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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 2.

References, Calculation Notes and Comments

Refer todrawings **QW-02-001,QW-02-003**

Calculation based on

TECHNICAL STANDERDS AND COMMENTARIES

FOR

PORT AND HARBOUR FACILITIES IN JAPAN

Design condition **Refer to Design Condotions of this report**

Rev	Prepared by	Prepared Date	No. of Pages	Checked by	Checked Date	Reviewed by	Reviewed Date	Superseded by Calc No.
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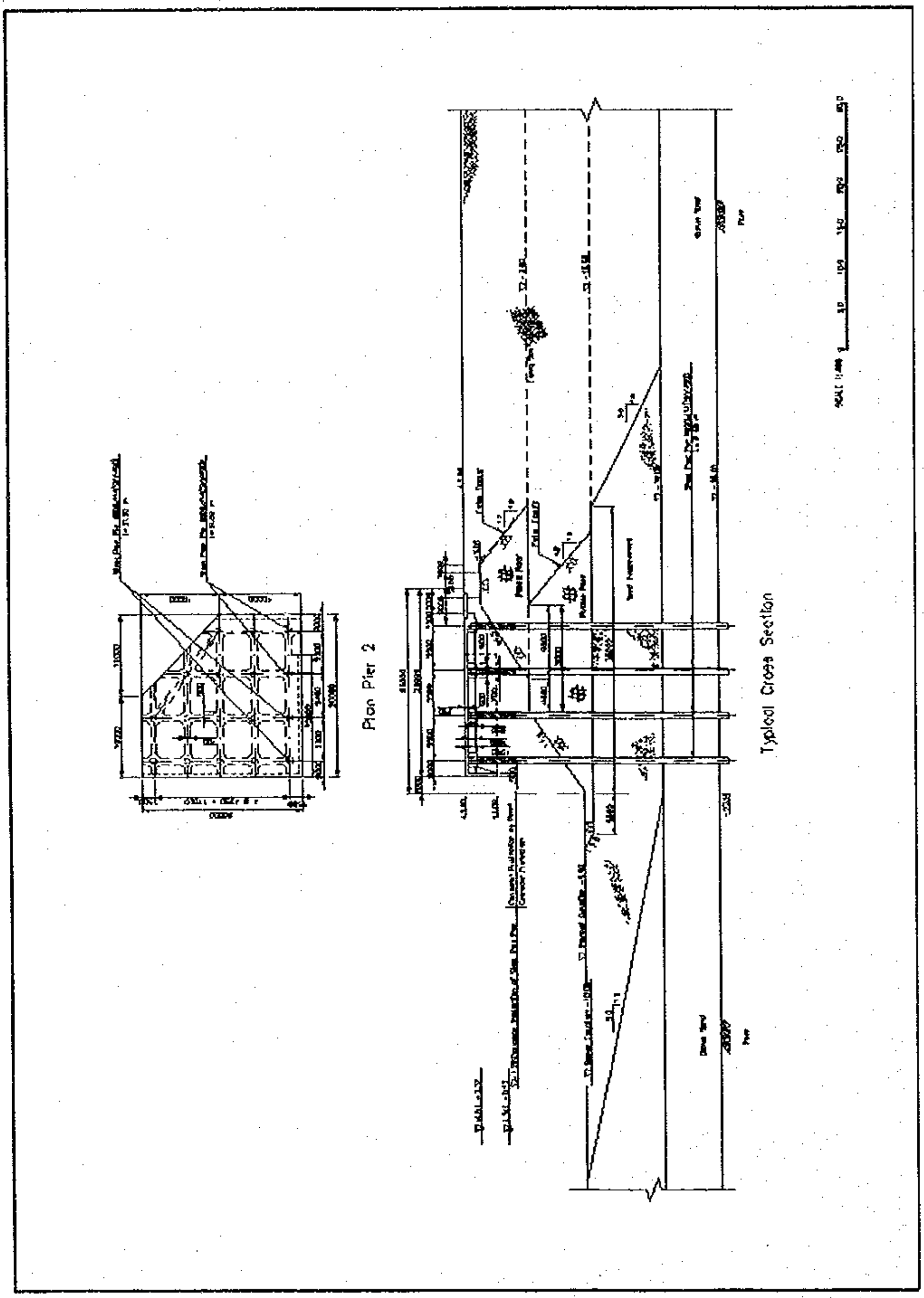
4 . Basic Design of Platform2 (Passenger Berth)

1) Outline structure of a platform 2



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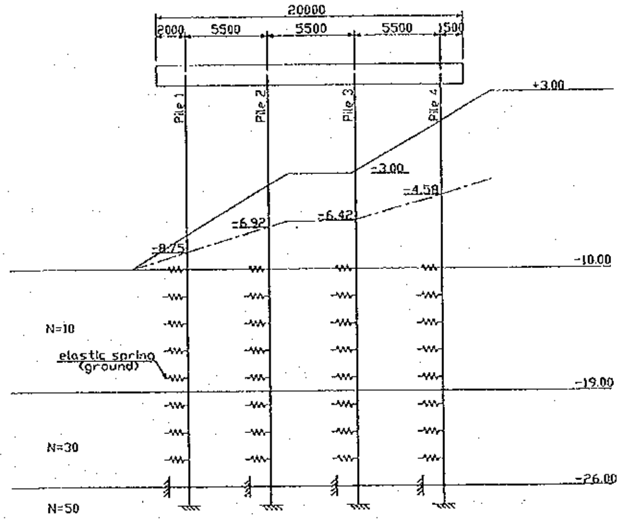
		26/07/2002		08/08/2002

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×D (N/cm²) kh : coefficient of horizontal subgrade reaction(N/cm³)

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

ϕ 800×t14 Section area A = 345.7 cm² (Corrosion consideration A' = 320.6 cm²)

Geometrical moment of inertia I = 267,050 cm⁴

(Corrosion consideration I' = 247,019 cm⁴

Section modulus Z = 6,686 cm³

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

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 : 304.95 m^3

Weight of superstructure : 上部工全重量 7,318.8 → 7,320.0 kN

conversion to equivalent uniform distribution load

$$w' = 7,320 / (20.0\times 20.0-(10.0\times 10.0/2)) = 20.91 \text{ kN/m}^2$$

(2) Surcharge

Surcharge $w = 10.0$ kN/m^2

Total of Surcharge $W' = 10.0\times(20.0\times 20.0-(10.0\times 10.0/2)) = 3,500$ kN

(3) Calculation of Earthquake Force

$P = (7,3200+3,500)\times 0.20 = 2,165.0$ 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			
case 1	Earthquake	7,320.00	3,500.00	2,165.00	Extraordinary	Sea→Land	1.50
case 2	Earthquake	7,320.00	3,500.00	2,165.00	Extraordinary	Land→Sea	1.50
case 3	Earthquake	7,320.00	3,500.00	2,165.00	Extraordinary	Parallel to the face line	1.50

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)	861.7	410.8	482.7	9.1
	Pile 2	968.7	862.4	934.3	
	Pile 3	1,025.1	1,000.3	1,072.2	
	Pile 4 (Land side)	1,202.2	1,027.8	1,099.7	
case2 Earthquake Land→Sea	Pile 1 (Sea side)	862.4	787.8	859.7	9.1
	Pile 2	1,013.1	612.3	684.2	
	Pile 3	1,031.8	594.6	666.5	
	Pile 4 (Land side)	1,201.7	363.1	435.0	
case3 Earthquake Parallel to the face line	Pile 1 (Sea side)	959.6	806.8	878.7	10.3
	Pile 2	989.7	1,064.2	1,135.1	
	Pile 3	931.8	1,084.0	1,155.9	
	Pile 4 (Land side)	1,014.1	918.2	990.1	

※The moment compounded the moment about the parallel direction to the face line, and the moment about the right-angled 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 the face line)

Pile 2 : case3 (Earthquake、 Action direction Parallel to the face line)

Pile 3 : case1 (Earthquake、 Action direction Sea→Land)

Pile 4 : case1 (Earthquake、 Action direction Sea→Land)

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6) Stress Examination of Piles

Passenger Berth ,Platform 2 φ800*t14

Stress Calculation (Case3) Pile 1

Pile	Dimension	φ800*t14		SKK 490		
	Cross-sectional Area	A= 345.7 cm^2				
	Section modulus	Z= 6,676 cm^3				
	Radius of qyration of area	r= 27.8 cm^2				
	Bulkling length	l= 1300 cm				
		l/r= 46.8				
Section force	Bending Moment	M= 959.6 kN·m				
	Axial Force	N= 806.8 kN				
Stress	Allowable Bending Stress	σ ba= 185 N/mm^2				
	Allowable Axial Compressive Stress	σ ca= 148 N/mm^2				
	Premium Coefficient	1.5				
	Bending Stress	σ b= 144 N/mm^2	<	278 N/mm^2	O.K.	
	Axial Compressive Stress	σ c= 23 N/mm^2	<	222 N/mm^2	O.K.	
	Examination of menbers simultaneously subject to axial	0.62			O.K.	

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Passenger Berth ,Platform 2 ϕ800*t14

Stress Calculation (Case3) Pile 2

Pile	Dimension	ϕ800*t14	SKK 490	
	Cross-sectional Area	A= 345.7 cm^2		
	Section modulus	Z= 6,676 cm^3		
	Radius of qyration of area	r= 27.8 cm^2		
	Bulkling length	l= 1123 cm		
		l/r= 40.4		
Section force	Bending Moment	M= 989.7 kN·m		
	Axial Force	N= 1,064.2 kN		
Stress	Allowable Bending Stress	σ ba= 185 N/mm^2		
	Allowable Axial Compressive Stress	σ ca= 156 N/mm^2		
	Premium Coefficient	1.5		
	Bending Stress	σ b= 148 N/mm^2	< 278 N/mm^2	O.K.
	Axial Compressive Stress	σ c= 31 N/mm^2	< 234 N/mm^2	O.K.
	Examination of menbers simultaneously subject to axial	0.67		O.K.

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Passenger Berth ,Platform 2 ϕ800*t14

Stress Calculation (Case1) Pile 3

Pile	Dimension	ϕ800*t14		SKK 490		
	Cross-sectional Area	A=	345.7 cm^2			
	Section modulus	Z=	6,676 cm^3			
	Radius of qyration of area	r=	27.8 cm^2			
	Bulkling length	l=	1075 cm			
		l/r=	38.7			
Section force	Bending Moment	M=	1,025.1 kN·m			
	Axial Force	N=	1,000.3 kN			
Stress	Allowable Bending Stress	σ ba=	185 N/mm^2			
	Allowable Axial Compressive Stress	σ ca=	158 N/mm^2			
	Premium Coefficient		1.5			
	Bending Stress	σ b=	154 N/mm^2	<	278 N/mm^2	O.K.
	Axial Compressive Stress	σ c=	29 N/mm^2	<	237 N/mm^2	O.K.
	Examination of menbers simultaneously subject to axial		0.68			O.K.

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Passenger Berth ,Platform 2 ϕ800*t14

Stress Calculation (Case1) Pile 4

Pile	Dimension	ϕ800*t14	SKK 490		
	Cross-sectional Area	A= 345.7 cm^2			
	Section modulus	Z= 6,676 cm^3			
	Radius of qyration of area	r= 27.8 cm^2			
	Bulkling length	l= 900 cm			
		l/r= 32.4			
Section force	Bending Moment	M= 1,202.2 kN·m			
	Axial Force	N= 1,027.8 kN			
Stress	Allowable Bending Stress	σ ba= 185 N/mm^2			
	Allowable Axial Compressive Stress	σ ca= 165 N/mm^2			
	Premium Coefficient	1.5			
	Bending Stress	σ b= 180 N/mm^2	<	278 N/mm^2	O.K.
	Axial Compressive Stress	σ c= 30 N/mm^2	<	248 N/mm^2	O.K.
	Examination of menbers simultaneously subject to axial	0.77			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)

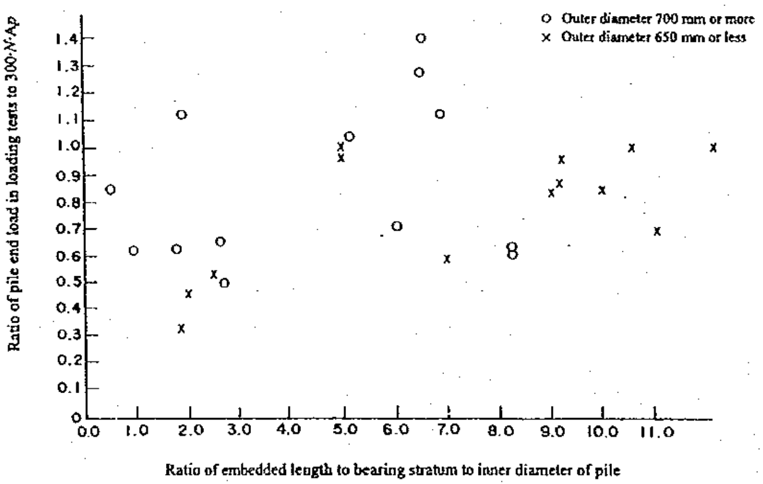
As : total circumferential area of pile (m^2)

※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

$N2 = (0.8\times50 + 3\times0.8\times30) / (4\times0.8) = 35$

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

$Ap = 0.8^2\times \pi/4 = 0.503\ m^2$

Circumferential area of pile per 1m $As' = 0.8\times \pi = 2.51\ m^2/m$

$Ru = 300\times0.6\times42\times0.503 + (9.5\times10 + 6.0\times30)\times2.51$

$= 4{,}492.93$ 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 $Ra = 4{,}493 / 1.5 = 2{,}995$ kN $\geqq$ 1,135 kN O.K

(Maximum Axial Force case3 (Earthquake Condition、

Action direction : Parallel to face line、Pile3)

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 -6.33m(virtual ground surface). Therefore, it is aimed at the -6.33m ～ -26m foundation.

Level	Hi (m)	soil	N	γ_t(kN/m³)	G_0(kN/m²)	V_{si}(m/s)
-6.33～-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

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

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b) Natural Period of Platform 2

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 (=0.80m)

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 (=10,820 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	79.8	1.3	247,020	13.00	7.08	21.24	0.00304	3.29	16.29	1,372
Pile 2	79.8	1.3	247,020	11.23	3.92	11.76	0.00262	3.81	15.04	1,743
Pile 3	79.8	1.3	247,020	10.75	3.27	9.81	0.00251	3.99	14.74	1,853
Pile 4	79.8	1.3	247,020	9.00	2.33	7.00	0.00231	4.34	13.34	2,498

The number of piles of individual pile rows is as follows.

Pile 1 and Pile 2 : 5 、 Pile 3 : 4 、 Pile 4 : 3

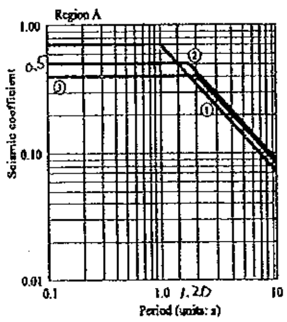
sum of horizontal spring constant

$$\Sigma K_H = (5 \times 1{,}372 + 5 \times 1{,}743 + 4 \times 1{,}853 + 3 \times 2{,}498) = 30{,}482 \text{ kN/m}$$

natural period pf a Platform 2 $Ts = 2 \times \pi \times \sqrt{(10{,}820 / (9.81 \times 30{,}482))} = 1.20$ 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

$P = 10{,}820 \times 0.50 = 5{,}410$ 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)	number of pile	K_{Hi}	$K_{Hi} / \Sigma K_{Hi}$	Hi(kN/piese)
Pile 1	16.29	5.0	6,862	0.225128	1,217.943
Pile 2	15.04	5.0	8,714	0.285880	1,546.610
Pile 3	14.74	4.0	7,411	0.243121	1,315.287
Pile 4	13.34	3.0	7,495	0.245871	1,330.160
		ΣK_{Hi} =	30,482		

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	M_1
Pile 1	16.29	1,217.943	9,917.70
Pile 2	15.04	1,546.610	11,630.02
Pile 3	14.74	1,315.287	9,691.03
Pile 4	13.34	1,330.160	8,871.14

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)

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

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$L_{i,i+1}$: 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.

$M_{1,2} = 1.0 \times M_1 = 1.0 \times 10{,}284.35 = 9{,}917.70$ kN・m

$M_{2,1} = 0.5 \times M_2 = 0.5 \times 12{,}059.96 = 5{,}815.01$ kN・m

$M_{2,3} = 0.7 \times M_2 = 0.7 \times 12{,}059.96 = 8{,}141.01$ kN・m

$M_{3,2} = 0.7 \times M_3 = 0.7 \times 10{,}049.30 = 6{,}783.72$ kN・m

$M_{3,4} = 0.5 \times M_3 = 0.5 \times 10{,}049.30 = 4{,}845.52$ kN・m

$M_{4,3} = 1.0 \times M_4 = 1.0 \times 9{,}199.09 = 8{,}871.14$ kN・m

The interval of each pile is as follows.

Pile 1～Pile 2 : 5.30m 、Pile 2～Pile 3 : 5.40m 、Pile 3～Pile 4 : 5.30m。

The axial force of individual piles is as follows.

$N_1 = -(9{,}917.70+5{,}815.01)/5.30 = -2{,}968.44$ kN

$N_2 = ((9{,}917.70+5{,}815.01)/5.30)-((8{,}141.01+6{,}783.72)/5.40) = 204.60$ kN

$N_3 = ((8{,}141.01+6{,}783.72)/5.40)-((4{,}845.52+8{,}871.14)/5.30) = 175.79$ kN

$N_4 = ((4{,}845.52+8{,}871.14)/5.30) = 2{,}588.05$ kN

	Pile 1	Pile 2	Pile 3	Pile4
Deadweight + Surcharge※1	2,855.96	3,397.08	2,852.29	1,825.83
Ni	-2,968.44	204.60	175.79	2,588.05
Total (Ni)	-112.48	3,601.68	3,028.08	4,413.88

※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

$Z_p = 4/3 \times (r^3-(r-t)^3) = 4/3 \times (399^3-(399-13)^3) = 8{,}011{,}657.33\ mm^3$

(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' = 32,059.95 mm^2

$M'_{p0} = Z_p f_y = 8{,}011{,}657.33 \times 315 / 1{,}000{,}000 = 2{,}523.67$ kN・m

$N'_0 = A f_y = 32{,}059.95 \times 315 / 1{,}000 = 10{,}098.89$ kN

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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	-112.48	50,494.43	-0.00222750
Pile 2	3,601.68	50,494.43	0.0713282
Pile 3	3,028.08	40,395.54	0.0749608
Pile 4	4,413.88	30,296.66	0.1456886

※N0 is the value which multiplied N'0 by the number of each pile.

(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)	杭頭ﾓｰﾒﾝﾄ (kN·m)
Pile 1	12,618.36	12,618.28	> 9,917.70
Pile 2	12,618.36	12,539.24	> 11,630.02
Pile 3	10,094.69	10,024.79	< 9,691.03
Pile 4	7,571.02	7,373.63	< 8,871.14

※M_{p0} is the value which multiplied M'_{p0} by the number of each pile.

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	16.29	12,618.28	1,549.59
Pile 2	15.04	12,539.24	1,667.52
Pile 3	14.74	10,024.79	1,360.58
Pile 4	13.34	7,373.63	1,105.62
	P_{uall} =		5,683.31

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The pile head moment of "Pile 3" and "Pile 4" exceeds the fully plastic state moment. Therefore, other piles shall share a part of horizontal load of acting on "PIle 3" and "Pile 4".

a ') Calculation of Member Forces Acting on Individual Piles

The redistributed horizontal load is shown below.

	free length of a pile Li (m)	number of pile	K_{Hi}	K_{Hi} / ΣK_{Hi}	Hi(kN/piese)
Pile 1	16.29	5.0	6,862	0.225128	1,340.000
Pile 2	15.04	5.0	8,714	0.285880	1,660.000
Pile 3	14.74	4.0	7,411	0.243121	1,330.000
Pile 4	13.34	3.0	7,495	0.245871	1,080.000
		ΣK_{Hi} =	30,482		

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

	free length of a pile Li (m)	Hi	M_i
Pile 1	16.29	1,340.000	10,911.61
Pile 2	15.04	1,660.000	12,482.67
Pile 3	14.74	1,330.000	9,799.44
Pile 4	13.34	1,080.000	7,202.77

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

$M_{1,2} = 1.0 \times M_1 = 1.0 \times 10,911.61 = 10,911.61$ kN・m

$M_{2,1} = 0.5 \times M_2 = 0.5 \times 12,482.67 = 6,241.34$ kN・m

$M_{2,3} = 0.7 \times M_2 = 0.7 \times 12,482.67 = 8,737.87$ kN・m

$M_{3,2} = 0.7 \times M_3 = 0.7 \times 9,799.44 = 6,859.61$ kN・m

$M_{3,4} = 0.5 \times M_3 = 0.5 \times 9,799.44 = 4,899.72$ kN・m

$M_{4,3} = 1.0 \times M_4 = 1.0 \times 7,202.77 = 7,202.77$ kN・m

The interval of each pile is as follows.

Pile 1~Pile 2 : 5.30m 、Pile 2~Pile 3 : 5.40m 、Pile 3~Pile 4 : 5.30m。

The axial force of individual piles is as follows.

N_1 = - (10,911.61+6,241.34)/5.30 = -3,236.41 kN

N_2 =((10,911.61+6,241.34)/5.30)-((8,737.87+6,859.61)/5.40) = 347.98 kN

N_3 = ((8,737.87+6,859.61)/5.40)-((4,899.72+7,202.77)/5.30) = 604.93 kN

N_4 = ((4,899.72+7,202.77)/5.30) = 2,283.49 kN

	Pile 1	Pile 2	Pile 3	Pile 4
Deadweight + Surcharge※1	2,855.96	3,397.08	2,852.29	1,825.83
Ni	-3,236.41	347.98	604.93	2,283.49
Total (Ni)	-380.45	3,745.06	3,457.22	4,109.32

※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	-380.45	50,494.43	-0.0075344
Pile 2	3,745.06	50,494.43	0.0741679
Pile 3	3,457.22	40,395.54	0.0855843
Pile 4	4,109.32	30,296.66	0.1356360

※N0 is the value which multiplied N'0 by the number of each pile.

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

No.	M_{p0} (kN·m)	M_p (kN·m)	杭頭モーメント (kN·m)
Pile 1	12,618.36	12,617.48	> 10,911.61
Pile 2	12,618.36	12,532.82	> 12,482.67
Pile 3	10,094.69	10,003.61	> 9,799.44
Pile 4	7,571.02	7,399.83	> 7,202.77

※M_{p0} is the value which multiplied M'_{p0} by the number of each pile.

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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	16.29	12,617.48	1,549.49
Pile 2	15.04	12,532.82	1,666.67
Pile 3	14.74	10,003.61	1,357.71
Pile 4	13.34	7,399.83	1,109.55
P_{uall} =			5,683.42

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

$P_y = 0.82\ P_{uall} = 0.82 \times 5,683.42 = 4,660.40$ 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 2

$R_a = \sqrt{(2\mu_a - 1)} \times P_y = \sqrt{(2 \times 1.3 - 1)} \times 4,660.40 = 5,894.99$ kN

・Earthquake force of using for examination of load carrying capacity

$k_h W = 0.50 \times 10,820 = 5,410$ kN $\leqq$ Ra O.K

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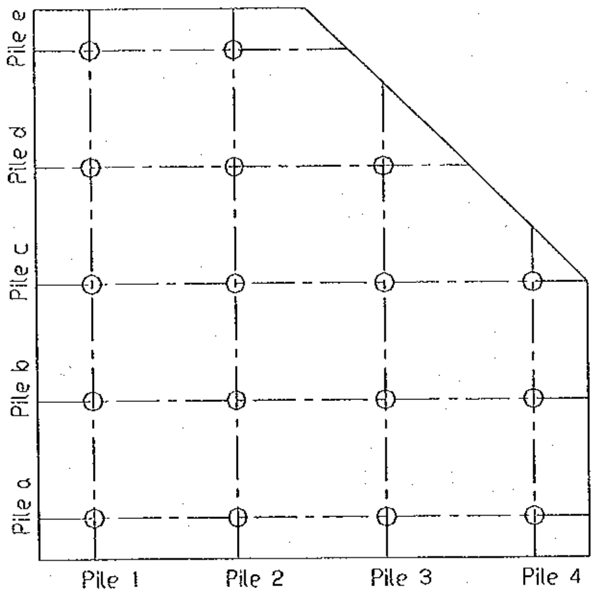
<Appending Data>

1) Cross-Section Force Figure

The number of the pile shown in a cross-sectional force figure is shown in the following figures.



