	○	○			1	1			1	1								
		Hard layer exists		-	-	△	△																
	Bearing layer	Can be considered as permeable layer		△	-	-	○	0			1	0			1	0			1	0			1
		Can be considered as impermeable layer		○	-	○	○																
Impact on bank(e.g. differential settlement,etc.)				○	△	△	△																
Construction condition	Construction depth	3m or less		○	○	×	△																
		3-10m		×	×	△	○									-2	-2	0	1	-2	-2	0	1
		10-20m		×	×	○	○	-2	-2	1	1	-2	-2	1	1								
		20-30m		×	×	△	○																
		30m or more		×	×	△	○																
	Construction period	Sufficiently long		○	○	△	△																
		Somewhat long		○	○	○	△																
		Short		○	○	△	○	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1
	Many past construction case examples			○	△	△	○																
	Restricted work area			×	×	△	△	−2	−2	0	0	−2	−2	0	0	−2	−2	0	0	−2	−2	0	0
	Poor trafficability			○	○	△	△	1	1	0	0	1	1	0	0								
Environmental condition	Low vibration, low noise			○	○	×	△									1	1	-2	0	1	1	-2	0
	Impact on groundwater			○	○	△	△																
	Impact on adjacent structures			○	○	×	○									1	1	-2	0	1	1	-2	0
	Deformation prevention of surrounding ground			○	○	△	○									1	1	−2	0	1	1	−2	0
Advantage of method	Settlement acceleration			-	-	○	-																
	Settlement prevention			○	○	-	○																
	Strength enhancement			○	○	○	○	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Embankment stabilization			○	○	○	○																
	Lateral flow prevention				○	△	○																
	Liquefaction prevention			○	○	○	△																
	Reduced permeability			△	○	×	△																
Economy				○	○	△	△	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0
								1	2	4	6	1	2	4	6	2	3	−4	4	2	3	−4	4

○: Fitted (1). △: Studies required (0). ×: Can be unfit (-2). -: Not applicable

Note: SCP method stands for sand compaction pile method.

Table12-1.7 Site conditions related to pile foundation works

condition for selection		Target facility	Bahr-Yusef Reg.		Ibrahimia Reg.	
			Weir Body	Downstream Apron L-shaped Retaining Wall	Weir Body	Downstream Apron L-shaped Retaining Wall
Ground condition	Condition to the bearing layer	Extremely soft layer exists in intermediate layer	Soft clay layer (N value≦5) is distributed around the Foundation depth（BH-N2')		—	—
		Extremely stiff layer exists in intermediate layer	—	—	—	—
		Gravel exists in the intermediate layer	—	—	—	—
		Liquefiable layer exists	—	—	—	—
	Condition of bearing laye	Depth until bearing layer	Approx. 14.0m	Approx. 10.0m	Approx. 10.0m	Approx. 8.0m
		Soil property	Sand Layer		Sand Layer	
		Large dip（30 degree or more）	—	—	—	—
		Unevenness of bearing layer is severe	Bearing layer consists of the mixture of the construction waste and canal deposit, which makes a large variety in the property of the soil. Therefore, bearing layer has significant difference in its depth place by place.		—	—
	Condition of ground water		—	—	—	—
Structural features	Scale of load		Vertical load is normal. Lateral load is smaller than vertical load.	Vertical load is small. Lateral load is smaller than vertical load.	Vertical load is normal. Lateral load is smaller than vertical load.	Vertical load is small. Lateral load is smaller than vertical load.
	Support style		Bearing Pile	Bearing Pile	Bearing Pile	Bearing Pile
Construction condition	Underwater construction		—	—	—	—
	Narrow work space		Double sheet pile method restricts the work space for the construction		Double sheet pile method restricts the work space for the construction	
	Batter pile		—	—	—	—
	Impact of toxic gas		—	—	—	—
	Countermeasures against vibration and noise		—	—	It is necessary to take measures against the vibration considering the railway and bank protection work with more than 10m height on the right bank.	
	Impact on adjacent structures		—	—	There is the railway and bank protection work with more than 10m height on the right bank	

Table12-1.8 Available pile foundation method and its evaluation

Selection condition			Driven pile: RC pile	Driven pile: Steel pipe pile	Cast-in-place RC pile	Bahr-Yusef Reg. Weir body Driven pile: RC pile	Bahr-Yusef Reg. Weir body Driven pile: Steel pipe pile	Bahr-Yusef Reg. Weir body Cast-in-place RC pile	Bahr-Yusef Reg. L type wall Driven pile: RC pile	Bahr-Yusef Reg. L type wall Driven pile: Steel pipe pile	Bahr-Yusef Reg. L type wall Cast-in-place RC pile	Ibrahimia Reg. Weir body Driven pile: RC pile	Ibrahimia Reg. Weir body Driven pile: Steel pipe pile	Ibrahimia Reg. Weir body Cast-in-place RC pile	Ibrahimia Reg. L type wall Driven pile: RC pile	Ibrahimia Reg. L type wall Driven pile: Steel pipe pile	Ibrahimia Reg. L type wall Cast-in-place RC pile
Ground condition	Condition to the bearing layer	Extremely soft layer exists in intermediate layer	○	○	○	1	1	1	1	1	1						
		Extremely stiff layer exists in intermediate layer	×	△	○												
		Gravel exists in the intermediate layer: Gravel diameter: 5cm or less	△	○	○												
		Gravel exists in the intermediate layer: Gravel diameter: 5～10cm	×	△	○												
		Gravel exists in the intermediate layer: Gravel diameter: 10～50cm	×	×	×												
		Liquefiable layer exists	△	○	○												
	Condition of bearing layer	Depth until bearing layer: less than 5m	×	×	×												
		Depth until bearing layer: 5～15m	○	○	△	1	1	0	1	1	0	1	1	0	1	1	0
		Depth until bearing layer: 15～25m	○	○	○												
		Depth until bearing layer: 25～40m	△	○	○												
		Depth until bearing layer: 40～60m	×	○	○												
		Depth until bearing layer: 60m or more	×	△	△												
		Soil property: Cohesive soil(20≦N)	○	○	○												
		Soil property: Sand & Gravel(30≦N)	○	○	○	1	1	1	1	1	1	1	1	1	1	1	1
		Large dip（30 degree or more）	×	○	△												
		Unevenness of bearing layer is severe	△	○	○	0	1	1	0	1	1						
	Condition of ground water	Ground water level : close to ground surface	○	○	○												
		Spring volume : very large	○	○	○												
		Artesian groundwater: more than 2m from the ground surface	○	○	×												
		Velocity of groundwater: 3m/min or more	○	○	×												
Structural features	Scale of load	Vertical load is small	○	○	○				1	1	1				1	1	1
		Vertical load is average	△	○	○	0	1	1				0	1	1			
		Vertical load is large	×	○	○												
		Horizontal load is relatively small to vertical load	○	○	○	1	1	1				1	1	1			
		Horizontal load is relatively large to vertical load	×	○	○				−2	1	1				−2	1	1
	Support style	Bearing pile	○	○	○	1	1	1	1	1	1	1	1	1	1	1	1
		Friction pile	○	○	○												
Construction condition	Underwater construction	Water depth : less than 5m	○	○	○												
		Water depth : more than 5m	△	○	△												
	Narrow work space		△	△	△	0	0	0	0	0	0	0	0	0	0	0	0
	Batter pile		△	○	×												
	Impact of toxic gas		○	○	○												
	Surrounding circumstance	Countermeasures against vibration and noise	×	×	○							−2	−2	1	−2	−2	1
		Impact on adjacent structures	×	△	○							−2	0	1	−2	0	1
						5	7	6	3	7	6	0	3	6	−2	3	6

○: Fitted (1). △: Studies required (0). ×: Can be unfit (-2).

12-1-3 Result of the examination of thefoundation method

The primary selection of steel pile, and in-place concrete-pile foundation types available were compared for workability of construction and economy to decide which foundation type to use for the Bahr Yusef, Ibrahimia, and L type wall.

As for the deep mixing treatment method, the improved soil foundation method considered the regulator and improved soil foundation to be one body structure. Therefore, the bottom layer of improved soil needed a certain bearing capacity to ensure stability.

However, the one body structure caused a long moment arm of horizontal force because of the depth of the improved soil. It

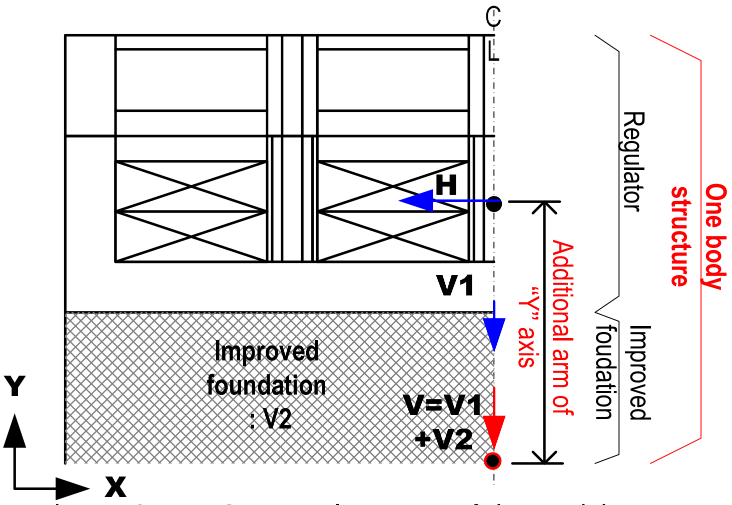
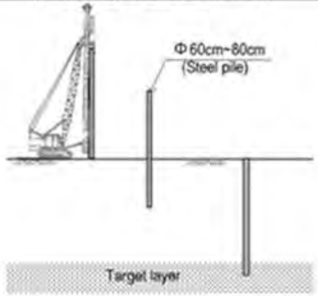
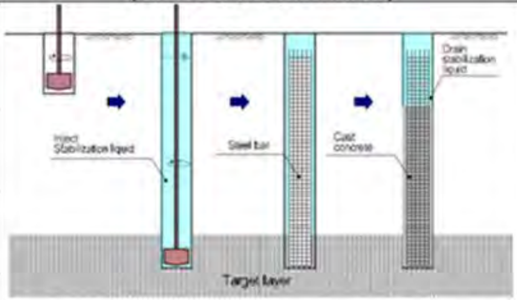
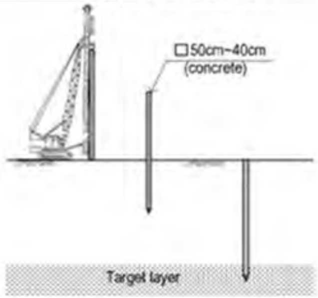


Figure12-1.15 Structural concept of deep mixing treatment method

increased moment by horizontal force. To ensure the long term stability of the bearing capacity of the bottom of the improved soil, a range of soil improvements should be considered. These are done not only through a theoretical equation, but by ensuring consecutive stable bearing layers observed from the actual borehole.

As a result of the evaluation, the cast-in-place RC pile was the foundation selected for the Bahr Yusef and Ibrahimia regulators, as well as the L type walls. These were approved at the 22nd TAC meeting, as they were deemed the most economically advantageous and have been successfully used before in Egypt. The same should be applied to the small, Badraman, Abo Gabal, and Sahelyia regulators.

Table12-1.9 Comparison table of pile foundation

Foundation type	Steel pipe pile (driven by vibro-hammer)	Cast-in-place RC pile (reverse circulation method)	Pre-cast concrete pile (driven by hammer)
Construction process			
Construction method	Driving the steel piles manufactured in the factory using a vibro-hammer into the ground until they reach the target layer. Both end-bearing and surface friction must be taken into consideration when accounting for allowable bearing capacity.	Constructing reinforced concrete piles in-place in the machine-drilled hole. Side surface of borehole is protected by the hydrostatic pressure of stabilization liquid. Both end-bearing and surface friction must be taken into consideration when accounting for allowable bearing capacity.	Driving the concrete piles made onsite by hammer into the ground until they reach the target layer. Both end-bearing and surface friction must be taken into consideration when accounting for allowable bearing capacity.
1. Reliability of Foundation (Evaluation) E: Excellent G: Good P: Poor	G: This is the type mostly used in Japan, but rarely used in Egypt. Therefore, lack of construction experience may be an issue. E: Since the steel is quality-controlled in the factory, high quality is ensured. P: Friction between the pile surface and the ground is smaller than that with concrete. E: High resilience to vertical and horizontal stress is expected. G: No corrosion will occur because piles are driven underground. G: It is possible to check the actual bearing capacity by reaction force during driving. 2points	E: This is the type mostly used in Egypt. Therefore, significant construction experience is expected. G: Concrete quality is relatively difficult to control onsite. E: The friction between the pile surface and the ground is the strongest of all three types, giving high stability to the foundation. E: High resilience to vertical and horizontal stress is expected. E: Pile does not corrode. G: It is possible to check the actual bearing capacity of the target layer using dug soil. 3points	E: This is the type mostly used in Egypt. Therefore, significant construction experience is expected. P: In the case of short piles (less than 5m), the quality of concrete is relatively easy to control onsite, but much harder for longer piles. P: Since the pile is shaped like a column, piles may be broken or damaged during driving work. P: High resilience to vertical stress and low resilience to horizontal stress are expected. E: Pile does not corrode. G: It is possible to check the actual bearing capacity by reaction force during driving. G: The friction between the pile surface and the ground is stronger than that with the steel pipe pile. 1point
2. Ease of Construction (Evaluation) E: Excellent G: Good P: Poor	E: Construction period is the shortest of all three options. E: Construction is not affected by groundwater level. P: Since the piles are transported from stockyard to site, special attention is required to prevent damages incurred en route, particularly to longer piles. G: Block-up by the soil can be generally expected, which makes the bearing capacity on the edge of piles, On the other hand, it is not usually considered in Egypt. Therefore, Enhancement works such as concrete injections may be necessary. E: Since the amount of soil replaced by driving the piles is the least of all three options, no treatment of dug soil is necessary.	P: Since this type requires more steps than the pile driving method, the required work period is longer. G: Borehole should be protected using stabilization liquid. In case groundwater level is very high, casing/stand pipes may be necessary to protect the dug hole, which elevates costs. E: Since the piles are made at the construction yard, there is no transportation impact. E: Pile length is easily adjustable depending on the depth of the borehole. P: Muddy water treatment and dug soil removal are required. G: The work yard is smaller than that in the pre-cast	P: The required work period and the number of piles are the most extensive of all three options. E: Construction is not influenced by groundwater level. P: Since the piles are transported from stockyard to site, special attention is required to prevent damages incurred en route (through vibration for instance), particularly to longer piles. E: Bearing capacity at the bottom of piles can be anticipated. E: Since very little soil is replaced by driving the piles, no treatment for dug soil is necessary. P: The work yard is the largest of all three options because of the concrete casting works required.

Foundation type		Steel pipe pile (driven by vibro-hammer)		Cast-in-place RC pile (reverse circulation method)		Pre-cast concrete pile (driven by hammer)	
		E: The work yard is the smallest of all three options. 3points		concrete pile. 2point		1point	
3. Environmental Aspect (Evaluation) E: Excellent G: Good P: Poor		G: Noise and vibration during driving are slightly more than when using cast-in-place concrete. G: Insignificant impact on adjacent structures. 2points		E: Noise and vibration are the lowest of all three options. E: Insignificant impact on adjacent structures. 3points		P: Noise and vibration are the highest of all three options. P: Impact on adjacent structures must be considered. 1point	
4. Economic Aspect Construction cost for foundation treatment (in Japanese Yen)		112,000,000 yen (ratio : 1.22) Note: materials in Egypt factored into above figure. 2points		92,000,000 yen (ratio : 1.00) Note: materials in Egypt factored into above figure. 3points		158,000,000 yen (ratio : 1.72) Note: materials in Egypt factored into above figure. 1point	
Name of Regulator		**Bahr Yusef regulator**	**Ibrahimia regulator**	**Bahr Yusef regulator**	**Ibrahimia regulator**	**Bahr Yusef regulator**	**Ibrahimia regulator**
Pile specifications	**regulator body**	φ600mm L=14.0m n=108 piles	φ600mm L=10.5m n=96 piles	φ1000mm L=14.0m n=70 piles	φ1000mm L=10.5m n=70 piles	□500mm L=14.0m n=156 piles	□500mm L=10.5m n=144 piles
	L-type wall	φ600mm L=8.5m n=84 piles (42 piles x2 locations)	φ600mm L=8.0m n=66 piles (33 piles x2 locations)	φ1000mm L=8.5m n=54 piles (27 piles x2 locations)	φ1000mm L=8.0m n=54 piles (27 piles x2 locations)	□500mm L=8.5m n=150 piles (75 piles x2 locations)	□500mm L=8.0m n=150 piles (75 piles x2 locations)
Construction period with one machine		1.4 month	1.2 month	3.5 month	3.5 month	1.9 month	1.9 month
		66,000,000	46,000,000	51,000,000	41,000,000	88,000,000	70,000,000
Evaluation		**Total points: 9 points** **Good** ✓This type has some good advantages but is inferior to the cast-in-place RC pile in terms of reliability of foundation and economy. ✓This method is rarely used in Egypt, therefore, lack of construction experience is a disadvantage.		**Total points: 11 points** **Excellent (recommended)** ✓This type has many good advantages such as reliability of foundation, environmental impact, and economy. ✓In addition, this is the method generally used in Egypt, therefore, construction experience is an advantage.		**Total points: 4 points** **Moderate** ✓Regardless of the advantages of this option, quality is less stable than in the other options.	

12-2 Specifications of piles

The pile diameters of the cast-in place RC piles available in Egypt are; 800mm, 900mm, 1,000mm, 1,100mm and 1,200mm. As the odd-numbered pile diameters 900mm and 1,100mm in size are difficult to find in Egypt, they are excluded from consideration. Accordingly, the available piles are 800mm, 1,000mm and 1,200mm in diameter.

The study of pile specifications takes both Egyptian and Japanese codes into consideration. The following tables shows the same basic loading condition as in the stability analysis and a comparison of both codes.

(1) Loading case

Table12-2.1 Loading condition for pile design sourced by stability analysis

Case	Condition	Direction	Water level			Gate situation	Additional condition
Case 1	Normal	Long.	U.S.	WL47.00m	HWL	Open gate	—
			D.S.	WL47.00m	HWL		
Case 2	Normal	Long.	U.S.	WL46.55m	Max.WL	Close gate	sedimentation (0.3m depth)
			D.S.	WL39.50m	Low		
Case 3	Normal	Long.	U.S.	—	No WL	Open gate	—
			D.S.	—	No WL		
Case 4	Normal	Lateral.	U.S.	WL46.55m	Max.WL	Open gate	—
			D.S.	WL46.55m	Max.WL		
Case 5	Normal	Lateral.	U.S.	WL46.55m	Max.WL	Close gate	sedimentation (0.3m depth)
			D.S.	WL39.50m	Low		
Case 6	Normal	Lateral.	U.S.	—	No WL	Open gate	—
			D.S.	—	No WL		
Case 7	Seismic	Long.	U.S.	WL46.55m	Max.WL	Close gate	sedimentation (0.3m depth)
			D.S.	WL39.50m	Low		
Case 8	Seismic	Long.	U.S.	—	No WL	Open gate	—
			D.S.	—	No WL		
Case 9	Seismic	Lateral.	U.S.	WL46.55m	Max.WL	Open gate	—
			D.S.	WL46.55m	Max.WL		
Case 10	Seismic	Lateral.	U.S.	WL46.55m	Max.WL	Close gate	sedimentation (0.3m depth)
			D.S.	WL39.50m	Low		
Case 11	Seismic	Lateral.	U.S.	—	No WL	Open gate	—
			D.S.	—	No WL		
Case 12	Seismic	Long.	U.S.	WL46.55m	Max.WL	Open gate	—
			D.S.	WL46.55m	Max.WL		
Case 13	Normal (Maintenance)	Long.	U.S.	WL46.55m	Max.WL	Maintenance gate	—
			D.S.	WL45.82, 45.13m	Low		

※Maximum operation water level at U.S. is same as head level of gate (WL46.30 + 0.25m＝EL46.55) to ensure safety

※At fully closed gate situation, water level at D.S. is same as apron level（EL39.5）.

(2) Method of evaluation of vertical bearing capacity and pull-out strength

The safety ratio between the calculated vertical bearing capacity and pull-out strength is considered in the table below.

Table12-2.2 Safety ratio for vertical bearing capacity and pull-out strength

	Japanese code		Egyptian code (applied)	
Pile conditions	vertical bearing capacity	pull-out strength	vertical bearing capacity	pull-out strength
Normal	3	6	3	3
Seismic	2	3	2	2

i) Examination of vertical bearing capacity

The vertical bearing capacity for one pile is calculated using the following equation.

Japanese code

$$Ra = \frac{1}{n}(Ru - Ws) + Ws - W$$

Where, Ra: vertical allowable bearing capacity (downward) at pile head (kN/pile)
Ru: ultimate bearing capacity of pile determined by the foundation（kN/ pile）
Ws: effective mass of soil replaced by pile（kN）
W: effective mass of pile and soil inside of the pile（kN）
n: Safety ratio

a. Ru: Ultimate bearing capacity of pile determined by the foundation

Bearing capacity is estimated using the following formula.

$$Ru = qd \cdot A + U \cdot \Sigma Li \cdot fi$$

Where, Ru: ultimate bearing capacity of pile determined by the foundation（kN/ pile）
A: area of pile tip (m^2)
qd: ultimate bearing capacity of pile tip per unit area（kN/m^2）
U: circumference of pile（m）
Li: penetration depth for surface friction layer（m）
fi: maximum surface friction per unit area for surface friction layer（kNm^2）

Egyptian code (applied)

$$Ra = \frac{1}{n}(Ru - P)$$

b. Estimation of ultimate bearing capacity per unit area of pile tip (qd)

Table12-2.3 Ultimate bearing capacity per unit area of pile tip (Unit: kN/m^2)

Foundation type \ Driven method	Japanese code	Egyptian code
	In-placed con-pile	In-placed con-pile
Gravelly layer and sandy layer (N > 30)	3,000	90N (include safety ratio)
Sturdy gravelly layer (N > 50)	5,000	90N (include safety ratio)
Hard cohesive soil	3qu	9 C

qu: unconfined compressive strength (kN/m^2)
N: N value (SPT)

c. Calculation of maximum surface friction per unit area (fi)

Table12-2.4 Surface friction per unit area (Unit: kN/m^2)

Foundation type \ Driven method	Japanese code		Egyptian code	
	Driven pile	In-placed con-pile	Driven pile	In-placed con-pile
Sand	2N（≦100）	5N（≦200）	N (include safety ratio)	N (include safety ratio)
Clay	C or 10N（≦150）	C or 10N（≦150）	C（≦100）	0.4C（≦100）

Note: Due to inaccuracy, it is assumed that there is no surface friction under the soft layer condition (N≦2).

The vertical bearing capacity in the Egyptian code is between “soil failure" and "settlement of pile." The applied allowable displacement on the settlement of regulators is between 50mm to

60mm per pile and should be considered in pile design.

ii) Examination of pull-out direction

The pull-out direction per pile unit can be obtained by the formula below.

Japanese code

$$Pa = \frac{1}{n} Pu + W$$

Where Pa: vertical allowable pull-out strength at pile head (kN/pile)
n: safety ratio (refer Table 2-6-2.1)
Pu: ultimate pull-out strength of pile determined by the foundation (kN/pile)
W: effective mass of pile (kN/pile)

"Pa" must be less than the allowable tensile capacity in axis direction. "Pu" is calculated using the following equation (function of the maximum surface friction per unit area), according to the second paragraph of the equation for ultimate bearing capacity as follows.

$$Pu = U \cdot \Sigma Li \cdot fi$$

Egyptian code (applied)

$$Pa = \frac{1}{n} Pu + P$$

iii) Allowable bearing capacity by pile type

Japanese code

$$P = \sigma \cdot A$$

Where P: allowable bearing capacity by the type of pile（N）
σ: allowable stress of pile itself（N/mm^2）
A: sectional area of pile（mm^2）

Egyptian code (applied: same as Japanese code)

$$P = \sigma \cdot A$$

(3) Method of counterforce against pile and displacement of footing

Japanese code

This is calculated using the "displacement method" that assumes the following conditions.

- ✓ Pile foundation is a two-dimensional structure.
- ✓ Pile is linear elastic given any force such as pushing, pulling and bending. Vertical, horizontal, and rotational spring are constant values regardless of load at the pile head. A value accounting for the pushing and pull-out is applied to the spring constant.
- ✓ Footing is the rigid body, and the center of rotation is the centroid of group piles.

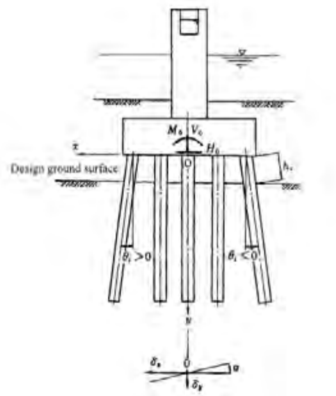


Figure 12-2.1 Model of displacement method

Egyptian code (applied)

It is the same as Japanese code

(4) Design of pile body and layout

The calculations arrived at by the displacement method provide the horizontal force and moment that act on the pile, and as such must be taken into consideration in pile body design.

Table 12-2.5: Allowable stress of pile (Egyptian code)

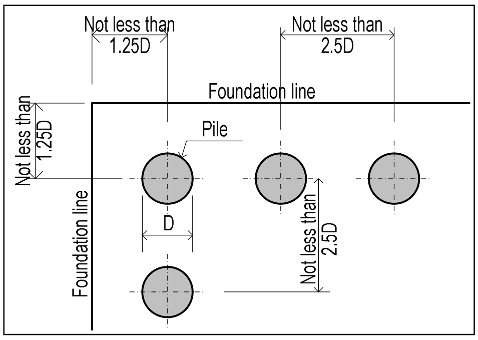
Pile type	Normal	Seismic
In-placed con-pile	σc: 9.5N/mm^2 σs: 200N/mm^2	σc: 10.9N/mm^2 σs: 230N/mm^2

The allowable stress of steel pile is applied to the Egyptian figures provided in the working group meeting, shown in Table 12-2.5. In addition, 15mm allowable horizontal displacement at pile head is applied. This figure is sourced from the Japanese standard since there is no figure provided in the Egyptian code.

(5) Pile layout

Layout should follow Japanese standards, as their underlying concept is to avoid the negative impact of the interaction of closely set piles. The minimum distance between piles is shown in Table 12-2.6.

Table 12-2.6: Necessary distance between piles

Japanese code	Egyptian code
	✓ Spacing between piles is no less than 2.5 D for bearing piles. (←our case) ✓ Spacing between piles is no less than 3.0 D for friction piles.

12-3 Results of pile foundation design

The design method of the pile foundation in both the Egyptian and the Japanese codes applies the displacement method. Therefore, the number of piles should be in accordance with the Japanese code because the design method was consolidated according to the Egyptian code. After that, the number of piles arrived at by the Japanese code should be re-evaluated against the Egyptian code.

The pile foundation designs are shown in Table 12-3.1, and Figures 12-3.1, and 12-3.2. The comparison between piles is shown in Tables 12-3.2 and 12-3.3.

Table12-3.1 Specifications of pile design at Bahr Yusef and Ibrahimia regulators

Structure	Nos. of piles	dia.	Length of piles	note
Bahr Yusef regulator	8x9=72	1,000mm	13.5m	Cast in-place concrete pile
Ibrahimia regulator	7x8=56	1,000mm	15.0m	Cast in-place concrete pile
Bahr Yusef L-type wall	2x8=16	1,000mm	7.5m	Cast in-place concrete pile
Ibrahimia L-type wall	2x8=16	1,000mm	7.0m	Cast in-place concrete pile

Table12-3.2 Comparison table of economic pile specifications at Bahr Yusef and Ibrahimia regulators

Bahr Yusef Reg

Dia pile	weir dir.	flow dir.	length	Compressive(kN/pile) : normal			Stress in pile body(kN/mm2) : seismic						Dia. Steel	nos./pile	Cost(LE)
(mm)			(m)	Actual		Allowable	σc		σca	σs		σsa	(mm)		
800	10	9	14.0	1,587.25	<	1,598.97	10.15	<	10.93	108.48	<	230	φ32	17	3,758,629
1,000	8	7	16.5	2,540.21	<	2,601.60	10.17	<	10.93	122.35	<	230	φ32	20	3,460,204
1,000	9	8	13.5	1,981.25	<	1,993.31	10.67	<	10.93	174.29	<	230	φ25	14	2,855,727
1,000	10	9	12.0	1,587.37	<	1,706.45	9.58	<	10.93	175.87	<	230	φ33	11	3,372,756
1,200	7	6	17.5	3,378.20	<	3,474.82	10.69	<	10.93	158.83	<	230	φ32	16	3,105,815
1,200	8	7	14.5	2,539.51	<	2,749.67	10.51	<	10.93	219.82	<	230	φ22	15	2,922,933
1,200	9	8	12.0	1,978.99	<	2,179.94	8.31	<	10.93	169.55	<	230	φ22	14	3,107,958

Ibrahimia Reg

Dia pile	weir dir.	flow dir.	length	Compressive(kN/pile) : normal			Stress in pile body(kN/mm2) : seismic						Dia. Steel	nos./pile	Cost(LE)
(mm)			(m)	Actual		Allowable	σc		σca	σs		σsa	(mm)		
800	9	8	15.0	1,980.17	<	2,029.80	10.40	<	10.93	99.49	<	230	φ32	17	3,237,118
800	10	9	12.5	1,590.93	<	1,635.84	10.77	<	10.93	126.61	<	230	φ32	8	2,649,235
1,000	7	6	19.0	3,381.66	<	3,424.72	10.85	<	10.93	116.92	<	230	φ32	23	3,167,174
1,000	8	7	15.0	2,540.71	<	2,633.03	10.24	<	10.93	126.34	<	230	φ25	11	2,365,002
1,000	9	8	12.0	1,981.55	<	2,057.73	10.21	<	10.93	168.11	<	230	φ22	11	2,375,476
1,000	10	9	10.0	1,585.93	<	1,668.96	8.13	<	10.93	133.46	<	230	φ22	11	2,507,964
1,200	6	5	21.0	4,583.53	<	4,697.98	10.23	<	10.93	118.18	<	230	φ32	30	3,307,029
1,200	7	6	15.5	3,378.49	<	3,395.82	9.36	<	10.93	124.22	<	230	φ32	15	2,753,879
1,200	8	7	12.0	2,541.10	<	2,591.17	8.72	<	10.93	149.02	<	230	φ22	15	2,497,987
1,200	9	8	9.5	1,979.09	<	2,003.85	6.78	<	10.93	115.84	<	230	φ22	15	2,593,857

L type wall - Bahr Yusef

Dia pile	weir dir.	flow dir.	length	Compressive(kN/pile) : normal			Stress in pile body(kN/mm2) : normal						Dia. Steel	nos./pile	Cost(LE)
(mm)			(m)	Actual		Allowable	σc		σca	σs		σsa	(mm)		(2sets)
800	3	9	7.0	592.62	<	655.25	9.482	<	9.50	199.36	<	200	φ32	15	1,345,516
800	3	10	7.0	533.36	<	655.25	8.846	<	9.50	190.66	<	200	φ32	14	1,432,117
800	3	11	6.5	484.87	<	622.45	8.543	<	9.50	189.07	<	200	φ32	13	1,437,768
1,000	2	8	7.5	942.88	<	1,030.99	9.075	<	9.50	193.50	<	200	φ32	24	1,001,270
1,000	3	6	7.5	970.36	<	1,030.99	7.898	<	9.50	199.56	<	200	φ32	20	1,280,000
1,000	3	7	7.0	840.99	<	892.24	7.333	<	9.50	194.10	<	200	φ32	18	1,335,494
1,000	3	8	7.0	735.87	<	892.24	6.854	<	9.50	189.52	<	200	φ25	25	1,418,760
1,200	2	7	7.0	1,138.51	<	1,158.81	7.579	<	9.50	199.88	<	200	φ32	26	1,255,522
1,200	2	8	7.0	996.19	<	1,158.81	7.026	<	9.50	196.46	<	200	φ32	23	1,342,969
1,200	3	5	8.0	1,252.37	<	1,874.66	6.353	<	9.50	193.99	<	200	φ32	23	1,397,025
1,200	3	6	7.5	1,058.50	<	1,206.69	5.913	<	9.50	194.678	<	200	φ25	30	1,453,547
1,200	3	7	7.0	920.04	<	1,158.81	5.641	<	9.50	195.784	<	200	φ25	26	1,513,867
1,200	3	8	7.0	805.04	<	1,158.81	5.282	<	9.50	191.901	<	200	φ25	23	1,642,201

L type wall - Ibrahimia

Dia pile	weir dir.	flow dir.	length	Compressive(kN/pile) : normal			Stress in pile body(kN/mm2) : normal						Dia. Steel	nos./pile	Cost(LE)
(mm)			(m)	Actual		Allowable	σc		σca	σs		σsa	(mm)		(2sets)
800	3	9	6.5	568.17	<	684.15	9.424	<	9.50	185.316	<	200	φ32	17	1,341,216
800	3	10	6.5	511.35	<	684.15	9.327	<	9.50	197.787	<	200	φ32	14	1,362,997
800	3	11	6.5	464.87	<	684.15	8.809	<	9.50	191.898	<	200	φ32	13	1,437,768
					<			<			<				
1,000	2	8	7.0	827.66	<	1,480.96	7.675	<	9.50	199.042	<	200	φ32	24	939,146
1,000	3	6	7.0	936.20	<	1,480.96	8.064	<	9.50	190.875	<	200	φ32	22	1,264,796
1,000	3	7	7.0	802.46	<	1,480.96	7.563	<	9.50	196.156	<	200	φ32	18	1,335,494
1,000	3	8	6.0	712.16	<	726.90	7.459	<	9.50	197.304	<	200	φ32	17	1,318,850
					<			<			<				
1,200	2	7	6.5	1,121.57	<	1,329.64	8.004	<	9.50	198.258	<	200	φ32	28	1,226,587
1,200	2	8	6.0	997.83	<	1,069.70	7.772	<	9.50	199.189	<	200	φ32	27	1,278,857
1,200	3	5	7.0	1,251.10	<	1,905.13	6.664	<	9.50	191.900	<	200	φ32	25	1,309,795
1,200	3	6	6.5	1,073.20	<	1,329.64	6.270	<	9.50	192.222	<	200	φ32	22	1,386,235
1,200	3	7	6.0	953.49	<	1,069.70	6.180	<	9.50	196.646	<	200	φ25	31	1,429,321
1,200	3	8	6.0	834.31	<	1,069.70	5.839	<	9.50	195.440	<	200	φ25	27	1,536,095

Table12-3.3 Pile bearing capacity according to Egyptian code
(Comparison between "soil failure" and "settlement of pile")

