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DESIGN CALCULATION COVER SHEET

Project	Detailed Design on Port Reactivation Project in La Union Province	**Project Code**	JC1N004
Section	**Civil**	Calc. File No.	
Sub-Section	**Quaywall**	Calc. Index No.	

Subject: **Passenger Berth**

Calculation Objective:

Stability of Platform 1.

References, Calculation Notes and Comments

Refer to drawings **QW-02-001,QW-02-004**

Calculation based on

TECHNICAL STANDERDS AND COMMENTARIES

FOR

PORT AND HARBOUR FACILITIES IN JAPAN

Rev	Prepared		No. of	Checked		Reviewed		Superseded
	by	Date	Pages	by	Date	by	Date	by Calc No.
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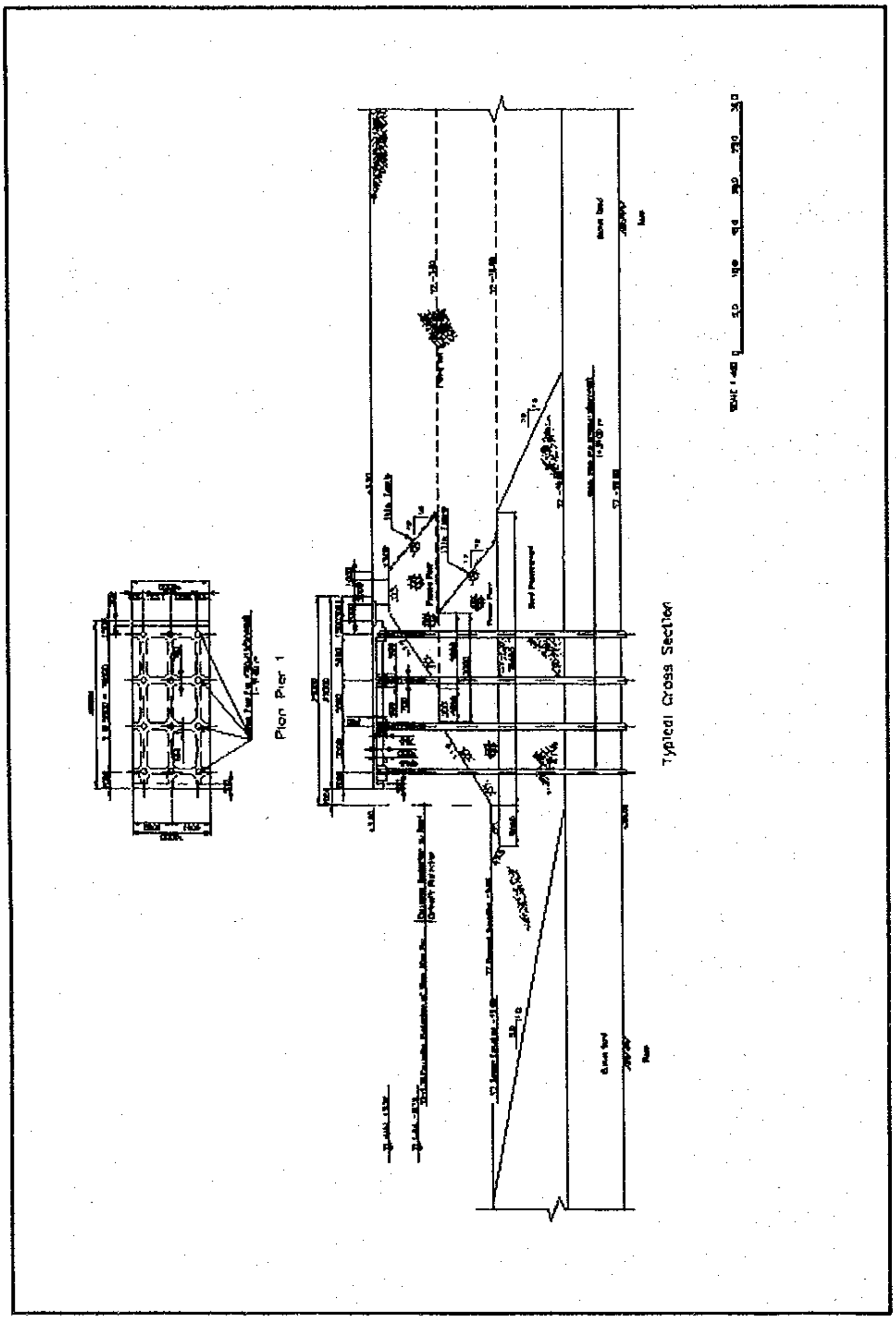
3．Basic Design of Platform1 (Passenger Berth)

1）Outline structure of a platform



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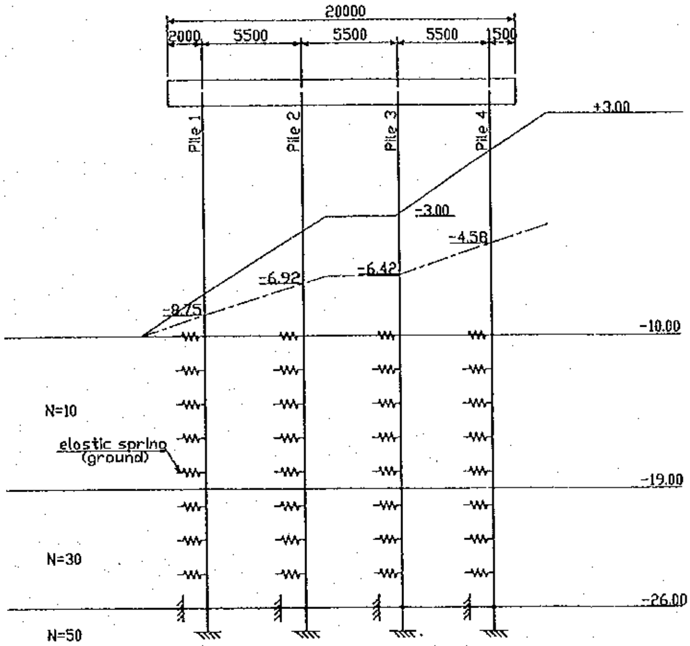
2) Analysis model

Member forces acting on individual piles are calculated in 3-dimensional analysis.



Analysis model outline figure (Frame model)

An analysis model is taken as frame structure. (In which the ground is evaluated as an elastic spring.)

A transverse direction spring constant of ground (Kh) is computed using the following formulas.

$Kh = kh \times D$ (N/cm^2)　　kh : coefficient of horizontal subgrade reaction(N/cm^3)

D : pile width (cm)

Ground level	Average N-value	kh(N/cm³)	pile width(m)	Kh(kN/m²)
Virtual ground surface				
		3.5	0.70	2,450
-10.00				
	10	15	0.70	10,500
-19.00				
	30	45	0.70	31,500
-26.00				

○Dimensions of Steel Pipe Pile

φ700×t12　Section area $A = 259.4\ cm^2$ (Corrosion consideration $A' = 237.4\ cm^2$)

Geometrical moment of inertia $I = 153{,}511\ cm^4$

(Corrosion consideration $I' = 140{,}099\ cm^4$)

Section modulus $Z = 4{,}386\ cm^3$

Type of Steel : SKK490 (Design Yield Strength 315 N/mm²)

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3) Calculation of Load

The external forces acting on a platform 1 is shown below.

・Deadweight ・Surcharge ・Earthquake Force

(1) Calculation of Deadweight of the Superstructure

Volume of superstructure : 140.85 m^3

Weight of superstructure : 3,380.4 kN → 3,385 kN

conversion to equivalent uniform distribution load

$$w' = 3{,}380.4 / (10.0 \times 20.0) = 16.90 \text{ kN/m}^2$$

(2) Surcharge

Surcharge w = 10.0 kN/m^2

Total of Surcharge $W' = 10.0 \times 20.0 \times 10.0 = 2{,}000$ kN

(3) Calculation of Earthquake Force

$P = (3{,}385+2{,}000) \times 0.20 = 1{,}077$ kN

4) Examination case

The load generalization table of each examination case

Case		Vertical Forces (kN)		Horizontal Forces (kN)	Condition	Action direction	Premium coefficient
		Deadweight	Surcharge	Earthquake Force			
case1	Earthquake	3,385.00	2,000.00	1,077.00	Extraordinary	Sea→Land	1.50
case2	Earthquake	3,385.00	2,000.00	1,077.00	Extraordinary	Land→Sea	1.50
case3	Earthquake	3,385.00	2,000.00	1,077.00	Extraordinary	Parallel to face line	1.50

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5) Section force of pile

Computed section force acting on pile is shown below as a result of analysis.

Case	Pile	Maximum Moment kN・m	Axial force kN	Maximum Axial force kN	Displacement cm
case1 Earthquake Sea→Land	Pile 1 (Sea side)	532.6	339.1	404.5	9.0
	Pile 2	623.8	433.1	496.8	
	Pile 3	655.6	466.3	527.2	
	Pile 4 (Land side)	799.0	593.2	650.6	
case2 Earthquake Land→Sea	Pile 1 (Sea side)	529.9	607.0	666.7	9.1
	Pile 2	627.9	511.6	575.0	
	Pile 3	652.8	458.3	525.4	
	Pile 4 (Land side)	796.4	246.4	316.1	
case3 Earthquake Parallel to face line	Pile 1 (Sea side)	686.9	764.1	817.4	12.7
	Pile 2	690.9	765.6	818.8	
	Pile 3	612.9	751.3	804.5	
	Pile 4 (Land side)	626.7	708.8	762.0	

※The moment of case3 compounded the moment about the parallel direction to the face line, and the moment about the vertical direction to the face line.

The following cases perform the stress examination of piles from the result of analysis.

Pile 1 : case3 (Earthquake、Action direction : Parallel to face line)
Pile 2 : case3 (Earthquake、Action direction : Parallel to face line)
Pile 3 : case3 (Earthquake、Action direction : Parallel to face line)
Pile 4 : case1 (Earthquake、Action direction : Sea→Land)

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6) Stress Examination of Piles

Passenger Berth ,Platform 1 φ700*t12

Stress Calculation (Case3) Pile 1

Pile	Dimension	φ700*t12		SKK 490		
	Cross-sectional Area	A= 259.4 cm^2				
	Section modulus	Z= 4,386 cm^3				
	Radius of gyration of area	r= 24.3 cm^2				
	Buckling length	l= 1300 cm				
		l/r= 53.5				
Section force	Bending Moment	M= 686.9 kN·m				
	Axial Force	N= 764.1 kN				
Stress	Allowable Bending Stress	σba= 185 N/mm^2				
	Allowable Axial Compressive Stress	σca= 140 N/mm^2				
	Premium coefficient	1.5				
	Bending Stress	σb= 157 N/mm^2	<	278 N/mm^2	O.K.	
	Axial Compressive Stress	σc= 29 N/mm^2	<	210 N/mm^2	O.K.	
	Examination of members simultaneously subject to axial force and bending moment	0.70			O.K.	

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Passenger Berth ,Platform 1 φ700*t12

Stress Calculation (Case3) Pile 2

Pile	Dimension	φ700*t12	SKK 490		
	Cross-sectional Area	A=	259.4 cm^2		
	Section modulus	Z=	4,386 cm^3		
	Radius of gyration of area	r=	24.3 cm^2		
	Buckling length	l=	1117 cm		
		l/r=	46.0		
Section force	Bending Moment	M=	690.9 kN·m		
	Axial Force	N=	765.6 kN		
Stress	Allowable Bending Stress	σ ba=	185 N/mm^2		
	Allowable Axial Compressive Stress	σ ca=	149 N/mm^2		
	Premium coefficient		1.5		
	Bending Stress	σ b=	158 N/mm^2	< 278 N/mm^2	O.K.
	Axial Compressive Stress	σ c=	30 N/mm^2	< 224 N/mm^2	O.K.
	Examination of members simultaneously subject to axial force and bending moment		0.70		O.K.

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Passenger Berth ,Platform 1 ϕ700*t12

Stress Calculation (Case3) Pile 3

Pile	Dimension	ϕ700*t12	SKK 490
	Cross-sectional Area	A= 259.4 cm^2	
	Section modulus	Z= 4,386 cm^3	
	Radius of gyration of area	r= 24.3 cm^2	
	Buckling length	l= 1067 cm	
		l/r= 43.9	
Section force	Bending Moment	M= 612.9 kN·m	
	Axial Force	N= 751.3 kN	
Stress	Allowable Bending Stress	σ ba= 185 N/mm^2	
	Allowable Axial Compressive Stress	σ ca= 152 N/mm^2	
	Premium coefficient	1.5	
	Bending Stress	σ b= 140 N/mm^2 < 278 N/mm^2	O.K.
	Axial Compressive Stress	σ c= 29 N/mm^2 < 227 N/mm^2	O.K.
	Examination of members simultaneously subject to axial force and bending moment	0.63	O.K.

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Passenger Berth ,Platform 1 　　　　φ700*t12

Stress Calculation (Case3) Pile 4

Pile	Dimension	φ700*t12	SKK 490			
	Cross-sectional Area	A= 259.4 cm^2				
	Section modulus	Z= 4,386 cm^3				
	Radius of gyration of area	r= 24.3 cm^2				
	Buckling length	l= 883 cm				
		l/r= 36.3				
Section force	Bending Moment	M= 799.0 kN·m				
	Axial Force	N= 593.2 kN				
Stress	Allowable Bending Stress	σ ba= 185 N/mm^2				
	Allowable Axial Compressive Stress	σ ca= 161 N/mm^2				
	Premium coefficient	1.5				
	Bending Stress	σ b= 182 N/mm^2	<	278 N/mm^2	O.K.	
	Axial Compressive Stress	σ c= 23 N/mm^2	<	241 N/mm^2	O.K.	
	Examination of members simultaneously subject to axial force and bending moment	0.75			O.K.	

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7) Examination of Bearing Capacity of Pile

Ultimate bearing capacity(Ru) is computed using the following formulas.