	Prepared by	Y. Ando	Checked by	R. NISHIMURA	
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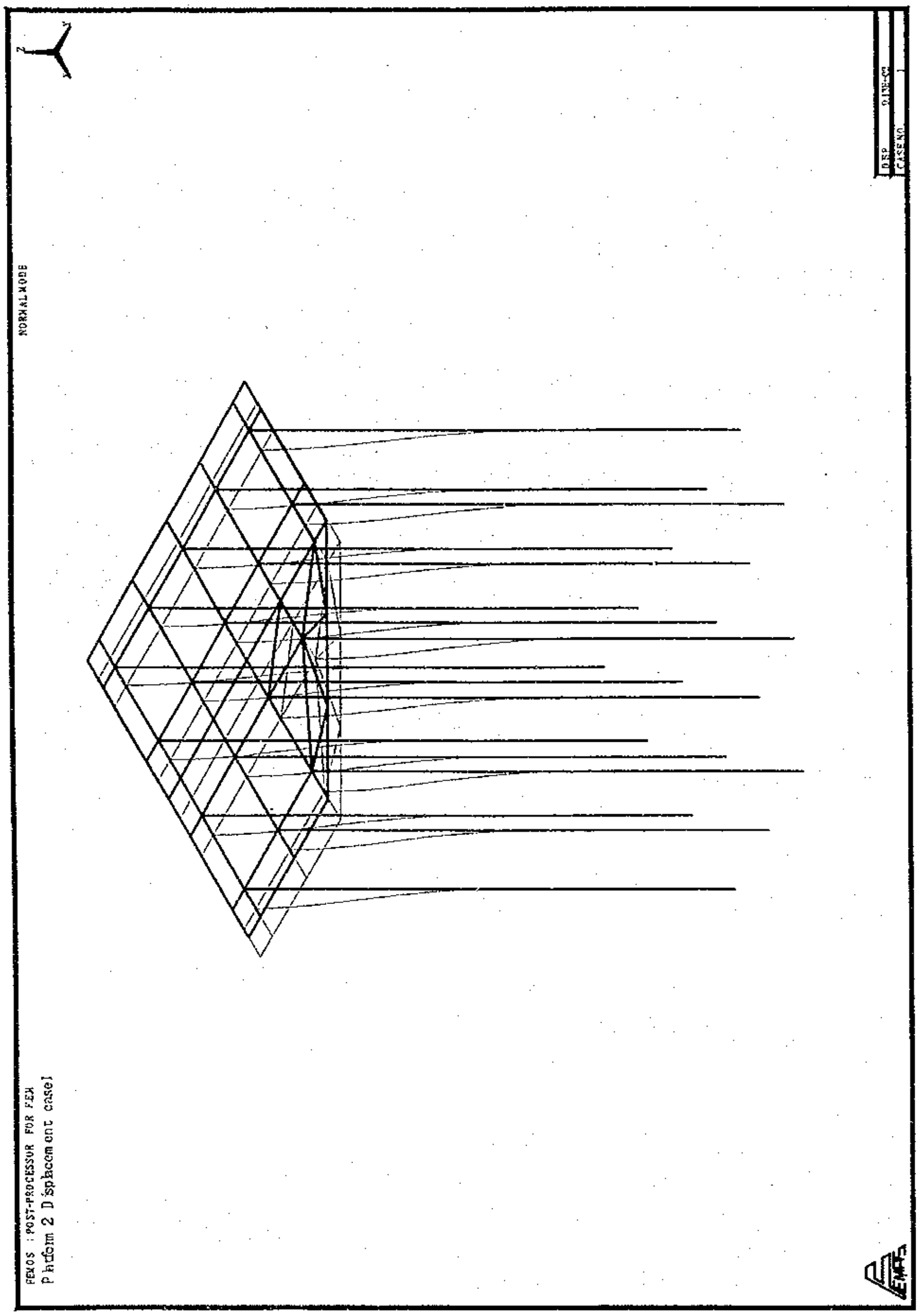
（1） case1 （Earthquake　Sea→Land）

・Displacement



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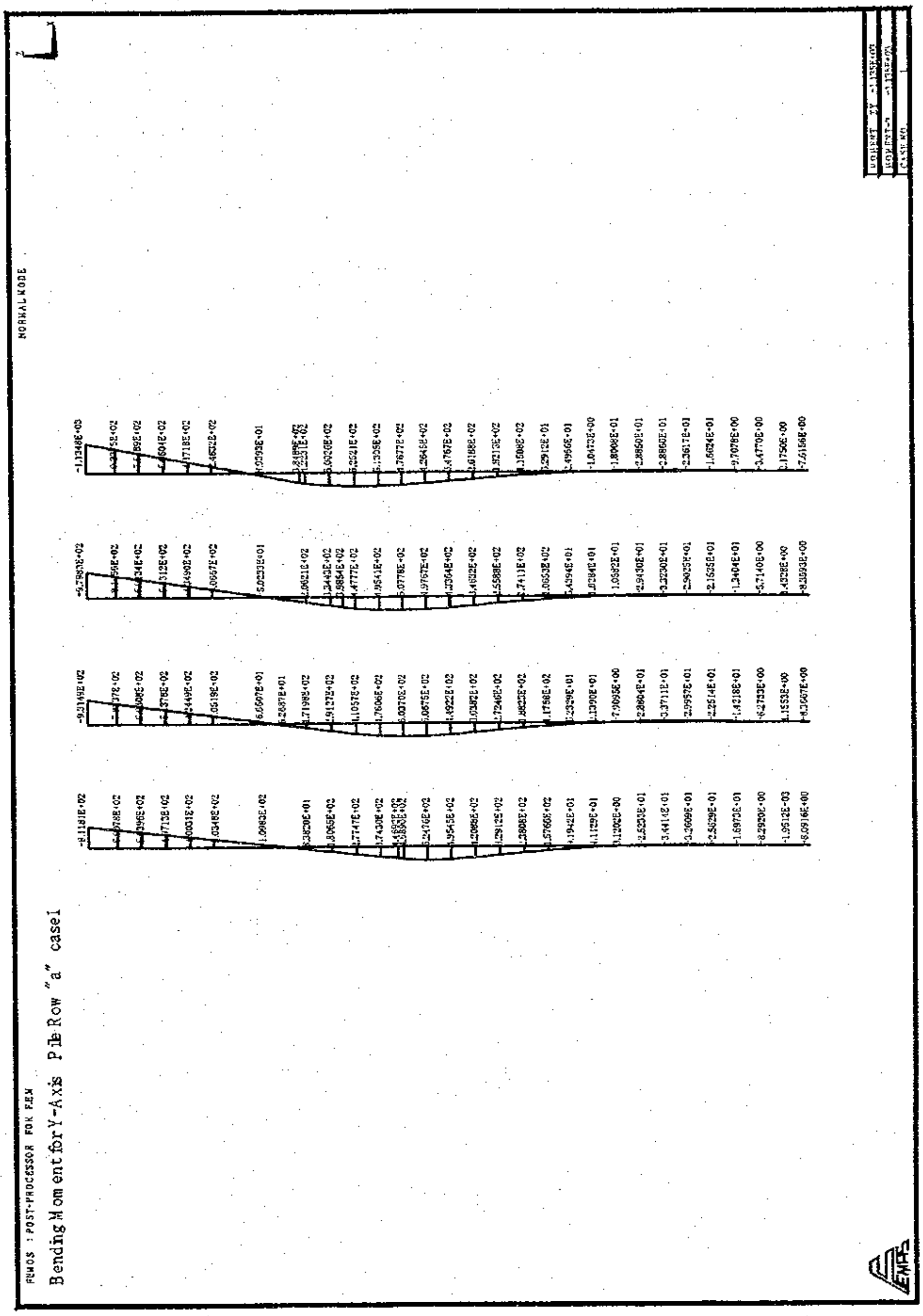
・Bending Moment for Y-Axis (Pile Row "a" Pile 1 (Left Side)～Pile 4 (Right Side))



	Prepared by	Y. Ando	Checked by R. NISHIMURA
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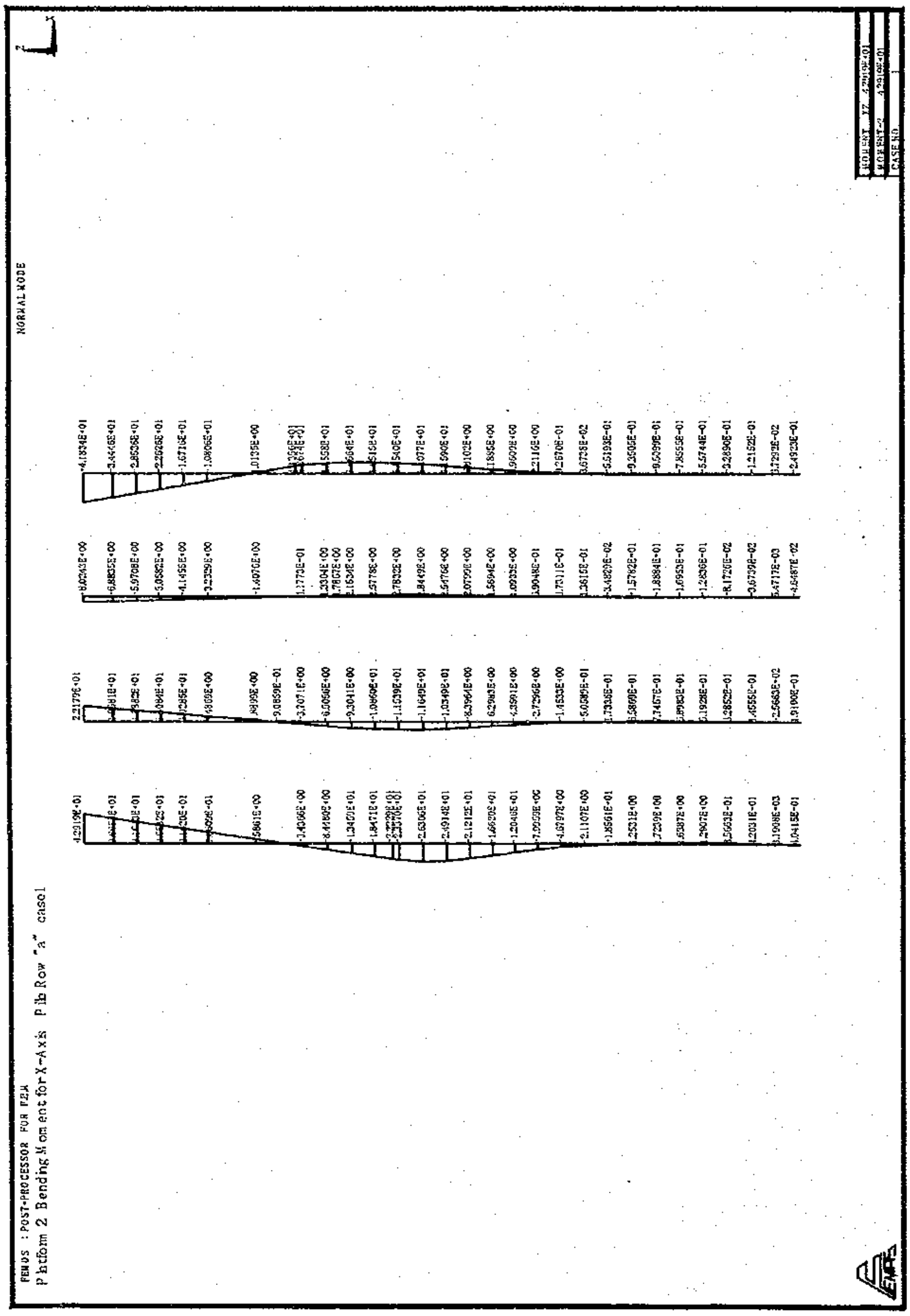
・Bending Moment for X-Axis (Pile Row "a" Pile 1 (Left Side)~Pile 4 (Right Side))



		Prepared by	Y. Ando	Checked by R. NISHIMURA
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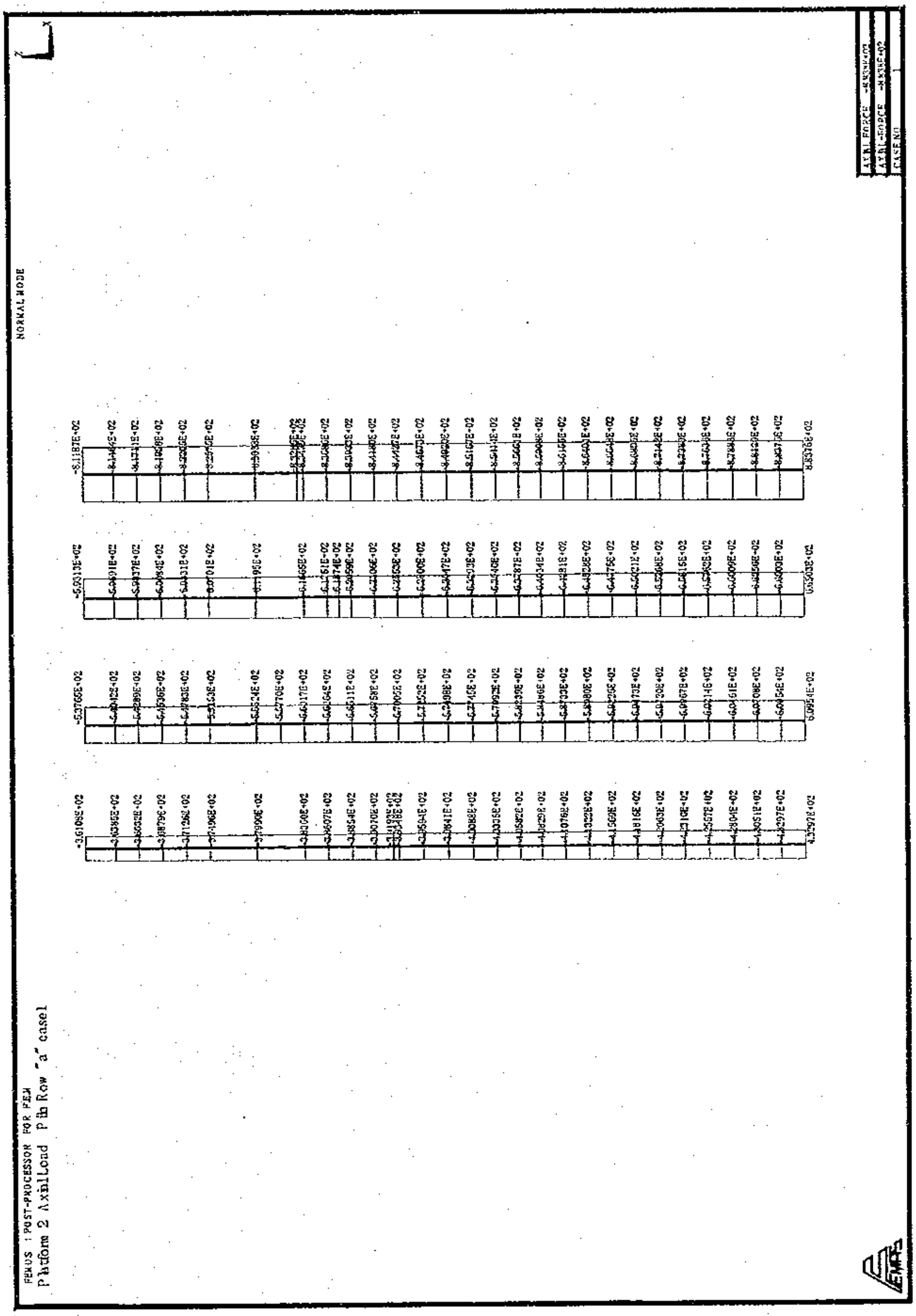
References/ Notes

・Axial Force (Pile Row "a" Pile 1 (Left Side)～Pile 4 (Right Side))



		Prepared by	Y. Ando	Checked by	R. NISHIMURA
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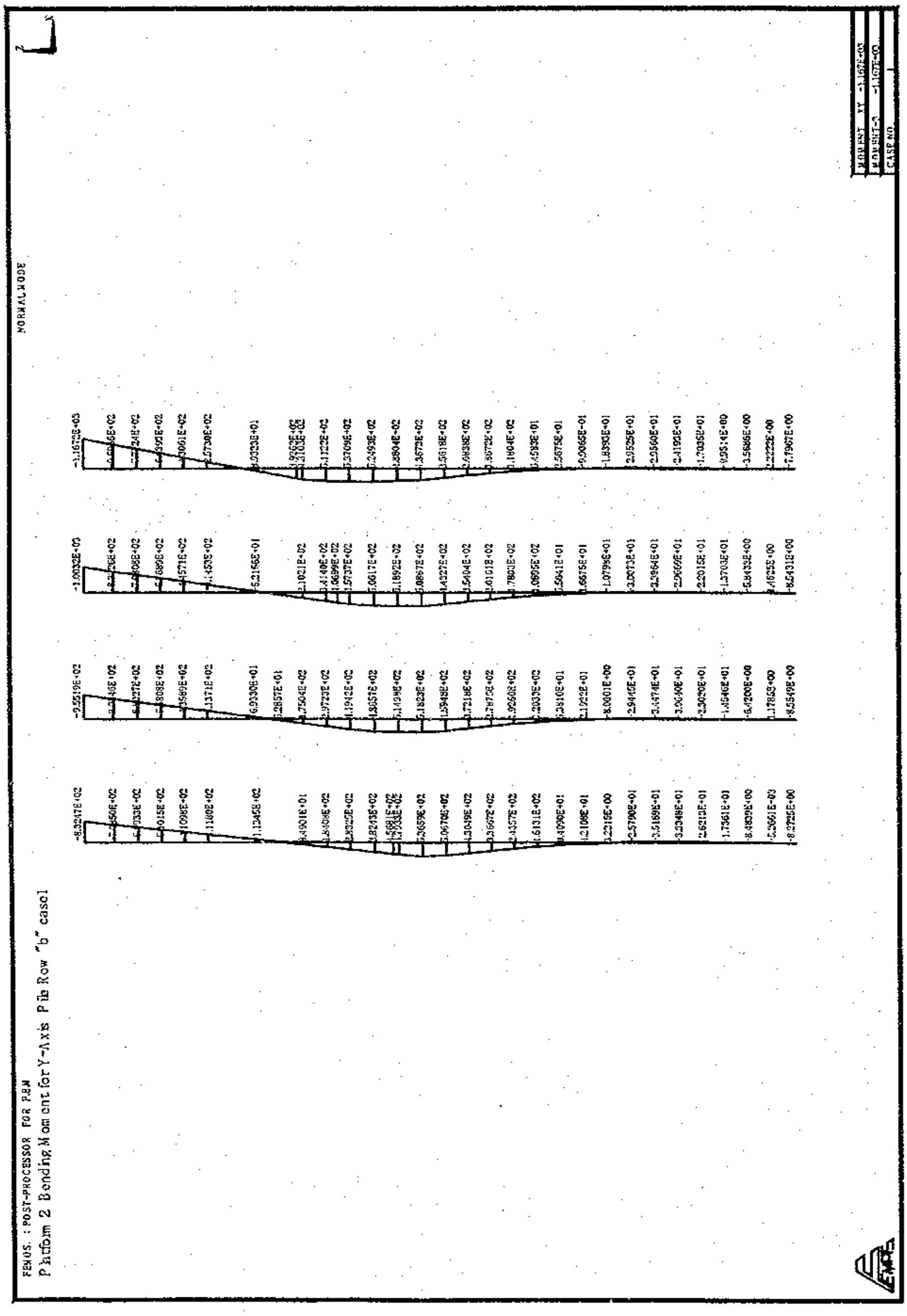
・Bending Moment for Y-Axis (Pile Row "b" Pile 1 (Left Side)~Pile 4 (Right Side))



		Prepared by Y. Ando		Checked by E. NISHIMURA
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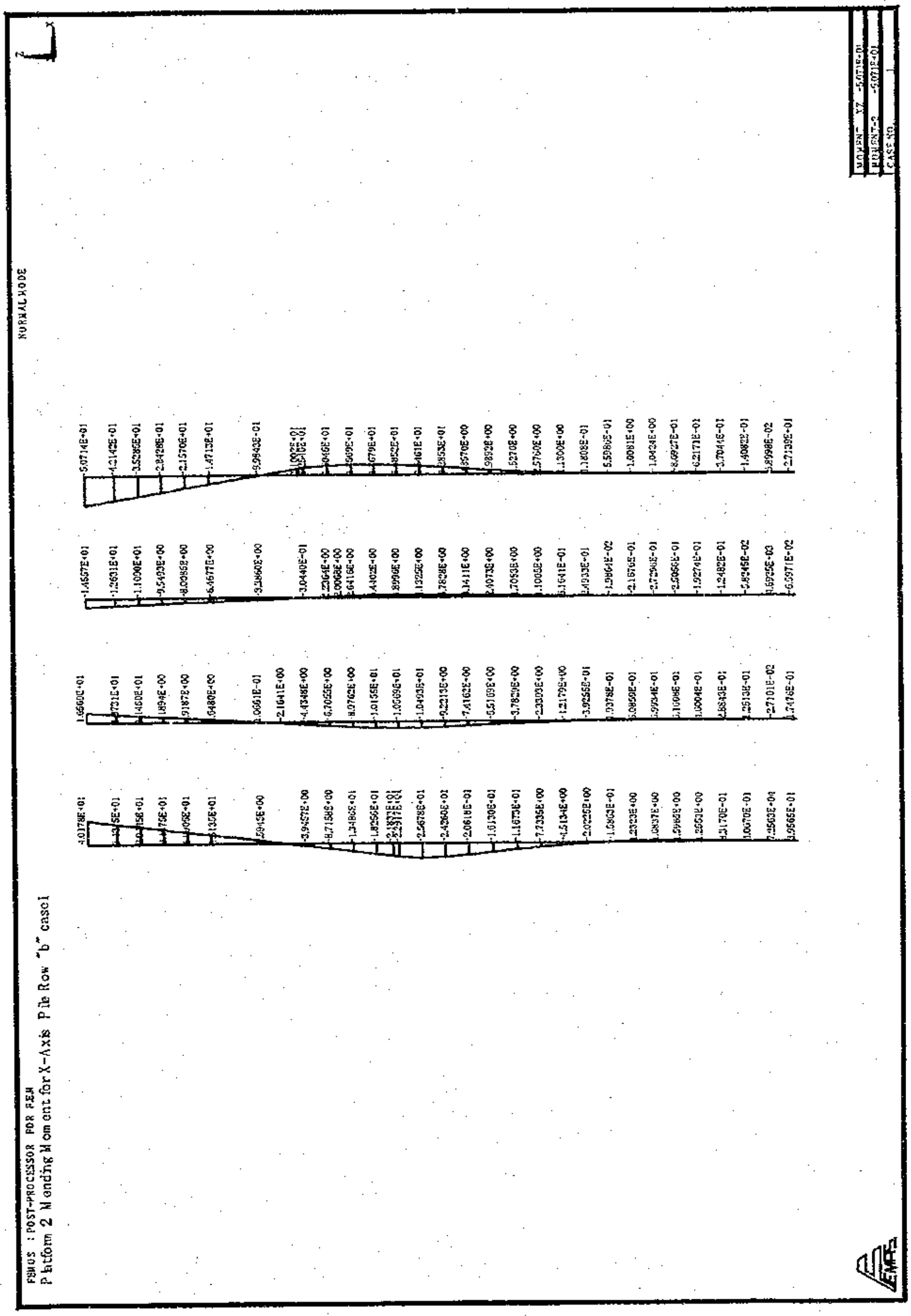
・Bending Moment for X-Axis (Pile Row "b" Pile 1 (Left Side)~Pile 4 (Right Side))



	Prepared by Y. Ando	Checked by R. NISHIMURA	
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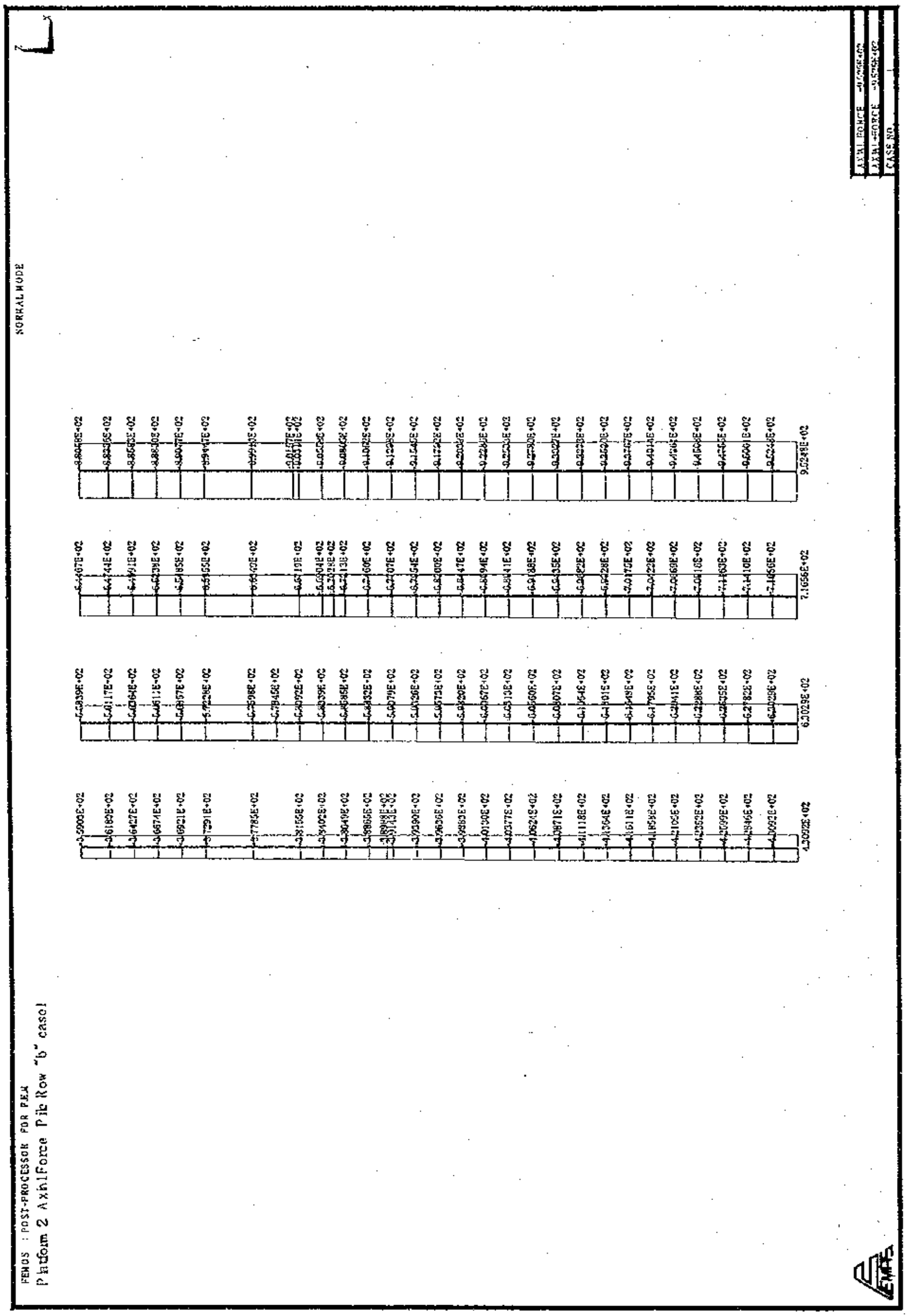
・Axial Force (Pile Row "b" Pile 1 (Left Side)~Pile 4 (Right Side))



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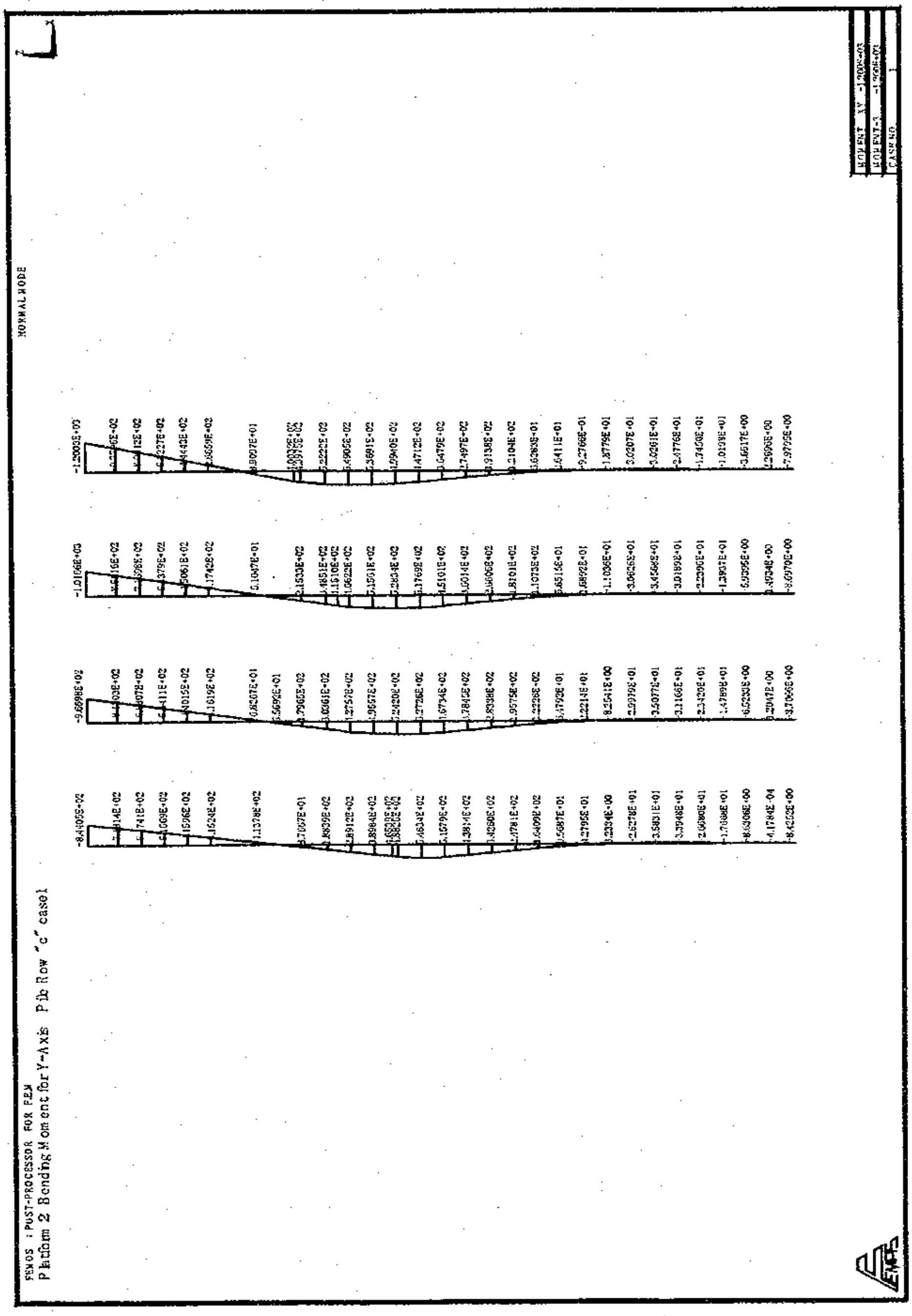
・Bending Moment for Y-Axis (Pile Row "c" Pile 1 (Left Side)~Pile 4 (Right Side))