	EGY code										
	Qallowable according to soil failure										Qallowable by settelement
	Dia	Length	Bearing capacity at pile end			Pile friction capacity				Qallowable by soil failure	
			Bearing range	N	Qb-allowable	Friction range	N ave. F	safe factor	Qb-allowable		
	(mm)	(m)	(m)	ave. of Be. rabge	(kN)	(m)	ave. of Fr. rabge	for SPT	(kN)	(kN)	(50 - 60) mm (kN)
Bahr Yusef	1,000	13.5	4.00	40.0	2,827.4	8.5	13.6	1	363.2	**3191**	**1778 - 2051 (applied)**
Ibrahimia	1,000	15.0	4.00	40.0	2,827.4	10.0	26.2	1	823.1	**3651**	**2382 - 2776 (applied)**

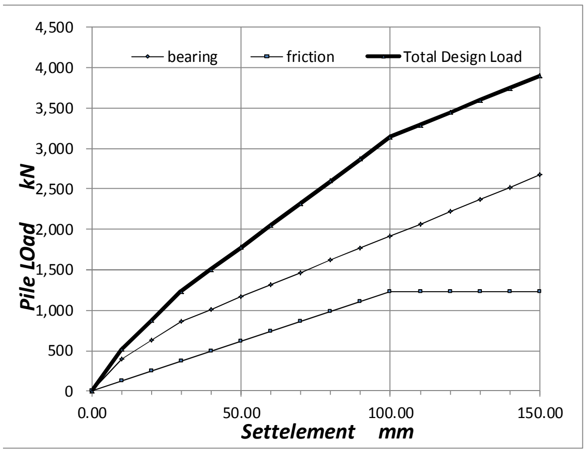
Table12-3.4 Comparison between bearing capacity in Egyptian code and Japanese code

	Egyptian code Allowable bearing capacity by settlement (kN/pile)	Japanese code Allowable bearing capacity by soil failure (kN/pile)	Judgement
Bahr Yusef	less than 2051	1993.31(reg.), 1030.99(L type)	Allowable bearing capacities by Japanese code are less than "allowable by soil failure" by Egyptian code and allowable one by Japanese are within the allowable one by settlement in Egyptian code. Therefore the pile arrangement by its designs are acceptable and complied with Egyptian code.
Ibrahimia	less than 2776	2,633.03(reg.), 1480.96(L type)	

Table12-3.5 Bearing capacity for target settlement

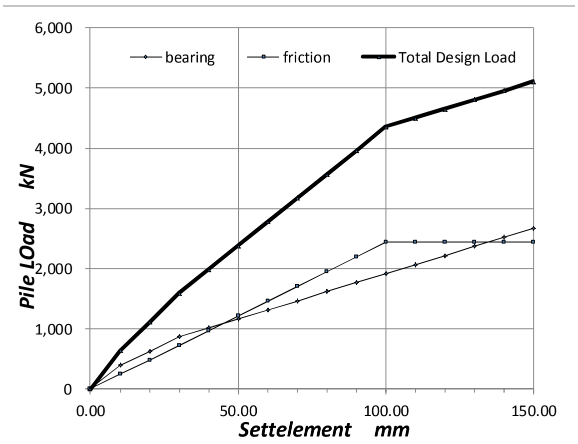
Bahr Yusef

Design Settlement (mm)	Allowable bearing capacity per unit for design settlement	Bearing capacity kN/pile	Friction on surface kN/pile	Total Load kN/pile	Allowable B.C. by JP code kN/pile	Assumed settlement (mm)
0		0	0	**0**	50mm-60mm	
10	5	393	123	**515**		
20	8	628	245	**873**		
30	11	864	368	**1,232**		
40	13	1,014	490	**1,505**		
50	15	1,165	613	**1,778**	**1993**	**57.9**
60	17	1,316	735	**2,051**		
70	19	1,466	858	**2,324**		
80	21	1,617	980	**2,597**		
90	23	1,767	1,103	**2,870**		
100	24	1,918	1,225	**3,143**		
110	26	2,068	1,225	**3,293**		
120	28	2,219	1,225	**3,444**		
130	30	2,369	1,225	**3,595**		
140	32	2,520	1,225	**3,745**		
150	34	2,670	1,225	**3,896**		



Ibrahimia

Design Settlement (mm)	Allowable bearing capacity per unit for design settlement	Bearing capacity kN/pile	Friction on surface kN/pile	Total Load kN/pile	Allowable B.C. by JP code kN/pile	Assumed settlement (mm)
0		0	0	**0**	50mm-60mm	
10	5	393	243	**636**		
20	8	628	487	**1,115**		
30	11	864	730	**1,594**		
40	13	1,014	974	**1,988**		
50	15	1,165	1,217	**2,382**	**2633**	**56.4**
60	17	1,316	1,461	**2,776**		
70	19	1,466	1,704	**3,170**		
80	21	1,617	1,948	**3,564**		
90	23	1,767	2,191	**3,958**		
100	24	1,918	2,435	**4,352**		
110	26	2,068	2,435	**4,503**		
120	28	2,219	2,435	**4,653**		
130	30	2,369	2,435	**4,804**		
140	32	2,520	2,435	**4,955**		
150	34	2,670	2,435	**5,105**		



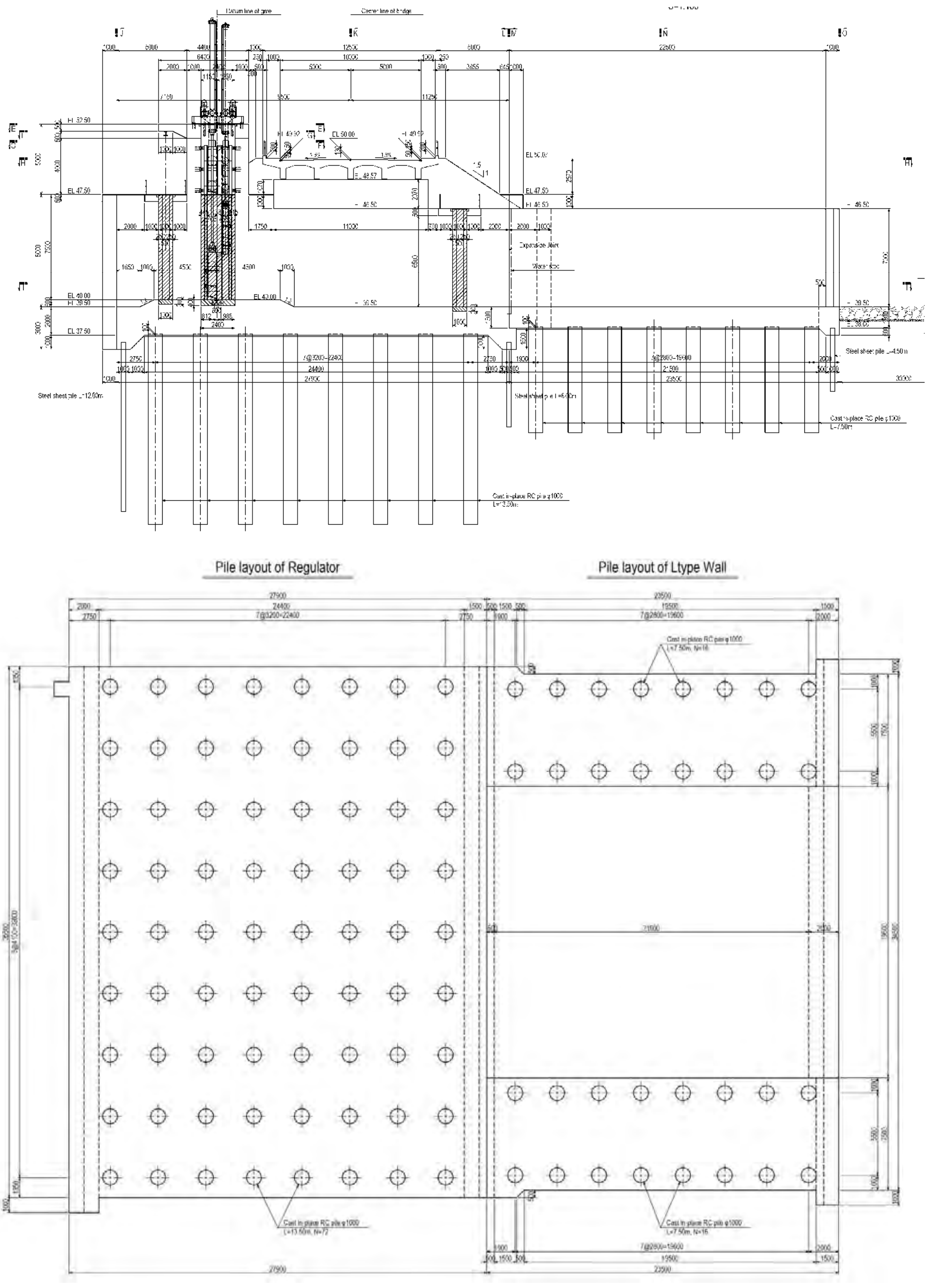


Figure12-3.1 Pile layout and design of Bahr Yusef regulator and L-type wall

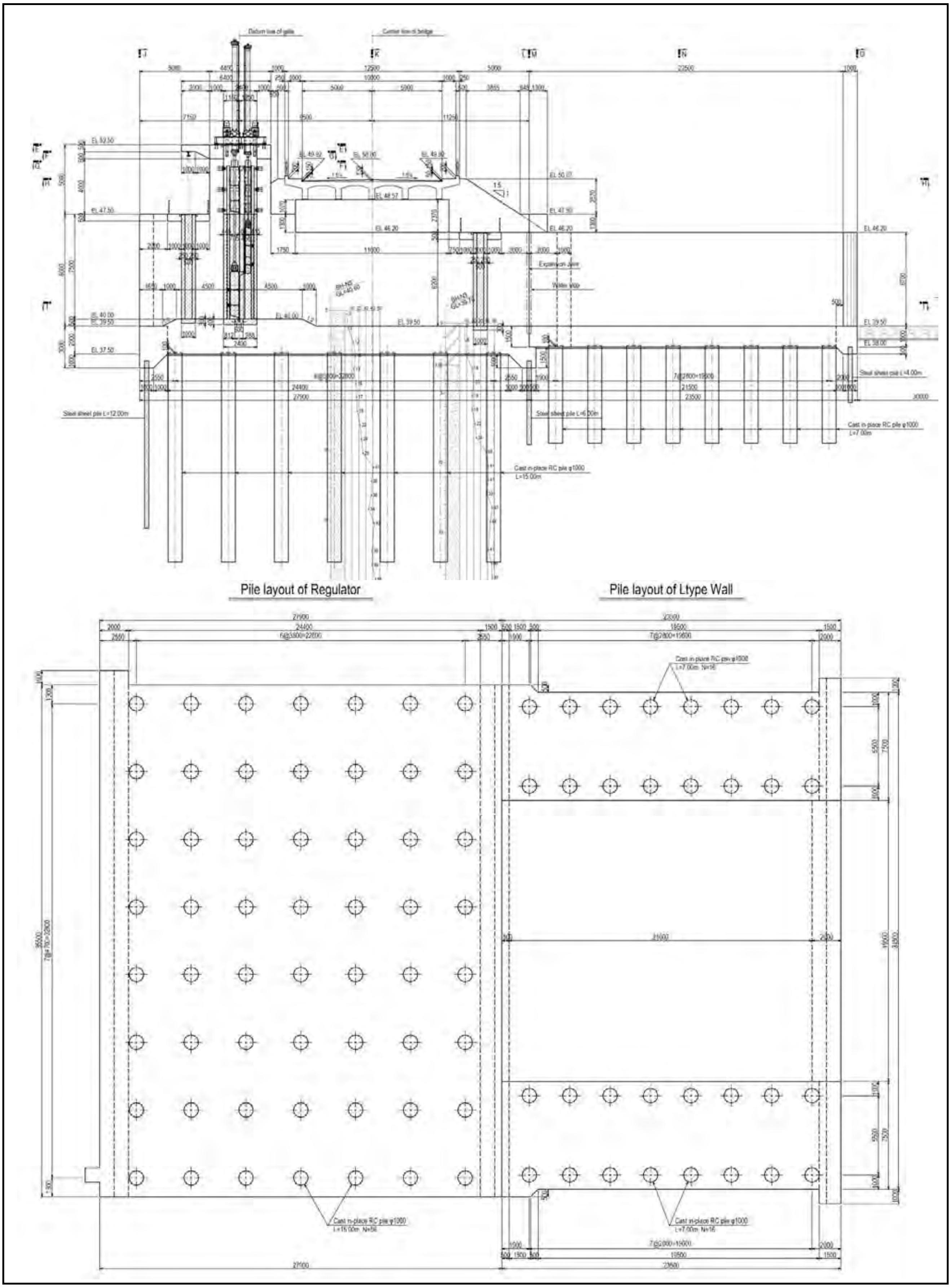


Figure12-3.2 Pile layout and design of Ibrahimia regulator and L-type wall

13. Design of Bank Protection Works

13-1 Selection of construction method

The bank protection principally depends on the surface conditions of the construction area. The steel sheet pile method is applied in the area where it is hard to work with cofferdam in dry conditions, whereas the stone pitching method is applied in the area where it is possible to work in dry conditions.

As the results of the 3D flow analysis and the hydraulic model study done by Egyptian side, it was confirmed that vortexes were generated on downstream left bank of the Bahr Yusef Regulator and on the downstream right bank of the Ibrahimia Regulator. Therefore, it was decided to shape the flow channels by embankments as a solution to minimize the vortexes. Through the comparative analysis regarding the engineering methods as described below, the gabion construction method was chosen for the bank protection method at these embankments.

13-2 Design of steel sheet pile work

(1) Policy to select type of steel sheet pile work

Considering the shape of the structure, conditions of the foundation, workability and construction costs, the free-standing cantilever selected steel sheet pile method is best. From a safety perspective, tie-rod steel sheet pile method can be also selected in case the free-standing cantilever sheet pile does not have enough stability considering its structure.

(2) Cross-sectional map for steel sheet pile

There are thirteen types to be considered, all shown in Figure 13-2.1.

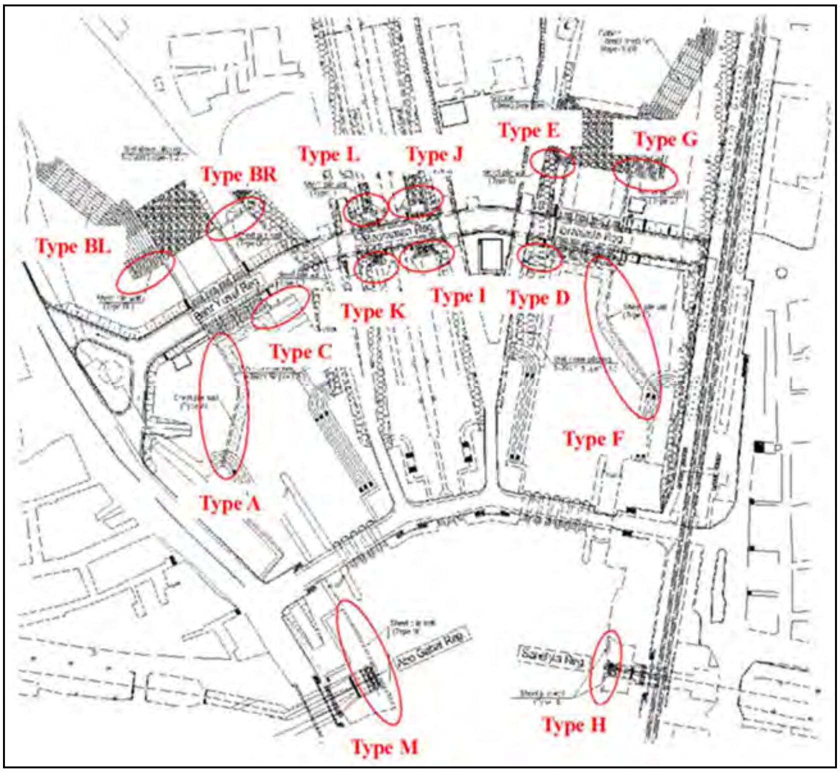


Figure13-2.1 Location map for each type of sheet pile

(3) Type and scale of the sheet pile method

① Steel materials in use

Upon the supply of the steel materials (e.g. steel sheet piles, steel channel and tie-rods) for the sheet pile construction work, tie-rods including attachment are procured from Japan based on the results of the study of materials procurement, and other materials supplied by the third party countries where Egypt has the procurement record thereof.

The steel sheet piles that were adopted were procured from ArcelorMittal, the world's largest steel manufacturer, having its main office in Luxemburg. The cross-sectional performance and the specifications of the steel sheet piles in use are shown in Table 13-2.1 and in Table 13-2.2 respectively.

Table 13-2.1 Sectional performance of steel sheet piles

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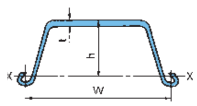


	Type	Width	Height	Thickness	Sectional area	Mass		Moment of inertia	Elastic section modulus
						single pile	wall		
		w mm	h mm	t mm	A cm^2/m	kg/m	kg/m^2	I cm^4/m	Z cm^3/m
Steel Sheet pile	PU12	600	180	9.8	140.0	66.1	110	21,600	1,200
	PU18	600	215	11.2	163.0	76.9	128	38,650	1,800
	PU22	600	225	12.1	183.0	86.1	144	49,460	2,200
	PU28	600	227	15.2	216.0	101.8	170	64,460	2,840
	PU32	600	226	19.5	242.0	114.1	190	72,320	3,200
Reference (Japan)	SP-Ⅱw	600	130	10.3	131.2	61.8	103	13,000	1,000
	SP-Ⅲw	600	180	13.4	173.2	81.6	136	32,400	1,800
	SP-Ⅳw	600	210	18.0	225.5	106.0	177	56,700	2,700

Table 13-2.2 Specifications of steel materials

	Grade	Yield point	Tensile Strength	Allowable Stress
		N/mm^2	N/mm^2	N/mm^2
Steel Sheet pile	S270GP	270	410	165
	S320GP	320	440	195
	S355GP	355	480	215
	S390GP	390	490	235
	S430GP	430	510	260
Reference (Japan)	SY295	295	490	180
	SY390	390	540	235

② Design method of steel sheet pile work

The design method of steel sheet pile work is different depending upon the structure types and many design methods have been proposed. In this design, the following design methods were used:

- The free-standing cantilever steel sheet pile method: Y. L. Chang's formula
- Tie-rod steel sheet pile method: Free earth support method

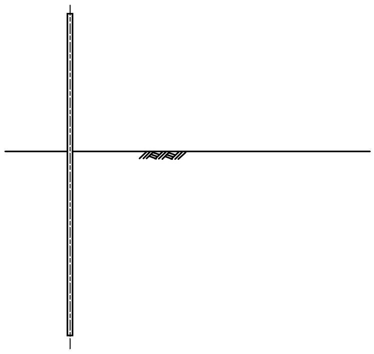
On the corrosion-resistant protection of the steel sheet piles, it was confirmed to use the "Corrosion-resistant Coating Method" that is widely used in Egypt through the discussions with the Design WG. Therefore, no corrosion allowance was considered in the design.

For the tie-rod steel sheet pile method, it is necessary to construct the embankments by installing the brace type steel sheet piles in the embankments in order to secure the structural safety of the tie-rod steel sheet pile work. The steps of the tie-rod type steel sheet pile work and embankment work are shown in Figure 13-2.2.

Therefore, the design of the tie-rod steel sheet pile work is conducted including the design of the completed form and the design in the conditions that the front steel sheet piles are in free-standing state during the construction and the primary embankment form is also set.

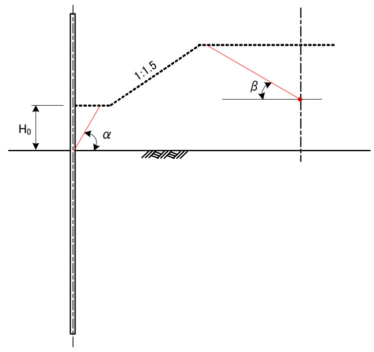
The results of examination of the steel sheet pile work are shown in Table 13-2.3 to Table 13-2.5 and Figure 13-2.3 to Figure 13-2.5.

Step 1



● Place the front steel sheet pile.

Step 2

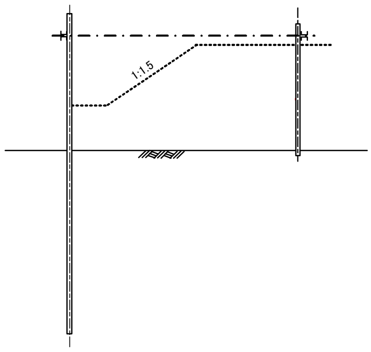


● Construct the primary embankment.

The embankment is constructed at the height (H_0) to secure the safety of the free-standing front steel sheet pile, and formed so as to give no further impact of the embankment weight on the domain within the active collapse angle (α).

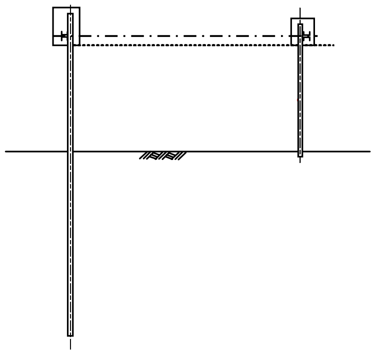
The section in the level of passive collapse angle (β) or larger is secured to expect the passive earth pressure for the brace type steel sheet pile.

Step 3



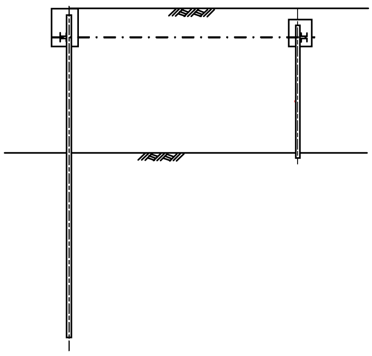
● Install the tie-rod and waling material.

Step 4



● Construct the secondary embankment and the head concrete.

Step 5



● Construct the embankment up to the planed height and complete it.

Figure 13-2.2 Construction procedure of tie-rod type steel sheet pile work

Table13-2.3 Result of the consideration for bank protection works (1/3)

	Regulator Name	New Bahr Yusef Regulator																			
	Type	A			BL-1			BL-2		BR-1			BR-2			C-1			C-2		
	Construction Length	66.60m			6.60m			6.60m		4.80m			9.00m			3.60m			9.00m		
	Sheet Pile Type	Tie-Rod			Tie-Rod			Free-standing cantilever		Tie-Rod			Tie-Rod			Tie-Rod			Tie-Rod		
		Long time	Sort time (Seismic)	During construction (H=3.00m)	Long time	Sort time (Seismic)	During construction (H=2.00m)	Long time	Sort time (Seismic)	Long time	Sort time (Seismic)	During construction (H=2.00m)	Long time	Sort time (Seismic)	During construction (H=3.50m)	Long time	Sort time (Seismic)	During construction (H=3.50m)	Long time	Sort time (Seismic)	During construction (H=4.00m)
Front sheet pile	Model	PU18			PU18			PU18		PU18			PU18			PU18			PU18		
	Length m	21.50			16.50			11.00		16.50			11.50			19.00			17.00		
	Stress N/mm^2	157 (<165)	86 (<190)	35 (<165)	114 (<165)	60 (<190)	40 (<165)	78 (<165)	60 (<190)	114 (<165)	61 (<190)	40 (<165)	25 (<165)	17 (<190)	63 (<165)	157 (<165)	86 (<190)	48 (<165)	41 (<165)	36 (<190)	67 (<165)
	Penetration depth m	14.20			9.70			7.70		9.70			7.20			11.70			12.20		
		(>14.14)	(>7.58)	(>7.29)	(>9.38)	(>5.51)	(>7.57)	(>7.47)	(>7.55)	(>9.38)	(>5.52)	(>7.57)	(>6.80)	(>5.49)	(>7.15)	(>11.58)	(>7.92)	(>6.87)	(>12.10)	(>11.31)	(>7.06)
	Horizontal displacement mm			29.48 (<50.00)			32.72 (<50.00)	35.12 (<50.00)	27.70 (<75.00)			32.72 (<50.00)			32.38 (<50.00)			39.04 (<50.00)			40.56 (<50.00)
Bracing sheet pile	Model	PU12			PU12					PU12			PU12			PU12			PU12		
	Length m	6.00			6.00					6.00			6.00			6.00			6.00		
	Stress N/mm^2	57 (<165)	37 (<190)		42 (<165)	26 (<190)				42 (<165)	26 (<190)		17 (<165)	13 (<190)		57 (<165)	37 (<190)		27 (<165)	25 (<190)	
	Penetration depth m	5.70			5.70					5.70			5.70			5.70			5.70		
		(>5.43)	(>5.43)		(>5.43)	(>5.43)				(>5.43)	(>5.43)		(>5.43)	(>5.43)		(>5.43)	(>5.43)		(>5.43)	(>5.43)	
	Horizontal displacement mm	8.11 (<50.00)	5.27 (<75.00)		5.93 (<50.00)	3.65 (<75.00)				5.93 (<50.00)	3.67 (<75.00)		2.43 (<50.00)	1.80 (<75.00)		8.11 (<50.00)	5.27 (<75.00)		3.86 (<50.00)	3.52 (<75.00)	
Tie-Rod	Diameter φ mm	Φ46			Φ42					Φ42			Φ25			Φ46			Φ32		
	Pitch @ m	@2.40			@2.40					@2.40			@2.40			@2.40			@2.40		
	Stress N/mm^2	170 (<176)	111 (<264)		150 (<176)	92 (<264)				150 (<176)	92 (<264)		173 (<176)	128 (<264)		170 (<176)	111 (<264)		168 (<176)	153 (<264)	
Wale	Specification	2×UPN-220×80			2×UPN-200×75					2×UPN-200×75			2×UPN-180×70			2×UPN-220×80			2×UPN-180×70		
	Stress N/mm^2	139 (<140)	90 (<210)		130 (<140)	80 (<210)				130 (<140)	80 (<210)		68 (<140)	50 (<210)		139 (<140)	90 (<210)		108 (<140)	98 (<210)	
Location of bracing sheet pile	m	11.00			11.00					11.00			6.50			10.00			6.50		
		(>7.33)	(>8.63)		(>7.04)	(>8.36)				(>7.04)	(>8.35)		(>5.59)	(>6.43)		(>7.33)	(>8.63)		(>5.88)	(>6.45)	

Table13-2.4 Result of the consideration for bank protection works (2/3)

Regulator Name		New Ibrahimia Regulator																	
Type		D-1			D-2		E-1			E-2		F			G-1			G-2	
Construction Length		3.60m			5.40m		3.00m			1.80m		72.60m			6.60m			6.00m	
Sheet Pile Type		Tie-Rod			Free-standing cantilever		Tie-Rod			Free-standing cantilever		Tie-Rod			Tie-Rod			Free-standing cantilever	
		Long time	Sort time (Seismic)	During construction (H=4.50m)	Long time	Sort time (Seismic)	Long time	Sort time (Seismic)	During construction (H=4.50m)	Long time	Sort time (Seismic)	Long time	Sort time (Seismic)	During construction (H=3.50m)	Long time	Sort time (Seismic)	During construction (H=3.50m)	Long time	Sort time (Seismic)
Front sheet pile	Model	PU18			PU12		PU12			PU12		PU18			PU12			PU12	
	Length m	16.00			9.50		13.50			8.00		17.50			15.00			9.50	
	Stress N/mm^2	157	86	79	106	99	135	74	38	31	34	157	86	43	135	75	62	88	78
		(<165)	(<190)	(<165)	(<165)	(<190)	(<165)	(<190)	(<165)	(<165)	(<190)	(<165)	(<190)	(<165)	(<165)	(<190)	(<165)	(<165)	(<190)
	Penetration depth m	8.70			6.70		7.50			6.50		10.20			9.00			7.00	
		(>8.55)	(>1.96)	(>7.44)	(>6.39)	(>6.59)	(>7.44)	(>1.25)	(>6.31)	(>6.06)	(>6.33)	(>9.90)	(>5.85)	(>6.71)	(>8.92)	(>4.97)	(>5.89)	(>6.17)	(>6.31)
	Horizontal displacement mm			36.67	48.11	46.60			12.26	9.57	10.92			33.22			43.37	36.83	33.51
				(<50.00)	(<50.00)	(<75.00)			(<50.00)	(<50.00)	(<75.00)			(<50.00)			(<50.00)	(<50.00)	(<75.00)
Bracing sheet pile	Model	PU12					PU12					PU12			PU12				
	Length m	6.00					6.00					6.00			6.00				
	Stress N/mm^2	57	37				42	28				57	37		42	28			
		(<165)	(<190)				(<165)	(<190)				(<165)	(<190)		(<165)	(<190)			
	Penetration depth m	5.70					5.70					5.70			5.70				
		(>5.43)	(>5.43)				(>5.43)	(>5.43)				(>5.43)	(>5.43)		(>5.43)	(>5.43)			
	Horizontal displacement mm	8.11	5.27				5.97	3.93				8.11	5.27		5.97	3.99			
		(<50.00)	(<75.00)				(<50.00)	(<75.00)				(<50.00)	(<75.00)		(<50.00)	(<75.00)			
Tie-Rod	Diameter φ mm	Φ46					Φ42					Φ46			Φ42				
	Pitch @ m	@2.40					@2.40					@2.40			@2.40				
	Stress N/mm^2	170	111				150	99				170	111		150	101			
		(<176)	(<264)				(<176)	(<264)				(<176)	(<264)		(<176)	(<264)			
Wale	Specification	2×UPN-220×80					2×UPN-200×75					2×UPN-220×80			2×UPN-200×75				
	Stress N/mm^2	139	90				131	86				139	90		131	88			
		(<140)	(<210)				(<140)	(<210)				(<140)	(<210)		(<140)	(<210)			
Location of bracing sheet pile	m	9.00					8.00					10.50			9.00				
		(>7.33)	(>8.63)				(>6.57)	(>7.60)				(>7.33)	(>8.63)		(>6.57)	(>7.65)			

Table13-2.5 Result of the consideration for bank protection works (3/3)

Regulator Name			New Sahelyia Regulator			New Badraman Regulator (Diroutiah)				New Badraman Regulator (Badraman)				New Abo Gabal Regulator		
Type			H			I		J		K		L		M		
Construction Length			19.20m			6.60m		4.20m		6.60m		3.60m		45.00m		
Sheet Pile Type			Tie-Rod			Free-standing cantilever		Free-standing cantilever		Free-standing cantilever		Free-standing cantilever		Tie-Rod		
			Long time	Sort time (Seismic)	During construction (H=3.50m)	Long time	Sort time (Seismic)	Long time	Sort time (Seismic)	Long time	Sort time (Seismic)	Long time	Sort time (Seismic)	Long time	Sort time (Seismic)	During construction (H=3.40m)
Front sheet pile	Model		PU12			PU12		PU12		PU18		PU12		PU12		
	Length	m	11.00			9.00		8.00		10.00		8.00		9.50		
	Stress	N/mm^2	93 (<165)	52 (<190)	49 (<165)	104 (<165)	71 (<190)	45 (<165)	28 (<190)	87 (<165)	59 (<190)	58 (<165)	36 (<190)	49 (<165)	28 (<190)	46 (<165)
	Penetration depth	m	5.75			5.50		5.60		6.20		5.30		5.30		
			(>5.29)	(>1.58)	(>5.36)	(>5.21)	(>5.21)	(>5.21)	(>5.21)	(>6.06)	(>6.06)	(>5.25)	(>5.25)	(>1.39)	(>0.86)	(>5.23)
	Horizontal displacement	mm			31.29 (<50.00)	39.00 (<50.00)	26.84 (<75.00)	12.81 (<50.00)	7.93 (<75.00)	35.12 (<50.00)	23.83 (<75.00)	18.13 (<50.00)	11.16 (<75.00)			23.16 (<50.00)
Bracing sheet pile	Model		PU12											PU12		
	Length	m	6.00											6.00		
	Stress	N/mm^2	35 (<165)	24 (<190)										25 (<165)	18 (<190)	
	Penetration depth	m	5.70											5.70		
			(>5.43)	(>5.43)										(>5.43)	(>5.43)	
	Horizontal displacement	mm	4.90 (<50.00)	3.34 (<75.00)										3.60 (<50.00)	2.51 (<75.00)	
Tie-Rod	Diameter φ	mm	Φ42											Φ32		
	Pitch @	m	@2.40											@2.40		
	Stress	N/mm^2	151 (<176)	103 (<264)										156 (<176)	109 (<264)	
Wale	Specification		2×UPN-180×70											2×UPN-160×65		
	Stress	N/mm^2	137 (<140)	93 (<210)										130 (<140)	91 (<210)	
Location of bracing sheet pile		m	7.50											6.50		
			(>6.14)	(>7.08)										(>5.54)	(>6.29)	

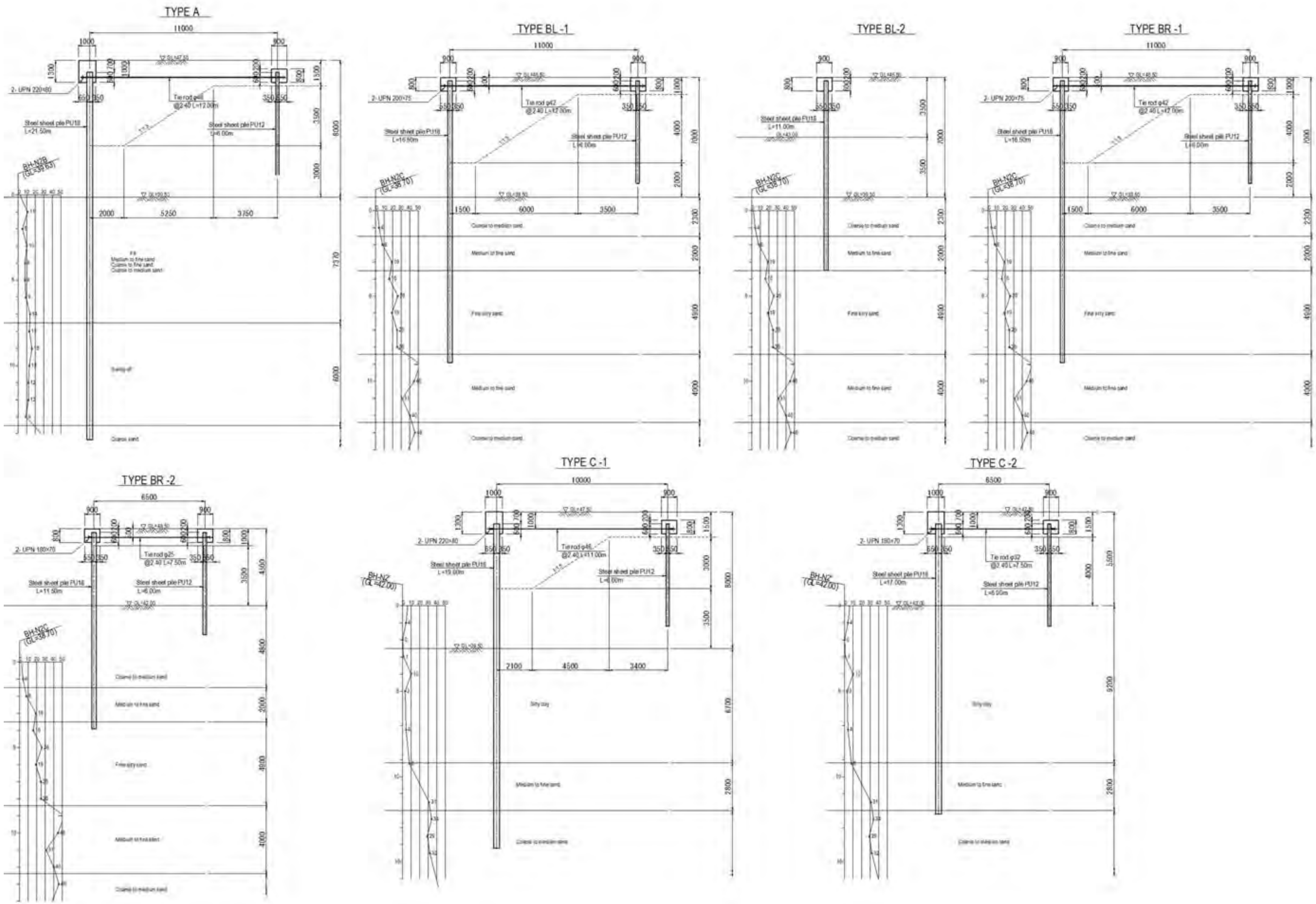


Figure13-2.3 Cross-sectional map of the sheet pile method for each case (case A – C) (1/3)

