4.1.2

Diaphragm Wall

CONTENTS

1. INTRODUCTION

In this paper, the design calculation of cofferdam for the intermediate sewage pumping station is made.

The cofferdam of the intermediate sewage pumping station will be constructed by diaphragm wall method. This cofferdam constructed by diaphragm wall is used as permanent wall of the intermediate sewage pumping station.

Calculation of diaphragm wall uses an Elasto-plastic analysis method.

2. DESIGN CONDITION

2-1 DESIGN CODES

(1) Structure design index (1998)

Japan Sewage Works Agency.

(2) Temporary structure index for earth works of road (1990).

Japan Road Association.

(3) Specification for Highway Bridges: Part 4 (1990).

Japan Road Association.

(4) Standard Specification for Design and Construction of Tunneling: Open cut method, (1996). Japan Society of Civil Engineering.

(5) Standard Specification for Design and Construction of Concrete Structures: (1996). Japan Society of Civil Engineering.

2-2 DESIGN PARAMETERS

2-2-1 Structural Parameters

(1) Concrete

Show the allowable stress of concrete in slurry in the following table.

a) Temporary structure

(N/mm²)

Concrete Strength		f'ck	30	35	40
Concrete Strength in the water			24	27	30
Compressive stress	For bending moment	σ'ca	12.0	13.5	15.0
	For axial force		10.0	11.0	12.5
Shearing stress	When a diagonal re-bar is used.	τa1	0.59	0.63	0.68
	When a diagonal re-bar is not used.	τa2	2.55	2.70	2.85
Bond stress of re-bar			1.80	1.95	2.10

b) Permanent structure

(N/mm²)

Concrete Strength		f'ck	30	35	40
Concrete Strength in the water			24	27	30
Compressive stress	For bending moment	σ'ca	8.0	9.0	10.0
	For axial force		6.5	7.5	8.5
Shearing stress	When a diagonal re-bar is used.	τa1	0.39	0.42	0.45
	When a diagonal re-bar is not used.	τa2	1.70	1.80	1.90
Bond stress of re-bar			1.20	1.30	1.40

c) When the temporary structure is used as the permanent structure.

(N/mm²)

Concrete Strength		f'ck	30	35	40
Concrete Strength in the water			24	27	30
Compressive stress	For bending moment	σ'ca	10.0	11.0	12.5
	For axial force		8.0	9.4	10.5
Shearing stress	When a diagonal re-bar is used.	τa1	0.49	0.53	0.56
	When a diagonal re-bar is not used.	τa2	2.13	2.25	2.38
Bond stress of re-bar			1.50	1.63	1.75

(2) Reinforcement

Show the allowable tension stress of reinforcement in the following table.

(N/mm²)

Type of reinforcement					SD295A,B	SD345
Design yield strength of reinforcement				fy	450	500
In the slurry	Temporary structure			σ_{sa}	270	300
	When the temporary structure is used as the permanent structure	Temporary structure			225	250
		Permanent structure	Long term		160	160
			Short term		270	300

(3) Steel

Show the allowable stress of steel in the following table.

(N/mm²)

Type of steel		SS400	SM490
Allowable tension stress		210	280
Allowable compressive stress		l / r ≦ 18 210 18 < l / r ≦ 92 140 – 0.82 (l / r – 18) x1.5 92 < l / r $\frac{1,200,000}{6,700+(l/r)^2}\times 1.5$ l :Buckling length (mm) r :Radius of gyration (mm)	l / r ≦ 16 280 16 < l / r ≦ 79 185 – 1.2 (l / r – 16) x1.5 79 < l / r $\frac{1,200,000}{5,000+(l/r)^2}\times 1.5$ l :Buckling length (mm) r :Radius of gyration (mm)
Allowable Bending stress	Tension side	210	280
	Compression side	l / b ≦ 4.5 210 4.5 < l / r ≦ 30 140 – 2.4 (l / b – 4.5) x1.5 l : Fixed distance of flange (mm) r :Width of flange (mm)	l / r ≦ 4.0 280 4.0 < l / r ≦ 30 185 – 3.8 (l / b – 4.0) x1.5 l : Fixed distance of flange (mm) r :Width of flange (mm)
Allowable shearing stress		120	160
Allowable bearing stress		315	420

(4) Sheet pile

Show the allowable stress of sheet pile in the following table.

(N/mm²)

Type of steel				SY295
Base-metal part	Allowable tensile stress			270
	Allowable compressive stress			270
Welding part	Factory welding	Butt welding	Tensile stress	240
			Compressive stress	240
			Shearing stress	130
	Site welding	Butt welding	Tensile stress	216
			Compressive stress	216
			Shearing stress	120

2-2-2 Ground Surface Level

The following original ground surface level is applied.

EL+2.00m

2-2-3 Ground Water Level

The following original ground water level is applied.

EL+0.20m

2-2-4 Geotechnical Parameters

A summary of the geotechnical parameters used for the structural analysis, is given in following table.

Table Geotechnical design parameters

Layer	Level	Depth (m)	γ_b (kN/m³)	N – value	ϕ' (deg)	C (kN/m²)	E'_c (kN/m²)
Made ground	EL+2.00m (GL) ~ EL – 0.10m	2.10	18.0 (9.0)	3	30	0.0	840
Soft clay	EL – 0.10m ~ EL – 2.10m	2.00	14.0 (5.0)	1	0	6.0	700
Soft clay	EL – 2.10m ~ EL – 7.10m	5.00	20.0 (11.0)	5	24	22.0	3,500
Medium Stiff clay (1st Clay)	EL – 7.10m ~ EL – 18.0m	10.90	20.0 (11.0)	10	27	20.0	7,000
Silty sand (1st Sand)	EL – 18.0m ~ EL – 40.8m	22.80	20.0 (11.0)	20	32	20.0	14,000
Very stiff clay (1st Clay)	EL – 40.8m ~	-	20.0 (11.0)	48	0	70.0	33,600

Legend:

γ_b ... Bulk unit weight

ϕ' ... Effective internal friction angle

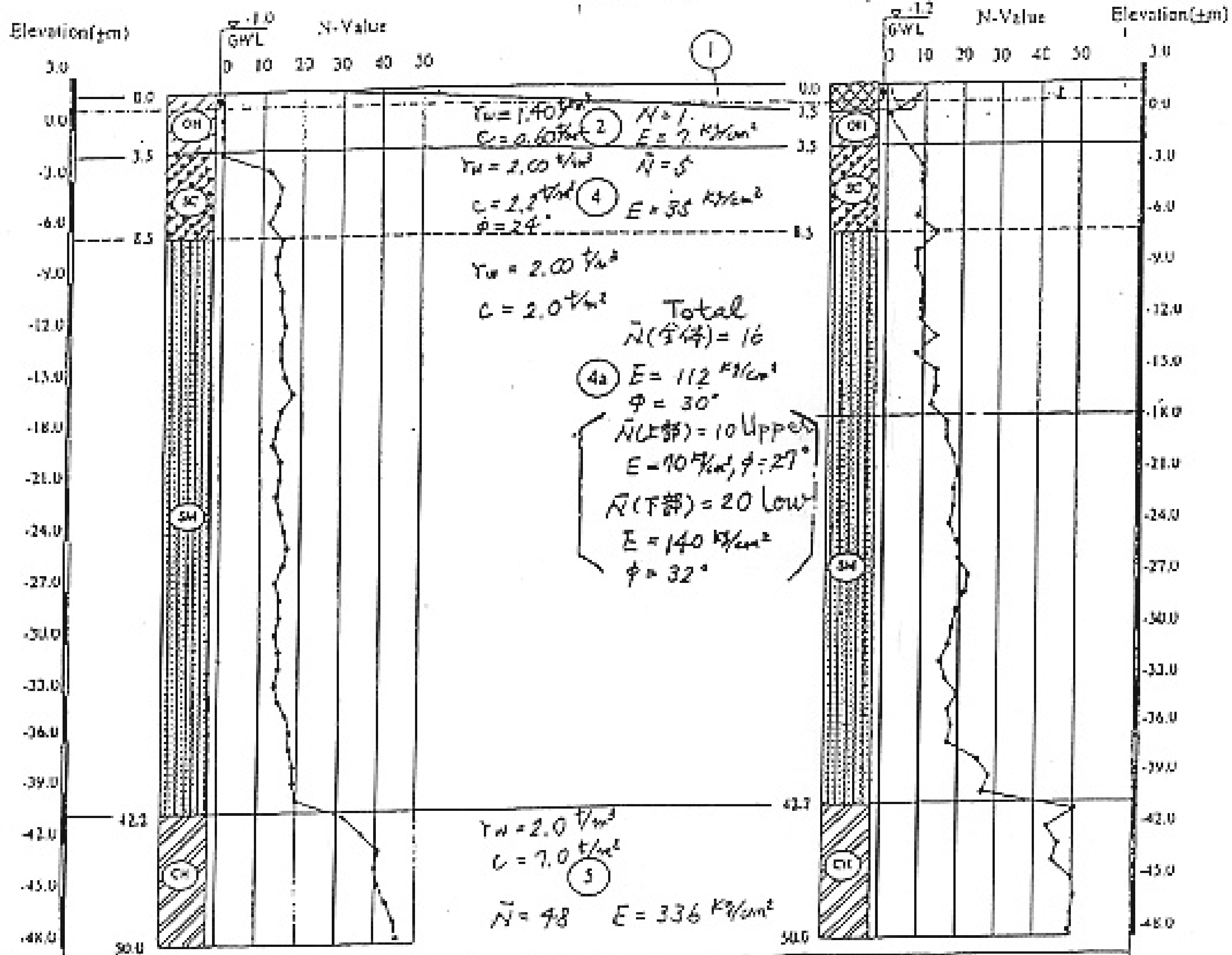
C_u ... Shear strength

E'_c ... Drained Young's modulus for loading/reloading

ENGINEERING GEOLOGY CROSS SECTION A-A

Intermediate Sewage Pumping Station Site

SCALE: Vertical 1/300
Horizontal 1/500



BORING NUMBER	SP-01	DSP-01
DEPTH (m)	50	50
ELEVATION (m)	1.35	1.40
DISTANCE (m)	70	

Boring data

LEGEND

1. Ground made : Soft, blackish grey SANDY
2. Very soft, high plasticity, blackish grey OR
4. Loose greenish grey CLAYEY SAND
4a. Medium dene, yellowish grey SILTY SAND
5. Hard, high plasticity, yellowish brownish gr

地下水位
(Ground water Level)
SP01 +0.35m
SP02 +0.25m
DSP01 +0.20m

採用 (Decide) +0.20m

2-3 LOAD CATEGORIES AND COMBINATION

A load takes the following into consideration.

The categories with respective nomenclature are given as follows;

(1) W ... dead load

(2) Q ... live load

(3) P_w ... water pressure

(4) P ... earth pressure

(5) T... other loads

Each load category can be divided into sub-groups that cover all expected actions and analysis purposes. Herewith, each load category is designated by a letter that represents the load category itself and an index number that assign it to a specific sub-group or analysis purpose. Generally, loads that occur together can group, prior to the actual analysis.

2-3-1 Dead load (W)

Self Weight (W_1)

The volume used in calculating self-weights is based on the nominal dimensions of the structure.

$$W_1 = \gamma \cdot V$$

In calculating the dead load due to self-weight, the following unit weight (γ) is applied.

* Reinforced concrete	25.0 kN/m^3
* Mass concrete	23.0 kN/m^3
* Back fill concrete	24.0 kN/m^3
* Steel	78.5 kN/m^3

2-3-2 Live load (Q)

A uniform traffic surcharge of 10 kN/m^2 is applied.

2-3-3 Water pressure load (P_w)

Water pressure load is calculated as follows.

$$P_w = \gamma_w \cdot z_w$$

Where:

γ_w ... unit weight of water (=10.0 kN/m^3)

z_w ... depth below water table for the load case considered

2-3-4 Earth pressure (P)

(1) Soil Overburden (P_V)

The load due to weight of soil overburden in drained condition is calculated as follows.

Sand layer

$$P_V = \gamma_b \cdot z_o + \gamma' \cdot z_w$$

Clay layer

$$P_V = \gamma_b \cdot z_o$$

where:

γ_b ... Bulk unit weight of soil (given in section 2-2-4)

γ' ... buoyant unit weight ($= \gamma_b - \gamma_w$)

γ_w ... unit weight of water (=10.0 kN/m^3)

z ... depth from surface

z_o ... depth from surface to water table

z_w ... depth below water table

(2) Lateral Earth Pressure (P_H)

a) Static earth pressure

Static earth pressure is calculated multiplying the soil overburden by the respective coefficient of lateral pressure (k_{os}) given in the following.

- Sand layer

  $k_{os} = 1 - \sin\phi$

  where, ϕ' : Effective internal friction angle

- Clay layer

N – value	k_{os}
N ≧ 8	0.5
4 ≧ N < 8	0.6
2 ≧ N < 4	0.7
N < 2	0.8

The static earth pressure load, P_{HS}, is calculated as follows.

$$P_H = (P_V + q) \cdot k_{os}$$

where, q: live load

b) Active earth pressure

Active earth pressure is calculated multiplying the soil overburden by the respective coefficient of lateral pressure (k_{os}) given in the following.

- Sand layer

  $k_{os} = \tan^2(45 - \phi/2)$

  where, ϕ : Effective internal friction angle

- Clay layer

N – value	Shallower than the excavate depth k_{oa1}		Deeper than the excavate depth k_{oa2}
	Formula	Minimum	
N P 8	0.5 – 0.01H	0.3	0.5
4 ≦ N < 8	0.6 – 0.01H	0.4	0.6
2 ≦ N < 4	0.7 – 0.025H	0.5	0.7
N < 2	0.8 – 0.025H	0.6	0.8

The active earth pressure load, P_H, is calculated as follows.

Sand

$$P_H = (P_V + q)\cdot k_{oa} - 2\cdot c\cdot \sqrt{k_{oa}}$$

where, P_V : Vertical pressure.

q : Live load.

Clay

Shallower than the excavate depth

$$P_H = (P_{V1} + q)\cdot k_{oa1}$$

Deeper than the excavate depth

$$P_H = (P_{V1} + q)\cdot k_{oa1} + P_{V2}\cdot k_{oa2}$$

where, P_{V1} : Vertical pressure of the shallower than the excavate depth.

P_{V2} : Vertical pressure of the deeper than the excavate depth.

c) Passive earth pressure

Passive earth pressure is calculated multiplying the soil overburden by the respective coefficient of lateral pressure (k_{op}) given in the following.

- Sand and clay layer

$$k_{op} = \frac{\cos^2\phi}{\left[1-\sqrt{\dfrac{\sin(\phi+\delta)\cdot\sin\phi}{\cos\delta}}\right]^2}$$

where, ϕ : Effective internal friction angle

δ : Frictional angle with the cofferdam and the soil ($=\phi/3$)

The active earth pressure load, P_H, is calculated as follows.

Sand and clay layer

$$P_H = (P_V + q)\cdot k_{op} + 2\cdot c\cdot \sqrt{k_{op}}$$

2-3-5 Other loads (T)

(1) Effect of Temperature (T_1)

$T_1 = 150.0\ kN/m^2$

(2) Vertical load on strut (T_2)

Vertical loads on strut are the self-weight of strut and $5.0\ kN/m^2$.

(3) Buckling control load (T_3)

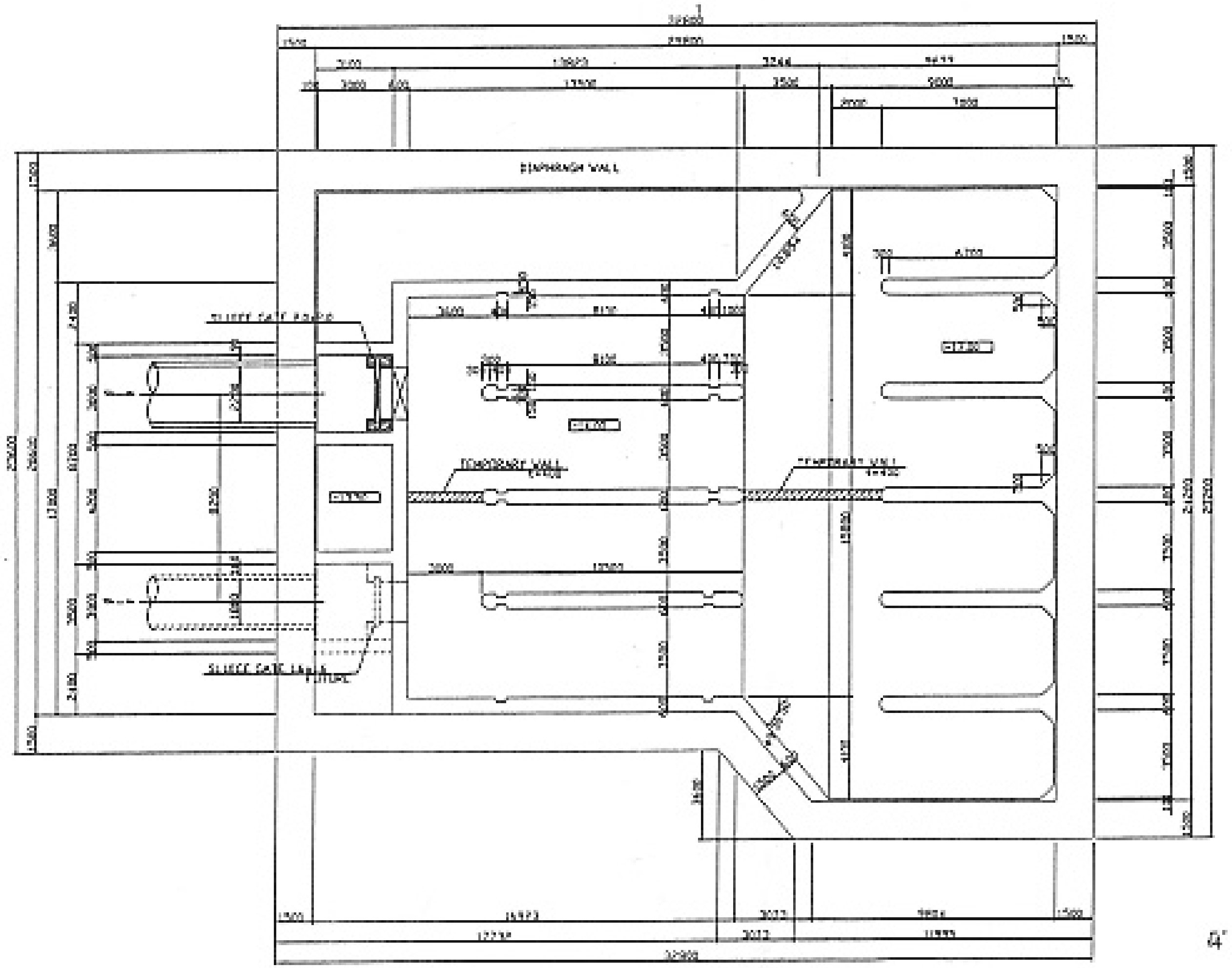
Vertical advantage force is 2% of axial force of strut.

3. SHAPE AND DIMENSIONS

INTERMEDIATE PUMPING STATION STRUCTURAL(1)

S=1:100

1-1



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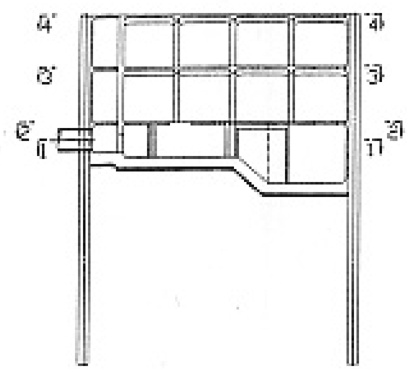


NO	DATE	DESCRIPTIONS	BY	APPD
		REVISIONS		

PROJECT MANAGEMENT UNIT FOR WATER ENVIRONMENT IMPROVEMENT FOR HO CHI MINH CITY

THE DETAILED DESIGN ON HO CHI MINH CITY WATER ENVIRONMENT IMPROVEMENT PROJECT IN THE SOCIALIST REPUBLIC OF VIET NAM

SCALE : S=1:100

JAPAN INTERNATIONAL COOPERATION AGENCY

PACIFIC CONSULTANTS INTERNATIONAL

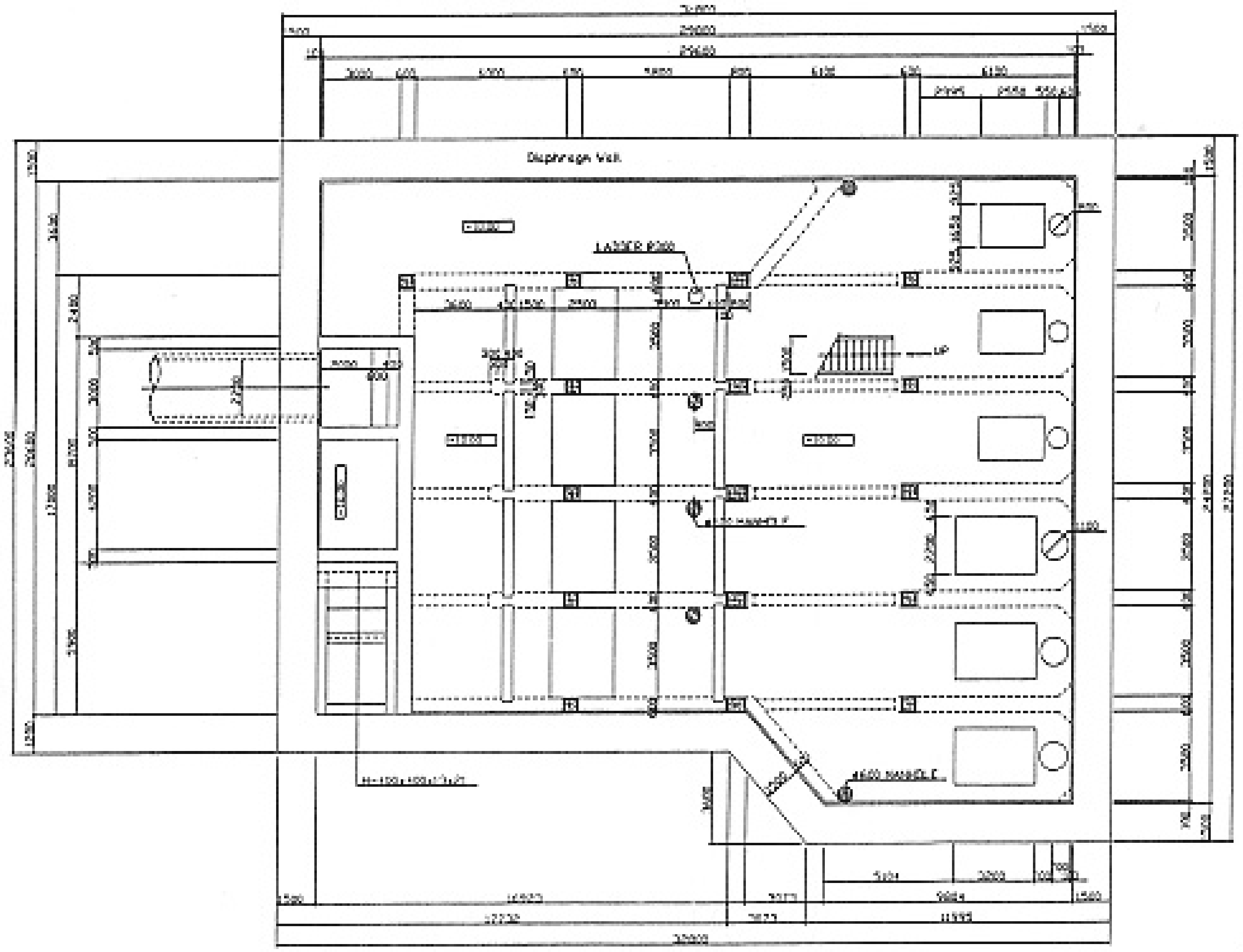
DESIGNED BY | CHECKED BY

DATE: | DWG.No.