	Prepared by	Y. Ando	Checked by R. NISHIMURA
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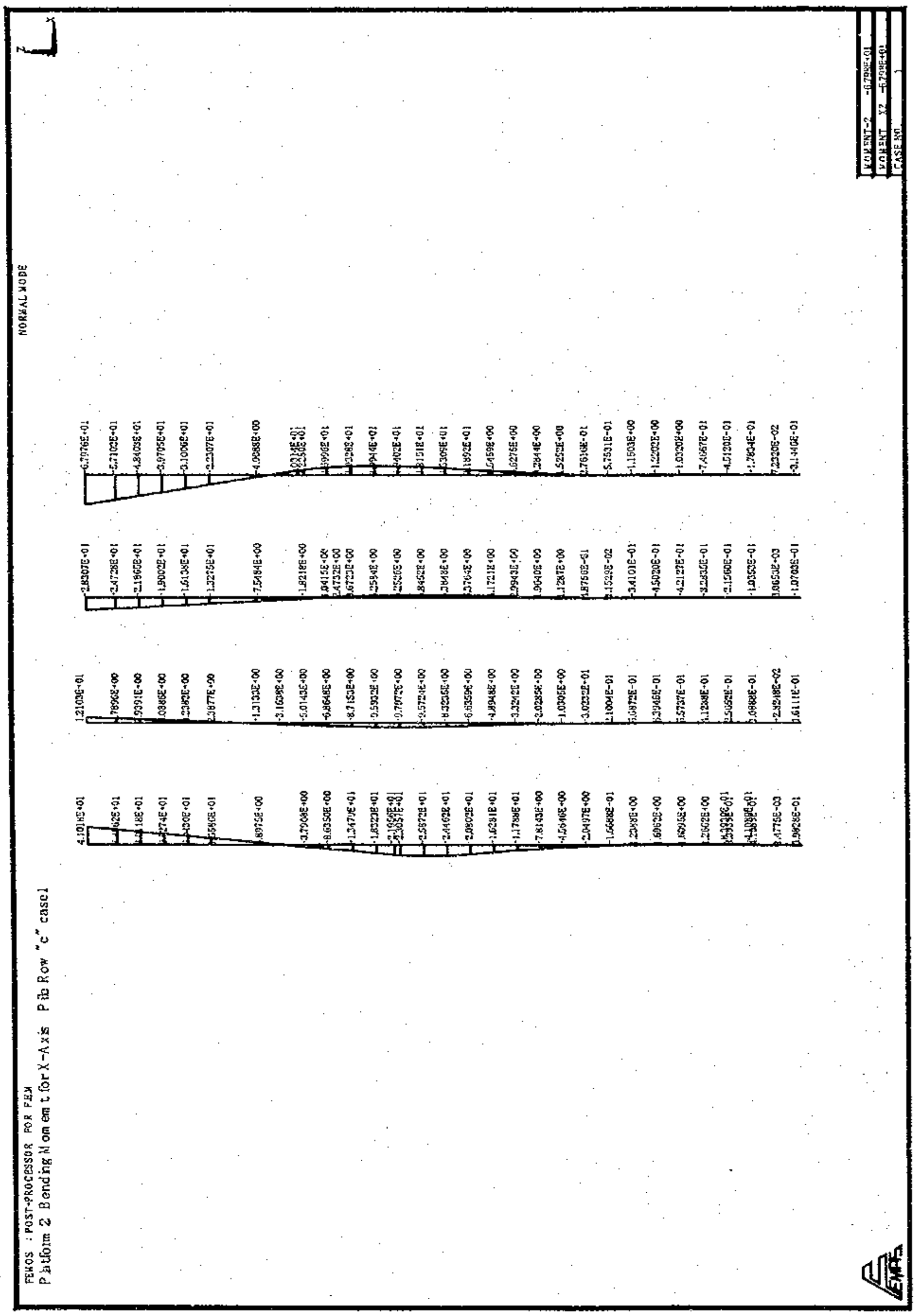
・Bending Moment for X-Axis (Pile Row "c" Pile 1 (Left Side)~Pile 4 (Right Side))



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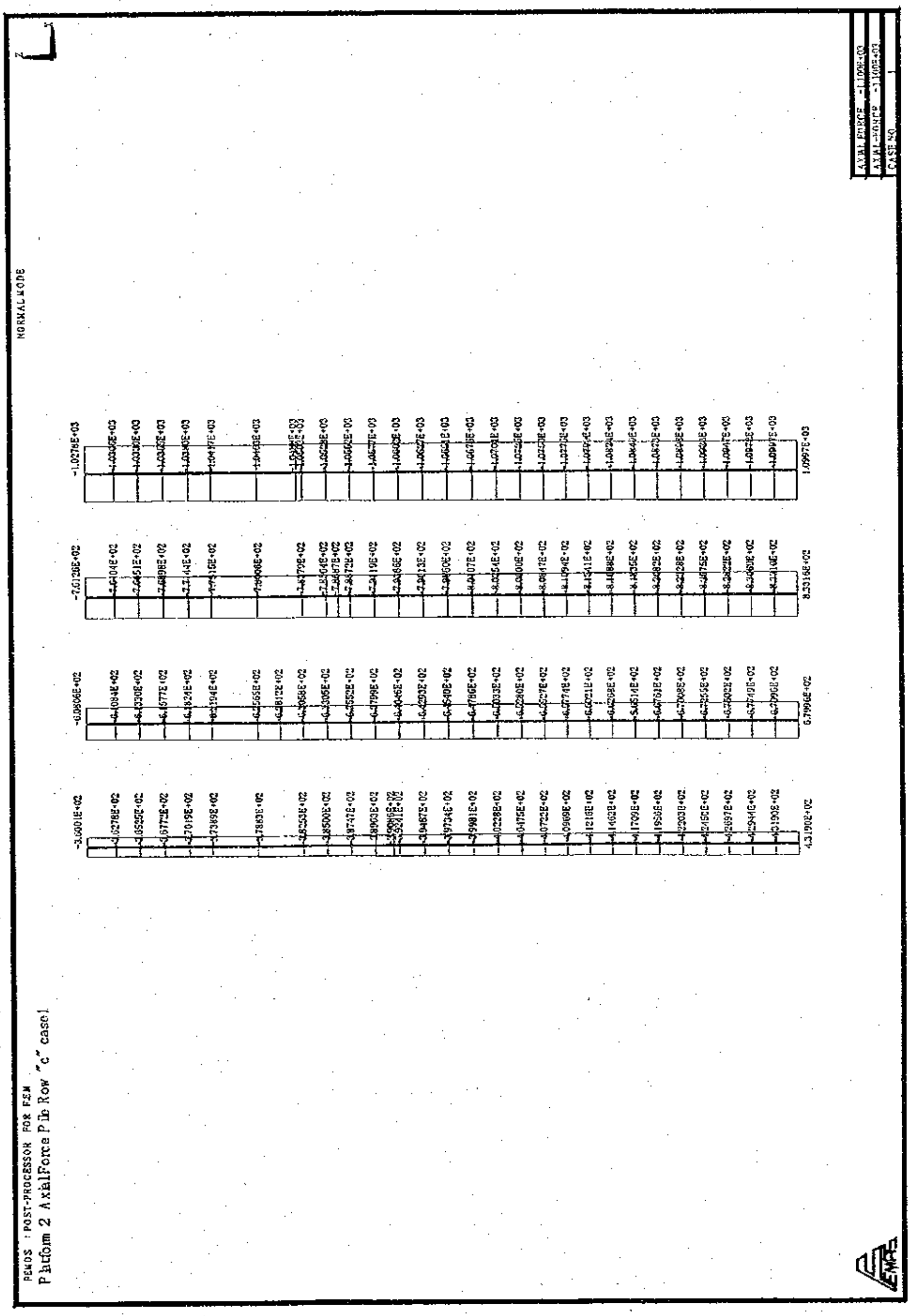
• Axial Force (Pile Row "c" Pile 1 (Left Side)~Pile 4 (Right Side))



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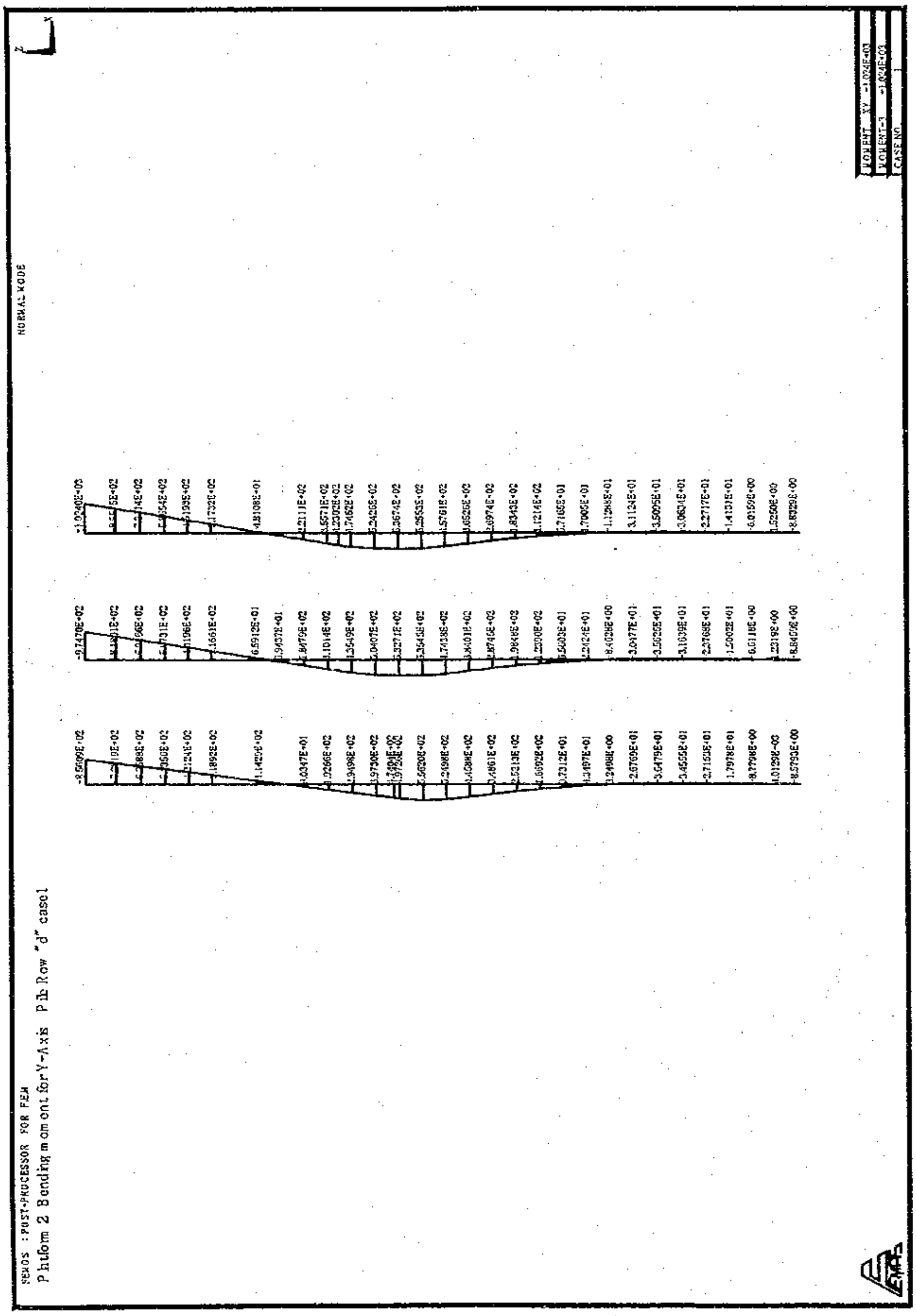
・Bending Moment for Y-Axis (Pile Row "d" Pile 1 (Left Side)～Pile 3 (Right Side))



		Prepared by Y. Ando	Checked by R. NISHIMURA
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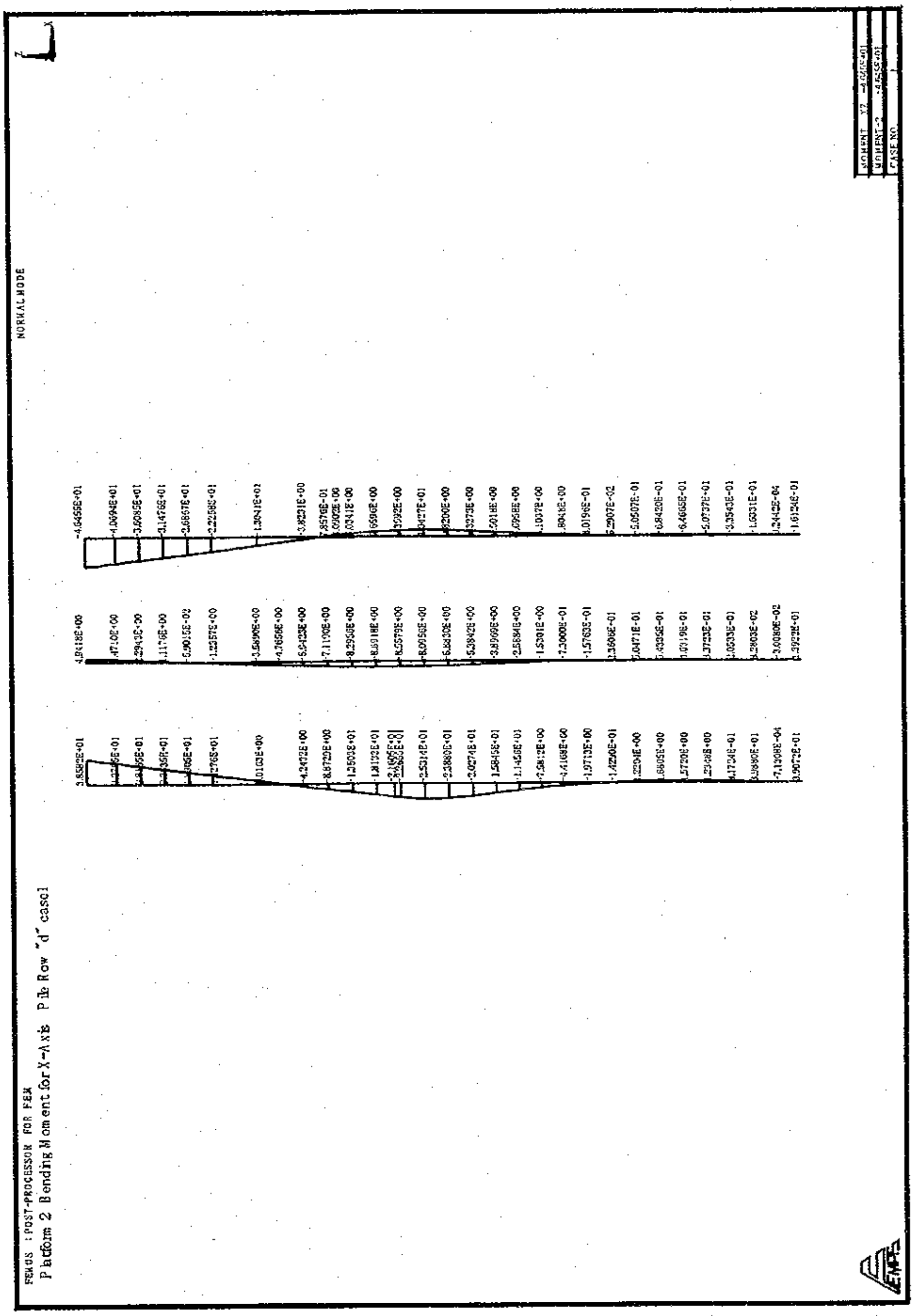
・Bending moment for X-Axis (Pile Row "d" Pile 1 (Left Side)～Pile 3 (Right Side))



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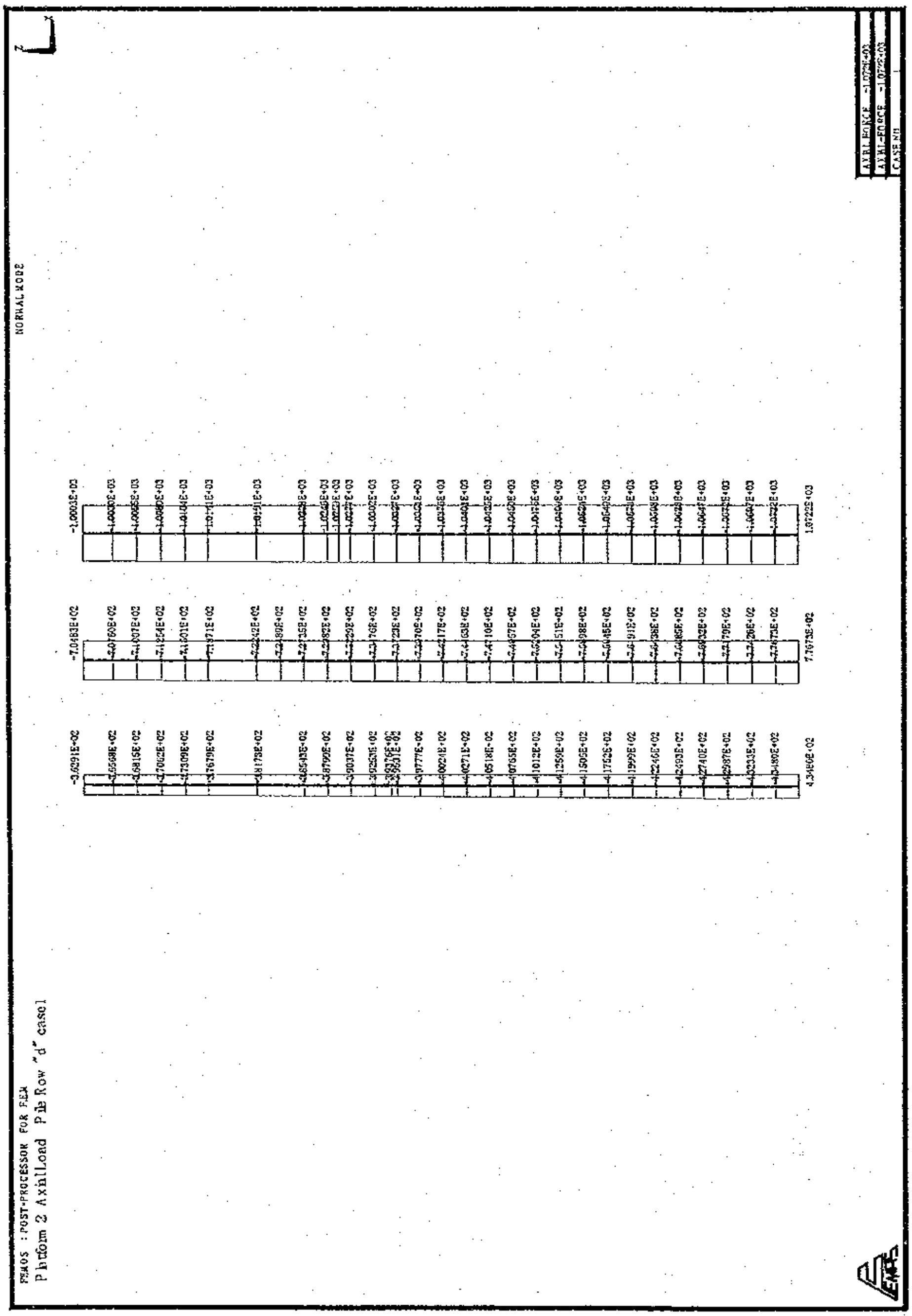
・Axial Load (Pile Row "d" Pile 1 (Left Side)～Pile 3 (Right Side))



	Prepared by	Y. Ando	Checked by R. NISHIMURA
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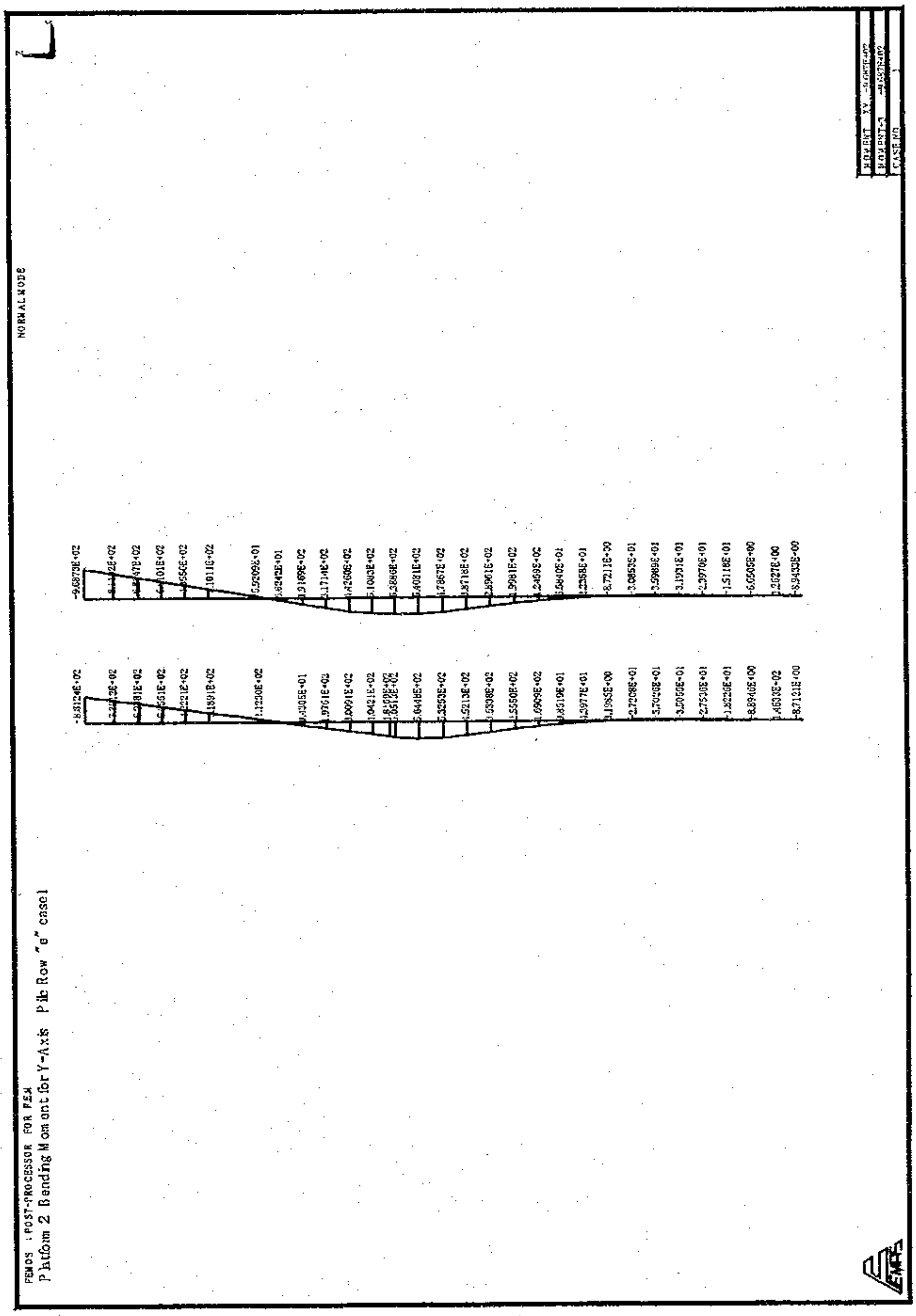
・Bending Moment for Y-Axis (Pile Row "e" Pile 1 (Left Side)~Pile 2 (Right Side))



	Prepared by	Y. Ando	Checked by R. NISHIMURA
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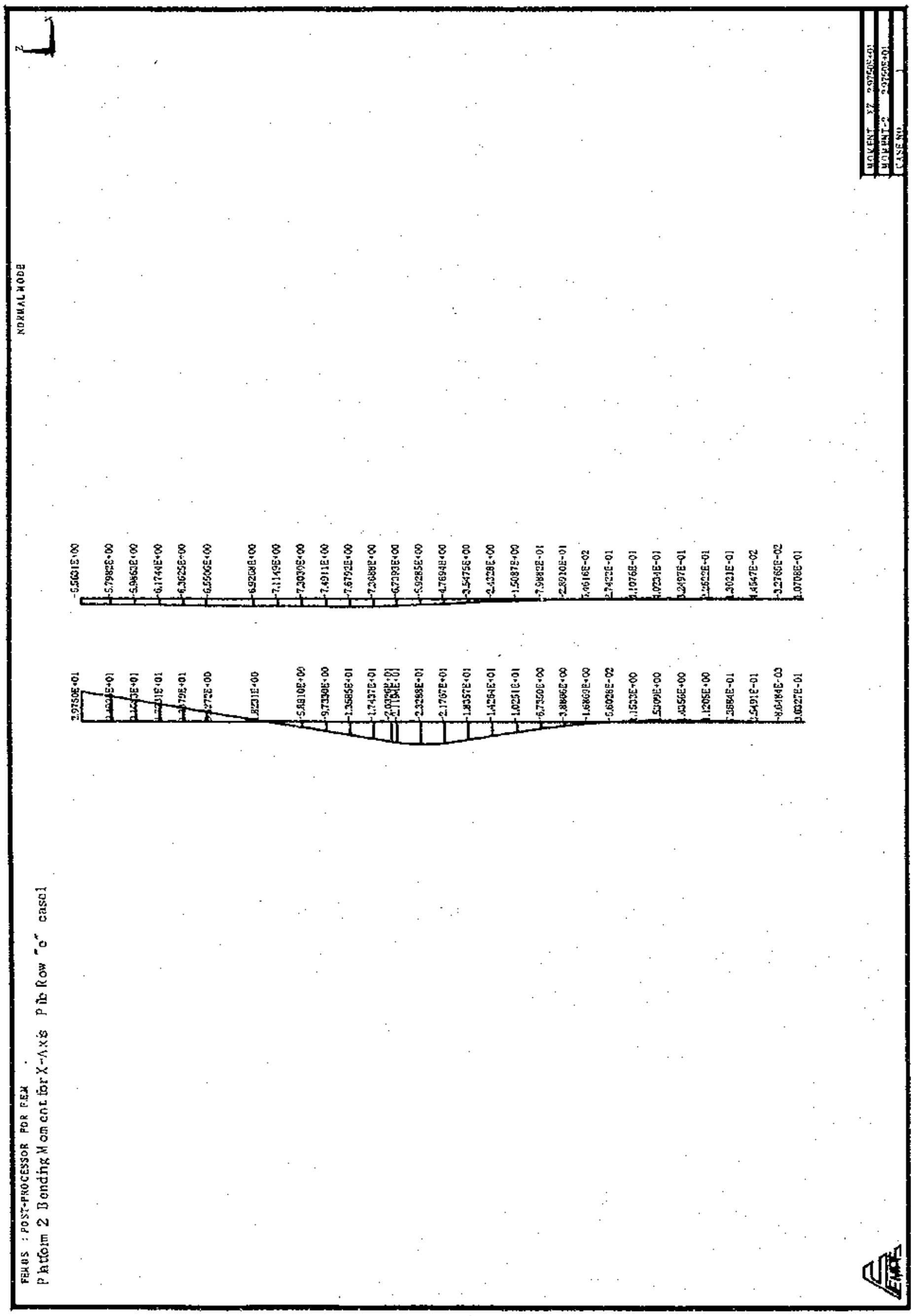
・Bending Moment for X-Axis (Pile Row "e" Pile 1 (Left Side)~Pile 2 (Right Side))