$Ru = 300 \times q \times N \times Ap + N' \times As$ (kN)

Where q : Closed area ratio of pile

N : N-value of the ground around pile toe

$N = (N1+N2)/2$

N1 : N-value at the toe of pile

N2 : mean N-value in the range from the toe of pile to the level 4B above

B : diameter or width of pile (m)

N' : mean N-value for total penetration length of pile

Ap : toe area of pile (m^2)

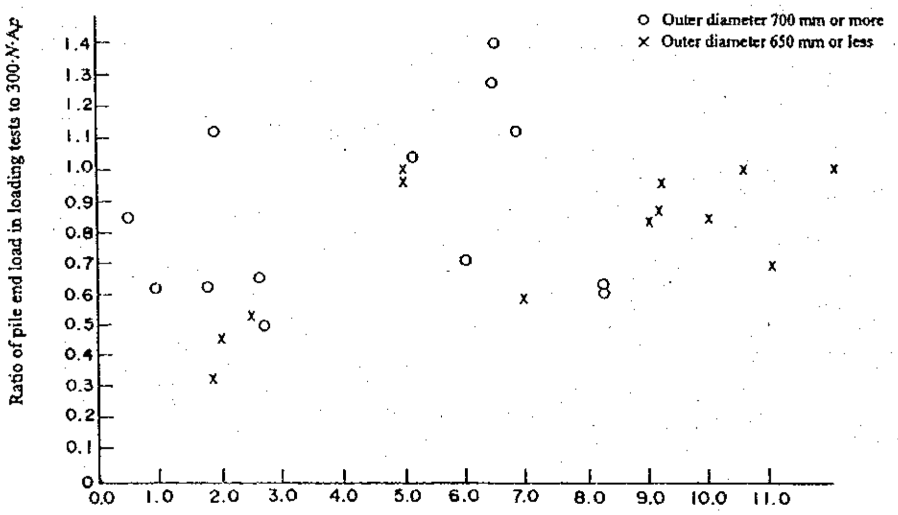
As : total circumferential area of pile (m^2)

※The pile installation method assumes from Soil Condition that it is the pile installation by inner excavation. Therefore, the 2nd term of the upper formula is made into "N×As." (see "Highway Bridge Specifications and the Commentary(in Japan)") (According to the standard, it is "2×N×As".)

(1) Closed area ratio of pile

The piles shall drive only the length of pile diameter into the bearing stratum (below -26m).

The Closed area ratio is set to "q= 0.6" from the following figures.



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(2) Calculation of ultimate bearing capacity

$N2 = (0.7\times50 + 3\times0.7\times30) / (4\times0.7) = 35$

$N = (50+35) / 2 = 42.5 \rightarrow 42$

$Ap = 0.7^2\times \pi /4 = 0.385\ m^2$

Circumferential area of pile per 1m $As' = 0.7\times \pi = 2.20\ m^2/m$

$Ru = 300\times0.6\times42\times0.385 + (9.5\times10 + 6.0\times30)\times2.20$

$= 3{,}516$ kN

(3) Examination of Bearing Capacity

The allowable bearing capacity is calculated using the following formulas.

$Ra = Ru / F$

where

Ra : allowable bearing capacity

Ru : ultimate bearing capacity

F : safety factor (= 1.50 : earthquake condition)

a) Examination of Bearing Capacity(Earthquake Condition)

Allowable bearing capacity $Ra = 3{,}516 / 1.5 = 2{,}344$ kN $\geqq$ 818.8 kN O.K

(Maximum case3 (Earthquake Condition、
Action direction : Parallel to face line、Pile2)

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8) Examination of Earthquake-Resistant Performance

The examination of earthquake-resistant is performed by the "simplified method" from the following things.

- An object institution does not have complicated structure.
- A raking pile is not included.

The simplified method evaluates the load carrying capacity of pier by summing up the strength of the steel pipe piles, while assuming that the pier superstructure is a rigid body.

(1) Determination of seismic coefficient for examination

The seismic coefficient for examinations is obtained for the different regional classification in a structure installation position and the natural periods of the ground and the pile-supported section. Regional classification is set as region category A.

a) Natural Period of the Ground

The natural period of the ground is computed using the following formulas.

$T_g=4\Sigma H_i/V_{si}$

T_g ; natural period of the ground (s)

H_i ; thickness of the i-th layer (m)

V_{si} ; shear wave velocity in the i-th layer $V_{si}=\sqrt{(G_0\, g/\gamma_t)}$ (m/s)

G_0 ; shear modulus (kN/m²)

- sandy ground $G_0=14{,}400N^{0.68}$ (kN/m²)

g ; gravitational acceleration (=9.8m/s²)

γ_t ; wet unit weight (kN/m³)

N ; standard penetration test value

The natural period of the ground is computed for the engineering foundation.

The crown height of rubble is set as -6.5m(virtual ground surface). Therefore, it is aimed at the -6.5m ～ -26m foundation.

Level	Hi (m)	soil	N	γ_t(kN/m³)	G_0(kN/m²)	V_{si}(m/s)
-6.50～-10.0	3.50	sandy	2.33	20.0	25,596	112.05
-10.0～-20.0	10.0	sandy	10	20.0	68,923	183.87
-20.0～-26.0	6.0	sandy	30	20.0	145,481	267.13

- Natural Period of the Ground

$T_g=4\times(3.50/112.05+10.0/183.87+6.0/267.13)=0.432s$

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b) Natural Period of Platform 1

The coefficient of horizontal subgrade reaction and the characteristic value of a pile are computed using the following formulas.

- coefficient of horizontal subgrade reaction $k_h = 2 \times 1.5N$ (N/cm³)
- characteristic value of a pile $\beta = \sqrt[4]{(k_h D/(4EI))}$ (cm⁻¹)
- horizontal spring constant $K_H = 12 \times EI/(Li^3)$ (kN/m)
- natural period pf a Platform 1 $Ts = 2 \times \pi \times \sqrt{(W / (g \times K_H))}$ (s)

where N : average N-value of the ground down to a depth of about $1/\beta$

D : diameter or width of the pile (=0.70m)

Li : free length of a pile 、 $= hi + 1/\beta$

hi : vertical distance between the pile head and the virtual ground surface

W : sum of deadweight and surcharge during an earthquake (=5,385 kN)

The calculation result of the spring constant of individual pile

	D (cm)	thickness of pile(cm)	I (cm⁴)	hi (m)	N	kh	β (cm⁻¹)	1/β (m)	Li (m)	K_H (kN/m)
Pile 1	69.8	1.1	140,099	13.00	6.78	20.34	0.00335	2.98	15.98	824
Pile 2	69.8	1.1	140,099	11.17	3.35	10.05	0.00281	3.56	14.73	1,053
Pile 3	69.8	1.1	140,099	10.67	2.69	8.07	0.00266	3.76	14.43	1,120
Pile 4	69.8	1.1	140,099	8.83	2.33	7.00	0.00257	3.89	12.72	1,633

The number of piles of individual pile rows is three,

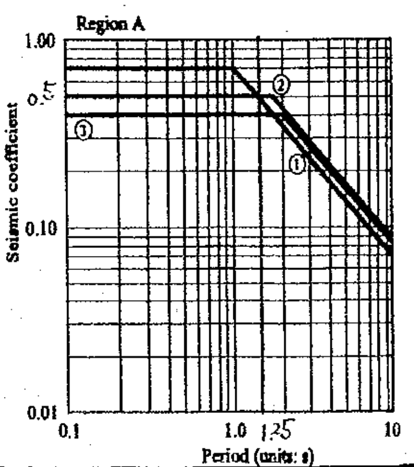
sum of horizontal spring constant

$$\Sigma K_H = (3 \times 824 + 3 \times 1{,}053 + 3 \times 1{,}120 + 3 \times 1{,}633) = 13{,}888 \text{ kN/m}$$

natural period of a Platform 1 $Ts = 2 \times \pi \times \sqrt{(5{,}385 / (9.81 \times 13{,}888))} = 1.25$ s

c) Determination of seismic coefficient for examination

From the following figures, seismic coefficient for examination by reference is set to "kh=0.5".



Legend
① $T_g < 0.1$s
② $0.1\text{s} \leqq T_g < 0.5$s
③ $0.5\text{s} \leqq T_g$
T_g ; natural period of the ground calculated with equation(s)

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(2) Examination of Load Carrying Capacity Using Simplified Method

In the examination of the load carrying capacity of pier using the simplified method, the pile-supported section shall be represented with a frame structure model and the horizontal displacement ductility factor of the pile-supported section shall be used. Examination is performed using the following formulas.

$R_a \geqq k_h W$

$R_a = \sqrt{(2\mu_a - 1 + \theta(\mu_a - 1)^2)} \times P_y$

R_a ; load carrying capacity during an earthquake (kN)

k_h ; seismic coefficient derived

W ; deadweight of pier and surcharge acting during an earthquake (kN)

μ_a ; allowable displacement ductility factor (=1.3 ; Class A)

θ ; =0 (see "TECHNICAL STANDARDS AND COMMENTARIES FOR PORT AND HARBOUR FACILITIES IN JAPAN")

P_y ; the horizontal force corresponding to the elastic limit $=0.82P_{uall}$ (kN)

P_{uall} ; the horizontal load level at which the bending moment of all piles of the wharf reach the fully plastic state moments both at the pile heads and underground virtual fix points $=\Sigma 2M_{pi}/L_i$ (kN)

M_p ; fully plastic state moment $=M_{p0}\cdot\cos(\alpha\pi/2)$ (kN·m)

L_i ; The length of individual pile $=h_i+1/\beta$ (m)

M_{p0} ; fully plastic state moment of steel pipe pile when no axial force is acting $=Z_p f_y$ (kN·m)

Z_p ; plastic sectional modulus of steel pipe pile $=4/3\times(r^3-(r-t)^3)$ (mm^3)

f_y ; design yield strength of steel pipe pile (N/mm^2)

SKK490 ; 315 N/mm^2

r ; radius of steel pipe pile (mm)

t ; thickness of steel pipe pile (mm)

α ; ratio of the acting axial force N to the yield axial force $N_0(=A\times fy)$ when no bending moment is acting $=N/N_0$

A ; cross-sectional area of steel pipe pile (mm^2)

The case where the examination of load carrying capacity is performed is the case where load acts on land from the sea.

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a) Calculation of Member Forces Acting on Individual Piles

Earthquake force of using for examination of load carrying capacity

$P = 5{,}385 \times 0.50 = 2{,}693$ kN

The horizontal force acting on the heads of individual piles may be calculated using following formula.

$H_i = (K_{Hi} / \Sigma K_{Hi}) \times P$ (kN)

K_{Hi} : horizontal spring constant of individual piles

	free length of a pile Li (m)	K_{Hi}	$K_{Hi} / \Sigma K_{Hi}$	Hi(kN)
Pile 1	15.98	824	0.177959	159.747
Pile 2	14.73	1,053	0.227468	204.191
Pile 3	14.43	1,120	0.241933	217.175
Pile 4	12.72	1,633	0.352640	316.553
	ΣK_{Hi} =	4,629		

※The number of piles of individual pile rows is three.
"Hi" is the horizontal force per a pile.

The pile head moments (Mi) of individual piles may be calculated using following formula.

$M_i = (1/2) \times L_i \times H_i$ (kN・m)

	free length of a pile Li	Hi	Mi
Pile 1	15.98	159.747	1,276.44
Pile 2	14.73	204.191	1,503.38
Pile 3	14.43	217.175	1,566.46
Pile 4	12.72	316.553	2,013.77

The axial force of individual piles may be calculated using following formula.

$N_i = ((M_{i-1,i} + M_{i,i-1}) / L_{i-1,i}) - ((M_{i,i+1} + M_{i+1,i}) / L_{i,i+1})$

where

$M_{i-1,i}$: bending moment acting on the head of the (i-1)-th pile due to the horizontal force of the side beam of the i-th pile (kN・m)

$M_{i,i-1}$: bending moment acting on the head of the i-th pile due to the horizontal force of the side beam of the (i-1)-th pile (kN・m)

$M_{i,i+1}$: bending moment acting on the head of the i-th pile due to the horizontal force of the side beam of the (i+1)-th pile (kN・m)

$M_{i+1,i}$: bending moment acting on the head of the (i+1)-th pile due to the horizontal force of the side beam of the i-th pile (kN・m)

References/ Notes

$L_{i-1,i}$: The interval of the pile of the (i-1)-th pile and i-th pile.

$L_{i,i+1}$: The interval of the pile of the i-th pile and (i+1)-th pile.

Since a pile interval is 3 spans, it is bending moment by the following formulas.

$M_{1,2} = 1.0 \times M_1 = 1.0 \times 1,276.44 = 1,276.44$ kN・m

$M_{2,1} = 0.5 \times M_2 = 0.5 \times 1,503.38 = 751.69$ kN・m

$M_{2,3} = 0.7 \times M_2 = 0.7 \times 1,503.38 = 1,052.37$ kN・m

$M_{3,2} = 0.7 \times M_3 = 0.7 \times 1,566.46 = 1,096.52$ kN・m

$M_{3,4} = 0.5 \times M_3 = 0.5 \times 1,566.46 = 783.23$ kN・m

$M_{4,3} = 1.0 \times M_4 = 1.0 \times 2,013.77 = 2,013.77$ kN・m

A pile interval is 5.5m.

The axial force of individual piles is as follows.

$N_1 = -(1,276.44+751.69)/5.50 = -368.75$ kN

$N_2 = ((1,276.44+751.69)/5.50)-((1,052.37+1,096.52)/5.50) = -21.96$ kN

$N_3 = ((1,052.37+1,096.52)/5.50)-((783.23+2,013.77)/5.50) = -117.84$ kN

$N_4 = ((783.23+2,013.77)/5.50) = 508.55$ kN

	Pile 1	Pile 2	Pile 3	Pile4
Deadweight + Surcharge※1	427.45	498.22	495.19	374.14
Ni	-368.75	-21.96	-117.84	508.55
Total (Ni)	58.70	476.26	377.35	882.69

※1 : It computes in static analysis.

b) Calculation of the element characteristics of a pile

The element characteristics of a pile consider corrosion.

(i) Sectional modulus of steel pipe pile in elastic domain

$Z_p = 4/3 \times (r^3 - (r-t)^3) = 4/3 \times (349^3 - (349-11)^3) = 5,192,103$ mm^3

(ii) Fully plastic state moment of steel pipe pile when no axial force acting (M_{po}) and The yield axial force (N_0)

Cross-section area of steel pipe pile A' = 23,741 mm^2

$M_{po} = Z_p f_y = 5,192,103 \times 315 / 1,000,000 = 1,635.51$ kN・m

$N_0 = A f_y = 23,741 \times 315 / 1,000 = 7,478.42$ kN

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c) Calculation of Fully Plastic State Moment (M_p)

(i) Calculation of "α (=N/No)"

No.	N (kN)	N_0 (kN)	α (=N/N_0)
Pile 1	58.70	7,478.42	0.0078490
Pile 2	476.26	7,478.42	0.0636852
Pile 3	377.35	7,478.42	0.0504587
Pile 4	882.69	7,478.42	0.1180311

※The number of piles of individual pile rows is three.

(ii) Calculation of fully plastic state moment (M_p)

Fully plastic state moments are computed using the following formulas.

