

### 3.1 Baru Pumping Station

#### 3.1.3 Stress Analysis of Gate

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Name of Structure	Baru Gate	Category of calculation	Stress Analysis	Page	1 / 77
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Stress Analysis was done at following part of gate.

1. Gate frame    2. Pier & Footing    3. O/M Bridge

General characteristics of material are as follows:

- Young's module of reinforced concrete:  
 $245,000 \text{ kg/cm}^2 = 2.45 \text{ tf/m}^2$
- Unit weight of reinforced concrete:  
 $2.5 \text{ t/m}^3$
- Linear expansion coefficient:  
 $1.0 \times 10^{-5}$

### 1. Gate frame

Following two cases were analyzed.

Case-A (model for front view of gate)    Case-B (model for side view of gate)

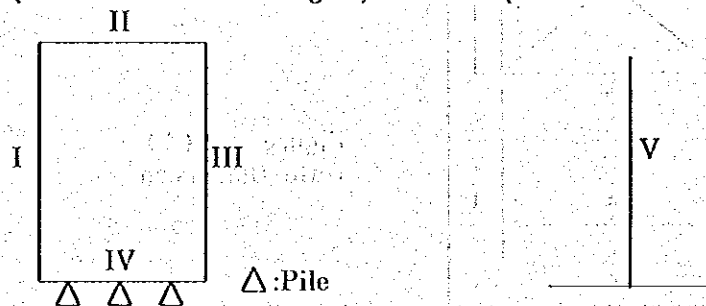


Figure-1 Analyzed Case

### Case-A

#### 1) Gate dimensions

Gate dimensions and frame for stress analysis is assumed as the Figure-2.

#### 2) Cross sectional area and moment of inertia

- I, III: cross sectional area (A):  $1.03 \text{ m}^2$   
moment of inertia (I):  $0.0228 \text{ m}^4$
- II: cross sectional area (A):  $0.8 \text{ m}^2$   
moment of inertia (I):  $0.0107 \text{ m}^4$
- IV: cross sectional area (A):  $1.4 \text{ m}^2$   
moment of inertia (I):  $0.0572 \text{ m}^4$

#### 3) Load condition

Case-A1: Normal condition, Gate open  
Case-A3: Seismic condition, Gate open

Case-A2: Normal condition, Gate close  
Case-A4: Seismic condition, Gate close

Loads to be considered are as follows:

- self-weight
- gate + hoist                       $4.5/2 + (3.5-0.5)/2 = 3.75$
- motor                               $3.5 - 1.5 \times 2 = 0.5 \text{ t}$
- control room \*1

Name of Structure	Baru Gate	Category of calculation	Stress Analysis	Page	2 / 77
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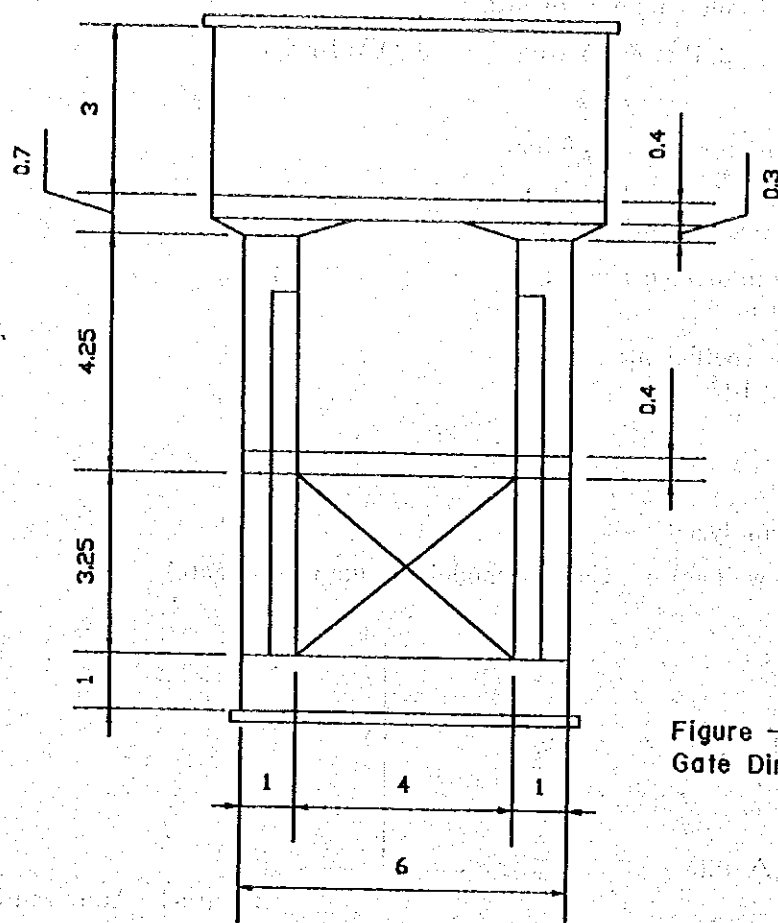


Figure - 2 (1)  
Gate Dimension

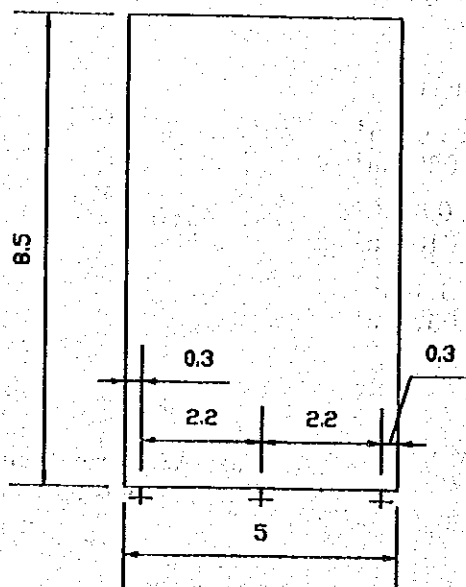


Figure - 2 (2)  
Assumed frame for  
stress Analysis.

Name of Structure	Baru Gate	Category of calculation	Stress Analysis	Page	3 / 77																													
<div>- embedded materials <span>3 / 2 = 1.5 t</span></div> <div>- earth pressure *2</div> <div>- earthquake force</div> <div>*1: total weight of control room: 50 t → 50 / 5 = 10 t/m</div> <div>*2: earth pressure</div> <div>(normal condition)</div> <div>Total earth pressure (E): <span>V: 4.16 t</span> <span>H: 23.57 t</span></div> <div>earth pressure by surcharge (S): <span>V: 1.82 t</span> <span>H: 10.31 t</span></div> <div>E: (V) 4.16 / 8 x 2 = 1.04, (H) 23.57 / 8 x 2 = 5.89 <span>Y = 1.02</span></div> <div>S: (V) 1.82 / 8 x 2 = 0.46, (H) 10.31 / 8 x 2 = 2.58 <span>Y = 1.63</span></div> <div>(earthquake condition)</div> <div>Total earth pressure (E): <span>V: 36.69 t</span></div> <div>E: (V) 9.173 t, Y = 0.95</div> <div>Load conditions are shown in Figure-3 to Figure-6.</div>																																		
4) Results of stress analysis																																		
Summary of results are as follows: (details, see attached Figures-7 to 10)																																		
<table><tr><th rowspan="2"></th><th colspan="2">Normal</th><th colspan="2">Seismic</th></tr><tr><th>A1 (gate open)</th><th>A2 (gate close)</th><th>A3 (gate open)</th><th>A4 (gate close)</th></tr><tr><td>Bending Moment</td><td>45.493</td><td>44.485</td><td>47.831</td><td>53.120</td></tr><tr><td>Shear Stress</td><td>59.747</td><td>57.497</td><td>65.753</td><td>62.998</td></tr><tr><td>Axial Stress</td><td>58.697</td><td>56.447</td><td>64.524</td><td>61.939</td></tr><tr><td>Displacement</td><td>0.4105</td><td>0.4337</td><td>1.4600</td><td>1.4199</td></tr></table>							Normal		Seismic		A1 (gate open)	A2 (gate close)	A3 (gate open)	A4 (gate close)	Bending Moment	45.493	44.485	47.831	53.120	Shear Stress	59.747	57.497	65.753	62.998	Axial Stress	58.697	56.447	64.524	61.939	Displacement	0.4105	0.4337	1.4600	1.4199
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Case-B																																		
1) Assumed dimensions																																		
Model for Case-B is assumed as a beam as shown in Figure-1 with the height of 8.5 m.																																		
2) Cross sectional area and moment of inertia																																		
cross sectional area (A): 1.03 m²																																		
moment of inertia (I): 0.3433 m⁴																																		
3) Load condition																																		
Case-B1: Normal condition, Gate open			Case-B2: Normal condition, Gate close																															
Case-B3: Seismic condition, Gate open			Case-B4: Seismic condition, Gate close																															
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<div>- self-weight</div> <div>- gate + hoist <span>4.5/2 + (3.5-0.5)/2 = 3.75</span></div> <div>- motor <span>(3.5 - 1.5 x 2)/2 = 0.25 t</span></div> <div>- control room *1</div> <div>- embedded materials <span>3 / 2 = 1.5 t</span></div> <div>- earthquake force</div> <div>*1: total weight of control room: 11.5 t → 11.5 / 2 = 5.75 t/m</div>																																		