		Prepared by	Y. Ando	Checked by R. NISHIMURA
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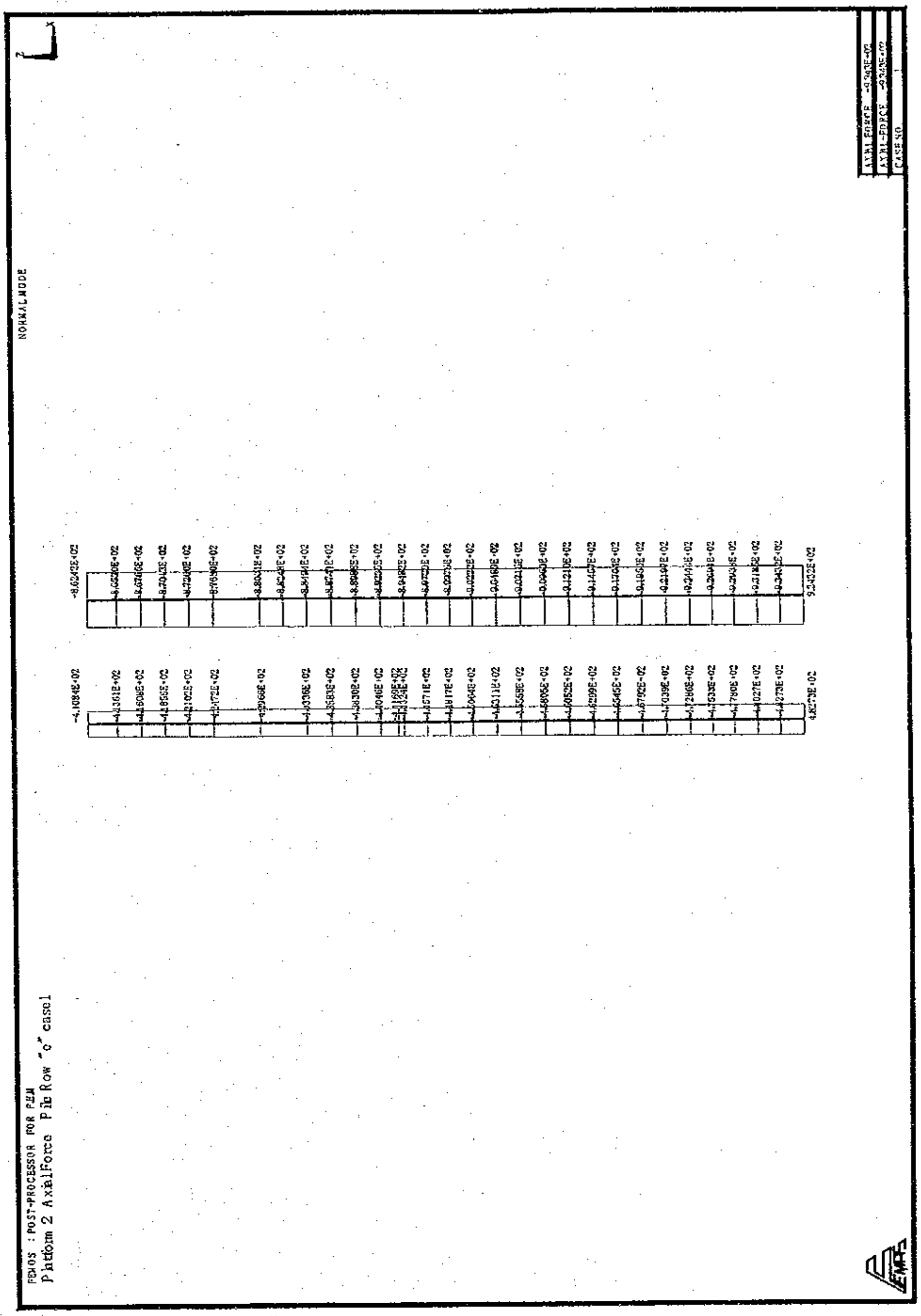
• Axial Force (Pile Row "e" Pile 1 (Left Side)~Pile 2 (Right Side))



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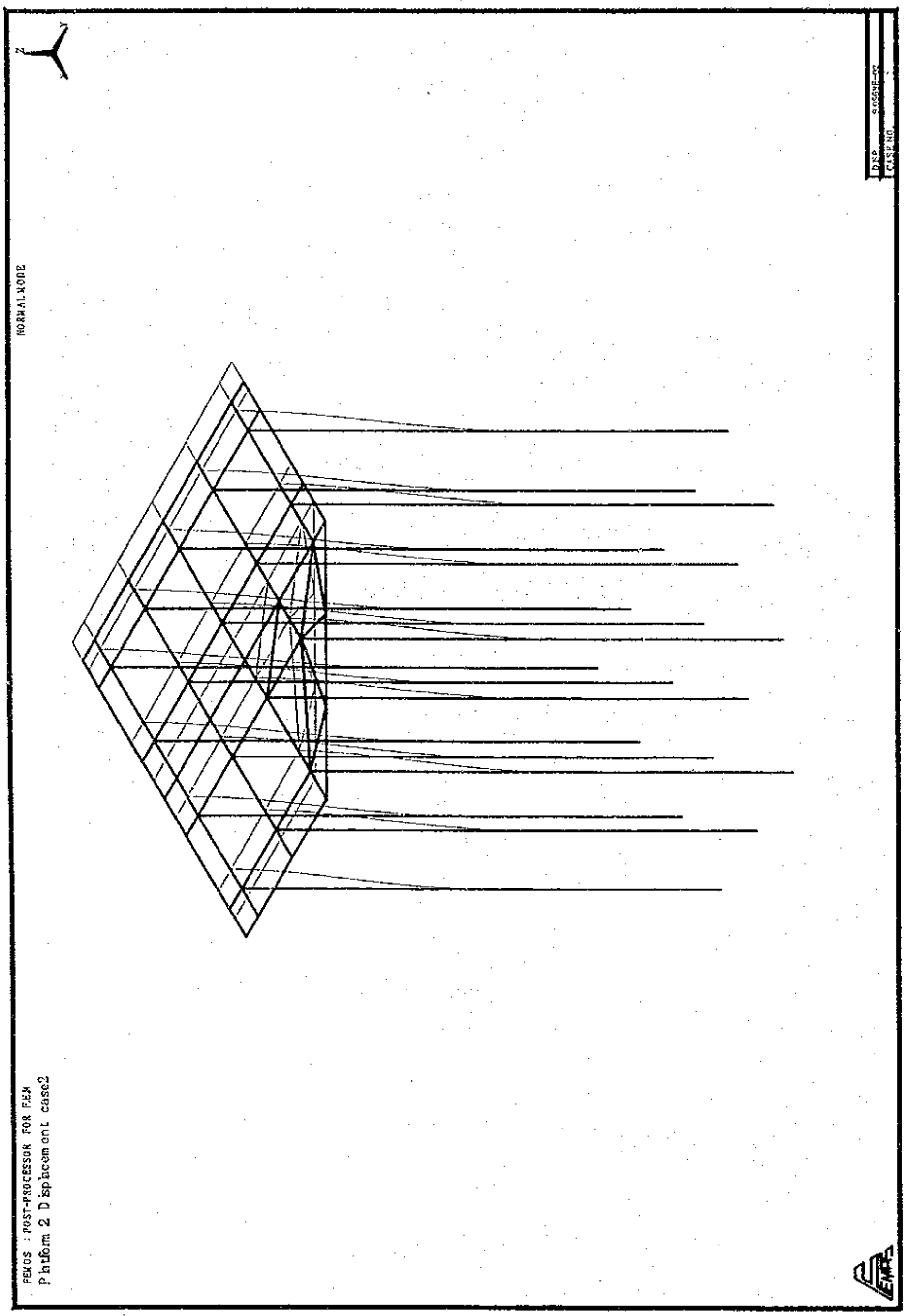
（2） case2 （Earthquake Land→Sea）



・Displacement

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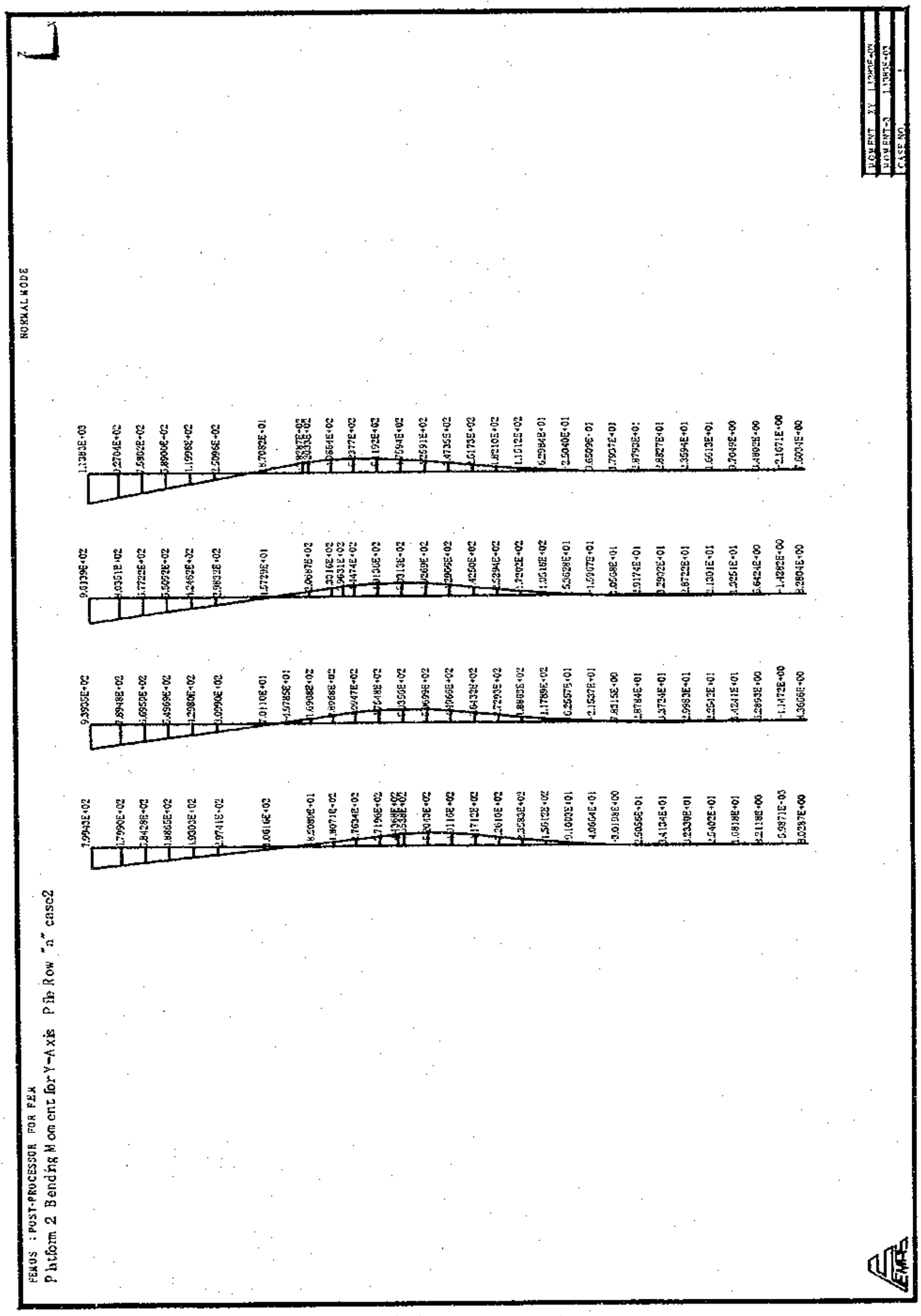
・Bending Moment for Y-Axis (Pile Row "a" Pile 1 (Left Side)~Pile 4 (Right Side))



	Prepared by	Y. Ando	Checked by	R. NISHIMURA
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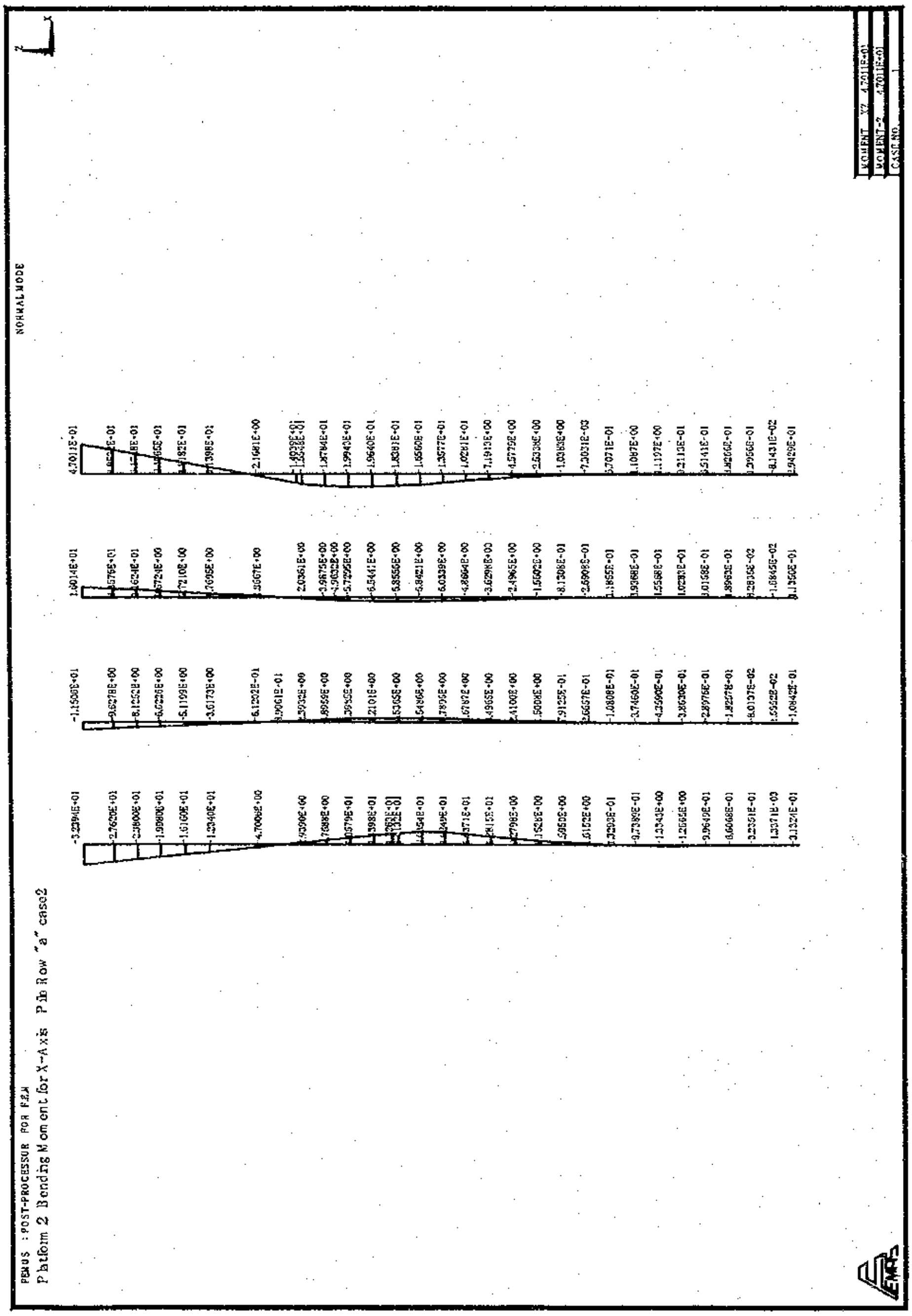
• Bending Moment for X-Axis（Pile Row "a"　Pile 1 (Left Side)~Pile 4 (Right Side))



		Prepared by	Y.Ando	Checked by R. NISHIMURA
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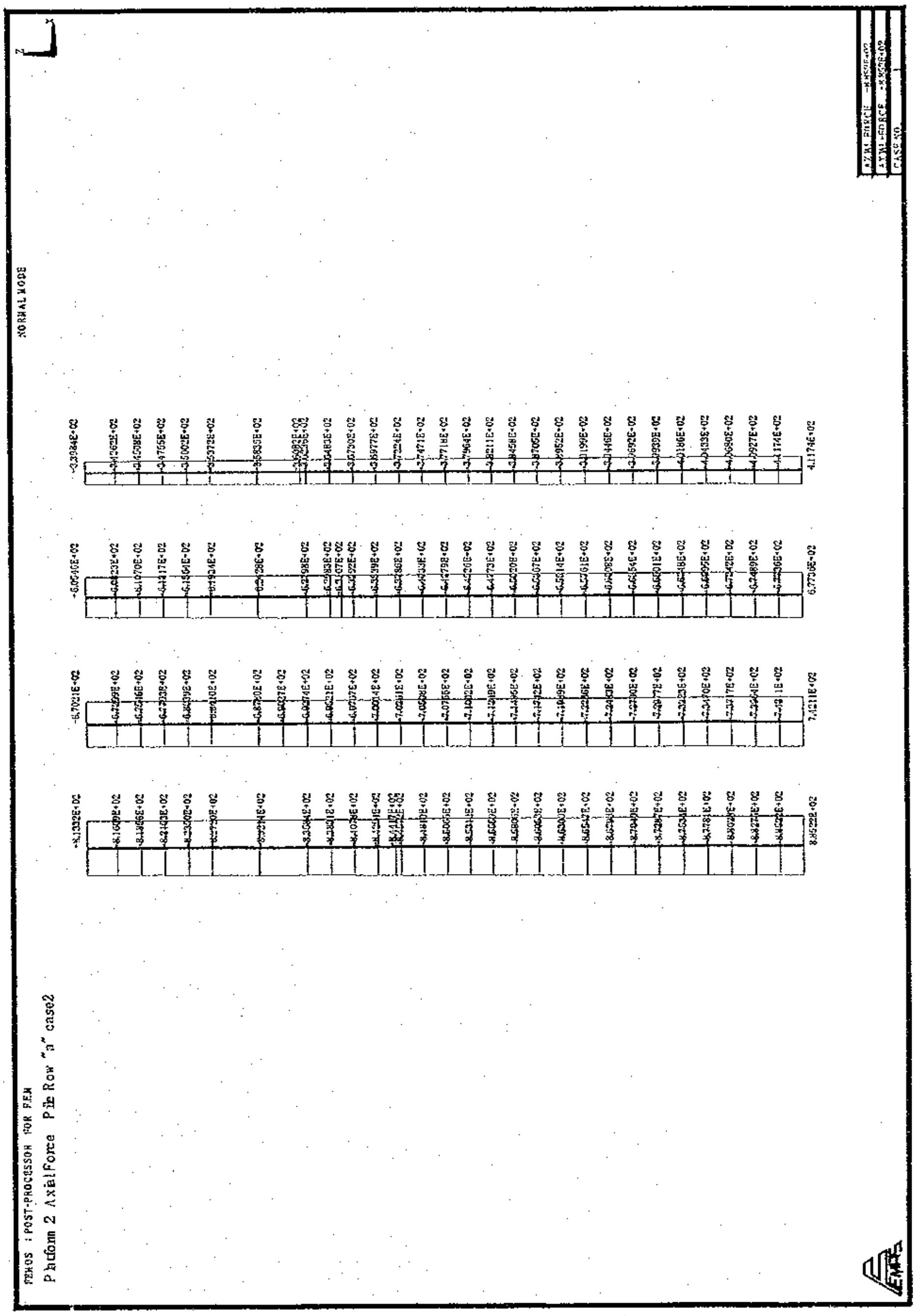
・Axial Force (Pile Row "a" Pile 1 (Left Side)~Pile 4 (Right Side))



	Prepared by Y.Ando	Checked by R. NISHIMURA	
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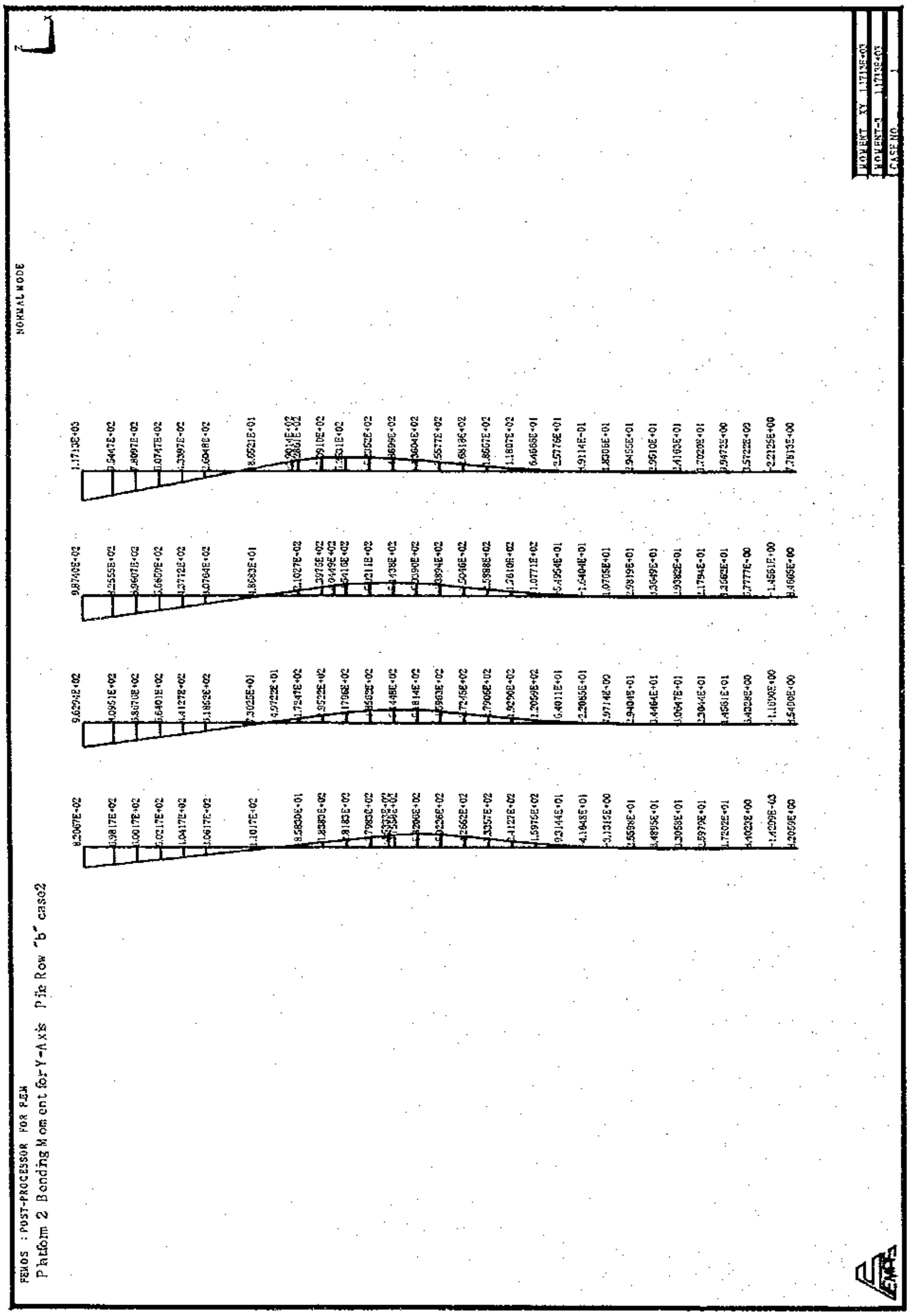
・Bending Moment for Y-Axis (Pile Row "b" Pile 1 (Left Side)~Pile 4 (Right Side))



		Prepared by	Y. Ando	Checked by	R. NISHIMURA
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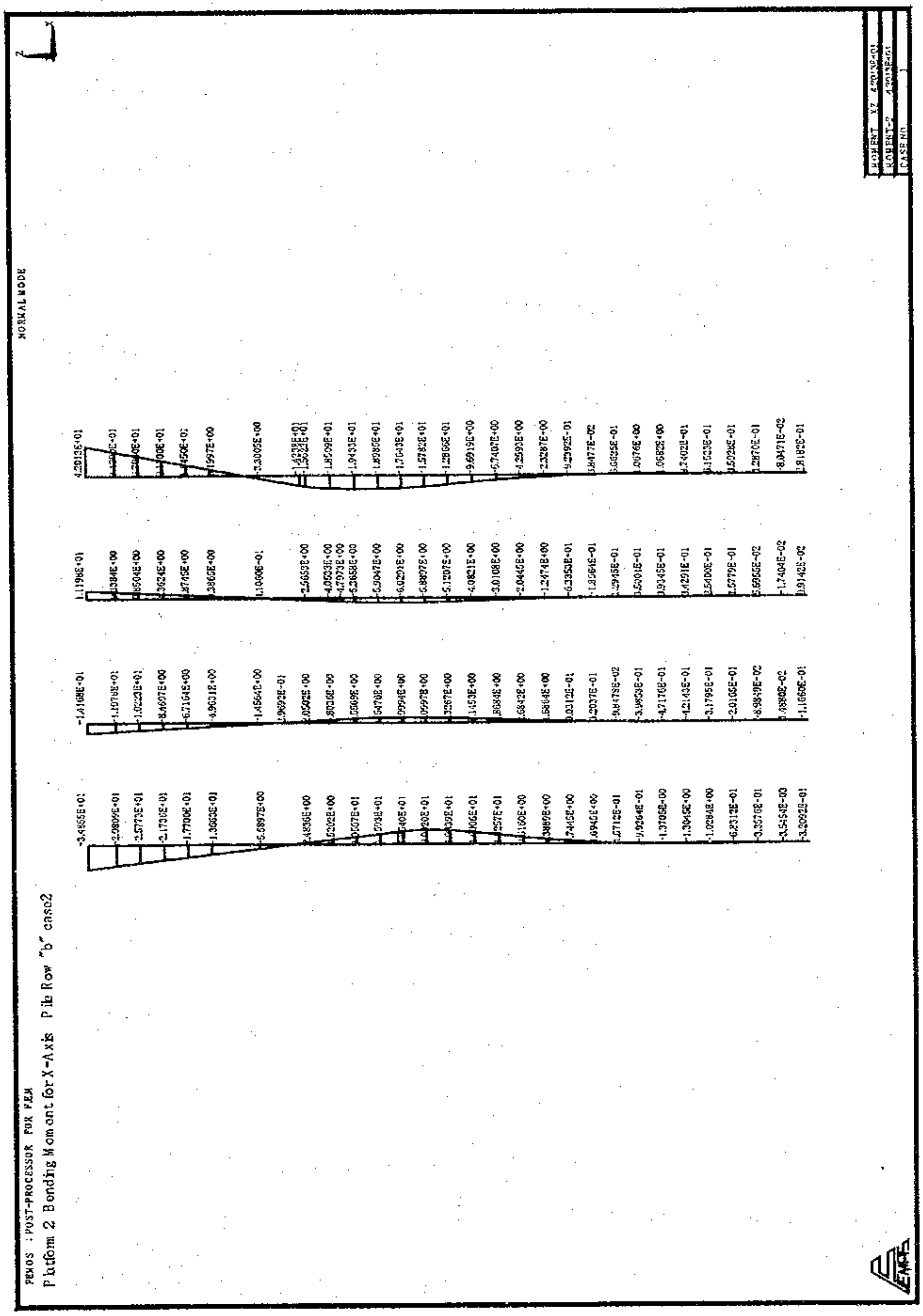
• Bending Moment for X-Axis (Pile Row "b" Pile 1 (Left Side)~Pile 4 (Right Side))