$Mp = Mp_0 \times \cos(\alpha \times \pi/2)$ (kN・m)

No.	M_{p0} (kN・m)	M_p (kN・m)	Mi (kN・m)
Pile 1	1,625.51	1,635.39	> 1,276.44
Pile 2	1,625.51	1,627.34	> 1,503.38
Pile 3	1,625.51	1,630.38	> 1,566.46
Pile 4	1,625.51	1,607.48	< 2,013.77

※The number of piles of individual pile rows is three.

d) Calculation of the Horizontal Force (Py) Corresponding to the Elastic Limit

The horizontal force (Py) corresponding to the elastic limit is computed using the following formulas.

$Py = 0.82 \times P_{uall}$

where P_{uall} : the horizontal load level at which the bending moments of all the piles of the pier reach the fully plastic state moments (= ΣHj (kN))

Hj : the horizontal load level at which the bending moments of individual piles reach the fully plastic state moments (=2×Mpi / Li) (kN)

Mpi : fully plastic state moment of individual pile

No.	L_i (m)	M_{pi} (kN・m)	H_i (kN)
Pile 1	15.98	1,635.39	204.67
Pile 2	14.73	1,627.34	221.03
Pile 3	14.43	1,630.38	226.04
Pile 4	12.72	1,607.48	252.69
	P'_{uall} =		904.43

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The pile head moment of "Pile4" exceeds the fully plastic state moment. Therefore, other piles shall share a part of horizontal load of acting on "Pile4".

a ') Calculation of Member Forces Acting on Individual Piles

The redistributed horizontal load is shown below.

	free length of a pile Li(m)	K_{Hi}	K_{Hi} / ΣK_{Hi}	Hi(kN/本)
Pile 1	15.98	824	0.177959	203.000
Pile 2	14.73	1,053	0.227468	220.000
Pile 3	14.43	1,120	0.241933	225.000
Pile 4	12.72	1,633	0.352640	250.000
	ΣK_{Hi} =	4,629		

※The number of piles of individual pile rows is three.

"Hi" is the horizontal force per a pile.

The pile head moments (Mi) of individual piles are shown below.

	free length of a pile Li(m)	Hi	M_i
Pile 1	15.98	203.000	1,622.05
Pile 2	14.73	220.000	1,619.78
Pile 3	14.43	225.000	1,622.90
Pile 4	12.72	250.000	1,590.39

Since a pile interval is 3 spans, it is bending moment by the following formulas.

$M_{1,2} = 1.0 \times M_1 = 1.0 \times 1{,}622.05 = 1{,}622.05$ kN・m

$M_{2,1} = 0.5 \times M_2 = 0.5 \times 1{,}619.78 = 809.89$ kN・m

$M_{2,3} = 0.7 \times M_2 = 0.7 \times 1{,}619.78 = 1{,}133.85$ kN・m

$M_{3,2} = 0.7 \times M_3 = 0.7 \times 1{,}622.90 = 1{,}136.03$ kN・m

$M_{3,4} = 0.5 \times M_3 = 0.5 \times 1{,}622.90 = 811.45$ kN・m

$M_{4,3} = 1.0 \times M_4 = 1.0 \times 1{,}590.39 = 1{,}590.39$ kN・m

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A pile interval is 5.5m.

The axial force of individual piles is as follows.

N_1 = - (1,622.05+809.89)/5.50 = -442.17 kN

N_2 = ((1,622.05+809.89)/5.50)-((1,133.85+1,136.03)/5.50) = 29.47 kN

N_3 = ((1,133.85+1,136.03)/5.50)-((811.45+1,590.39)/5.50) = -23.99 kN

N_4 = ((811.45+1,590.39)/5.50) = 436.70 kN

	Pile 1	Pile 2	Pile 3	Pile 4
Deadweight + Surcharge※1	427.45	498.22	495.19	374.14
Ni	-442.17	29.47	-23.99	436.70
Total (Ni)	-14.72	527.69	471.20	810.84

※1 : It computes in static analysis.

c ') Calculation of Fully Plastic State Moment (M_p)

(i) Calculation of " α (=N/N_0)"

No.	N (kN)	N_0 (kN)	α (=N/N_0)
Pile 1	-14.72	7,478.42	-0.00196845
Pile 2	527.69	7,478.42	0.0705612
Pile 3	471.20	7,478.42	0.0630075
Pile 4	810.84	7,478.42	0.1084237

※The number of piles of individual pile rows is three.

(ii) Calculation of fully plastic state moment (M_p)

No.	M_{p0} (kN·m)	M_p (kN·m)	Mi (kN·m)
Pile 1	1,625.51	1,635.50	> 1,622.05
Pile 2	1,625.51	1,625.48	> 1,619.78
Pile 3	1,625.51	1,627.51	> 1,622.90
Pile 4	1,625.51	1,611.85	> 1,590.39

※The number of piles of individual pile rows is three.

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d') Calculation of the Horizontal Force (Py) Corresponding to the Elastic Limit

No.	L_i (m)	M_{pi} (kN·m)	H_i (kN)
Pile 1	15.98	1,635.50	204.68
Pile 2	14.73	1,625.48	220.77
Pile 3	14.43	1,627.51	225.64
Pile 4	12.72	1,611.85	253.37
P'_{uall} =			904.46

The number of piles of individual pile rows is three.

Therefore, the horizontal load level at which the bending moments of all the piles of the platform1 reach the fully plastic state moments is as follows.

$P_{uall} = P'_{uall} \times 3 = 904.46 \times 3 = 2{,}713.41$ kN

- Calculation of the horizontal force (Py) corresponding to the elastic limit

$P_y = 0.82\ P_{uall} = 0.82 \times 2{,}713.41 = 2{,}225.00$ kN

e) Examination of Earthquake-Resistant Performance

As for the allowable displacement ductility factor (μa), importance level adopts the value 1.30 of the class-A.

- Calculation of the Load Carrying Capacity of the Pile-Supported Section during an Earthquake(Ra) of Platform 1

$R_a = \sqrt{(2\mu_a - 1)} \times P_y = \sqrt{(2 \times 1.3 - 1)} \times 2{,}225.00 = 2{,}814.42$ kN

- Earthquake force of using for examination of load carrying capacity

$k_h W = 0.50 \times 5{,}385 = 2{,}692.50$ kN $\leqq$ Ra O.K

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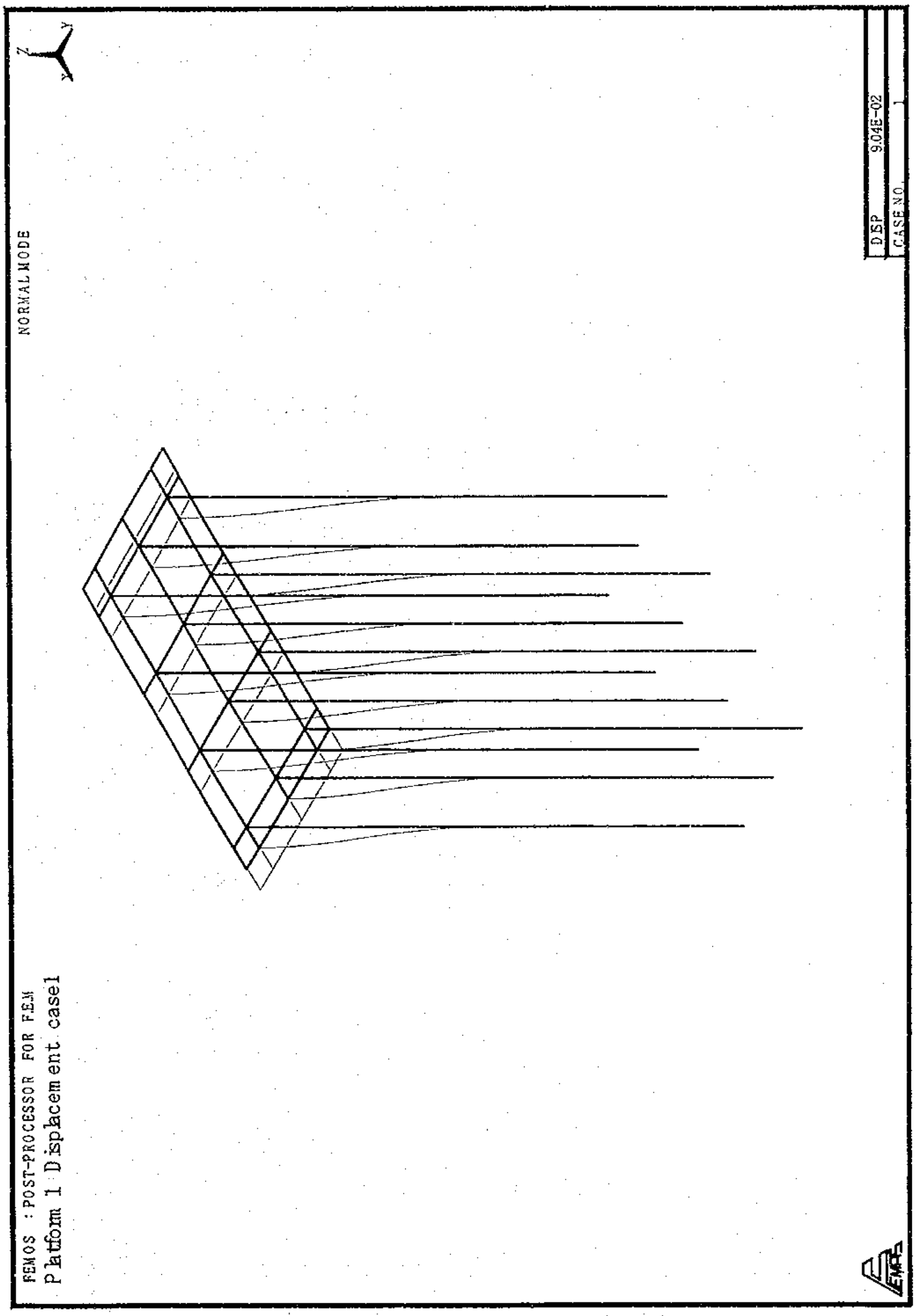
<Appending Data>

1) Cross-Section Force Figure

(1) Case1 (Earthquake Sea→Land) ・Displacement



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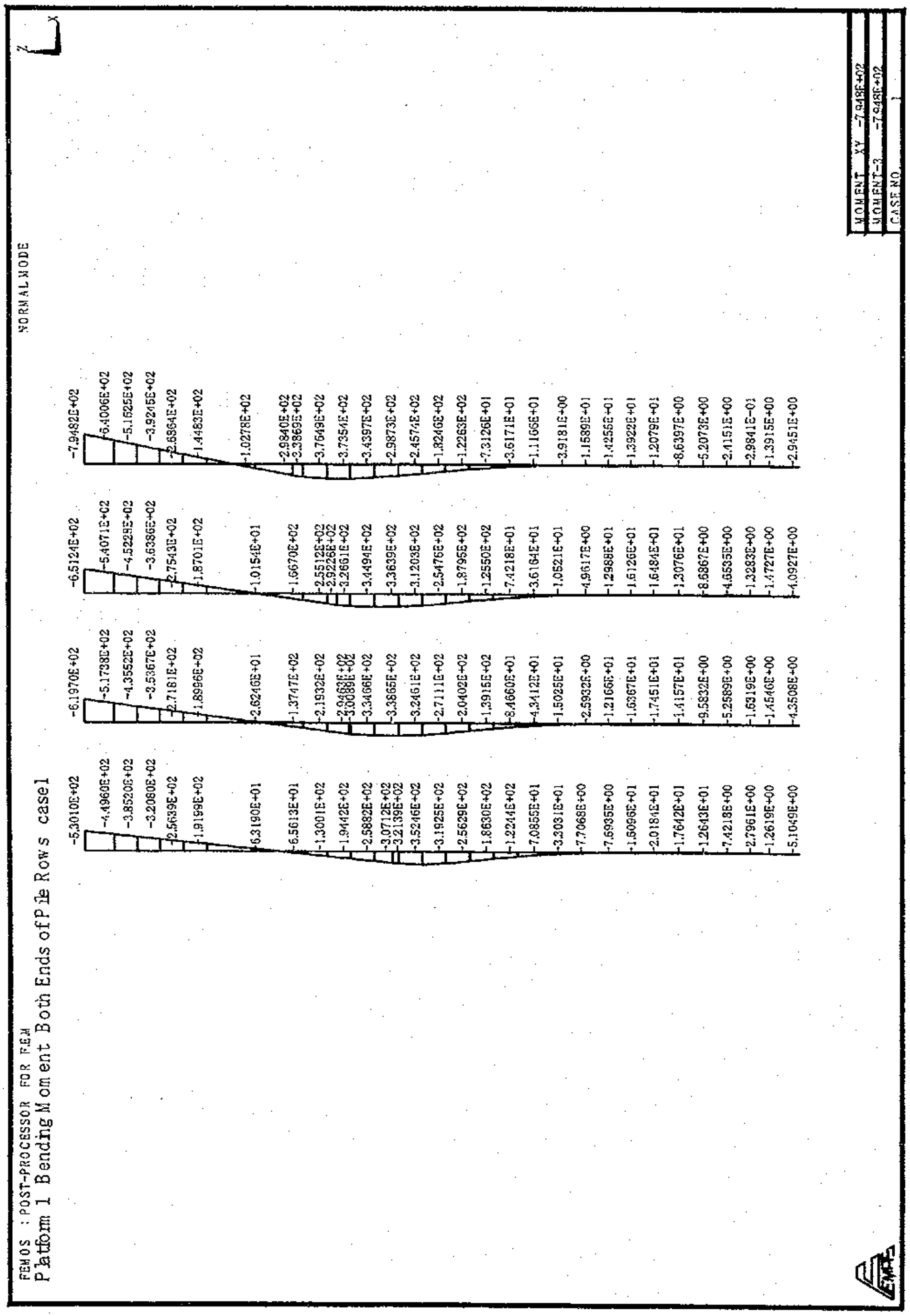
References/ Notes

・Bending Moment (Both Ends of Pile Rows Pile 1 (Left Side)~Pile 4 Right Side))