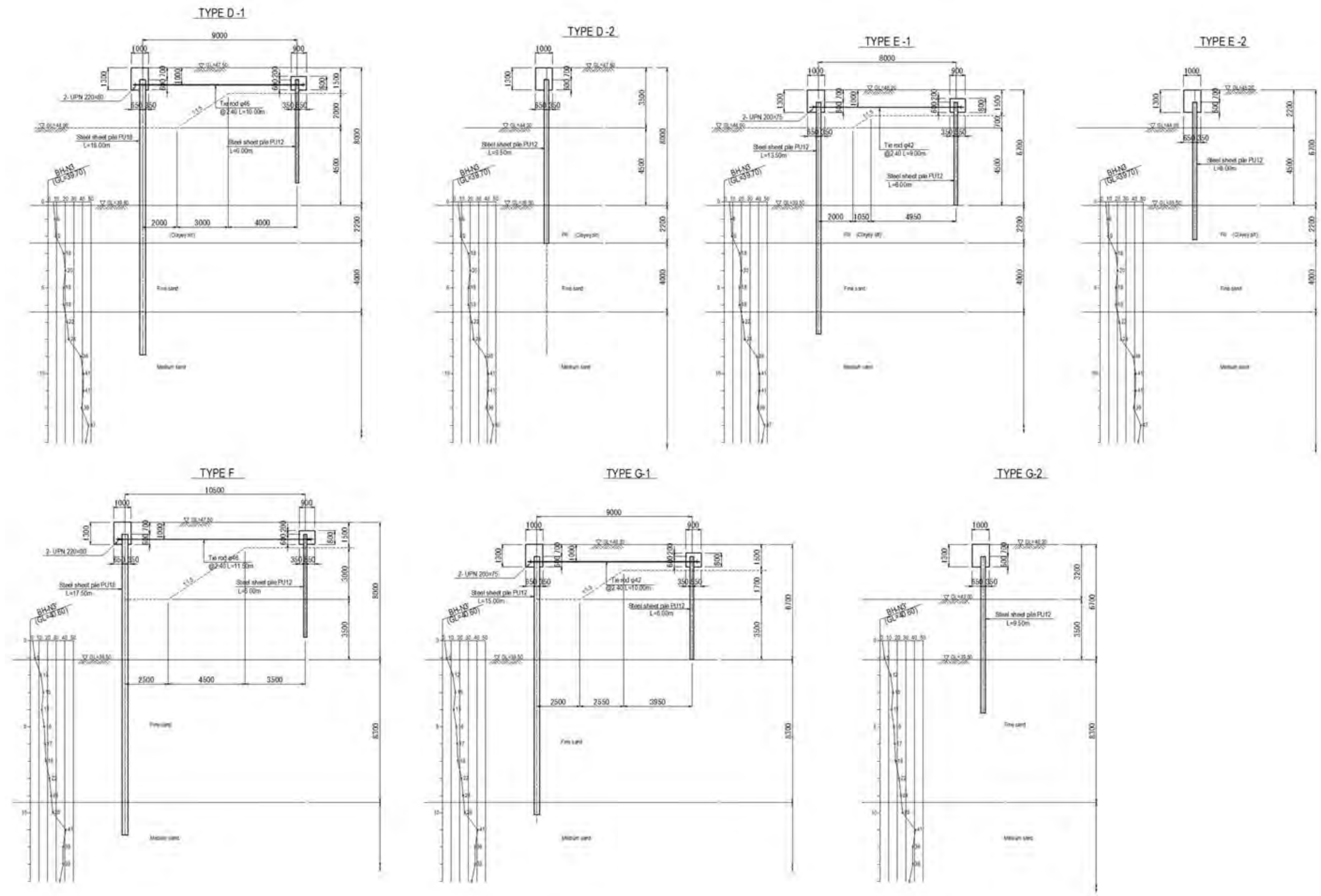


Figure13-2.4 Cross-sectional map of the sheet pile method for each case (case D – G) (2/3)

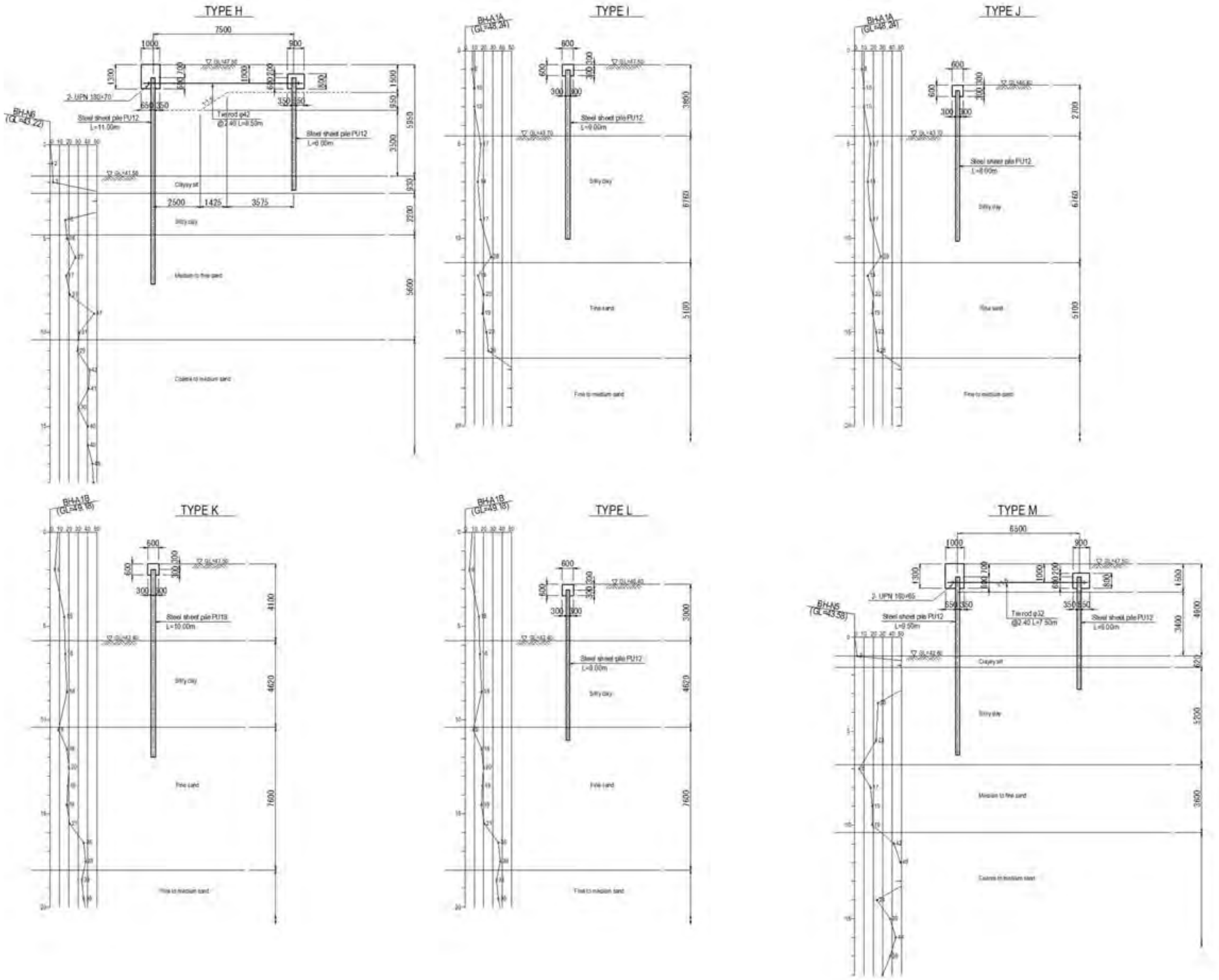


Figure13-2.5 Cross-sectional map of the sheet pile method for each case (case H – M) (3/3)

13-3 Design of bank slope protection work

(1) Wet stone pitching

Wet stone pitching is used, which was also used in the construction of the Dahab regulator. A drainage hole and backfill material are employed to drop the residual water level. Stone for the protection work should be heavy enough so as not to be displaced naturally, and also to satisfy the value calculated by Hudson Formula below.

$$W = \frac{\gamma r \cdot H_D^3}{K_D(\gamma r/w_0 - 1)^3 \cot\alpha}$$

Where, W : Weight of the stone on the slope (kN)

γr : Unit weight of the stone γr= 26 kN/m^3

w_0 : Unit weight of the waterW$_0$= 10 kN/m^3

α : Angle comprised by the slope and horizontal lines $\alpha = 33^\circ$ 41' (1 : 1.5)

K_D : Constant determined by the stone type (K_D= 2 is applied in the study)

H_D : Wave height on the front of slope (H_D= 0.50 m is applied in the study)

∴ W = 0.264 kN

Thus, the weight of stone for pitching should be W=0.30kN (rounded to safe side), which is around 30cm in average diameter.

The standard cross-sectional map is shown below.

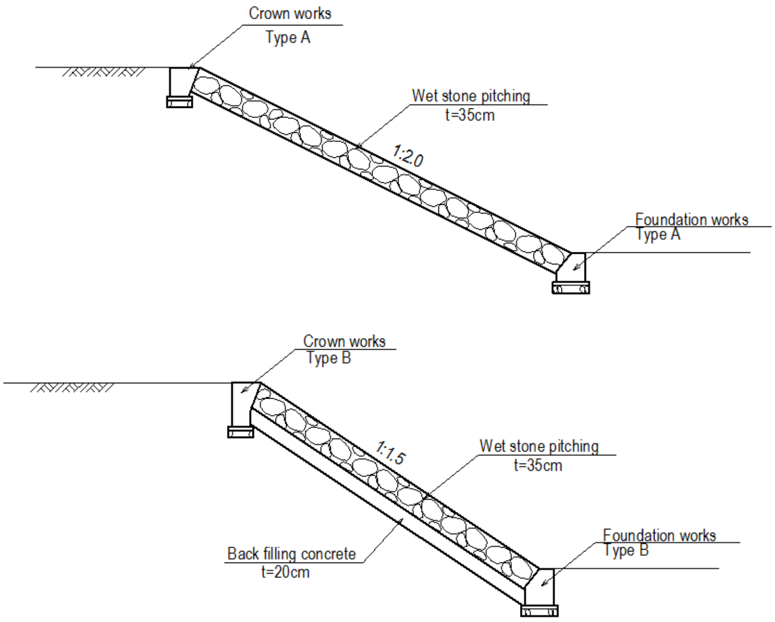


Figure 13-3.1 Standard cross-sectional map of wet stone pitching works

(2) Gabion

The flow channel shaping works are carried out for the purpose of preventing the vortexes generated in the dead water areas on the downstream left bank of the Bahr Yusef Regulator and on the downstream right bank of the Ibrahimia Regulator. The resulting embankment and bank protection works are done apart from the tentative cofferdam works to be executed in the main work. The runoff prevention measure is one of the construction conditions for the works.

Based on these, the comparative analyses were made among the steel sheet pile method, the wet stone pitching method and the gabion construction method (stacking type or pitching type). (Table 13-3.1 and 13-3.2.) As the result of repeated discussions with the Design WG, the pitching type (with the slope gradient 1:2.0) gabion construction method was decided on the prerequisite that the construction works should be done under the low water level condition during the winter closure period, and approved in the 25th TAC Meeting.

The standard cross-sectional map of the gabion construction method and the results of slope stability calculations (Fs = 1.648 > Fa = 1.5) are shown below.

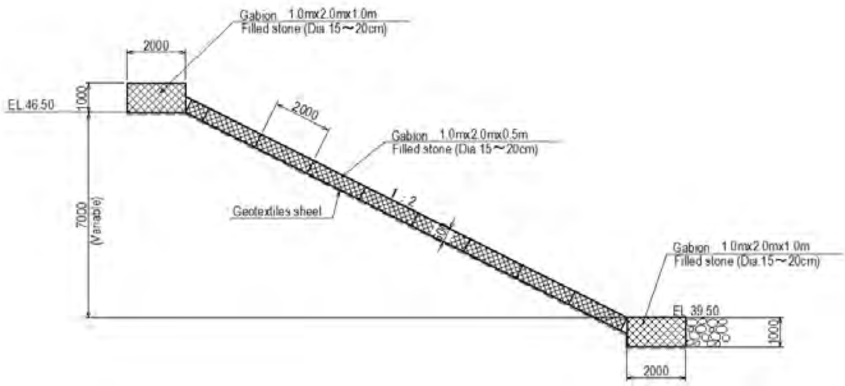


Figure 13-3.2 Standard sectional map of gabion construction method

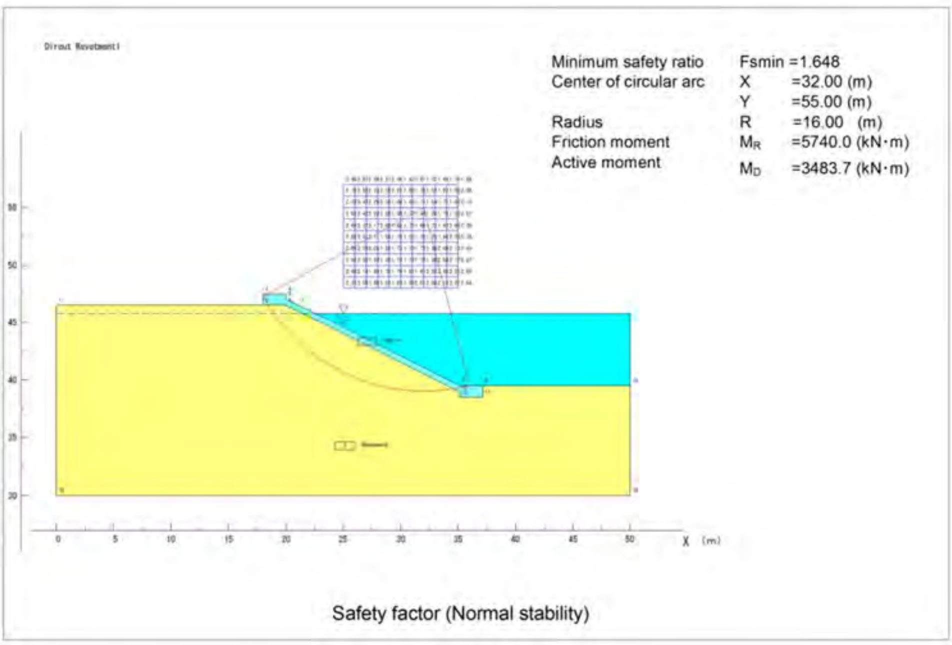


Figure 13-3.3 Diagram of stability calculation results of gabion construction method

Table 13-3.1 Comparative analyses of downstream revetment works (1/2)

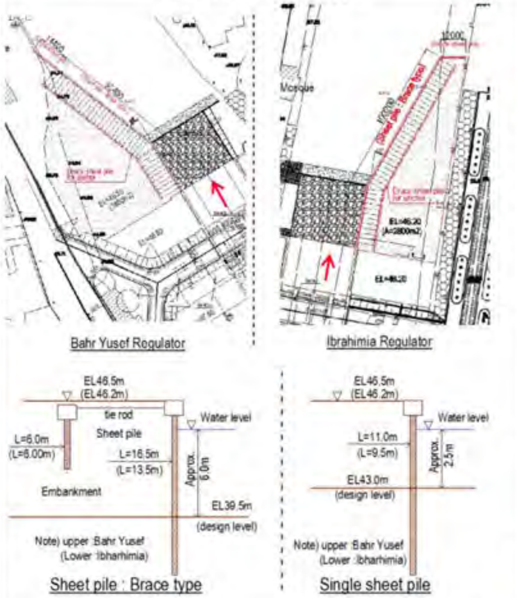
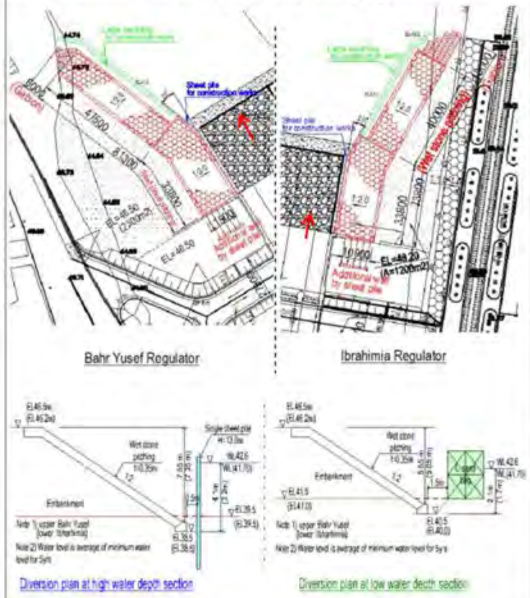
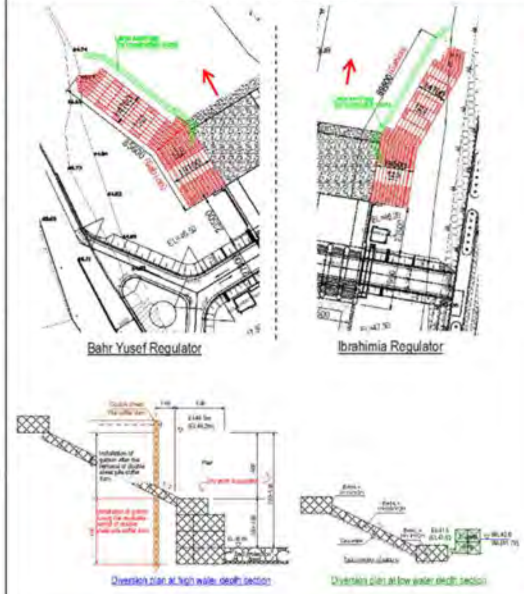
Items	Plan A : Steel sheet type	Plan B : Wet stone pitching type	Plan C : Gabion walls
Plan			
1. Hydraulic aspect	- The bank shape is most smooth among three plans because the alignment of sheet pile make the shape smooth without gaps between regulator and sheet pile wall. - The hydraulic roughness on the wall surface is the smallest among three plans **(Good)**	- The bank shape is fairly smooth but there are gaps between the alignment of regulator and stone pitching wall. - The hydraulic roughness on the wall surface is larger than "Plan A". **(Moderate)**	- The bank shape is fairly smooth but there are gaps between the alignment of regulator and gabion wall. - The hydraulic roughness on the wall surface is larger than "Plan A" **(Moderate)**
2. Structural aspect	- The strength is enough as the retaining wall, - The anti-corrosion painting is required on the surface of sheet pile. - The brace sheet piles are necessary to enhance main sheet pile to resist the high stress by water and earth soil. **(Good)**	- The strength is enough as the retaining wall - Any corrosion is not concerned. - To make the boundary between the regulator and wet stone pitching, the additional walls by sheet pile wall of brace type are required. These are 11.5m for Bahr Yusef and 10.9m for Ibrahimia. **(Good)**	- The strength is moderate as the retaining wall, but flexible structure can follow and protect the vulnerable canal bank and bed. - The galvanized flame such as anti-corrosion measure should be applied. **(Good)**
3. Ease of construction	-The construction works is as following steps 1) Spread of the soil to the target area until the workable level of the sheet driving 2) Driving the sheet pile along the alignment and, set the anchor and tie rod 3) Compaction of the soil - Since the sheet pile walls is available as the coffer dam, the works are not affected by the canal water. - However, the construction works is complicated among three plans. - In addition, in the Ibrahimia regulators, the harmful effect to the railway would be concerned when the sheet piles are driven close	-The construction works is as following steps 1) Spread of the soil to the target area until the design embankment level. 2) Driving the sheet piles and setting the large sand bags along the alignment of bank as the diversion works 3) Construction of the wet stone pitching during the winter closure 4) Removal of the sheet pile and the large sand bags, but removal of sheet pile is so difficult after the construction of wet stone pitching - The structure type is not difficult, but the construction yard enable the dry works must be secured for the concrete works. - Considering the reasonable diversion works to secure the necessary construction yard, the works must be done during winter	-The construction works is as following steps 1) Firstly, during the available periods of double sheet pile coffer dam, the gabions at the close area to the regulator are constructed in advance. The way of gabion installation is shown in the above illustration. 2) After the removal of the double sheet pile coffer dam, the other area of gabions are constructed with utilization of the large sand bag coffer dam to secure the construction yard. - To avoid heavy diversion works, the construction works are divided by two terms. - Therefore the diversion works such as sheet pile is not required. - In addition, the works of gabions are available unless its water

Table 13-3.2 Comparative analyses of downstream revetment works (2/2)

Items	Plan A : Steel sheet type	Plan B : Wet stone pitching type	Plan C : Gabion walls
	the railway **(Not Good)**	closure. - However, the gap between the base concrete level and canal water level will be approx. 4~3m near the regulator. Therefore, the sheet pile diversion should be applied in order to resist high water pressure. Its water level is identified in the record of water level for 5yrs during winter closure. - While, the other area does not need the sheet pile diversion, but the sandbag diversion is available. **(Moderate)**	depth is not so deep. - Compared to the wet stone pitching, the construction period is short. **(Good)**
4. construction periods	Construction periods without embankment and concrete cap on sheet pile Bahr Yusef : approx. **0.8 month (approx. 95m)** Ibrahimia : approx. **0.8 month (approx. 100m)** **(Good)**	Construction periods without embankment Bahr Yusef : approx. **1.7 month (approx. 1,500m^2)** Ibrahimia : approx. **1.5 month (approx. 1,400m^2)** **(Not good)**	Construction periods without embankment Bahr Yusef : **0.4 month (approx. 600nos)** Ibrahimia : **0.6 month (approx. 790nos)** **(Good)**
5. Economical aspect	**Ratio : 1.69** **(Total : USD 1.0 million)** Items 1) Sheet pile and other works 2) Embankment works include transportation 3) Diversion works for the construction **(Not good : Expensive)**	**Ration : 1.05** **(Total : USD 0.63 million)** Items 1) wet stone pitching and other works 2) Embankment works include transportation 3) Diversion works for the construction **(Good)**	**Ration : 1.00** **(Total : USD 0.60 million)** Items 1) Gabions include stone and other works 2) Embankment works include transportation 3) Diversion works for the construction **(Very Good)**
Evaluation	**Fairly Recommendable** - The hydraulic function is very good and the structural durability is as well. - However, the careful construction works is required because of the complicated structure and necessity of careful driving sheet pile close the railway. - The construction cost is **most expensive among three plans**.	**Fairly Recommendable** -.The hydraulic function is good and structural durability is enough for conditions, in addition, structure is typical as bank protection. - However, under the condition of canal water during the construction, **the expensive diversion works such as sheet pile cofferdam is required** in order to prevent the canal water. - In addition, construction period is longer than other plans, its period **overrun for the available construction period of winter closure**.	**Recommendable** - The hydraulic function is good, and structural durability is fairly enough for corrosion, but flexible structure enable to follow and protect the vulnerable canal bank and bed. - The construction works are most speedy among three plans and its **works is possible to finish during winter closure.** - In addition, the construction works are **available by simple diversion works** such as sand bags. - The construction cost is **not expensive** compared to the other plan.

14. Design of Ancillary Road and Bridge

14-1 Design conditions

(1)   Width of the ancillary road

Based on the discussion conclusions at the F/S stage, the effective width of ancillary road was designed at. However, in D/D stage, TAC decided at the14th TAC meeting, that the road plan should take future traffic into account. The road width at the three downstream regulators (new Bahr Yusef, Badraman, and Ibrahimia) should also consider the future increase in traffic in Dirout city.

According to the traffic survey study report, the required road width is approximately 25m. Based on this result, TAC and D/D consultant have agreed to apply 12.5m width (half of required road width) for the design, and the remaining 12.5m will be covered by the new bridges being planned as part of the city development plan. Regarding the two upstream small scale regulators (new Sahelyia and Abo Gabal), the width of the road was set at 6.5m to include maintenance usage.

The following is the breakdown of road for each width:

12.5m = 10.0m (for 2 carriage ways) + 2.0m (for 2 sidewalks) + 0.5m (for 2 handrails)

6.5m =6.0m (for carriage way) + 0.5m (for 2 handrail)

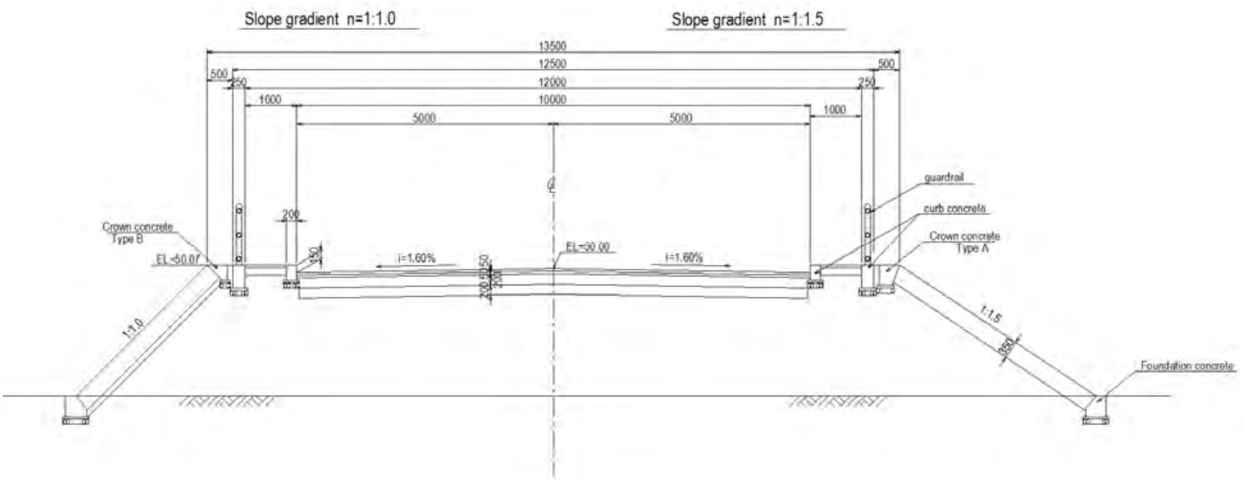


Figure14-1.1 Layout of ancillary road

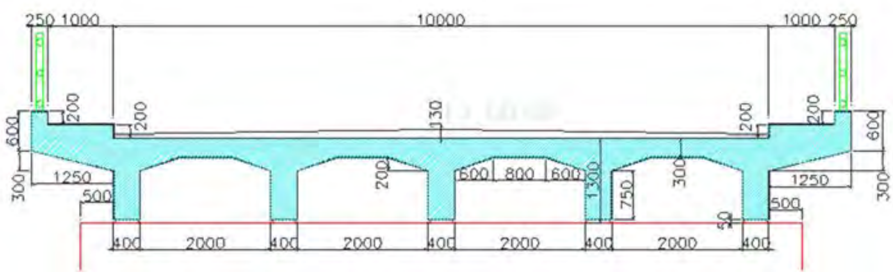


Figure14-1.2 Layout of bridge

(2) Design load

In order to determine the design load for the ancillary road and bridge, the following loads should be applied in order to comply with Egyptian code.

Table14-1.1 Design load for the ancillary road and bridge

Point where the load acts	Concentrated lad (by the car) Q (kN)	Equal distribution load q (kN/m^2)
Lane ①	300	9.0
Lane ②	200	2.5
Lane ③	100	2.5
The other lane	0	2.5
The other area (q)	0	2.5

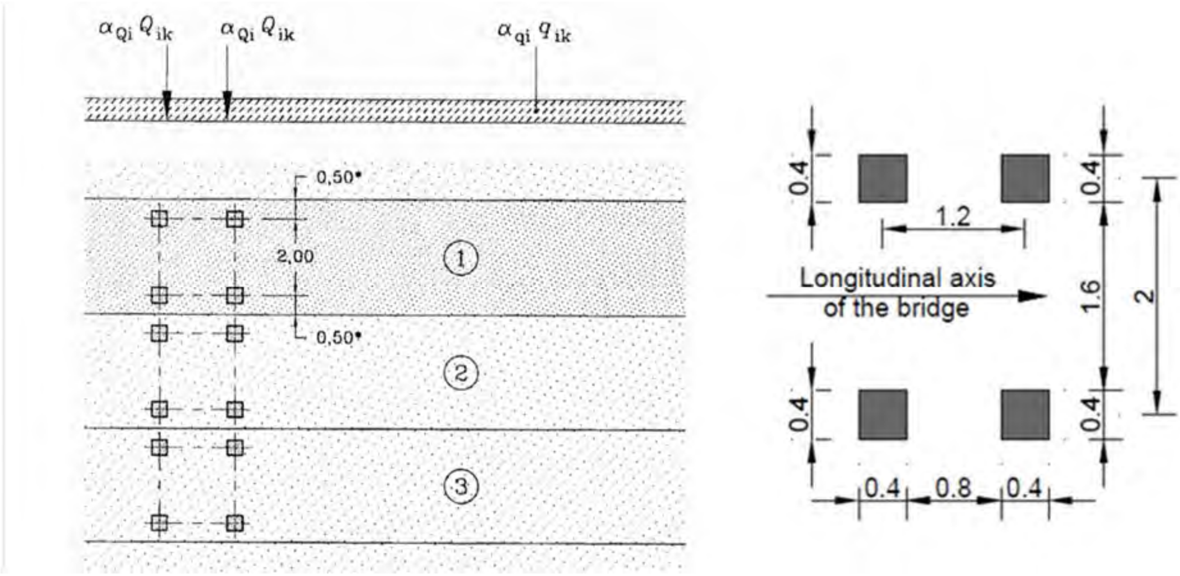


Figure14-1.3 Sketch of acting point of the design load

(3) Road alignment

Figure 14-1.4 shows the location of NDGRs and their ancillary roads.

The following two points were approved by TAC at the21st TAC meeting.

- Considering the heavy traffic on the existing national road along the Bahr Yusef canal, a traffic island will be constructed at the intersection between the road on the new Bahr Yusef regulator and the existing national road to avoid traffic jams.
- The design area of the study is until the slope for the railway, which is located along the right bank of Ibrahimia canal.

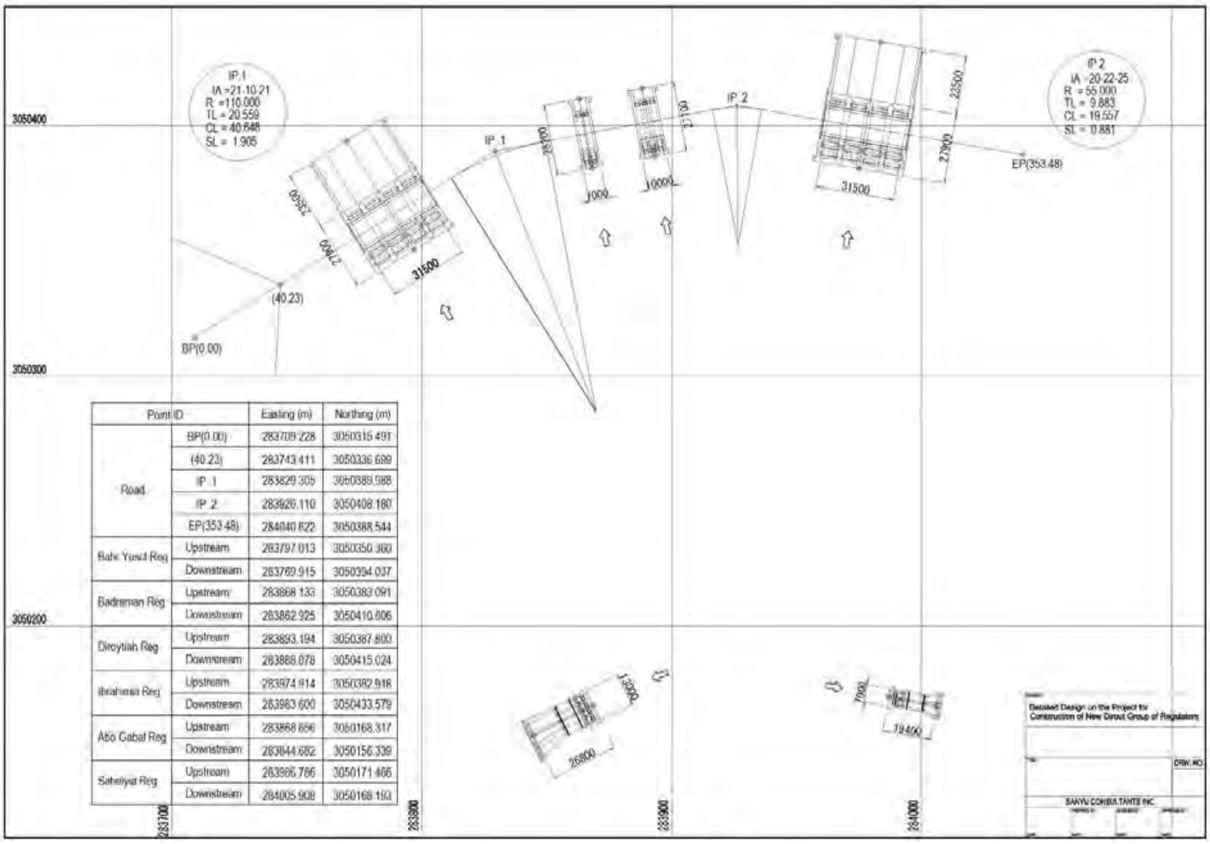


Figure 14-1.4 Drawing of the design road alignment

14-2 Structural design for the ancillary bridge

The structural design of the ancillary bridge was basically made in accordance with the Egyptian code, and the items that were not provided in the Egyptian code were in accordance with the Eurocode or AASHTO.

The calculations of cross sections were made for three bridges for the large-scale regulators (Bahr Yusef and Ibrahimia regulators), Badraman regulator (Diroutiah canal) and Badraman regulator (Badraman canal). The calculated cross sections are shown in Figure 14-2.1.

Further details are in structural calculations in the Appendix.