INTERMEDIATE PUMPING STATION STRUCTURAL(2)

S=1:100

2-2



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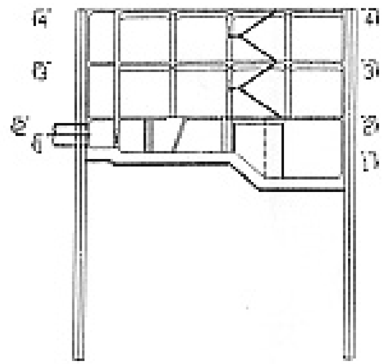

NO	DATE	DESCRIPTIONS	BY	APRD
		REVISIONS		

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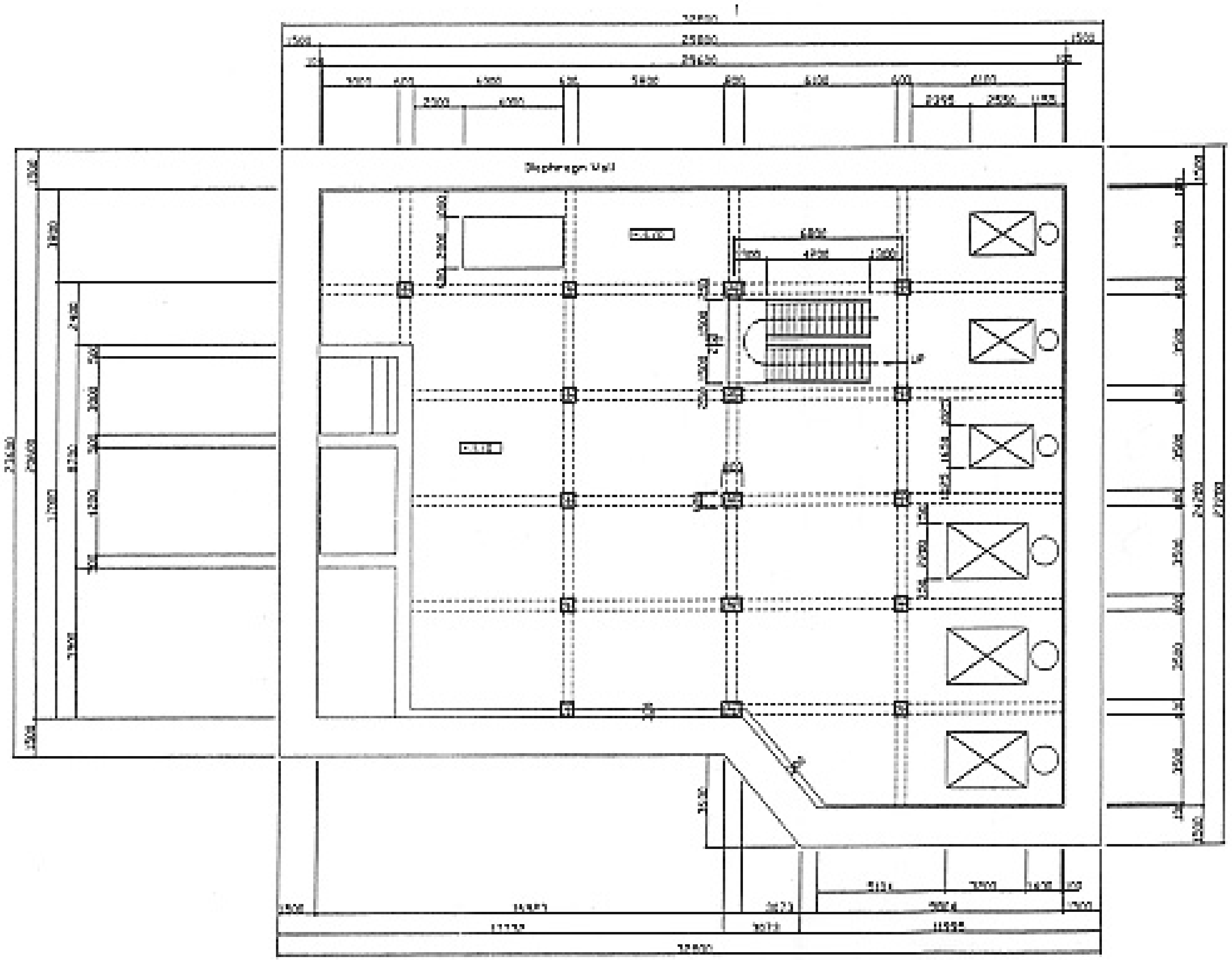
DATE:	DWG.No.

INTERMEDIATE PUMPING STATION STRUCTURAL(3)

S=1:100

3-3



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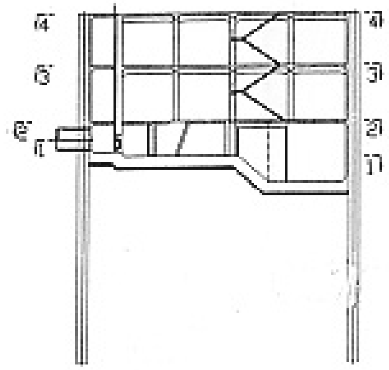

NO.	DATE	DESCRIPTIONS	BY	APPD

REVISIONS

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SCALE : S=1:100

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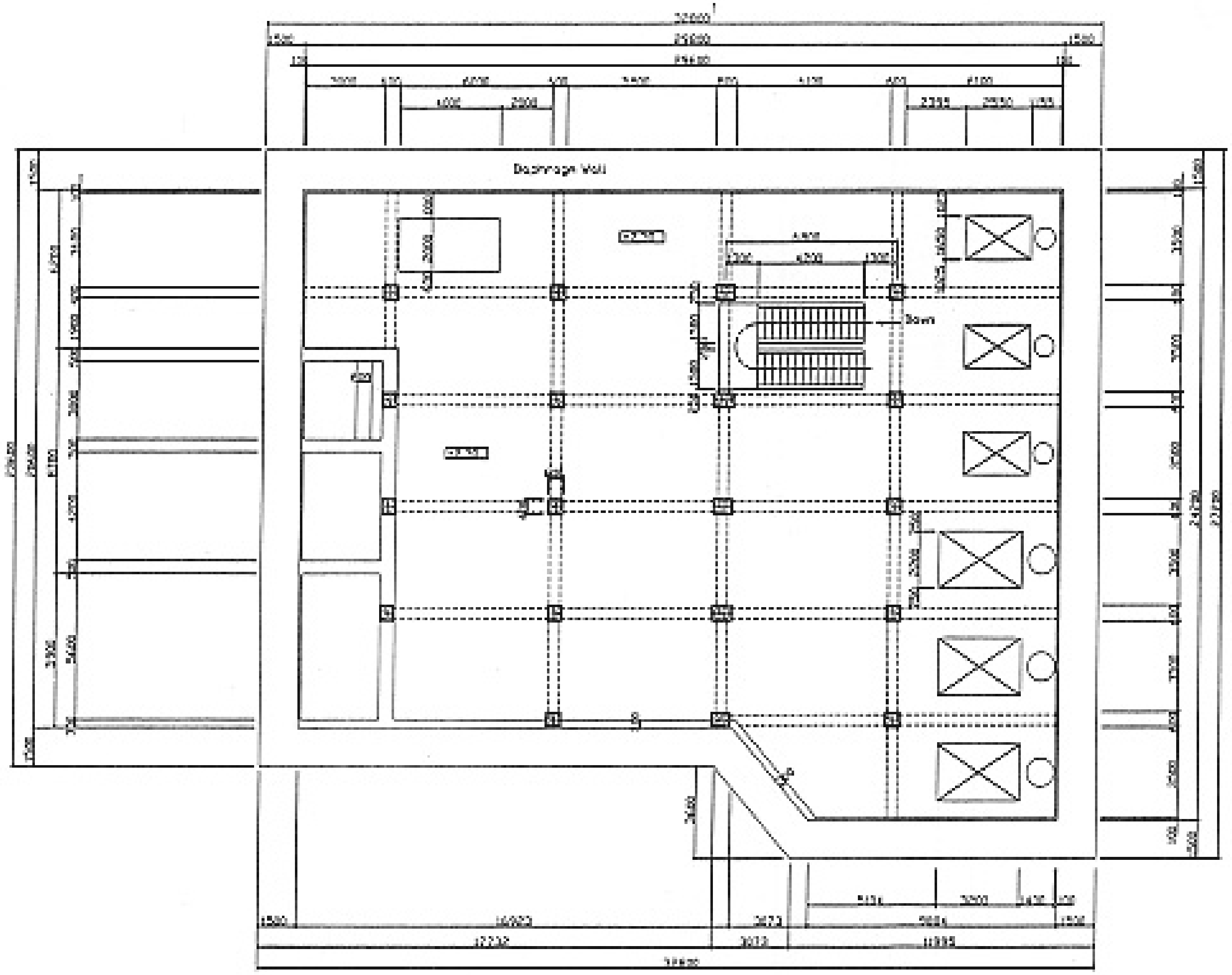
INTERMEDIATE PUMPING STATION STRUCTURAL(4) S=1:100

4-4



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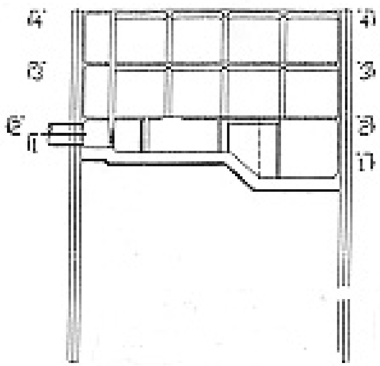

NO.	DATE	DESCRIPTIONS	BY	APPD

REVISIONS

PROJECT MANAGEMENT UNIT FOR WATER ENVIRONMENT IMPROVEMENT FOR HO CHI MINH CITY

THE DETAILED DESIGN ON HO CHI MINH CITY, WATER ENVIRONMENT IMPROVEMENT PROJECT IN THE SOCIALIST REPUBLIC OF VIET NAM

SCALE : S=1:100

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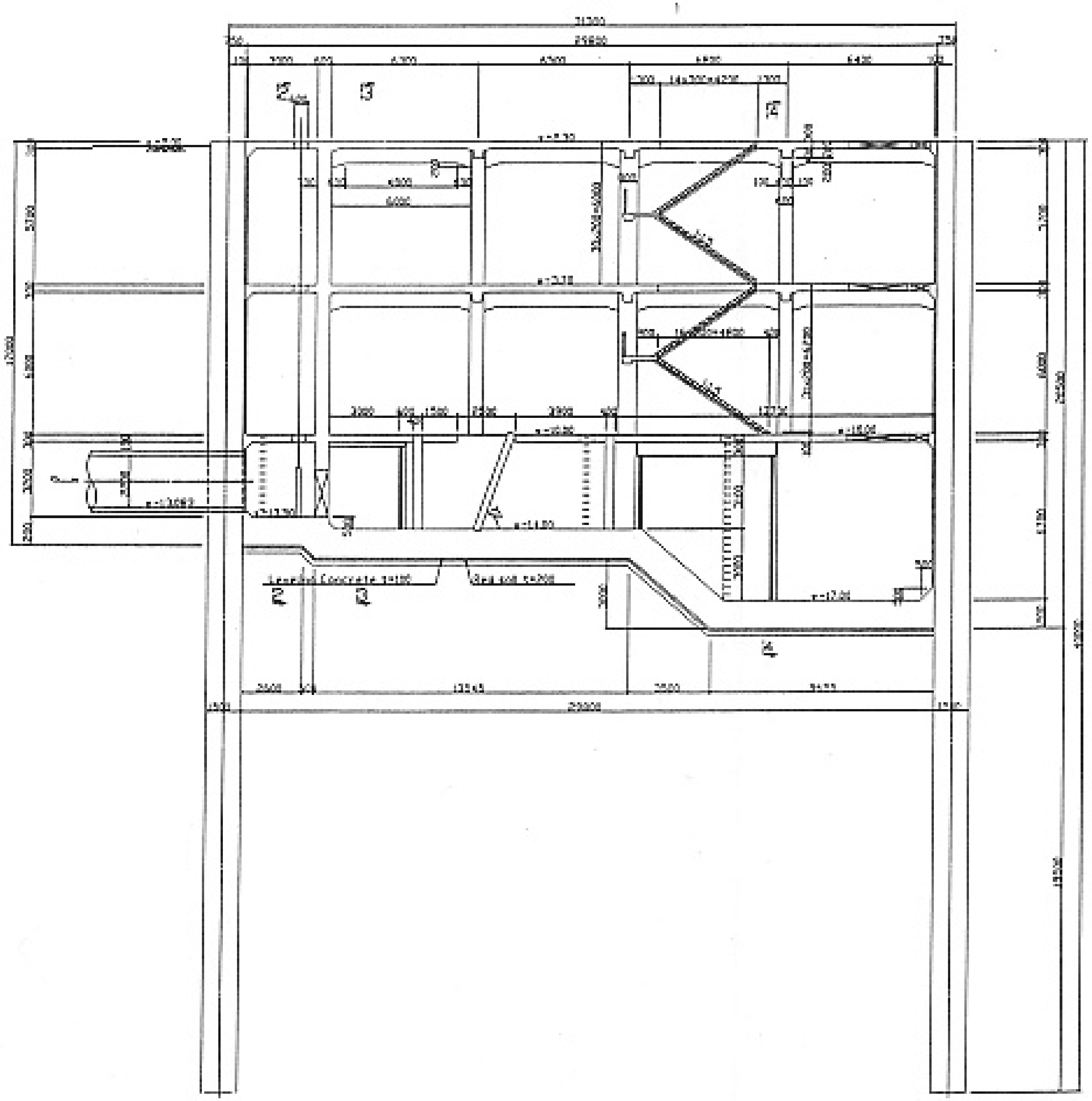
INTERMEDIATE PUMPING STATION STRUCTURAL(5)

S=1:100

5-5



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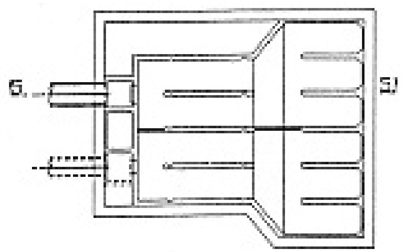

NO	DATE	DESCRIPTIONS	BY	APPD

REVISIONS

PROJECT MANAGEMENT UNIT FOR WATER ENVIRONMENT IMPROVEMENT FOR HO CHI MINH CITY

THE DETAILED DESIGN ON HO CHI MINH CITY WATER ENVIRONMENT IMPROVEMENT PROJECT IN THE SOCIALIST REPUBLIC OF VIET NAM

SCALE : S=1:100

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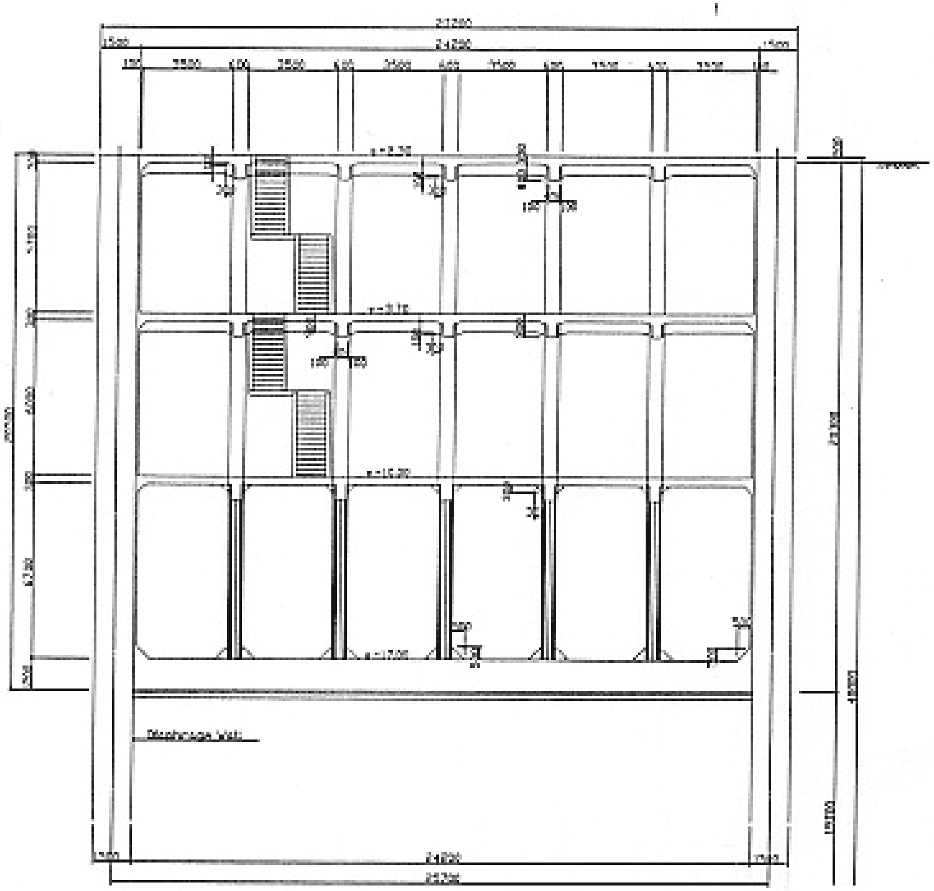
INTERMEDIATE PUMPING STATION STRUCTURAL(7)   S=1:100

8-8



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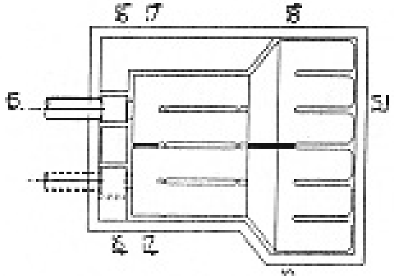

NO.	DATE	DESCRIPTIONS	BY	APPD.

REVISIONS

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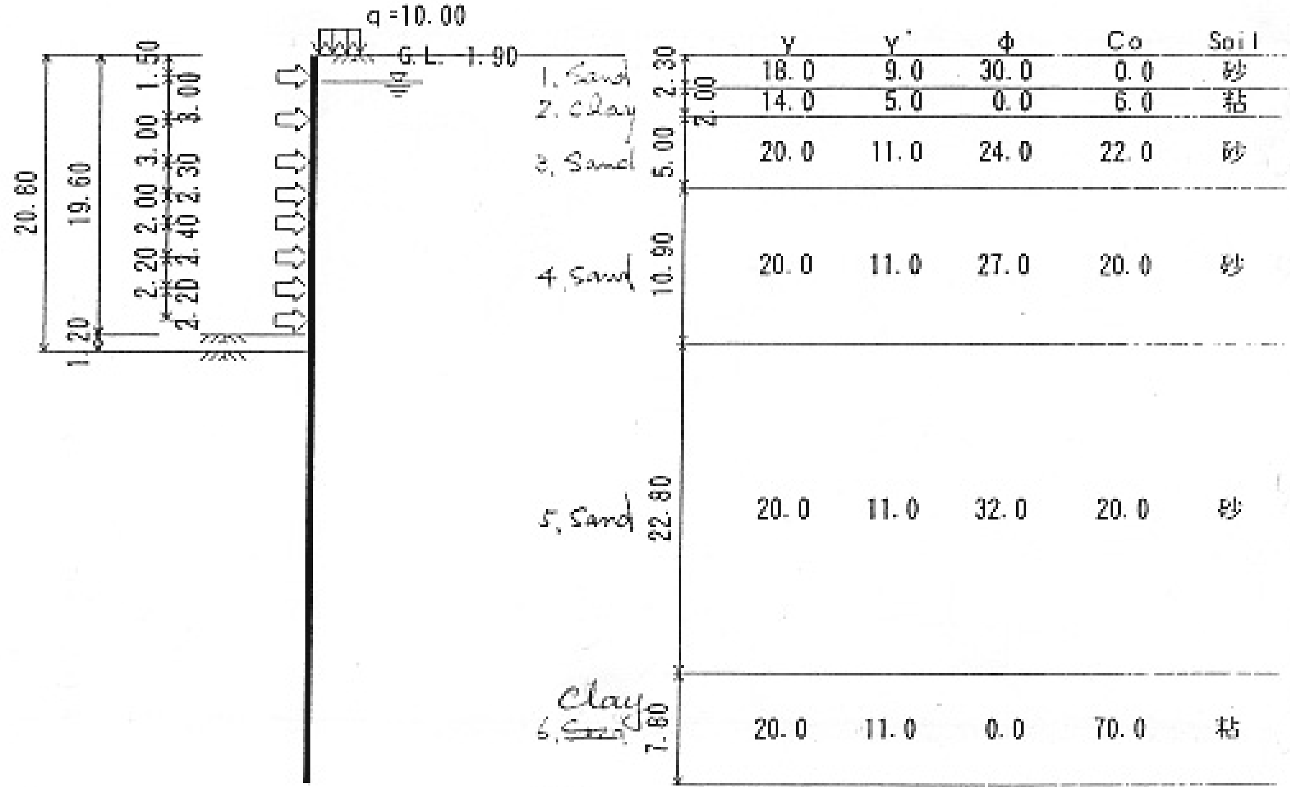
4. STUDY ON LENGTH OF WALL

4-1 STUDY ON PENETRATION LENGTH BY EARTH PRESSURE BALANCE

4-1-1 Ground condition



Soil parameters

Soil N Value / wet density / in water density / internal angle / cohesion / added cohesion

No	層厚 h m	土質	N値	湿潤重量 γt kN/m³	水中重量 γ' kN/m³	摩擦角 φ 度	粘着力 co kN/m²	粘着増分 Δc kN/m²
1	2.30	砂質	3.0	18.0	9.0	30.0	0.0	0.0
2	2.00	粘性	1.0	14.0	5.0	0.0	6.0	0.0
3	5.00	砂質	5.0	20.0	11.0	24.0	22.0	0.0
4	10.90	砂質	10.0	20.0	11.0	27.0	20.0	0.0
5	22.80	砂質	20.0	20.0	11.0	32.0	20.0	0.0
6	7.80	粘性	48.0	20.0	11.0	0.0	70.0	0.0

Thickness of layer

4-1-2 Strut position

段	支保工深さ G. L. - m
1	1. 50
2	4. 50
3	7. 50
4	9. 80
5	11. 80
6	14. 20
7	16. 40
8	18. 60

depth of strut

4-1-3 The calculation of the requirement penetration length

(1) Before final excavation

The required penetration length decided from a balance of moment by the soil pressure of bottom from the strut. The ground water pressure is assumed zero at the tip of wall.

The pressure that acted on the wall was calculated with the formula of the section 2-3-4. Excavation level of this case is GL – 19.6 m.