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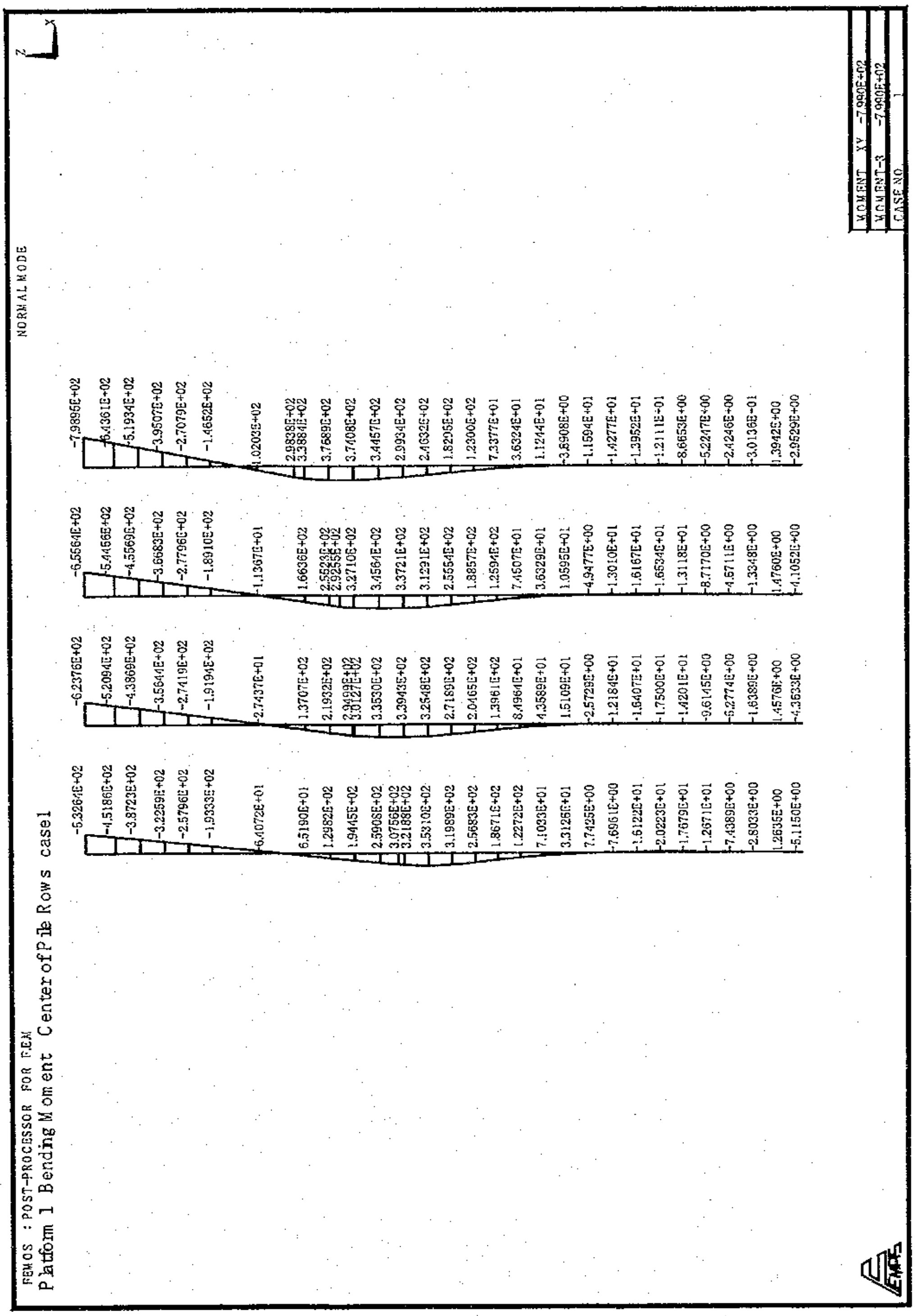
・Bending Moment (Center of Pile Rows Pile 1 (Left Side)~Pile 4 (Right Side))



	Prepared by	Y. Ando	Checked by	R. NISHIMURA
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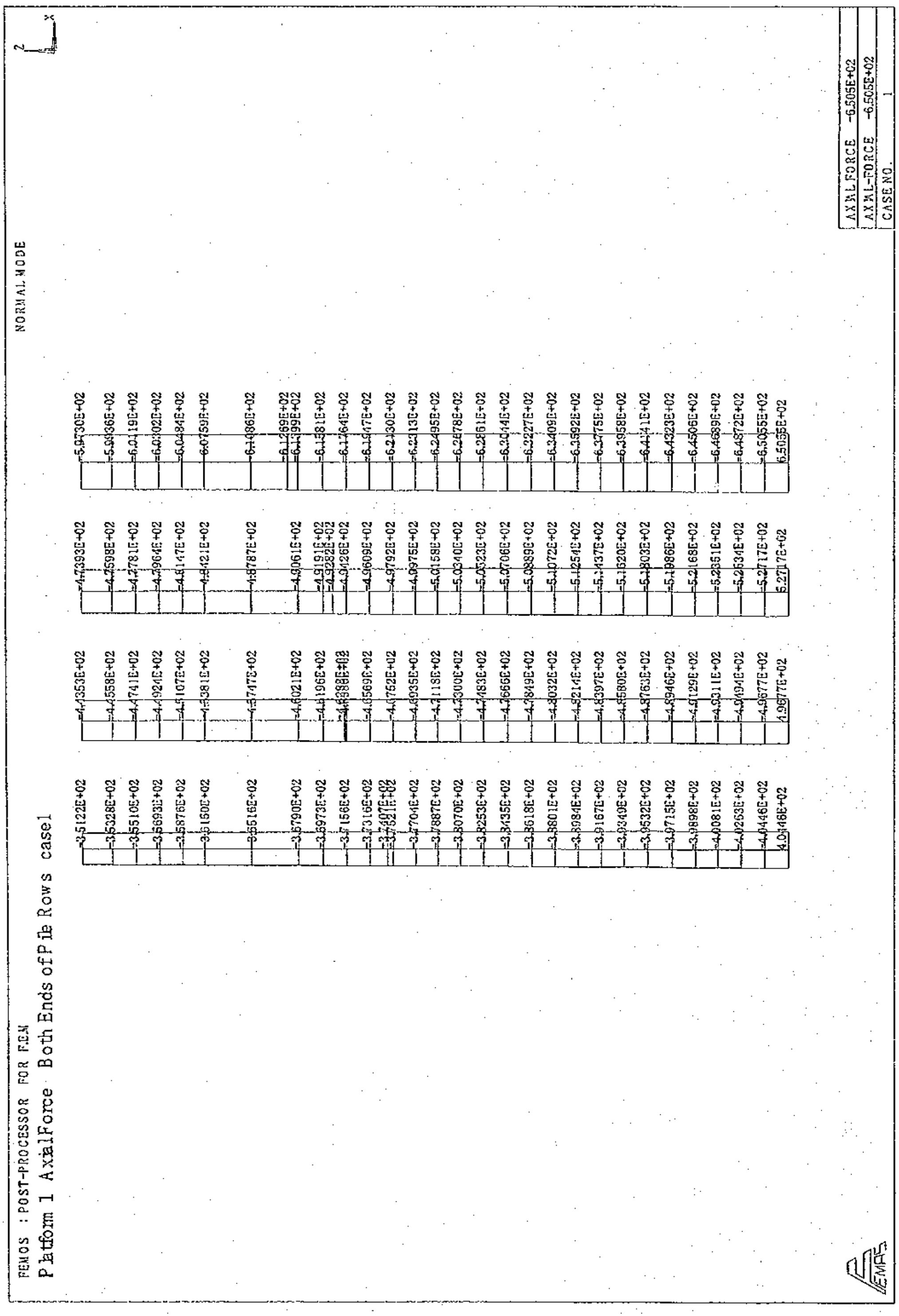
・Axial Force（Both Ends of Pile Rows Pile 1 (Left Side)～Pile 4 (Right Side)）



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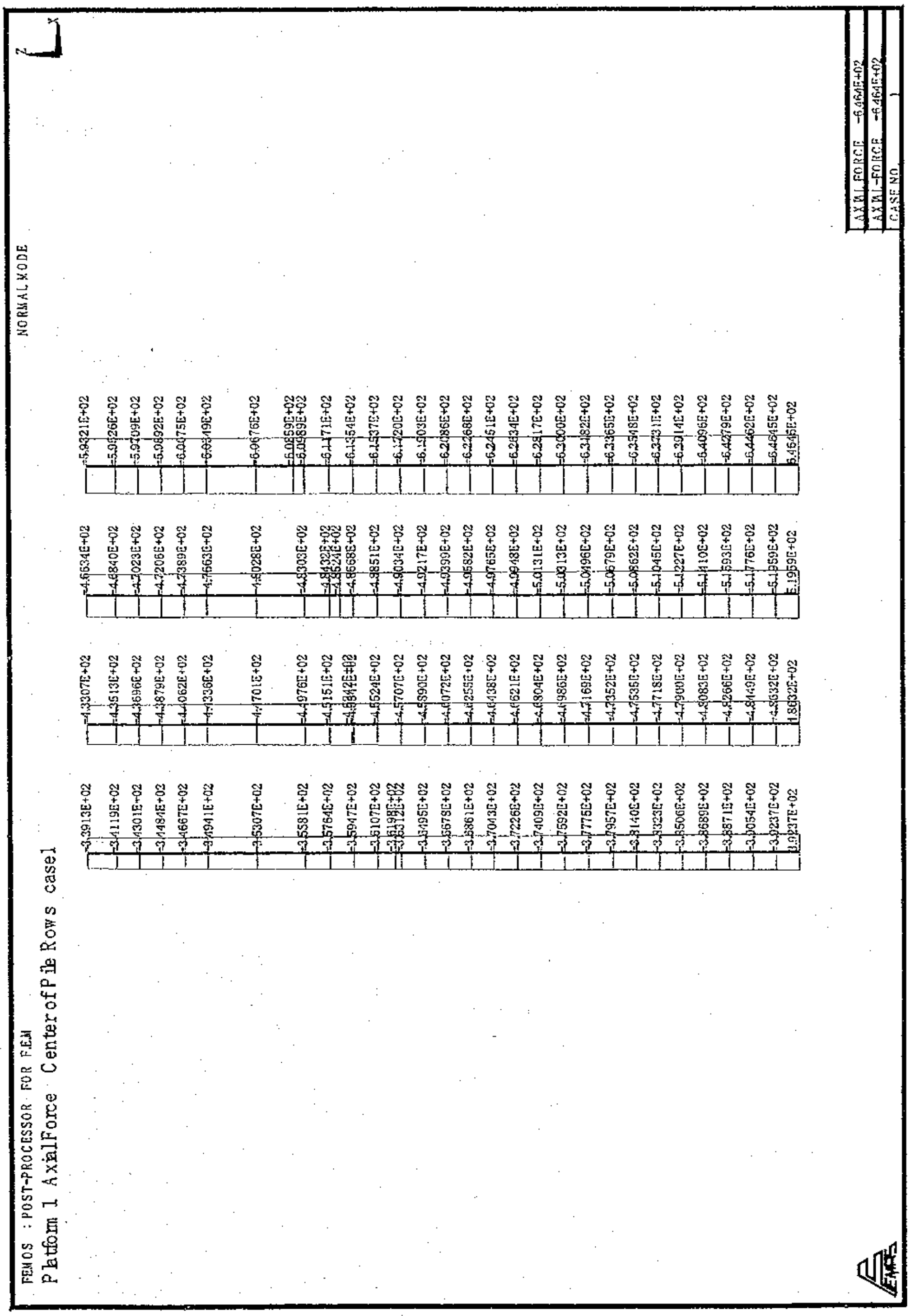
・Axial Force (Center of Pile Rows Pile 1 (Left Side) ～Pile 4 (Right Side))



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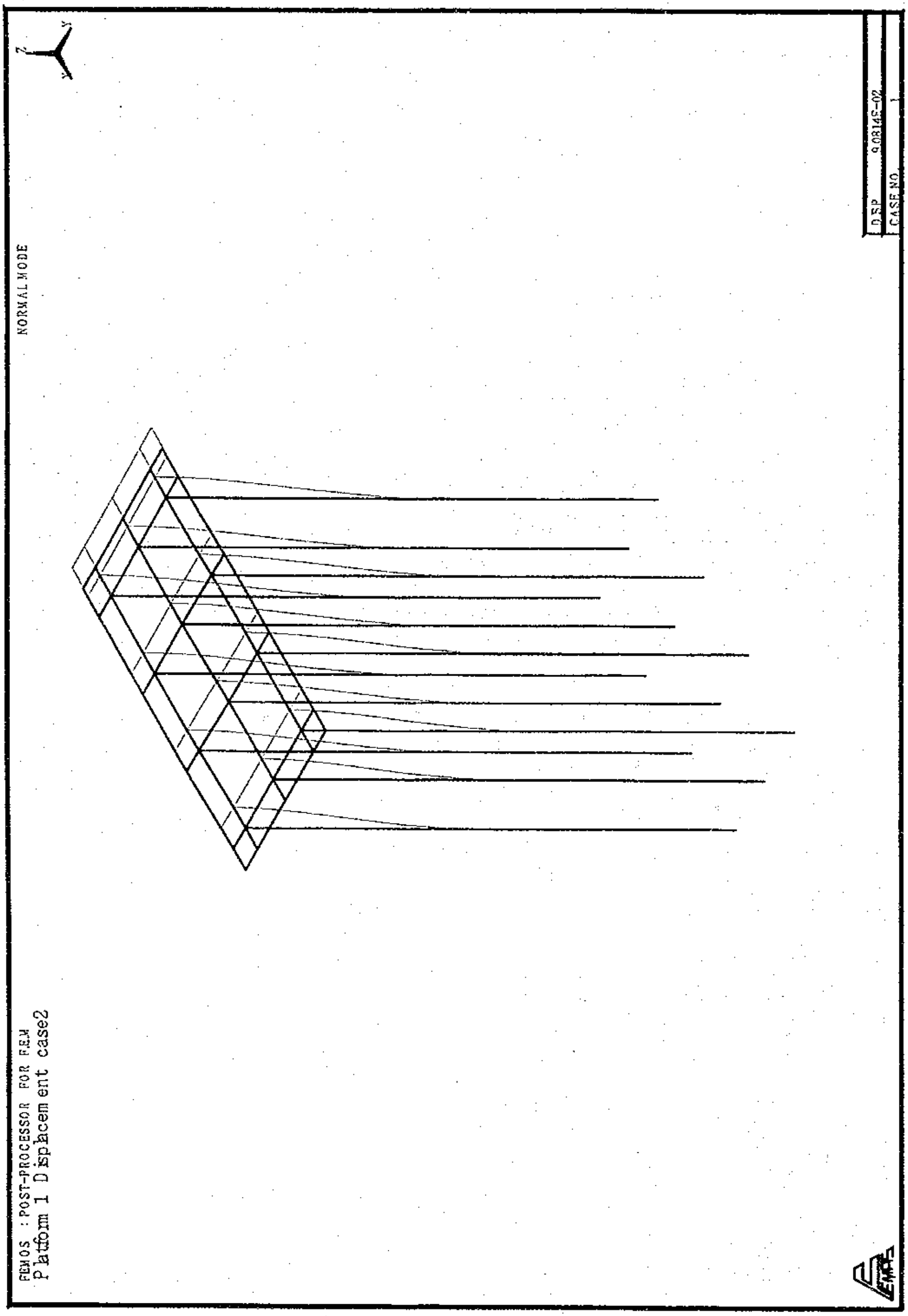
(2) Case2 (Earthquake Land→Sea)