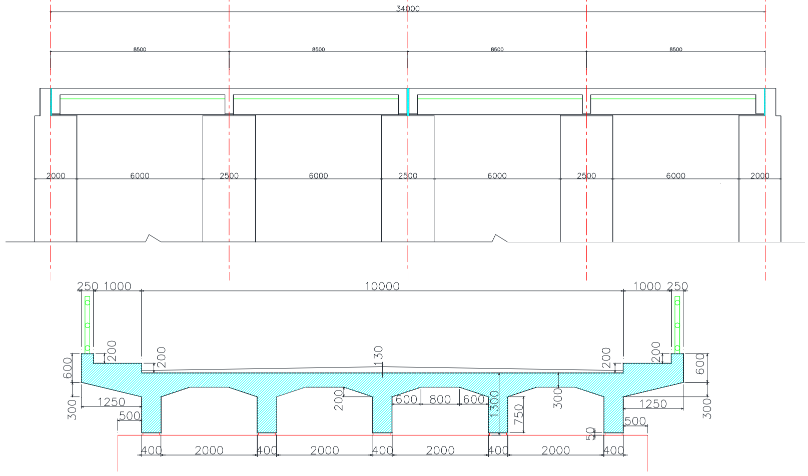
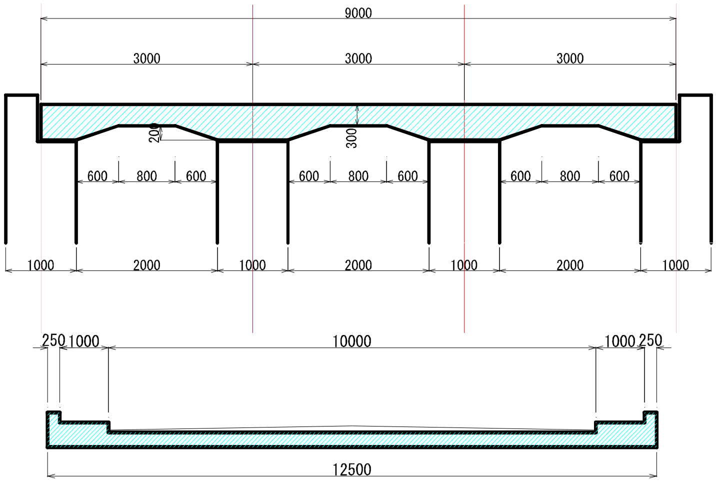
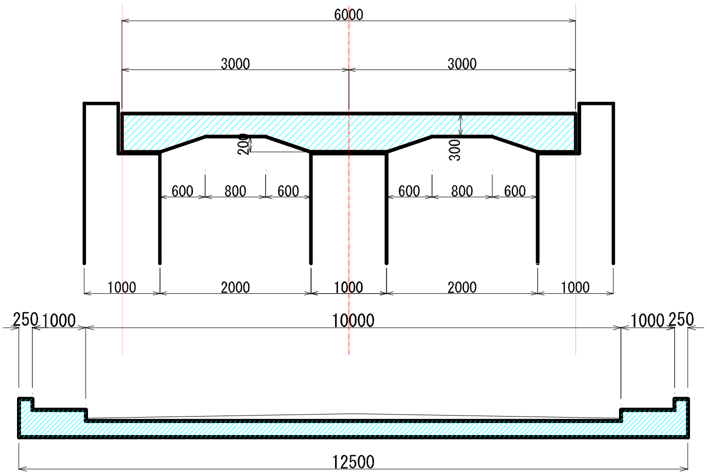
Name of Bridge	General Diagram of Bridge Type and Structure
Large-scale regulators Bahr Yusef regulator Ibrahimia regulator	Bridge type: RC 2-span continuous 5-slab main girder bridge × 2 bridges 
Badraman regulator Diroutiah canal	Bridge type: RC 3-span continuous floor slab bridge 
Badraman regulator Badraman canal	Bridge type: RC 2-span continuous floor slab bridge 

Figure 14-2.1 Schematic diagrams of ancillary bridges

15. Design of Gate Facilities

Gate facilities shall be designed in accordance with the following features.

1) Easy and reliable operation
2) Sufficient water tightness and high durability
3) Safety against predictable load
4) Easy and safe operation and maintenance

15-1 Design of gate leaf

15-1-1 Design conditions

The following table shows the design conditions of gate facilities agreed upon with the Egyptian government. Items to be noted are as follows.

1) The operating speed of the gate is usually taken to be 0.3 m/min, as it considers the effect of upstream and downstream water level fluctuations caused by water discharge. However, sometimes higher speed is applied when sudden closing is required, and slower speed is applied for highly accurate discharge control. As a result of discussions, operating speed is set at 0.3 m/min for all gate facilities.

2) The major parts of the gate leaf are made of rolled steel, except the parts where maintenance and repair works are difficult, as well as the sliding surfaces such as the skin plate of the double leaf gate, the wheels, and the gate guide frames.

3) Beside the lateral and bottom side seal, a rubber seal is attached to the upper side of the lower leaf of the double leaf gate to secure water-tightness at the sliding surface.

4) Design water level is the same as the gate crest height (=Normal water level EL46.30m＋Freeboard 25cm). Downstream water height is not considered in the design for safety reasons.

Table 15-1.1 Design condition of gate facilities

		Large regulators		Small regulators				Remarks
Name		**Bahr Yusef**	**Ibrahimia**	**Badraman**	**Diroutiah**	**AboGabal**	**Sahelyia**	
Gate type		Double leaf Fixed wheel gate	Double leaf Fixed wheel gate	Single leaf Slide gate	Single leaf Slide gate	Single leaf Slide gate	Single leaf Slide gate	
Clear width of opening		6.00m	6.00m	2.00m	2.00m	2.00m	2.00m	
Total height		6.55m	6.55m	2.65m	2.35m	2.95m	3.55m	
Number of gate		4	4	2	3	4	2	
Gate crest elavation		EL46.55m	EL46.55m	EL46.55m	EL46.55m	EL46.55m	EL46.55m	Freeboard=0.25m
Gate sill elevation		EL40.00m	EL40.00m	EL43.90m	EL44.20m	EL43.60m	EL43.00m	
Design water level(Upstream)		EL46.55m	EL46.55m	EL46.55m	EL46.55m	EL46.55m	EL46.55m	
Design water height		6.55m	6.55m	2.65m	2.35m	2.95m	3.55m	
Bottom height when lifted up		EL47.50m	EL47.50m	EL47.50m	EL47.50m	EL47.50m	EL47.50m	HHWL+0.5m
Lifting height		7.50m	7.50m	3.60m	3.30m	3.90m	4.50m	
Operating speed		0.3m/min	0.3m/min	0.3m/min	0.3m/min	0.3m/min	0.3m/min	
Control method		Remote/Local control	Remote/Local control	Remote/Local control	Remote/Local control	Remote/Local control	Remote/Local control	
Hoist type (Number of rod per gate)		Hydraulic cylinder	Hydraulic cylinder	Electric rack gear (2-rods)	Electric rack gear (2-rods)	Electric rack gear (2-rods)	Electric rack gear (2-rods)	
Seal type		3-side rubber seal 1)	3-side rubber seal 1)	3-side rubber seal	3-side rubber seal	3-side rubber seal	3-side rubber seal	
Materials	Skin plate	Stainless steel	Stainless steel	Rolled steel	Rolled steel	Rolled steel	Rolled steel	
	Main beam	Rolled steel	Rolled steel	Rolled steel	Rolled steel	Rolled steel	Rolled steel	
	Wheels	Stainless steel	Stainless steel	-	-	-	-	
	Gate guide frame	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	
	Bolt,Nut &Washer	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	
	Hydraulic pipe	Stainless steel	Stainless steel	-	-	-	-	
Deflection		1/800	1/800	1/800	1/800	1/800	1/800	
Allowable stress		According to JIS (Japanese Industrial Srandards) or relevant standards						

Note: 1) Lower leaf has a upper side seal. (4-side seal)

15-1-2 Gate leaf structure

The gate leaf structure can be a 'shell' type or a 'plate girder' type. Which type is selected is determined by the width and height of the leaf or the control method; whether to discharge by overflow or not. With the girder type, the depth of the main girder supporting the horizontal load becomes large depending on the span width. Since higher vertical rigidity is required to keep the deflection caused by self-weight within the allowable range, the design of the structure becomes uneconomical. On the other hand, each cross-sectional part of the shell type leaf can function well structurally and its shape is hydraulically desirable.

For these reasons, the ratio between height and width of the gate leaf is an index to select the structural type. Shell type is adopted when the ratio is less than 1/5 to 1/6, otherwise the girder type is selected.

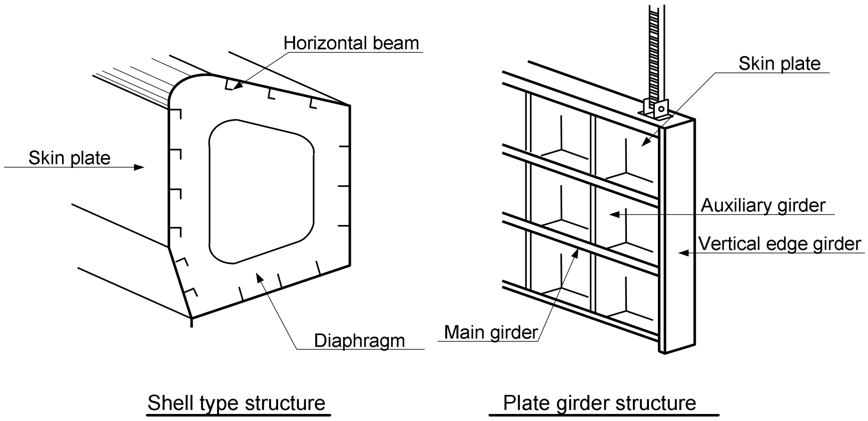


Figure 15-1.1 Structure of gate leaf

The ratio of the leaves of large scale regulators is as follows.

Upper leaf: H/L＝3.30m/6.0m＝1/1.82

Lower leaf: H/L＝3.40m/6.0m＝1/1.76

Therefore the plate girder type is suitable for both upper and lower leaf structures. For the same reason, all the small scale regulators are plate girder type.

The height of the upper and lower leaves of double leaf gate was designed as shown in Figure 15-1.2. In order to avoid water from overflowing onto the lower leaf top, the upper leaf should be placed on the downstream side.

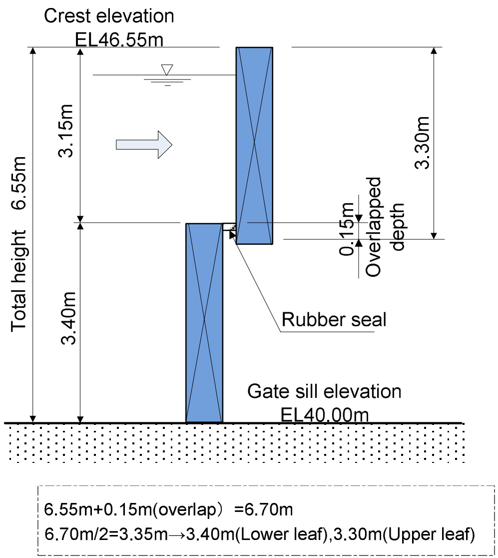


Figure 15-1.2 Height of double leaf gate

15-1-3 Design load

In designing a gate, the following loads and their combinations shall be taken into account: weight of the gate, hydrostatic pressure, sediment pressure, wave pressure, buoyancy, hydrodynamic pressure caused by earthquake, effects of temperature changes, and so on.

(1) Hydrostatic pressure

Hydrostatic pressure of the reservoir water acts on the contact face of a hydraulic gate at a square. Hydrostatic pressure is determined from the following formula.

P= Woho

Where, P: Hydrostatic pressure at a given point on the contact face (kN/m^2)

Wo: Weight of water per unit volume (kN/m^3)

ho: Head from water level just upstream of a gate plus wave height (m)

(2) Sediment pressure

The sediment pressure for the vertical force should be taken as the weight of the sedimentary silt in the water, and the horizontal force should be determined by the following formula.

$Pe=CeW_1d$

Where Pe: Horizontal force of sediment pressure at a given point on the contact face (kN/m^2)

Ce: Sediment pressure factor (Ce=0.3-0.6)

W_1: Unit weight of sedimentary silt in water (kN/m^3)

d: Depth from deposit level of sediment to given point on contact face (m)

$W_1=W- (1-v)\ W_o$

Where, W_1: Apparent unit weight of sedimentary silt (kN/m^3)

v: Void ratio of sedimentary silt (0.30- 0.45)

W_o: Unit weight of water (kN/m^3)

(3) Wave height by wind

Where the upstream face of a weir is almost vertical, the wave height should be determined by the S.M.B (Sverdrup-Munk- Bretschneider) method.

$hw =0.00086\ V^{1.1}F^{0.45}$

Where, hw: Total wave height (one third maximum wave) (m)

F: Distance to opposite bank (m)

V: Wind velocity (average of 10 minutes) (m/s)

(4) Wave height by earthquake

Wave height by earthquake is calculated by the following formula.

$$he = \frac{k \cdot \tau}{2\pi}\sqrt{g \cdot H}$$

Where, *h*e: Wave height (m)

k: Design seismic coefficient

τ : Frequency of the earth quake (s)

g: Acceleration of gravity (=9.8m/sec2)

H: Design depth of water in the river (m)

(5) Hydrodynamic pressure caused by earthquake

Hydrodynamic pressure caused by earthquake is obtained by Westergard's formula.

$$p_d = \frac{7}{8} Wok\sqrt{Hh}$$

Where, Pd : Dynamic water pressure (kN/m^2)
Wo: Unit weight of water (kN/m^3)
k: Design seismic coefficient
H: Design depth of water in the river (m)
h: Calculation depth (m)

15-1-4 Allowable stress

Allowable stresses of JIS materials for leaf, guide frame, and fixed part are given in tables below. However, allowable stresses for stoplogs for maintenance, and the setting frames are corrected by multiplying the following values by 1.5. Allowable stresses of standardized materials other than JIS, such as BS, DIN, or ASTM, are examined respectively.

Table 15-1.2 Allowable stress of structural steel

(Unit: N/mm^2)

<table>
<tr><th rowspan="2">Steel
Stress</th><th colspan="2">SS400,SM400,SMA400</th><th colspan="2">SM490</th><th colspan="2">SMA490</th></tr>
<tr><th>Thickness≤40mm</th><th>>40</th><th>Thickness≤40mm</th><th>>40</th><th>Thickness≤40mm</th><th>>40</th></tr>
<tr><td>1.Axial tensile stress (for net sectional area)</td><td>120</td><td rowspan="5">0.92 times the left stress</td><td>160</td><td rowspan="5">0.94 times the left stress</td><td>180</td><td rowspan="5">0.95 times the left stress</td></tr>
<tr><td>2.Axial compressive stress (for gross sectional area)

Compressive member
l: buckling length of member (mm)
r: radius of gyration of area for the cross section of members (mm)

Compressive splice plate</td><td>$\frac{l}{r} \leq 20$: 120
$20 < \frac{l}{r} \leq 93$:
$120 - 0.75(\frac{l}{r} - 20)$
$93 < \frac{l}{r}$: $\frac{1,000,000}{6,700 + (\frac{l}{r})^2}$

120</td><td>$\frac{l}{r} \leq 15$: 160
$15 < \frac{l}{r} \leq 80$:
$160 - 1.12(\frac{l}{r} - 15)$
$80 < \frac{l}{r}$: $\frac{1,000,000}{5,000 + (\frac{l}{r})^2}$

160</td><td>$\frac{l}{r} \leq 14$: 180
$14 < \frac{l}{r} \leq 76$:
$180 - 1.33(\frac{l}{r} - 14)$
$76 < \frac{l}{r}$: $\frac{1,000,000}{4,500 + (\frac{l}{r})^2}$

180</td></tr>
<tr><td>3. Bending stress
girder's tensile side (for net sectional area)

girder's compressive side (for gross sectional area)

Aw: gross sectional area of web plate (mm^2)
Ac: gross sectional area of compressive flange (mm^2)
l: distance between fixed points of compressive flange (mm)
b: width of compressive flange (mm)

$K = \sqrt{3 + \frac{Aw}{2Ac}}$
When directly fixed to the skin plate etc.</td><td>120

$\frac{l}{b} \leq \frac{9}{K}$: 120
$\frac{9}{K} < \frac{l}{b} \leq 30$:
$120 - 1.1(K\frac{l}{b} - 9)$
But, say
$\frac{Aw}{Ac} < 2, K = 2$ with

120</td><td>160

$\frac{l}{b} \leq \frac{8}{K}$: 160
$\frac{8}{K} < \frac{l}{b} \leq 30$:
$160 - 1.6(K\frac{l}{b} - 8)$
But, say
$\frac{Aw}{Ac} < 2, K = 2$ with

160</td><td>180

$\frac{l}{b} \leq \frac{7}{K}$: 180
$\frac{7}{K} < \frac{l}{b} \leq 27$:
$180 - 1.9(K\frac{l}{b} - 7)$
But, say
$\frac{Aw}{Ac} < 2, K = 2$ with

180</td></tr>
<tr><td>4. Shearing stress</td><td>70</td><td>90</td><td>105</td></tr>
<tr><td>5. Bearing stress</td><td>180</td><td>240</td><td>270</td></tr>
</table>

Table 15-1.3 Allowable stress of cast steel and carbon steel

(Unit: N/mm²)

Type of steel \ Type		Axial tensile stress	Axial compressive stress	Bending stress	Shearing stress	Bearing stress
Cast steel	SC450	110	110	110	65	165
	SC480	120	120	120	70	180
	SCW410	120	120	120	70	180
Carbon steel for machine structural use	S20C	120	120	120	70	180
	S25C	130	130	130	75	195
	S35C	150	150	150	85	225
	S45C	170	170	170	95	255

Table 15-1.4 Allowable stress of joint steel

(Unit: N/mm²)

Type \ Type of steel	SS400,SM400		SM490	
	Thickness≦40mm	>40	Thickness≦40mm	>40
Bolts	SS400,S20C		S35C	
1. Shearing stress Finishing bolts Anchor bolts	 75 50	Same as at left	 100 65	Same as at left
2. Bearing stress Finishing bolts	180	Multiply stress by 0.92 as mentioned on left	230	Multiply stress by 0.94 as mentioned on left

15-2 Design of hoisting equipment

15-2-1 Operating load

Operating load is calculated for a safe combination of the following factors.

1) Dead weight of movable parts of a leaf, 2) Friction at roller, 3) Friction of sealing rubber, 4) Friction by piled sand, 5) Floating load, 6) Vertical hydraulic forces, 7) Other.

The weight of hoisting shaft should be added to the dead weight of movable parts of a leaf as it is a load on the hoisting device. Once it is clear whether the gate can close by self-weight or not, the dead weight of leaf itself shall be considered.

15-2-2 Rack gear type hoist

Rack gear type hoist consists of rack shaft, stand (base frame), hoist, local control board and coupling of the shaft. Hoist is composed of power part, speed reducer, transmission, drive system, manual operation device, opening meter and protection devices, and it is standardized as a unit in Japan.

Strength design tests on the rack shaft are conducted for tensile stress, compressive stress, and buckling stress because tensile force acts on the shaft when opening, and compressive force works on it when closing.

In addition to the rack gear type, the spindle type whose leaf and hoist are connected by screw spindle is also popular for small scale gate facilities. When the small gate facilities are procured from the local market or countries other than Japan, the spindle type is applicable as long as equipment specifications are satisfied.

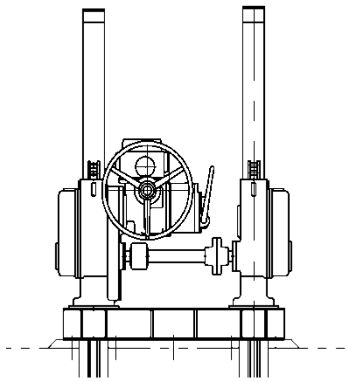


Figure 15-2.1 Rack gear type hoist

15-2-3 Hydraulic hoisting equipment

Hydraulic hoisting equipment consists of hydraulic cylinder, hydraulic unit, local control board, opening meter, protection device, and other maintenance instruments. The hydraulic unit is integrated with the hydraulic pump, electric motor, control valve, and oil tank. It generates hydraulic pressure to drive the hydraulic cylinders properly and control them.

(1) Number of hydraulic units

More than one gate facility can share the same hydraulic unit. It is necessary for gate facilities, which function as flood control or disaster prevention, to have one hydraulic unit per gate in case a single hydraulic unit causes more than one gate to malfunction at the same time. The Dirout Group of Regulators is movable weirs along irrigation canals. Their importance as a disaster prevention facility is not high, since water discharge is controlled by the Ibrahimia head regulators. The upstream spillway facility can also work in case of an emergency. As a result of discussions, it was decided to install one hydraulic unit for four gates of one regulator. In addition, to secure reliable gate operation, a duplexed hydraulic circuit including standby hydraulic pumps, shall be built inside the hydraulic unit, as well as a power generator situated beside a commercial power source.

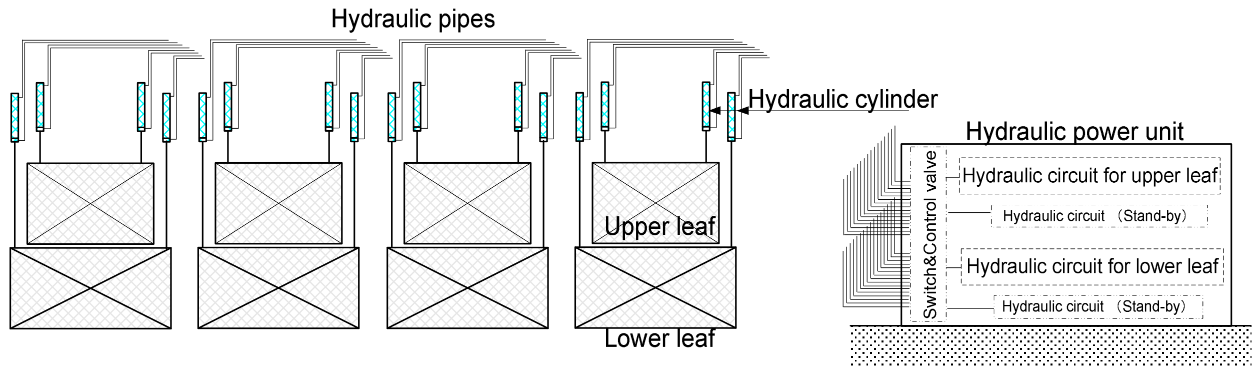


Figure 15-2.2 Layout of hydraulic unit

(2) Layout of hydraulic equipment

Three alternatives are examined for the layout of hydraulic equipment.

Plan A: Hydraulic unit is placed in the remote control room where monitoring and operations are carried out.

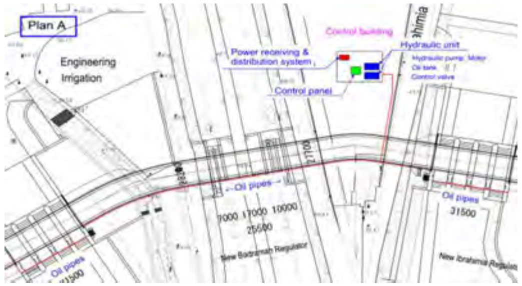
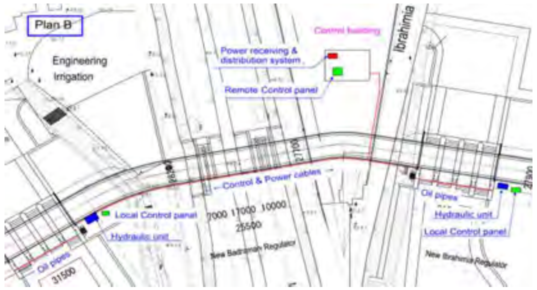
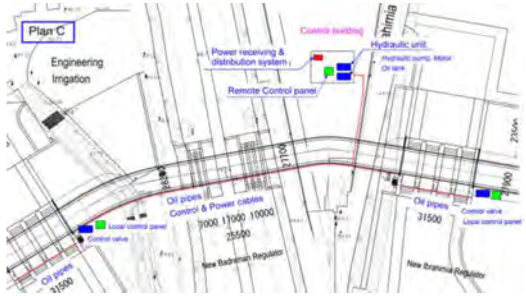
Plan B: Two hydraulic units are placed adjacent to the regulators making local and remote control possible.

Plan C: Only the hydraulic power source is placed in the remote control room, and a switch and control valve are installed at each regulator.

An important between plan A and plan B is the number of hydraulic pipes running from the hydraulic unit to each gate facility. In plan C, hydraulic pipes for four gates are shared and diverted to each hydraulic cylinder at the regulator.

Discussions with the Egyptian government resulted in an agreement to adopt plan B, where the hydraulic unit is placed in the local control room constructed adjacent to the regulator to ensure local control. This system is the same as that of the existing Ibrahimia head regulator.

Table 15-2.1 Comparison between hydraulic hoisting systems

		Plan A	Plan B	Plan C
Diagram				
Components	Control house	1) Power receiving and distribution system 2) Hydraulic unit (hydraulic pump, motor, oil tank, control valve) 3) Remote control panel	1) Power receiving and distribution system 2) Remote control panel	1) Power receiving and distribution system 2) Hydraulic unit (hydraulic pump, motor, oil tank, control valve)
	Control house to regulators	Hydraulic pipes (32 pipes×2 lines)	Power cables & control cables	1) Hydraulic pipes (2 pipes×2 lines) 2) Power cables & control cables
	Regulators	1) Hydraulic pipes 2) Hydraulic cylinders	1) Hydraulic unit (hydraulic pump, motor, oil tank, control valve) 2) Local control panel 3) Hydraulic pipes 4) Hydraulic cylinders	1) Control valve 2) Local control panel 3) Hydraulic pipes 4) Hydraulic cylinders
Advantages		1) Since most of the equipment is located in the remote control house, operation and maintenance is easy and security levels are superior. 2) Since the hydraulic pipes are separately connected to a hydraulic power source and an actuator. The risk that all the gates fail to operate at the same time is low.	1) Small space needed in the remote control house for equipment. 2) Both remote and local control are possible. 3) Since the hydraulic pipes are separately connected to a hydraulic power source and an actuator. The risk that all the gates fail to operate at the same time is low.	1) Because the number of pipes laid along the road is small, construction is easier than in "Plan A." 2) Smaller space than "Plan B" needed for equipment in the remote control house.
Disadvantages		1) Because the number of pipes laid along the road is large, construction is not easy. 2) Largest space needed for equipment in the remote control house. 3) Local control is impossible.	1) Since the hydraulic unit is located outdoors, measures against weather and security are required.	1) If troubles arise on the main pipes, there is a possibility that all gates cannot be operated.

15-3 Design of control equipment

15-3-1 Control system

The operation of the gate shall be equipped with local control devices capable of manual operation at the close distance of the hoisting equipment in all facilities, and remote control equipment shall be provided to carry out centralized management of multiple facilities.

The conceptual diagram of the operation control facility is shown in the figure below.

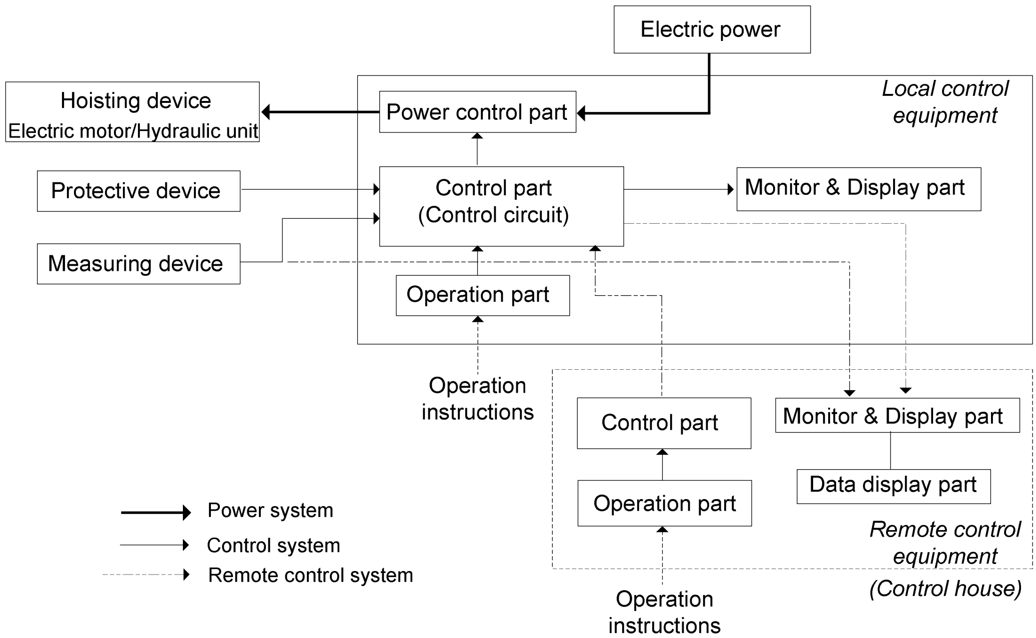


Figure 15-3.1 Conceptual diagram of control and operation

The operational mechanism of the gate is based on the local control, among which the manual operation is a mechanism that can give priority over the automatic control system. Since it is difficult to monitor the gate and hoisting equipment directly by visual observation from a distance, monitoring system to observe the information such as gate opening, status of gate performance and water level should be provided without depending on CCTV (Closed-Circuit Television) that Egyptian government does not want. In addition, the variable-value control method shall be adopted to maintain the set discharge and follow the flow rate or the amount of its change.

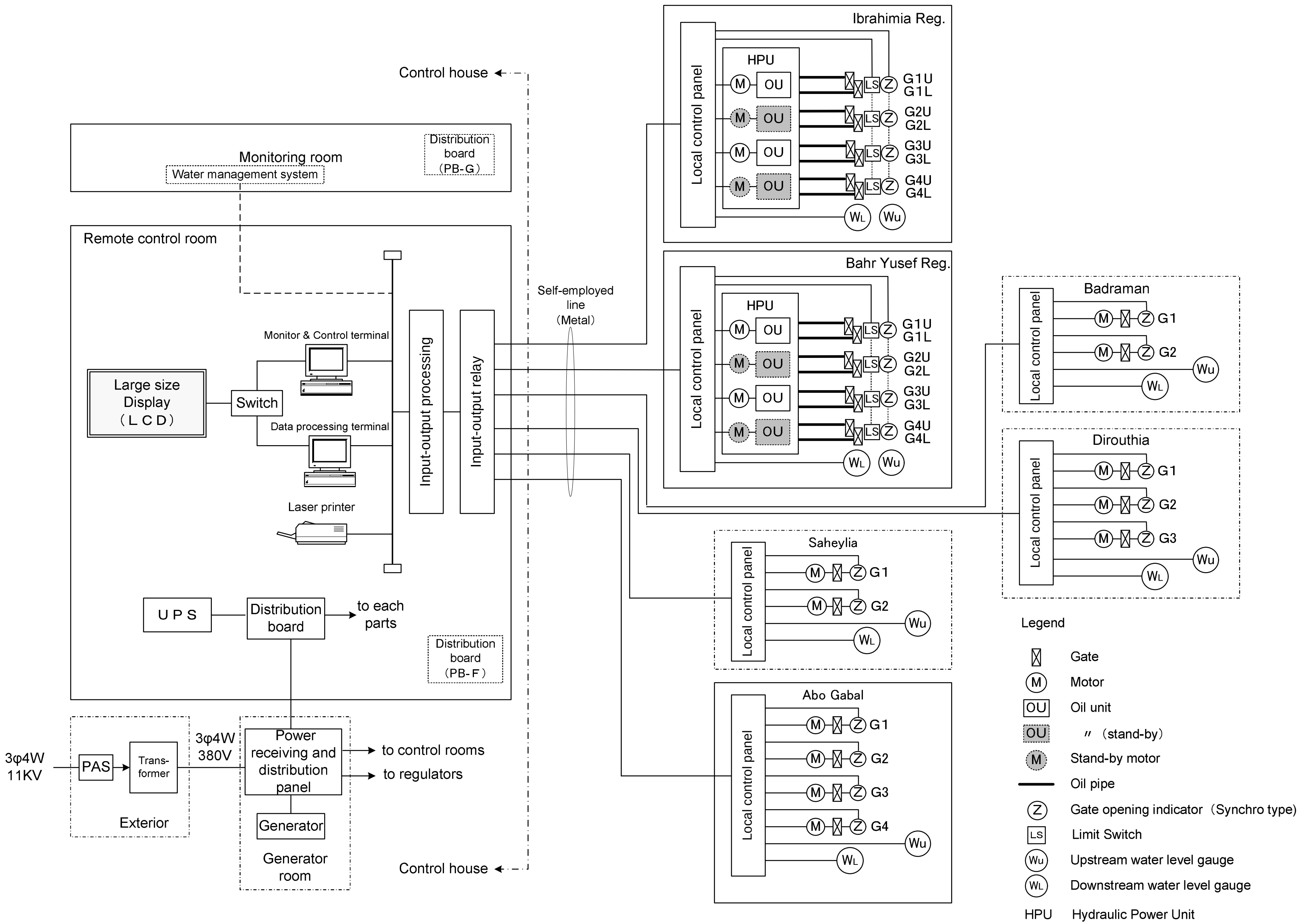


Figure 15-3.2 Monitoring control system configuration diagram

15-3-2 Local control equipment

The local control panel consists of an operation part for operating the gate, a display part for monitoring the operation state, a control part for controlling the operation, and a power supply part for receiving the power supply. The structure of the panel should make it possible to operate the gate precisely and easily, and malfunction does not occur. In order to prioritize the local control rather than the remote control, a switch of local and remote control is provided, and an emergency stop function that makes the gate surely stop by tripping the MCCB (Molded Case Circuit Breaker) for electric motor is provided.

The minimum required status indication items, fault indication and buzzer alarm are as shown in the table below. Also, data transfer between the remote place shall be as follows.

1) Control signal: Control signal such as open / close command from a distance
2) Emergency stop signal: Emergency stop signal from a distance
3) Condition monitoring signal: Operating state monitoring information of the gate from the local side
4) Measurement information: Measurement information such as degree of opening, current and oil pressure from the local side
5) Operating signal: Gate operating signal from local side

Table 15-3.1 Major status indication items

Indication	Status	Electric actuator	Hydraulic actuator	Remarks
POWER SOURCE	Power source on	○	○	
LOCAL	Local control on	○	○	
REMOTE	Remote control on	○	○	
↑	Gate is working to open	○	○	
↓	Gate is working to close	○	○	
UPPER POSITION	Gate is stopped at the upper position	○	○	
LOWER POSITION	Gate is stopped at the lower position	○	○	
PUMP ON	Hydraulic pump is working		○	
OIL PRESSURE ESTABLISHED	oil pressure established under pumping		○	

Table 15-3.2 Major fault indication items

Indication	Detection method	Electric actuator	Hydraulic actuator	Measure to deal with
EARTH LEAKAGE	Leakage relay	○	○	Cause investigation and recovery
3E MOTION	Three element relay(open-phase, phase-reversal and overload)	○	○	Cause investigation and reset
MCCB TRIP	Molded Case Circuit Breaker trips	○	○	Cause investigation
EMERGENCY UPPER POSITION	Limit switch	○		Investigation
OPENING OVER TORQUE	Limit switch	○		Closing the gate and investigation
CLOSING OVER TORQUE	Limit switch	○		Opening the gate and investigation
OVER OIL PRESSURE	Pressure switch		○	Restart after investigation

OIL LEVEL DRAWDOWN	Float switch		○	fix the oil leakage, oil supply
OVER OIL TEMP	Temperature switch		○	Investigation, hydraulic oil cooling

15-3-3 Remote control equipment

In the remote control equipment, it is responsible for displaying the status of the gate, displaying abnormality and alarm, starting and stopping the operation, confirming and resetting the alarm. Switching between the local control and remote control is selected by the switch provided on the local control panel, but when switching to the local operation on the running of the remote operation, the opening and closing operation is immediately stopped. Even when the remote control system fails, the structure of the gate can be operated reliably with the local control panel.