1) Active side

Active earth pressure

$$pa = Ka\ (\Sigma \gamma h + q) - 2c\sqrt{(Ka)}\ ,\ Ka = \tan^2 (45 - \phi / 2)$$

No	深さ z G.L. -m	層厚 h m	γ kN/m³	φ 度	c kN/m²	Σγh+q kN/m²	Ka	pa kN/m²
1	0.00 1.90	1.90	18.0	30.0	0.0 0.0	10.00 44.20	0.33333	3.33 14.73
2	1.90 2.30	0.40	9.0	30.0	0.0 0.0	44.20 47.80	0.33333	14.73 15.93
3	2.30 4.30	2.00	5.0	0.0	6.0 6.0	47.80 57.80	1.00000	35.80 45.80
4	4.30 9.30	5.00	11.0	24.0	22.0 22.0	57.80 112.80	0.42173	0.00 19.00
5	9.30 16.40	7.10	11.0	27.0	20.0 20.0	112.80 190.90	0.37552	17.85 47.18
6	16.40 19.60	3.20	11.0	27.0	20.0 20.0	190.90 226.10	0.37552	47.18 60.39
7	19.60 20.20	0.60	11.0	27.0	20.0 20.0	226.10 232.70	0.37552	60.39 62.87
8	20.20 24.59	4.39	11.0	32.0	20.0 20.0	232.70 280.99	0.30726	49.33 64.16

Moment by active earth pressure

No	深さ z G.L. -m	層厚 h m	pa kN/m²	水平力 Pa kN	アーム長 y m	モーメント Ma kN・m
6	16.40 19.60	3.20	47.18 60.39	75.48 96.63	1.07 2.13	80.51 206.15
7	19.60 20.20	0.60	60.39 62.87	18.12 18.86	3.40 3.60	61.60 67.90
8	20.20 24.59	4.39	49.33 64.16	108.27 140.84	5.26 6.73	569.87 947.39
Σ				458.20		1933.42

Moment by water pressure

depth, thickness of layer, horizontal force, length of arm, bending moment

No	深さ z G. L. -m	層厚 h m	pw kN/m²	水平力 Pw kN	アーム長 y m	モーメント Mw kN・m
1	16. 40 19. 60	3. 20	145. 00 177. 00	232. 00 283. 20	1. 07 2. 13	247. 47 604. 16
2	19. 60 24. 59	4. 99	177. 00 0. 00	441. 62 0. 00	4. 86 6. 53	2147. 72 0. 00
Σ				956. 82		2999. 35

Total horizontal pressure Pa = 1415 kN

Total moment Ma = 1933 + 2999 = 4932 kN m

2) Passive pressure

Passive pressure

depth, thickness

$$pp = (q + \Sigma\gamma h)\,Kp + 2c\sqrt{(Kp)}, \quad Kp = \tan^2(45 + \phi/2)$$

No	深さ z G. L. -m	層厚 h m	γ kN/m³	φ 度	c kN/m²	Σγh+q kN/m²	Kp	pp kN/m²
7	19. 60 20. 20	0. 60	11. 0	27. 0	20. 0 20. 0	0. 00 6. 60	2. 66294	65. 27 82. 85
8	20. 20 24. 59	4. 39	11. 0	32. 0	20. 0 20. 0	6. 60 54. 89	3. 25459	93. 64 250. 81

Moment by passive earth pressure

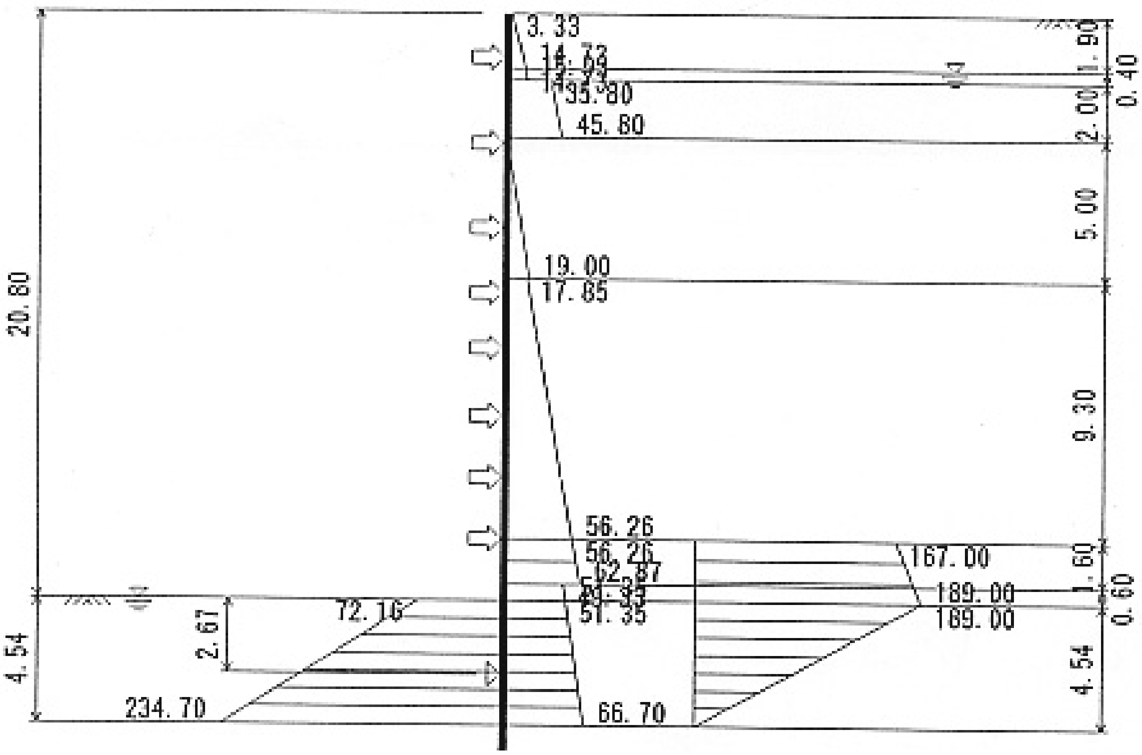
depth, thickness, horizontal force, length of arm, bending moment

No	深さ z G. L. -m	層厚 h m	pp kN/m²	水平力 Pp kN	アーム長 y m	モーメント Mp kN・m
7	19. 60 20. 20	0. 60	65. 27 82. 85	19. 58 24. 85	3. 40 3. 60	66. 58 89. 46
8	20. 20 24. 59	4. 39	93. 64 250. 81	205. 54 550. 52	5. 26 6. 73	1081. 85 3703. 16
Σ				800. 50		4941. 07

Total horizontal pressure Pp = 800 kN

Total moment Mp = 4941 kN m

Show a load figure in the following.



3) Balance of moment

Mp / Ma = 4941 / 4932 = 1.0 OK!

Balanced depth (Z) is 4.99 m

Therefor,

Penetration length D = Z x 1.2 = 5.99 m P 3.00 m (GL-25.59 m)

4) Depth of virtual supporting point

$$Y = \frac{Mp}{Pp} - L0$$

Where, L0 : Length between excavation level and strut

= 19.6 m – 16.4 m = 3.2 m

$$= \frac{4941}{800} - 3.2$$

= 2.97 m (GL-22.57 m)

(2) Final excavation

The pressure that acted on the wall is calculated with the formula of the section 2-3-4. Excavation level of this case is GL – 20.8 m.

1) Active side

Active earth pressure

depth thickness of layer Unit weight Internal angle

$$pa = Ka\ (\Sigma\gamma h + q) - 2c\sqrt{Ka}\ ,\quad Ka = \tan^2(45 - \phi/2)$$

No	深さ z G.L. -m	層厚 h m	γ kN/m³	φ 度	c kN/m²	Σγh＋q kN/m²	Ka	pa kN/m²
1	0.00 1.90	1.90	18.0	30.0	0.0 0.0	10.00 44.20	0.33333	3.33 14.73
2	1.90 2.30	0.40	9.0	30.0	0.0 0.0	44.20 47.80	0.33333	14.73 15.93
3	2.30 4.30	2.00	5.0	0.0	6.0 6.0	47.80 57.80	1.00000	35.80 45.80
4	4.30 9.30	5.00	11.0	24.0	22.0 22.0	57.80 112.80	0.42173	0.00 19.00
5	9.30 18.60	9.30	11.0	27.0	20.0 20.0	112.80 215.10	0.37552	17.85 56.26
6	18.60 20.20	1.60	11.0	27.0	20.0 20.0	215.10 232.70	0.37552	56.26 62.87
7	20.20 20.80	0.60	11.0	32.0	20.0 20.0	232.70 239.30	0.30726	49.33 51.35
8	20.80 25.34	4.54	11.0	32.0	20.0 20.0	239.30 289.24	0.30726	51.35 66.70

depth thickness of layer horizontal force length of arm bending moment

Moment by active earth pressure

No	深さ z G.L. -m	層厚 h m	pa kN/m²	水平力 Pa kN	アーム長 y m	モーメント Ma kN・m
6	18.60 20.20	1.60	56.26 62.87	45.01 50.30	0.53 1.07	24.01 53.65
7	20.20 20.80	0.60	49.33 51.35	14.80 15.41	1.80 2.00	26.64 30.81
8	20.80 25.34	4.54	51.35 66.70	116.57 151.41	3.71 5.23	432.88 791.35
Σ				393.50		1359.34

depth / thickness of layer / horizontal force / length of arm / bending moment

Moment by water pressure

No	深さ z G.L. -m	層厚 h m	pw kN/m²	水平力 Pw kN	アーム長 y m	モーメント Mw kN・m
1	18.60 20.80	2.20	167.00 189.00	183.70 207.90	0.73 1.47	134.71 304.92
2	20.80 25.34	4.54	189.00 0.00	429.03 0.00	3.71 5.23	1593.13 0.00
Σ				820.63		2032.76

Total horizontal pressure   Pa = 1214 kN

Total moment   Ma = 1359 + 2033 = 3392 kN m

2) Passive pressure

Passive pressure

depth / thickness of layer

pp= (q + Σγ h) Kp + 2 c √ (Kp) , Kp = tan² (45 + φ / 2)

No	深さ z G.L. -m	層厚 h m	γ kN/m³	φ 度	c kN/m²	Σγh+q kN/m²	Kp	pp kN/m²
8	20.80 25.34	4.54	11.0	32.0	20.0 20.0	0.00 49.94	3.25459	72.16 234.70

depth / thickness of layer / horizontal force / length of arm / bending of moment

Moment by passive earth pressure

No	深さ z G.L. -m	層厚 h m	pp kN/m²	水平力 Pp kN	アーム長 y m	モーメント Mp kN・m
8	20.80 25.34	4.54	72.16 234.70	163.81 532.76	3.71 5.23	608.27 2784.56
Σ				696.57		3392.83

Total horizontal pressure   Pp = 697 kN

Total moment   Mp = 3393 kN m

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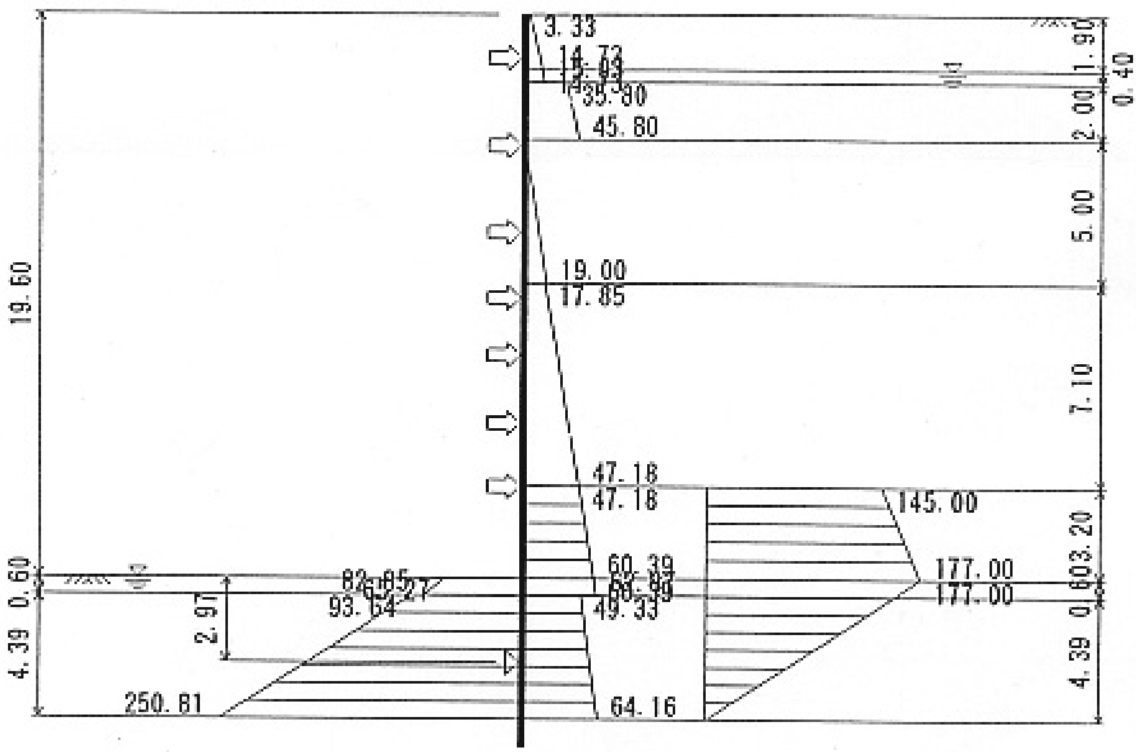


3) Balance of moment

Mp / Ma = 3393 / 3392 = 1.0 OK!

Balanced depth (Z) is 4.54 m

Therefor,

Penetration length D = Z x 1.2 = 5.45 m P 3.00 m (GL-26.25 m)

4) Depth of virtual supporting point

$$Y = \frac{Mp}{Pp} - L0$$

Where, L0 : Length between excavation level and strut

= 20.8 m – 18.6 m = 2.2 m

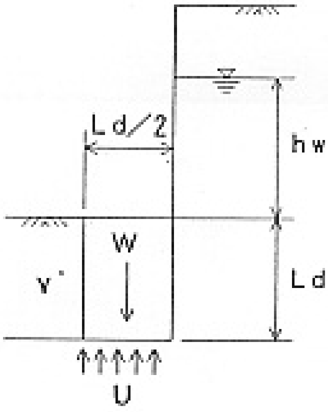
$$= \frac{3393}{697} - 2.2$$

= 2.67 m (GL-23.47 m)

4-2 STUDY ON BOILING

Boiling is checked with the following formula.

$$Fs = \frac{2 \cdot \gamma' \cdot Ld}{\gamma_w \cdot h_w}$$



where,

γ_b ... Bulk unit weight of soil (given in section 2-2-4)

γ' ... buoyant unit weight ($= \gamma_b - \gamma_w = 10.0$ kN/m^3)

γ_w ... unit weight of water (= 10.0 kN/m^3)

Ld ... penetration length (assumed = 11.34 m)

h_w ... depth below water table (= 18.9 m)

$$Fs = \frac{2 \times 10 \times 11.34}{10 \times 18.90}$$

= 1.2 P Fsa = 1.2 OK!

4-3 STUDY ON PENETRATION LENGTH BY ELASTO-PLASTIC ANALISYS

Penetration Length by Elasto-plastic analysis adopts the value that the rate of elastic region of the part penetration is more than 50%.

DW length (m)	Rate of elastic region (%)	
32.5	42.49	NG
33.5	45.12	NG
34.5	47.56	NG
35.5	49.92	NG
36.5	52.20	OK

4-4 SUMMARY OF PENETRATION LENGTH

Case		Excavation Depth (m)	Penetration Depth (m)	Length of wall (m)
Penetration length by earth pressure balance	Before final excavation	19.60	5.99	25.6
	Final excavation	20.80	5.45	26.3
Check on boiling		20.80	11.34	32.1
Penetration Length by Elasto-plastic analysis		20.80	15.70	36.5

Therefore, Diaphragm wall length is 36.5 m.

5. STUDY ON DIAPHRAGM WALL IN THE TEMPORARY CONDITION

Diaphragm wall in the temporary condition is calculated with an Elasto-plastic analysis method.

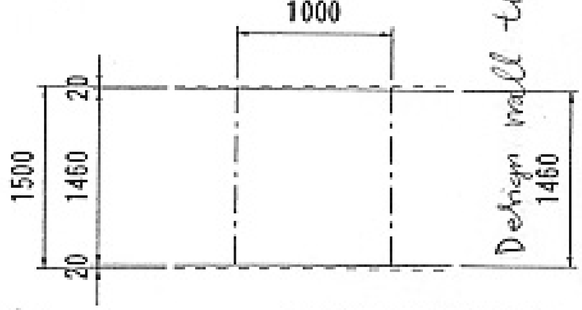
5-1 INPUT DATA

5-1-1 Specifications of diaphragm wall

(1) Length $L = 36.5$ m

(2) Moment of inertia $I = 0.1556\ m^4$

$$I = 1/12 \times b \times d^3 \times 0.6$$
$$= 1/12 \times 1.00 \times 1.46^3 \times 0.6$$
$$= 0.1556\ m^4$$



(3) Elastic modulus $E = 25{,}000{,}000\ kN/m^2$

(4) Calculation step $S = 13$

5-1-2 Spring constant of strut

(1) Strut

Spring constant of strut is calculated with the following formula.

$$Ks = \frac{2 \cdot \alpha \cdot E \cdot A}{L} \times \frac{1}{b}$$

where,

α : coefficient (=0.5)

E : Elastic modulus of strut (= $2.1 \times 10^8\ kN/m^2$)

A : Section area of strut

Type	Area (m^2)
H – 300 x 300 x 10 x 15	0.01184
H – 350 x 350 x 12 x 19	0.01719
H – 400 x 400 x 13 x 21	0.01720

L : Length of strut

No.1 ~ No.6 ⇒ L = 29.60 m

No.7 ~ No.8 ⇒ L = 24.00 m

b : Horizontal interval of strut (= 5.0 m)

Strut	Type	Area (m^2)	Spring constant (kN/m)
No.1	H – 300 x 300 x 10 x 15	0.01184	16,800
No.2	H – 300 x 300 x 10 x 15	0.01184	16,800
No.3	2 H – 300 x 300 x 10 x 15	0.02368	33,600
No.4	H – 300 x 300 x 10 x 15	0.01184	16,800
No.5	2 H – 300 x 300 x 10 x 15	0.02368	33,600
No.6	2 H – 300 x 300 x 10 x 15	0.02368	33,600
No.7	2 H – 300 x 300 x 10 x 15	0.02368	41,440
No.8	H – 300 x 300 x 10 x 15	0.01184	20.720

(2) Slab

Spring constant of slab is calculated with the following formula.

$$Kc = \frac{2 \cdot E \cdot A}{L \cdot (1+\phi_c)} \cdot \frac{1}{b \cdot (1-\varepsilon_c)} \cdot \beta$$

where,

E : Elastic modulus of concrete (= 2.5×10^7 kN/m^2)

A : Section area of slab

Type	Area (m^2)
Middle Slab	0.30
Base Slab	1.20

L : Length of slab (= 29.6 m)

b : Horizontal interval of strut (= 1.0 m)

ϕ_c : Creep coefficient of concrete (= 1.2)

ε_c : Drying shrinkage strain of concrete (= 180×10^{-6})

β : Coefficient of opening (= (L1 - L2) / L1)

L1 : Internal width (m)

L2 : Opening width (m)

Type	L1	L2	β
Middle Slab	24.0	11.55	0.519
Base Slab	24.0	0.00	1.00

Middle slab

$$Kc = \frac{2 \times 2.5 \times 10^7 \times 0.3}{29.6 \times (1+1.2)} \times \frac{1}{1.0 \times (1-180 \times 10^{-6})} \times 0.519$$

= 119,527 kN/m

Base slab

$$Kc = \frac{2 \times 2.5 \times 10^7 \times 1.2}{29.6 \times (1+1.2)} \times \frac{1}{1.0 \times (1-180 \times 10^{-6})} \times 1.00$$

= 921,210 kN/m

5-1-3 Coefficient of horizontal subgrade reaction

Coefficient of horizontal subgrade reaction is calculated with the following formula.

$$Kh = \frac{1}{0.3} \cdot \alpha \cdot E_0 \cdot \left(\frac{B}{0.3}\right)^{-\frac{3}{4}}$$

where,

E_0 : Modulus of deformation of ground (kN/m^2)

B : Loading width (= 10.0 m)

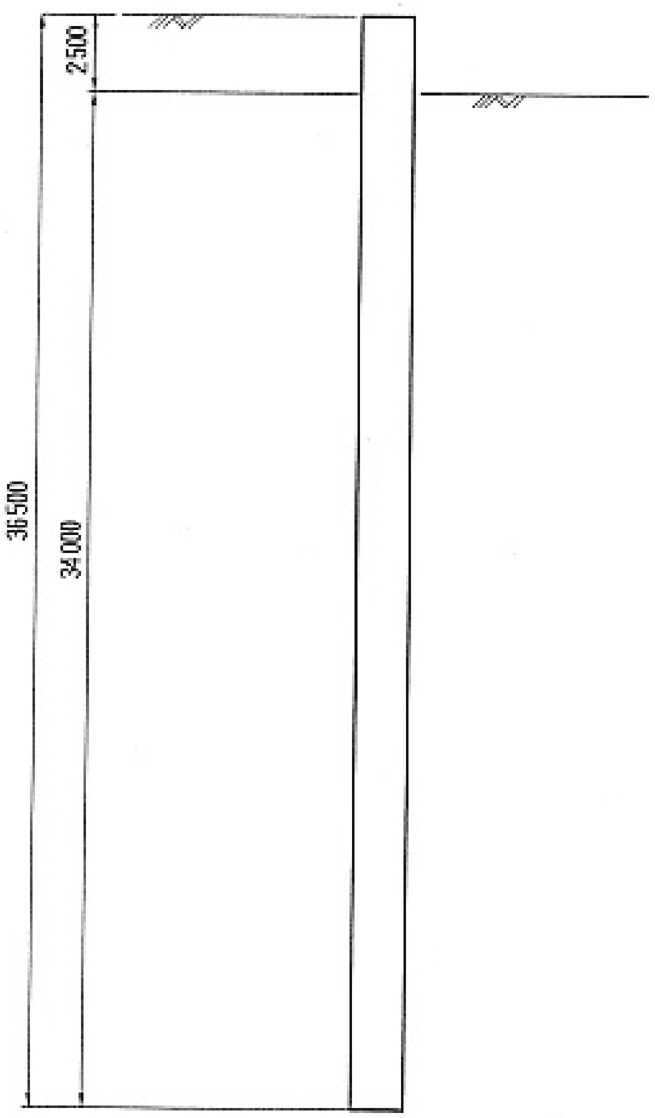
α : Coefficient (= 4)

Layer	E_0 (kN/m^2)	α	B (m)	Kh (kN/m^3)
Made ground	840	4	10.0	807
OH layer	700	4	10.0	673
SC layer	3,500	4	10.0	3,363
SM(u) layer	7,000	4	10.0	6,728
SM(l) layer	14,000	4	10.0	13,456
CH layer	33,600	4	10.0	32,294