・Displacement



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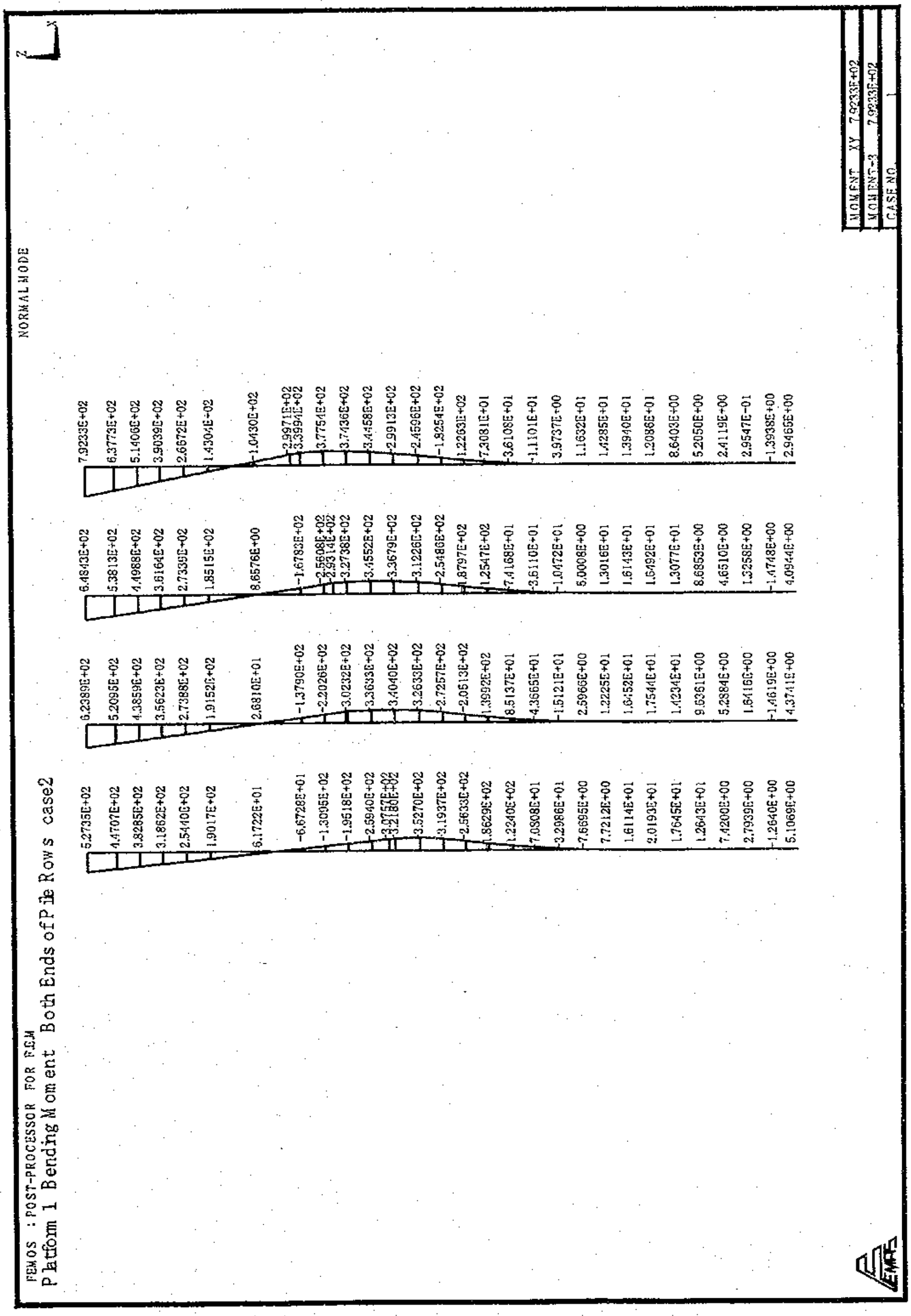
References/ Notes

• Bending Moment (Both Ends of Pile Rows Pile 1 (Left Side)~Pile 4 (Right Side))



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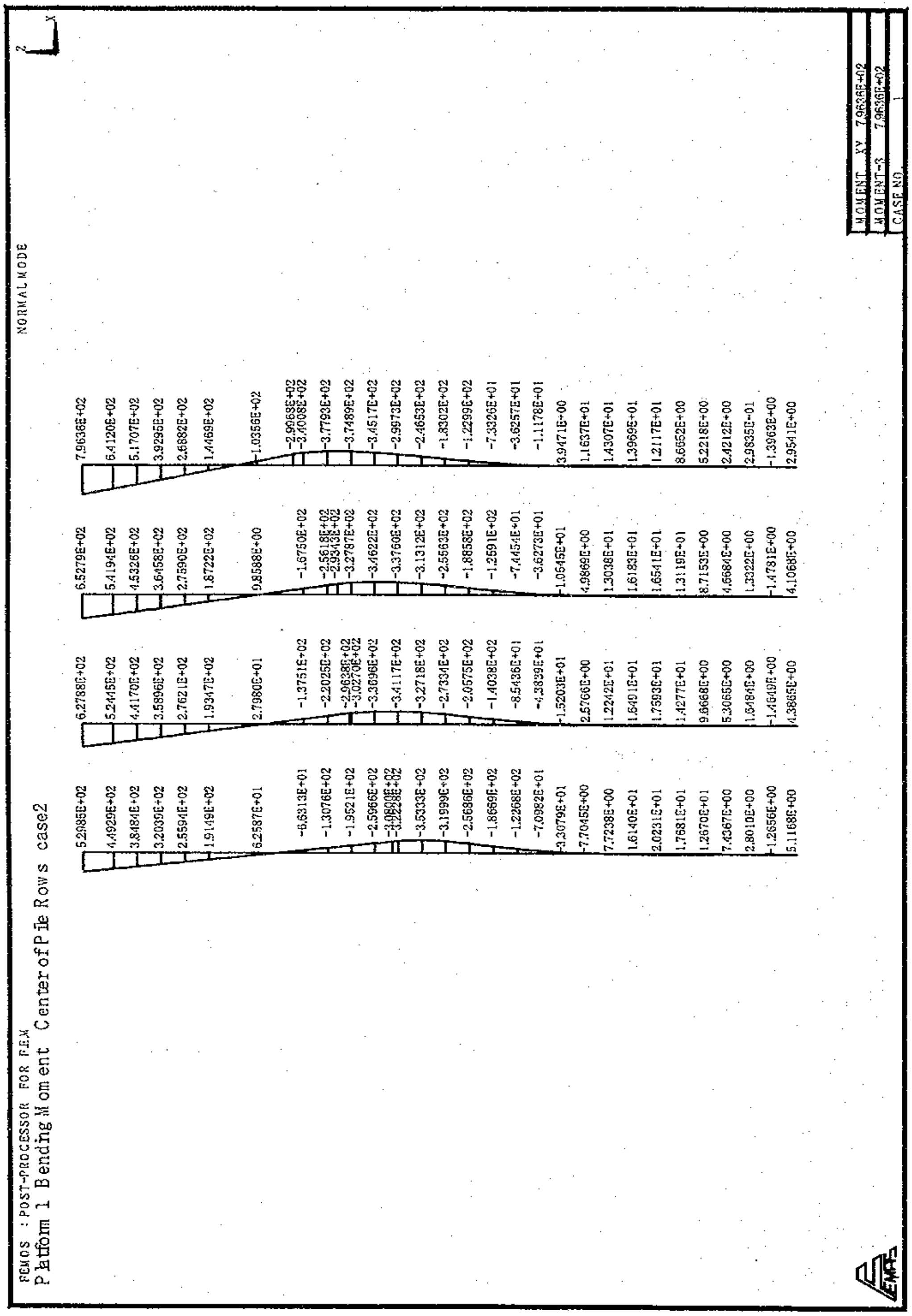
・Bending Moment (Center of Pile Rows Pile 1 (Left Side)~Pile 4 (Right Side))



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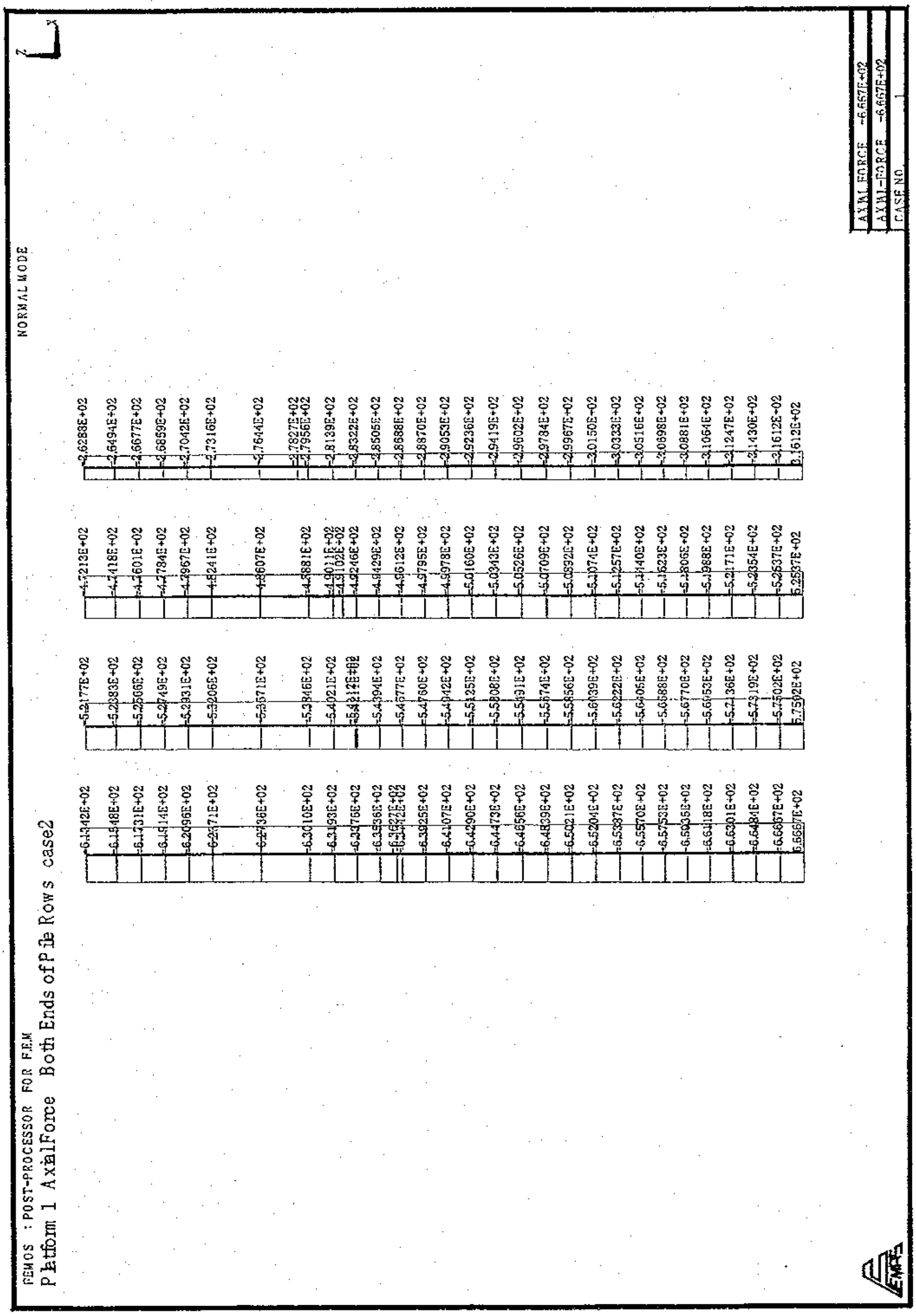
・Axial Force (Both Ends of Pile Rows Pile 1 (Left Side)~Pile 4 (Right Side))



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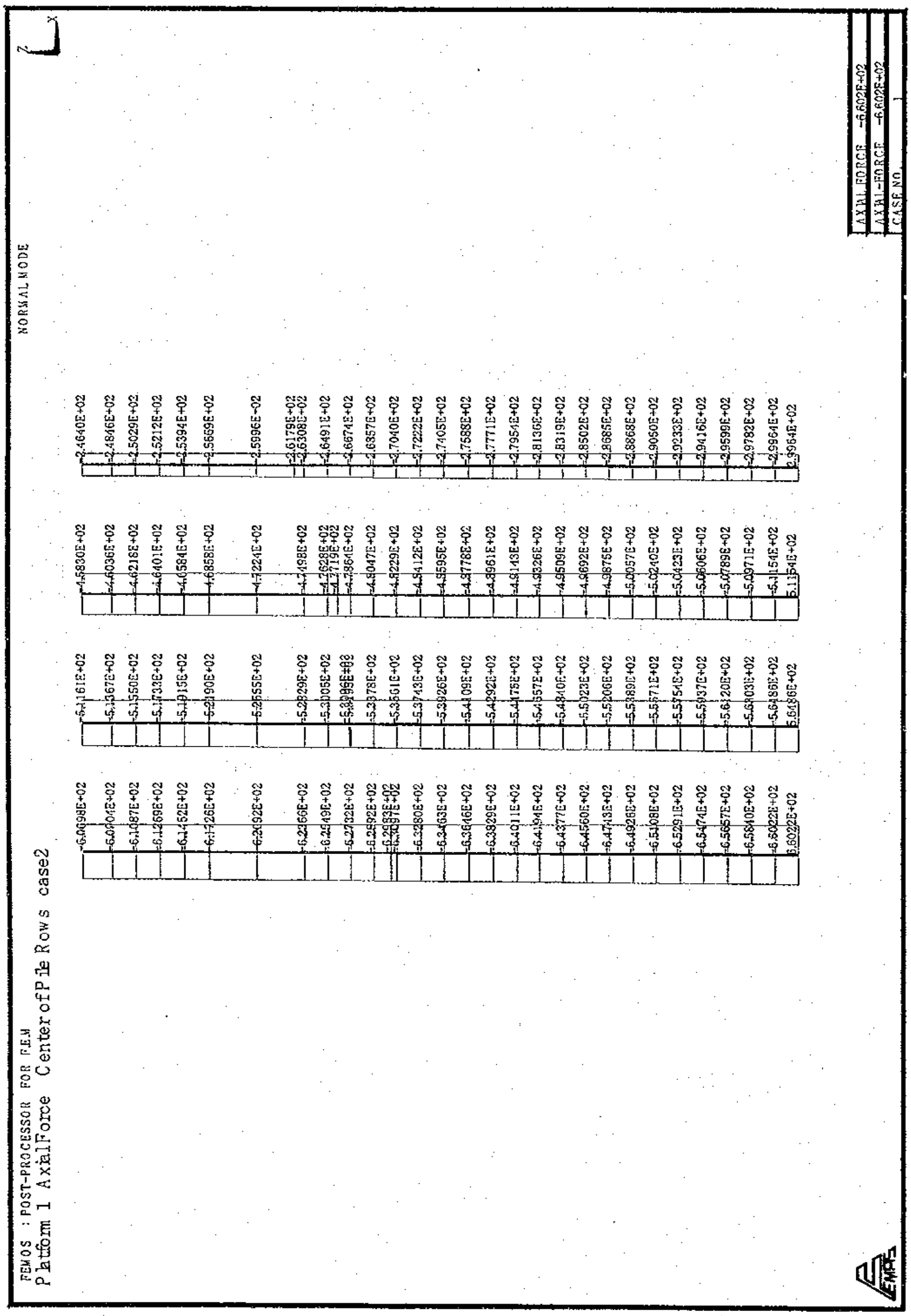
・Axial Force (Center of Pile Rows Pile 1 (Left Side)~Pile 4 (Right Side)