baru-1.0-normal

Case 1 : Baru-normal-open-1.0

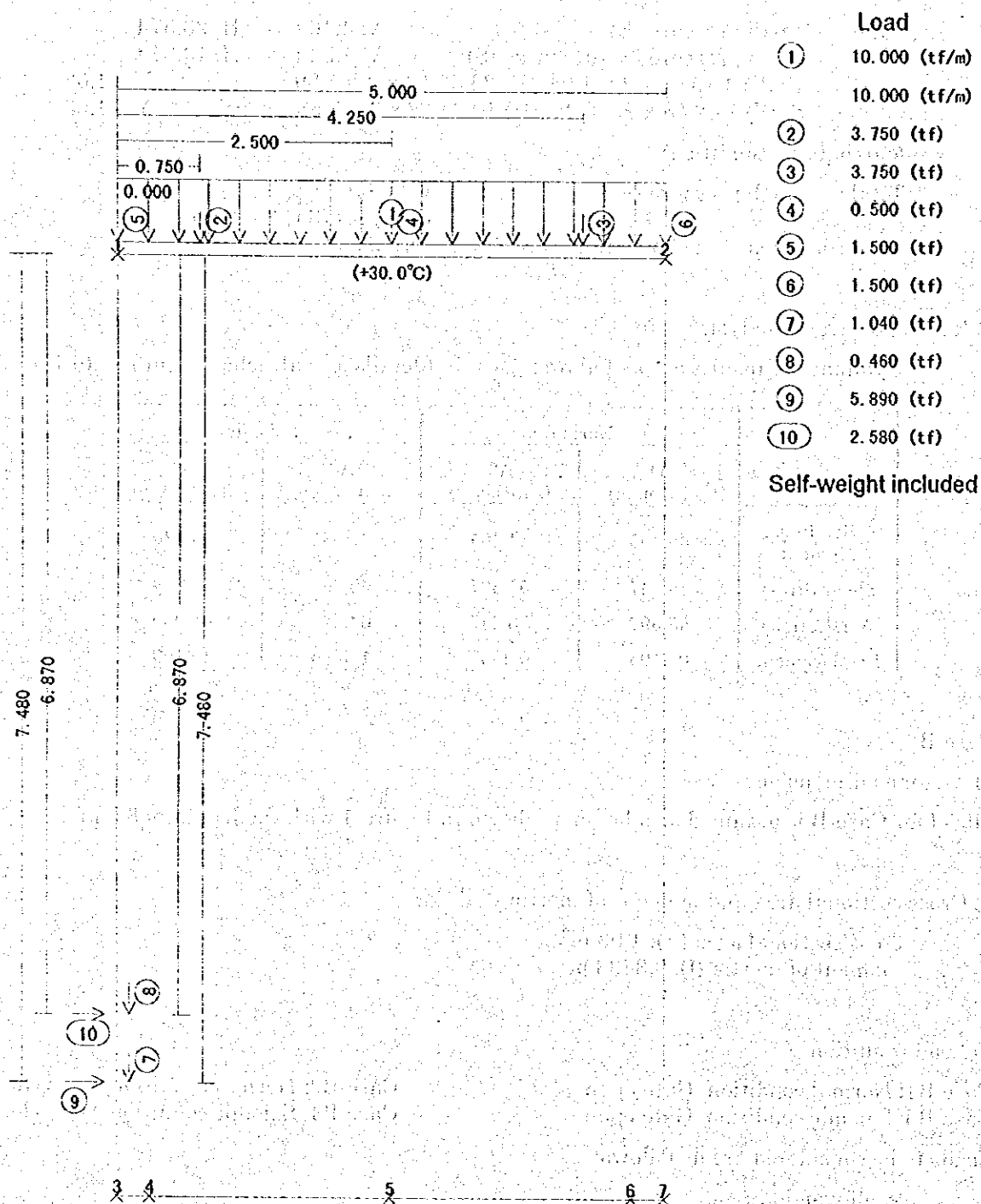


Figure - 3

baru-1.0-normal

Case 2 : Baru-nomal-close-1.0

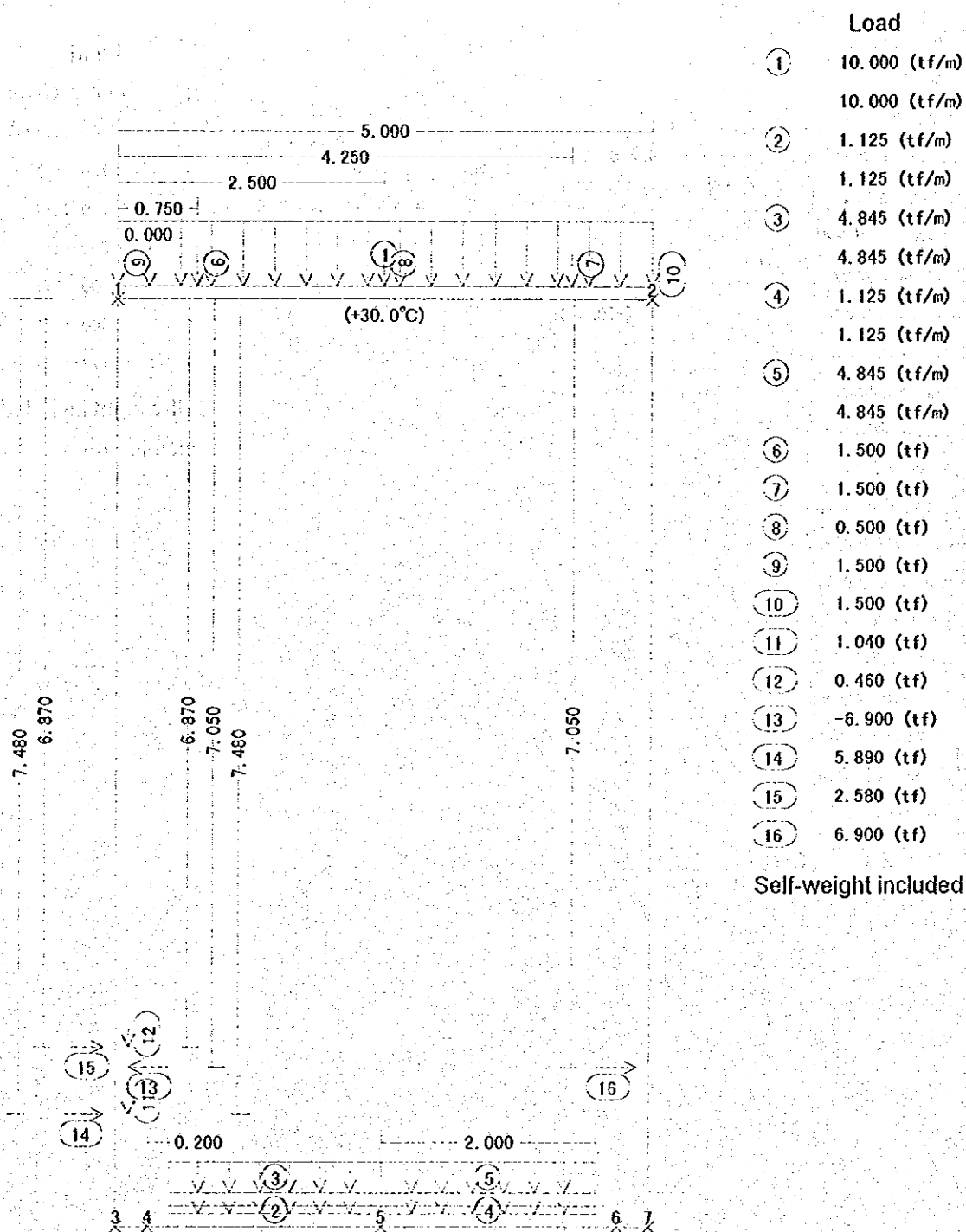
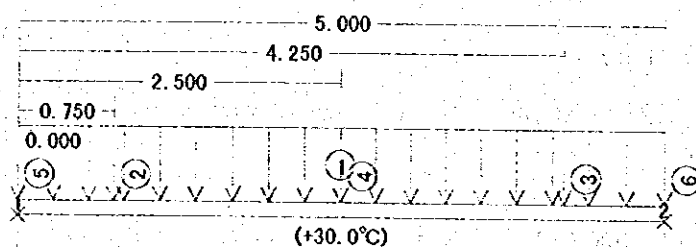