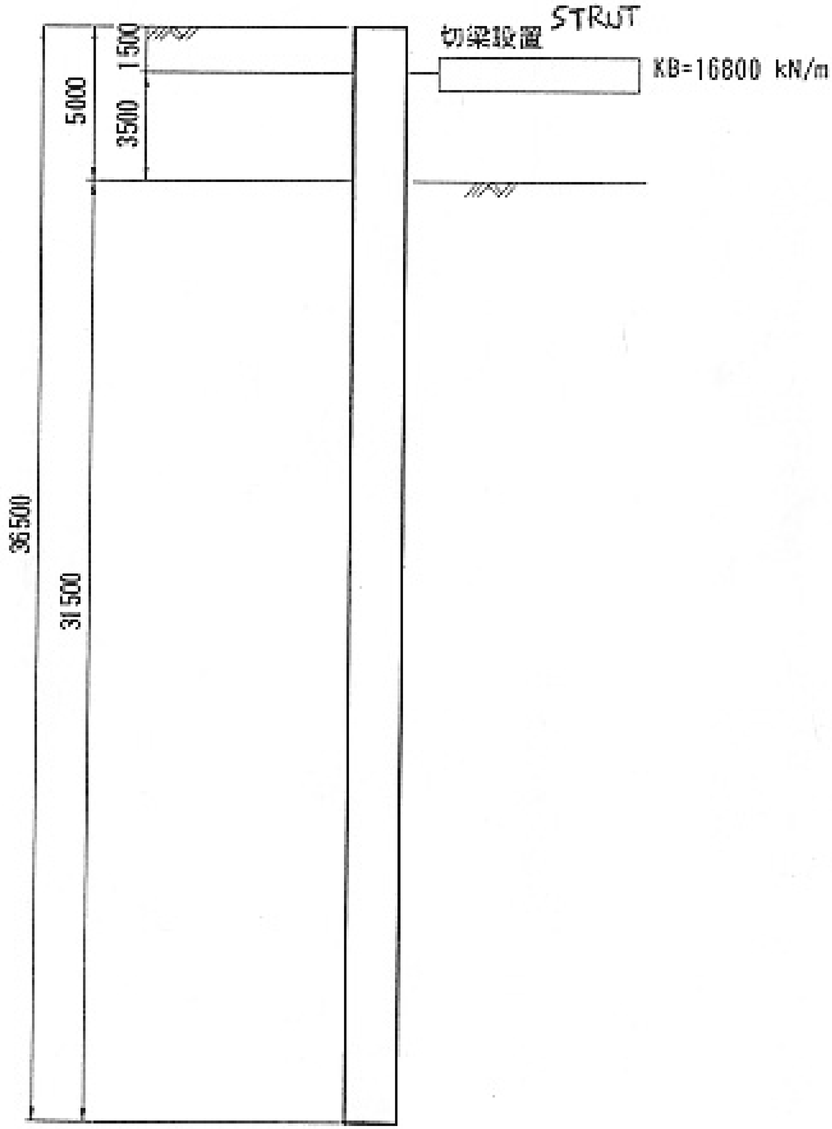
5-2 CALCULATION STEP

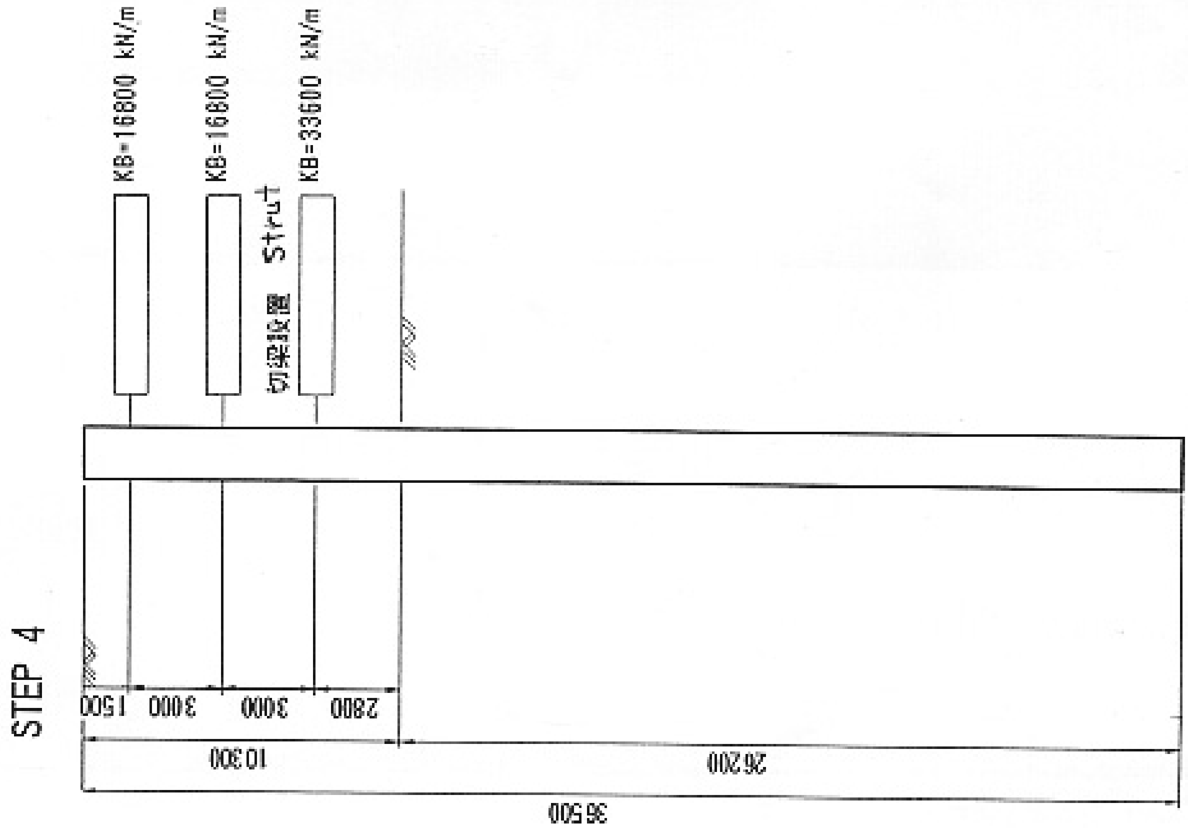
（e）施工ステップ図

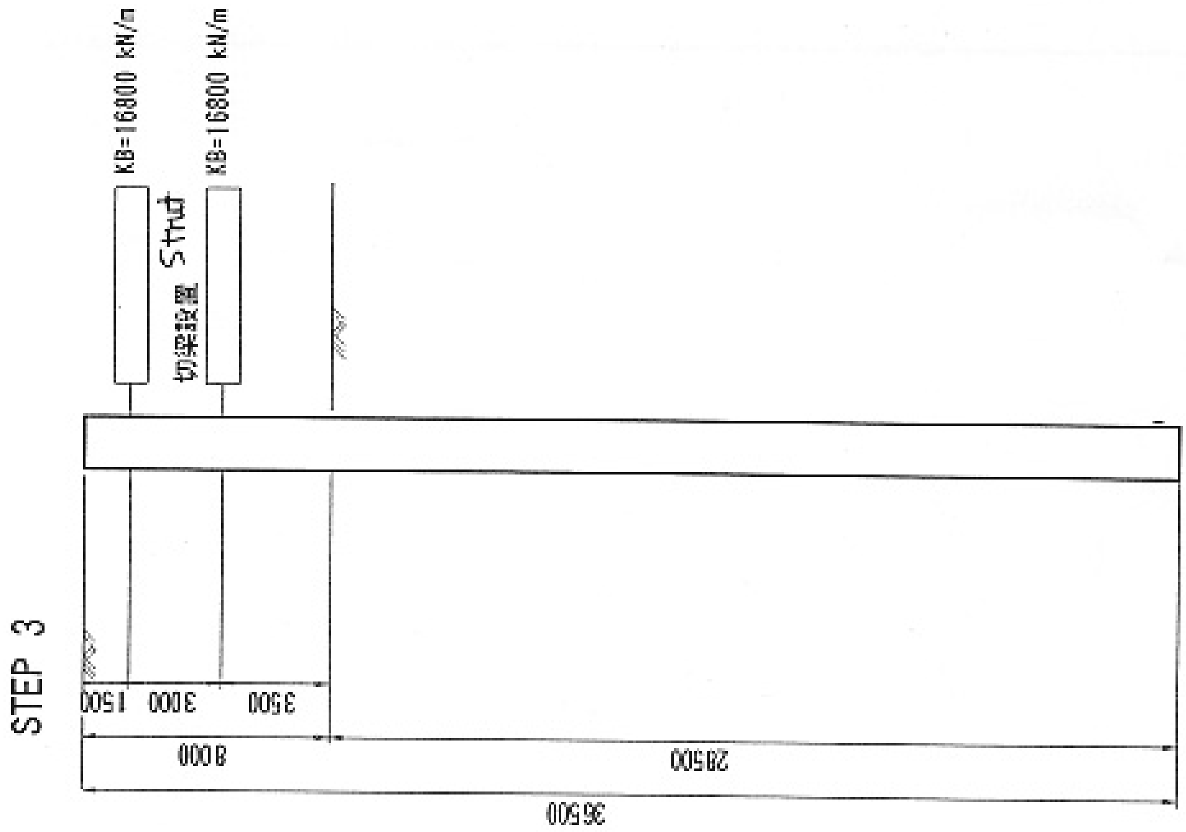
STEP1

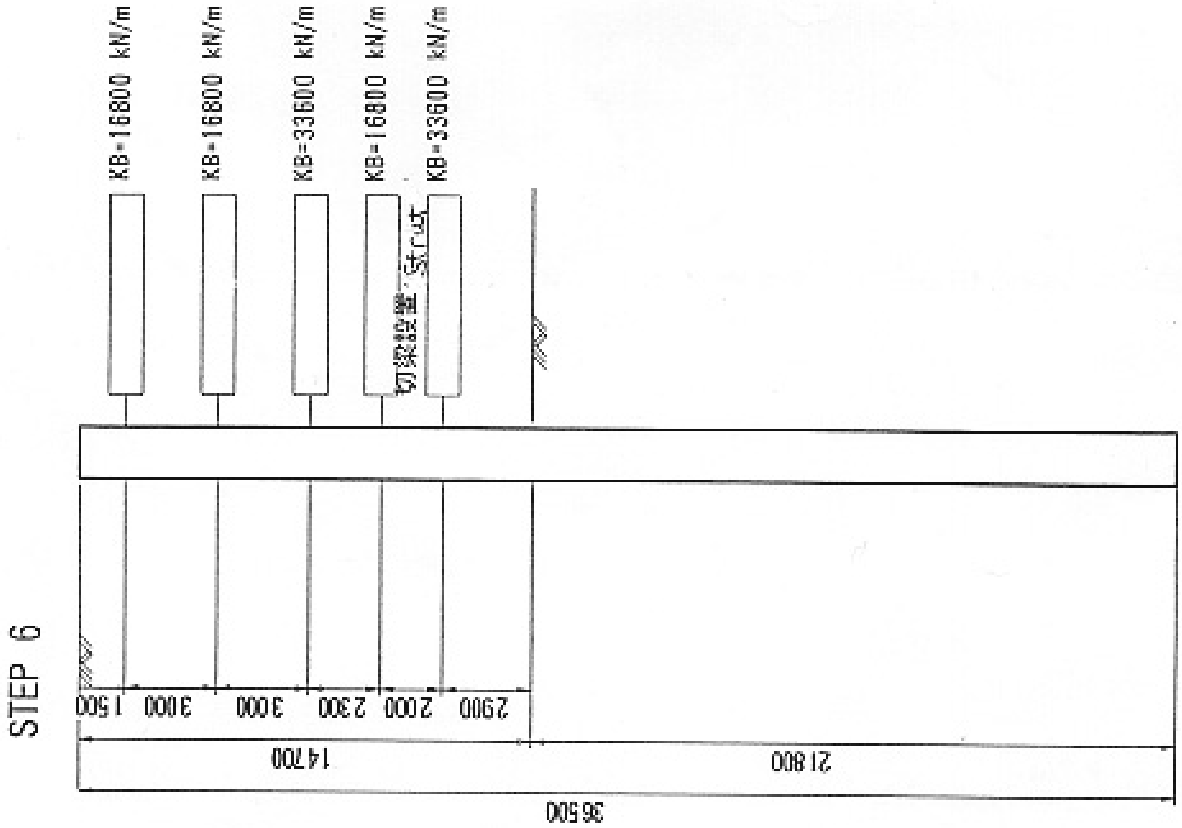


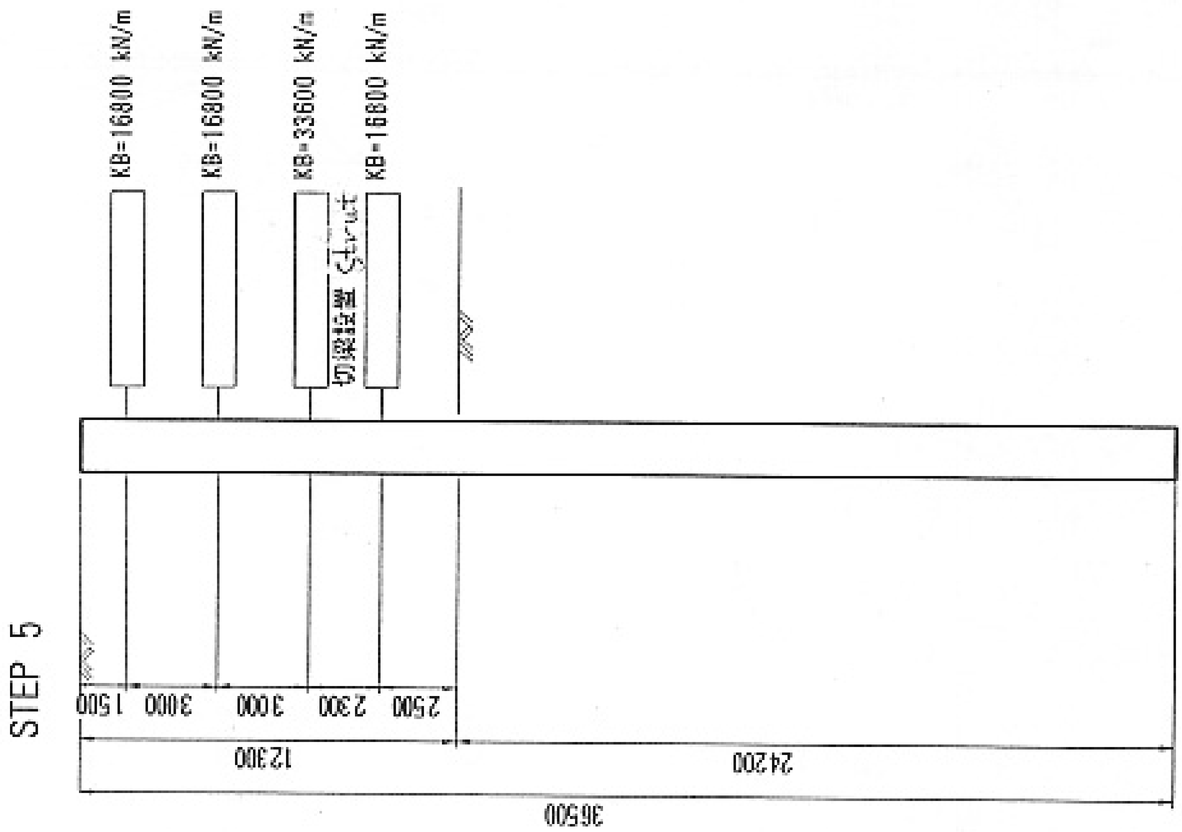
STEP2

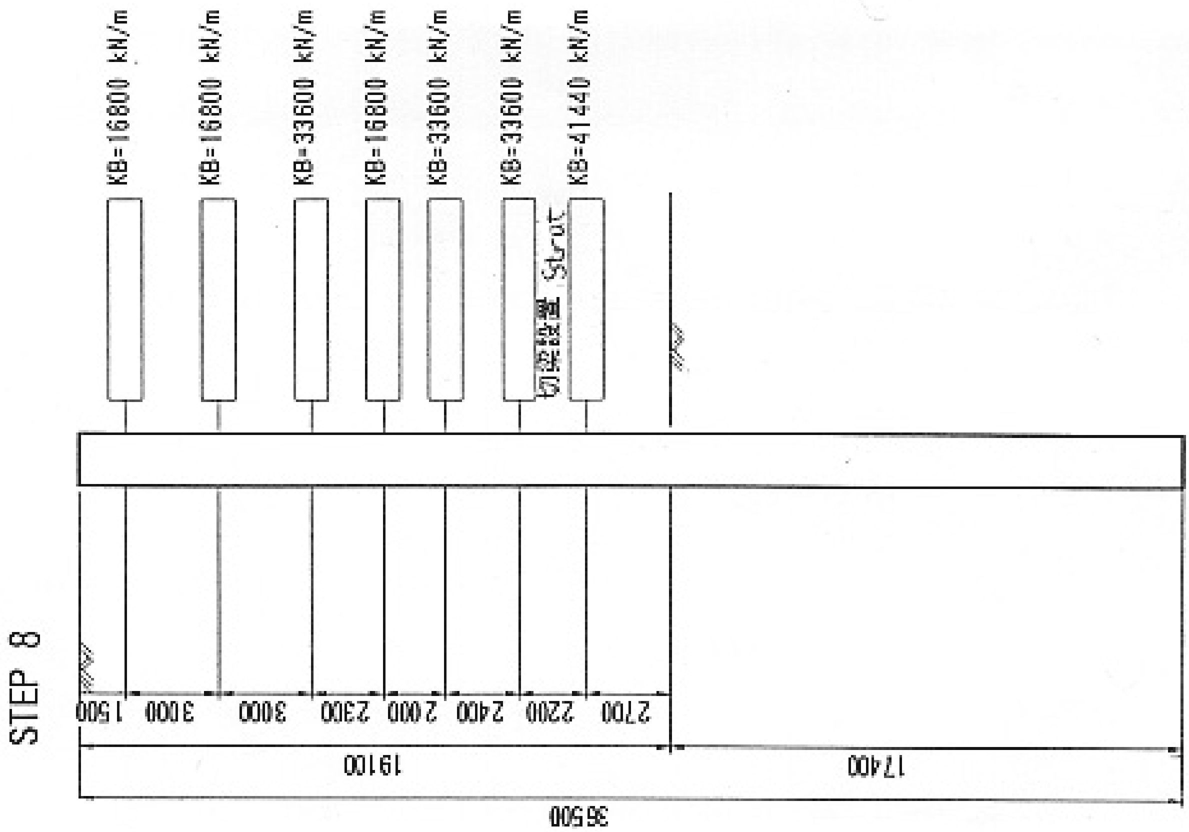


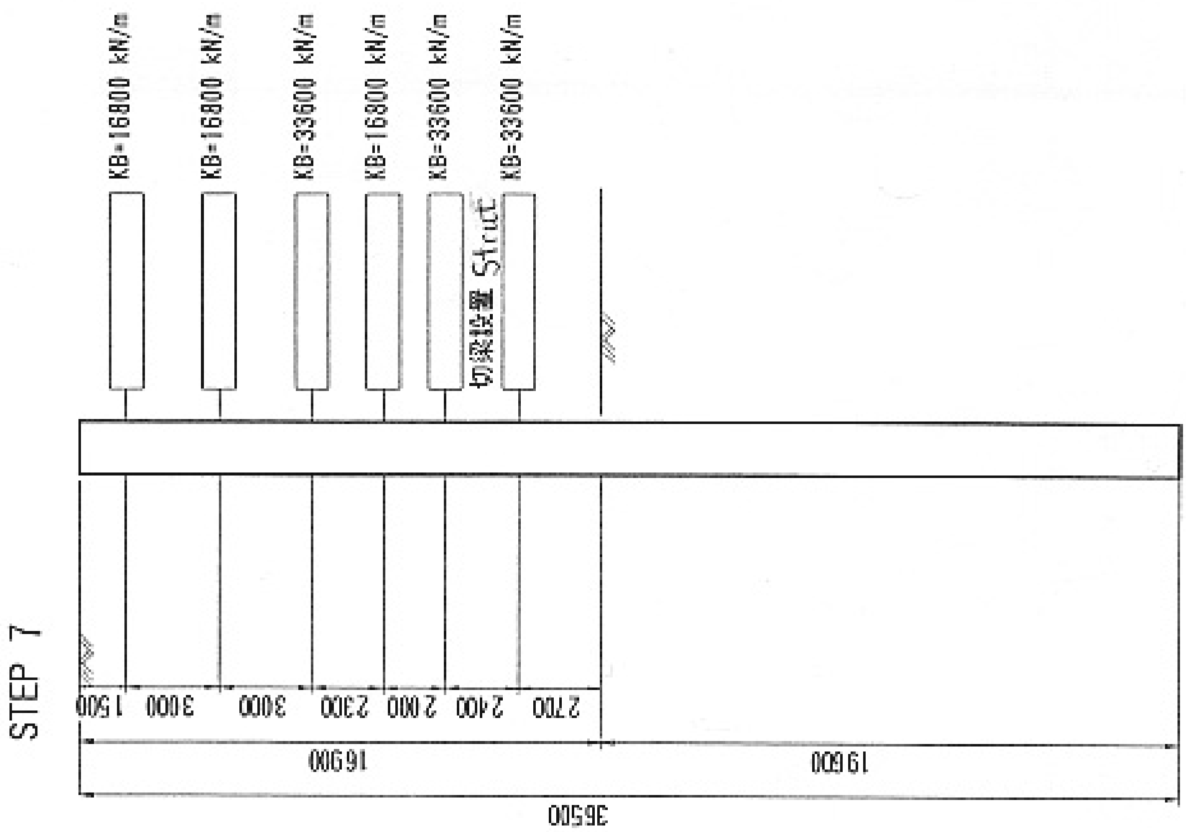

STEP 4
KB=16800 kN/m
KB=16800 kN/m
KB=33600 kN/m
切梁設置 Strut
1500
3000
3000
2800
10300
26200
36500


STEP 3
KB=16800 kN/m
KB=16800 kN/m
切梁設置 Strut
1500
3000
3500
8000
28500
36500


STEP 6
KB=16800 kN/m
KB=16800 kN/m
KB=33600 kN/m
KB=16800 kN/m
KB=33600 kN/m
切梁設置
1500
3000
3000
2300
2000
2900
14700
21800
36500


STEP 5
KB=16800 kN/m
KB=16800 kN/m
KB=33600 kN/m
KB=16800 kN/m
切梁設置
1500
3000
3000
2300
2500
12300
24200
36500


STEP 8
KB=16800 kN/m
KB=16800 kN/m
KB=33600 kN/m
KB=16800 kN/m
KB=33600 kN/m
KB=33600 kN/m
KB=41440 kN/m
切梁設置 Strut
1500
3000
3000
2300
2000
2400
2200
2700
19100
17400
36500


STEP 7
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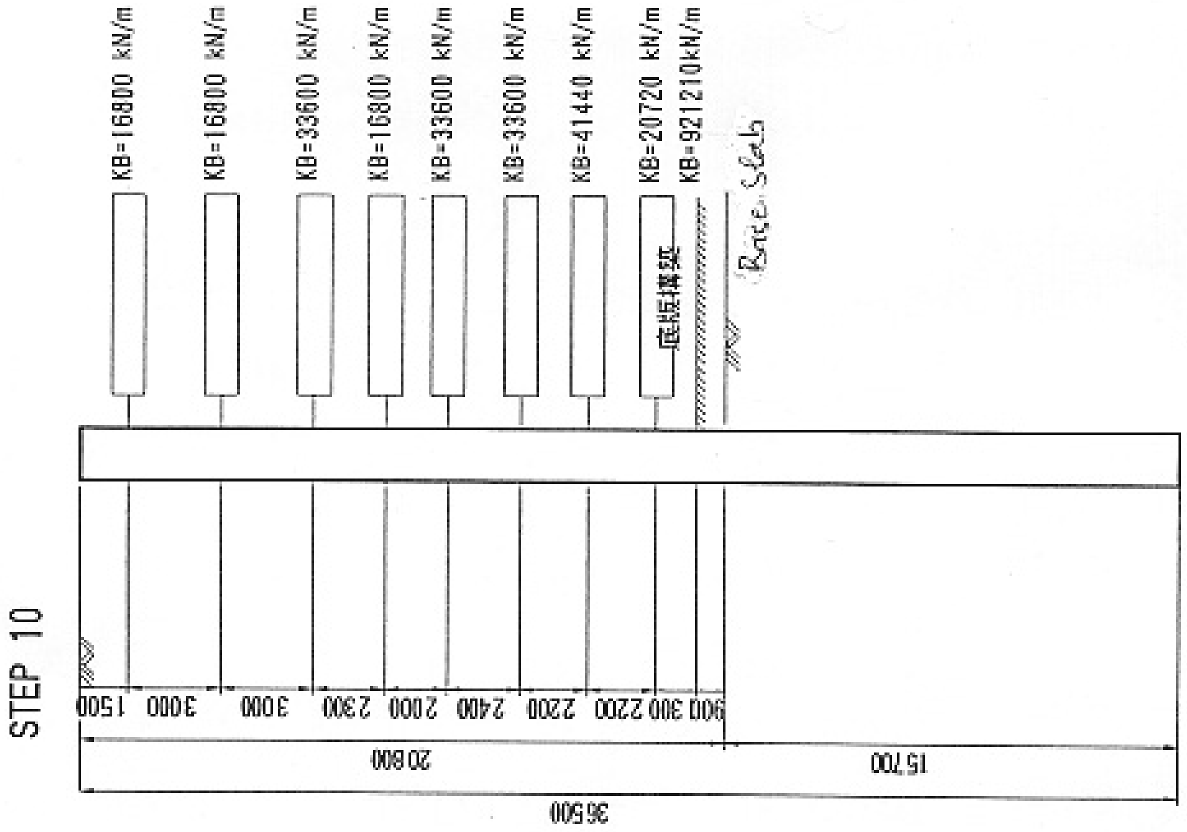
KB=16800 kN/m
KB=33600 kN/m
KB=16800 kN/m
KB=33600 kN/m
KB=33600 kN/m
切梁設置 Strut
1500
3000
3000
2300
2000
2400
2700
16900
19600
36500