Remote control equipment placed in the control room is composed of followings.

Table 15-3.3 Components of remote control equipment

Name	Main function
Data processing equipment	Data editing, calculation, filing, display / recording, alarm and control processing of each facility are performed.
Monitor & control equipment	From the facility control screen of the personal computer, a remote operation of the gates is performed by the mouse operation.
Printer	In addition to creating various forms for daily reports, monthly reports and operation records and other forms, hard copy printing on the monitor screen is carried out.
Input-output(I/O) processing equipment	Transmission of measuring, monitoring and control signals between the I/O relay equipment and local control panel as well as measuring devices, smoothing of input signal, scaled conversion, data checking, processing to the gate are conducted
Input-output(I/O) relay equipment	Transmission of measuring, monitoring and control signals between the local equipment such as control panel and measuring devices and the I/O processing equipment is carried out. Inductive surge absorption, signal insulation (analogue) to protect equipment from inductive lightning from outside line are performed.
UPS (Uninterruptible Power Supply)	It absorbs various disturbances of the commercial power supply (instantaneous power failure, voltage fluctuation, frequency fluctuation, waveform distortion, high frequency noise, etc.), and supplies uninterrupted and stable power (constant voltage, constant frequency).
Lightning protection transformer	It protects various electronic equipment constituting the system from induced lightning (foreign surge) entering from the external lead-in power line.

The remote operation equipment is placed in the regulators management room inside the control house. Considering the interval required for equipment maintenance and inspection, the minimum size shown in the figure below is necessary.

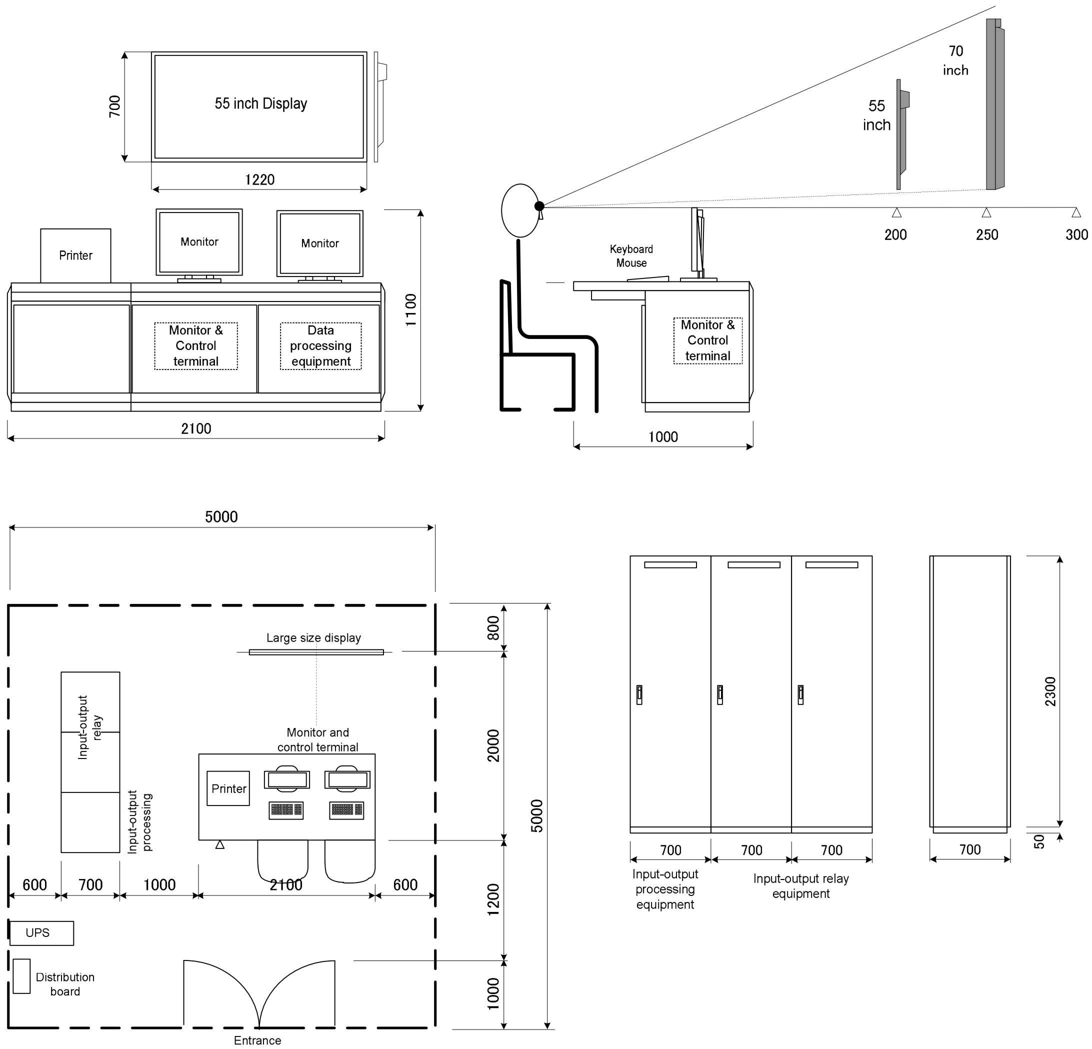


Figure 15-3.3 Minimum layout plan of regulator control room

15-3-4 Information processing equipment

The data processing equipment in the control room mounts and executes all software of the processing function. The control terminal device is equipped with software relating to operation and monitoring of the regulators, and when the data processing device is stopped, the operation terminal backs up basic functions such as data input, calculation, state monitoring, file processing and so on.

Main processing functions by software are as follows.

Table15-3.4 List of information processing function

Item	Function
System management	1.Program management (Activation/Stop/Transmission of operating information) 2.Memory area management 3.RAS (Reliability Availability Serviceability) 4.Time and schedule management 5.Sequence management 6.Event (Alarm/Warning) processing 7.Duplexed management
Calculation	1.Input data (1)Water level (Upstream and downstream) (2)Gate opening (3)Gate status 2.Calculation (1)Scale conversion (2)Calculation of discharge（H-Z-Q table or formula） (3)Trial calculation of gate opening（H-Z-Q table or formula） 3.Tabulation (1)Daily summary（Water level, discharge） (2)Monthly summary（Water level, discharge）
Status monitoring and alarm processing	1.Judgement of upper limit and lower limit（abnormal, alarm, warning, failure restoration） 2.Abnormal condition of devices (detection, alarm, failure restoration）
Display processing	1.Menu 2.Table (value) indication：Latest data, history data、daily report・monthly record, operation record 3.Trend graph indication：relation between water level and discharge 4.Schematic diagram display：Status of facilities 5.Configulation ：Constant value、data modification、time, etc. 6.Remote control display
Record	1.Daily report・monthly record 2.Operation record
Filing	1.Master file 2.External record file 3.Data supplement
Operation processing (Remote control of gate)	1.Control output（On-Off、setup value、output form）

15-4 Design of electric facilities

15-4-1 Power receiving equipment

In addition to securing the capacity for the power load of the gate facility, it is necessary for the power receiving equipment to secure a capacity capable of performing sufficient functions for the entire load equipment including the management load in the control house.

The construction site is in an urban area and it is possible to draw commercial power. The receiving voltage is 11 kV from the load capacity, the power voltage is three-phase four-wire type 380V class, the management voltage is single phase 220V or 100V class. The capacity of the transformer is 100kVA from the total load.

Table 15-4.1 Calculation of load capacity

Load	Capacity (kw)	Number	Voltage (V)	Efficiency	Phase factor	Load capacity (kVA)	Remarks
1.Three-phase							
Bahr Yusef	11.00	2	380	0.85	0.9	28.76	Oil pump
Ibrahimia	11.00	2	380	0.85	0.9	28.76	Oil pump
Badraman	0.65	2	380	0.85	0.9	1.70	Electric actuator
Diroutiah	0.65	3	380	0.85	0.9	2.55	Electric actuator
Abo Gabal	1.00	4	380	0.85	0.9	5.23	Electric actuator
Sahelyia	1.40	2	380	0.85	0.9	3.66	Electric actuator
sub-total						70.65	
2.Single-phase							
Lighting	0.40	6	210	1.00	0.9	2.67	Bahr Yusef& Ibrahimia
Local control panel							
Bahr Yusef	1.30	1	100	1.00	0.9	1.44	
Ibrahimia	1.30	1	100	1.00	0.9	1.44	
Badraman	0.80	1	100	1.00	0.9	0.89	
Diroutiah	1.05	1	100	1.00	0.9	1.17	
Abo Gabal	1.30	1	100	1.00	0.9	1.44	
Sahelyia	0.80	1	100	1.00	0.9	0.89	
Hydraulic unit	2.00	2	210	0.85	0.9	5.23	
【Control house】							
Control devices	5.00	1	100	1.00	0.9	5.56	
Air conditioners	2.00	1	210	0.85	0.9	2.61	
Indoor lighting	2.00	1	210	1.00	0.9	2.22	
sub-total						25.57	
Total						96.22	

Load capacity(kVA)＝Rated capacity(kW)／Efficiency／Phase factor

Power receiving equipment consists of followings.

Table15-4.2 Components of power receiving equipment

Equipment	Function
Incoming transformer panel	It accommodates transformers and switches that receive 3-phase 4-wire 11 kV and step down to 3-phase 4-wire 380 V.
Power receiving and distribution panel	It receives 3-phase 4-wire 380 V, supplies 3-phase 3-wire 380 V and single-phase 380 V / 220 V / 110 V power. Also, at the time of a power outage, it switches from commercial to emergency power generator and supplies uninterruptible power to the load.
Air load switch	A switch provided on the high voltage lead-in line, which is used as a switchgear between the electric power company and the consumer side. Install on the pillar and perform manual opening / closing operation. It also has a ground fault protection function.

15-4-2 Emergency generator

The emergency generator has a structure in which the engine and the generator are integrated, and when the commercial power supply is cut off, it secures the power supply of the power equipment necessary for maintaining the basic function of the gate equipment and the ancillary management equipment. From the viewpoint of noise prevention, cubicle type is recommended, and fuel tank mounting type is recommended for space saving. It can be said that the necessity of securing the power capacity during outage to operate the entire gate facilities, namely five regulators with fifteen gates simultaneously is small considering the current manual operation frequency and the impact on the beneficiary area when the gate operation becomes impossible. Therefore, it is sufficient to secure a power source that can operate one gate of either Bahr Yusef or Ibrahimia regulator with large discharge amount and one gate at a small scale regulator. In addition, in order to be able to manage the operation in the control house even at night, the following calculation was made on condition that the interior lighting functions.

(1) Generator output power

Generator output shall be selected based on the maximum calculated value among PG-1 to PG-3 shown below.

i) Capacity for steady state load (PG1)
ii) Capacity for maximum voltage drop on transient event (PG2)
iii) Capacity for maximum short time tolerance rate on transient event (PG3)
iv) Capacity including harmonic load or single phase load (PG4)

i) Capacity necessary for full load steady operation PG1

$PG1 = \Sigma Po / (\eta * \Phi) \times \alpha \times Sf$ (kVA)

ΣPo : Sum of total load output (kW)
η : Efficiency (0.85)
Φ : Phase factor (0.8)
α : Overall demand factor (0.9)
Sf : Coefficient of unbalanced load (When using Scott connection transformer, Sf=1.0)

$Sf = 1+0.6 \times \Delta P / \Sigma Po$

ii) Capacity required by allowable voltage drop PG2

$PG2 = Pm \times \beta \times C \times Xd \times (1-\Delta E) / \Delta E$ (kVA)

Pm : Motor output when startup capacity is maximum (kW)
β : Startup kVA per 1 kw on maximum capacity
C : Coefficient by startup method
Xd : Generator constant (0.25)
ΔE : Allowable voltage drop (0.25)

iii)Capacity necessary for starting maximum capacity motor at the end PG3

$PG3 = (fv1/\gamma g) \times \{(\Sigma Po-Pm) \times (\alpha / \eta \Phi) + Pm \times \beta \times C\}$

fv1 : Reduction coefficient on loading
γg : Tolerance rate against moment over load of generator (1.5)
ΣPo : Sum of steady load output (kW)
Pm : Motor output when startup capacity is maximum (kW)
α : Overall demand factor (0.9)

η : Efficiency（0.85）

Φ : Phase factor（0.8）

β : Startup kVA per 1 kw on maximum capacity

C : Coefficient by startup method

iv)Capacity required by allowable reversed phase current PG4

$$PG4 = (1/KG1) \times \{(0.432R)^2 + (1.23\Delta P)^2 x(1 - 3U + 3U^2)\}^{1/2} \ (kVA)$$

KG1 : Coefficient by allowable reversed phase current of generator（0.15）

R : Sum of harmonic load for generator（kW）, when no harmonic load R＝0

U : Single-phase unbalanced load coefficient

$U = (A-C) / (A+B-C)$、$A \geqq B \geqq C$

Single phase output value to each phase　A,B,C（kW）

$\Delta P = A+B-2C$

(2) Engine output power

Engine out put of generator must be more than the maximum capacity calculated by the following formulas.

i) Capacity necessary for full load steady operation　PE1

$$PE1 = PG \times \Phi g / \eta g \times 1.36 \quad (PS)$$

PG : Generator output(kVA)

ηg : Generator efficiency

Φg : Generating phase factor（0.8）

ii) Capacity necessary for starting maximum capacity motor at the end　PE2

$$PE2 = fv2 \{0.75/\eta'g) \times (\Sigma Po - Pm) \times (\alpha / \eta L) + Pm \times \beta \times C \times \Phi s / (\varepsilon \times \eta'g)\} \times 1.36$$

fv2 : Reduction coefficient on loading

$\eta'g$: Over load efficiency of generator（95% of commercial efficiency）

ΣPo : Sum of steady load output（kW）

Pm : Motor output when startup capacity is maximum（kW）

α : Overall demand factor（0.9）

ηL : Overall efficiency of base load（0.85）

ε : Allowable loading of engine on no load

β : Startup kVA per 1 kw on maximum capacity

C : Coefficient by startup method

Φg : Motor startup phase factor when startup capacity is maximum

（Squirrel : 0.4、Wire-wound : 0.8）

iii)Capacity　for moment over load tolerance rate　PE3

$$PE3 = fv3 / (\eta'g \times \gamma) \times \{(\Sigma Po - Pm) \times (\alpha / \eta L) + Pm \times \beta \times C \times \Phi s\} \times 1.36$$

fv3 : Reduction coefficient on loading

$\eta'g$: Over load efficiency of generator（95% of commercial efficiency）

γ : Tolerance rate against moment over load of generator（1.1）

ΣPo : Sum of steady load output（kW）

Pm : Motor output when startup capacity is maximum（kW）

α : Overall demand factor（0.9）

ηL : Overall efficiency of base load（0.85）

β : Startup kVA per 1 kw on maximum capacity

C：Coefficient by startup method

Φg：Motor startup phase factor when startup capacity is maximum

（Squirrel：0.4、Wire-wound：0.8）

Table 15-4.3 Objective load output for emergency generator

Load	Capacity (kw)	Number	Emergency generator Actual capacity (kw)	Counted number	Target capacity (kw)	Remarks
1.Three-phase						
Bahr Yusef	11.00	2	11.00	2	22.00	Oil pump
Ibrahimia	11.00	2	11.00			Oil pump
Badraman	0.65	2	0.65			Electric actuator
Diroutiah	0.65	3	0.65			Electric actuator
Abo Gabal	1.00	4	1.00			Electric actuator
Sahelyia	1.40	2	1.40	1	1.40	Electric actuator
sub-total					23.40	
2.Single-phase						
Lighting	0.40	6	0.40			Bahr & Ibrahimia
Local control panel						
Bahr Yusef	1.30	1	1.30	1	1.30	
Ibrahimia	1.30	1	1.30	1	1.30	
Badraman	0.80	1	0.80			
Diroutiah	1.05	1	1.05			
Abo Gabal	1.30	1	1.30			
Sahelyia	0.80	1	0.80	1	0.80	
Hydraulic unit	2.00	2	2.00	2	4.00	
【Control house】						
Control devices	5.00	1	5.00	1	5.00	
Air conditioners	2.00	1	2.00			
Indoor lighting	2.00	1	2.00	1	2.00	
sub-total					14.40	
Total					37.80	

Table 15-4.4 Calculation of the capacity of emergency generator

Required capacity of generator

Classification	Coefficient and applied values									Capacity（kVA）
PG1	ΣPo	η	Φ	α	Sf					
	37.8	0.85	0.8	0.8	1.000					44.5
PG2	Pm	β	C	Xd	ΔE					
	11.0	7.2	1.0	0.25	0.25					59.4
PG3	fv1	γg	ΣPo	Pm	α	η	Φ	β	C	
	1.0	1.5	37.8	11.0	0.8	0.85	0.8	7.2	1.0	73.8
PG4	KG1	R	ΔP	U						
	0.15	0	0	0						0.0

Required engine output power

Classification	Coefficient and applied values										Capacity（PS）
PE1	PG	ηg	Φg								
	75	0.857	0.8								95.2
PE2	fv2	η´g	ΣPo	Pm	α	ηL	β	C	Φs	ε	
	1	1.5	37.8	11	0.8	0.857	7.2	1	0.4	1.00	45.7
PE3	fv3	η´g	ΣP0	Pm	α	ηL	β	C	Φs	γ	
	1	1.5	37.8	11	0.8	0.857	7.2	1	0.4	1.10	46.7

From the results of calculation sheets above, emergency generator shall be selected to meet the required specification of 75kVA for generator capacity and 95.2PS (=71.7kw) for diesel engine.

(3)Fuel tank capacity

Fuel consumption rate F is obtained by following equation.

F=b×PS/r

where , b: Fuel consumption rate（＝0.22kg/PS･h）

PS: Output of diesel engine（PS)

r: Specific gravity of fuel（Light oil＝0.83）

Table 15-4.5 Necessary fuel tank capacity

Fuel consumption b (kg/PS･h)	Engine output PS (PS)	Specific weight γ	Fuel consumption F (L/hr)	Continuous run time t (hour)	Required tank T (litter)	Remarks
0.22	100	0.83	27	2	53	
0.22	100	0.83	27	6	159	
0.22	100	0.83	27	12	318	
0.22	100	0.83	27	24	636	

Generally, it is often planned to be able to operate for more than 2 hours in the case of a headwork facility, so a fuel tank of 53 liters or more is necessary according to the calculation results in the above table.

For reference, an example of a model of an emergency generator that satisfies the above conditions is shown below.　This model has a built-in fuel tank and its capacity is 225 liters.

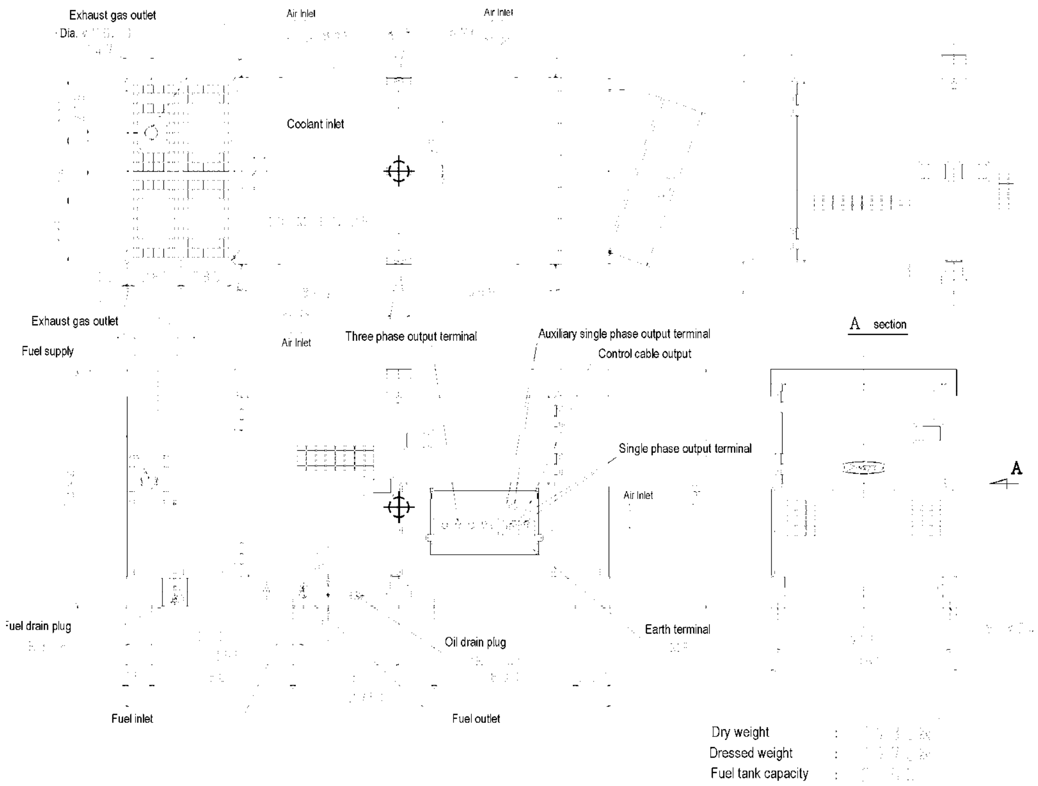


Figure 15-4.1 Outline drawing of an emergency generator

15-4-3 Specification of electric facilities

Minimum requirement of electric facilities are as follows.

I. Control equipment in the control house

1. Data processing equipment (Personal computer)

1）Personal computer body	
a)Memory	2GB
b)HDD	500GB×2（RAID1）
c)Optical drive	DVD drive or equivalent
d)I/O interface	RS-232C、USB、LAN port
e)RAS function	Included
2）LCD monitor	24 inch
3）Keyboard, mouse	Included
4）Operation system	Real-time OS（UNIX or Windows）
5）Power source	AC100V±10V
6）Structure	Tower type or rack mount
7）Placement	Mounted on a desk. Main body is under the desk, display is on the desk.

2. Monitor and control terminal(Personal computer)

1）Personal computer body	
a)Memory	2GB
b)HDD	500GB×2（RAID1）
c)Optical drive	DVD drive or equivalent
d)I/O interface	RS-232C、USB、LAN port
e)RAS function	Included
2）LCD monitor	24 inch
3）Keyboard, mouse	Included
4）Operation system	Real-time OS（UNIX or Windows）
5）Power source	AC100V±10V
6）Structure	Tower type or rack mount
7）Placement	Mounted on a desk. Main body is under the desk, display is on the desk.

3. LBP（Laser Beam Printer)

1)Recording type	Electrographic recording or semiconductor laser and xerographic type
2)Print color	24 bit full color
3)Paper	A3、B4、A4、B5、A5
4)Interface	LAN port
5)Paper feeding unit	2 sets（A4(B5)、A3(B4)）
6)Power source	AC100V±10V

4. I/O processing equipment

1）Component	
a）Processing part	
b)Input-output part	Contact input-output, Digital input-output Analogue input-output, Serial input-output
c）Network part	
d)Power source part	
2）I/O interface	
a）I/O relay equipment	Contact, digital, analogue
b)Data processing equipment	LAN（PC-LAN）

3）Power source	AC100V±10V
4）Structure	Indoor self-standing

5. I/O relay equipment

1）Component	
a）Monitoring input part	
Contact input part	Non-voltage contact
b）Measurement input part	
Analogue input part	DC4～20mA
Isolator	I/O insulation
c）Surge Protective Device	for measurement for contact
d)Control output part	
Contact output part	Non-voltage/Voltage contact(Open/Close、Start /Stop, etc.）
e)Power source part	
2）Transmission to external devices	
a）Monitoring signal	Non-voltage contact（DC110V50mA）
b)Analogue signal	DC4～20mA
c)Control output signal	on-voltage/Voltage contact(DC110V50mA）
3）Power source	AC100V±10V
4）Structure	Indoor self-standing

6. Switching hub（OA-LAN）

1)Structure	Desktop type
2)Transmission speed	10Mbps/100Mbps/1000Mbps
3)Reference format	IEEE802.3 10BASE-T IEEE802.3u 100BASE-TX IEEE802.3ab 1000BASE-T
4)Port number	10BASE-T/100BASE-TX/1000BASE-T 8 ports
5)Power source	AC100V±10V

7. UPS(Uninterruptible Power Supply)

1) Rating	Continuous duty
2) Cooling system	Natural air cooling or forced cooling
3) Driving type	Commercial power synchronizing inverter power supply （Hitless switching system）
4) Rated output	3kVA
5) AC input	
a) Phase	Single phase 2 wire
b) Voltage	100V±10V or 200V±20V
c) Frequency	50／60Hz±5％
6) AC output	
a) Phase	Single phase 2 wire
b) Voltage	100V
c) Voltage accuracy	less than ±3％
d) Frequency	50Hz
e) Battery type	Small seal type lead battery
f) Back-up type	10 minutes or more

8. .Lightning protective transformer

1) Rating	Continuous
2) Input power source	
a) Phase	Single phase 2 wire
b) Voltage	100V or 200V

3) Output power source	
a) Phase	Single phase 2 wire
b) Voltage	100V or 200V
4) Frequency	50Hz
5) Ratio of transformation	1:1 or 2:1
6) Capacity	
a) Single phase 2wire	5kVA
7) Cooling system	Dry-type self cooled
8) Ratio of voltage fluctuation	less than 3%（3kVA and more）
9) Surge breakdown voltage	10kV 1.2/50μS
10) Surge extraction rate	Balance: less than -40dB, Unbalance: less than -20dB

9. Distribution panel of devices

1）Structure	Indoor wall-hung type
2) MCCB	3P50AF×2
	2P30AF×10

II. Power receiving and transforming equipment

1. Incoming transformer panel

(1) Panel

1)Type	Outdoor self-standing（front and backside door）

(2)Devices inside of panel

1)Transformer	
a)Category	Dry molded type
b)Capacity	100kVA
c) Phase	3 phase
d) Voltage	Primary 11kV
	Secondary 380V-210V
e) Frequency	50Hz
f) Type	Indoor panel housed
g)Cooling	Dial thermometer（with alarm contact）
2)Disconnecting switch (DS)	
a) Rated voltage	11kV
b) Rated current	200A
c) Rated short-time withstand current	12.5kA
d) Operational method	by Hook bar
3)MCCB	4P225AF 1pcs

2. Power receiving and distribution panel

(1)Panel

1)Type	Indoor self-standing（front door）

(2)Devices of panel face

1）AC Voltage meter	1 pcs
2）AC current meter	10 pcs
3）Voltage switch	1 pcs
4）Current switch	10 pcs
5）Signal lamp	1 set
6）Switch	2pcs（Auto-manual、Commercial -generator）
7）Push button	5 pcs（Start、Stop、Reset、Emergency stop, failure restoration）
8）Others	1set

(3)Devices inside of panel

1）MCCB	4P225AF	2 pcs

2）MCCB	4P50AF	1 pcs
3）MCCB	4P30AF	1 pcs
4）MCCB	3P75AF	2 pcs
5）MCCB	3P50AF	6 pcs
6）MCCB	3P30AF	2 pcs
7）MCCB	2P30AF	9 pcs
8）Single phase transformer		1 pcs
Capacity	1KVA 380V/100V	
9）MC	4 pole or equivalent	1 pcs
10）Earth leakage relay		9 pcs
11）CT		9 pcs
12）Others	1 set	

3. Emergency generator

(1)Generator

1）Phase	3 phase 4 wire
2）Frequency	50Hz
3）Output	80kV
4）Voltage	200-400/220-440V
5）Power factor	0.8（lagging）

(2)Diesel engine

1)Type	Direct injection with supercharger
2）Rated speed	1500rpm
3）Fuel	Light diesel oil
4）Fuel tank（on-board）	225L
5）Fuel consumption	9.6/13.5L/h（50% load/75% load）

(3)Others

1）Sound（1m）	70dB（A）

4. Generator panel

(1)Structure	Indoor self-standing
(2)Components	
1）AC voltage meter	2 pcs
2）AC current meter	1 pcs
3）Frequency meter	1 pcs
4）Control part	1 set
5）Automatic voltage controller	1 set
6）DC power source （including battery）	1 set
7）MCCB	1 set
8）Others	1 set

5. Air load switch

1）Operation method	Manual
2）Rated voltage	11kVA
3）Rated frequency	50Hz
4）Rated current	400A
5）Direction	yes/no
6）Rated short-time withstand current	12.5kA
7）VT	On-board
8）Material of case	Steel
9）Salinity resistance	yes

10）Accessary	Ground relay、box
11)Option	Over-current relay, main circuit cutoff

III. Gate local equipment

1. Local control panel for electric motor gate

（1）Facilities

Gate type	Electric motor	
Number of gate（n）	Badraman	2 gates（0.65kW×2） n＝2
	Diroutiah	3 gates（0.65kW×3） n＝3
	Abo Gabal	4 gates（1.00kW×4） n＝4
	Sahelyia	2 gates（1.40kW×2） n=2

（2）Panel

1)Type	Outdoor self-standing（front door）

（3）Devices of panel face

1）AC voltage meter	1 pcs
2）AC current meter	n pcs
3）Opening indicator	n pcs
4）Indication lamp（common）	1set
5）Indication lamp（each gate）	n set
6）Push bottom	n×3 （stop）
7）Push bottom	3 pcs （reset、emergency stop、failure restoration）

（4）Devices inside of panel

1）MCCB	3P50AF	1 pcs
2) MCCB	3P30AF	n pcs
3) MCCB	2P30AF	5 pcs
4）Single phase transformer	1 pcs（1KVA 380V/200V）	
5）Single phase transformer	1 pcs（1KVA 380V/100V）	
6）Single phase transformer	1 pcs（0.5KVA 100V/100V）	
7）MC	n set（Open、close）	
8）Earth leakage relay	2 pcs	
9）3E relay	n pcs	
10)CT	n pcs	
11）Condenser	n pcs	
12）Synchro current converter		n pcs
13）Supplement relay	1 set	
14）Others	1 set	

2. Local control panel for hydraulic gate

（1）Facilities

Gate type	Hydraulic cylinder type	
Number of gate	Bahr Yusef	4-Upper leaf （Hydraulic pump 11kW）
		4-Lower leaf （Hydraulic pump 11kW）
	Ibrahimia	4-Upper leaf （Hydraulic pump 11kW）
		4-Lower leaf （Hydraulic pump 11kW）

（2）Panel

1)Type	Indoor self-standing(front door)

（3）Devices of panel face

1）AC voltage meter	1 pcs
2）AC current meter	2 pcs
3）Opening indicator	8 pcs
4）Water level indicator	2 pcs
5）Indication lamp(common)	1 set

6）Indication lamp(each gate)	8 set	
7）Switch	3 pcs（auto-manual、upper/lower：active-reserve）	
8）Push bottom	4 pcs（upper/lower pump start-stop）	
9）Push bottom	8×3（gate：open -close-stop）	
10）Push bottom	3 pcs（reset、emergency stop、failure restoration）	
（4）Devices inside of panel		
1）MCCB	3P50AF	2 pcs
2) MCCB	3P30AF	2 pcs
3) MCCB	2P30AF	3 pcs
4）Single phase transformer	1 pcs（1KVA 380V/200V）	
5）Single phase transformer	1 pcs（1KVA 380V/100V）	
6）Single phase transformer	1 pcs（0.5KVA 100V/100V）	
7）MC	4 pcs	
8）Earth leakage relay	3 pcs	
9）3E relay	4 pcs	
10) CT	4 pcs	
11）Condenser	4 pcs	
12）Synchro current converter	n pcs	
13）Supplement relay	1 set	
14）Others	1 set	

3. Distribution panel（Bahr Yusef and Ibrahimia Local control house ）

1）Structure	Indoor wall-hung type
2) MCCB	2P50AF×1
	2P30AF×5

15-5 Design of stoplogs

15-5-1 Installation method

Stoplog elements are stored in a warehouse near the control house, and transported from the warehouse to each regulator by truck. A truck crane of a certain capacity will place the stoplog elements into the gate grooves.

A semi-automatic lifting beam shall operate the stoplogs. The lifting beam must be capable of retraction after placing the stoplog elements. The lifting beam shall be equipped with guide rollers and lifting lugs to engage with the hoist.

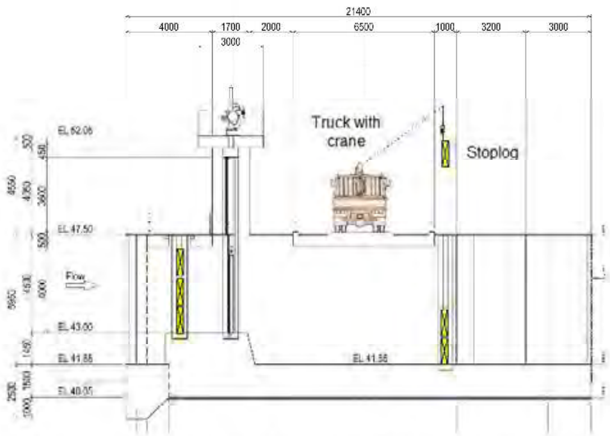


Figure 15-5.1 Stoplog installation method for small regulators

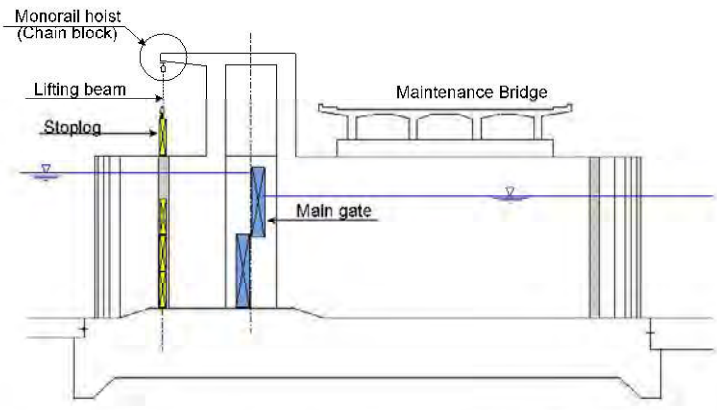


Figure 15-5.2 Stoplog installation method for large regulators (upstream side)

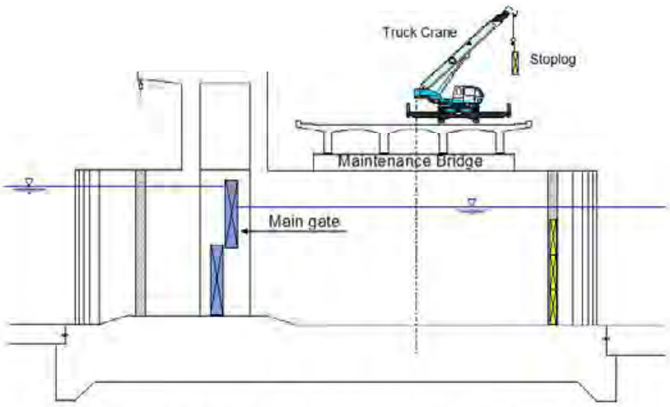


Figure 15-5.3 Stoplog installation method for large regulators (downstream side)

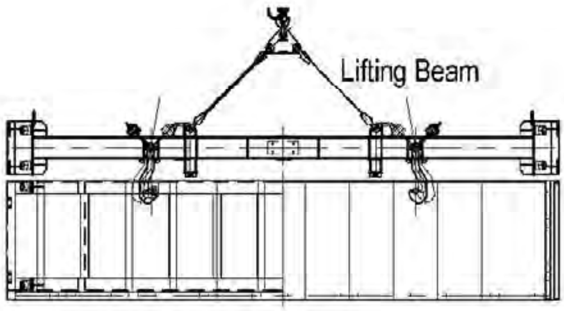


Figure 15-5.4 Lifting beam

15-5-2 Division number of stoplog

(1) Design principles

1) Two types of stoplog, for large regulators and for all small regulators are prepared.