Figure - 4

baru-1.0-seismic

Case 1 : baru-seismic-open-1.0

7:550



Load	
①	10.000 (tf/m)
	10.000 (tf/m)
②	3.750 (tf)
③	3.750 (tf)
④	0.500 (tf)
⑤	1.500 (tf)
⑥	1.500 (tf)
⑦	9.173 (tf)

Self-weight included

Seismic Force

KH = 0.11

⑦

3 4 5 6 7

Figure - 5



baru-1.0-seismic

Case 2 : Baru-seismic-close-1.0

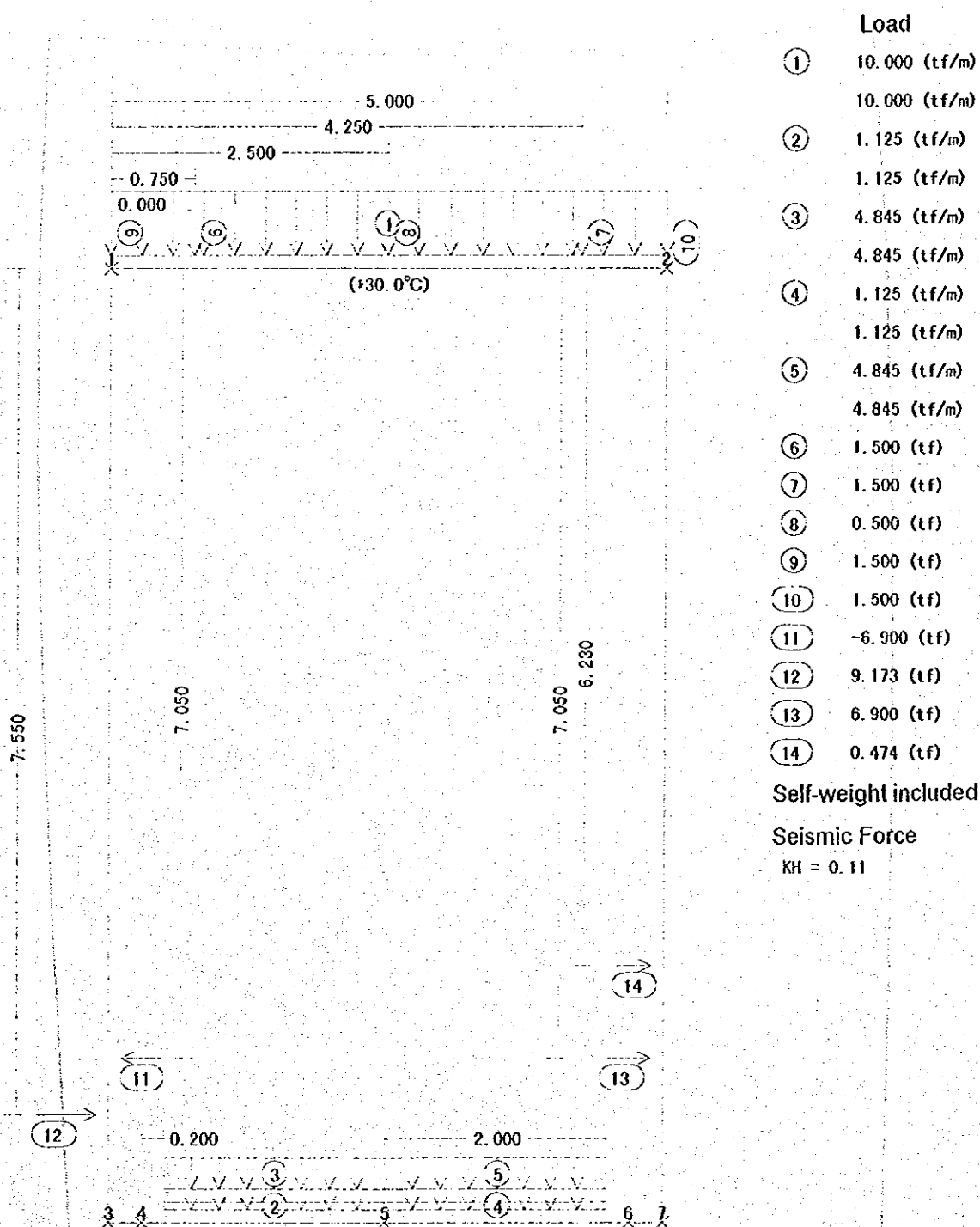


Figure - 6

baru-1.0-normal

Case 1: Baru-normal-open-1.0

Deformation

Scale : 0.434cm

max. : 0.410 cm

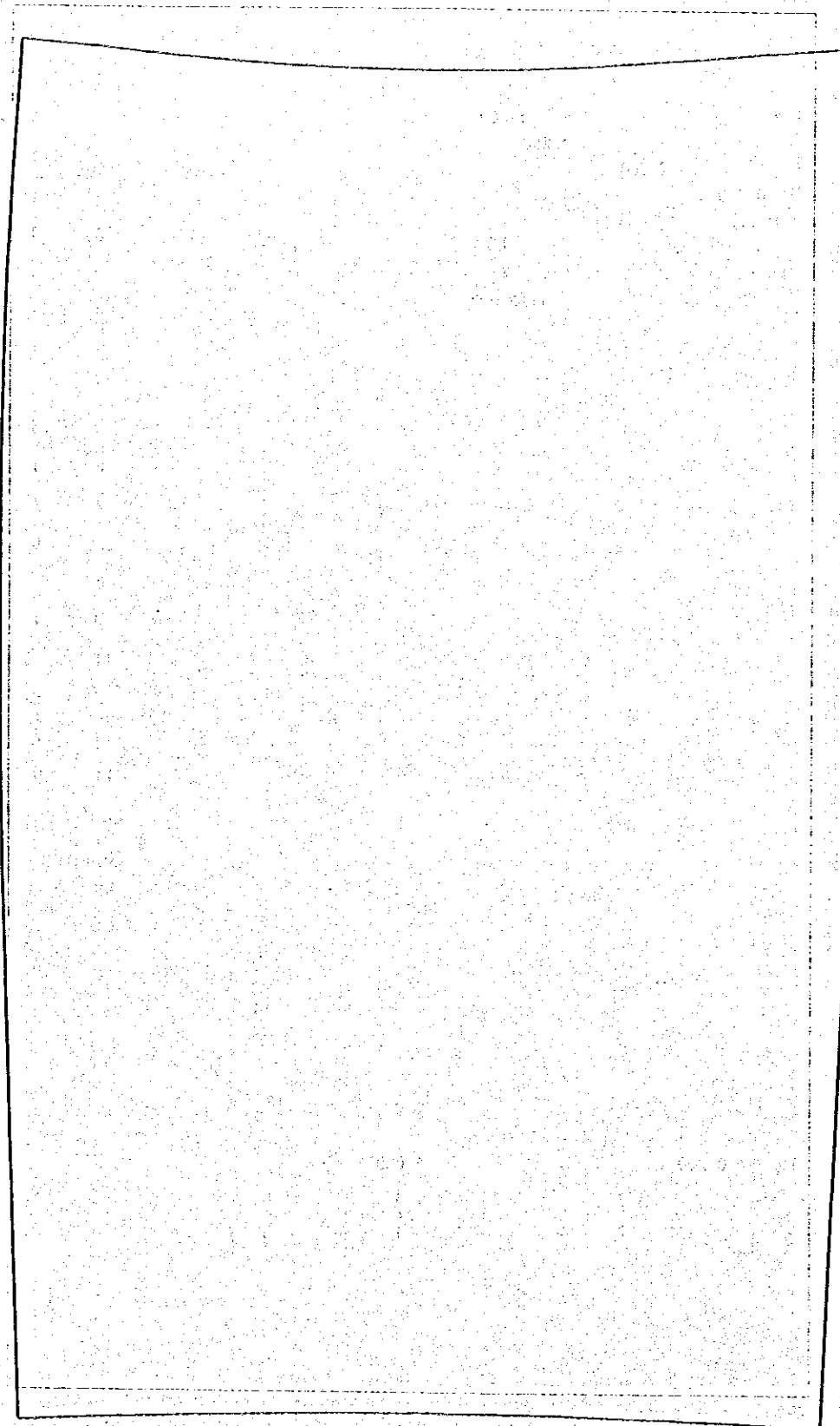


Figure - 7(1)