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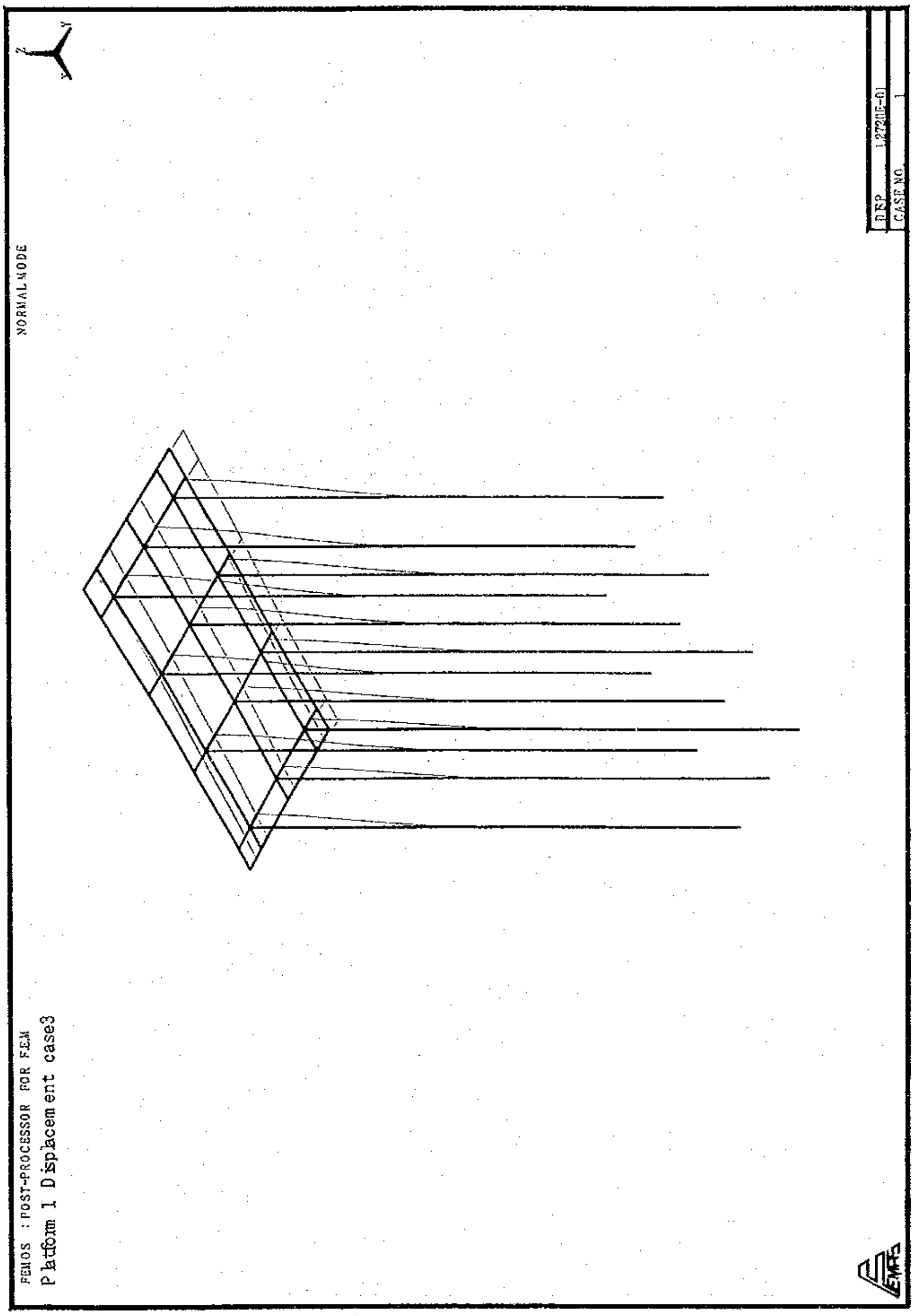
(3) Case3 (Earthquake Parallel Direction to the Face Line)

・Displacement



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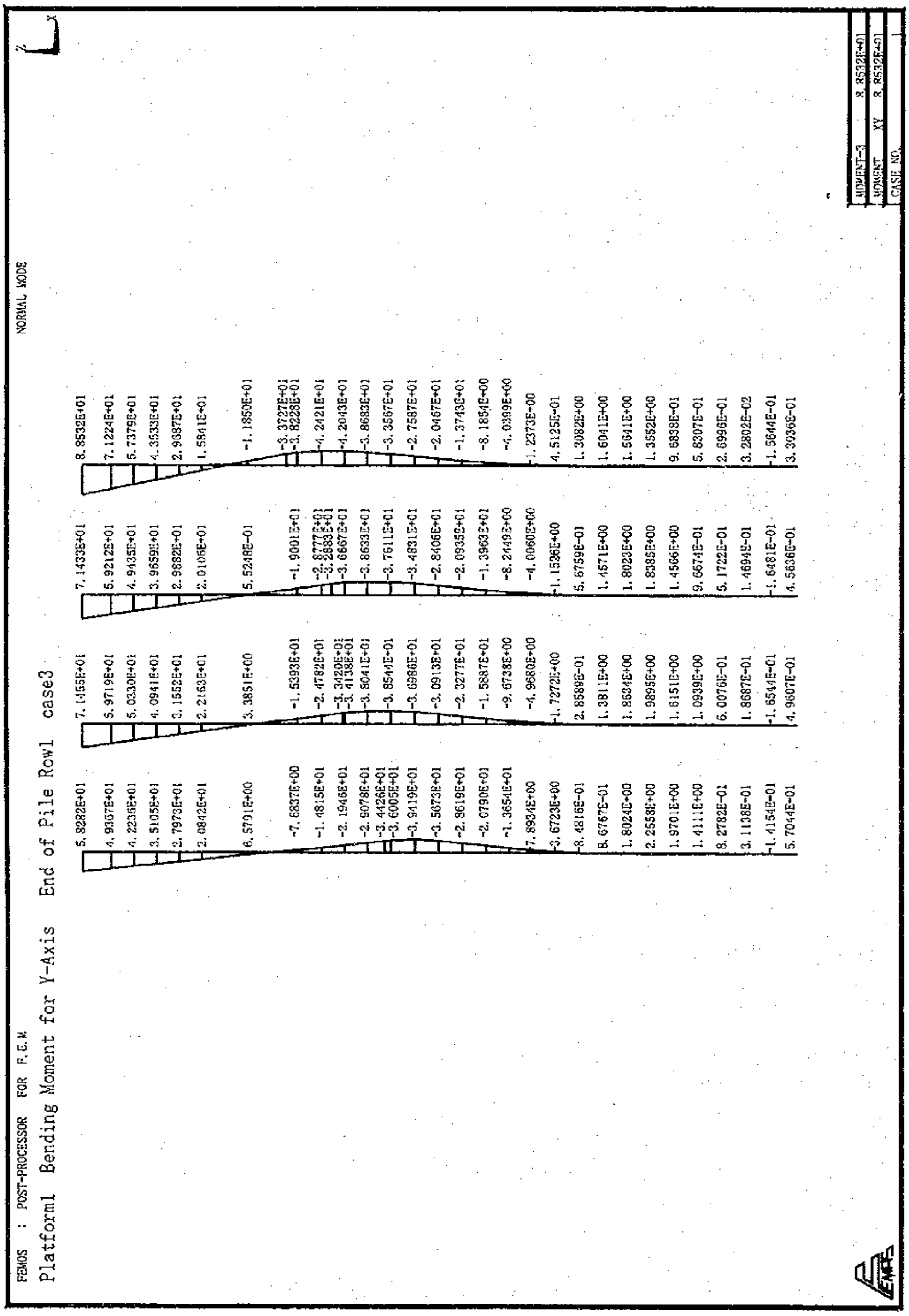
• Bending Moment for Y-Axis

(End of Pile Row 1 Pile 1 (Left Side)~Pile 4 (Right Side))



		Prepared by Y. Ando	Checked by R. NISHIMURA
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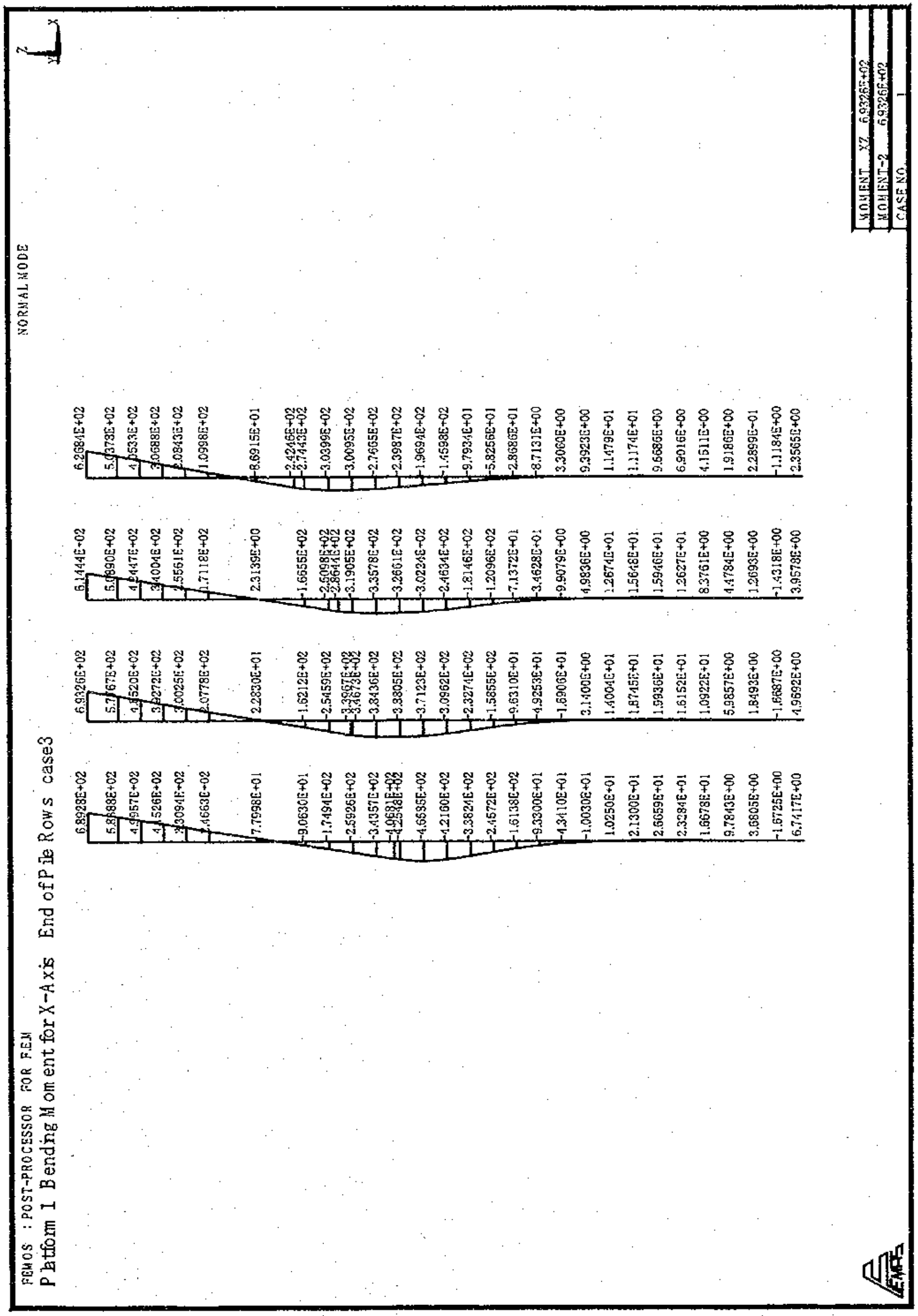
· Bending Moment for X-Axis

(End of Pile Row 1 Pile 1 (Left Side)~Pile 4 (Right Side))



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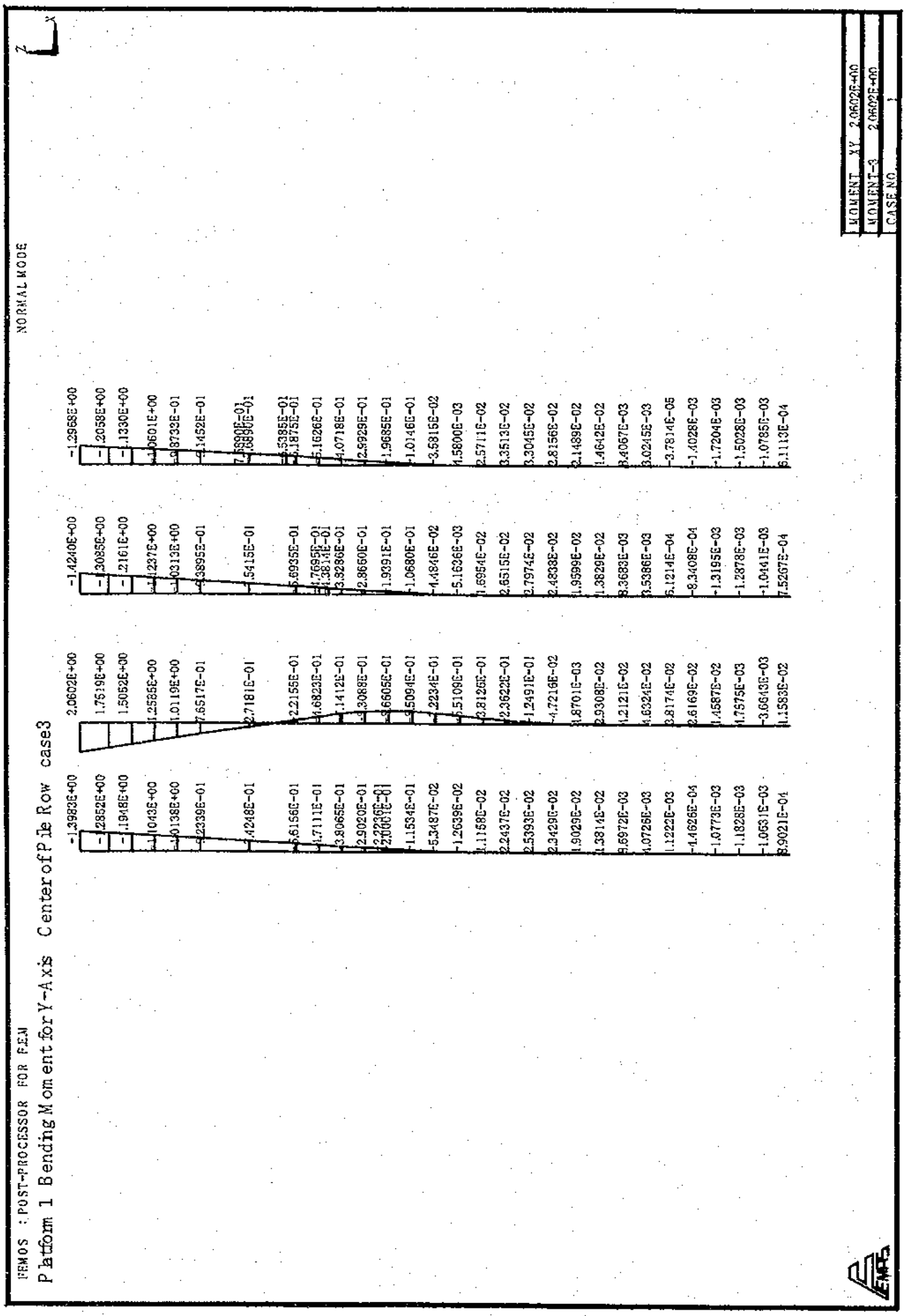
· Bending Moment for Y-Axis