2) Stoplogs are composed of small elements to make it possible to install them by truck crane.

3) Stoplog elements are identical and interchangeable and can be used both upstream and downstream.

4) The heights of elements are set using five 5cm units.

5) The height of any element for a large regulator should be less than 1.4m due to the limited space available to maneuver installation using the lifting beam.

Other basic conditions such as the necessary height of each regulator are shown on the next page.

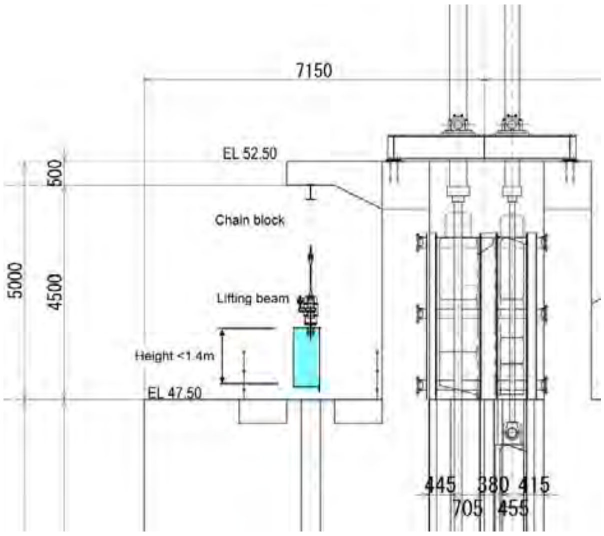


Figure 15-5.5 Maximum height of part of a stoplog for large regulators

(2) Result of study

A case study was conducted based on the conditions mentioned above. Because the required height of stoplogs determined by design water level is different depending on the regulator, the necessary number of pieces which make up the stoplog is also different, especially in the case of the small scale regulators. As a result, some extra height necessarily arises, and the most economical manner by which this extra height is minimized is sought.
Table 15-5.2 and Table 15-5.3 show the results of comparison.

Table 15-5.1 Design conditions of stoplogs

		Large regulators		Small regulators				Remarks
Name		**Bahr Yusef**	**Ibrahimia**	**Badraman**	**Diroutiah**	**AboGabal**	**Sahelyia**	
Type of stoplogs		Sliding	Sliding	Sliding	Sliding	Sliding	Sliding	
Number of stoplogs (sets) [1)]		1	1	2				
Clear width of opening		6.00m	6.00m	2.00m	2.00m	2.00m	2.00m	
Upstream (U/S)	Design water level	EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	NWL
	Gate sill elevation	EL40.00m	EL40.00m	EL43.90m	EL44.20m	EL43.60m	EL43.00m	
	Necessary height	6.55m	6.55m	2.65m	2.35m	2.95m	3.55m	Freeboard=0.25m
Downstream (D/S)	Design water level	EL45.82m	EL45.13m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	
	Gate sill elevation	EL39.50m	EL39.50m	EL43.40m	EL43.70m	EL42.75m	EL41.55m	
	Necessary height	6.57m	5.88m	2.75m	2.45m	3.40m	4.60m	Freeboard=0.25m
Lifting device	Upstream	Manual chain block	Manual chain block	Truck crane	Truck crane	Truck crane	Truck crane	
	Downstream	Truck crane	Truck crane	Truck crane	Truck crane	Truck crane	Truck crane	
Seal type		3-side rubber seal	3-side rubber seal	3-side rubber seal	3-side rubber seal	3-side rubber seal	3-side rubber seal	
Materials	Skin plate	Rolled steel	Rolled steel	Rolled steel	Rolled steel	Rolled steel	Rolled steel	
	Main beam	Rolled steel	Rolled steel	Rolled steel	Rolled steel	Rolled steel	Rolled steel	
	Side roller	Stainless steel	Stainless steel	-	-	-	-	
	Gate guide frame	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	
	Bolt,Nut &Washer	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	
Deflection		1/600	1/600	1/600	1/600	1/600	1/600	
Allowable stress		According to JIS (Japanese Industrial Srandards) or relevant standards						

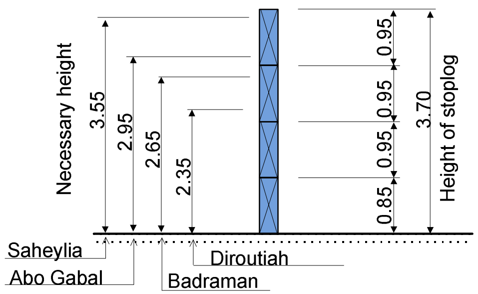
Note: 1) One set means a pair of a upstream stoplog and a downstream stoplog for a same vent.

Table 15-5.2 Comparison of the small scale stoplogs

		Badraman		Diroutiah		AboGabal		Sahelyia		Total	Appox. Weight
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream		
	Clear width	2.00m									
	Necessary height	2.65m	2.75m	2.35m	2.45m	2.95m	3.40m	3.55m	4.60m		
Option-1	Height of an element	1.55m									
	Number of elements	2	2	2	2	2	3	3	3	6	
	Total height	3.10m	3.10m	3.10m	3.10m	3.10m	4.65m	4.65m	4.65m		
	Extra height	0.45m	0.35m	0.75m	0.65m	0.15m	1.25m	1.10m	0.05m	4.75m	
Option-2	Height of an element	1.15m									
	Number of elements	3	3	3	3	3	3	4	4	8	
	Total height	3.45m	3.45m	3.45m	3.45m	3.45m	3.45m	4.60m	4.60m		
	Extra height	0.80m	0.70m	1.10m	1.00m	0.50m	0.05m	1.05m	0.00m	5.20m	
Option-3	Height of an element	0.95m									
	Number of elements	3	3	3	3	4	4	4	5	9	
	Total height	2.85m	2.85m	2.85m	2.85m	3.80m	3.80m	3.80m	4.75m		
	Extra height	0.20m	0.10m	0.50m	0.40m	0.85m	0.40m	0.25m	0.15m	2.85m	
Option-3A	Height of an element	0.95m (0.85m)*									310(290)kg
	Number of elements	3	3	3	3	4	4	4	5	9	
	Total height	2.75m	2.75m	2.75m	2.75m	3.70m	3.70m	3.70m	4.65m		
	Extra height	0.10m	0.00m	0.40m	0.30m	0.75m	0.30m	0.15m	0.05m	2.05m	

*The value in the parentheses shows the height of one irregular element. But this element is interchangeable with other elements.

Upstream



Downstream

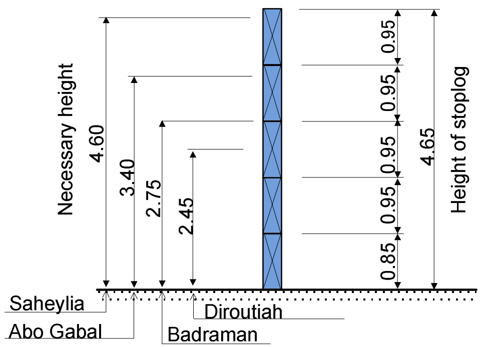
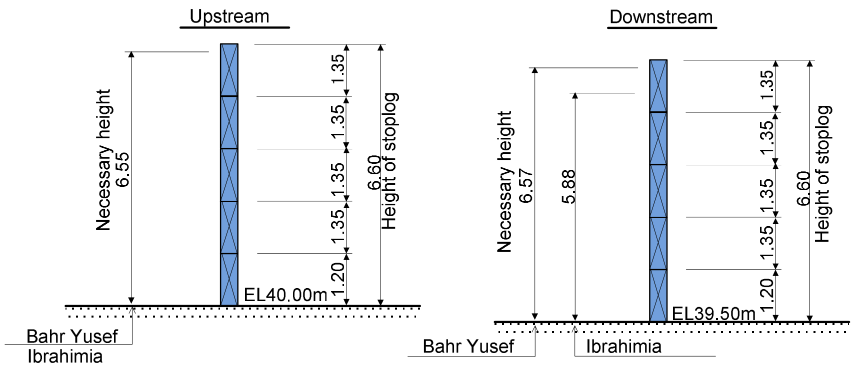


Table 15-5.3 Comparison of the large scale stoplogs

		Bahr Yusef		Ibrahimia		Total	Appox. Weight
		Upstream	Downstream	Upstream	Downstream		
	Clear width	6.00m					
	Necessary height	6.55m	6.57m	6.55m	5.88m		
Option-1	Height of an element	1.35m					
	Number of elements	5	5	5	5	20	
	Total height	6.75m	6.75m	6.75m	6.75m		
	Extra height	0.20m	0.18m	0.20m	0.87m	1.45m	
Option-2	Height of an element	1.10m					
	Number of elements	6	6	6	6	24	
	Total height	6.60m	6.60m	6.60m	6.60m		
	Extra height	0.05m	0.03m	0.05m	0.72m	0.85m	
Option-3	Height of an element	0.95m					
	Number of elements	7	7	7	7	28	
	Total height	6.65m	6.65m	6.65m	6.65m		
	Extra height	0.10m	0.08m	0.10m	0.77m	1.05m	
Option-1A	Height of an element	1.35m (1.20m)*					2.2(2.1) ton
	Number of elements	5	5	5	5	20	
	Total height	6.60m	6.60m	6.60m	6.60m		
	Extra height	0.05m	0.03m	0.05m	0.72m	0.85m	

*The value in the parentheses shows the height of one irregular element. But this element is interchangeable with other elements.



16. Architectural Design

16-1 Design of control house

(1) Planned construction site

Construction site of the control house is near the current office and the mosque between the new Badraman regulator and the new Ibrahimia regulator. The area of about 2,500 m^2 on the north side and about 900 m^2 on the south side is secured across the newly constructed road, and the existing building is relocated and removed by the Egyptian government before the construction work begins.

Figure 16-1.1 Present situation of the construction site

(2) Layout plan

In addition to the control house, stoplogs storage house and parking lot are placed in the above construction site.

Since the building area of the control house is assumed to be approximately 200 m^2, it can be placed on either the north side or the south side. However it is administratively advantageous to construct on the south side site that can be visually confirmed the gate facility and the water level condition of the new group of regulators, namely Bahr Yusef, Badraman and Ibrahimia regulator from the side. Meanwhile the construction area of stoplogs storage house is assumed about only 150 m^2, but it is difficult to place it in the south side area with the control house because a site for a crane or a large truck to enter for the purpose of carrying in and out of the stoplogs is necessary besides the building area.

Therefore, the stoplogs house is to be built in the north side site, and the remaining

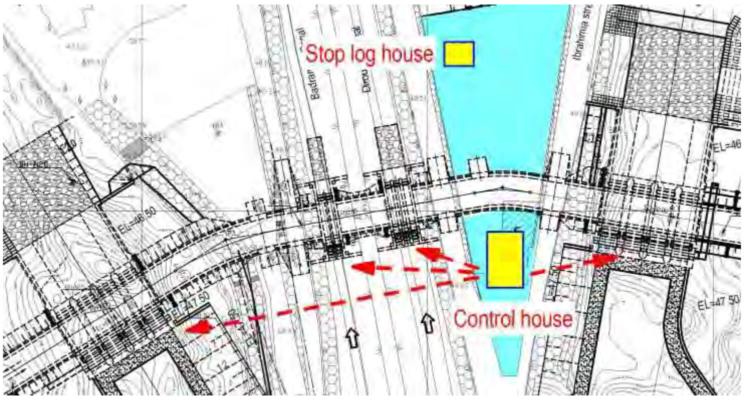


Figure 16-1.2 Layout of control house

site is used as the passage and parking space of the vehicle.

(3) Room arrangement

The monitoring room for the integrated water management in addition to the control room of Dirout group of regulators shall be arranged in the control house, with no resident staff. The other rooms to be constructed are as shown below, the layout of them is decided from the characteristics and functions of each room. The control house shall be two stories taking account of the necessary room area for the site area and the points that it is used by two different organizations.

1) Electrical room

It is a room to install the power receiving and distribution equipment as well as emergency generator. Considering the convenience of lead-in of commercial power supply, refueling of the generator and maintenance of the equipment, this room should be placed on the ground floor south side.

2) Control room of regulators

This room is placed on the first floor so that the gate facilities of Bahr Yusef and Ibrahimia regulator and upstream water level can be visually monitored. In addition, a balcony is set around the room for the purpose of monitoring from the outdoors, too.

3) Water management monitoring room

Since the water management system etc. are arranged and monitored, it is located at the position adjacent to the ground floor office.

4) Office

The offices for the integrated water management and Dirout group of regulators management are located on the ground floor and first floor. It is a room where staff perform daily office work, so place it near the first floor entrance or the stairs.

5) Meeting room

It is used for the meeting or the explanations to the visitors. It is placed on the first floor from the relationship between the area required for the meeting and the layout of other rooms.

6) Toilet, washing room

Considering the use of staff and visitors, they are separated by gender, and are set on the ground floor and the first floor respectively.

7) Warehouse

It is set up on each of the ground and first floor for storage of documents, furnishings, etc. and arrangement of servers.

In addition to the above, installation of locker rooms, hot-water supply rooms, reception and guard rooms, rest rooms, shower rooms, etc. were considered, however they were assumed unnecessary from the result of discussion..

(4) Area of rooms

The area of each room was decided to be as shown in the table below as a result of considering the number of staff to be employed, the size and arrangement of the equipment to be installed, the width of the passage necessary for maintenance and inspection, and the layout of the whole floor.

Table16-1.1 Approximate area of rooms

Rooms	Calculation	Remarks
Ground floor		
Monitoring room	5.75 × 6.50 = 37.38	
Power receiving/Generator room	5.75 × 3.90 = 22.43	
Office room	6.90 × 4.40 = 30.36	
Store room(Server room)	2.95 × 3.90 = 11.51	
Toilet/Washing room	3.85 × 3.90 = 15.02	Sub total 116.68
Corridor, Stairs, Hall	3.20 × 10.50 = 33.60	
〃	7.00 × 2.00 = 14.00	
	Sub total 164.3	m^2
First floor		
Control room	5.75 × 10.50 = 60.38	
Office room	3.10 × 4.40 = 13.64	
Meeting room	7.00 × 4.40 = 30.80	
Store room	2.95 × 3.90 = 11.51	
Toilet/Washing room	3.85 × 3.90 = 15.02	Sub total 131.34
Corridor, Stairs, Hall	10.25 × 2.00 = 20.50	
〃	3.20 × 3.90 = 12.48	
	Sub total 164.3	m^2
	Total 328.6	m^2
Traffic part	80.58	32.5%
Room area	248.02	

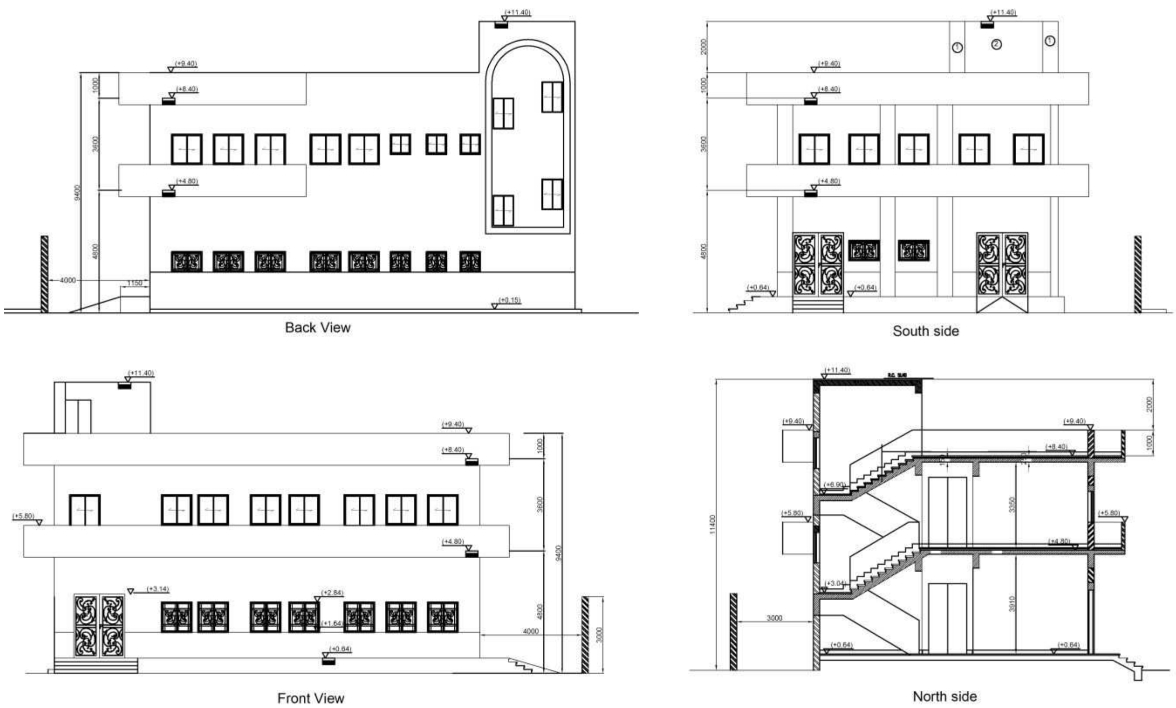
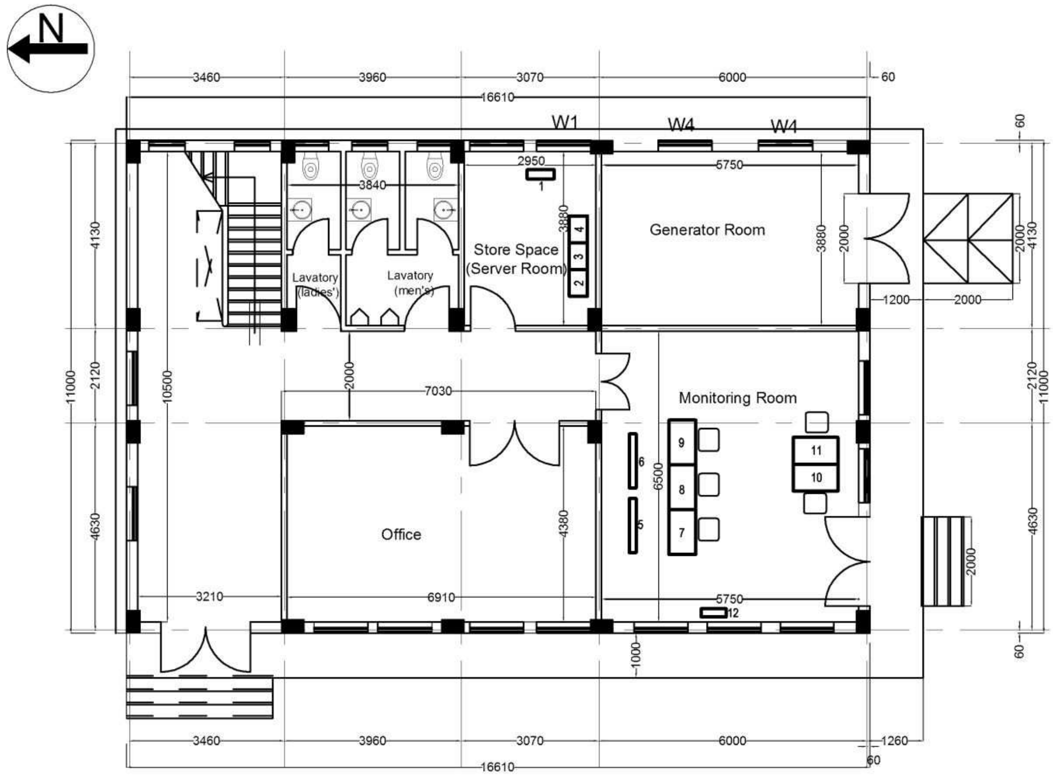
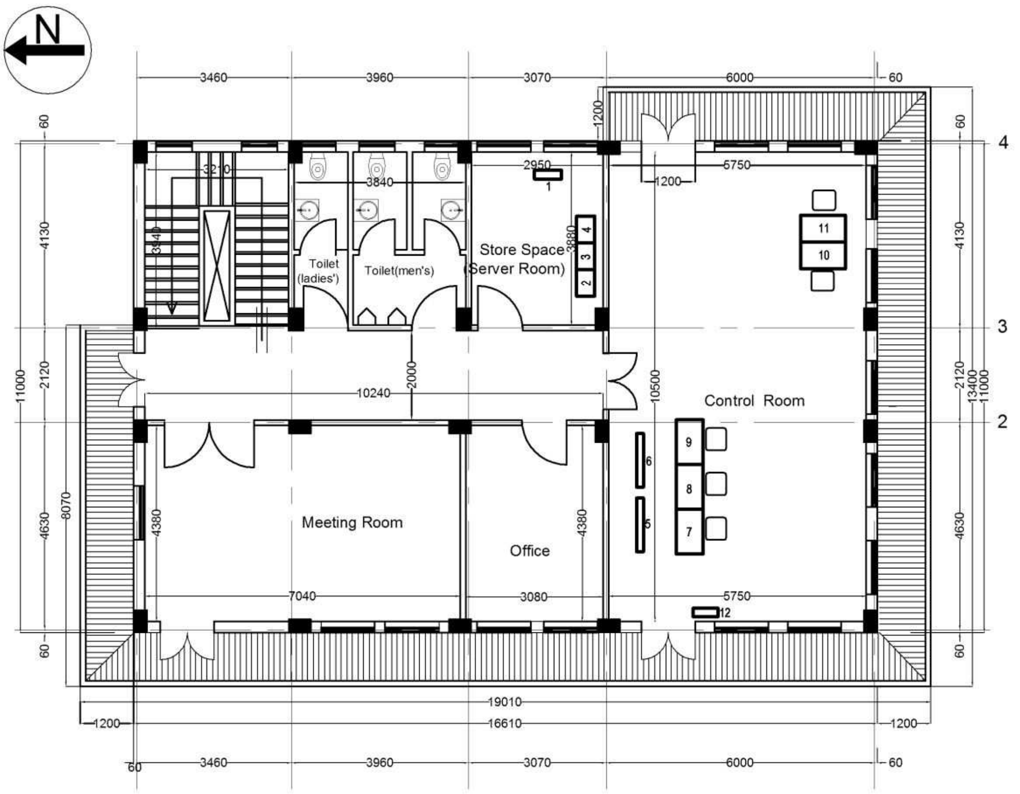


Figure 16-1.3 Elevation view of control house



Central Monitoring House for Integrated Water Management
Ground Floor



Control House for New Dirout Group of Regulators
First Floor

Figure 16-1.4 Floor plan of control house

(5) Disaster prevention equipment

1) Fire protection facility

Fire detector and alarm equipment shall be provided in each room, fire extinguish equipment shall be installed on each floor. Fire protection facilities are also provided in the local control rooms and the stop log house which are described in the following chapters.

2) Lightning protection system

Considering that the building height is about 10m and the frequency of occurrence of lightning strikes in the construction area, lightning protection facility shall not be provided.

16-2 Design of local control house

(1) Size of local control room

For the Bahr Yusef and the Ibrahimia regulator, a building that houses the hydraulic unit together with the local control panel is installed at a location adjacent to the regulator to protect the equipment from wind and rain, etc., and to ensure safe operation of the gate from within the operation room. The size of the operation room is decided in consideration of the arrangement of the hydraulic unit, local control panel and workability of them during operation, inspection, maintenance and replacement work.

The distance from the front of the hydraulic unit to the wall or other equipment is 100cm or more, and the three sides other than the front are separated by at least 60cm in consideration of tank cleaning, equipment inspection, etc. Even when inspection from the back side is unnecessary, a space of 60cm or more should be secured considering repainting work. Likewise, the local control panel secures a space of 100cm in front and 60cm or more around the panel except the front.

As a result of studying the arrangement based on the assumed size of hydraulic unit, the separately placed hydraulic tank, and the local control panel, it is decided that the interior dimension is 7.5m × 6.5m as shown in the Figure 16-2.1.

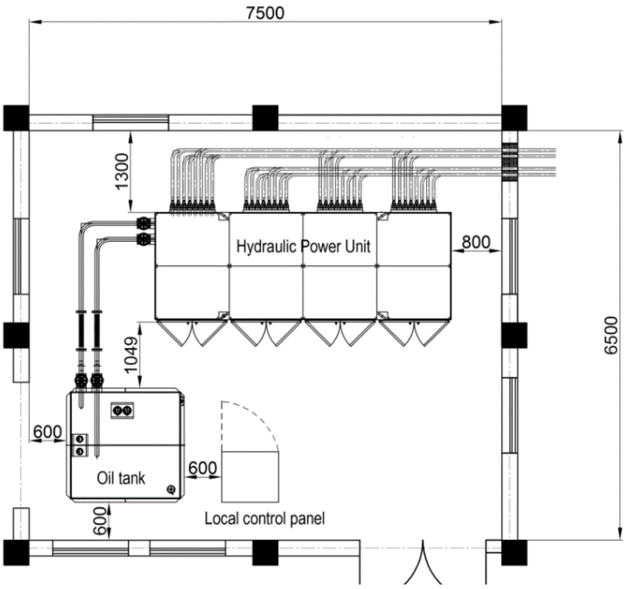


Figure 16-2.1 Layout of local control house

(2) Determination of construction site

1) Bahr Yusef regulator

Construction site of the local control house shall be the upstream side of the regulator so that the length of hydraulic pipe from the operation room to the hydraulic cylinder can be made as short as possible and the operation can be carried out visually confirming the state of the gate.

On the upstream side of the Bahr Yusef regulator a wide flat site is created by the steel sheet pile wall on the left bank side, whereas the right bank side can not secure enough site to build the control house. Therefore, a local control house is constructed on the upstream left bank side. In addition, in the upstream part of the left bank, the truck with the maximum loading capacity of about 4 tons will enter to the vicinity of the side pier of the regulator for carrying in and out of the stoplogs. For this reason, the house shall be constructed at a position 15m away from the side of pier considering the traveling locus of the truck. In addition, the stairway leading to the top of pier where the gate hoists are installed is constructed on the right bank side opposite to the side on which the stoplogs are carried in and out.

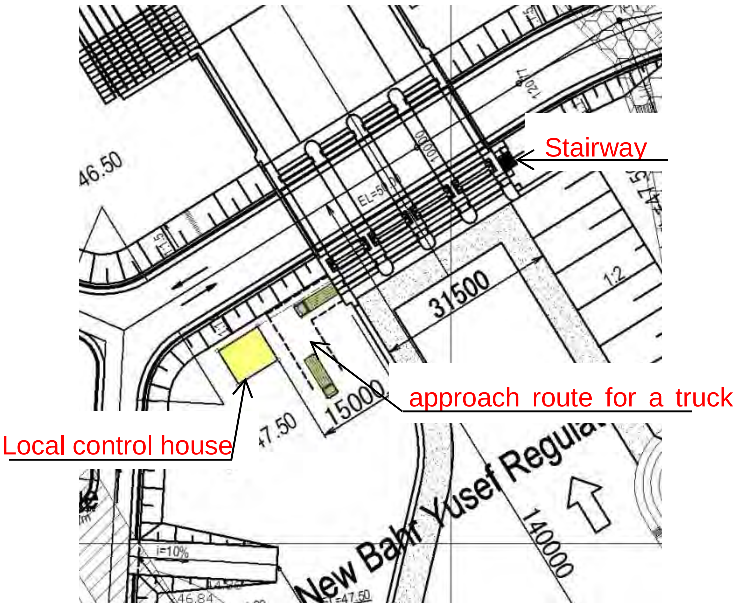


Figure 16-2.2 Layout plan for Bahr Yusef side

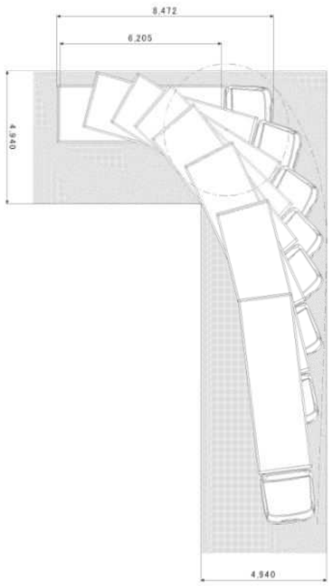


Figure 16-2.3 Travelling locus of truck

2) Ibrahimia regulator

With the same concept as the Bahr Yusef regulator, it is desirable to construct the local control house on the right bank upstream side where large area is created and it is convenient for management. However, access roads route running parallel to national railway, which are planned to be designed by the Egyptian government in the future, is assumed as shown by the broken line in the figure below.

Therefore, the local control house may interrupt the planning road route if the house is constructed at the same position as the Bahr Yusef regulator in consideration of the track entry path for carrying in and out of stoplogs. In addition, since access routes from the road (road surface elevation is about 50.0m) to the left bank side site (EL 47.50m) are also required, installation of the local control house on the right bank also interferes the travelling of vehicles for maintenance work. As a result of discussion with the Egyptian government, the local control house of the Ibrahimia regulator was to be installed on the downstream side of the right bank.

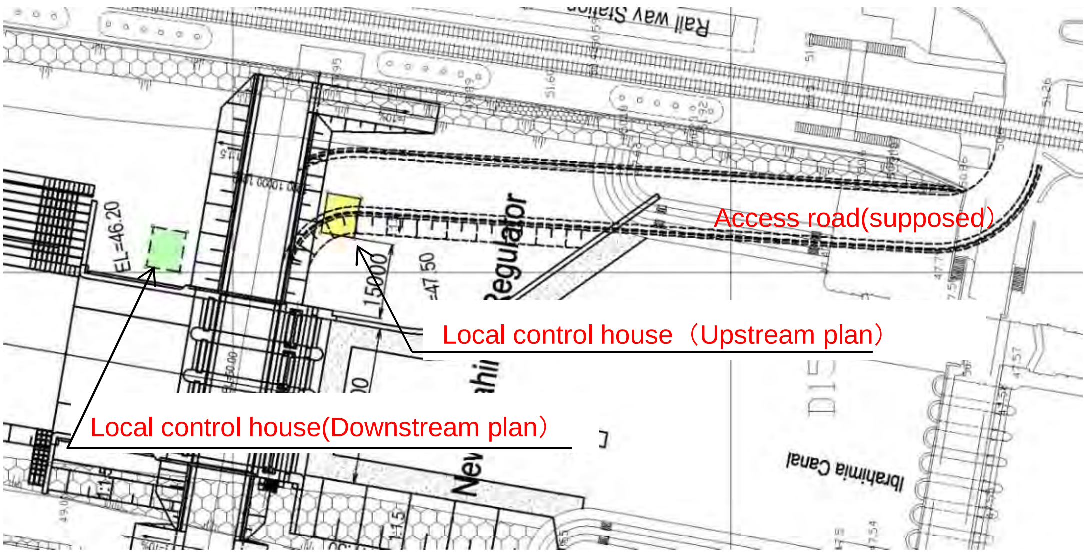


Figure 16-2.4 Layout plan for Ibrahimia side

16-3 Design of stoplogs storage house

(1) Storage equipment

The size of the stoplogs and the number of divisions were as follows as a result of the above examination. Although there is a method of keeping them outdoors without setting up a shed, it is desirable to keep the gates in a good condition for a long time and store it indoors so that it can be used without trouble at any time during main gate repair. In addition, workability is improved if a device is installed in the house that assists loading and unloading on the transportation vehicle.

Table 16-3.1 Size and quantity of stoplogs

	Small regulators		Large regulators		Remarks
	Type A	Type B	Type A	Type B	
Clear span length	2.00m	2.00m	6.00m	6.00m	
Gate height	0.85m	0.95m	1.20m	1.35m	
Quantity	4	14	4	16	
Estimated weight					
per one gate leaf	291.4 kg	311.1 kg	2074.5 kg	2214.6 kg	
Lifting beam	252.5 kg		911.7 kg		

(2) Method of carrying in and out

As a result of proposing the following two plans as a carrying in and out method of the stoplogs, plan B was adopted from the point of economy and difficulty in procurement of construction machine.

Table 16-3.2 Comparison of carrying in/out method

Item	Plan A	Plan B
Carrying method	Operate the manual traveling device installed on the truck to take out the carriage outdoors and load it onto a transport vehicle with a truck crane.	Lift a stoplog using a rail placed on the ceiling of the house and a manual chain block and load it on the transport vehicle in the warehouse.
Storage method	Fix some stoplogs on the storage stand for keeping them upright at regular intervals and store them with the carriage.	Secure and store some stoplogs on the storage stand for keeping them upright at regular intervals.
Building size	Since it can be a space only for the stoplogs storage, it is smaller than the plan-B and the height can be reduced. Approximate 15m×16m	Space for vehicle entry is necessary, and the size and height are larger than the plan-A. Approximate15m×20m (in case of single stack)
Economy	Including storage trucks and rail equipment for traveling is somewhat more expensive than plan-B.	Construction cost of the building itself is rather large, but it is inexpensive to include auxiliary equipment.
Other special instruction	Although the use of a truck crane of about 25t hanging is premised, its procurement is not easy in terms of cost.	Since the stoplogs are moved and loaded one by one, workability is inferior, but a large crane is unnecessary.