STEP 10
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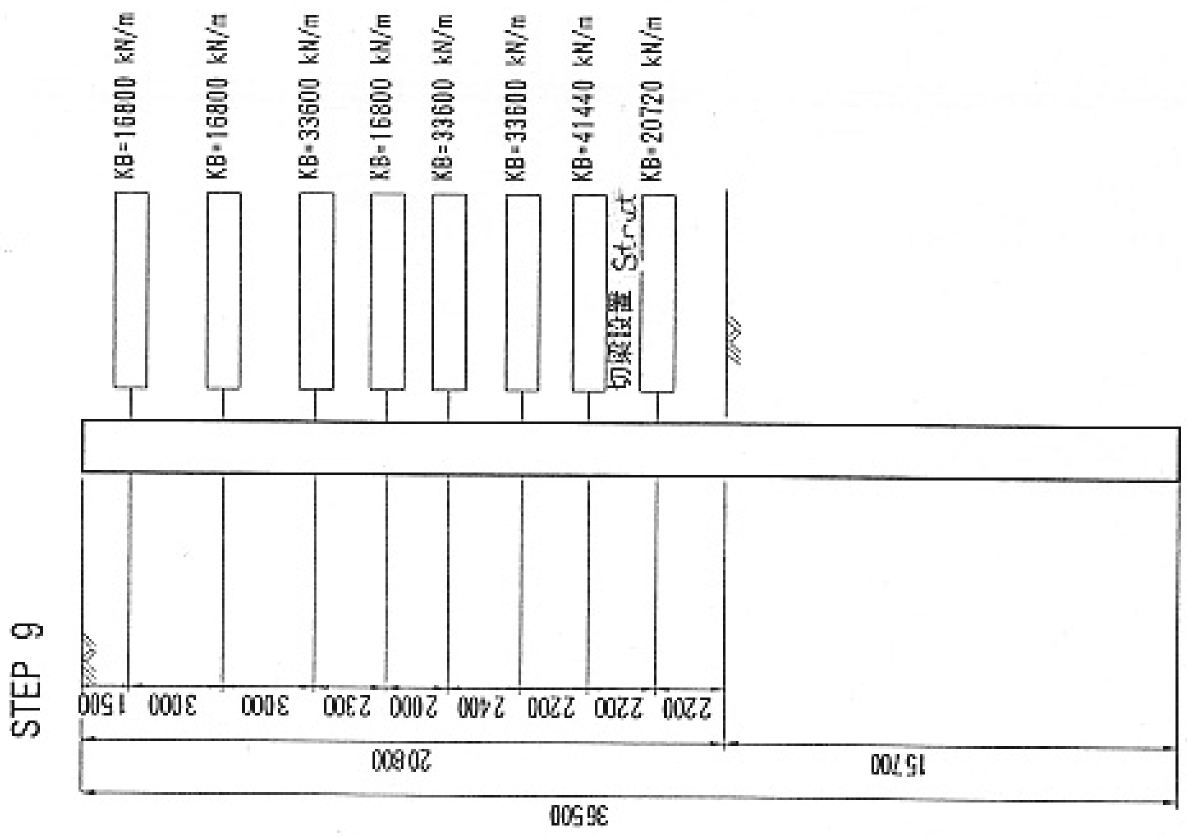
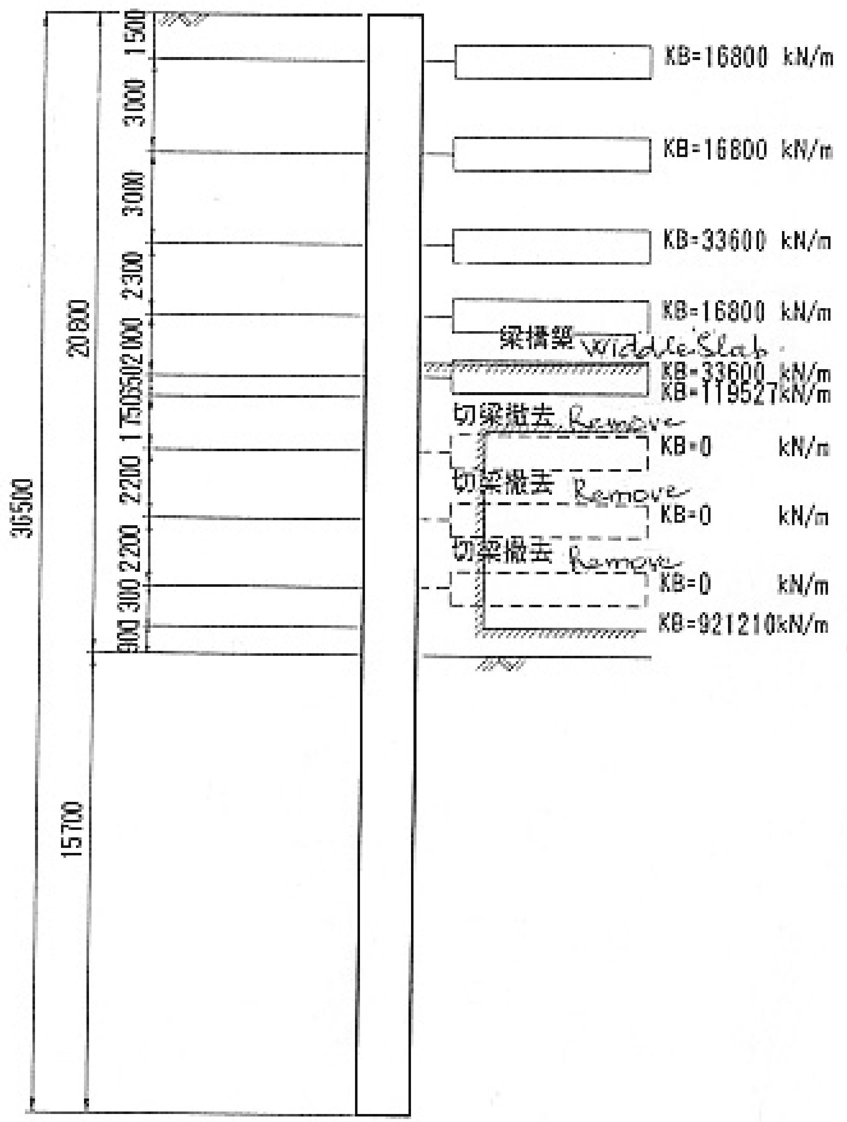
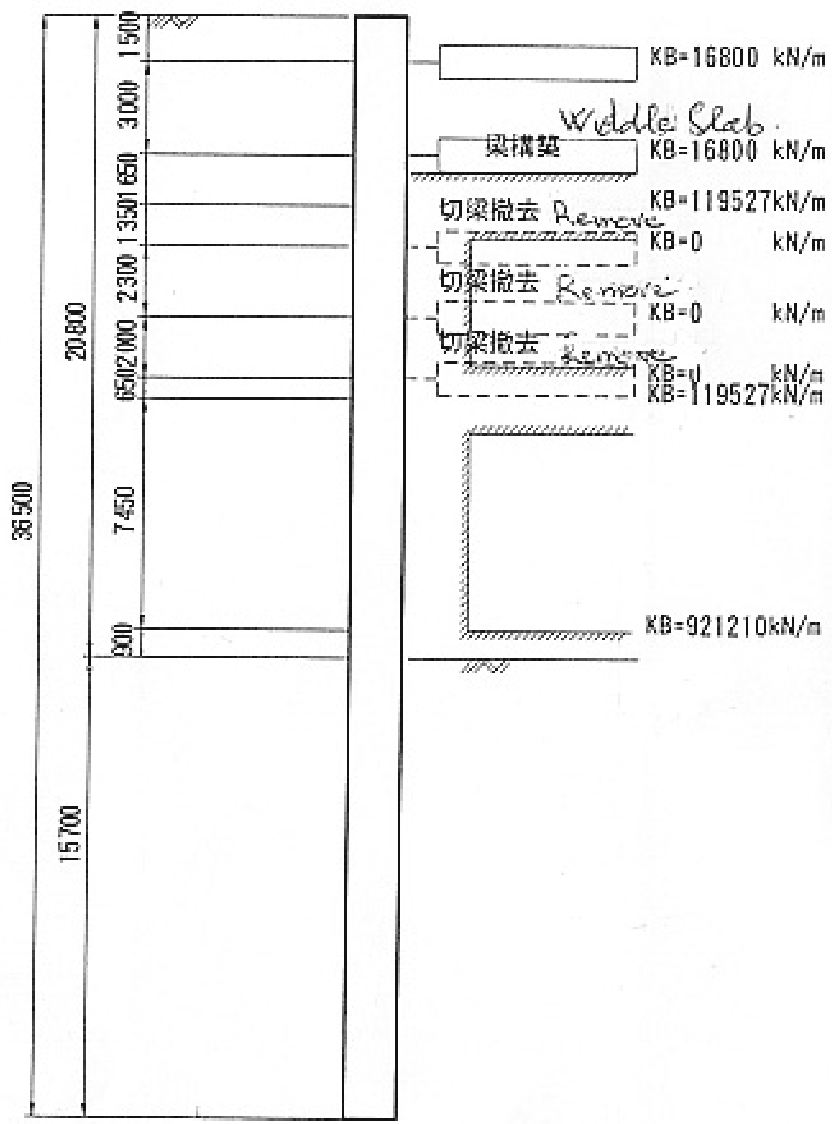
KB=16800 kN/m
KB=33600 kN/m
KB=16800 kN/m
KB=33600 kN/m
KB=33600 kN/m
KB=41440 kN/m
KB=20720 kN/m
KB=921210kN/m
底版構築
Base Slab
1500 3000 3000 2300 2000 2400 2200 2200 300 900
20800
15700
36500


STEP 9
KB=16800 kN/m
KB=16800 kN/m
KB=33600 kN/m
KB=16800 kN/m
KB=33600 kN/m
KB=33600 kN/m
KB=41440 kN/m
KB=20720 kN/m
切梁設置 Strut
1500 3000 3000 2300 2000 2400 2200 2200 2200
20800
15700
36500

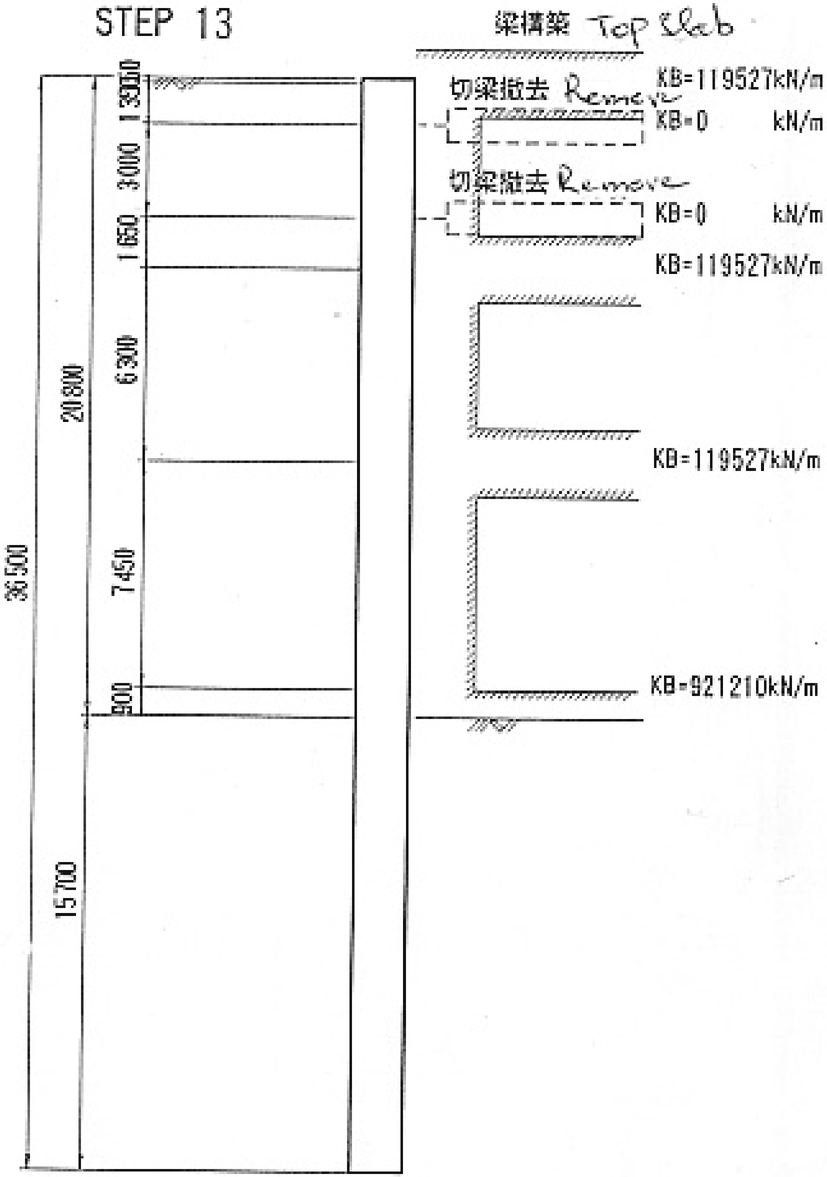
STEP 11



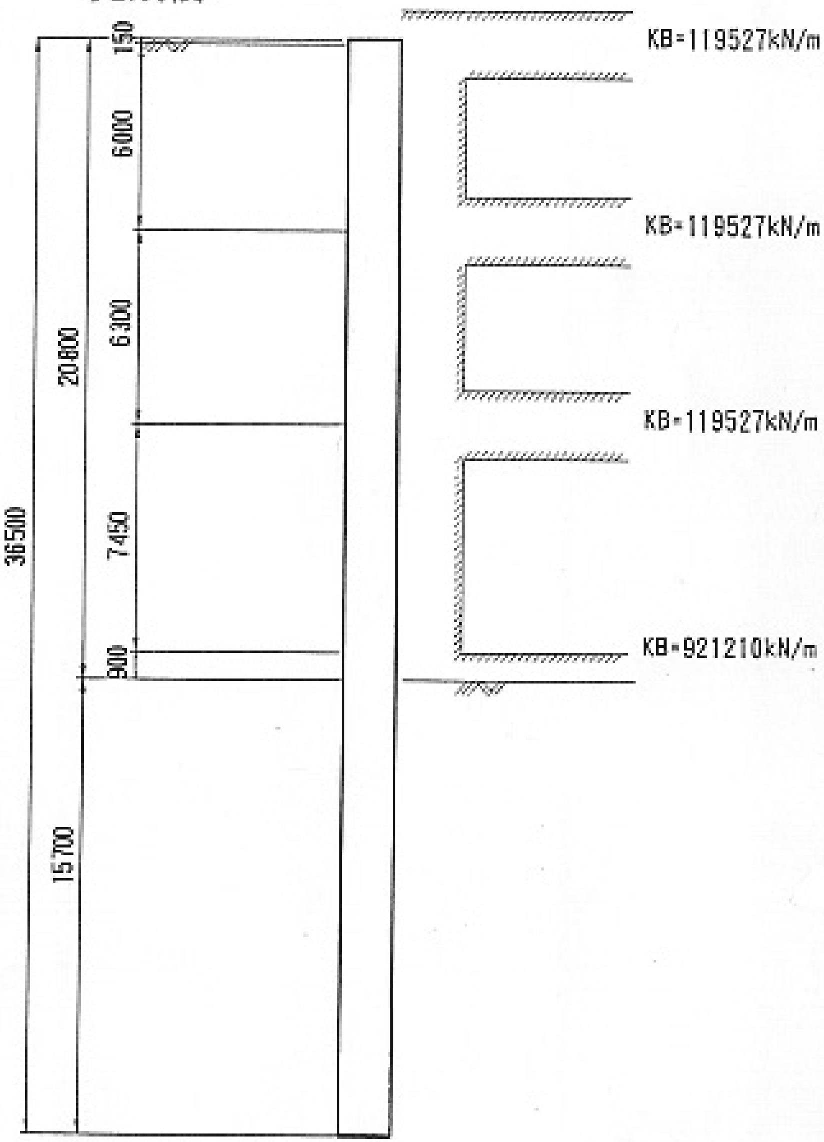
STEP 12



STEP 13



After compreting
完成後



5-3 CALCULATION RESULTS

5-3-1 Figures of maximum section force

a) Excavation level

b) Loading

c) Displacement

d) Bending moment

e) Shearing force

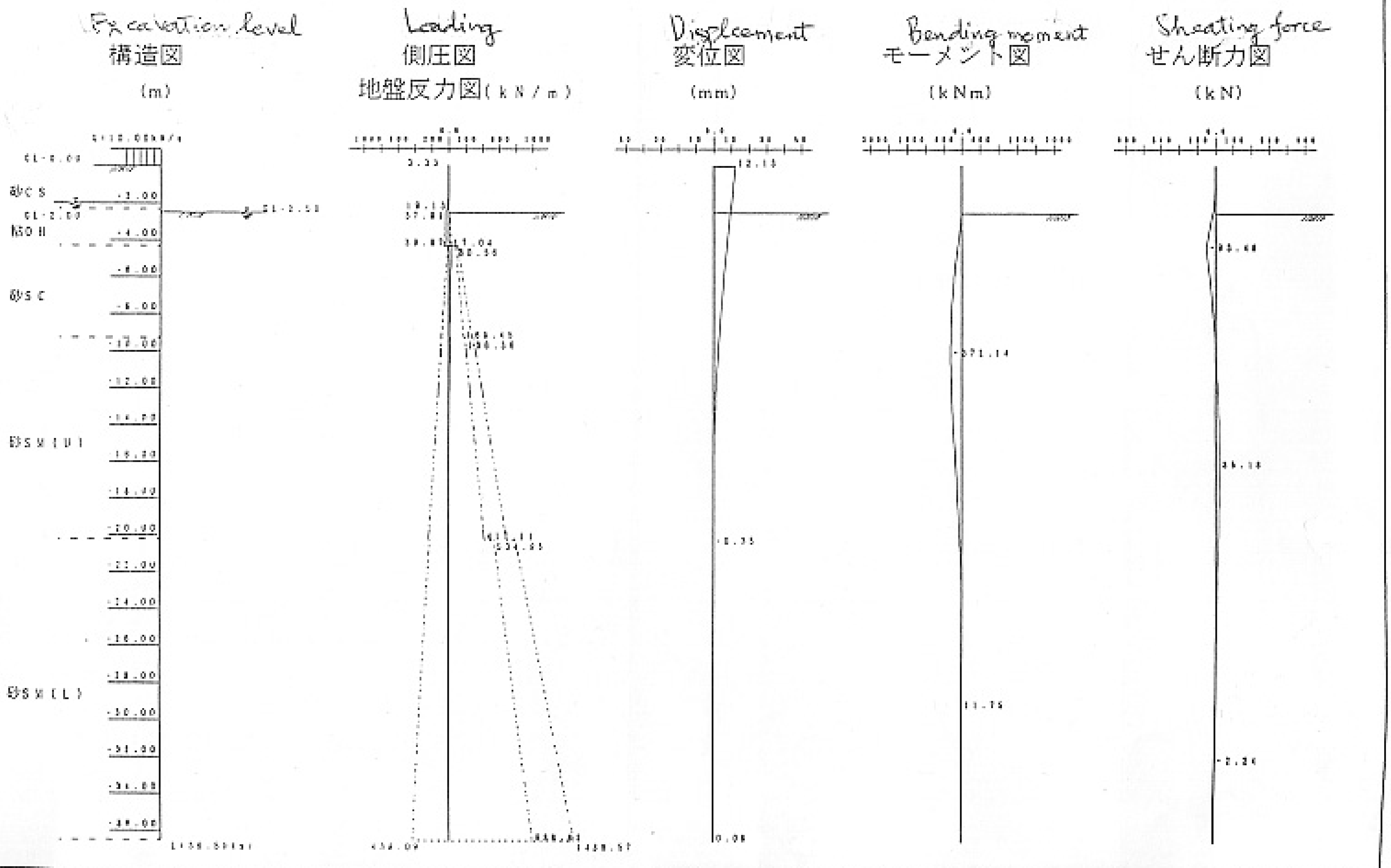
f) Step

Step 1	1st excavation
Step 2	2nd excavation
Step 3	3rd excavation
Step 4	4th excavation
Step 5	5th excavation
Step 6	6th excavation
Step 7	7th excavation
Step 8	8th excavation
Step 9	9th excavation (final excavation)
Step 10	Base slab construction
Step 11	2nd middle slab construction
Step 12	1st middle slab construction
Step 13	Top slab construction