baru-1.0-normal

Case 1: Baru-normal-open-1.0

Bending Moment Scale : 45.49tf·m max. : -45.49 tf·m

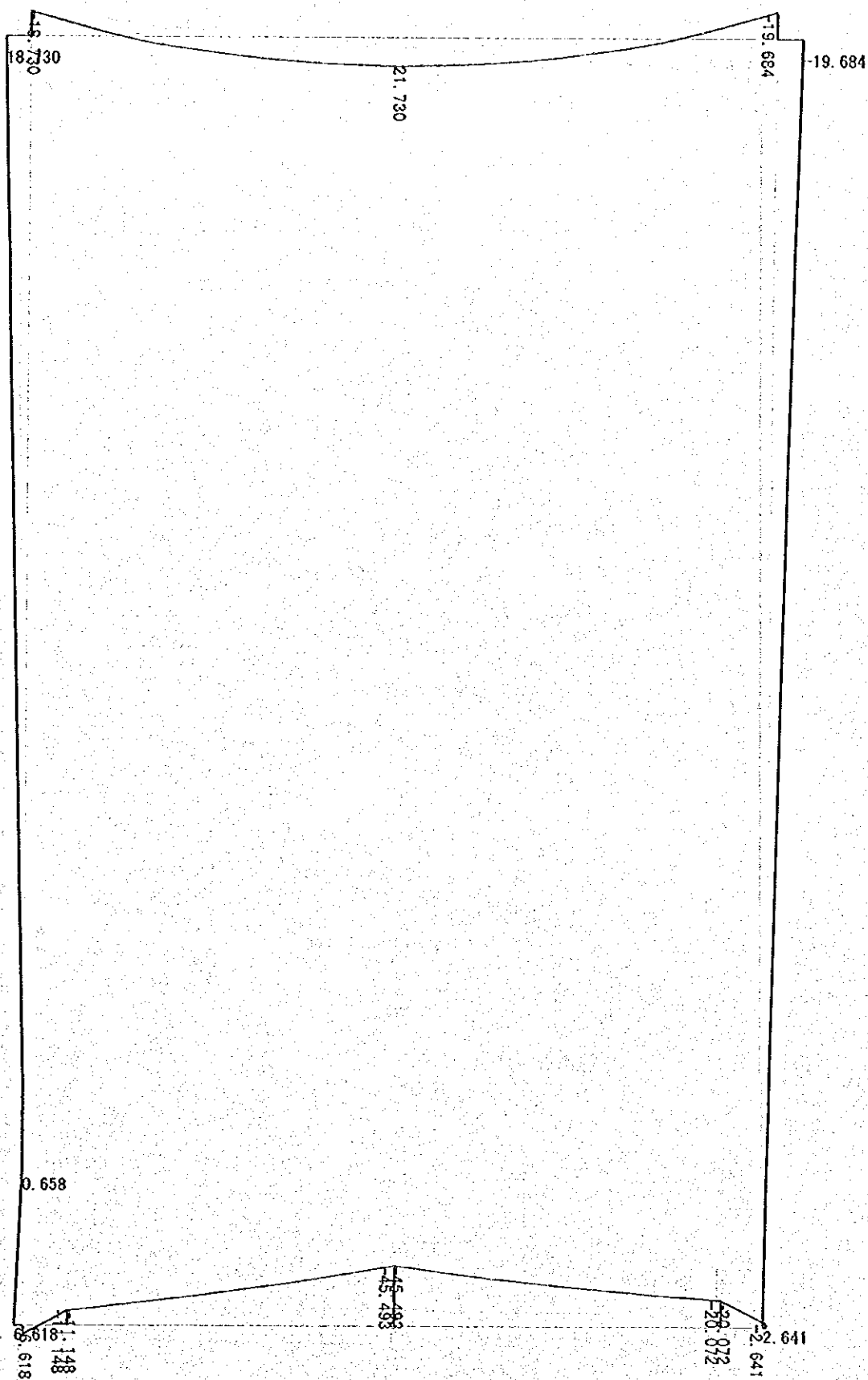


Figure - 7 (2)