	Prepared by Y. Ando		Checked by R. NISHIMURA
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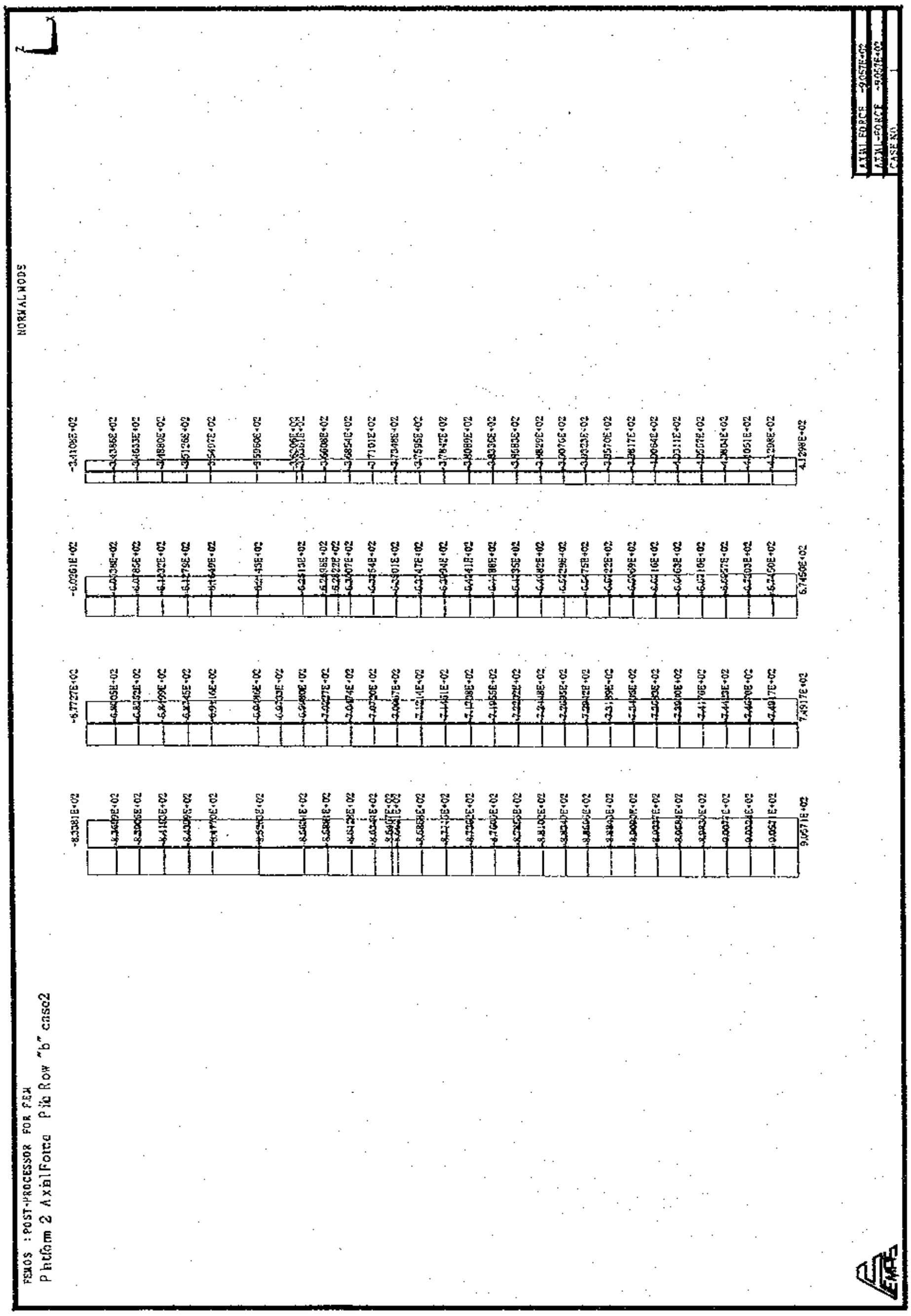
・Axial Force (Pile Row "b" Pile 1 (Left Side)～Pile 4 (Right Side))



		Prepared by Y. Ando	Checked by R. NISHIMURA
		26/07/2002	08/08/2002

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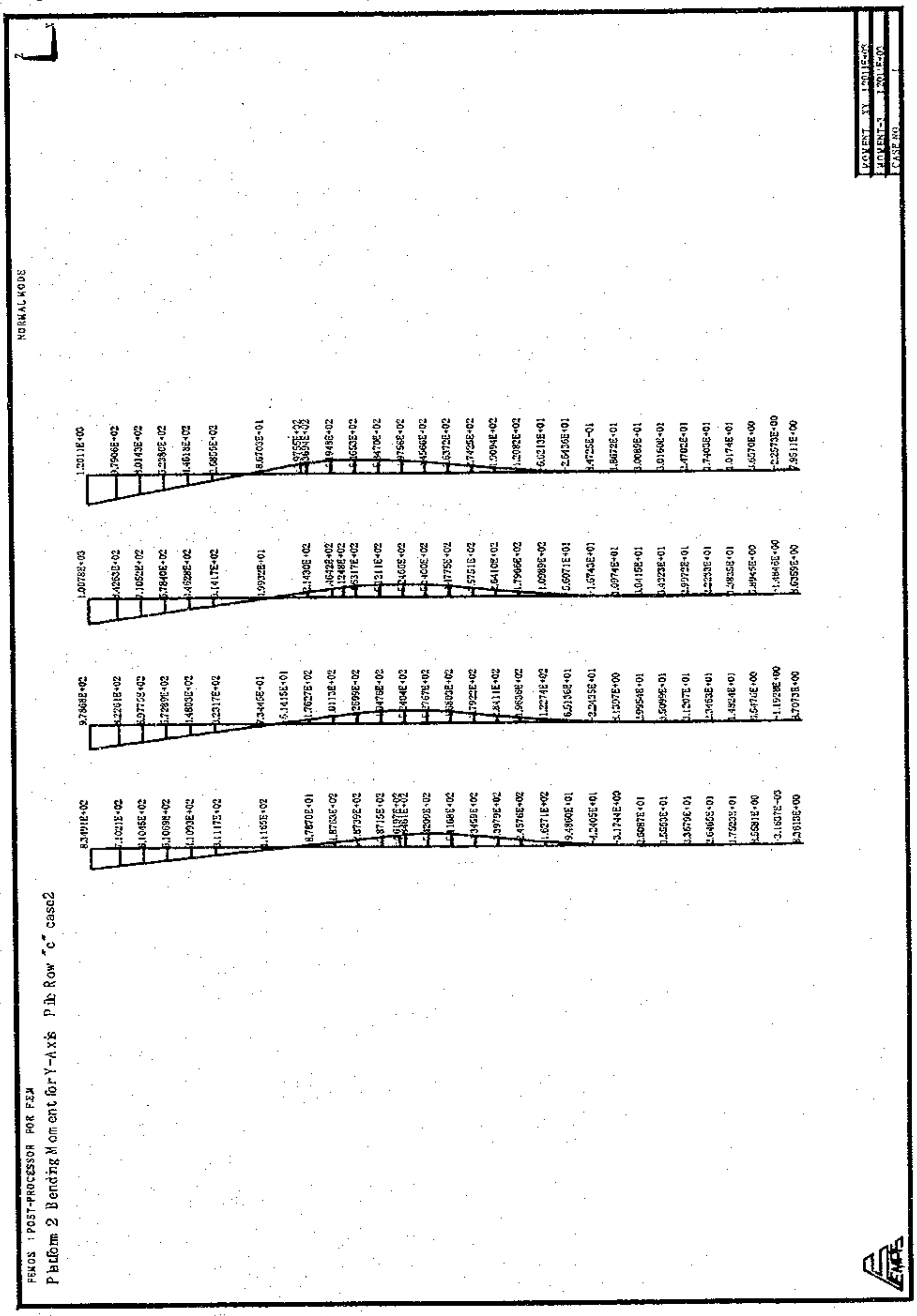
References/ Notes

・Bending Moment for Y-Axis (Pile Row "c" Pile 1 (Left Sidc)~Pile 4 (Right Side))



	Prepared by Y. Ando		Checked by R. NISHIMURA
		26/07/2002	08/08/2002

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References/
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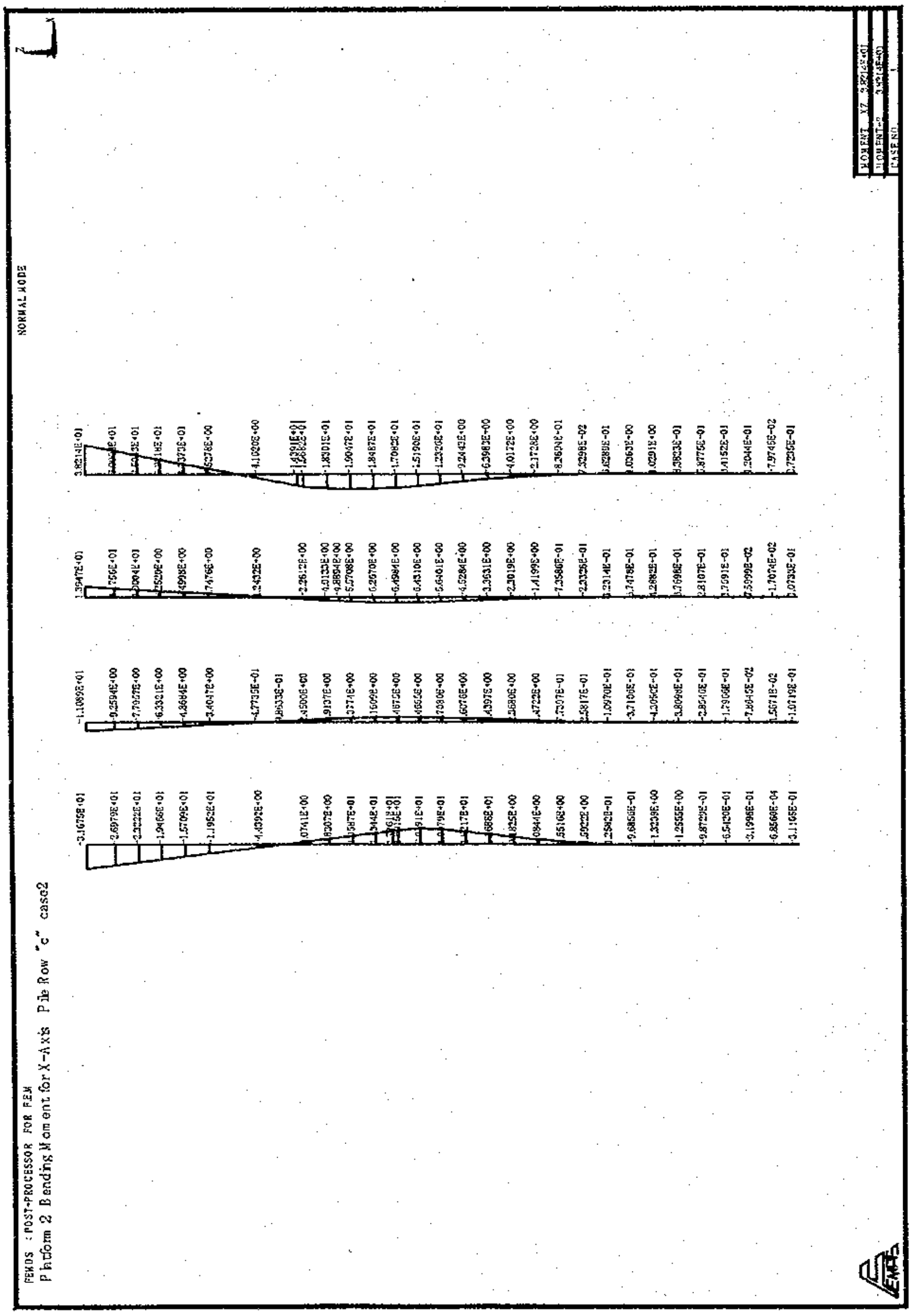
・Bending Moment for X-Axis (Pile Row "c" Pile 1 (Left Side)～Pile 4 (Right Side))



		Prepared by Y. Ando	Checked by R. NISHIMURA
		26 / 07 /2002	08 / 08 /2002

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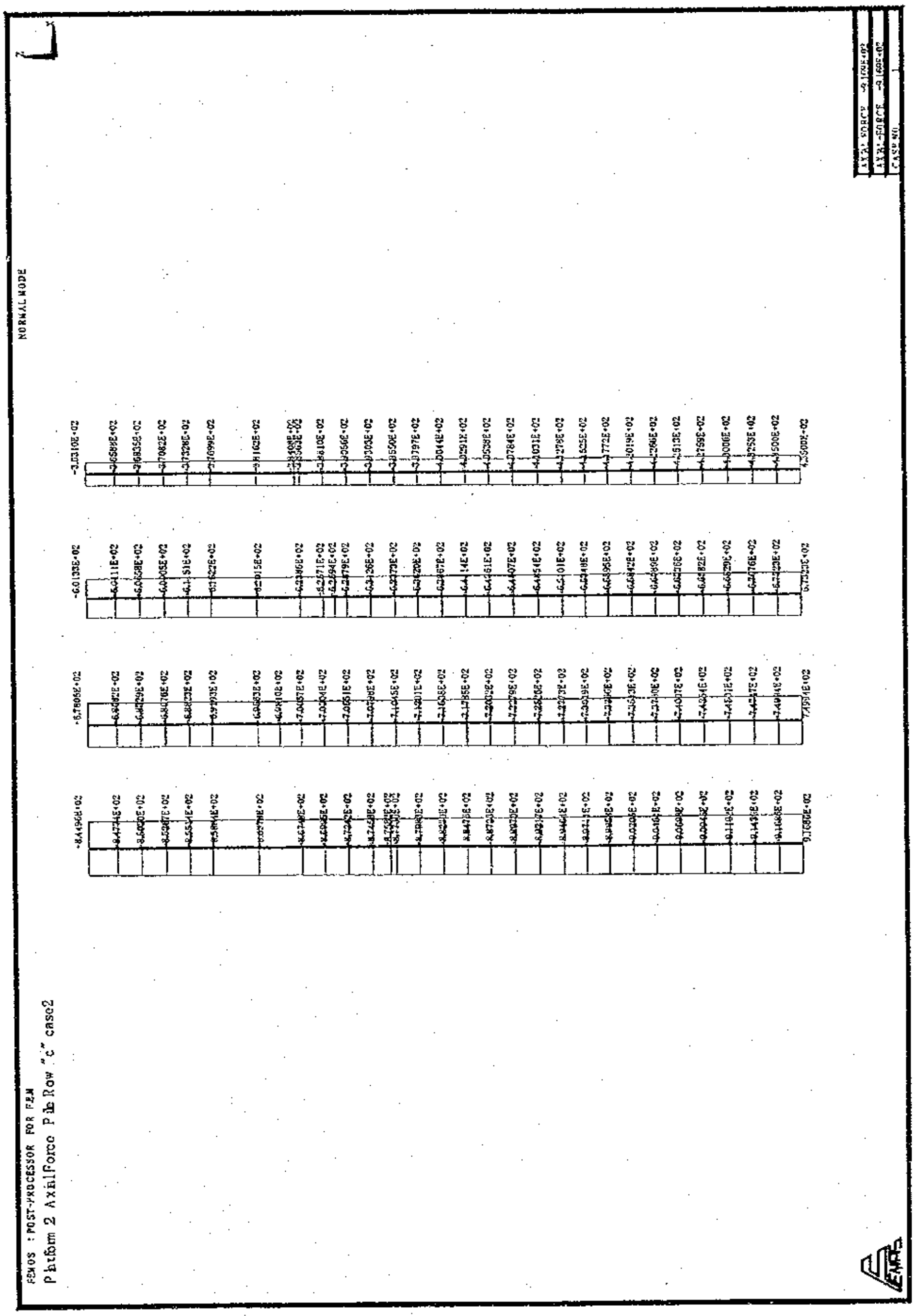
Section	Civil	Calc. Index No.	
Subject	Quaywall	Page No. 46	Rev.

References/ Notes

・Axial Force (Pile Row "c" Pile 1 (Left Side)~Pile 4 (Right Side))



		Prepared by	Y. Ando	Checked by	R. NISHIMURA
			26 / 07 /2002		08 / 06 /2002

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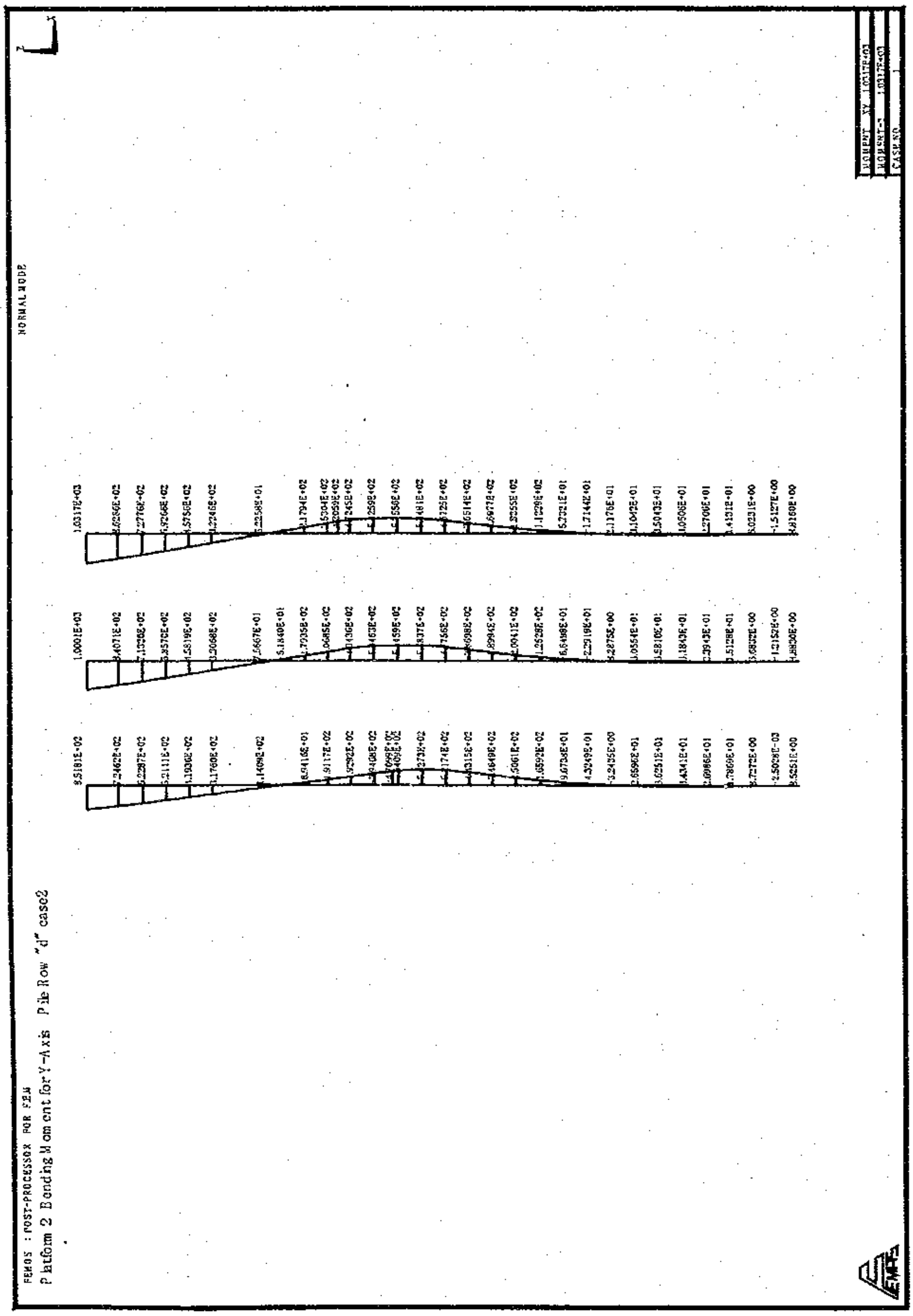
References/ Notes

・Bending Moment for Y-Axis (Pile Row "d" Pile 1 (Left Side)~Pile 3 (Right Side))



		Prepared by	Y. Ando	Checked by	R. NISHIMURA
			26 / 07 /2002		08 / 08 /2002

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Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
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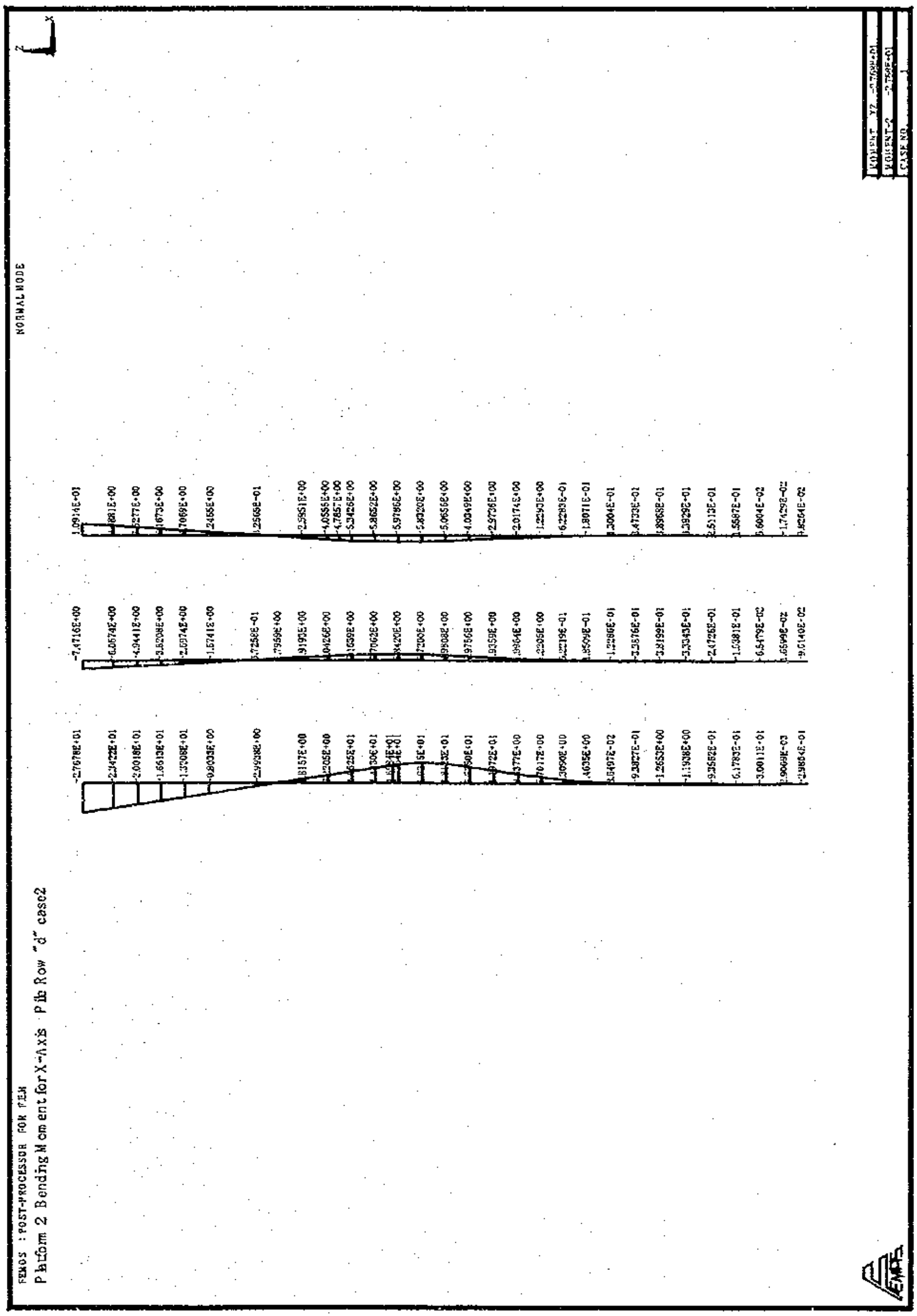
References/ Notes

・Bending Moment for X-Axis (Pile Row "d" Pile 1 (Left Side)~Pile 3 (Right Side))



	Prepared by	Y. Ando	Checked by R. NISHIMURA
		26 / 07 /2002	08 / 08 /2002

Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
Section	Civil	Calc. Index No.	
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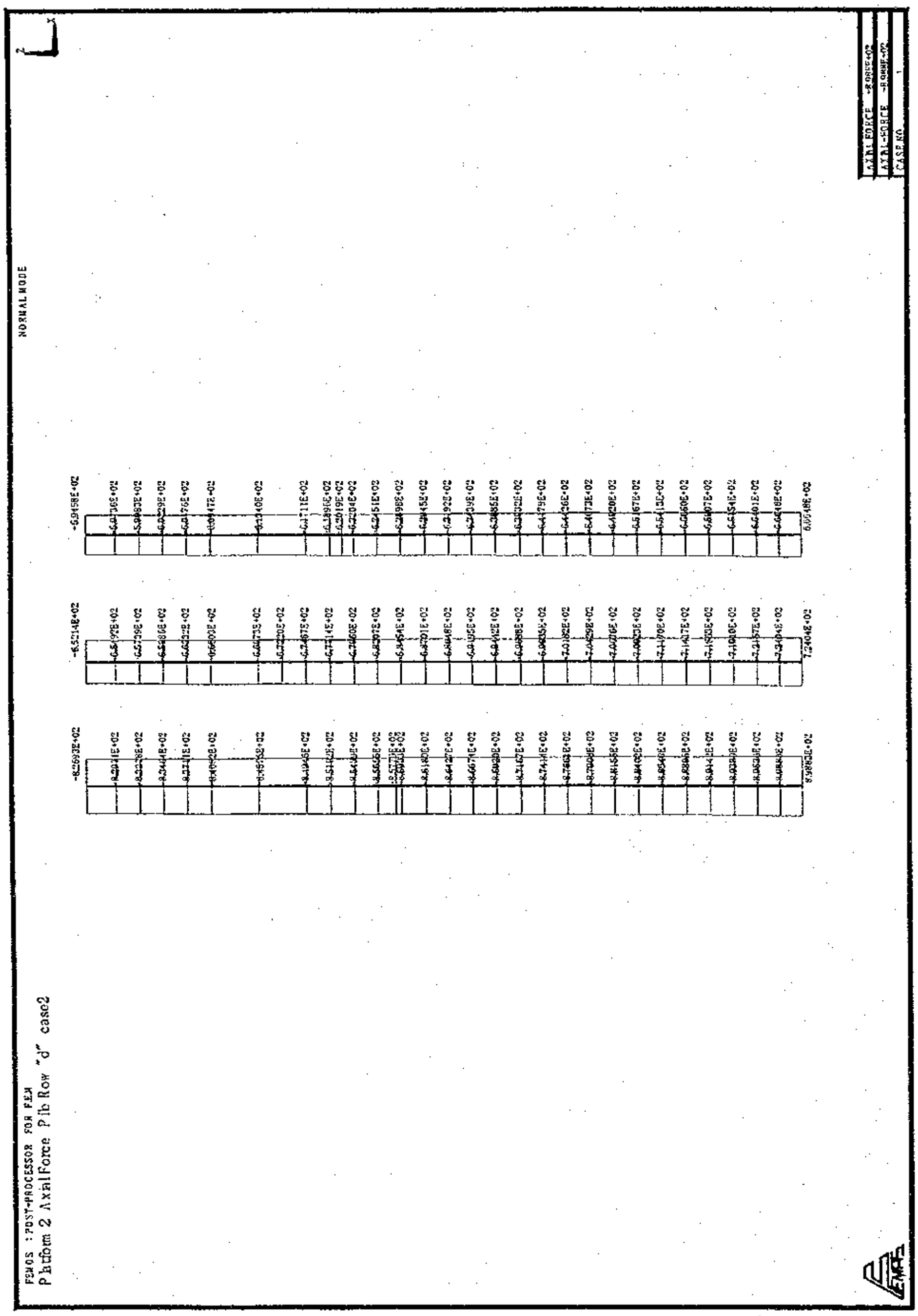
References/ Notes