(Center of Pile Row　Pile 1 (Left Side)～Pile 4 (Right Side))



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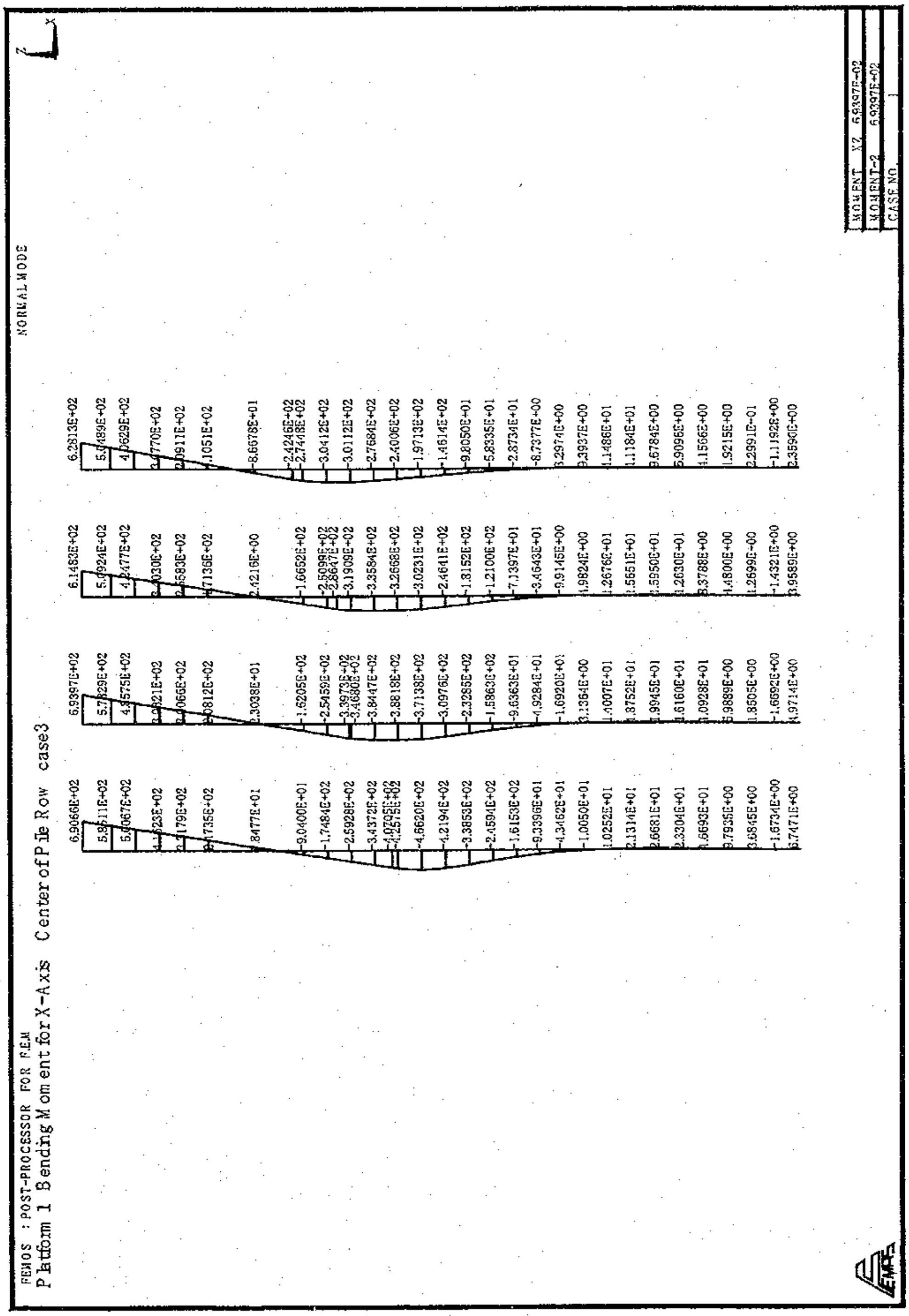
・Bending Moment for X-Axis

(Center of Pile Row Pile 1 (Left Side)~Pile 4 (Right Side))



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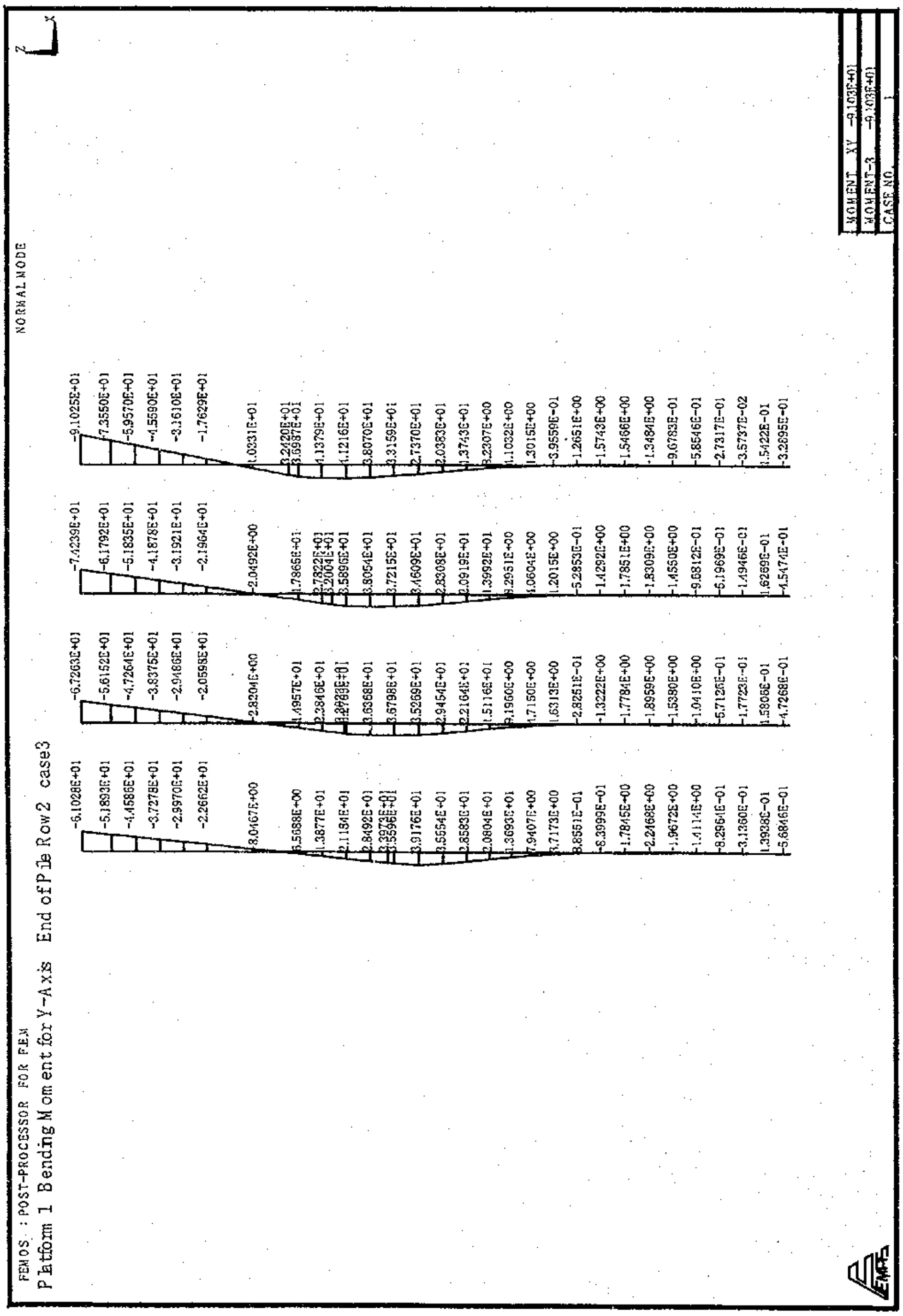
・Bending Moment for Y-Axis

(End of Pile Row 2　Pile 1 (Left Side)～Pile 4 (Right Side))



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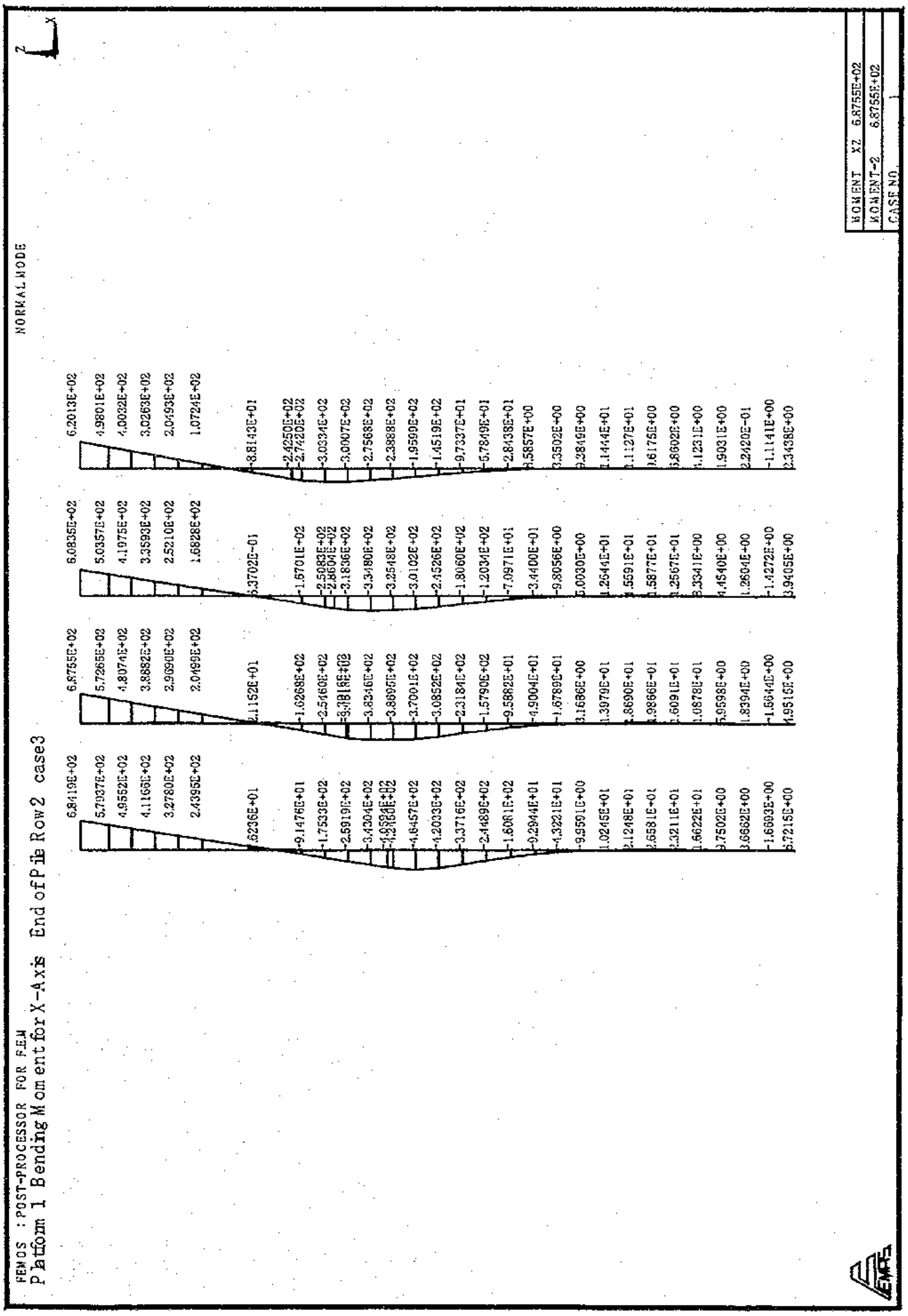
・Bending Moment for X-Axis

(End of Pile Row 2 Pile 1 (Left Side)～Pile 4 (Right Side))