baru-1.0-normal

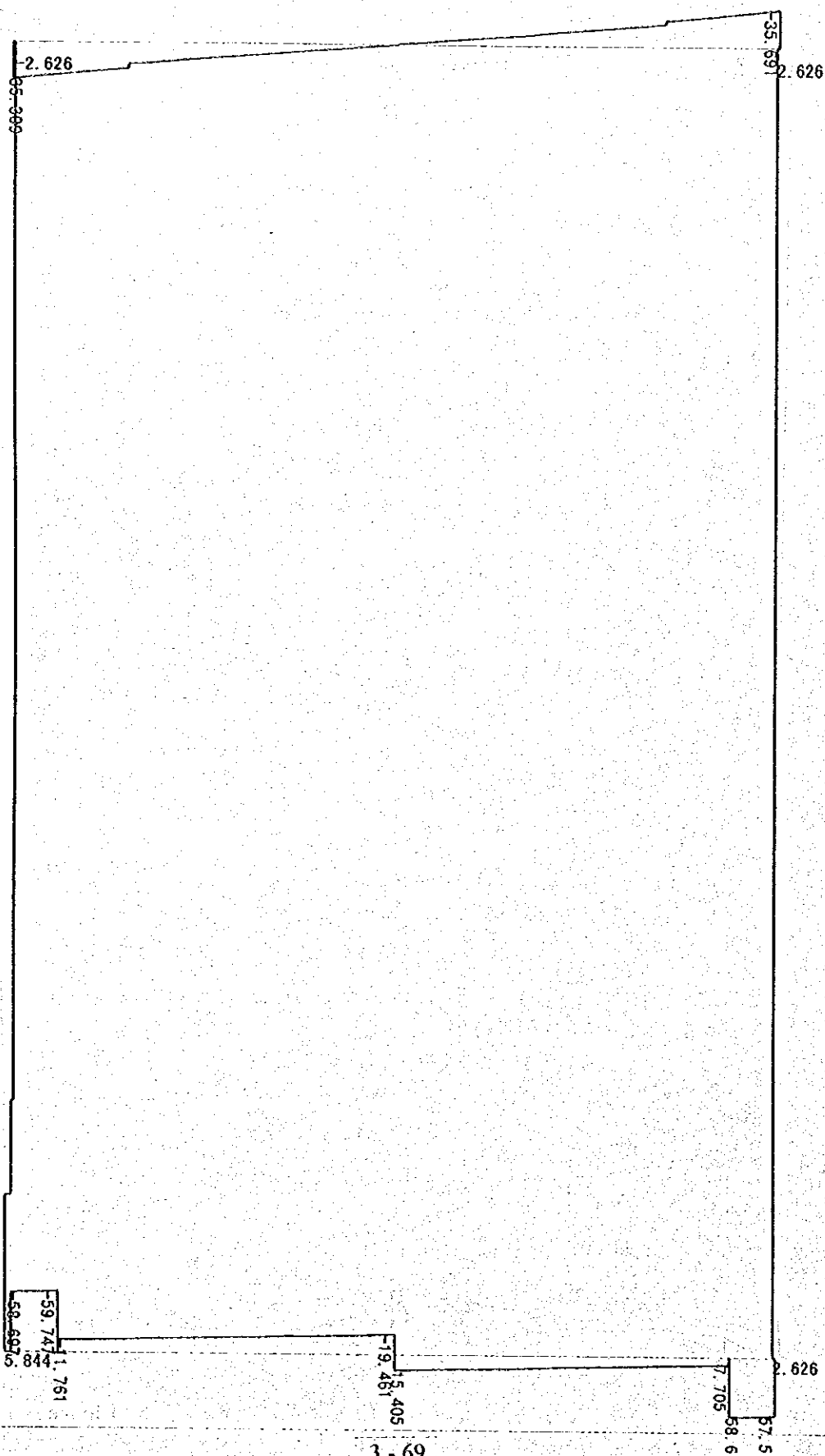
Case 1: Baru-normal-open-1.0

Shear Stress

Scale

: 59.75tf

max. : -59.75 tf

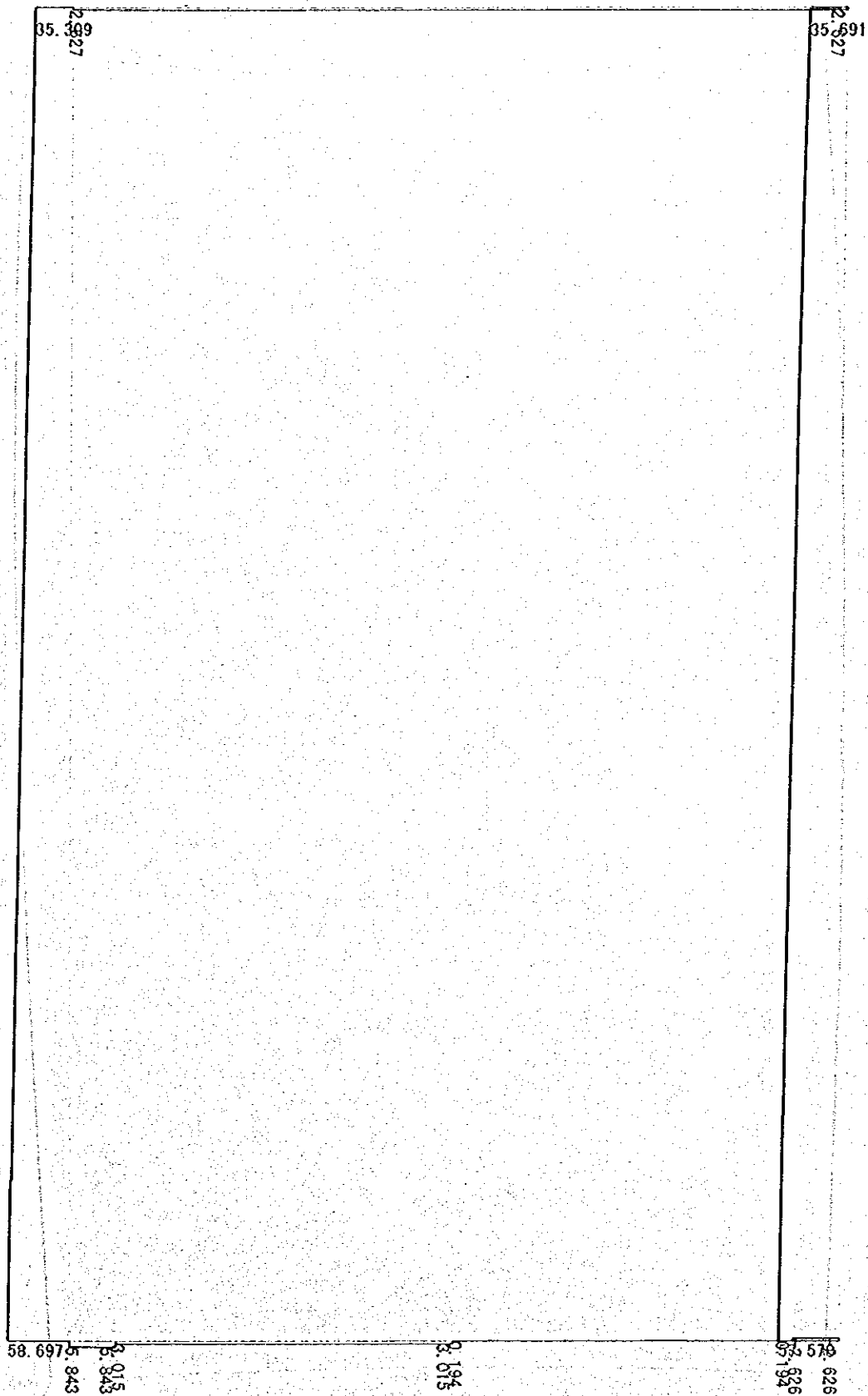


baru-1.0-normal

Case 1: Baru-normal-open-1.0

Axial Stress

Scale : 58.70tf max. : 58.70 tf

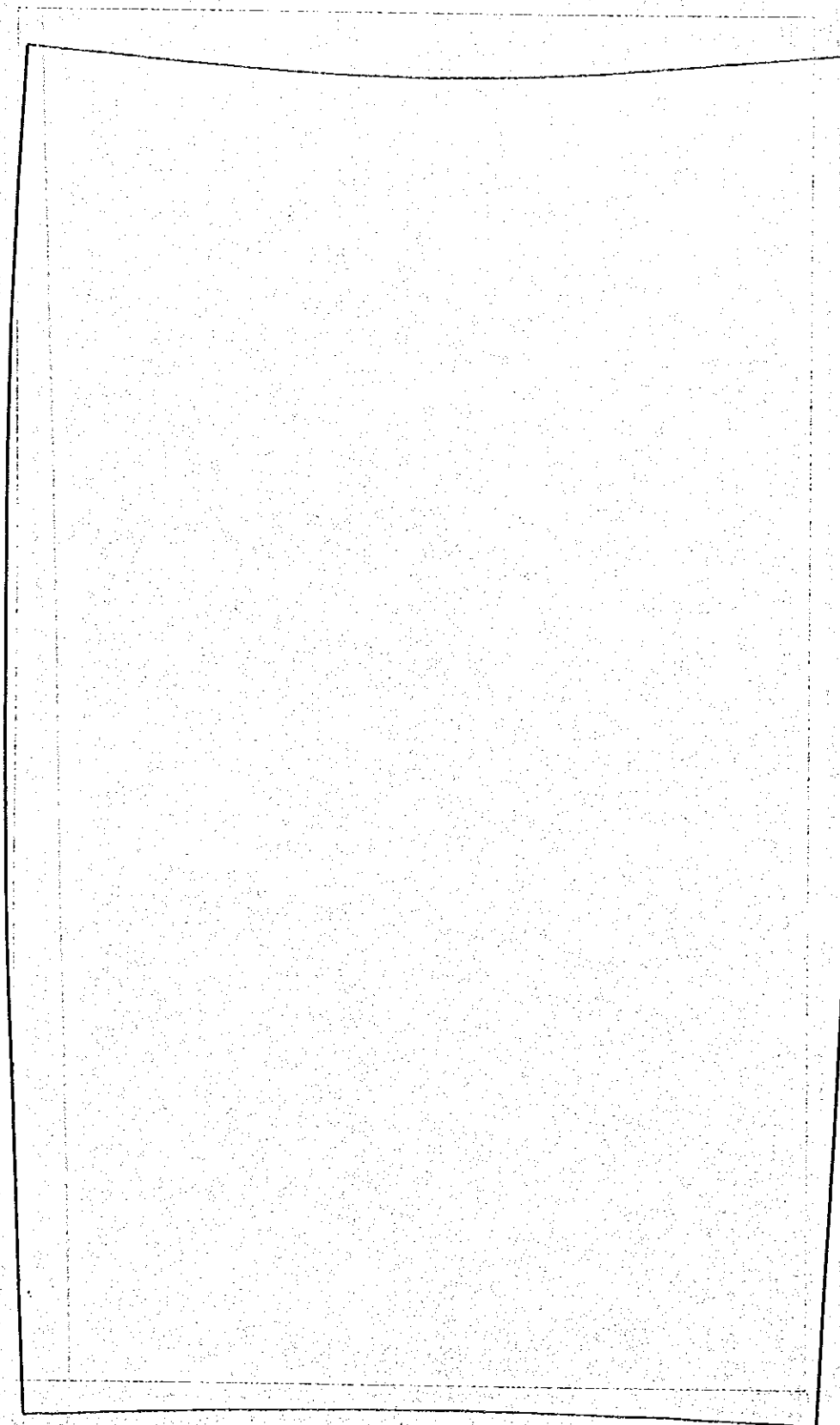