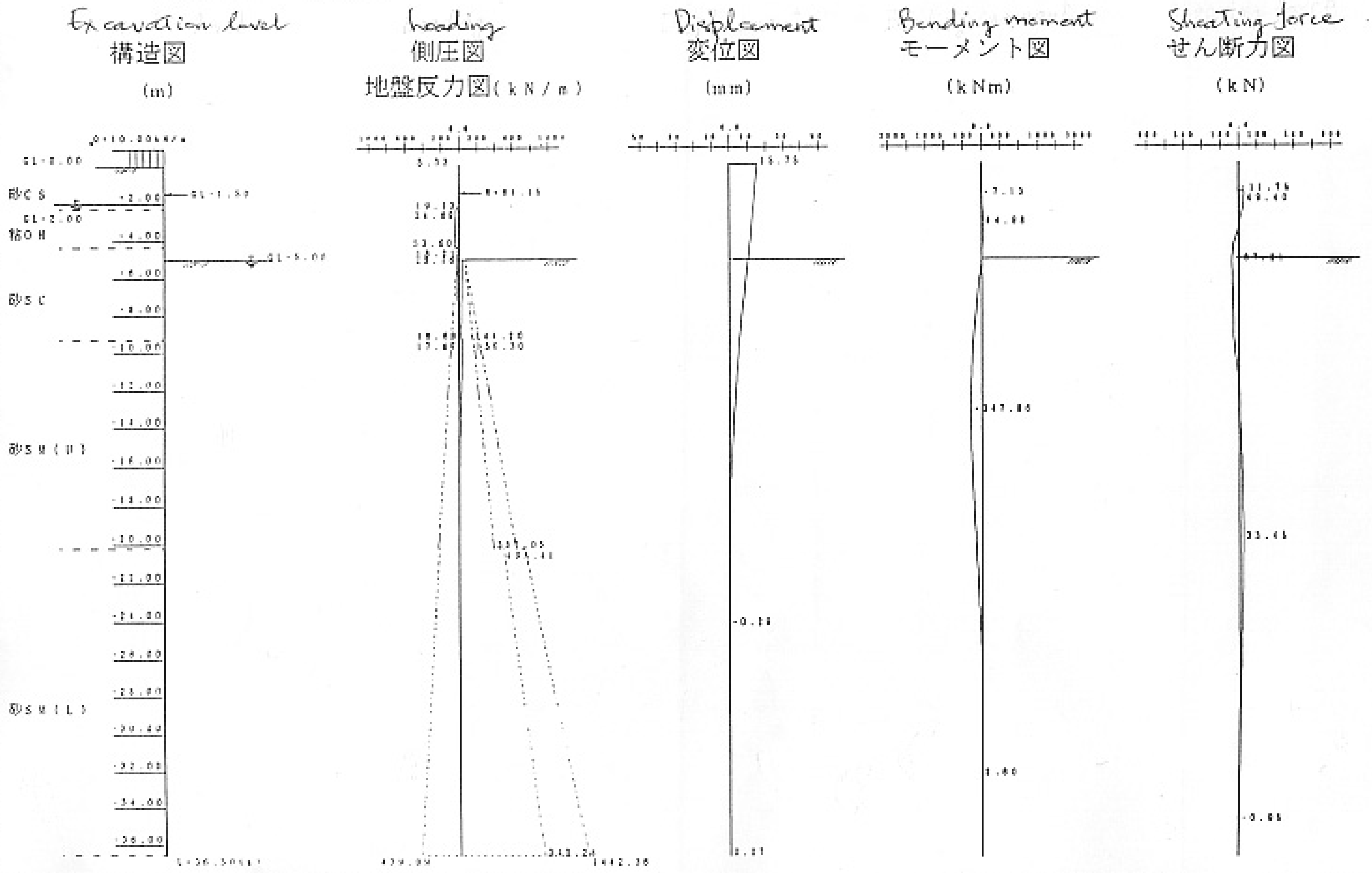
ベトナム下水道施設（1）

Sewer system in Viet Nam

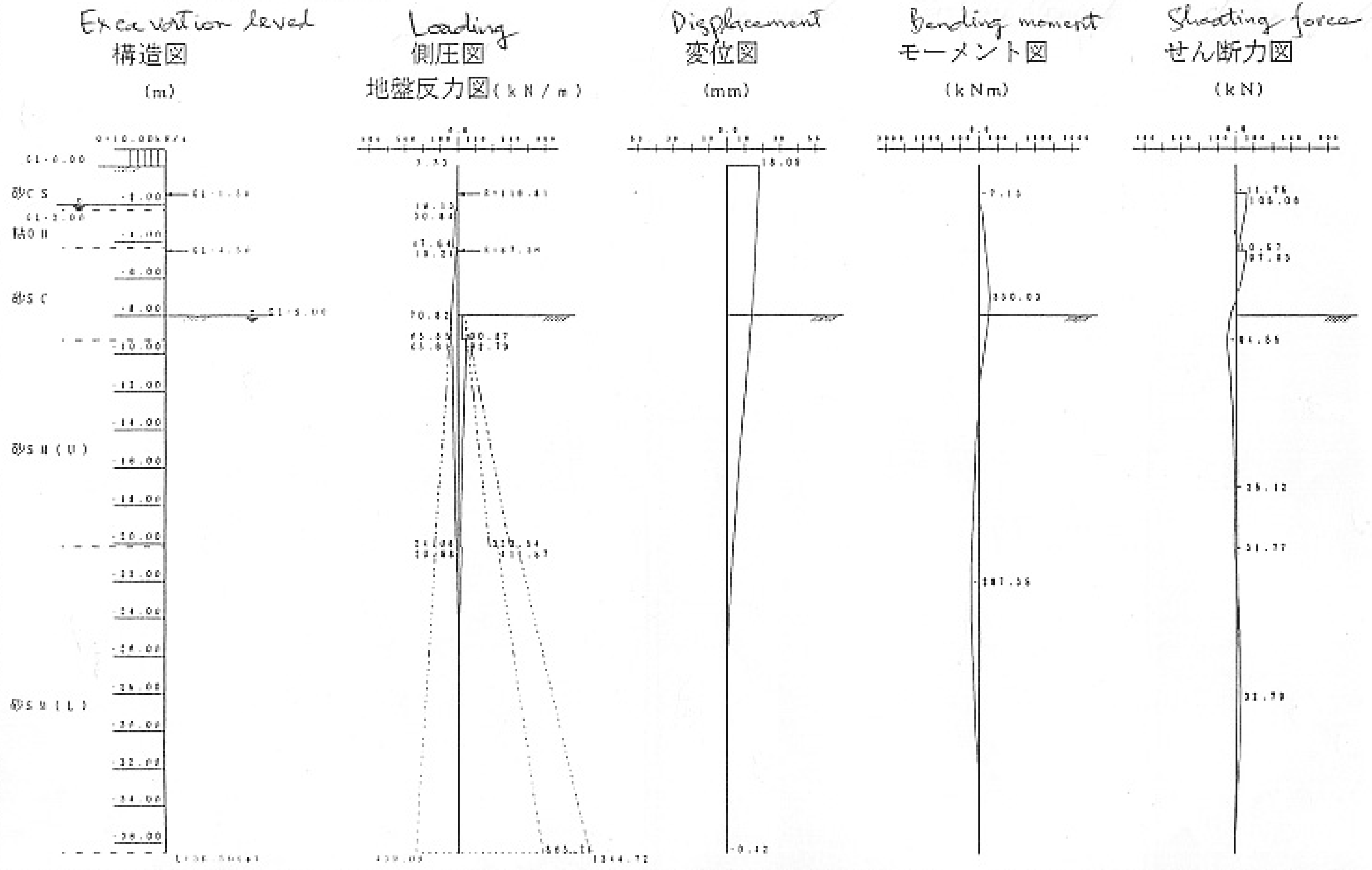
STEP 1　1次掘削



ベトナム下水道施設（1）
Sewer System in VietNam
ＳＴＥＰ２　２次掘削



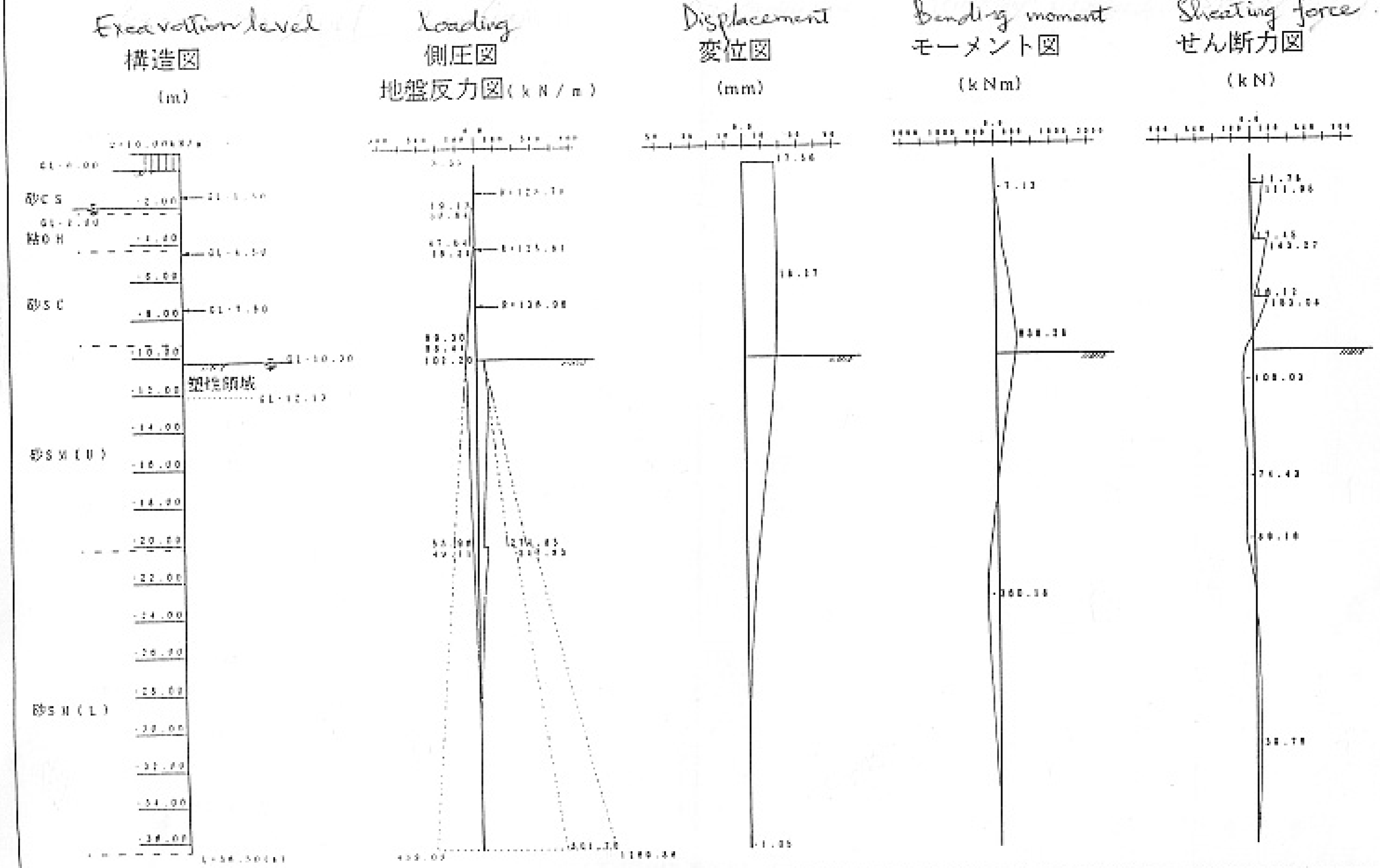
ベトナム下水道施設（1）
Sewer System in Viet Nam
STEP 3　3次掘削



ベトナム下水道施設（1）

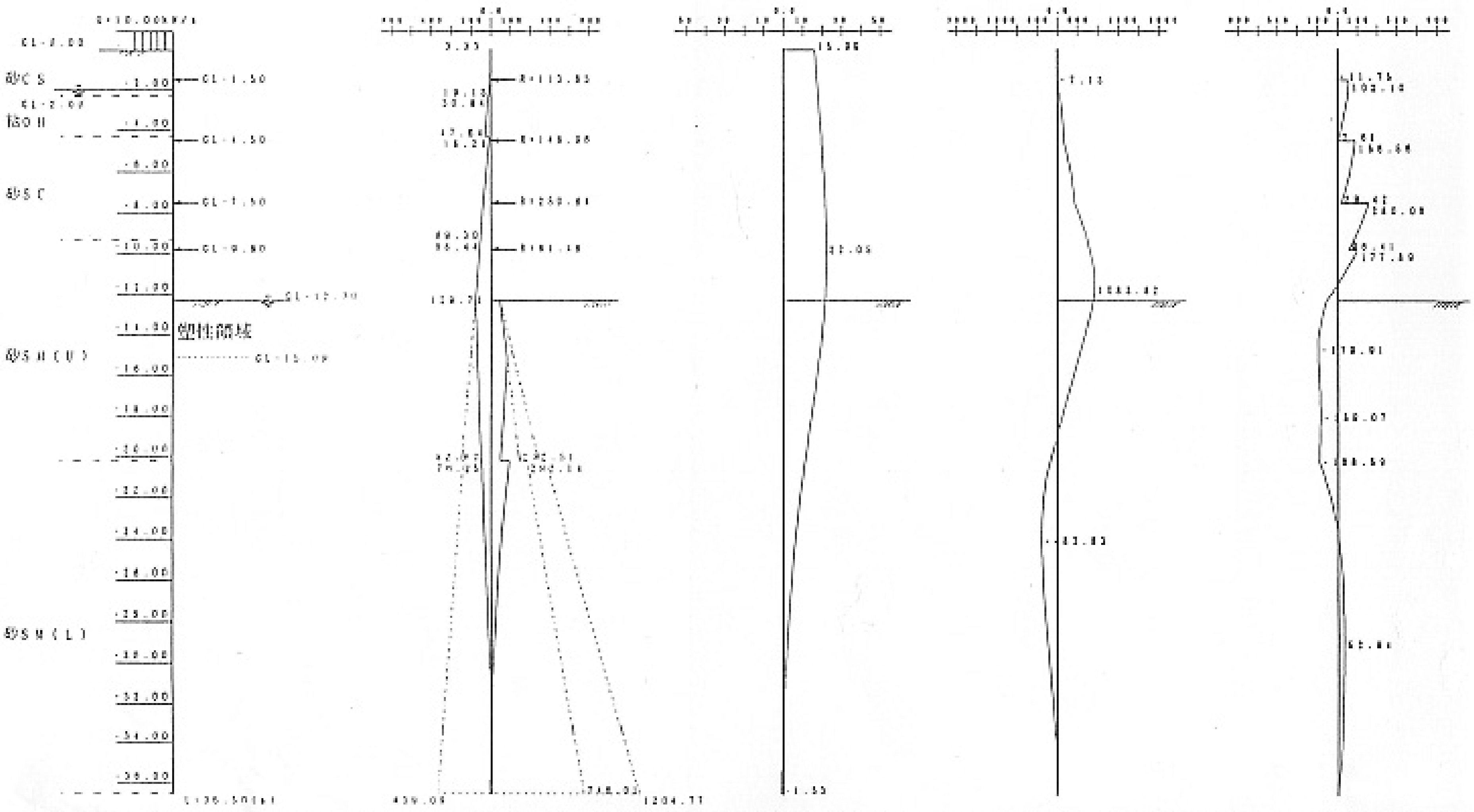
Sewer System in Viet Nam

STEP 4　4次掘削



ベトナム下水道施設（1）
Sewer System in Viet Nam
STEP5　5次掘削

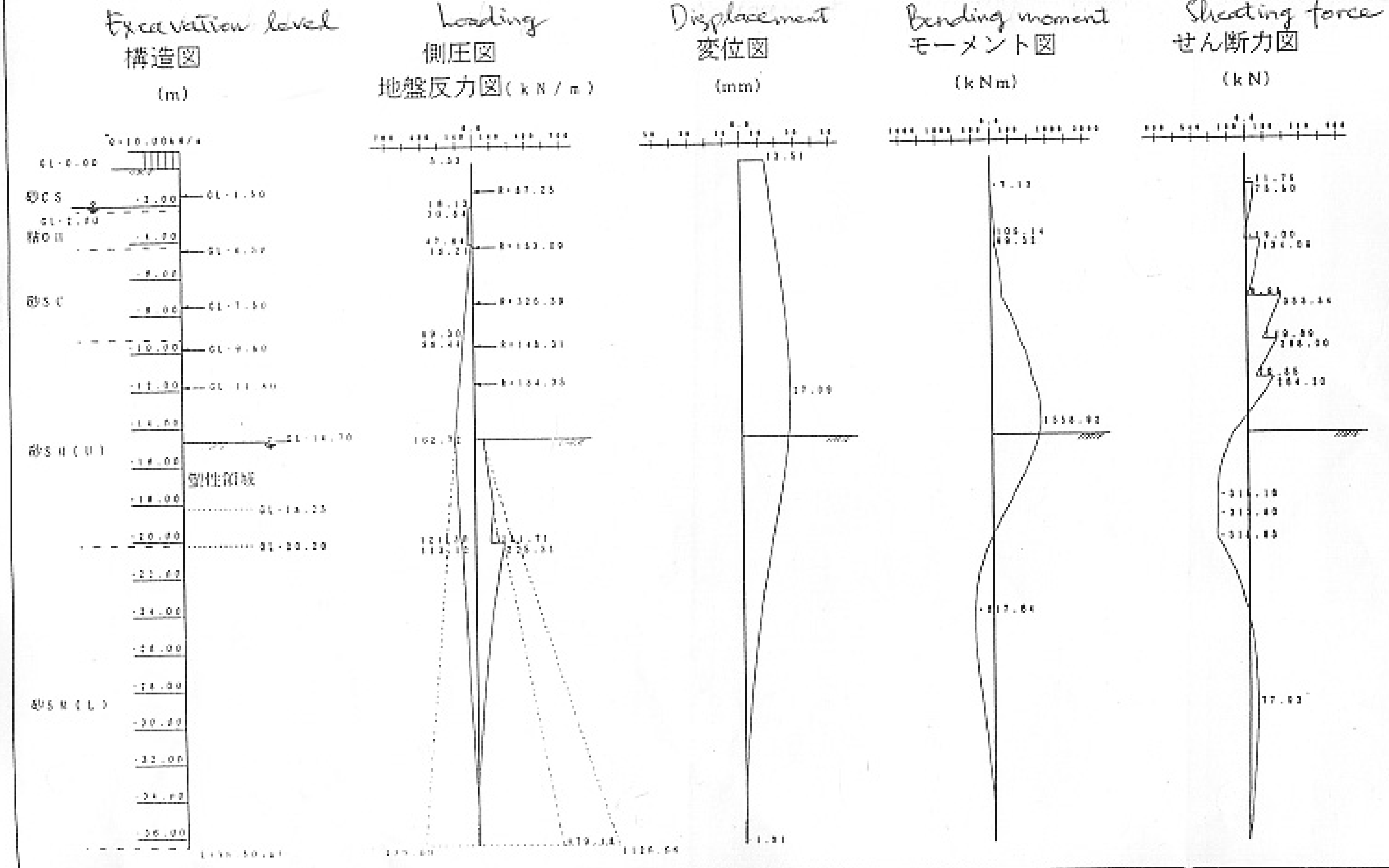
Excavation level 構造図 (m) | Loading 側圧図 地盤反力図(kN/m) | Displacement 変位図 (mm) | Bending moment モーメント図 (kNm) | Sheating force せん断力図 (kN)