・Axial Force (Pile Row "d" Pile 1 (Left Side)~Pile 3 (Right Side))



		Prepared by Y. Ando	Checked by R. NISHIMURA
		26 / 07 /2002	08 / 08 /2002

Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
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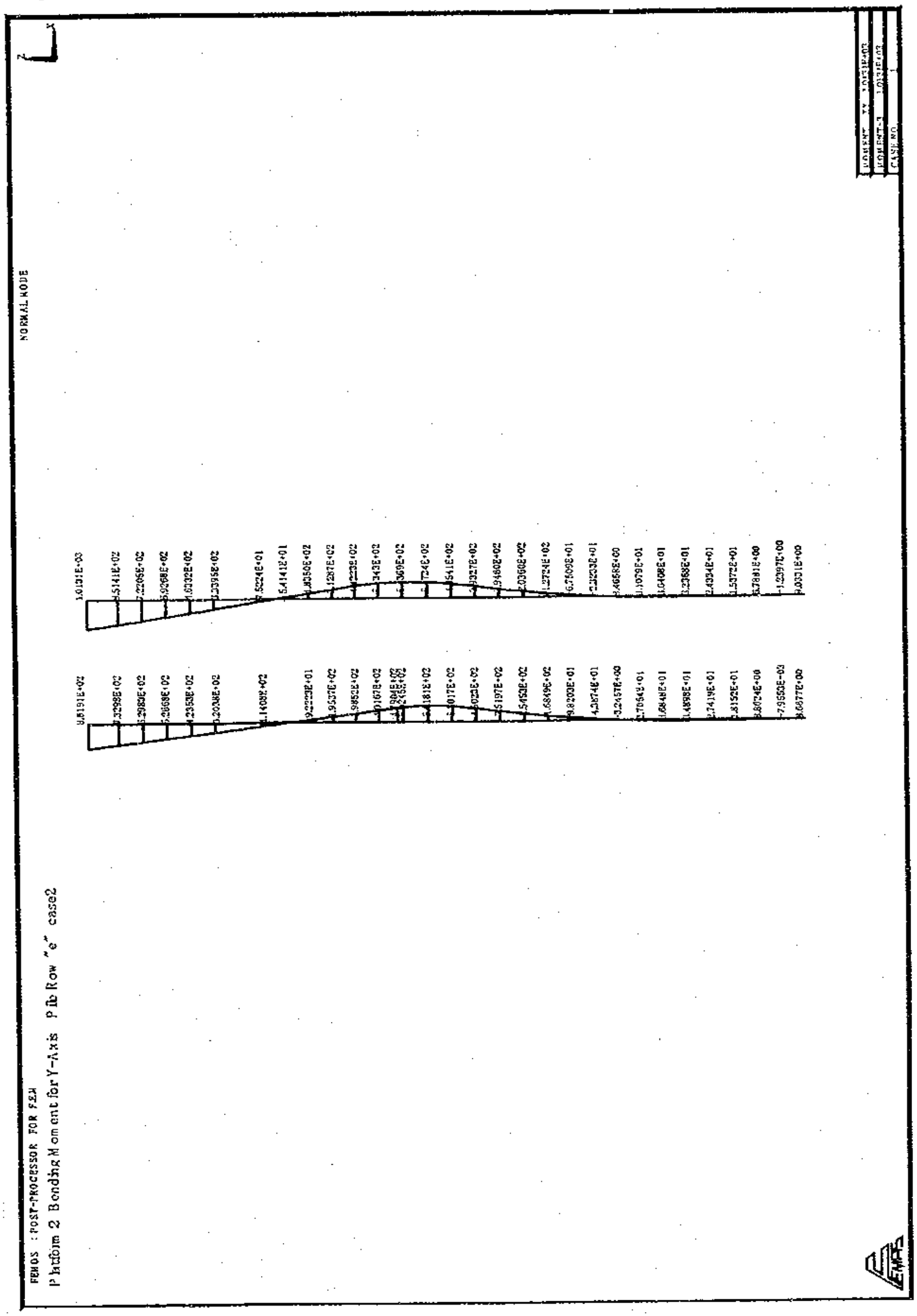
References/ Notes

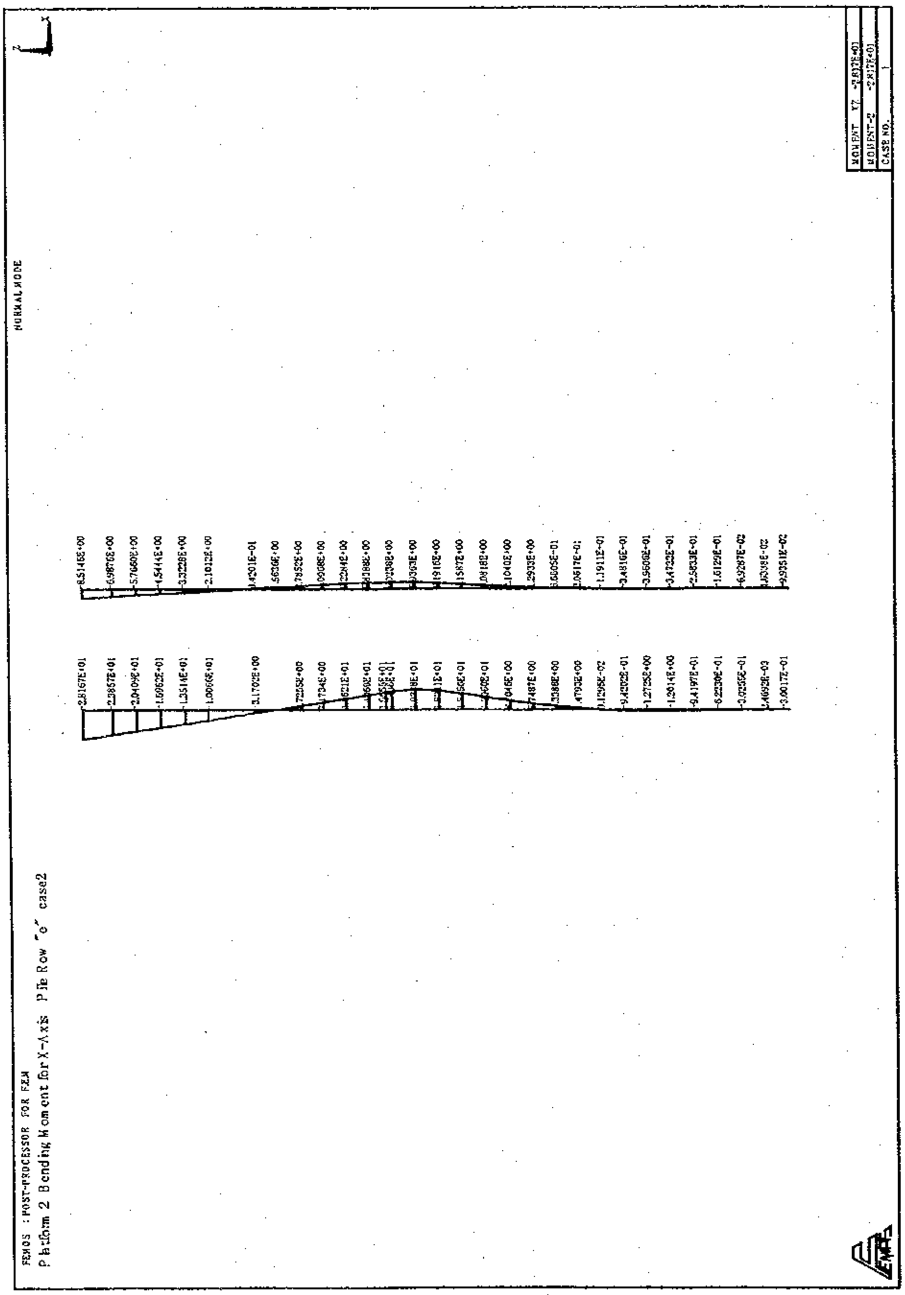
・Bending Moment for Y-Axis (Pile Row "e" Pile 1 (Left Side)~Pile 2 (Right Side))



		Prepared by	Y.Ando	Checked by E. NISHIMURA
			26 / 07 /2002	08 / 08 /2002

References/ Notes

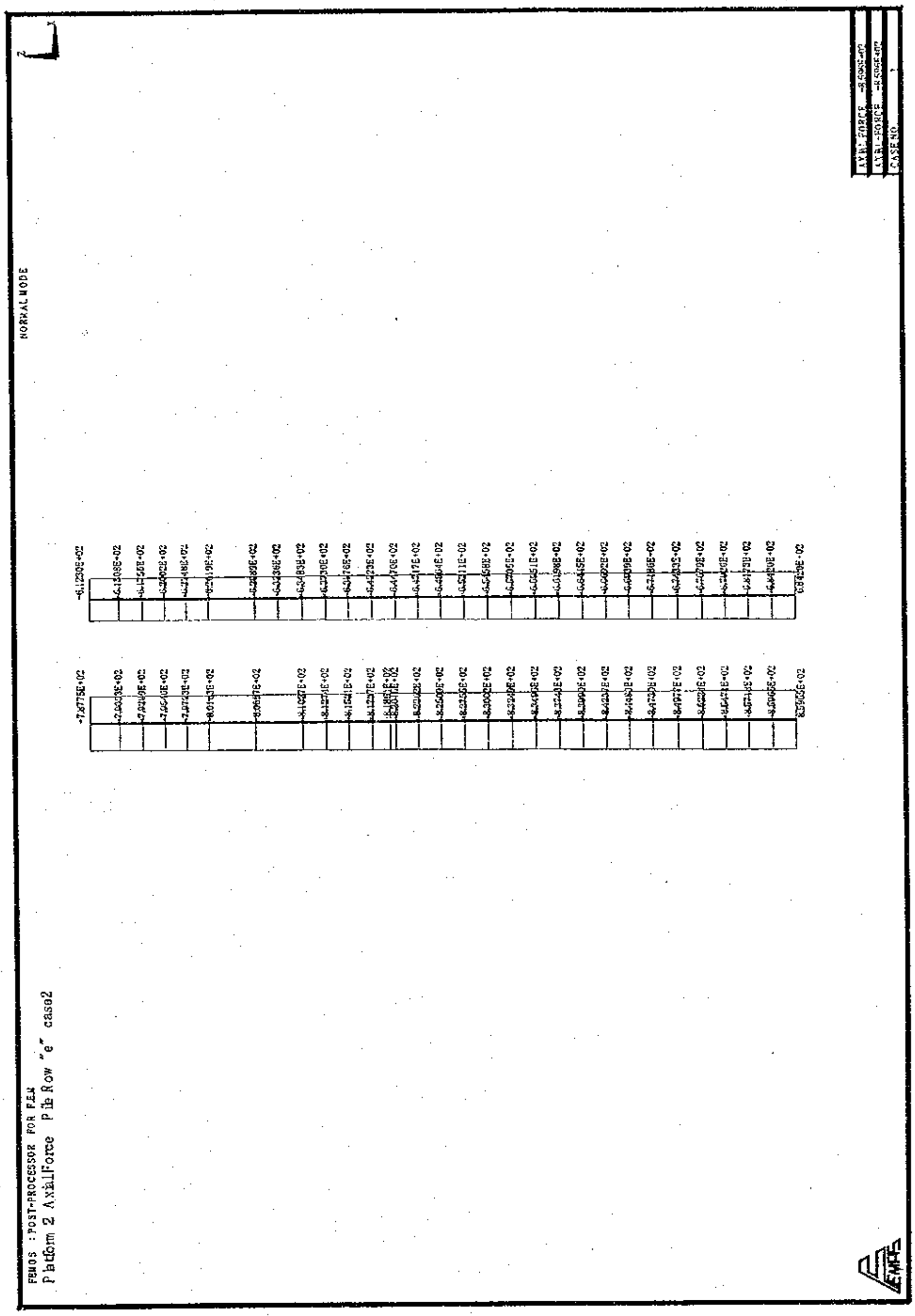
• Bending Moment for X-Axis (Pile Row "e" Pile 1 (Left Side)~Pile 2 (Right Side))



Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
Section	Civil	Calc. Index No.	
Subject	Quaywall	Page No. 52	Rev.

References/ Notes

・Axial Force (Pile Row "e" Pile 1 (Left Side)~Pile 2 (Right Side))



	Prepared by	Y. Ando	Checked by	R. NISHIMURA
		26 / 07 /2002		08 / 08 /2002

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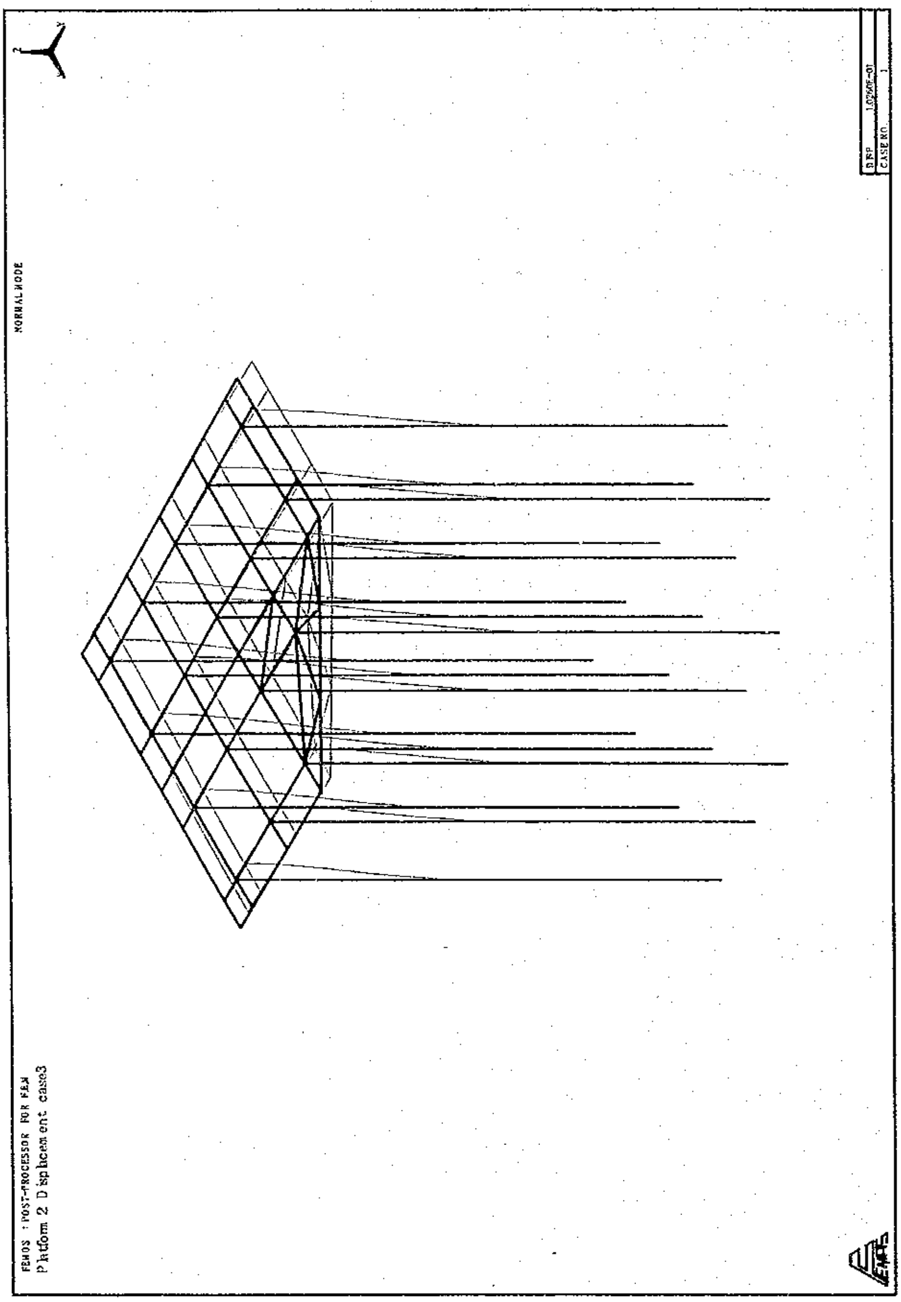
（3） case3 （Earthquake　The Parallel Direction to the Face Line）



・Displacement

		Prepared by	Y. Ando	Checked by	R. NISHIMURA
			26 / 07 /2002		08 / 08 /2002

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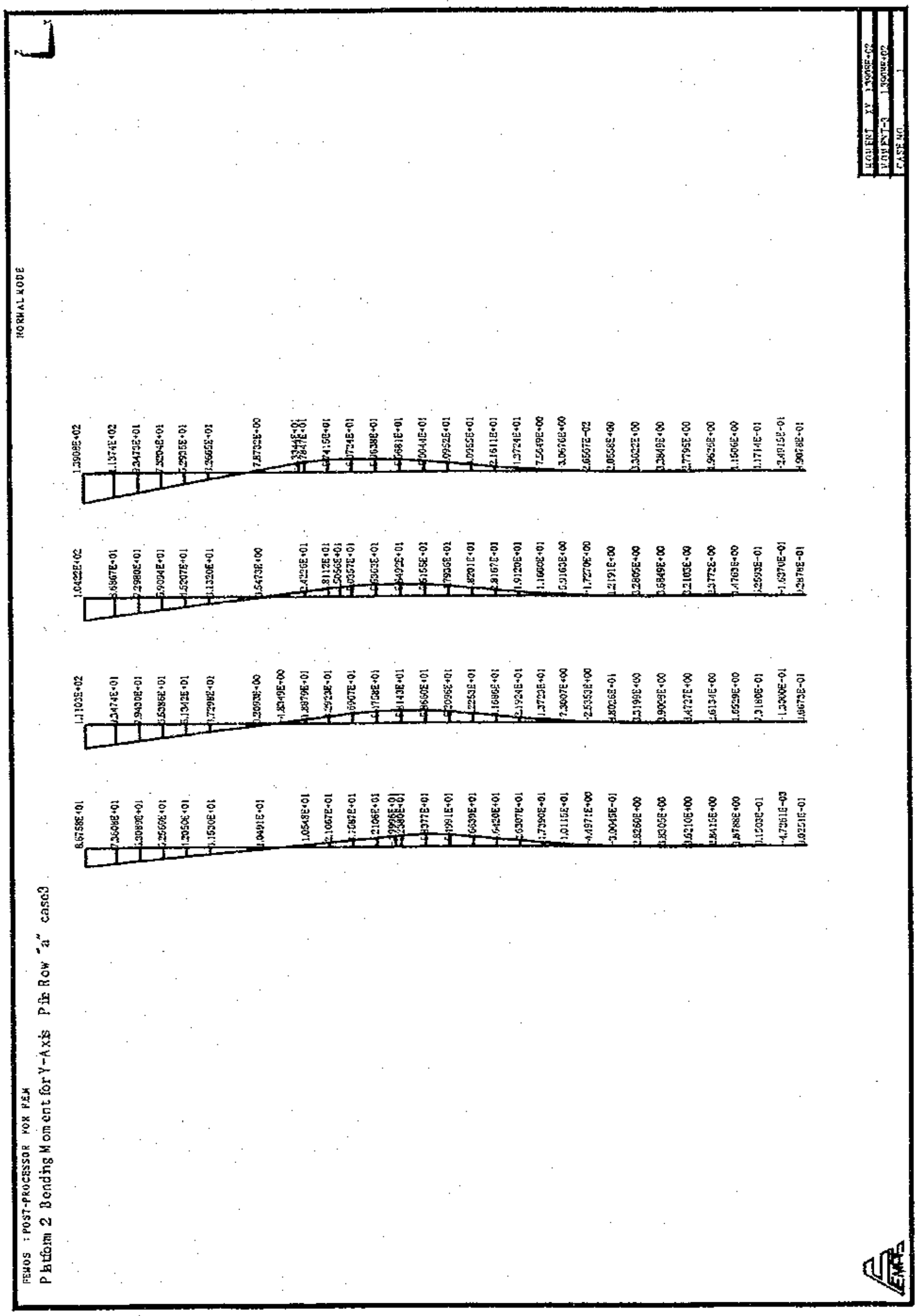
References/ Notes

・Bending Moment for Y-Axis (Pile Row "a" Pile 1 (Left Side)～Pile 4 (Right Side))



		Prepared by	Y. Ando	Checked by	R. NISHIMURA
			26/07/2002		08/08/2002

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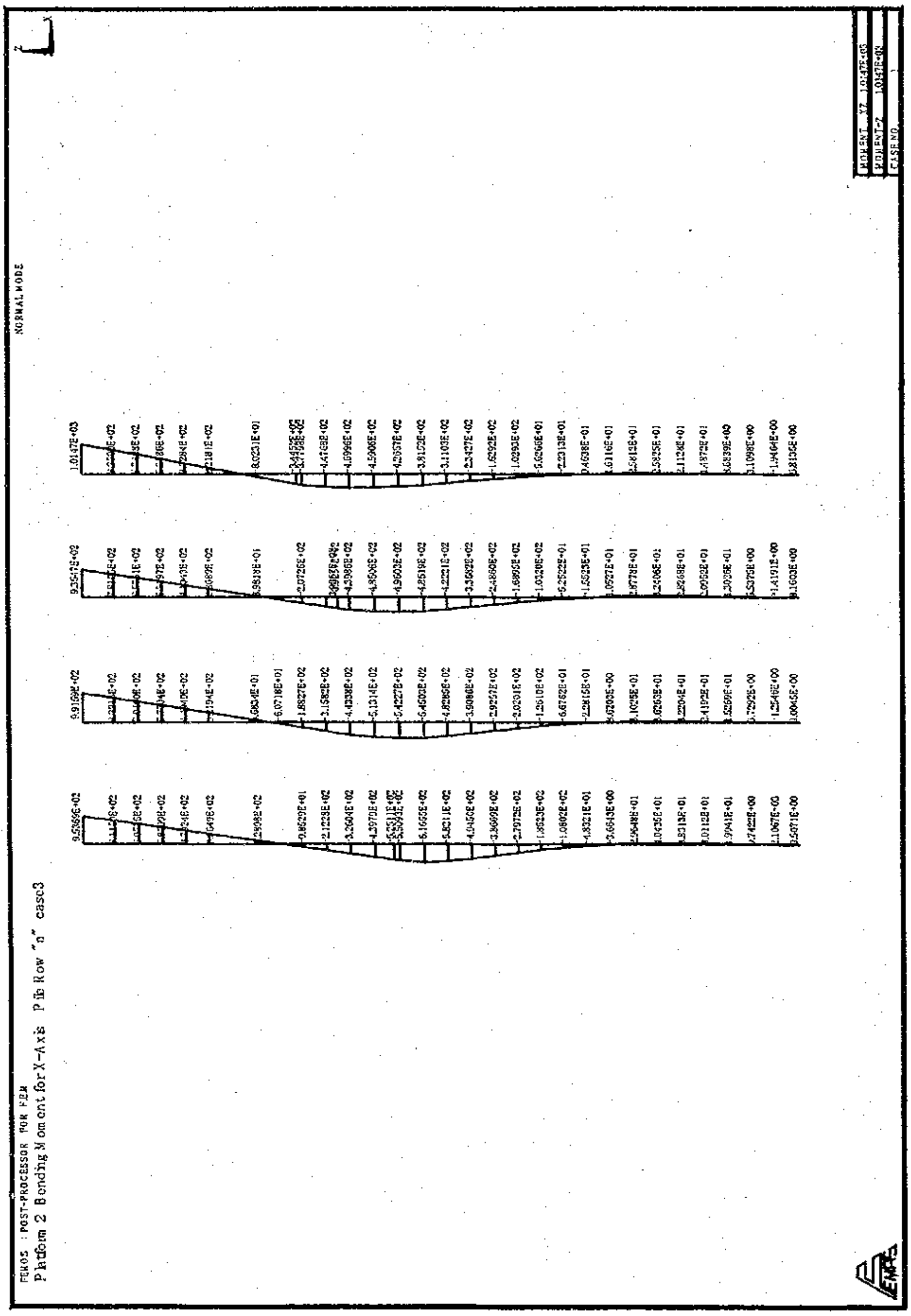
・Bending Moment for X-Axis (Pile Row "a" Pile 1 (Left Side)~Pile 4 (Right Side))



	Prepared by		Y. Ando	Checked by	R. NISHIMURA
			26 / 07 /2002		08 / 08 /2002

NIPPON KOEI CO.,LTD.

Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
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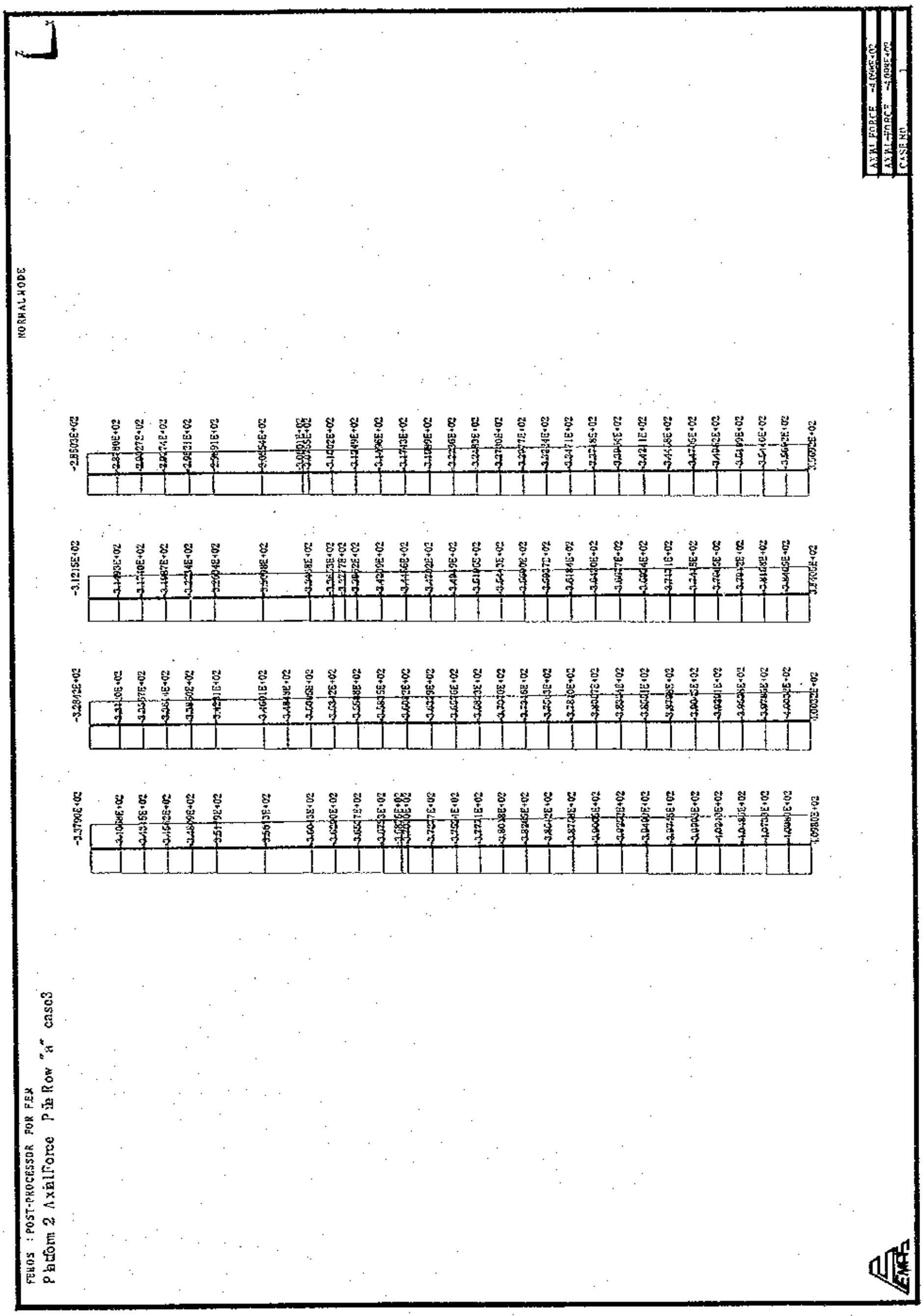
References/ Notes

・Axial Force (Pile Row "a" Pile 1 (Left Side)~Pile 4 (Right Side))



		Prepared by	Y. Ando	Checked by	R. NISHIMURA
			26 / 07 /2002		08 / 08 /2002

Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
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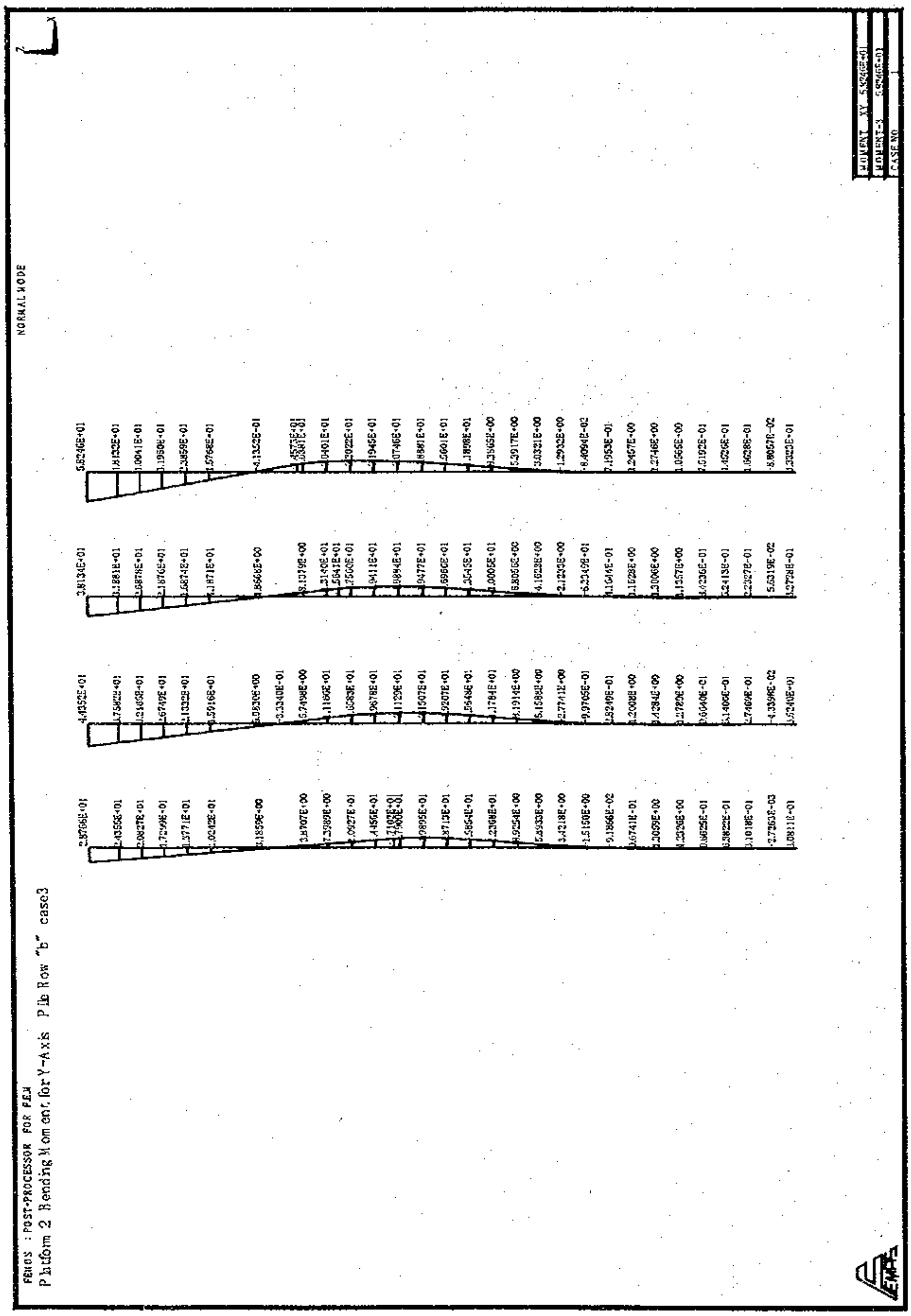
References/ Notes

・Bending Moment for Y-Axis (Pile Row "b" Pile 1 (Left Side)~Pile 4 (Right Side))



	Prepared by	Y. Ando	Checked by R. NISHIMURA
		26 / 07 /2002	08 / 08 /2002

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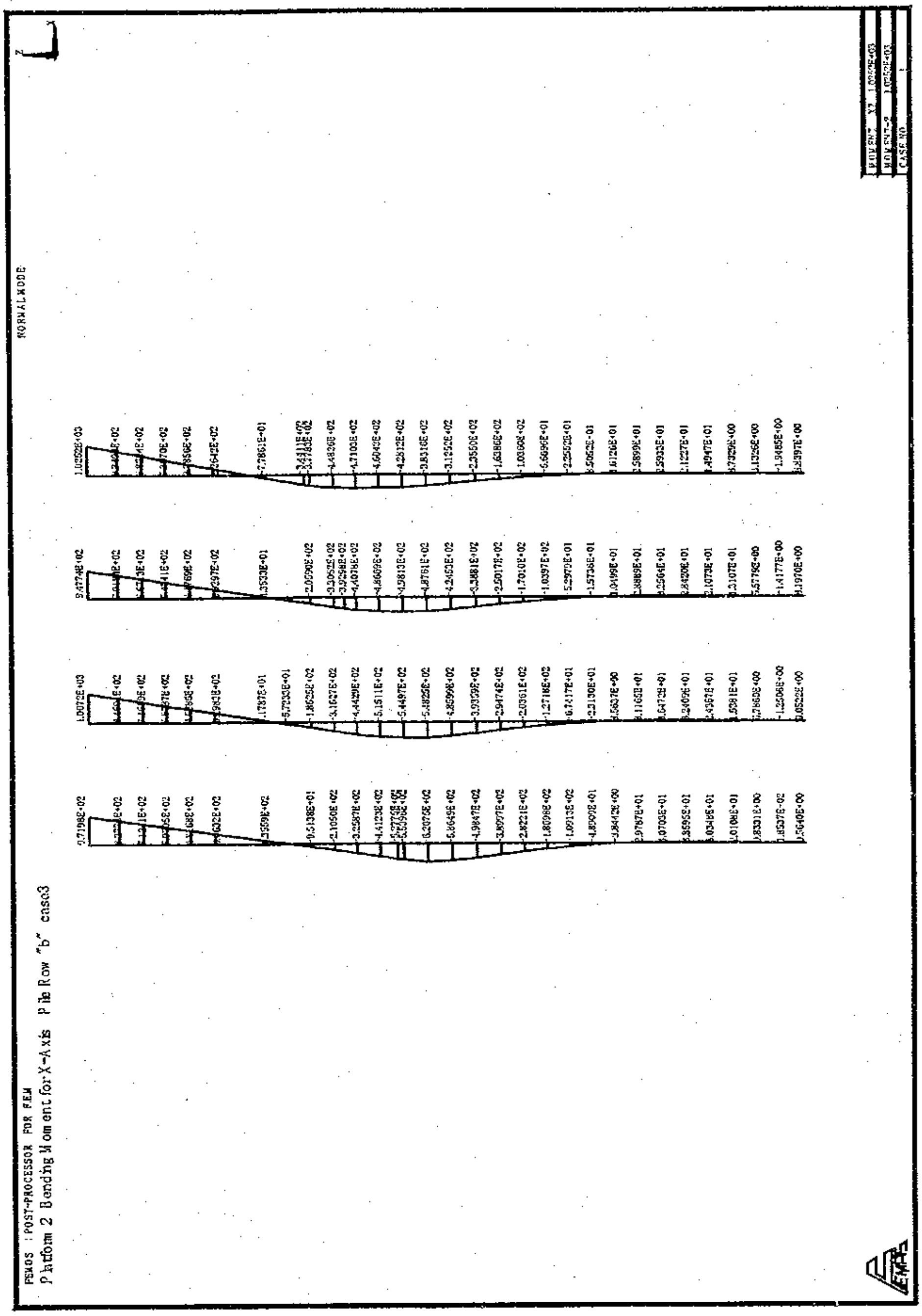
Section	Civil	Calc. Index No.	
Subject	Quaywall	Page No. 58	Rev.

References/ Notes

• Bending Moment for X-Axis (Pile ROW "b" Pile 1 (Left Side)~Pile 4 (Right Side))



	Prepared by	Y. Ando	Checked by	R. NISHIMURA
		26/07/2002		08/08/2002

Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
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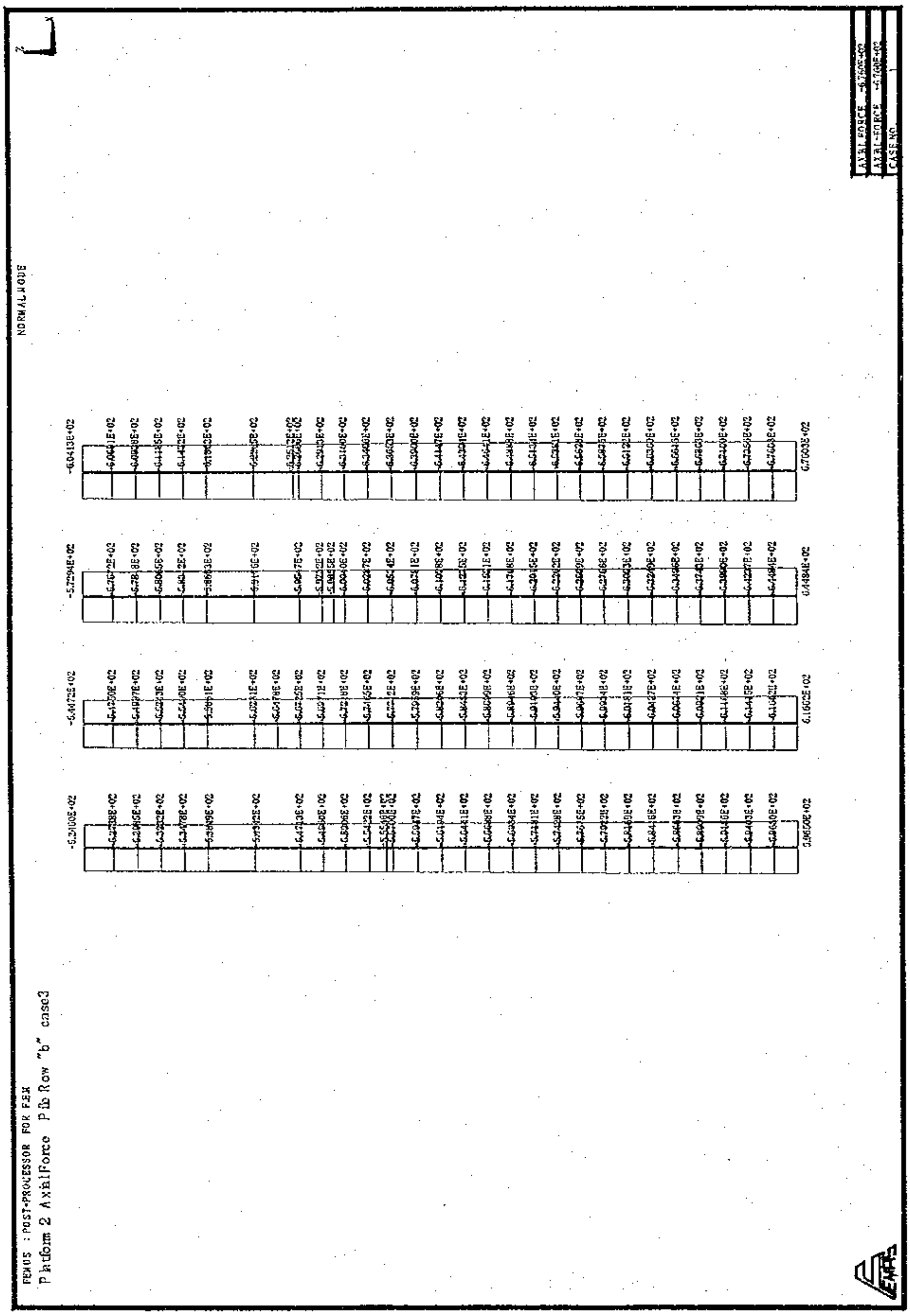
References/ Notes

• Axial Force (Pile Row "b" Pile 1 (Left Side)～Pile 4 (Right Side))



	Prepared by Y. Ando		Checked by R. NISHIMURA
		26 / 07 /2002	08 / 08 /2002

Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
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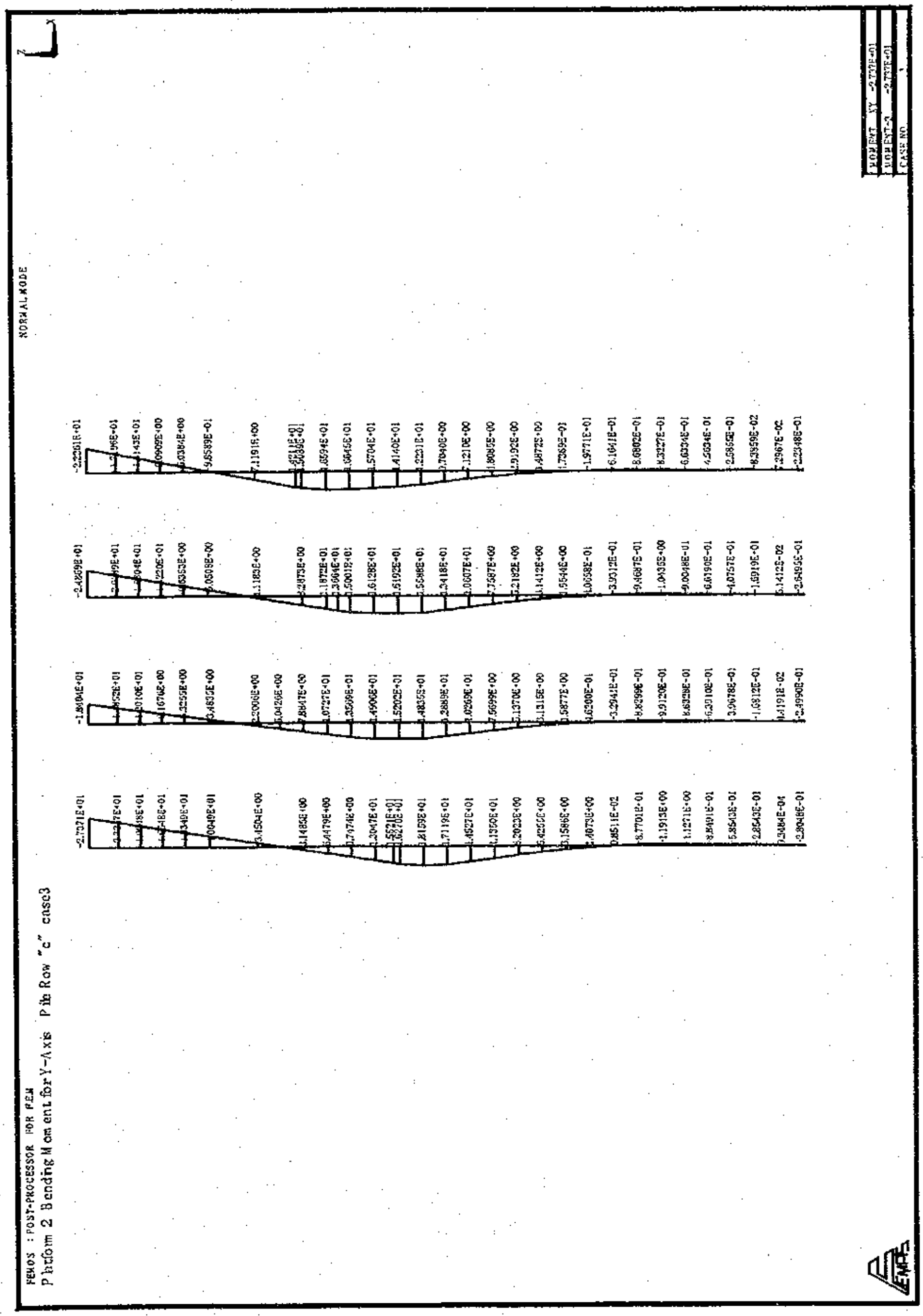
References/ Notes

・Bending Moment for Y-Axis (Pile Row "c" Pile 1 (Left Side)~Pile 4 (Right Side))



		Prepared by	Y. Ando	Checked by	R. NISHIMURA
			26/07/2002		08/08/2002

Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
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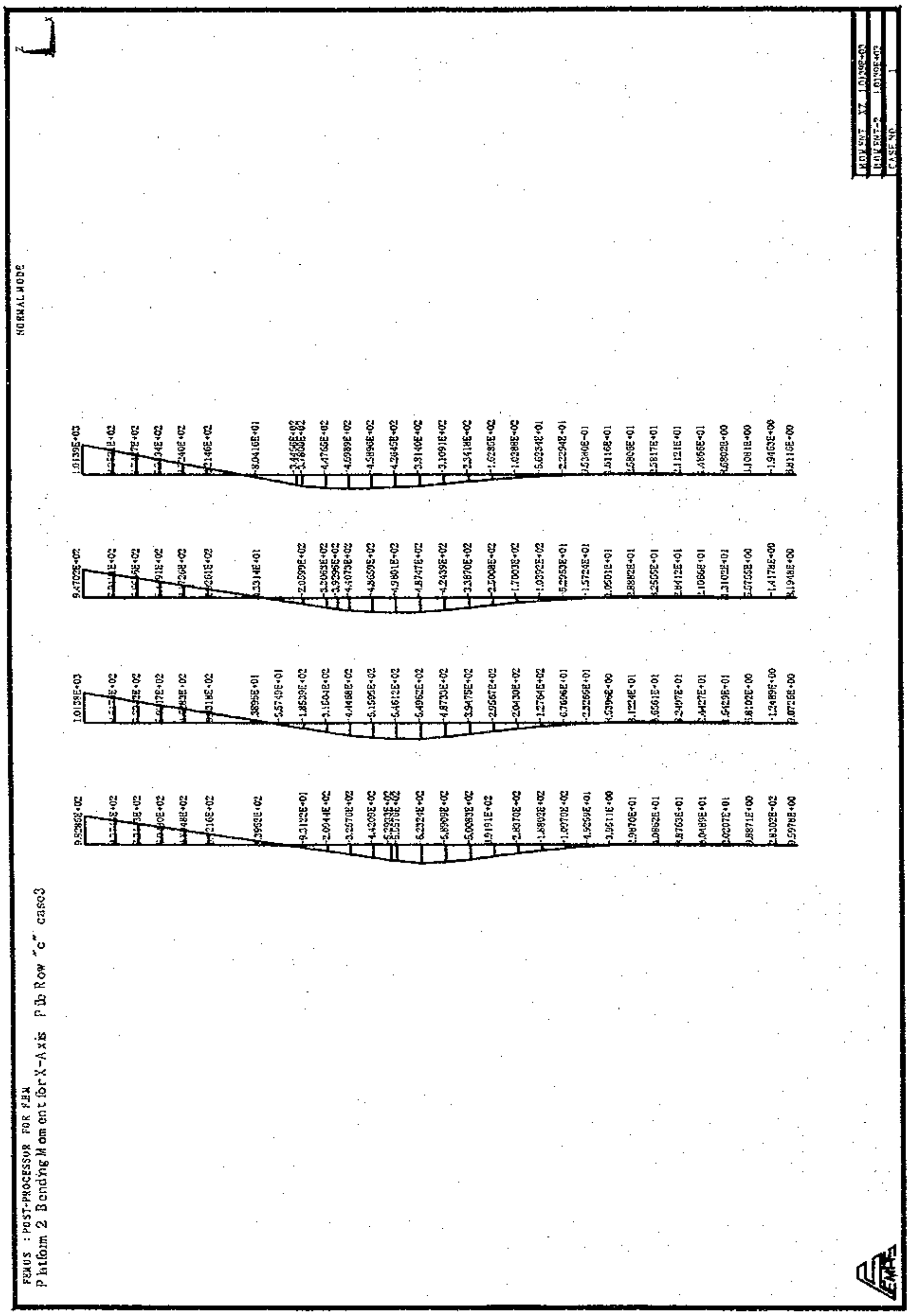
References/ Notes

・Bending Moment for X-Axis (Pile Row "c" Pile 1 (Left Side)~Pile 4 (Right Side))



		Prepared by Y. Ando	Checked by R. NISHIMURA
		26/07/2002	08/08/2002

Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
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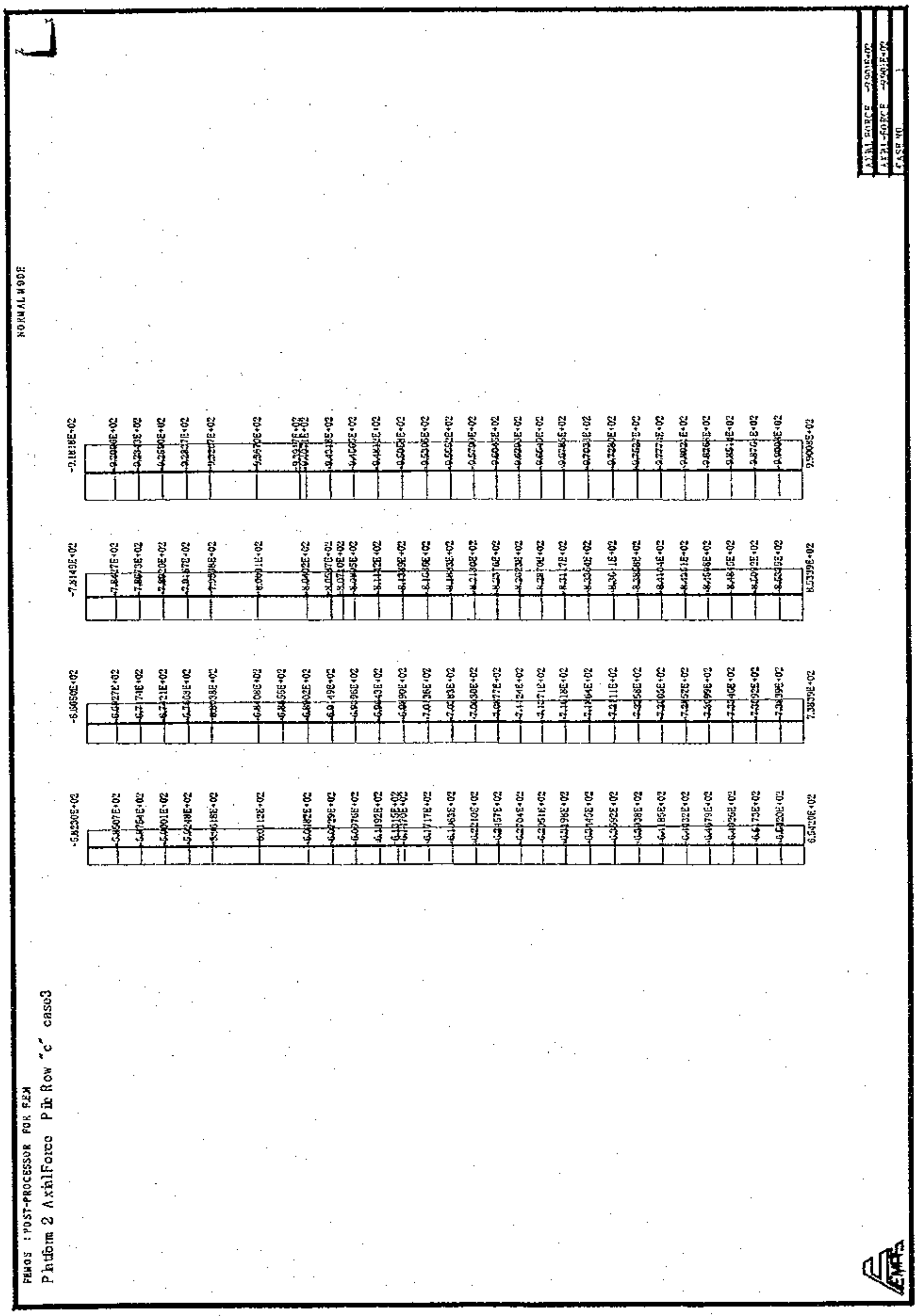
References/ Notes

・Axial Force (Pile Row "c" Pile 1 (Left Side)~Pile 4 (Right Side))