baru-1.0-normal

Case baru-normal-close-1.0

Deformation

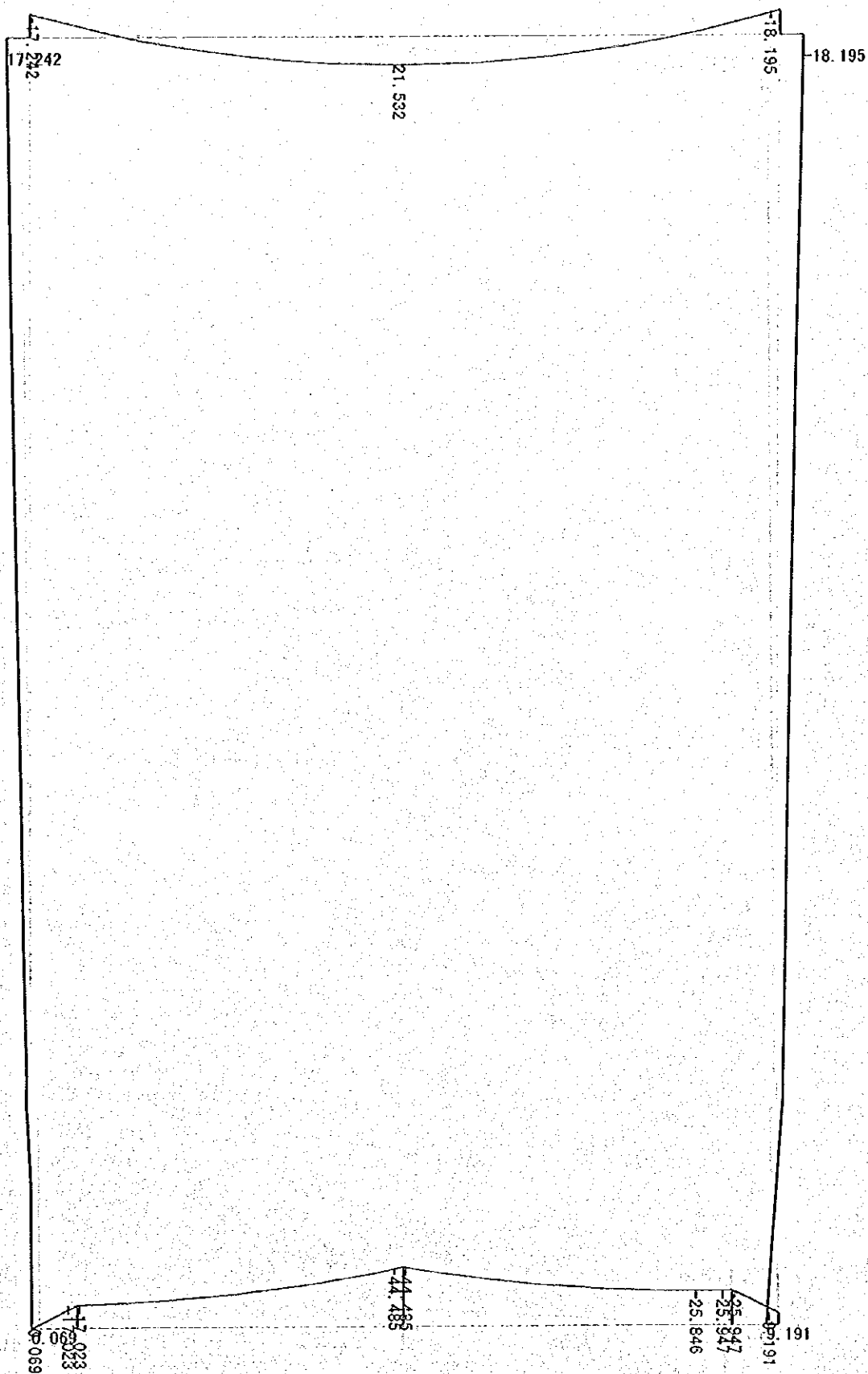
Scale : 0.434cm max. : 0.434 cm



baru-1.0-normal

Case 2: Baru-normal-close-1.0

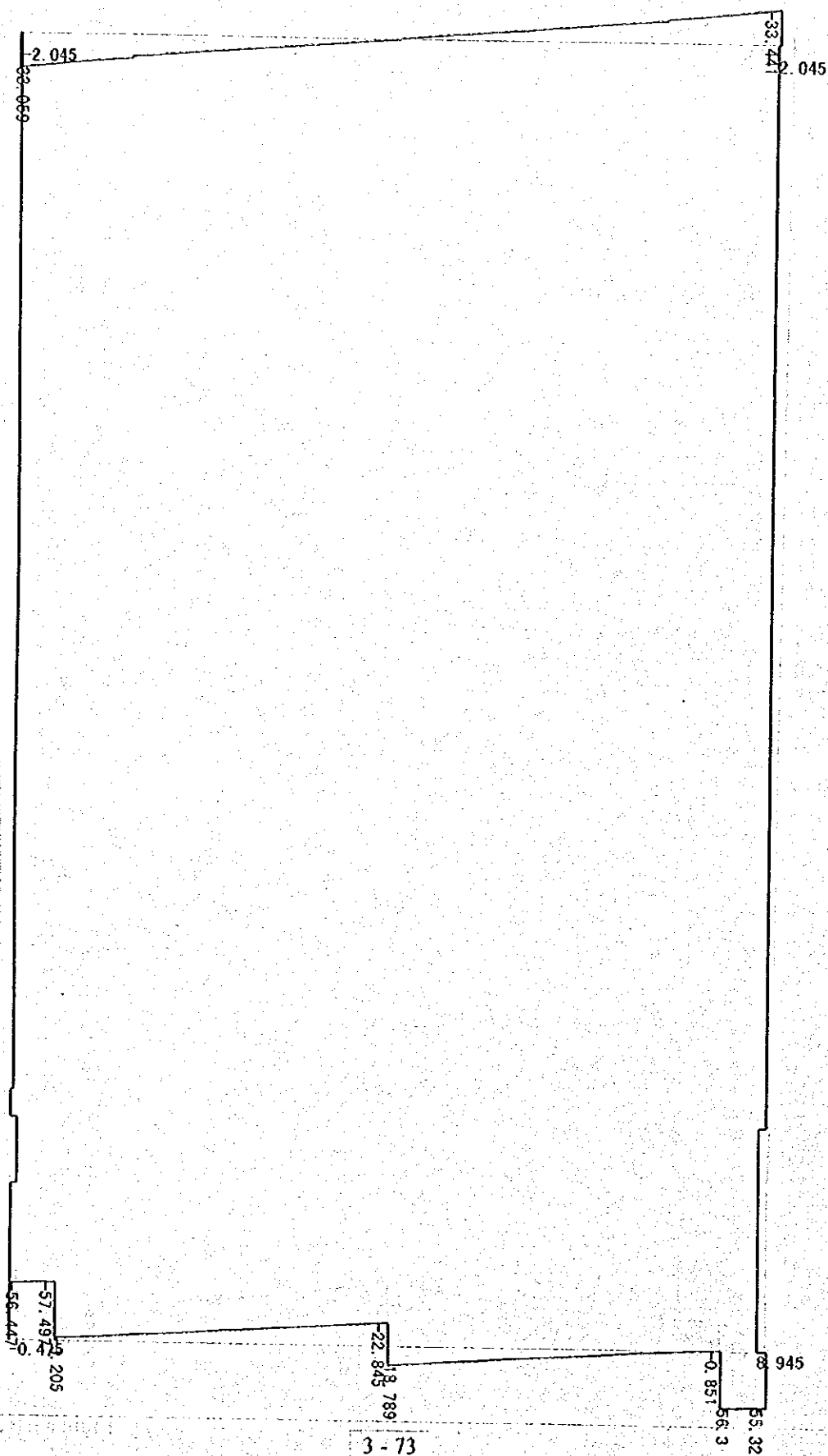
Bending Moment Scale : 45.49tf·m max. : -44.48 tf·m