ベトナム下水道施設（1）

Sewer System in Viet Nam

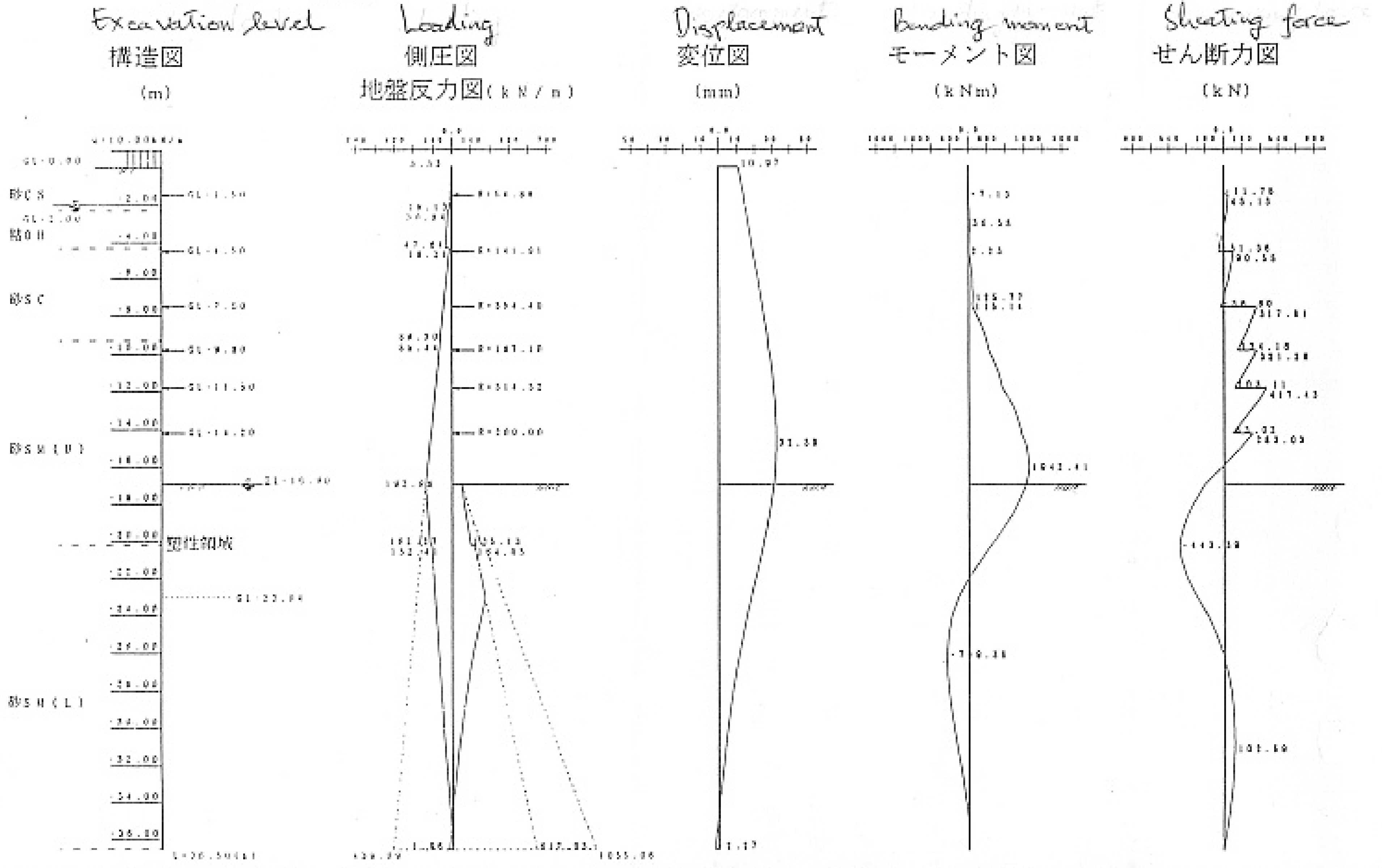
STEP6　6次掘削



ベトナム下水道施設（1）

Sewer System in Viet Nam

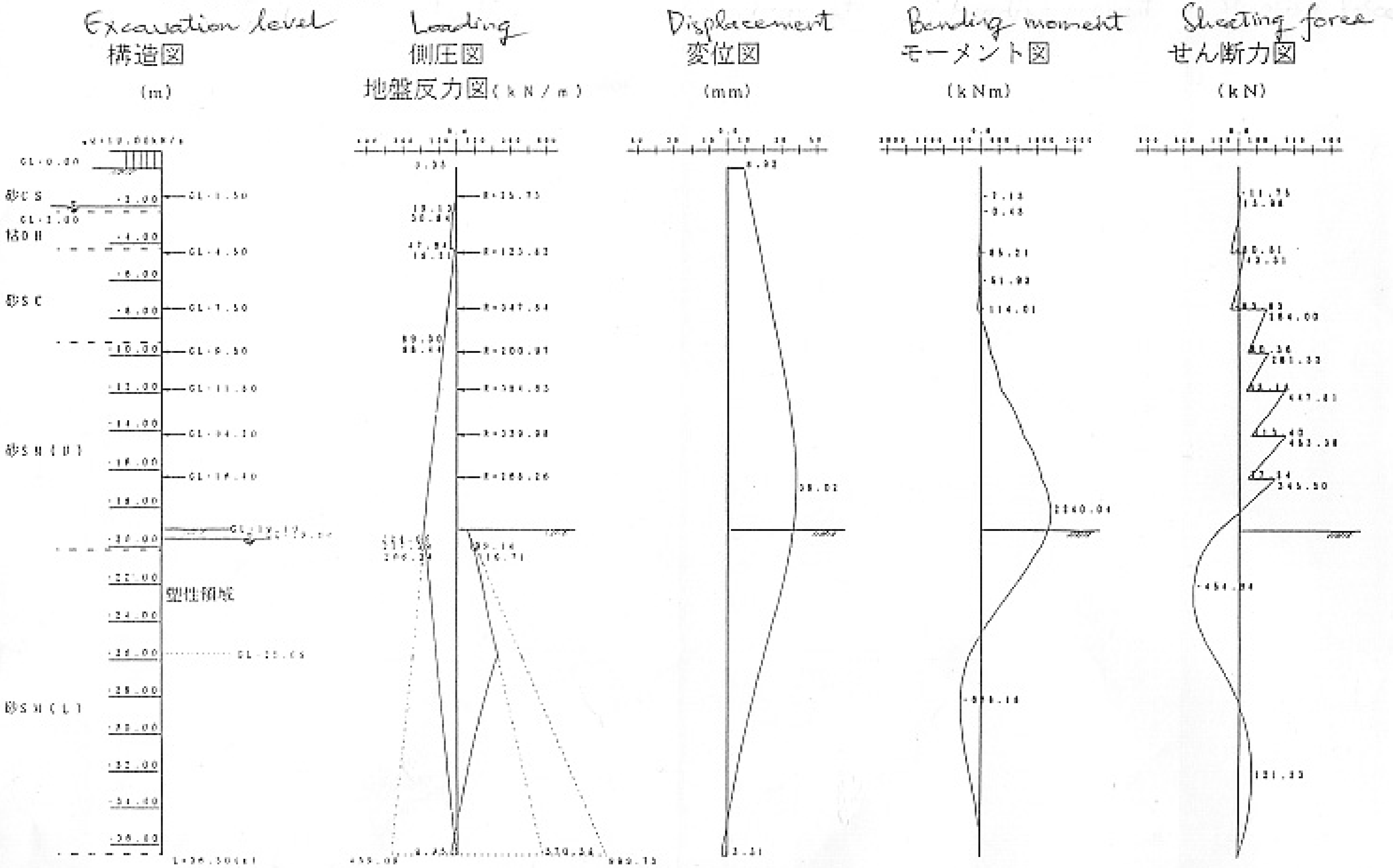
STEP7　7次掘削

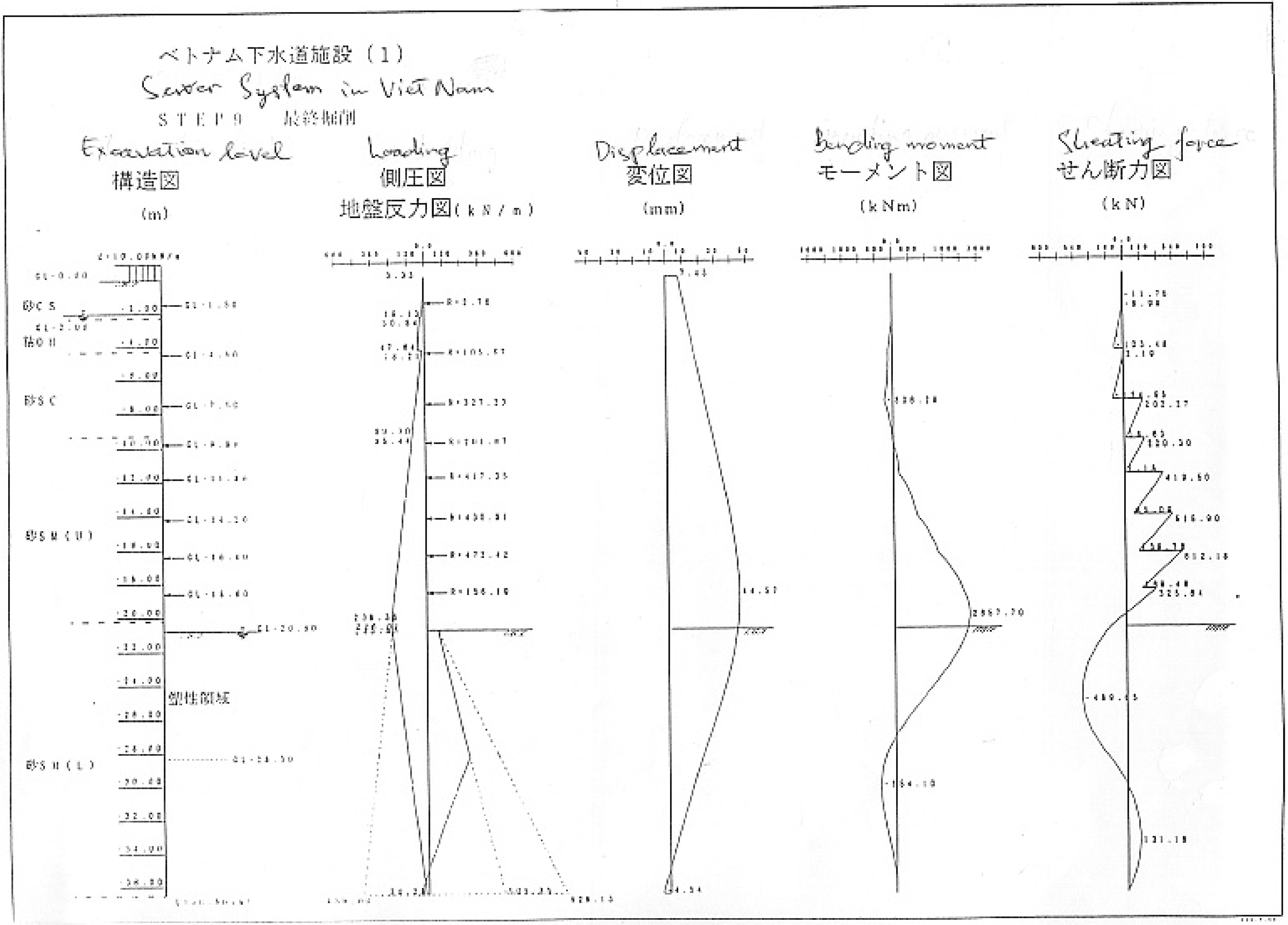


ベトナム下水道施設（1）

Sewer System in Viet Nam

STEP 8　8次掘削



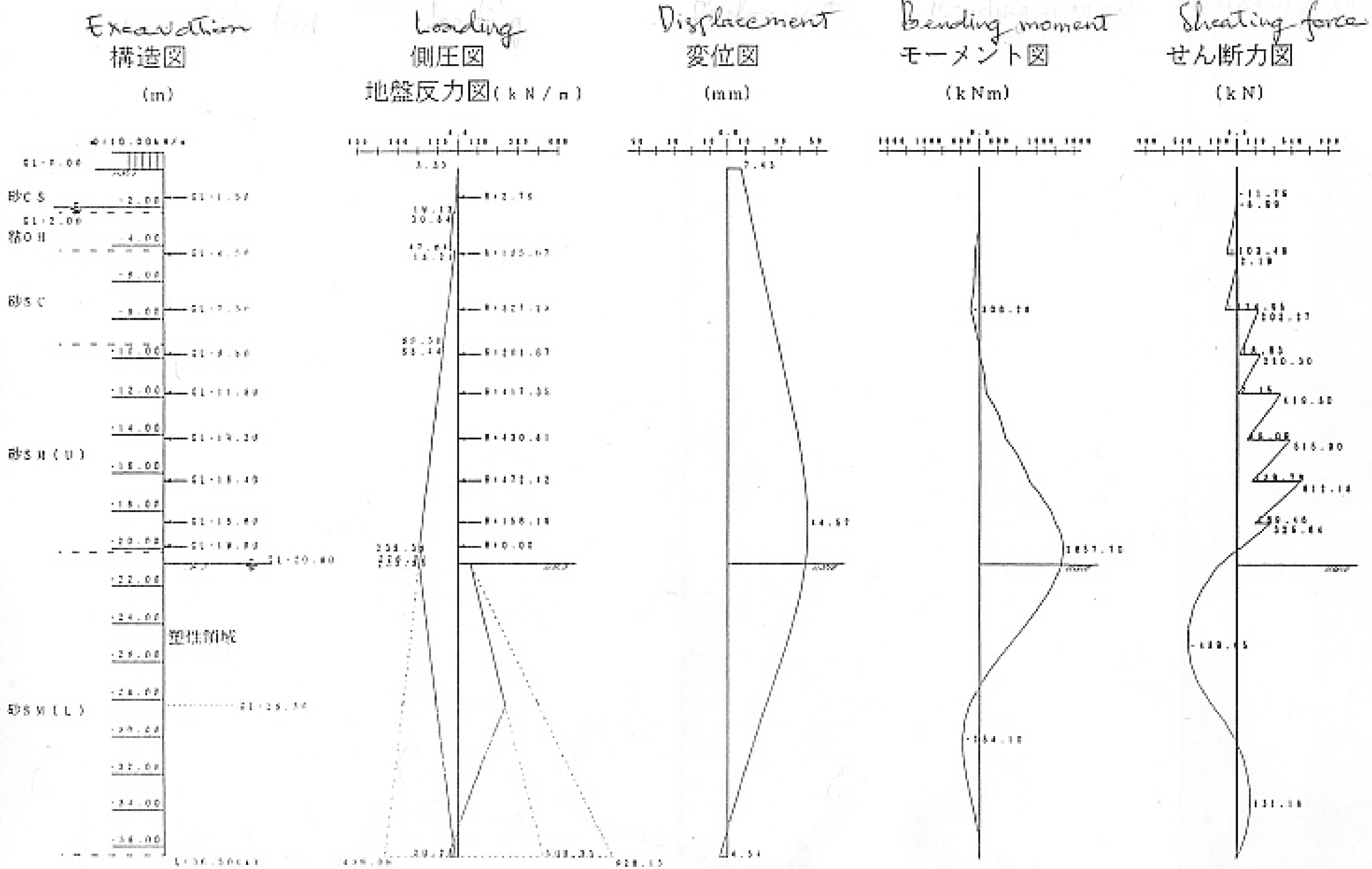


ベトナム下水道施設（1）
Sewer System in Viet Nam
STEP 9　最終掘削
Excavation level
構造図
(m)
Loading
側圧図
地盤反力図(kN/m)
Displacement
変位図
(mm)
Bending moment
モーメント図
(kNm)
Shearing force
せん断力図
(kN)
塑性領域

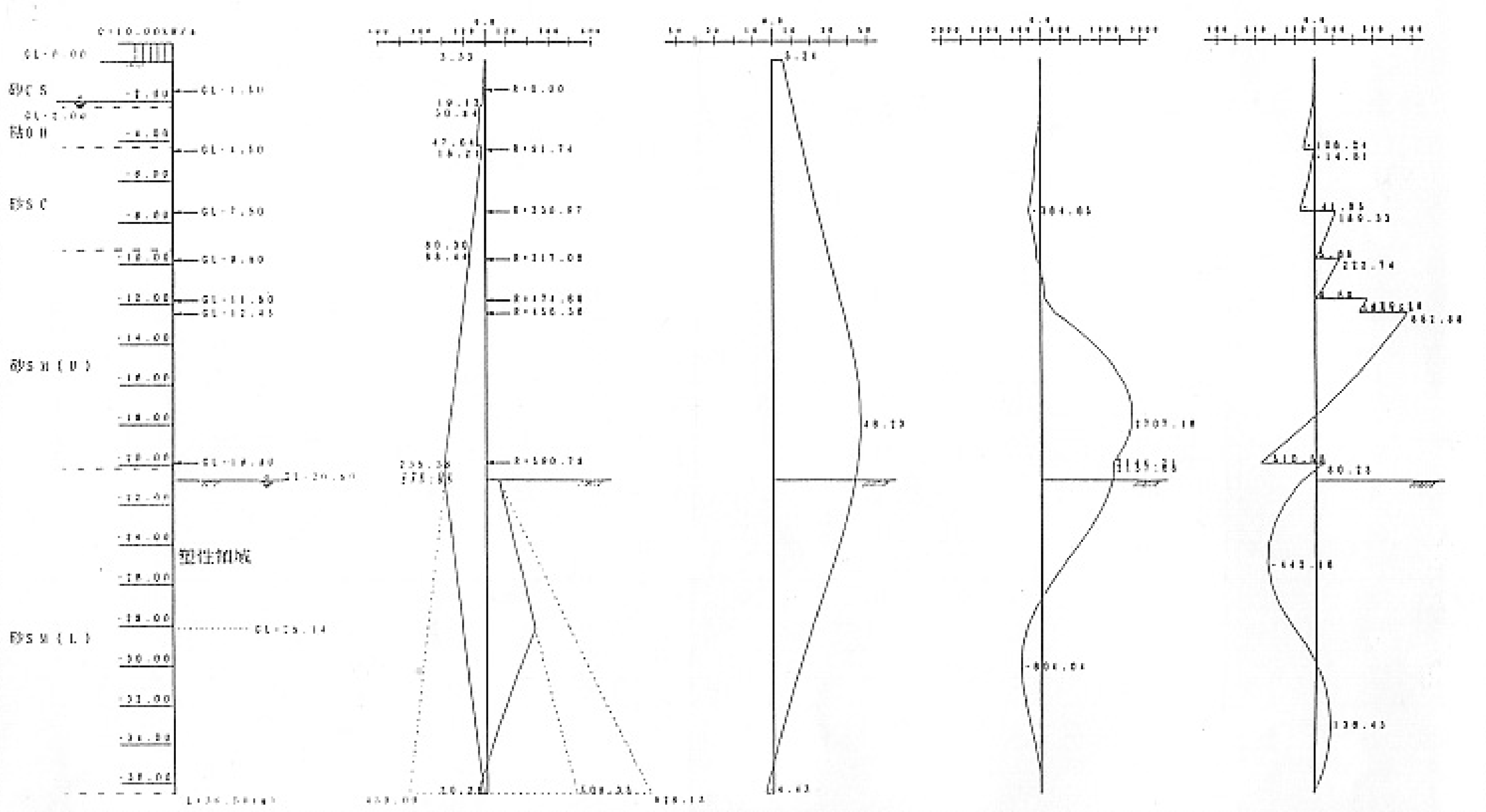
ベトナム下水道施設（１）

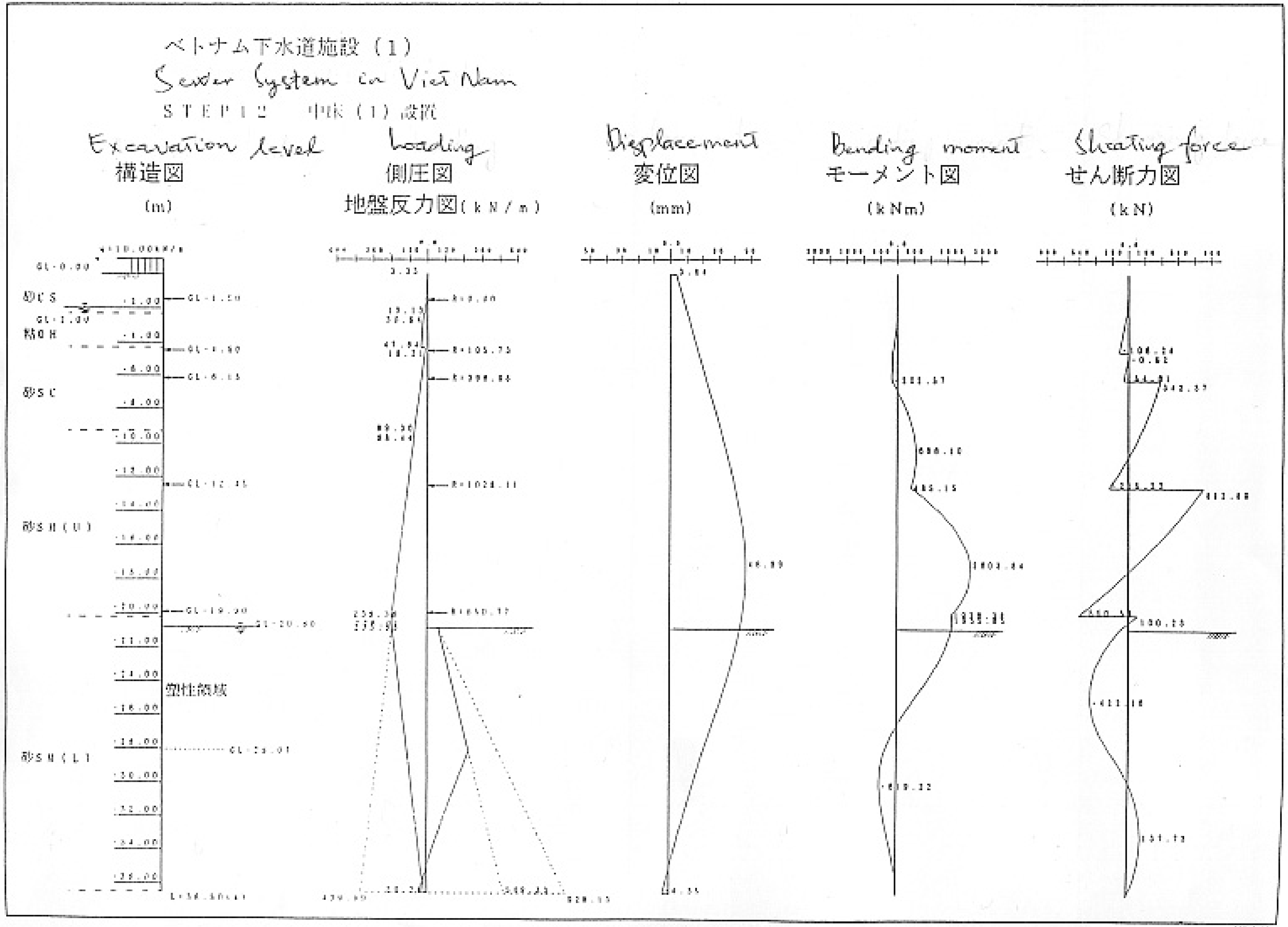
Sewer system in Viet Nam

ＳＴＥＰ１０　底版設置



ベトナム下水道施設（1）
Sewer System in Việt Nam
STEP 11 中圧（2）設置



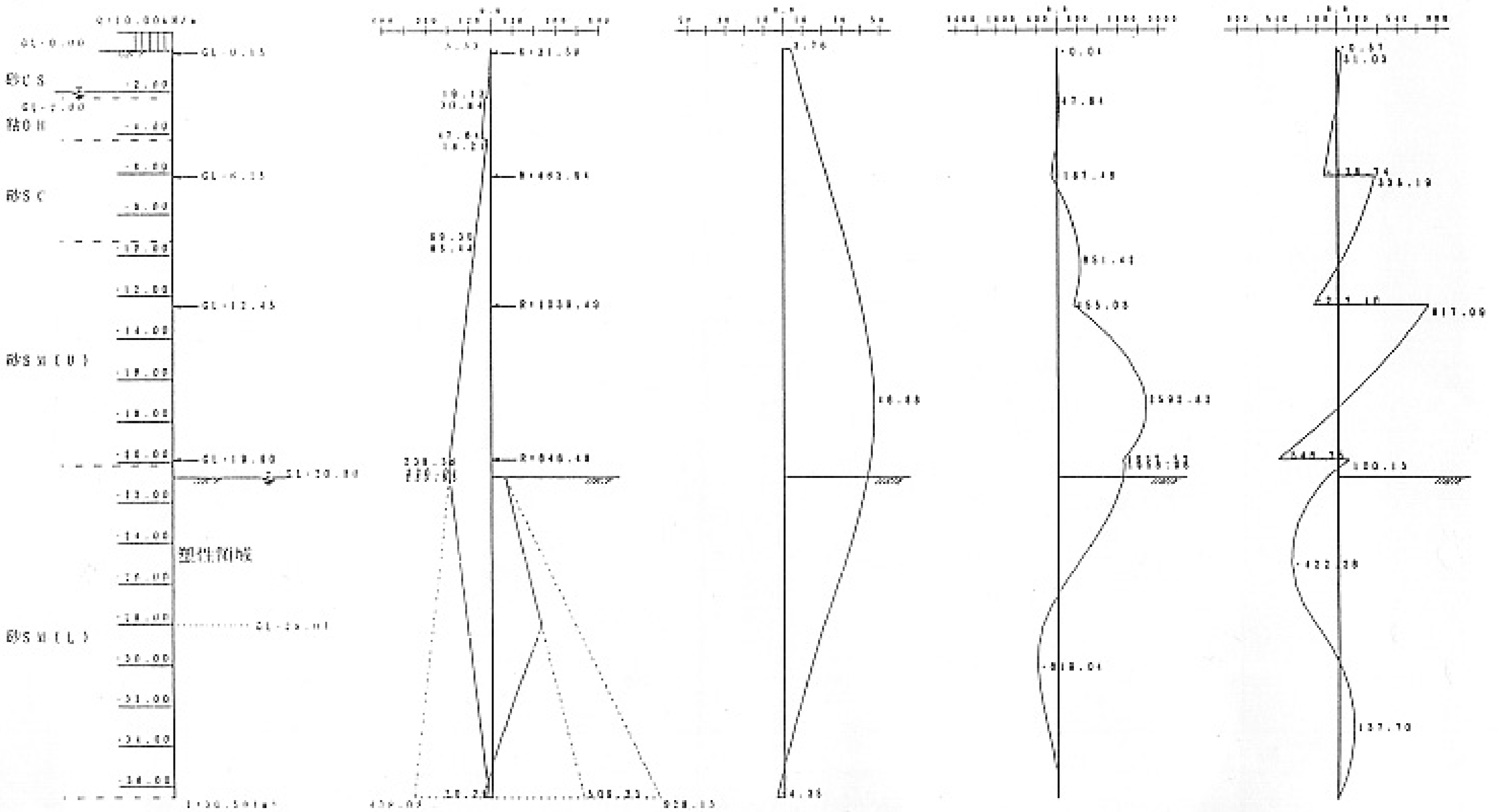

ベトナム下水道施設（1）
Sewer System in Viet Nam
STEP12 中床（1）設置
Excavation level
構造図
(m)
loading
側圧図
地盤反力図(kN/m)
Displacement
変位図
(mm)
Bending moment
モーメント図
(kNm)
Shearing force
せん断力図
(kN)
砂CS
粘OH
砂SC
砂SH(U)
砂SH(L)
塑性領域

ベトナム下水道施設（1）

Sewer System in Viet Nam

STEP13　頂版設置

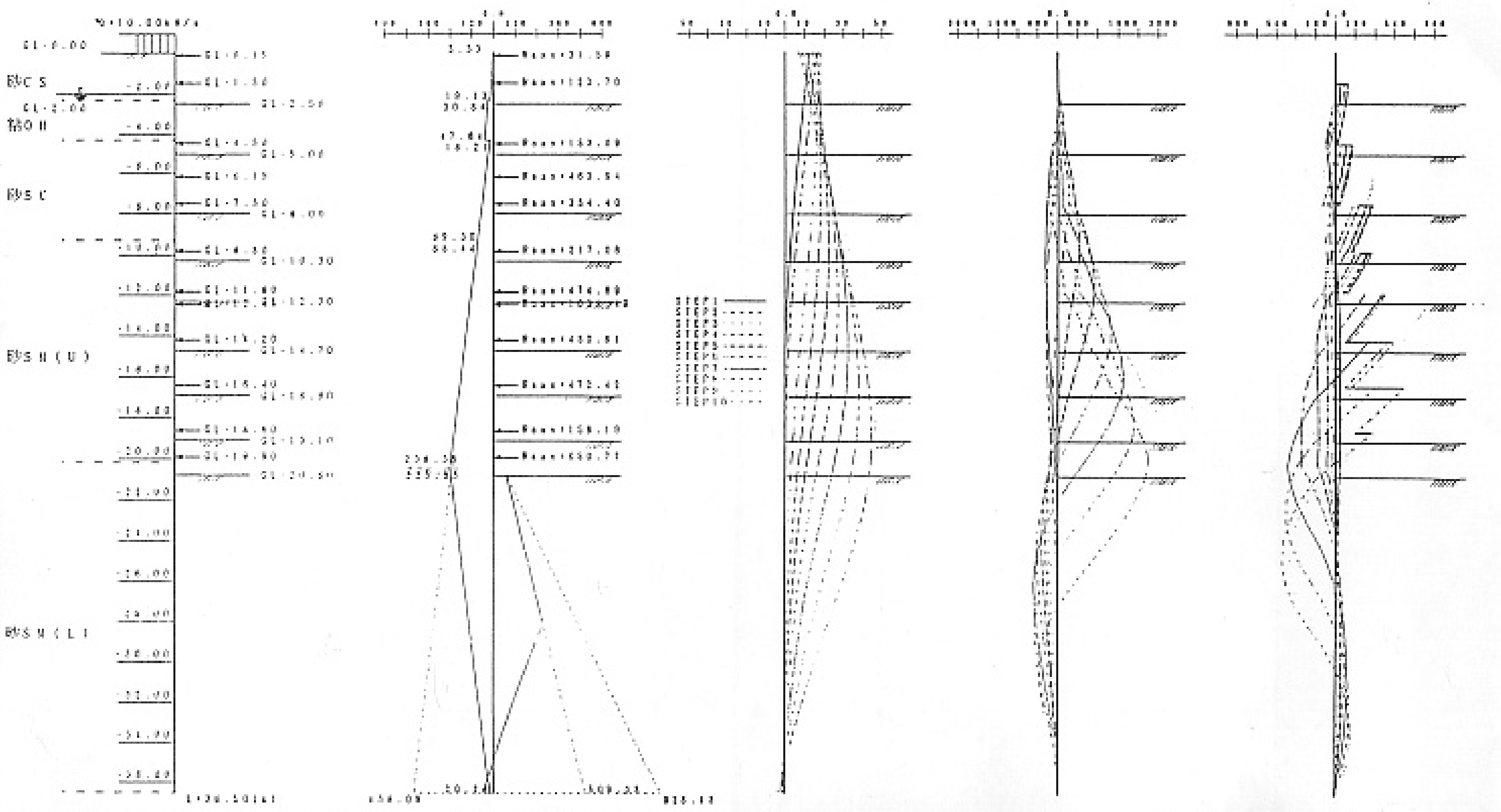
Excavation level	Loading	Displacement	Bending moment	Shearing force
構造図	側圧図 地盤反力図（kN/m）	変位図	モーメント図	せん断力図
(m)		(mm)	(kNm)	(kN)



ベトナム下水道施設（1）
Sewer System in Viet Nam

合成図

Excavation level 構造図 (m)	Loading 最終側圧図 地盤反力図（kN/m）	Displacement 変位図 (mm)	Bending moment モーメント図 (kNm)	Shearing force せん断力図 (kN)



5-3-2 Tables of maximum section force

(1) Summary of maximum section force

a) Displacement

b) Bending moment (maximum, minimum)

c) Shearing force

(2) Summary of support reaction

a) Strut

b) Slab

Sewer System in Vietnam

件名...ベトナム下水道施設（1） KASETSU-5X V 7.5-Rev 1 ページ104

maximum force and displacement Unit, displacement: m Bending moment: KN.m/m. shearing force KN/m)

［ 最大断面力および最大変位 一覧表 （単位 変位：mm モーメント：kN.m/m せん断力：kN/m） ］

上段：最大値 upper column : Maximum amount
下段：位置 lower 〃 : Place

施工ステップ番号 Step Number	変位 最大値 Maximum Displacement	モーメント 正の最大値 maximum Bending moment	モーメント 負の最大値 minimum bending moment	せん断力 最大値 maximum Shearing force
1:1次掘削 1st Excavation	12.13 GL 0.00	11.80 GL-28.72	-372.14 GL -9.97	-93.48 GL -4.30
2:2次掘削 2nd	15.75 GL 0.00	46.34 GL -3.25	-347.88 GL-12.94	-67.21 GL -5.00
3:3次掘削 3rd	18.09 GL 0.00	330.04 GL -7.02	-287.94 GL-22.32	105.06 GL -1.50
4:4次掘削 4th	18.27 GL -5.56	639.60 GL -9.47	-361.41 GL-23.37	153.08 GL -7.50
5:5次掘削 5th	22.05 GL -9.65	1090.50 GL-11.47	-484.76 GL-23.74	260.06 GL -7.50
6:6次掘削 6th	27.09 GL-12.35	1564.01 GL-13.74	-622.58 GL-24.48	333.34 GL -7.50
7:7次掘削 7th	32.40 GL-14.50	1943.50 GL-15.69	-710.19 GL-26.18	-443.39 GL-20.20
8:8次掘削 8th	38.03 GL-16.70	2242.21 GL-18.14	-670.38 GL-28.25	-458.58 GL-22.44
9:最終掘削 final	44.58 GL-18.79	2657.88 GL-20.04	-555.70 GL-30.19	612.18 GL-16.40

Sewer System in Vietnam

件名… ベトナム下水道施設（1）　　KASEITSU-5X V 1.5-Rev 1　ページ105

maximum force and displacement　Unit　Displacement　Bending moment : KN M/m　shearing force KN/m)

［ 最大断面力および最大変位　一覧表　（単位　変位：mm　モーメント：kN.m／m　せん断力：kN／m）　］

上段：最大値　upper : Maximum amount
下段：位置　lower : Place

施工ステップ番号 Step number	変位 最大値	モーメント 正の最大値	モーメント 負の最大値	せん断力 最大値
10:底版設置	44.58 GL-18.79	2657.88 GL-20.04	-555.70 GL-30.19	612.18 GL-16.40
11:中床（2）設置	46.24 GL-17.83	2726.94 GL-17.56	-604.70 GL-29.88	852.88 GL-12.45
12:中床（1）設置	46.93 GL-17.37	2616.68 GL-17.36	-621.94 GL-29.75	812.89 GL-12.45
13:頂版設置	46.93 GL-17.37	2607.21 GL-17.38	-621.75 GL-29.75	817.09 GL-12.45
最大値 最大位置 最大値のステップ	46.93 GL-17.37 (12)	2726.94 GL-17.56 (11)	-710.19 GL-26.18 (7)	852.88 GL-12.45 (11)
Maximum	Maximum displacement	maximum bending moment	minimum bending moment	Maximum shearing force