		Prepared by	Y. Ando	Checked by	R. NISHIMURA
			26/07/2002		08/08/2002

Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
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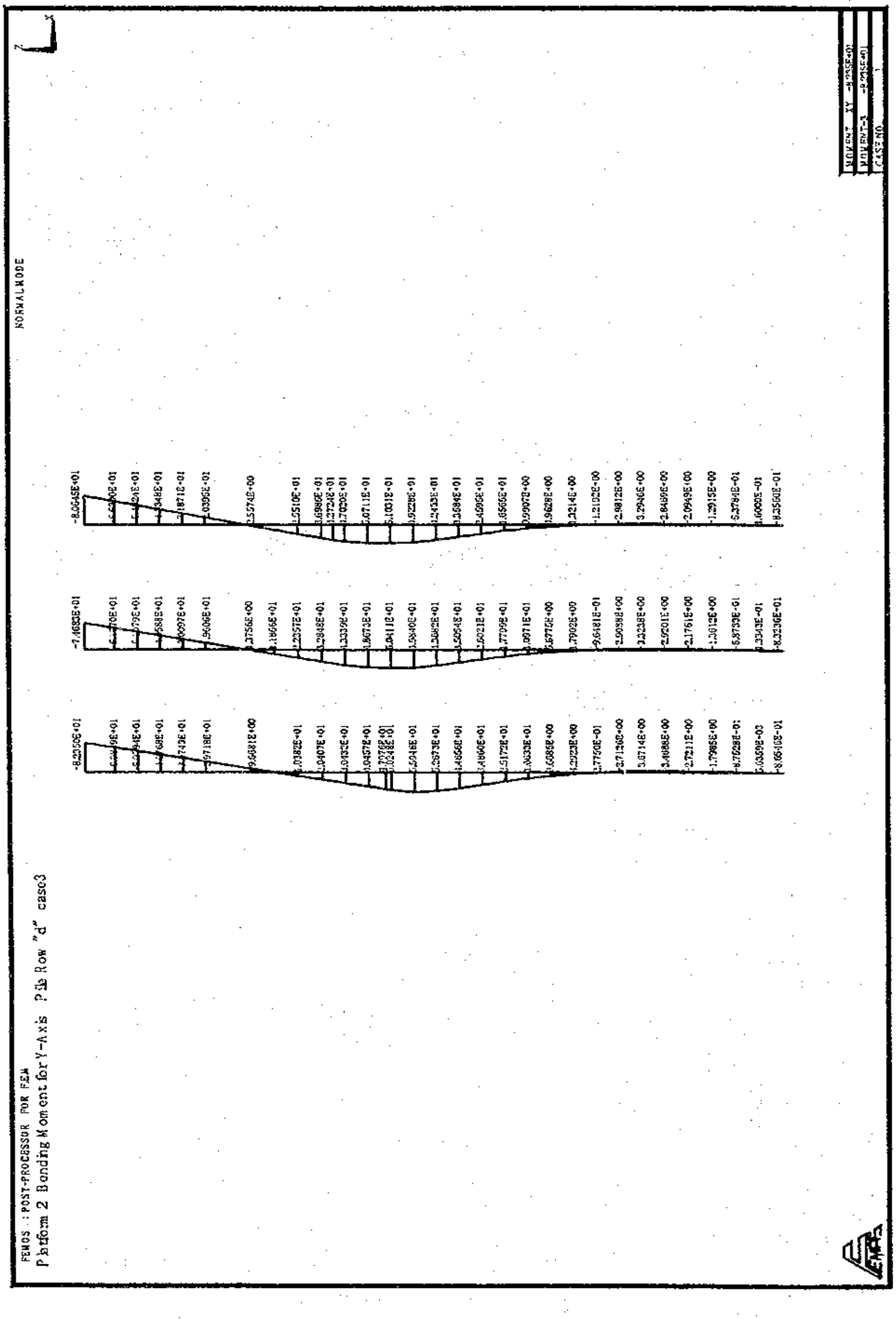
References/ Notes

・Bending Moment for Y-Axis (Pile Row "d" Pile 1 (Left Side)~Pile 3 (Right Side))



	Prepared by	Y. Ando	Checked by R. NISHIMURA
		26/07/2002	08/08/2002

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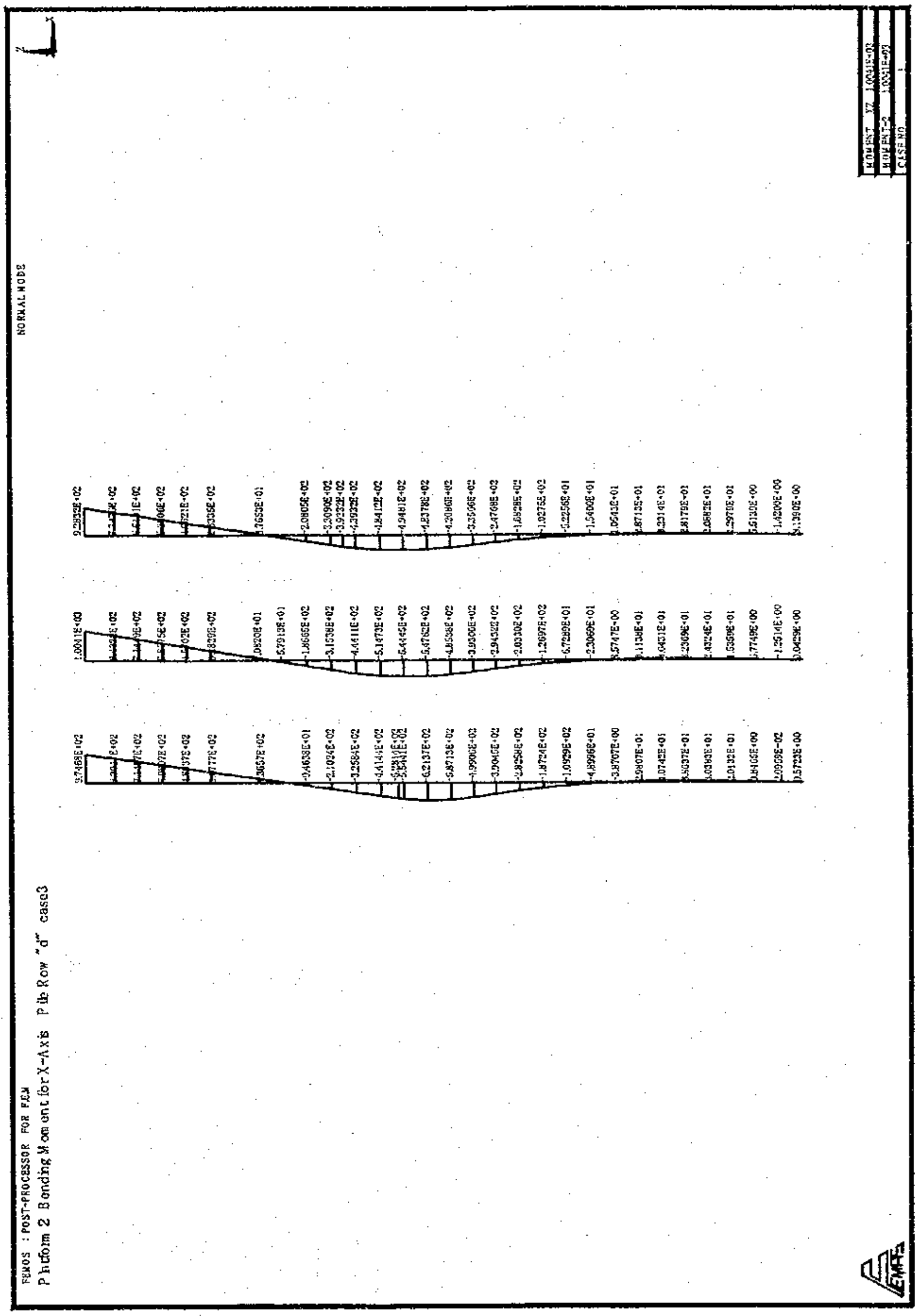
・Bending Moment for X-Axis (Pile Row "d" Pile 1 (Left Side)~Pile 3 (Right Side))



		Prepared by	Y. Ando	Checked by	R. NISHIMURA
			26 / 07 /2002		08 / 08 /2002

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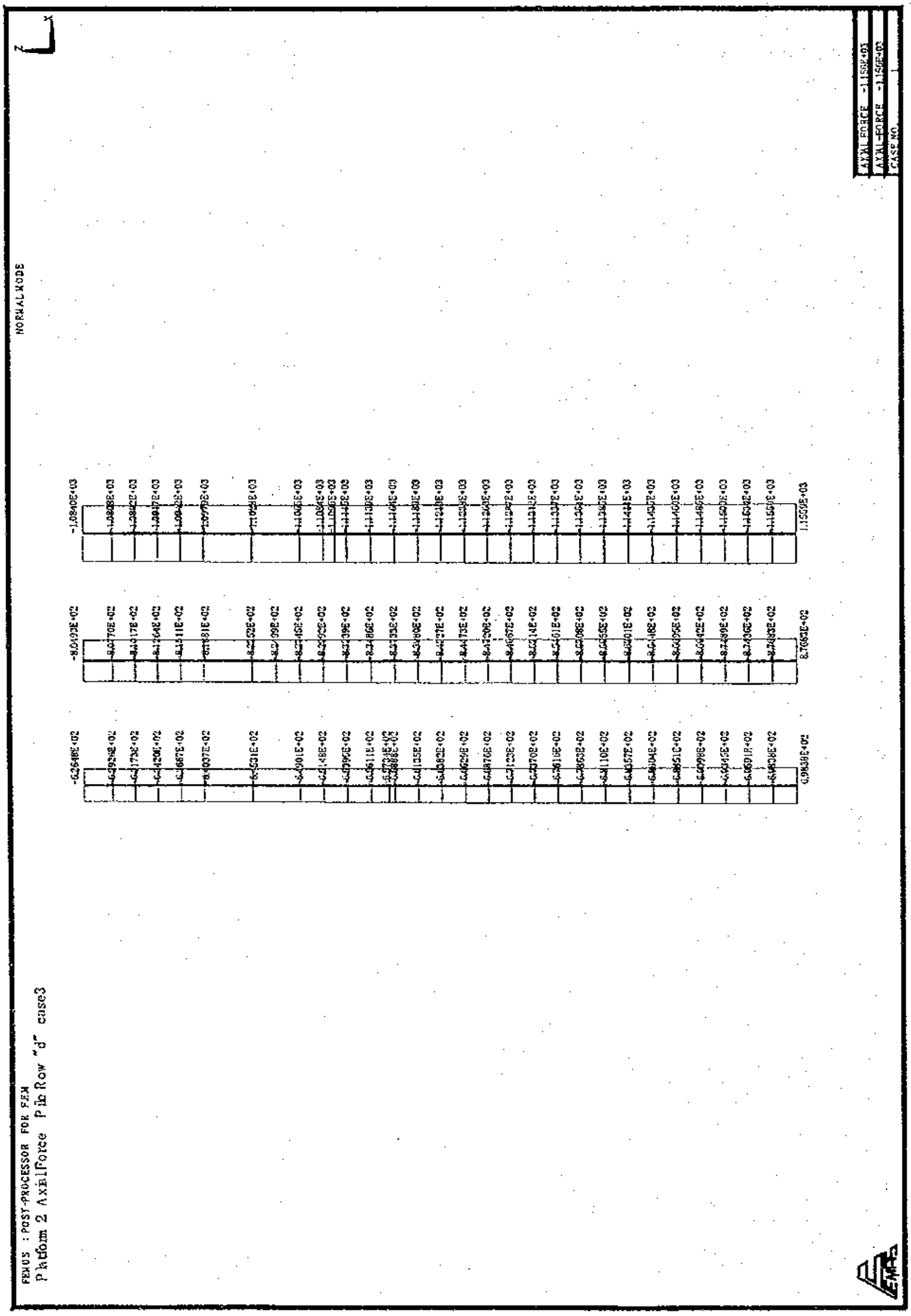
・Axial Force (Pile Row "d" Pile 1 (Left Side)~Pile 3 (Right Side))



	Prepared by	Y. Ando	Checked by R. NISHIMURA
		26 / 07 /2002	08 / 08 /2002

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Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
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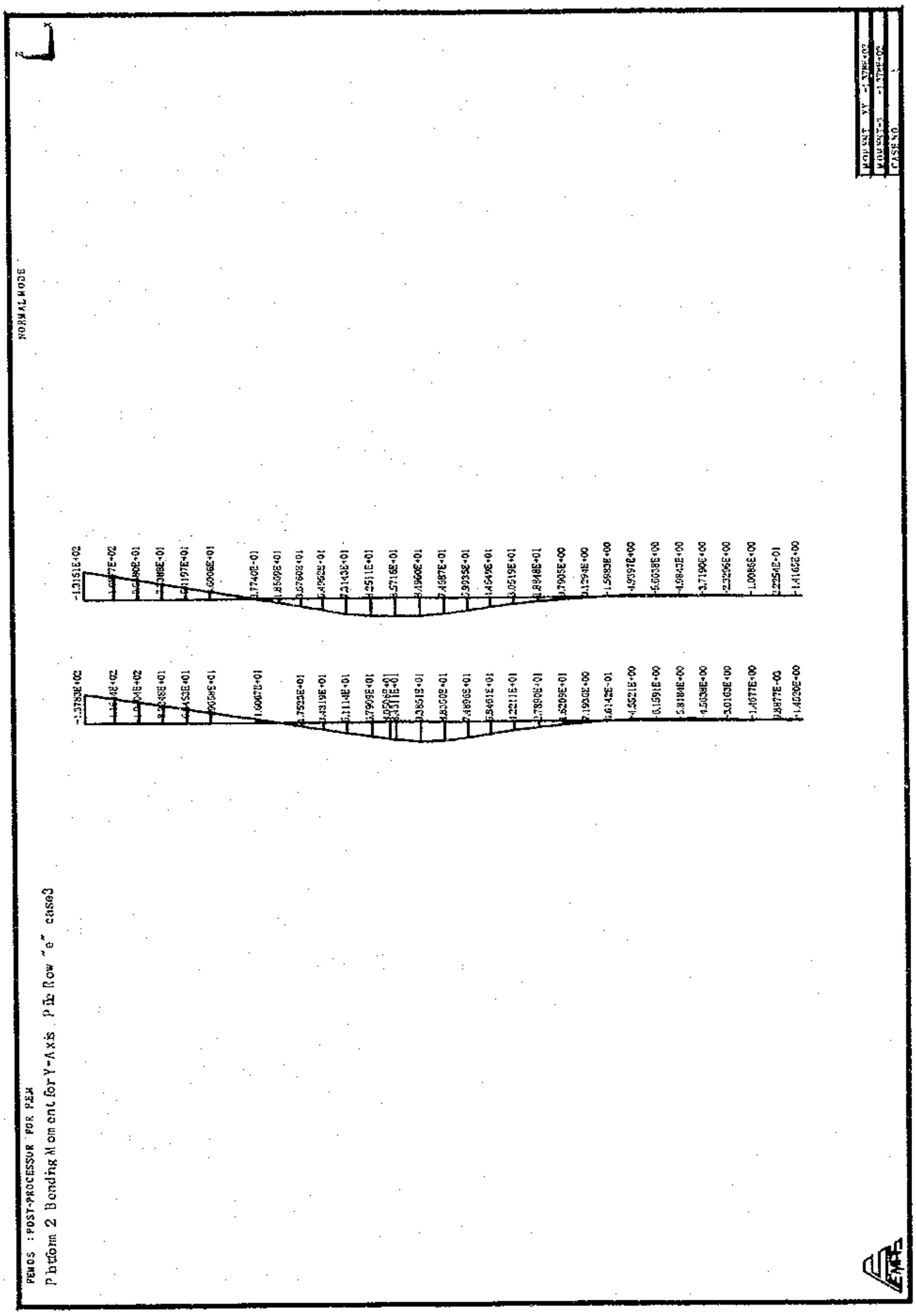
References/ Notes

• Bending Moment for Y-Axis (Pile Row "e" Pile 1 (Left Side)~Pile 2 (Right Side))



		Prepared by Y. Ando	Checked by R. NISHIMURA
		26 / 07 /2002	08 / 08 /2002

Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
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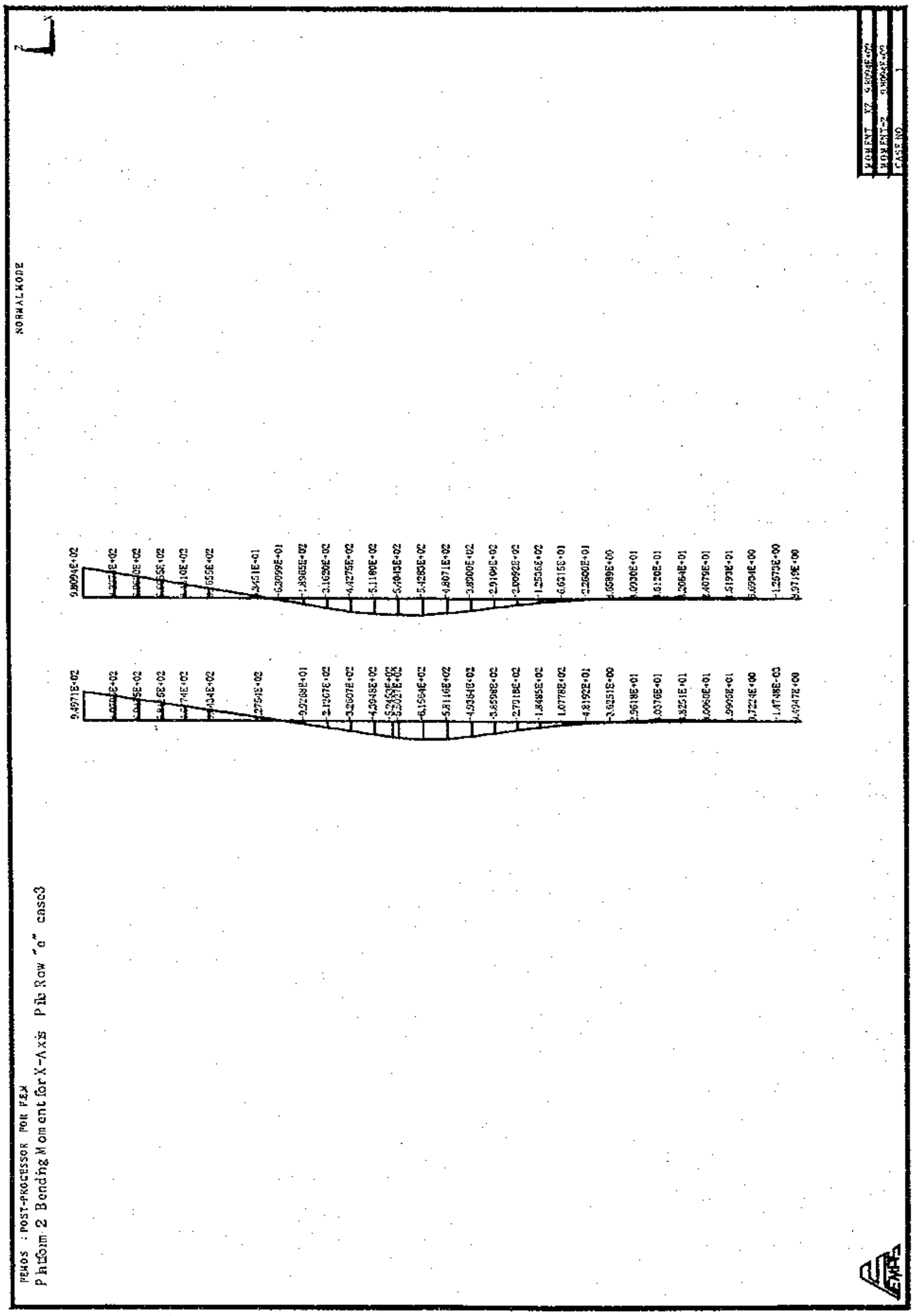
References/ Notes

・Bending Moment for X-Axis (Pile Row "e" Pile 1 (Left Side)~Pile 2 (Right Side))



		Prepared by	Y. Ando	Checked by	R. NISHIMURA
			26/07/2002		08/08/2002

Project	Detailed Design on Port Reactivation Project in La Union	Calc. File No.	
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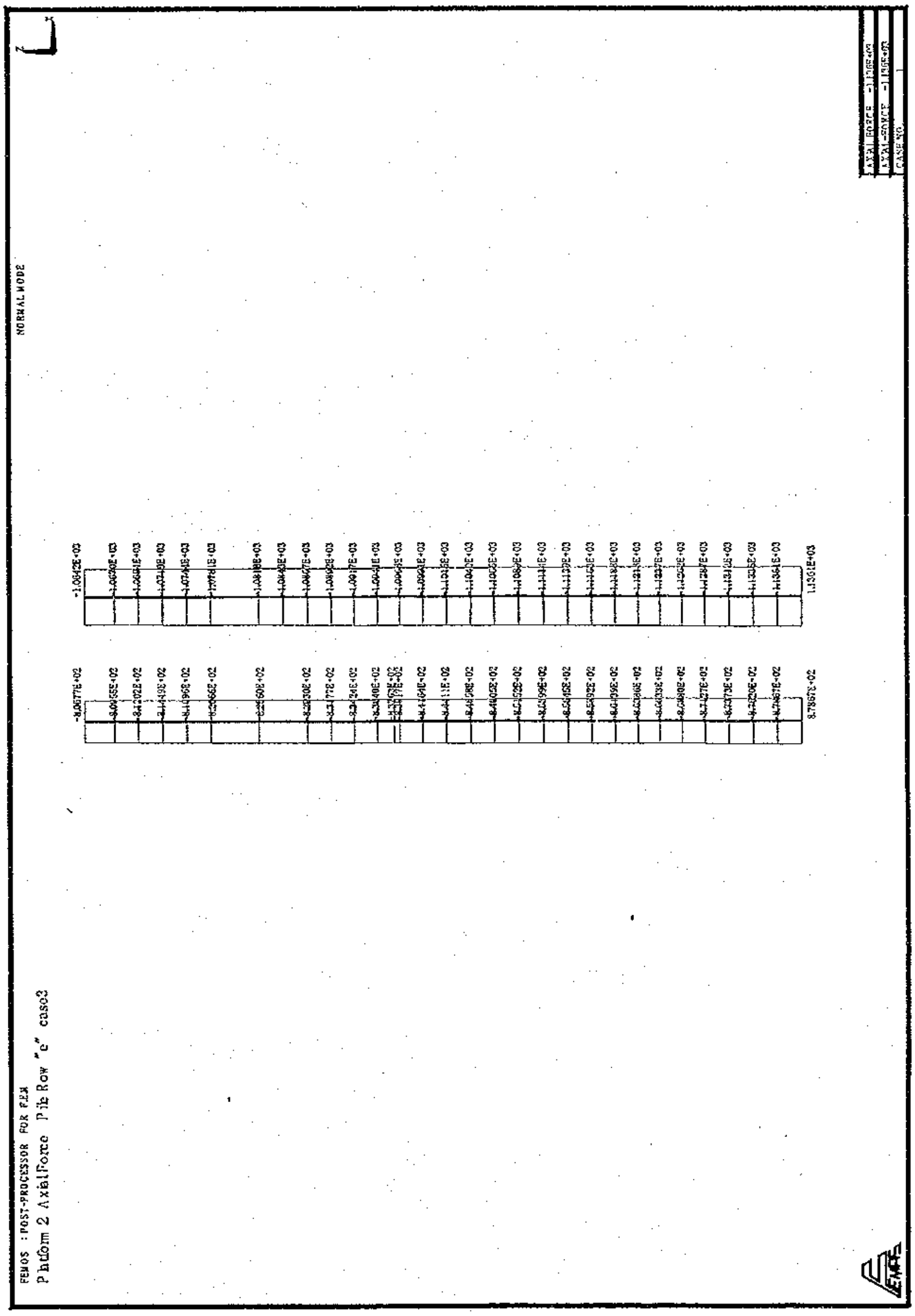
References/ Notes

・Axial Force (Pile Row "e" Pile 1 (Left Side)~Pile 2 (Right Side))



		Prepared by	Y. Ando	Checked by	R. NISHIMURA
			26 / 07 /2002		08 / 08 /2002

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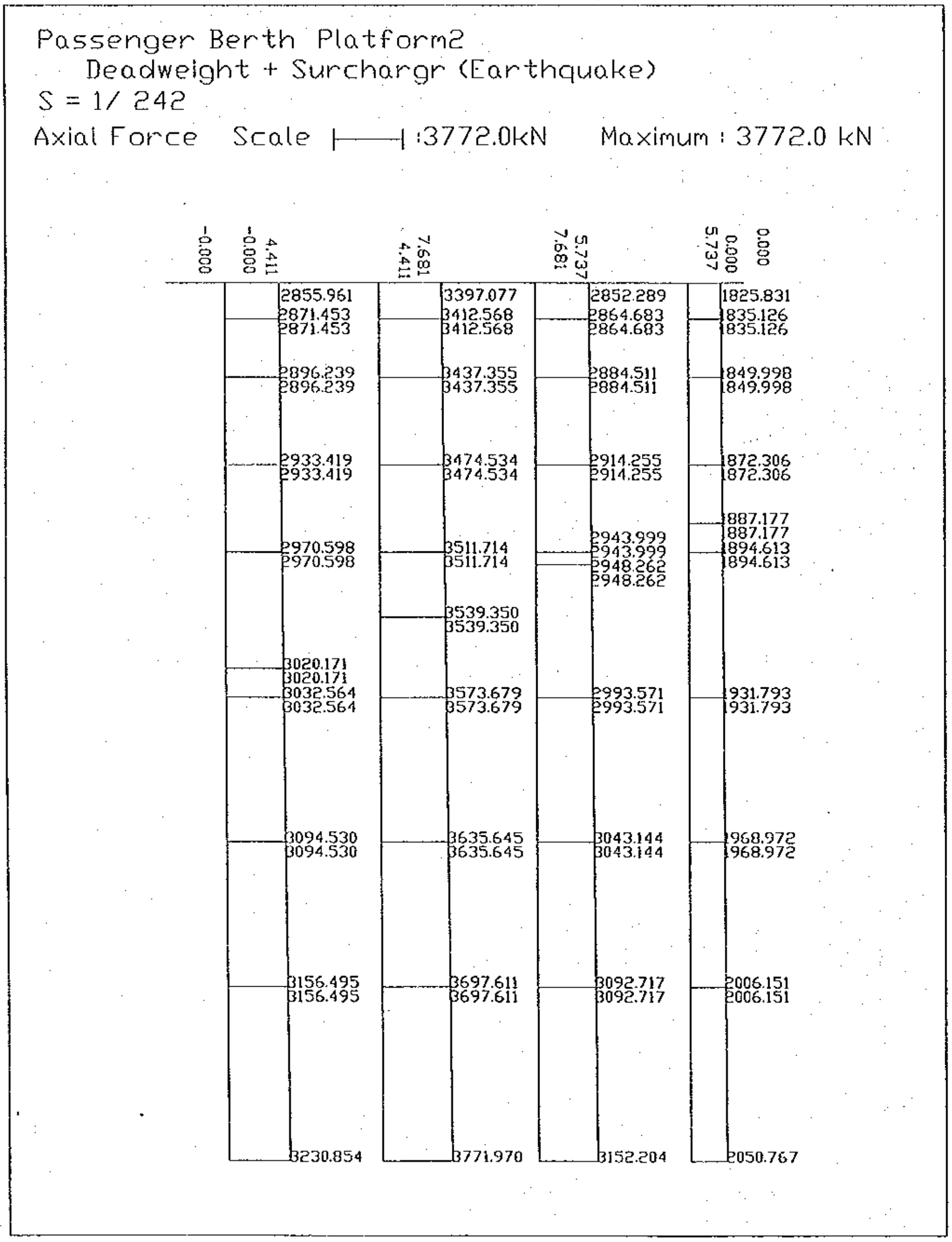
References/ Notes

(4) Earthquake Condition

Static Load (Deadweight and Surcharge) Action Condition Axial Force



(Cross-sectional force is the sum total for a pile number of each pile rows.)

	Prepared by Y. Ando	Checked by Z. NISHIMURA	
	26 / 07 /2002		08 / 08 /2002