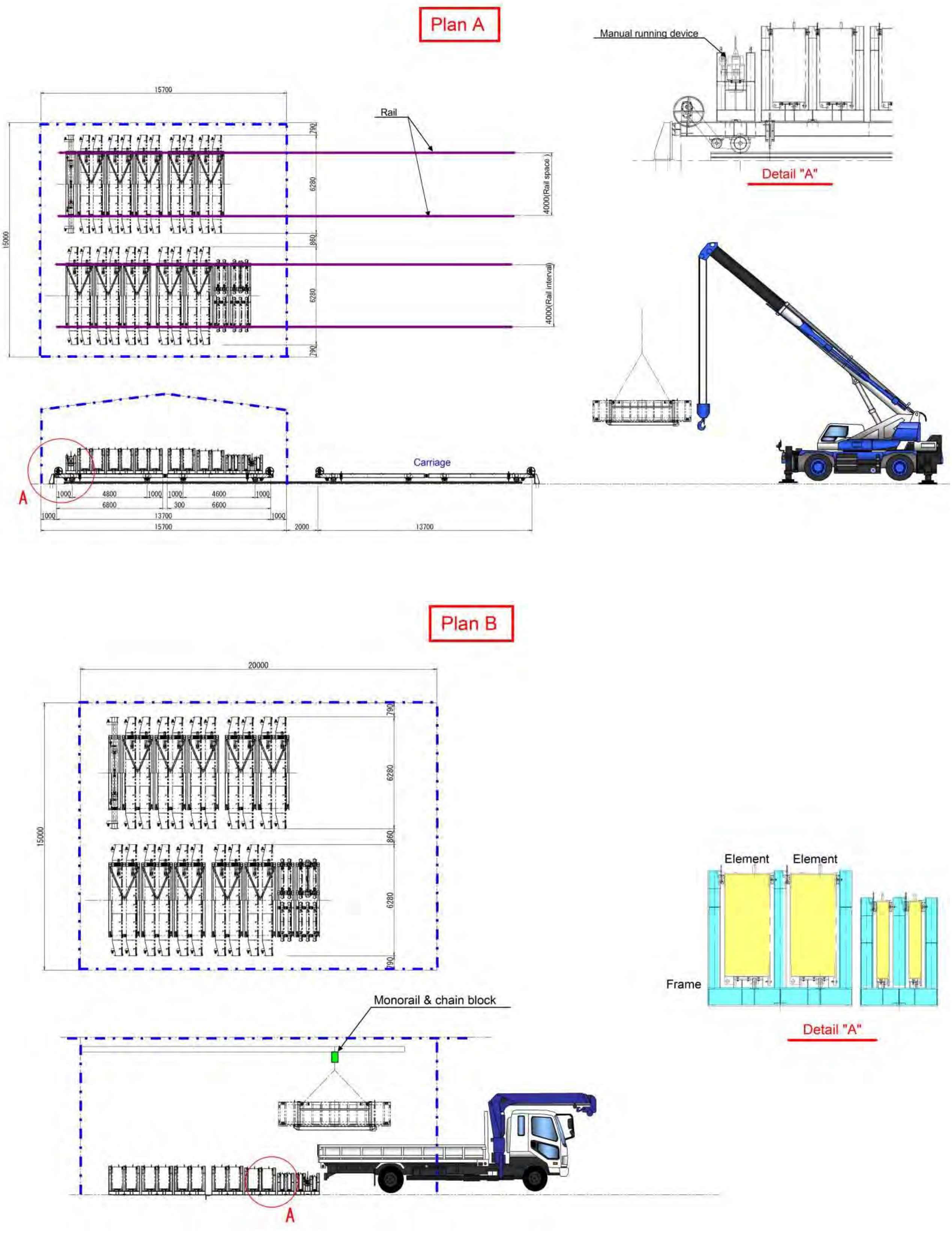


Figure 16-3.1 Study of carrying in and out method for stoplogs

(3) Study of construction area

As a result of examining the storage method to minimize the building area as much as possible, it was decided that the stoplogs for small scale regulators and large scale regulators are stacked in two layers as shown in the figure below. Considering the extra space for internal work, the size is 13.0m × 10.9m = 141.7m^2 in inner dimension. As mentioned above, it is built on the north side site on the opposite side across the road from the control house.

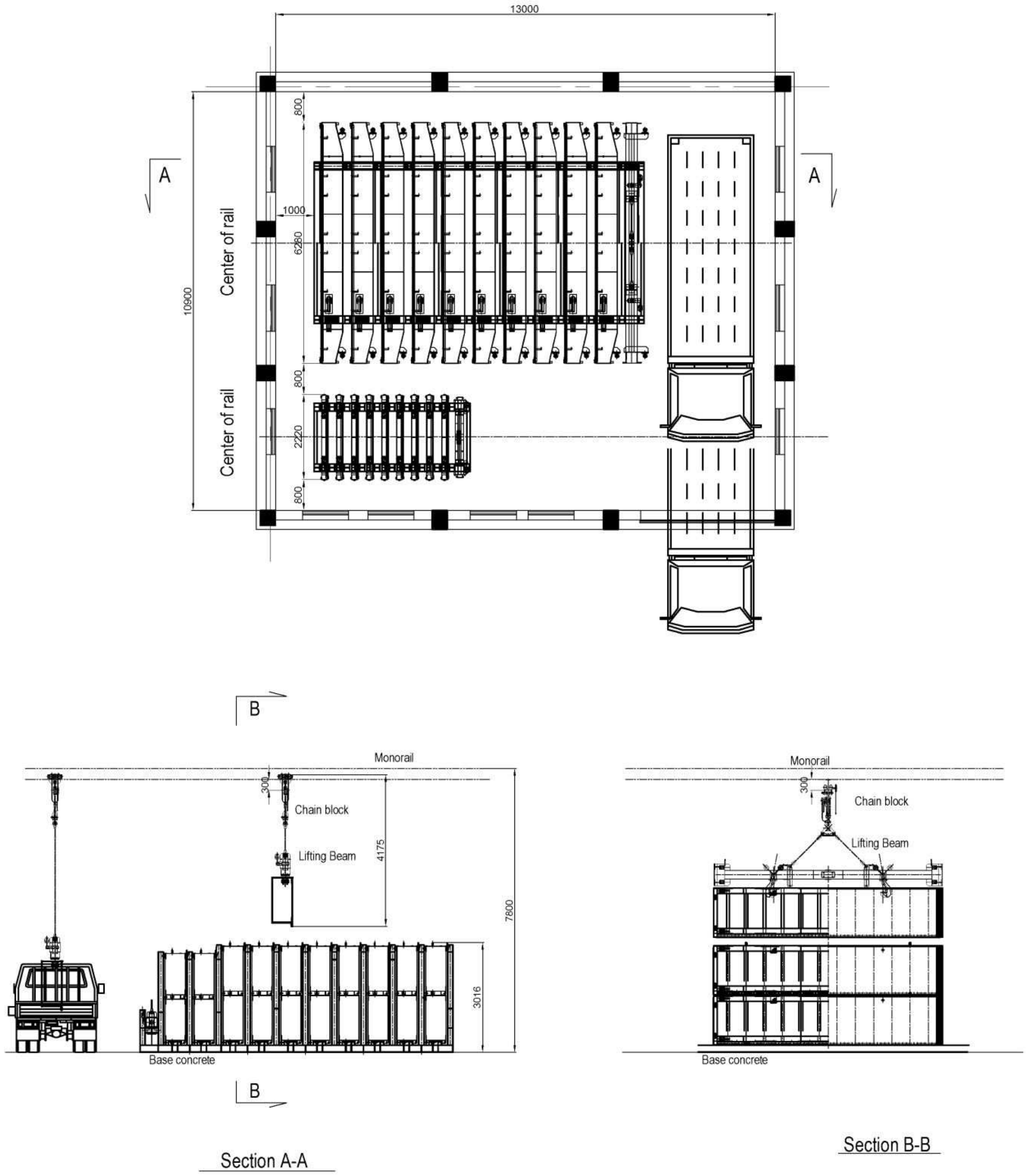


Figure 16-3.2 Layout plan inside the stoplogs house

17. Design of Auxiliary Facilities

17-1 Instrumentation equipment

In order to manage flow discharge properly, water gauges are installed to NDGRs.

(1) Type selection

Although there are several types of water gauges from the aspect of the detection mechanism, pressure type is recommended in consideration of accuracy and easiness of installation.

(2) Places to be installed

In order to manage the water level and calculate the flow rate, it is necessary to grasp the upstream and downstream water level in addition to the gate opening degree. For this reason, the water level gauges are installed at a total of 13 places, two places in each of the regulators (waterways) . The location of installation shall be a place where there is no influence of water level due to intake water or inflow water from the upstream and of wind wave as well as a convenient place for management. The positons proposed are shown in the figure below. To avoid the influence against floating debris or muddy soil, protection pipes should be installed. Also, to check the water level record, staff gauge shall be provided.

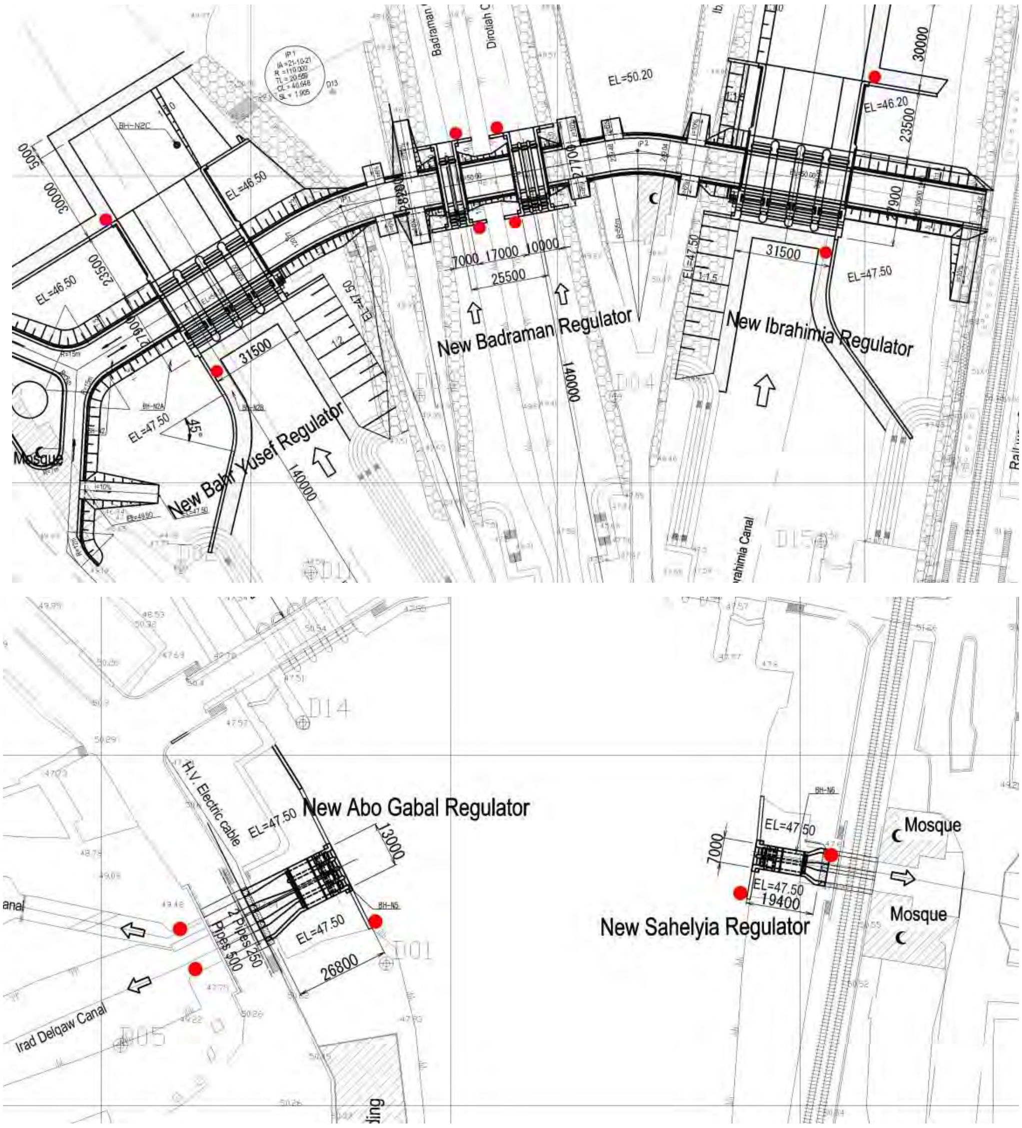
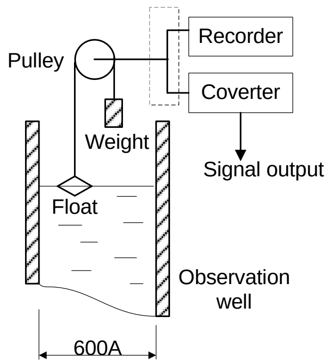
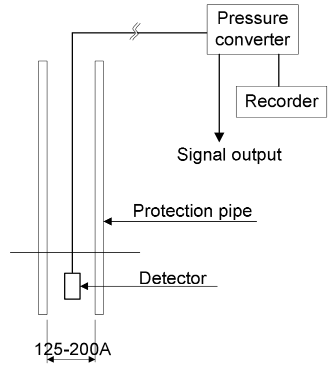
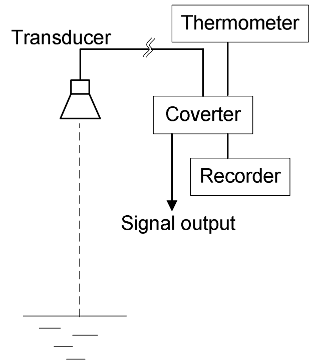


Figure17-1.1 Location of water gauges

Table17-1.1 Types and specifications of water gauges

Type	Float type	Pressure type (Crystal type)	Ultrasonic wave type
Mechanism	Water level is measured by the rotation angle of the pulley which is connected to the float fluctuated by the water level.	The difference of water pressure measured by the detector placed in the water is changed to electrical signal and converted to water level.	Ultrasonic waves are shot toward the water surface and the water level is shown through converting the time measured until receiving the reflection.
Figure			
Measurement range and accuracy	±1cm (0-10m) Shaft encoder type	±0.01%xFull Scale (±1cm /0-100m)	±1cm (0-10m)
Electric source	Not necessary	Necessary	Necessary
Temperature condition	-10 ºC ～40 ºC	Detector: -10 ºC～70 ºC Converter: -10 ºC～50 ºC:	Transducer: -20 ºC～70 ºC Converter: -10 ºC～40 ºC:
Output signal	Digital	Digital or Analog	Digital or Analog
Characteristics	1)Continuous measurement is possible. 2)Inclined installation is impossible. 3)Large observation well is necessary.	1) Accuracy is high. 2)Continuous measurement is possible. 3) Protection pipe is required but it is small. 4)Inclined installation is possible.	1)Continuous measurement is possible. 2)Transducer should be installed vertically toward the water surface. 3) Initial cost is high.

17-2 Road crossings

Since the local control house of Ibrahimia regulator was to be constructed on the downstream side of the regulator, the external hydraulic piping connecting the hydraulic cylinder and the hydraulic pressure generating device (hydraulic unit) installed inside the house must cross the road.

In principle, the hydraulic piping should be stored in the pit for maintenance and inspection and safety consideration except that it is underground piping in the case of traversing the riverbed. If an accident such as leakage of oil happens and obstructs the operation of the gate in the case of underground burial and direct burial in concrete, it is necessary to dig down the piping and restore it. This is undesirable considering the influence on traffic and a period required for recovery. Therefore, culvert structure shall be constructed under the road and the pipes shall be laid inside of it.

(1) Cross section of the culvert

The inner height of culvert shall be 1.8m or more for persons to enter for maintenance inspection. A total of 32 stainless steel pipes with a nominal diameter of 32A are to be placed inside the culvert, and they are fixed at certain intervals using supporting steel materials. Considering the area occupied by piping as shown below and the space for maintenance and inspection work, the culvert has a cross sectional shape of 1.8m in inner height and 1.8m in inner width and it is made of reinforced concrete.

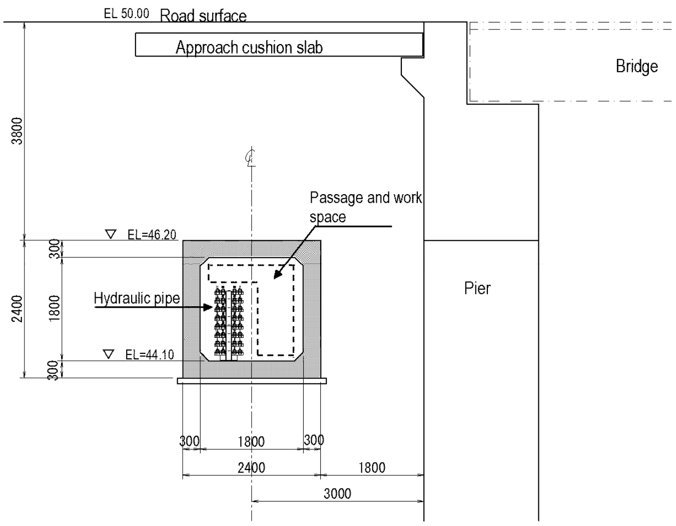


Figure17-2.1 Cross section of culvert

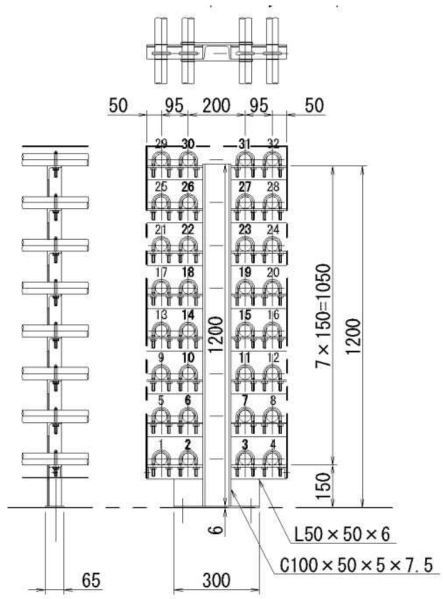


Figure17-2.2 Hydraulic piping inside the culvert

The top elevation of culvert shall be EL 46.20m in agreement with the ground altitude on the downstream side where the local control house is built. Although it is economically advantageous if the crossing position becomes closer to the regulator because the length of pipes also becomes shorter, the center of the culvert shall be 3.0m from the pier in consideration of necessary space for formwork and scaffolding during construction.

(2) Span arrangement

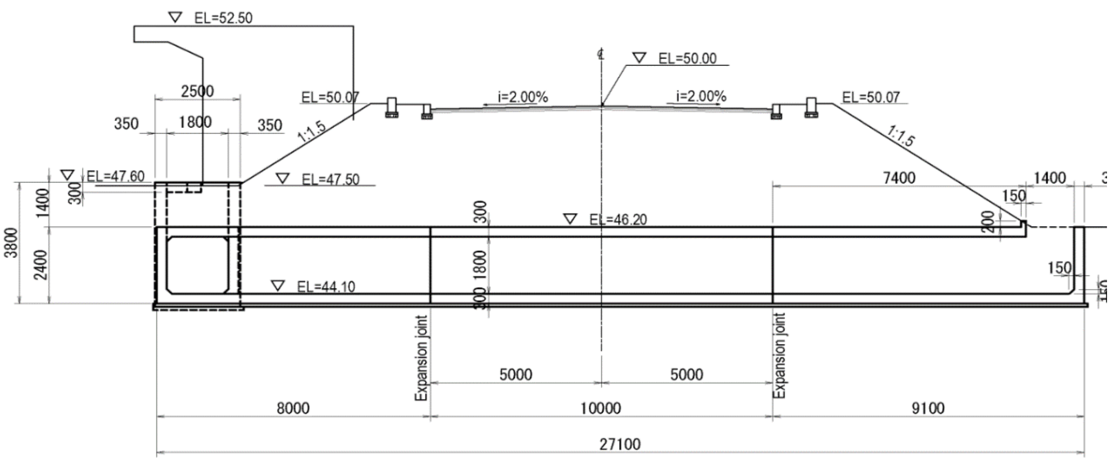


Figure17-2.3 Span arrangement in longitudinal direction

Since the culvert length in the longitudinal direction is close to 30m, it is divided by providing a joint for the purpose of preventing damage of the structure from the influence of drying shrinkage and unequal settlement after construction. The position of the joint shall be divided into three with a length of about 10m as shown in the figure avoiding the vicinity of the center of the road. An elastic material is used for the joint, and the dowel bar method is adopted to cope with the unequal settlement.

(3) Structural design

As load to be used for box culvert design, self weight, vertical earth pressure, horizontal earth pressure, live load, and water pressure are taken into consideration. Combinations of loads used for calculation of section force are calculated for the following two cases and the larger value of bending moment and shearing force at each point is considered.

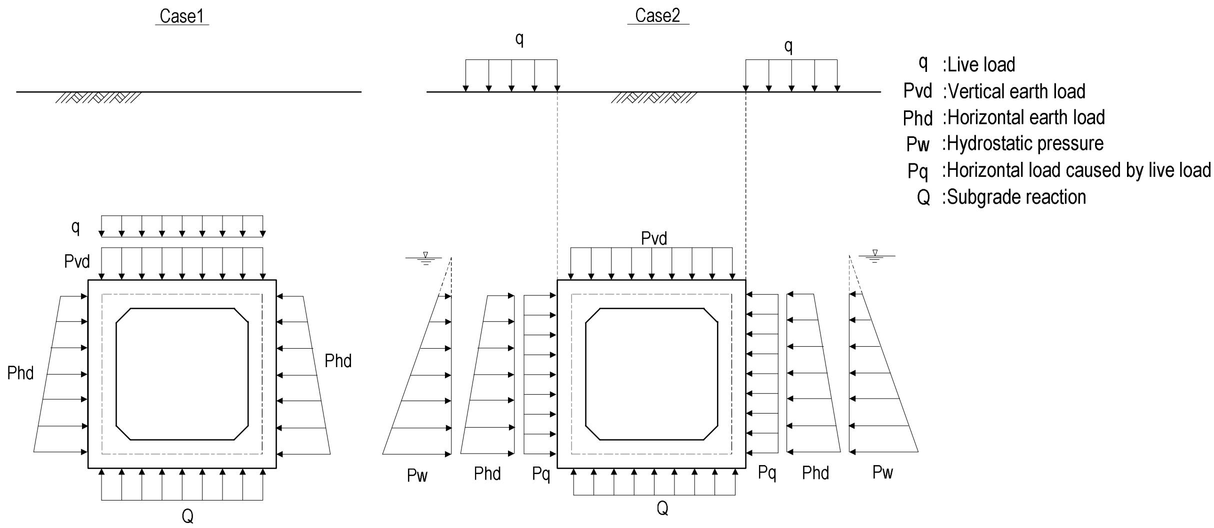


Figure17-2.4 Combined load to the culvert

The result of structural calculation on assumed cross section is shown in following table.

Table 17-2.1 Result of the structural calculation of box culvert

Check point			Side wall			Top slab		Bottom slab		Remarks
			Center	Bottom end	Top end	Center	Side end	Center	Side end	
			Inside	Outside	Outside	Inside	Outside	Inside	Outside	
Bending moment	M	(kNm)	5.628	27.967	23.851	24.541	23.550	27.866	27.460	
Axial force	N	(kN)	88.083	94.882	81.101	42.081	42.081	52.419	52.419	
Shearing force	S	(kN)	-	41.231	35.989	-	58.887	-	67.746	
Height of member	h	(m)	0.30	0.30	0.30	0.30	0.30	0.30	0.30	
Effective height	d	(m)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	
Bar arrangement			D16@200	D16@200	D16@200	D16@200	D16@200	D16@200	D16@200	
Compressive stre	σc	(N/mm^2)	0.65	4.60	3.92	4.27	4.09	4.81	4.75	
(Allowable value)	σca	(N/mm^2)	9.5	9.5	9.5	9.5	9.5	9.5	9.5	
Tensile stress	σs	(N/mm^2)	1.87	91.89	78.26	103.12	98.01	110.40	112.43	
(Allowable value)	σsa	(N/mm^2)	200	200	200	200	200	200	200	
Shearing stress	τ	(N/mm^2)	-	0.21	0.18	-	0.29	-	0.34	
(Allowable value)	τa	(N/mm^2)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
Judgement			OK	OK	OK	OK	OK	OK	OK	

18. Operation and Maintenance of Regulators

18-1 Water utilization management

It is desirable to conduct the water management of the group of regulator through developing an annual irrigation plan based on the farming plan of the beneficiary area such as the type of crops, acreage area and cropping time, closely cooperating with the administrators or related organizations.

Actual gate operation shall be controlled so that a predetermined flow rate is discharged according to the fluctuation of the water level in the upstream and downstream within the range of the design hydraulic condition of the regulators in the table below.

Table 18-1.1 Operational condition of gates

Name of regulator	Name of canal	Design max. discharge (m^3/s)	Design U/S high water level(m)	Design U/S low water level(m)	Design D/S high water level(m)
Bahr Yusef		227.0	46.30	45.90	45.82
Ibrahimia		186.0	46.30	45.90	45.13
Badraman	Badraman	9.0	46.30	45.90	45.90
	Diroutiah	12.0	46.30	45.90	45.90
AboGabal	AboGabal	7.0	46.30	45.90	45.90
	Irad Delgaw	9.0	46.30	45.90	45.90
Sahelyia		5.0	46.30	45.90	45.90

As an example, when the upstream water level is constant, the gate opening degree (assumed to be operated at the same opening degree at all gates) necessary for discharging the design maximum flow rate due to the change of the downstream water level was calculated.

The gate operation in discharging should be careful not to cause significant water level fluctuation in the downstream channel as much as possible, and to prevent scouring of river bank or bed protection due to leaning of streamline to one side, opening order and opening degree by one operation should be noted.

Table 18-1.2 Trial calculation result of gate openings at each downstream water level

Name	Discharge (m^3/s)	Width (m)	Qunatity	Gate sill elevation (m)	U/S water level (m)	U/S water height (m)	D/S water level (m)	D/S water height (m)	Gate openings (m)	Outflow form
Bahr Yusef	227.0	6.00	4	40.00	46.30	6.30	45.82	5.82	3.45	Submerged
							45.60	5.60	2.99	Submerged
							45.40	5.40	2.71	Submerged
							45.20	5.20	2.48	Submerged
							45.00	5.00	2.30	Submerged
Ibrahimia	186.0	6.00	4	40.00	46.30	6.30	45.13	5.13	2.09	Submerged
							44.80	4.80	1.86	Submerged
							44.60	4.60	1.75	Submerged
							44.40	4.40	1.65	Submerged
							44.20	4.20	1.55	Submerged
Badraman	9.0	2.00	2	43.90	46.30	2.40	45.90	2.00	0.97	Submerged
							45.60	1.70	0.74	Submerged
							45.30	1.40	0.60	Free flow
Diroutiah	12.0	2.00	3	44.20	46.30	2.10	45.90	1.70	0.85	Submerged
							45.30	1.10	0.57	Free flow
AboGabal	7.0	2.00	2	43.60	46.30	2.70	45.90	2.30	0.84	Submerged
							45.60	2.00	0.65	Submerged
							45.00	1.40	0.43	Free flow
Irad Delgaw	9.0	2.00	2	43.60	46.30	2.70	45.90	2.30	1.02	Submerged
							45.60	2.00	0.78	Submerged
							45.00	1.40	0.56	Free flow
Sahelyia	5.0	2.00	2	43.00	46.30	3.30	45.90	2.90	0.66	Submerged
							45.60	2.60	0.51	Submerged
							45.00	2.00	0.37	Submerged

18-2 Maintenance of civil engineering structures and buildings

In order to secure the function of the facility for the long term in the future, it is important to properly monitor and repair the condition. Recommended inspection content and frequency are shown below.

(1) Inspection

Periodic inspection is to monitor the presence of change in the state of the facility and the extent and transition of it if there is any change. It is desirable to conduct it once a month by visual observation or measurement using observation equipment. Inspection of apron which is always submerged is basically done during the annual winter closure period, the results of inspection should be recorded and kept to utilize it.

In general, changes often occur at the junction point of the structure, the change point of the section and the end of the revetment work, careful attention should be paid to the following events, especially.

1) Deformation

Settlement of pier ,weir body, base slab and apron

2) Abrasion

State of development of abrasion at the weir body, base slab and apron

3) Cracks on the concrete surface

Presence of cracks and their development at the weir body, base slab and apron

4) Leakage

Presence of water leakage and its amount changes from concrete joint and apron tip, etc.

5) Scouring

Presence of scouring and its development at the river bed protection and apron

6) Obstacles

Presence of sediments, driftwoods and other obstacles which disturb proper operation

(2) Maintenance

If some defects are found as a result of inspection, conduct detailed investigation as necessary to clarify the cause and the necessity of repair. When it is judged that repair is necessary, the repair work is carried out after studying the repair method and timing according to the damage degree of the structure.

18-3 Maintenance of equipment

Since equipment items such as observation equipment, mechanical equipment and electric equipment greatly influence the function and its maintenance of regulators combined with the civil engineering structure, it is necessary to implement appropriate management systematically. The flow of maintenance and management of gate facilities generally repeats the cycle of inspection, maintenance and actual operation. When aged deterioration advances, repair of equipment and updating of devices are carried out as necessary .

(1) Inspection

Inspection is a task of finding defects or damage of facilities, judging whether they function well or not. It is necessary to conduct comprehensive inspection as a system as a whole facility including a remote operation systematically.

Table 18-3.1 Inspection classes and cycle

Class	Cycle	Contents of inspection
Inspection on operation	Every operation time	It checks the presence of trouble at start of operation for discharge or intake, the situation such as presence of defects and change at the time of operation and the end of operation. In principle these are carried out every operation time.
Daily inspection	Everyday or less than one month	To maintain the equipment in a state to operate properly all the time, confirm the operation status of each equipment, breakage, looseness of bolts and nuts by visual inspection, touch examination and test hammer focusing on damage detection at the initial stage.
Periodic inspection	Every three or six months or every few years	Detailed inspection and measurement of each part is carried out by expert engineers, and slight maintenance such as refueling of each part and replacement of parts may also be carried out in some cases.

(2) Maintenance

Maintenance is a work such as parts replacement or repair to respond to failures, damage, fatigue, deterioration of facilities and equipment, to prevent these or to maintain the function of facilities based on the judgment result of inspection. Regular maintenance is mainly carried out using tools, machinery and equipment. Main maintenance contents and recommended cycle for large scale regulators (hydraulic cylinder type roller gate) and small scale regulators (electric rack type slide gate) are shown in the following table.

Table 18-3.2 Contents and cycle of maintenance

Cycle	Items		Contents of maintenance
	Classification	Target facility	
Three years	Hoist	Small regulators	Replace of grease for rack or spindle shaft
		All regulators	Replace of grease for shaft coupling
Five years	Gate leaf	Large regulators	Replace of grease for oil supply device and overhaul
	Hoist	Large regulators	Overhaul and inspection of hydraulic unit components Replacement of hydraulic oil and cleaning of oil tank
		Small regulators	Overhaul and inspection of hoisting equipment Lubrication of reduction gear
Ten years	Gate leaf	Large regulators	Overhaul and inspection of roller and sheave
		All regulators	Repainting（8 to 10 years interval） Replacement of seal rubber (10 to15 years interval)
	Hoist	Large regulators	Overhaul and inspection of hydraulic unit components Overhaul and inspection of hydraulic cylinder
		Small regulators	Overhaul and inspection of hoisting equipment
		All regulators	Overhaul and inspection of shaft coupling, bearing and opening indicator

Note) Ten years cycle maintenance is carried out including the contents of five years cycle maintenance work.

(3) Method to remove gate leaf

Figure 18-3.1 Hanging method of gate (Small regulators)

The upper part gate guide of small scale regulators can be removed so that replacement of seal rubber and inspection and maintenance of side part of gate leaf in the future can be carried out by taking out the gate.

Since the gate pier of large scale regulators consists of four separated columns, inspection and maintenance of the end part of the gate such as the main roller can be performed with the gate leaf lifted. When there is a necessity for equipment renewal or large-scale repair in the future, remove from the top slab using a large crane in the order of the hydraulic cylinder, base frame and the gate leaf.

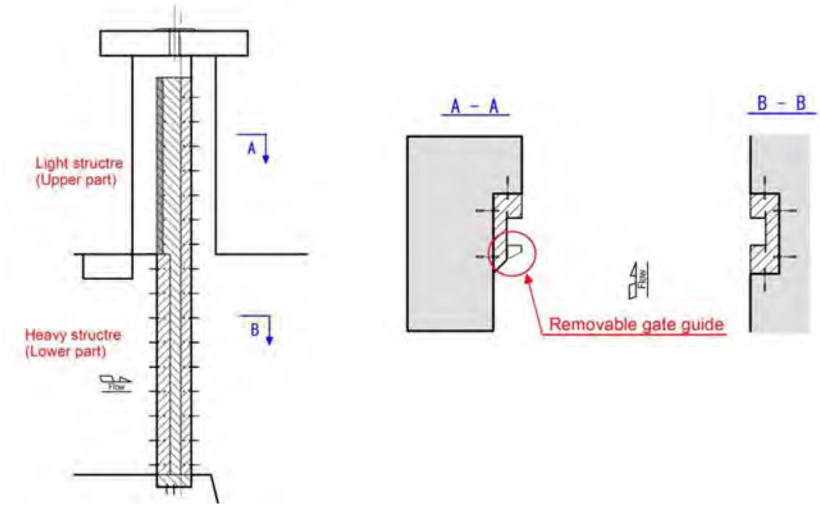


Figure 18-3.2 Structure of gate guide of small scale regulators

18-4 Record of maintenance

In order to inspect and maintain the equipment, it is necessary to understand the structural features, dimensions, specifications, handling method and judge the state. For that purpose, it is important to keep the completion documents and instruction manuals of equipment to utilize at any time. In addition, records of inspection and maintenance should be used not only as a record of them but also as materials for understanding the deterioration status with age and for long-term maintenance plan of the facility based on the future change prediction. Therefore, it is desirable to create a database and store the record using electronic media so that the history of inspection and maintenance can be utilized for a long time.

Table 18-4.1 Recommended storage period of maintenance record

Item	Classification	Period	Remarks
Completion documents	New and renewal	Permanent	Specification, design calculation, drawing, construction management record, etc.
Construction photos		Permanent	During and completion of construction
Inspection record	Daily inspection	1 year	
	Inspection on operation	3 years	
	Periodic inspection	5 years	
Maintenance record	Maintenance record	Permanent	
	Periodic maintenance	5 years	
Operation record	Operation record	Permanent	Unusual state should be noted
	Failure record	Permanent	

18-5 Management of target canal bed elevation

Around DGRs, the removal of sedimentation in the canal is carried out in January by stopping the intake from upstream, which is called “Winter Closure” period and usually takes several weeks in every January. After completion of the construction of NDGRs, fluctuations of the canal bed elevation due to sediment deposition and scouring are expected including the area between DGRs and NDGRs. Since the excessive change in the canal bed height may affect the stability of the regulators' body, the connecting bank protection works and the smooth gate operation as well, appropriate management is required. The basic management policy during the construction period and the future period is described below.

(1) During the construction of the NDGRs

The NDGRs is planned to be constructed in the temporary cofferdam using steel sheet piles. Since the cofferdam is designed to be stable under the current ground level condition based on the survey result, dredging works around the sheet pile area should be avoided. The design ground height of double steel sheet pile is designed as follows.

Table 18-5.1 Design bed elevation for cofferdam works

Location	Design bed level of double sheet pile works
Bahr Yusef regulator	EL 39.00m
Ibrahimia regulator	EL 39.00m
Abo Gabal regulator	EL 43.00m
Sahelyia regulator	EL 43.00m

(2) Beginning of the first operation of NDGRs and their future maintenance

The sediment in front of the gates can be removed by gate operation if it is less than a certain amount, but the sediment remaining on the gate sill may have a negative impact to the gate closing operation. Therefore, it is desirable to grasp and manage the sedimentation condition once a year so that the bed height around the regulators is kept below the gate sill height. On the other hand, if the canal bed elevation becomes significantly lower due to excessive dredging, the stability of the regulators and the connecting bank protection works of steel sheet piles is badly affected. For this reason, it is necessary to control the canal bed level within the range of elevation shown in the table below on the basis of the height of the regulators and the design bed elevation of the bank protection works.