Sewer System in Vietnam

件名...ベトナム下水道施設（1）　　KASETSU-5A V 1.5-Rev 1　ページ106

[切梁反力 (strut) 一覧表 (単位：kN/m) (Unit)]

ステップ (Step)	切梁番号（切梁が設置されたステップ番号） 2 GL -1.50	3 GL -4.50	4 GL -7.50	5 GL -9.80	6 GL-11.80	7 GL-14.20	8 GL-16.40	9 GL-18.60 ← strut Level
1:1次掘削 1st Excavation								
2:2次掘削 2nd	61.148							
3:3次掘削 3rd	116.815	67.357						
4:4次掘削 4th	123.697	125.813	136.961					
5:5次掘削 5th	113.849	148.959	250.636	81.482				
6:6次掘削 6th	87.246	153.086	326.393	148.311	184.351			
7:7次掘削 7th	54.880	141.909	354.403	187.103	314.324	200.004		
8:8次掘削 8th	25.733	123.820	347.838	200.971	384.634	339.962	288.263	
9:最終掘削 Final Excavation	2.764	105.668	327.229	201.672	417.354	430.812	472.422	156.186
10:底版設置	2.764	105.668	327.229	201.672	417.354	430.812	472.422	156.186
11:中床（2）設置	0.000	91.738	330.975	217.061	474.686	CUT	CUT	CUT
12:中床（1）設置	0.000	105.727	CUT	CUT	CUT	CUT	CUT	CUT
13:頂版設置	CUT	CUT	CUT	CUT	CUT	CUT	CUT	CUT
最大値 (Maximum)	123.697	153.086	354.403	217.061	474.686	430.812	472.422	156.186

1st Excavation

2nd 〃

Support Reaction 1

Sewer System in Viet Nam

件名...ベトナム下水道施設（1）　　KASEISU-5X V 7.5-Rev 1　ページ107

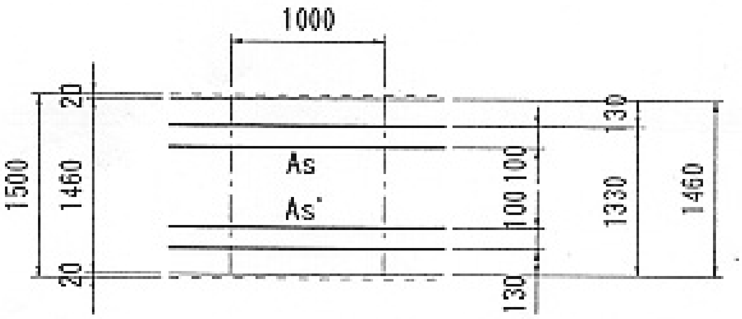
[切梁反力 (Strut) 一覧表 (単位 : kN/m) (Unit)]

ステップ (Step)	切梁番号（切梁が設置されたステップ番号） 10	11	12	13					Number of Strut
	GL-19.90	GL-12.45	GL -6.15	GL -0.15					← Strut Level
1:1次掘削 1st	Base slab	middle Slab2	middle slab1	Top slab					→ 1st Excavation
2:2次掘削 2nd									→ 2nd Excavation
3:3次掘削 3rd									→ 3rd Excavation
4:4次掘削 4th									→ 4th Excavation
5:5次掘削 5th									→ 5th Excavation
6:6次掘削 6th									→ 6th Excavation
7:7次掘削 7th									→ 7th Excavation
8:8次掘削 8th									→ 8th Excavation
9:最終掘削 Final excavation									→ Final Excavation
10:底版設置	0.000								
11:中床（2）設置	590.777	456.356							
12:中床（1）設置	650.774	1028.113	396.984						
13:頂版設置	646.480	1039.469	463.937	31.594					
最大値 (maximum)	650.774	1039.469	463.937	31.594					

Support Reaction 2

5-4 CHECK ON STRESS

5-4-1 Arrangement of reinforcement bar



5-4-2 Resisting moment

Specification of reinforced concrete

- Concrete grade — f'ck = 24 N/mm^2 (in slurry)
  σca = 10 N/mm^2
- Reinforcement bar grade — SD295A,B
  σsa = 225 N/mm^2
- Minimum pitch of re-bars — @150
- Minimum amount of re-bars — 0.002 bd = 0.002 x 133 x 100 = 26.6 cm^2

5-4-3 Bending moment

(1) Calculation results of resisting moment

・仮設時の抵抗モーメント Bending moment Axial force by self weight

配置位置 Depth /position	配　筋 Bar Arrangement		掘削側(in) Mr Inside (kN·m)	背面側(out) Mr outside (kN·m)	自重による軸力 (kN)
GL- 0.00	D25@150 1段	in	932.01	932.01	0.00
	D25@150 1段	out			
GL- 8.60(U)	D25@150 1段	in	1115.21	1115.21	316.05
	D25@150 1段	out			
GL- 8.60(L)	D29@150 1.5段	in	1802.34	1112.73	316.05
	D25@150 1段	out			
GL-13.96(U)	D29@150 1.5段	in	1906.80	1224.36	513.03
	D25@150 1段	out			
GL-13.96(L)	D32@150 2段	in	2808.48	2808.48	513.03
	D32@150 2段	out			
GL-23.40(U)	D32@150 2段	in	2984.23	2984.23	859.95
	D32@150 2段	out			
GL-23.40(L)	D29@150 1.5段	in	2087.39	1424.56	859.95
	D25@150 1段	out			
GL-29.90(U)	D29@150 1.5段	in	2209.40	1547.00	1098.83
	D25@150 1段	out			
GL-29.90(L)	D25@150 1段	in	1546.70	1546.70	1098.83
	D25@150 1段	out			
GL-36.50	D25@150 1段	in	1675.15	1675.15	1341.38
	D25@150 1段	out			

Moment Calculation

■抵抗モーメントの計算 Rectangular

ケース番号 Number タイトル title	No. 1 [矩 形] GL-0.00(in, out)	No. 2 [矩 形] GL-8.60U(in, out)	No. 3 [矩 形] GL-8.60L(in)	No. 4 [矩 形] GL-8.60L(out)
断面寸法 B1 H1 (m) B2 H2 Dimension B3 H3	1.000 1.460 0.000 0.000 ——— 0.000	1.000 1.460 0.000 0.000 ——— 0.000	1.000 1.460 0.000 0.000 ——— 0.000	1.000 1.460 0.000 0.000 ——— 0.000
Moment 抵抗モーメントMr' kN-m 軸 力 N kN Axial force	932.009 0.000	1115.206 316.050	1802.335 316.050	1112.734 316.050
鉄筋量 Bar Arrangement d1 /As1 (m) (cm2)	1.330 33.782 (6.667-D25)	1.330 33.782 (6.667-D25)	1.330 42.829 (6.667-D29)	1.330 33.782 (6.667-D25)
d2 /As2 (m) (cm2)	0.130 33.782 (6.667-D25)	0.130 33.782 (6.667-D25)	1.230 21.411 (3.333-D29)	0.230 21.411 (3.333-D29)
d3 /As3 (m) (cm2)	——— ——— ———	——— ——— ———	0.130 33.782 (6.667-D25)	0.130 42.829 (6.667-D29)
Total 合計 cm2	67.564	67.564	98.022	98.022
Check of stress 応力度 σc σca N/mm2 σs σsa	4.3 < 10.0 225.0 < 225.0	5.3 < 10.0 225.0 < 225.0	7.0 < 10.0 225.0 < 225.0	5.0 < 10.0 225.0 < 225.0
Neutral Axis 中立軸 x m	0.2964	0.3456	0.4213	0.3325
Modulus of elasticity ratio ヤング係数比	n = 15.00	n = 15.00	n = 15.00	n = 15.00

Moment Calculation

■抵抗モーメントの計算 Rectangular

ケース番号 Number タイトル title	No. 5 [矩 形] GL-13.96U(in)	No. 6 [矩 形] GL-13.96U(out)	No. 7 [矩 形] GL-13.96L(in, out)	No. 8 [矩 形] GL-23.40U(in, out)
断面寸法 B1 H1 (m) B2 H2 Dimension B3 H3	1.000 1.460 0.000 0.000 ——— 0.000	1.000 1.460 0.000 0.000 ——— 0.000	1.000 1.460 0.000 0.000 ——— 0.000	1.000 1.460 0.000 0.000 ——— 0.000
moment 抵抗モーメントMr' kN-m 軸 力 N kN Axial force	1906.800 513.030	1224.356 513.030	2808.402 513.030	2984.230 859.950
鉄筋量 Bar Arrangement d1 /As1 (m) (cm2)	1.330 42.829 (6.667-D29)	1.330 33.782 (6.667-D25)	1.330 52.949 (6.667-D32)	1.330 52.949 (6.667-D32)
d2 /As2 (m) (cm2)	1.230 21.411 (3.333-D29)	0.230 21.411 (3.333-D29)	1.230 52.949 (6.667-D32)	1.230 52.949 (6.667-D32)
d3 /As3 (m) (cm2)	0.130 33.782 (6.667-D25)	0.130 42.829 (6.667-D29)	0.230 52.949 (6.667-D32)	0.230 52.949 (6.667-D32)
d4 /As4 (m) (cm2)	——— ——— ———	——— ——— ———	0.130 52.949 (6.667-D32)	0.130 52.949 (6.667-D32)
Total 合計 cm2	98.022	98.022	211.796	211.796
Check of stress 応力度 σc σca N/mm2 σs σsa	7.4 < 10.0 225.0 = 225.0	5.5 < 10.0 225.0 = 225.0	8.2 < 10.0 225.0 = 225.0	8.9 < 10.0 225.0 < 225.0
Neutral Axis 中立軸 x m	0.4408	0.3574	0.4719	0.4950
Modulus of elasticity Ratio ヤング係数比	n = 15.00	n = 15.00	n = 15.00	n = 15.00

Moment Calculation

■抵抗モーメントの計算 Rectangular

ケース番号 number タイトル title		No. 9 [矩 形] GL-23.40L (in)		No. 10 [矩 形] GL-23.40L (out)		No. 11 [矩 形] GL-29.90U (in)		No. 12 [矩 形] GL-29.90U (out)	
断面寸法 (m) Dimension	B1 H1	1.000	1.460	1.000	1.460	1.000	1.460	1.000	1.460
	B2 H2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	B3 H3	———	0.000	———	0.000	———	0.000	———	0.000
Moment 抵抗モーメントMr' kN·m			2087.387		1424.563		2209.398		1547.004
軸 力 N kN Axial Force			859.950		859.950		1098.830		1098.830
鉄筋量 Bar Arrangement	d1 /As1 (m) (cm2)	1.330	42.829	1.330	33.782	1.330	42.829	1.330	33.782
		(6.667-D29)		(6.667-D25)		(6.667-D29)		(6.667-D25)	
	d2 /As2 (m) (cm2)	1.230	21.411	0.130	52.949	1.230	21.411	0.230	21.411
		(3.333-D29)		(6.667-D32)		(3.333-D29)		(3.333-D29)	
	d3 /As3 (m) (cm2)	0.130	33.782	———	———	0.130	33.782	0.130	42.829
		(6.667-D25)			———	(6.667-D25)		(6.667-D29)	
Total	合計 cm2		98.022		86.731		98.022		98.022
Check of stress 応力度 N/mm2	σc σca	8.2 <	10.0	6.4 <	10.0	8.8 <	10.0	6.9 <	10.0
	σs σsa	225.0 =	225.0	225.0 =	225.0	225.0 <	225.0	225.0 <	225.0
Neutral Axis 中立軸	x m		0.4719		0.3983		0.4914		0.4198
Modulus of elasticity ヤング係数比 ratio		n =	15.00	n =	15.00	n =	15.00	n =	15.00

Moment Calculation

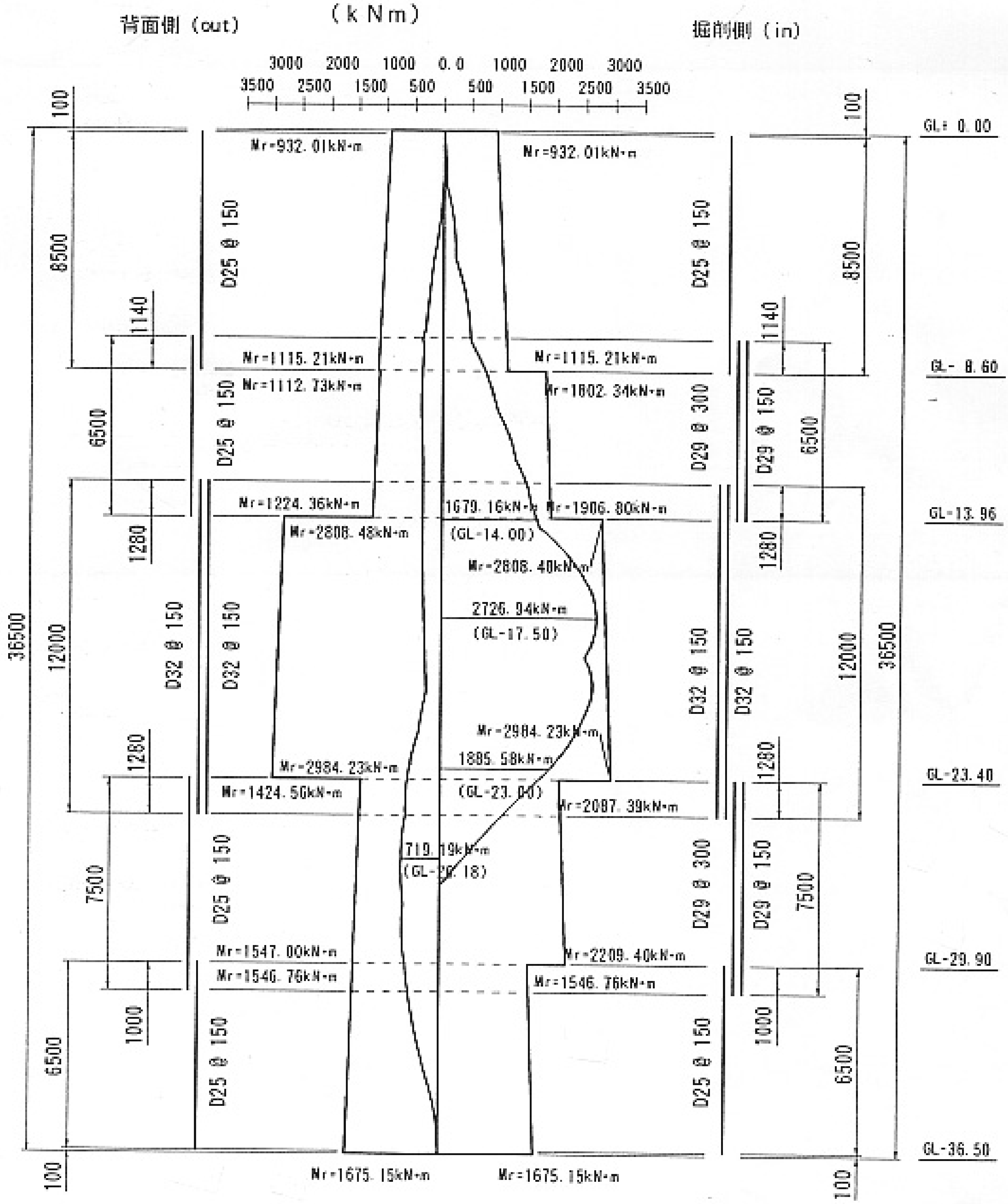
■抵抗モーメントの計算 Rectangular

ケース番号 number タイトル title		No. 13 [矩 形] GL-29.90L (in, out)		No. 14 [矩 形] GL-36.50U (in, out)	
断面寸法 (m) Dimension	B1 H1	1.000	1.460	1.000	1.460
	B2 H2	0.000	0.000	0.000	0.000
	B3 H3	———	0.000	———	0.000
Moment 抵抗モーメントMr' kN-m			1546.695		1675.148
軸 力 N kN Axial Force			1098.830		1341.380
鉄筋量 Bar Arrangement	d1 /As1 (m) (cm2)	1.330	33.782	1.330	33.782
		(6.667-D25)		(6.667-D25)	
	d2 /As2 (m) (cm2)	0.130	33.782	0.130	33.782
		(6.667-D25)		(6.667-D25)	
	合計 cm2		67.564		67.564
Check of stress 応力度 N/mm2	σc σca	7.3 <	10.0	7.9 <	10.0
	σs σsa	225.0 <	225.0	225.0 <	225.0
Neutral Axis 中立軸	x m		0.4364		0.4590
Modulus of elasticity ヤング係数比 ratio		n =	15.00	n =	15.00

Moment (Temporary use)

抵抗モーメント図（仮設時）

（kNm）



注）背面側のGL-13.96～-23.40m間は、完成時（本体利用時）を考慮して決定した。

5-4-4 Shearing force

(1) Calculation of resisting shearing force

a) The allowable shearing force that it can be borne only with concrete

The allowable shearing force that it can be borne only with concrete is calculated with the following formula.

$Scr = \tau a \cdot b \cdot d$

where, τa : Allowable shearing stress of concrete

(= 0.49 N/mm^2, f'ck = 24 N/mm^2 (in slurry))

b : Unit width (= 100 cm)

d : Effective depth (= 133 cm)

Scr = (0.49 x 100) x 100 x 133

= 651,700 N

= 651 kN

b) The allowable shearing force in consideration of stirrup

The allowable shearing force in consideration of stirrup is calculated with the following formula.

Sr = Sh + Sc

$Sh = \sigma sa \cdot d \cdot As / (1.15 \cdot a)$

where, σsa : Allowable tensile stress of concrete (= 225 N/mm^2, SD295A,B)

d : Effective depth (= 133 cm)

As : Section area of stirrup (cm^2/ m)

a : Pitch of stirrup (cm)

Diameter of stirrup	As		σsa	d	a	Sh (kN)
D13	4.223	@300	225	133	30.0	366
D16	6.619	@300	225	133	30.0	574
D19	9.549	@300	225	133	30.0	828
D22	12.902	@300	225	133	30.0	1,119

$Sc = 1 / 2 \cdot \tau a \cdot b \cdot d = 1 / 2 \cdot Scr$

= 652 / 2 = 326 kN

Therefor,

Diameter of stirrup	Sh (kN)	Sc (kN)	Sr = Sh + Sc (kN)
D13	366	326	692
D16	574	326	900
D19	828	326	1,154
D22	1,119	326	1,445

(2) Check on bending stress

Moment Calculation

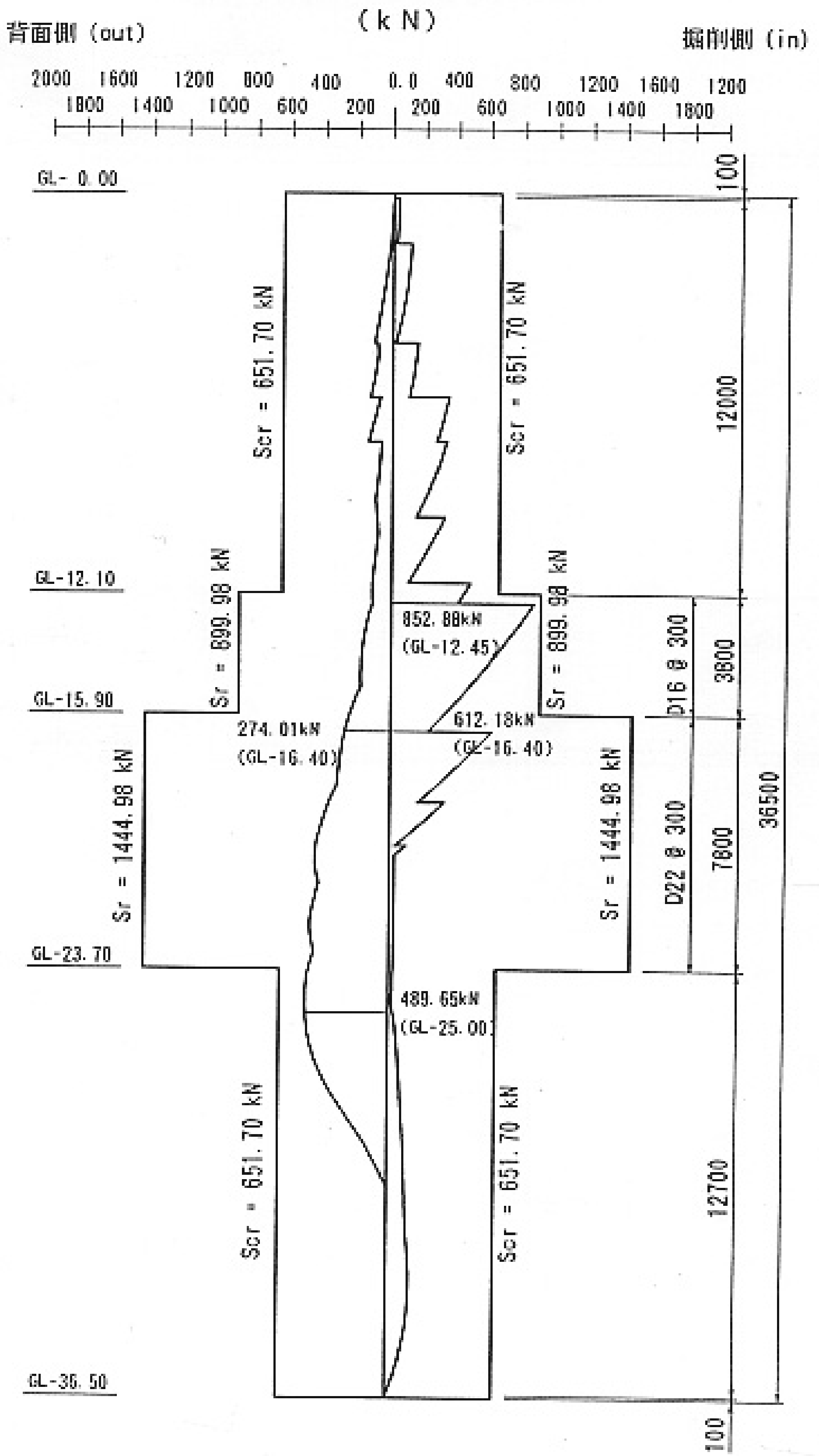
Rectangular

ケース番号 number / タイトル title	No. 1 [矩 形] GL-14.00		No. 2 [矩 形] GL-17.50		No. 3 [矩 形] GL-23.00		No. 4 [矩 形] GL-26.18	
断面寸法 (m) Dimension B1 H1	1.000	1.460	1.000	1.460	1.000	1.460	1.000	1.460
B2 H2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B3 H3	-------	0.000	-------	0.000	-------	0.000	-------	0.000
断面力 M kN·m		1679.160		2726.940		1885.580		719.190
N kN		514.500		643.130		845.250		962.110
鉄筋量 Bar Arrangement d1 /As1 (m) (cm2)	1.330	42.829	1.330	52.949	1.330	42.829	1.330	33.782
	(6.667-D29)		(6.667-D32)		(6.667-D29)		(6.667-D25)	
d2 /As2 (m) (cm2)	1.230	21.411	1.230	52.949	1.230	21.411	0.230	21.411
	(3.333-D29)		(6.667-D32)		(3.333-D29)		(3.333-D29)	
d3 /As3 (m) (cm2)	0.130	33.782	0.230	52.949	0.130	33.782	0.130	42.829
	(6.667-D25)		(6.667-D32)		(6.667-D25)		(6.667-D29)	
d4 /As4 (m) (cm2)	-------	-------	0.130	52.949	-------	-------	-------	-------
		-------	(6.667-D32)			-------		-------
合計 cm2		98.022		211.796		98.022		98.022
check of stress 応力度 N/mm2 σc σca	6.6 <	10.0	8.1 <	10.0	7.5 <	10.0	3.0 <	10.0
σs σsa	193.6 <	225.0	212.0 <	225.0	198.4 <	225.0	53.4 <	225.0
Natural Axis 中立軸 x m		0.4487		0.4834		0.4801		0.6118
Modulus of elasticity ヤング係数比	n =	15.00	n =	15.00	n =	15.00	n =	15.00

(2) Calculation results of resisting shearing force

Figure of Sharing Force (Temporary Case)

抵抗せん断力図(仮設時)



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