baru-1.0-normal

Case 2: Baru-normal-close-1.0

Shear Stress      Scale : 59.75tf      max. : -57.50 tf





baru-1.0-normal

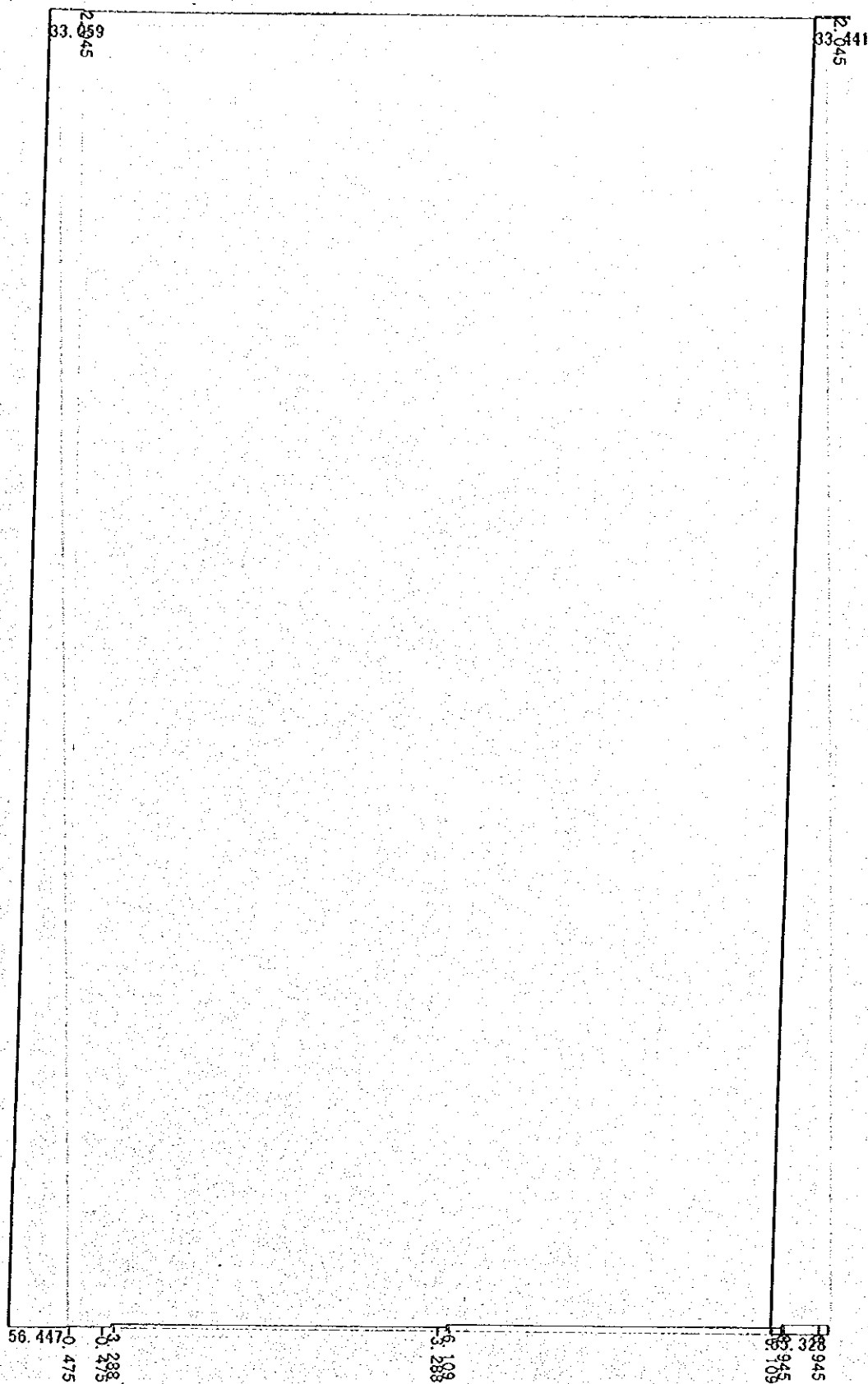
Case 2: Baru-normal-close-1.0

Axial Stress

Scale

: 58.70tf

max. : 56.45 tf

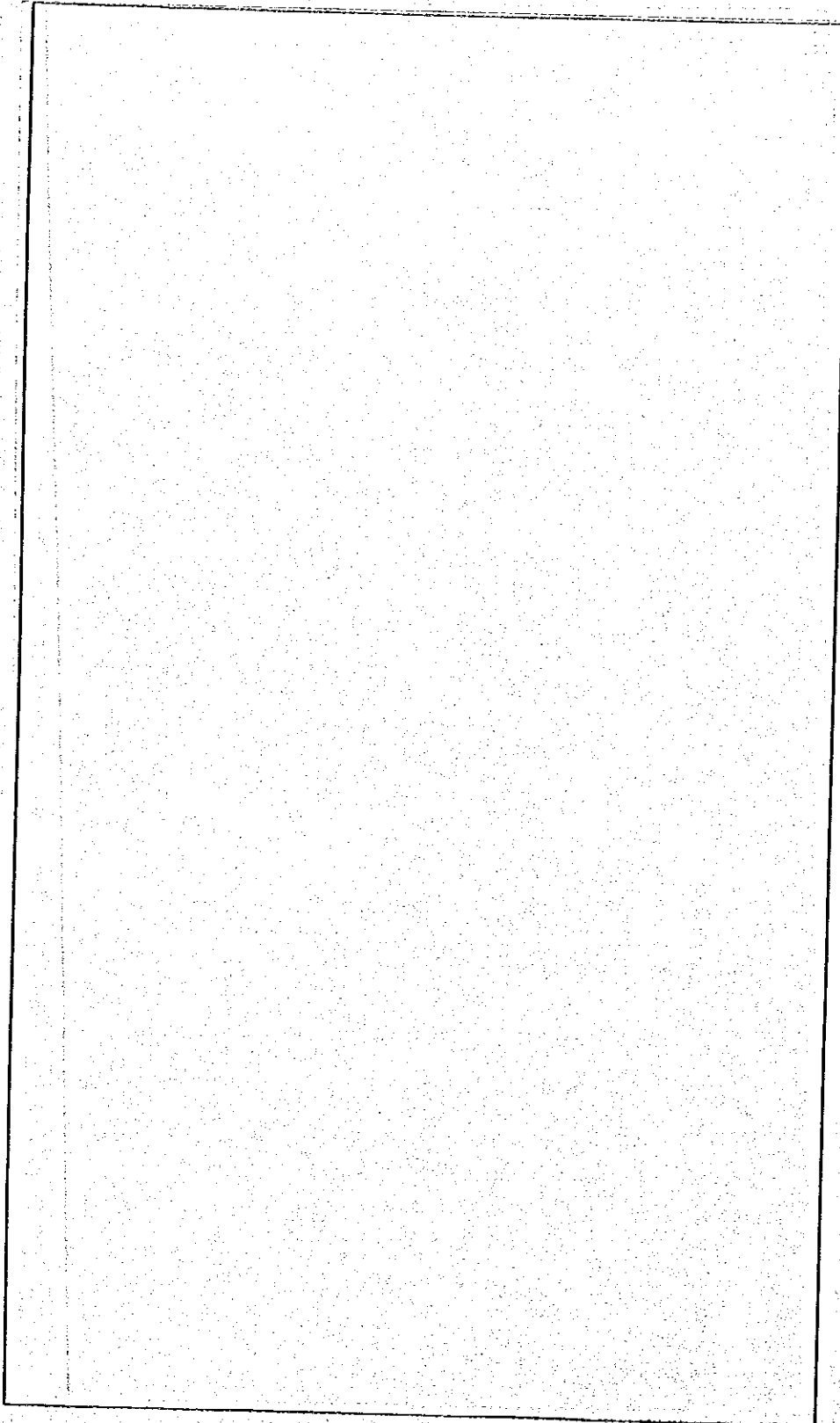


baru-1.0-seismic

Case 5: Baru-seismic-open-1.0 + Baru-seismic force-open-1.0

Deformation

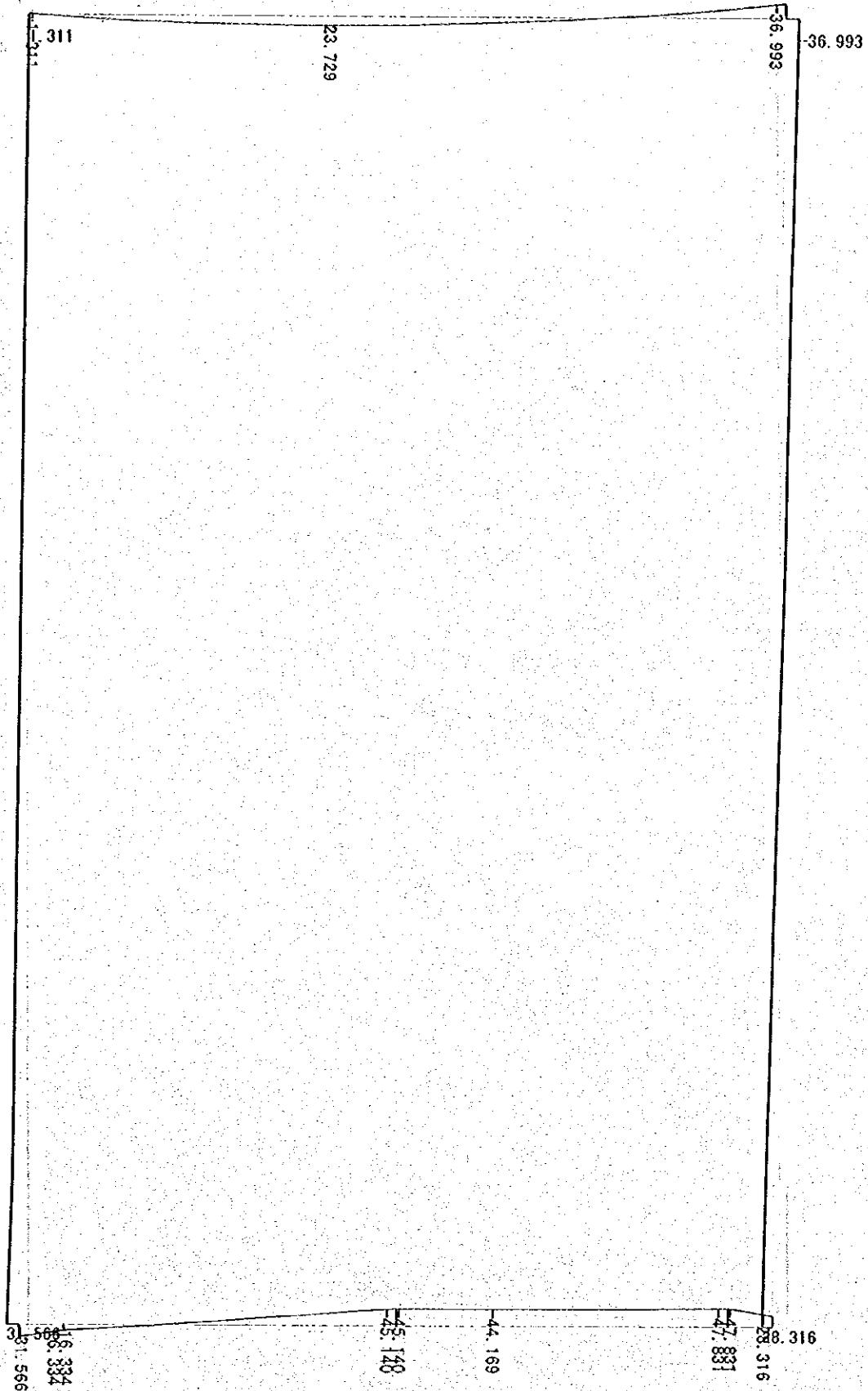
Scale : --- : 7.266cm max. : 1.460 cm