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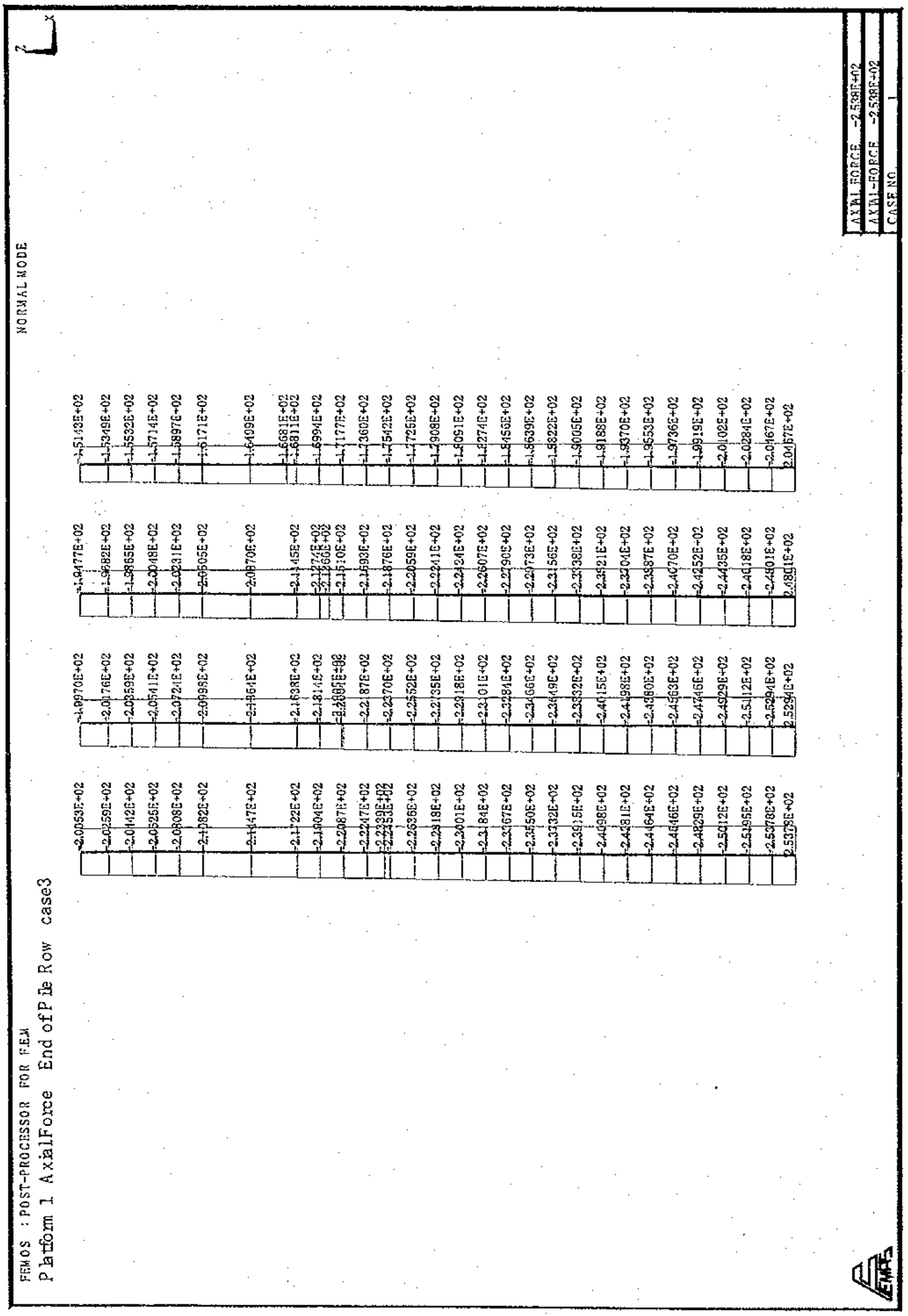
• Axial Force (End of Pile Row 1 Pile 1 (Left Side)~Pile 4 (Right Side))



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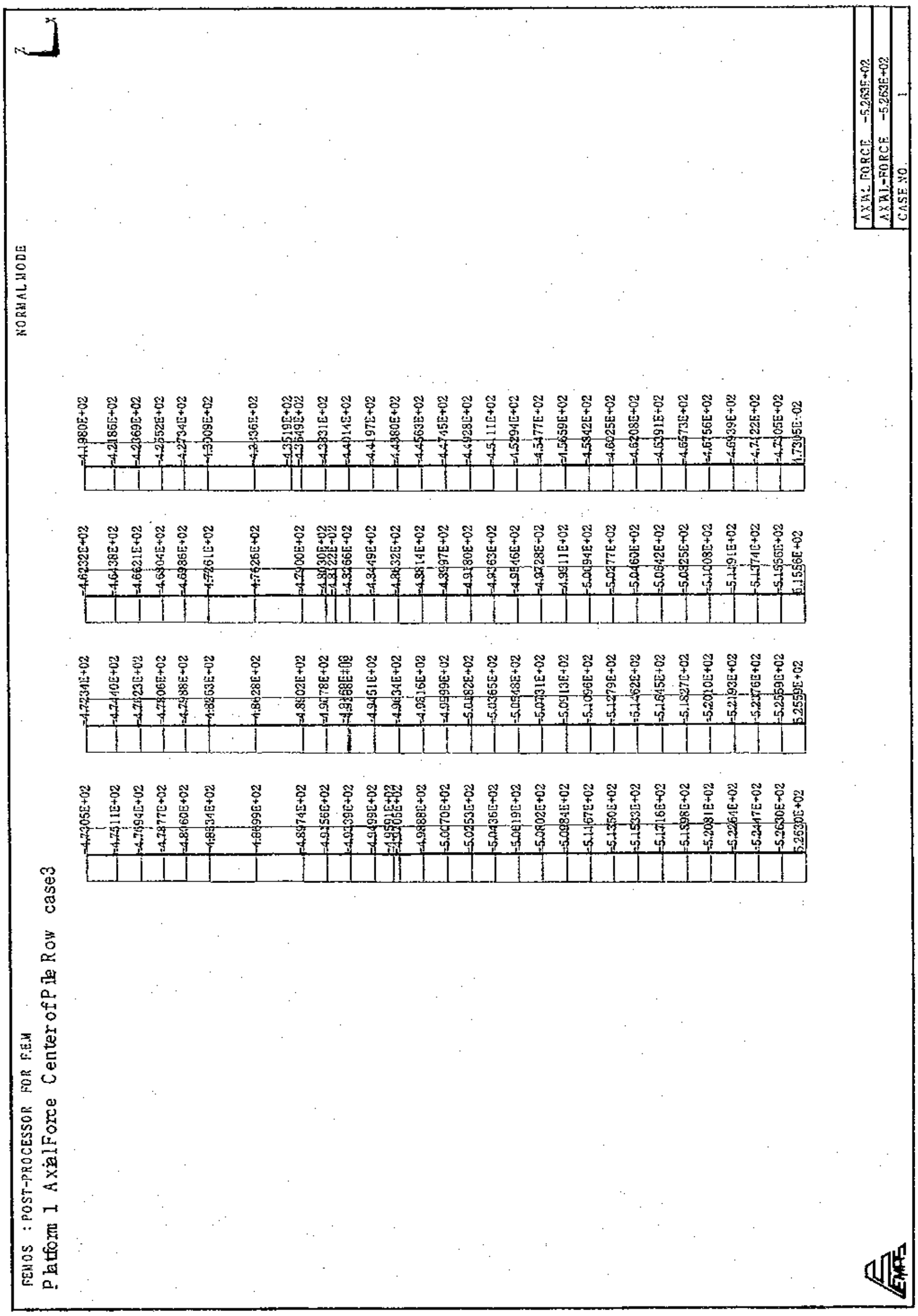
・Axial Force (Center of Pile Row Pile 1 (Left Side)~Pile 4 (Right Side))



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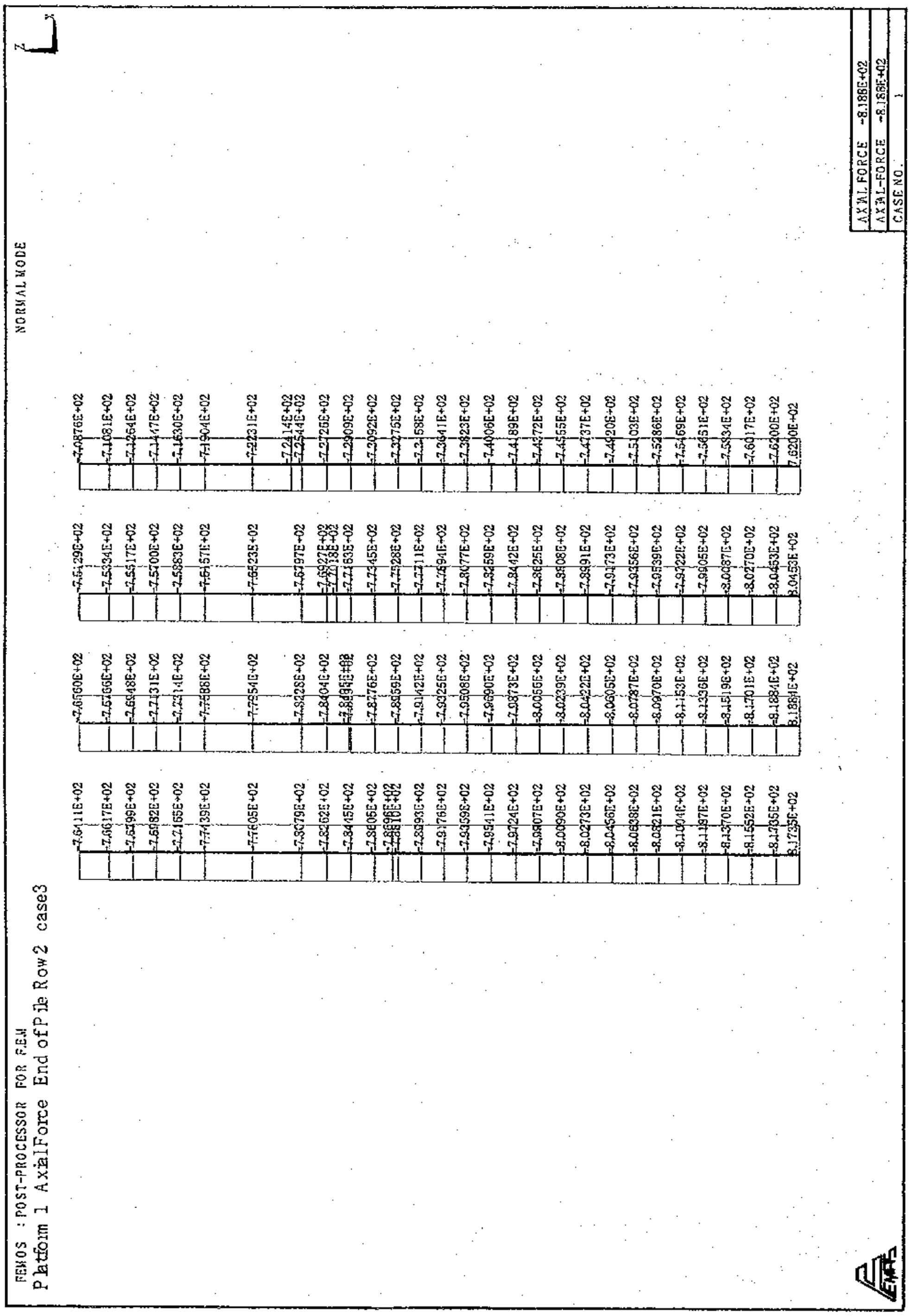
・Axial Force（End of Pile Row 2　Pile 1 (Left Side)～Pile 4 (Right Side))



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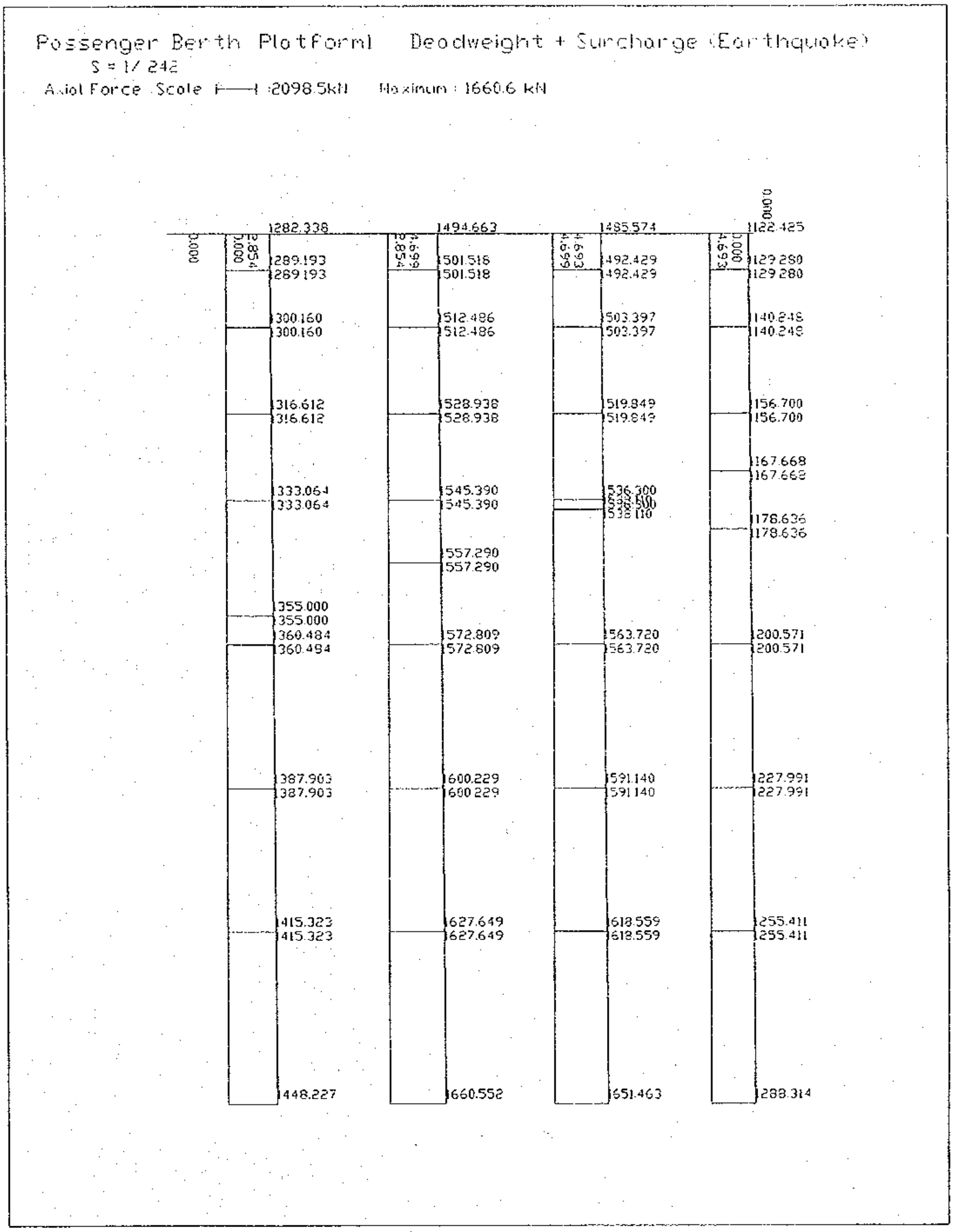
(4) Earthquake Condition

Static Load (Deadweight and Surcharge) Action Condition Axial Force



(Cross-sectional force is a value per three piles.)

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