Table 18-5.2 Management of canal bed elevation after the construction of NDGRs

Location	EL.(A) (m)	EL.(B) (m)	EL.(C) (m)	EL.(D) (m)	Management level	
					Highest (m)	Lowest (m)
Ibrahimia regulator	40.00	39.50	36.50	39.50	40.00	39.50
Abo Gabal regulator	43.60	42.75	40.25	42.60	43.60	42.60
Sahelyia regulator	43.00	41.55	39.05	41.55	43.00	41.55

Note: EL.(A);Gate sill elevation
EL.(D); Design bed elevation of bank protection works

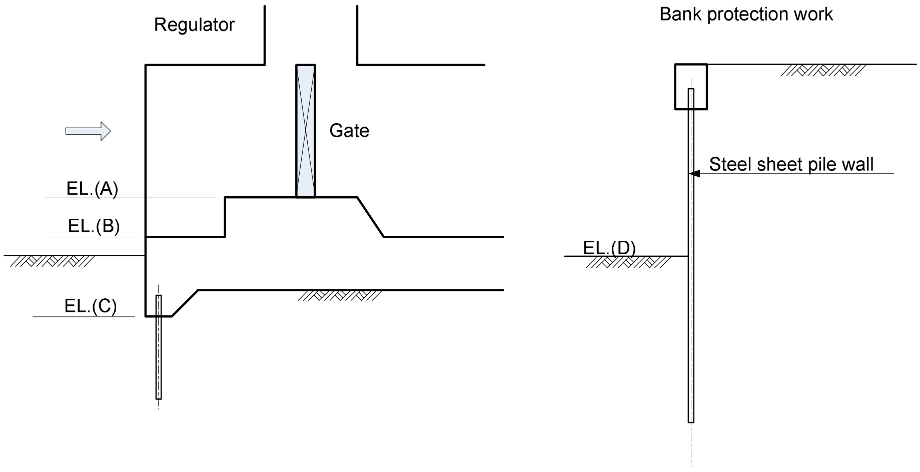


Figure 18-5.1 Explanatory drawings for EL.(A) to EL.(D)

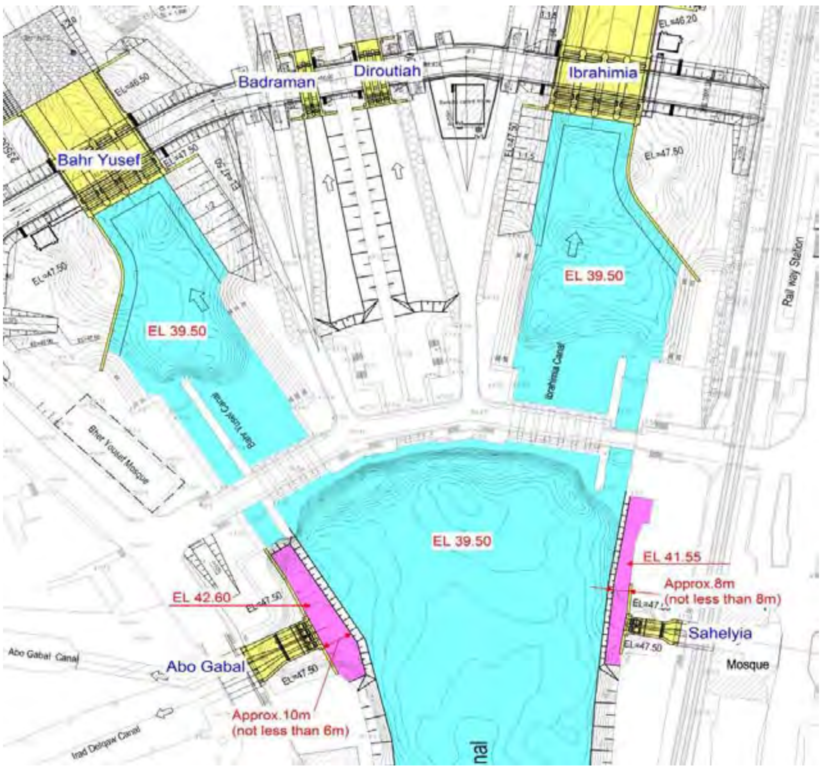


Figure 18-5.2 Canal bed elevation around the regulators

19. Examination of the Preservation Measures for Existing DGRs

19-1 Prerequisites for examination of preservation measures

The existing DGRs is the irrigation water supply facility having been in use for 145 years since its construction in 1872. As shown in Table 19-1.1, its year of construction is a long time ago even in Egypt, but it is still in active operation while rehabilitation and partial renewal works have been made.

In the construction project for the DGRs that will be implemented for the purpose of sustainable acquisition and supply of water resources to enhance the agriculture in Upper Egypt, the function of the existing DGRs as the regulator will be removed.

However, given that the existing DGRs has been the long time, the Egyptian government has decided that they should be preserved as a historical monument with a function of bridge.

In this chapter, the necessary and reasonable works of the rehabilitation and reinforcement for the preservation of the existing DGRs are suggested based on the results of the past surveys.

Table 19-1.1 History of rehabilitation and partial renewal of DGRs

1870	1872	Construction of the regulators was completed		1861:Delta Barrage
1880			1881	
1890			Silt clear lance (Canal dredging)	
1900	1900	Remodeling work		1902:Aswan Dam
	1907			Asyut Brrage Zefta Brrage
				1906:Esna Barrage
1910	1910 1911	Foundation Treatment (Cement grouting)	1912	
1920				
1930	1935	Abo Gabal intake regulator was constructed		1930:Naga Hammady Barrage 1935:(Delta Barrage)
1940				
1950				
1960	1962	Improvement work ・Extension of apron of Ibrahimia ・Driven wooden sheet pile ・Protection of the canal bed		
1970				1971:High Aswan Dam
1980				1994:(Esna Barrage)
1990				
2000	2001	Maintenance of regulator (Gates,Chains,etc.)	Canal dredging	2008:(Naga Hammady Barrage)
2010				
2020	2022	【NDGRs】 Completion of the construction		

As the prerequisites for the suggestions on the necessary and reasonable works, the following purposes were confirmed by the Design WG on 9th February, 2017:

- To preserve the existing DGRs as a historical monument.
- To remove the practical functions of regulators by the removal of the gates or keeping the gates open completely.
- To remain the bridge function with some traffic restrictions for large and heavy vehicles.

19-2 Survey results

(1) Survey results in the past years

The results of the survey on the existing DGRs were reported in the "*Preparatory survey for the rehabilitation and implement of Dirout Group of Regulators, October 2010*". The summary of the survey is shown in Table 19-2.1.　The items of the surveys are as follows:

- Visual survey
- Diving survey (photography by waterproof camera)
- Unconfined compression test (regulator surface and in the body)
- Permeability test in regulator body
- Boring survey in regulator body

Table 19-2.1 Results of past surveys (1/3)

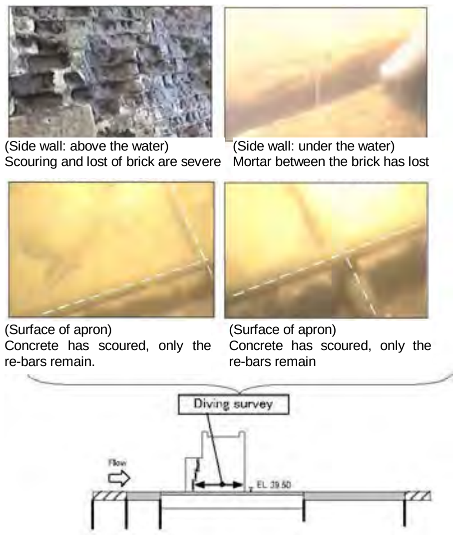
Name of Survey	Survey Results	Remarks
Visual Survey	• Chips of bricks and stones in a small range, and cracks of up to 2 mm in bricks were confirmed above the water surface. These deteriorations were not caused by the long-time stress impacts, but it is considered that they were the damage by temporary impacts and defects in the initial construction stage. (See Photo-1.) • Below the water surface, it was found that bricks had fallen out from the sides of the Ibrahimia regulator directly under the gate. In particular, substantial wear of about 30 cm (eye-estimation) was visually checked on the side of the regulator on the right bank of the Ibrahimia Regulator. The bricks themselves may have been worn and deteriorated during aging degradation, but the mortar surrounding bricks worn first and lost; this caused missing fallen out bricks in large area and repeated afterwards. Therefore, it is of concern that the wearing will be accelerated and expand in future. (See Photo-2.) • The regulator piers on the upstream side of the Ibrahimia, Badraman and Bahr Yusef regulators are protected by stone materials, but the ancient mortar made by finely smashing limestones and kneading the fine sand with water was used, is different from the present-day mortar. It was found that these mortar parts had fallen out or washout. Especially, on around the water surface, the mortar is susceptible to the washout due to the up and down movements of the water surface. The peel-off depth is unclear, but there is concern that the peel-off of mortar parts may cause the collapse of the regulator piers. (See Photo-3.)	 Photo-1 Ibrahimia regulator  Photo-2 6th gate from the right bank of the Ibrahimia regulator  Photo-3 Bahr Yusef regulator
Diving Survey	The diving survey (underwater camera photography) was made in the 2nd vent on the right bank of the Bahr Yusef regulator (Figure 1) and in the 5th vent on the right bank of the Ibrahimia regulator (for the days of January 2 to 4, 2010). • The mortar parts to join the bricks and stone materials eroded in the Bahr Yusef and the Ibrahimia regulators. There is concern that such loss of the mortar parts may weaken the integrity of the structure and expand the erosion of the bricks and stone materials. • Concrete was placed on the apron surfaces of the Bahr Yusef and Ibrahimia regulators in the rehabilitation work in 1962. The concrete parts were worn down and had been eroded away. In particular, it was found that only reinforcement bars remained in the Bahr Yusef regulator, having no rehabilitation effect at that time.	 Figure 1. The result of diving survey on the Bahr Yusef regulator

Table 19-2.2 Results of past surveys (2/3)

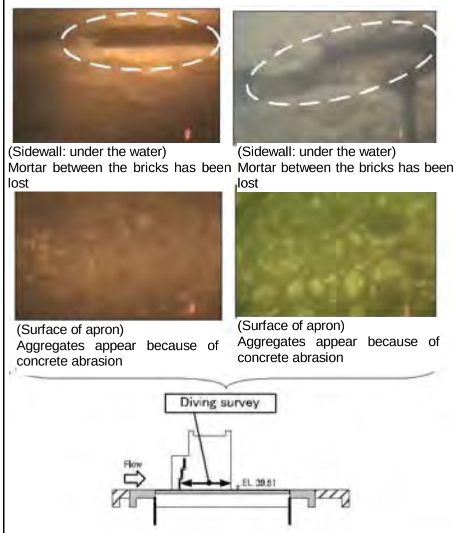
<table>
<tr><th>Name of Survey</th><th>Survey Results</th><th>Remarks</th></tr>
<tr><td>Diving Survey</td><td>
In the Ibrahimia regulator, the aggregates in the concrete were significantly exposed (10 cm to 20 cm) and the concrete thickness at the time of rehabilitation work was not kept. The placed concrete thickness of the aprons of the both regulators as checked in the drawing was about 25 cm in the Bahr Yusef canal and about 55 cm in the Ibrahimia canal.
From the above survey results, it is supposed that the rehabilitation of the aprons at that time was the apron reinforcement/expansion work associated with the upstream water level raised in the DGRs. It is confirmed that the reinforcement work for the aprons directly under the gates has almost lost the initial thickness. Therefore, the future acceleration of wear is of concern.
</td><td>


Figure 2. The result of diving survey on the Ibrahimia regulator
</td></tr>
<tr><td>Unconfined compression Test</td><td>
● <u>Unconfined strength of regulator surface</u>
From the results of the unconfined compression strength test on the cores sampled from the depth of about 50 cm under the regulator surface, it was found that the cores were lower than the endurance strength of 70 kg/cm^2 to 80 kg/cm^2 required strength of brick in Egypt (Egyptian Code for the Design and Implementation of brick and buildings ECP 204-2005).
Brick construction technology in Egypt had a long history and it is imagined that the construction technology similar to that of the present time was used in the past. Therefore, it is supposed that the regulator surface layer was under the weathering impact of the open air for a long period, resulting in the lower strength. This should be considered if the existing regulators are kept in continuous use by rehabilitation. The unconfined compression strength of each regulator is shown in Table 1.
● <u>Unconfined compression strength of regulator depth</u>
The unconfined compression strength tests of the foundation depths of the existing DGRs were conducted by the Water Research Center, Construction Research Institute at the time of this Study (2009) and in 2006. These unconfined test results are summarized in Table 2 and Table 3.
</td><td>
Table 1. Unconfined compression strength of regulator surface layers
<table>
<tr><th>Regulator</th><th>Test Value (kg/cm^2)</th><th>Standard Value (kg/cm^2)</th></tr>
<tr><td>Bahr Yusef</td><td>21</td><td rowspan="3">70～80</td></tr>
<tr><td>Ibrahimia</td><td>24</td></tr>
<tr><td>Badraman</td><td>13,7</td></tr>
</table>
Table 2. Unconfined compression strength of regulator pier depths
<table>
<tr><th>Regulator</th><th>Average Test Value in 2006 (kg/cm^2)</th><th>Average Test Value in 2009 (kg/cm^2)</th></tr>
<tr><td>Bahr Yusef</td><td>38.2</td><td>26.1</td></tr>
<tr><td>Ibrahimia</td><td>38.9</td><td>26.3</td></tr>
<tr><td>Badraman</td><td>38.7</td><td>10.0</td></tr>
</table>
Table 3. Unconfined compression strength of regulator foundation depths
<table>
<tr><th>Regulator</th><th>Average Test Value in 2006 (kg/cm^2)</th><th>Average Test Value in 2009 (kg/cm^2)</th></tr>
<tr><td>Bahr Yusef</td><td>40.7</td><td>80.3</td></tr>
<tr><td>Ibrahimia</td><td>39.6</td><td>72.3</td></tr>
<tr><td>Badraman</td><td>—</td><td>—</td></tr>
</table>
</td></tr>
</table>

Table 19-2.3 Results of past surveys (3/3)

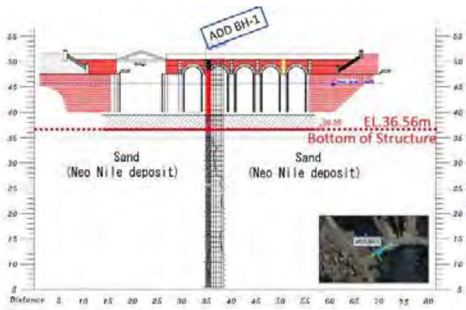
<table>
<tr><th>Name of Survey</th><th>Survey Results</th><th>Remarks</th></tr>
<tr><td>Permeability Test in the Regulators</td><td>The permeability test in the regulators was also conducted by the CRI, NWRC in 2006. These test results are summarized in Table-4.
According to the existing literature, the permeability value of general bricks is 10^{-6} cm/sec (E-06). In comparison with this value, it is confirmed that the permeability values of the existing DGRs are from 10 to 100 times higher.
In the tendency of the above permeability values, especially, the values of regulator piers are 1.2 to 1.6 times higher than the foundations. This means that the regulator piers are susceptible to the dryness and wetness due to water level variations. Further, it seems that the brick materials with high permeability increase the water absorption, facilitating the deterioration of the regulator piers. The tendency of deterioration coincides with the strength values in the unconfined compression test. The deterioration of bricks of the regulator piers and the reduction of adhesiveness of the mortar are of serious concern.</td><td>Table 4. Permeability test in regulators
<table>
<tr><th>Regulator</th><th>Position</th><th>Average Permeability Value in 2006 (cm/s)</th><th>Average Permeability Value in 2009 (cm/s)</th></tr>
<tr><td rowspan="2">Bahr Yusef</td><td>Pier</td><td></td><td>1.01E-04</td></tr>
<tr><td>Foundation</td><td>7.25E-05</td><td>8.43E-05</td></tr>
<tr><td rowspan="2">Ibrahimia</td><td>Pier</td><td></td><td>1.13E-04</td></tr>
<tr><td>Foundation</td><td></td><td>1.12E-04</td></tr>
</table></td></tr>
<tr><td>Boring Survey in the Regulators</td><td>The boring surveys in the regulators were made to assess the detailed deterioration and the foundation conditions within the Bahr Yusef and the Ibrahimia regulators (in December 2009).
● The deterioration conditions in the regulators are shown in the results of unconfined compression and permeability tests in the regulators.
● The clear traces of the grouting works which were done from 1900 to 1911 as reported could not be identified. It was observed that medium sand with N-value of 13 to 15 is identified under the foundations of the Bahr Yusef regulator, and that the foundation ground was weaker than that in the Ibrahimia regulator. (See Figure 3 and Figure 4.)</td><td>

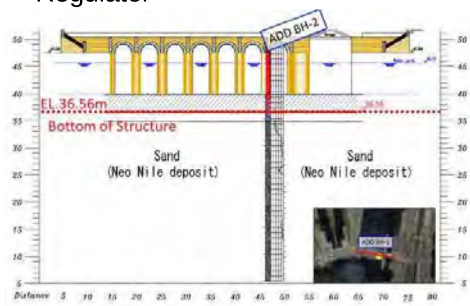
Figure 3. The result of the boring survey on the Bahr Yusef Regulator


Figure 4. The result of the boring survey on the Ibrahimia Regulator</td></tr>
</table>

(2) Available materials and works for the preservation

In order to the consider the prevailing works and methods for the preservation as historical monument in Egypt, the field survey on the Delta Barrage with the related agencies in RGBS was conducted. In the Study, the actual works and the applied materials for the preservation works were studied through the visual survey and the interview to the persons responsible at the site. The results of the field survey in the Delta Barrage are shown in Table 19-2.4, and the materials (photos) of the actual preservation measures are identified in Table 19-2.5 and Table 19-2.6.

Table 19-2.4 Field survey results in the Delta Barrage

<table>
<tr><td colspan="3">The old Delta Barrage is under the rehabilitation work by Ministry of Antiquities at present.
After the new Delta Barrage built in 1939, the function as a regulator was removed and the passage on of the regulator has been limited to pedestrians, bicycles and motorbikes. The staffs in charge of the regulator administration are stationed at the entrance of the regulator.</td></tr>
<tr><td colspan="3">Photos in Field Survey</td></tr>
<tr><td>1</td><td></td><td>Entrance tower on the east side of the barrage
The fences and stone blocks to prevent large size traffic are installed.
The surface of the gate tower was restored.</td></tr>
<tr><td>2</td><td></td><td>Entrance tower on the west side of the barrage.
The surface of structure has not been restored.</td></tr>
<tr><td>3</td><td> </td><td>All the gates are kept fully open. The hoisting device remains at the site.
The surfaces of the barrage piers are covered with mortar in the same color as the bricks.</td></tr>
<tr><td>4</td><td></td><td>Some damages were observed on the road of the bridge, which seems to be caused by the past passage of vehicles.</td></tr>
<tr><td>5</td><td></td><td>A part of mortar on the rehabilitated handrails was damaged and peeled off.
According to the staff, about 10 years has passed since the latest rehabilitation. Such works were regularly done.</td></tr>
</table>

Table 19-2.5 Photos of preservation measure cases (1/2)

No.	Photos of Preservation Measure Cases
1	**Gate Repair**   (Before rehabilitation)   (After rehabilitation)
2	**Rehabilitation of Bank Protection Works**  (Before rehabilitation)  (After rehabilitation)
3	**Rehabilitation of Steel Bridge**  (Before rehabilitation)  (After rehabilitation)
4	**Rehabilitaton of Hoisting Device**  (Before rehabilitation)  (After rehabilitation)

Table 19-2.6 Photos of preservation measure cases (2/2)

No.	Photos of Preservation Measure Cases
5	**Rehabilitation of Maintenance bridge**  (Before rehabilitation)  (After rehabilitation)
6	**Rehabilitation of Gate Operation Room**  (Before rehabilitation)  (After rehabilitation)
7	**Rehabilitation of Fences and Handrail**  (Before rehabilitation)  (After rehabilitation)  (Before rehabilitation)  (After rehabilitation)
8	**Others**  (Coating of lighting pole)  (Gondola for inspection and rehabilitation)

19-3 Recommendations for preservation measures

(1) Suggestion of evaluation method

In the preservation measures for the existing DGRs, it is recommended to make the examination in accordance with the following flow chart in considering the following points:

1. The function of the regulator is removed, that is, the gate operation for appropriate water distribution by the existing DGRs is never considered. Therefore, the up-lift pressure caused by the water level difference and the local impact of high flow velocity are substantially alleviated and the high-water level (Approx. WL.46.30 m) is kept even on the downstream side of the existing gates.
2. The traffic of large vehicles is limited on the ancillary bridge, which alleviates the traffic loads on the regulators.
3. The consideration for the landscape is required to preserve the DGRs as a historical monument

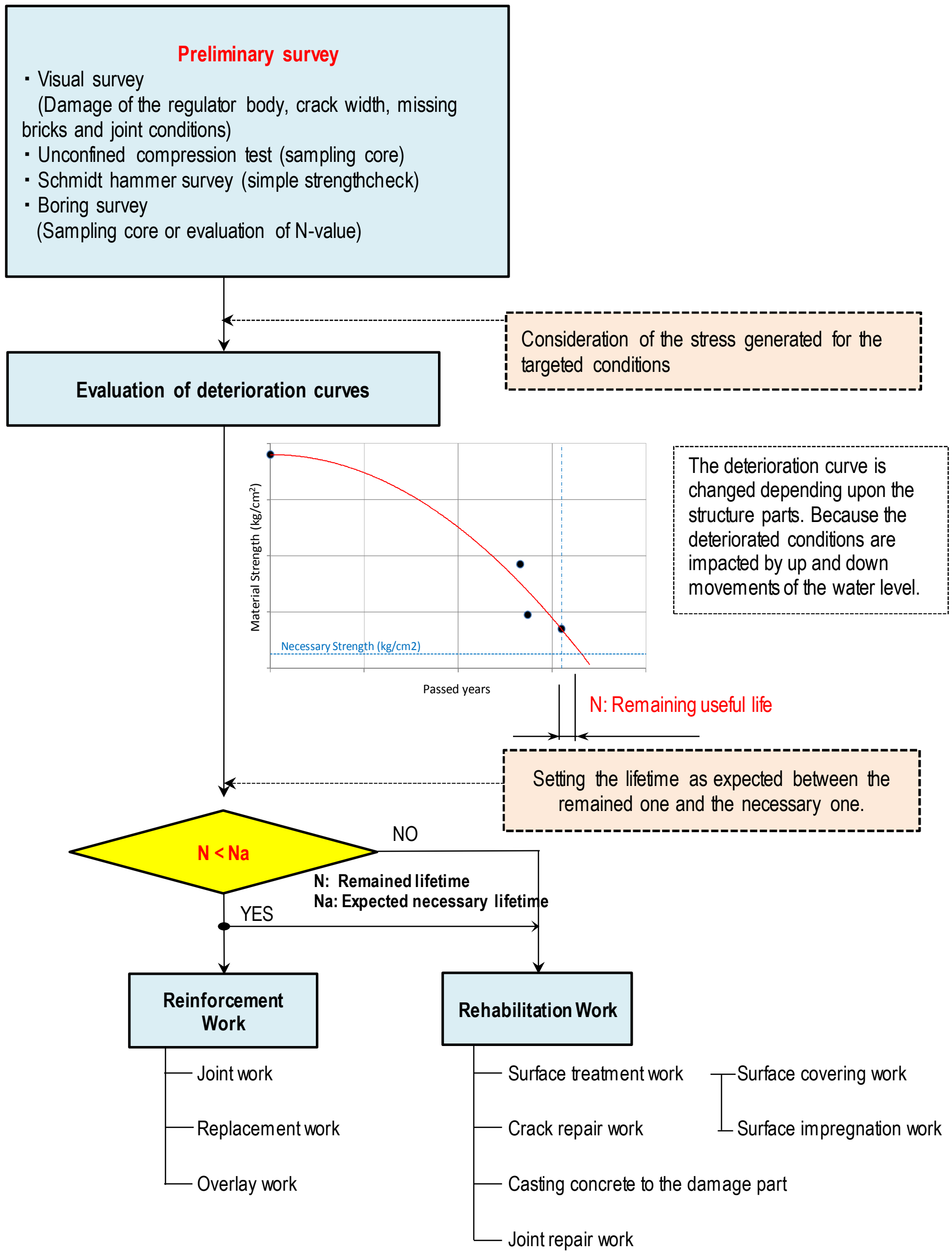
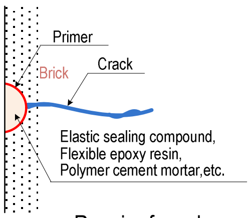
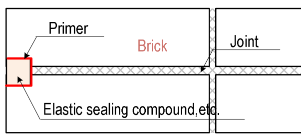


Figure 19-3.1 Flow of examination of appropriate measure works

Note : The deterioration curve is cited from the "*Preparatory survey for the rehabilitation and implement of Dirout Group of Regulators, October 2010*". The curves can be updated by the recent investigated data if the new survey is conducted.

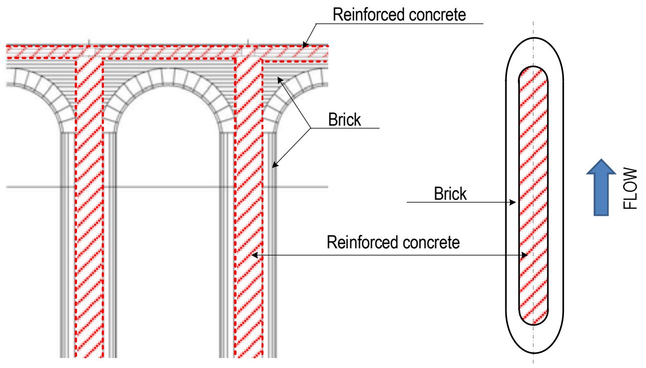
In examining the preservation measures of the existing DGRs, the effective measures as shown in Table 19-3.1 are recommended based on the prerequisites as mentioned in the beginning and the past survey. For the appropriate preservation measures, it should be taken into consideration the economic aspects, constructability, reliability and sustainability of the measures based on the detailed survey and careful consideration.

Table 19-3.1 Recommendations for preservation measures for DGRs

Preservation works		**Detailed contents of the works**	**Problems and Remarks**
Change of function	✓**Preservation of gates**	➢ The gate doors are fixed in the fully opened and preserved at the present positions. The same measures are applied to the hoists.	For the preservation, the study on the necessity of rehabilitation works (such as coating) should be required.
	✓**Traffic limitation of vehicles**	➢ The traffic limited to the pedestrians, bicycles and motorbikes, which the same as the Delta Barrage. ➢ Therefore, the parking blocks (stones) are stationed on the exits and entrances on the left and right banks of the ancillary bridge.	The measure will be implemented after the construction of the NDGRs.
Rehabilitation works	✓**Repair of cracks** ✓**Repair of joints between the main parts**	➢ The deterioration of the bricks used in the regulators is caused by repeated drying and wetting of cracks and joints (mortar). ➢ In order to prevent the more deterioration, it is essential to repair the cracks and joints before the expanding width or the gaps. ➢ The materials for the repair of cracks and joints should have excellent property in adhesiveness, flexibility and abrasion resistance as well as weather resistance and visual matching.  Repair of cracks  Repair of joints	If there are many cracks and damaged joints, it can be also necessary to apply the surface treatment or surface impregnation method for the impact of the drying and wetting into the regulators body.
	✓**Casting concrete to the damaged part**	➢ The parts where bricks fallen out are repaired with the materials without the visual gaps ➢ The exposed iron bars of the aprons that were confirmed by the diving survey should be repaired by covering the concrete. After the construction of the NDGRs, the present high flow velocity will not be caused, but joint bars between the original aprons will be installed to secure the stable concrete casting.	There is an idea to preserve the regulators as a historical monument including the present (decayed) state. Therefore, it is necessary to review before the rehabilitation of the damaged parts in this aspect.

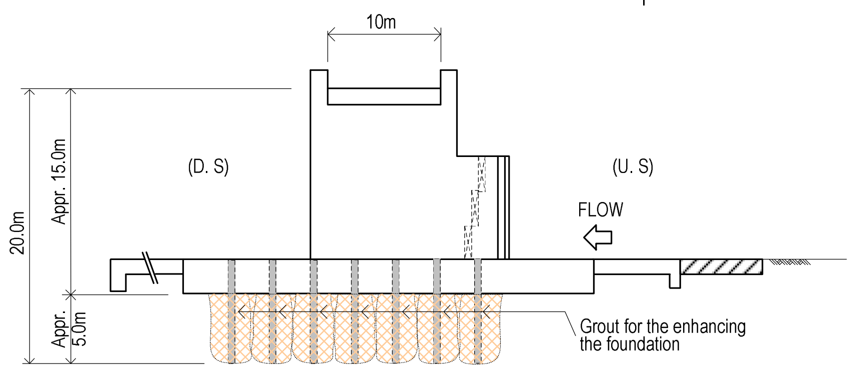
<table>
<tr>
<td>Reinforcement works</td>
<td>✓Replacing to the enhanced structure</td>
<td>

- ➢ If any reinforcing and enhancing work is required to the structure, the following method is recommended. This work requires much time and cost.
- ➢ A reinforced concrete pier is constructed in the regulator body of 1.85 meter wide to concentrate the tensional load into the reinforced concrete pier. As a result, only the compressive load by bricks own weight acts to them.



</td>
<td>It is necessary to check the structural stress by the detailed analysis (such as 3D finite element method).
In the construction work, it is necessary to examine the impacts (by such as vibrations) on the existing brick pieces.</td>
</tr>
<tr>
<td colspan="2">Others</td>
<td>

- ➢ If any void area are observed in the foundation by the boring survey, those void are filled and injected with grout materials.
- ➢ The reasonable number of the grout and the grouting pressure are subject to the foundation conditions and structure strength.



</td>
<td>The stress check is necessary to compare between the brick strength and the pressure stress by the grouting.</td>
</tr>
</table>

(2) Recommendation

Based on the present available data (2010), the following survey and the essential works are recommendable.

<u>Recommendable survey</u>

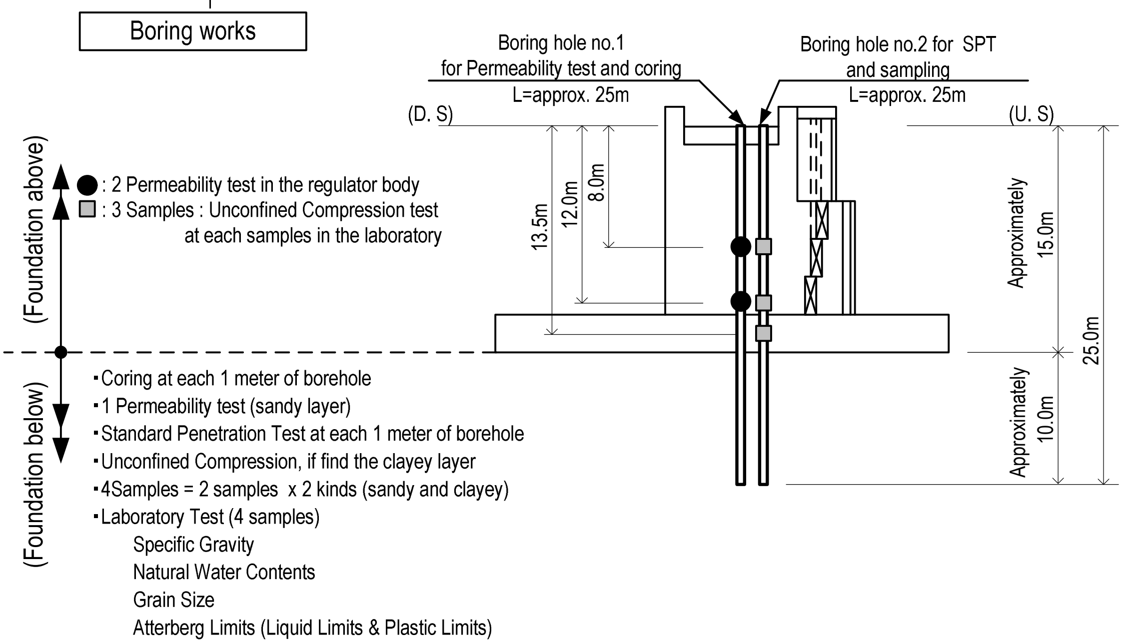
- ✓ To study and check the exact present status of the existing DGRs, two boring survey for each pier should be conducted. The unconfined test and the permeability test should be conducted for the sample cores taken from the boreholes.
- ✓ The investigated data should be compared to the past survey data. The data could be useful for

updating the deterioration curve to evaluate the structural life time remained.

✓ 3D finite element analysis could be useful for the entire evaluation of the present status of the existing DGRs. For the analysis, it is recommendable to take the support of organization that has the enough experience for the existing DGRs is recommendable (for example, CRI has the experience of the analysis for DGRs in 2006).

Table 19-3.2 Recommendable survey

Survey items	Contents
Visual check to the existing DGRs	・The visual survey should conduct during the winter closure which season is from December to January. ・Especially, the invisible place i.g., the apron and the edge of pier due to the under the water, should be careful investigated.
Boring survey	・Two borehole in one pier are necessary. One hole is for the permeability test and coring, the other is for the SPT and the sampling for the laboratory test. ・Inner diameter of borehole shall not be less than 86mm ・The following picture is shown the boring plan



Laboratory test	・The four samples from the borehole No.2 should be conducted as the following tests. ➢ Unconfined test to the brick part designated on the picture above and the clay layer at foundation below if any, ➢ Specific Gravity, ➢ Natural Water Contents, ➢ Grain Size, ➢ Atterberg Limits (Liquid limits and Plastic limits)
Structural analysis	・Finite element analysis should be done considering the brick strength evaluated by the unconfined test ・The following cases on the structural analysis are assumed. ・All gates completely opened + Present traffic conditions

	① All gates completely opened +Planned traffic conditions (Traffic limitation) ② All gates completely opened +Planned traffic conditions (Traffic limitation)+ Effect of structural enhancement by the enhancing works (If the enhancing works is implemented.)

Recommendable works for the preservation

- ✓ In order to reduce the burden load on the existing DGRs except for Abo Gabal and Sahelyia regulators, the passable traffic shall be restricted. The allowable traffic could be the pedestrian, small vehicle and motorcycle. Especially as to the small vehicle and motorcycle, the allowable velocity should be regulated.
- ✓ In addition, all the gates shall be opened completely to alleviate the up-lift pressure to the basement of the regulators because the gate operation of the existing DGRs will not be required. Furthermore, dredging works should be done before the gates make full open (refer to chapter “18-4 Management of target canal bed elevation”).
- ✓ The significant damages investigated in 2010 such as eroded or fallen out bricks inside of the vents, and eroded apron at Bahr Yusef and Ibrahimia regulators should be rehabilitated. These works need the appropriate diversion works even in the winter closure season.
- ✓ The enhancement of the foundation and the regulator body should be implemented depending on the results of boring survey and/or the 3D finite element analysis.