baru-1.0-seismic

Case 5: Baru-seismic-open-1.0 + Baru-seismic force-open-1.0

Bending Moment Scale : 160.18 tf·m max. : -47.83 tf·m



baru-1.0-seismic

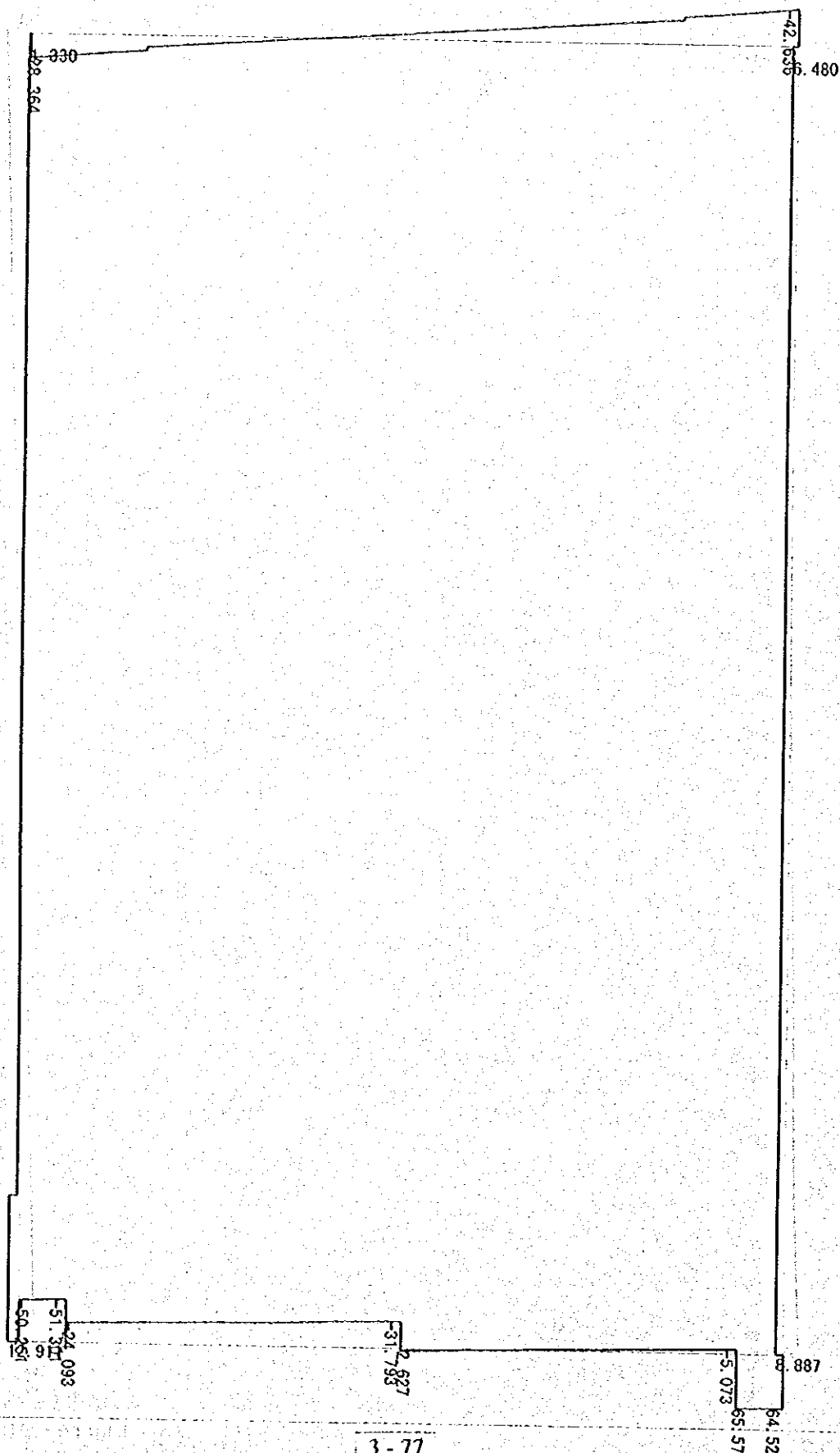
Case 5: Baru-seismic-open-1.0 + Baru-seismic force-open-1.0

Shear Stress

Scale

: 72.81tf

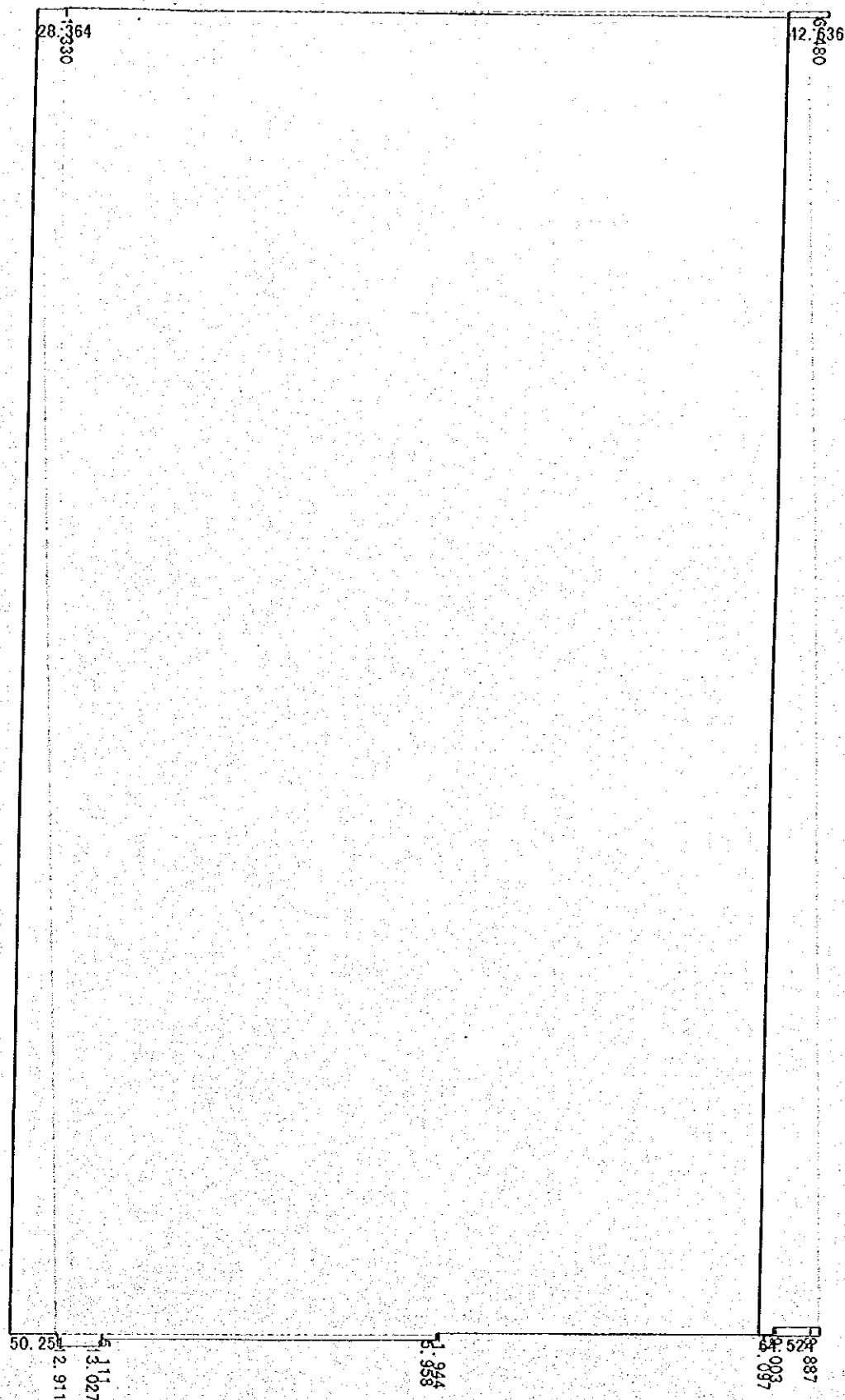
max. : 65.57 tf



baru-1.0-seismic

Case 5: Baru-seismic-open-1.0 + Baru-seismic force-open-1.0

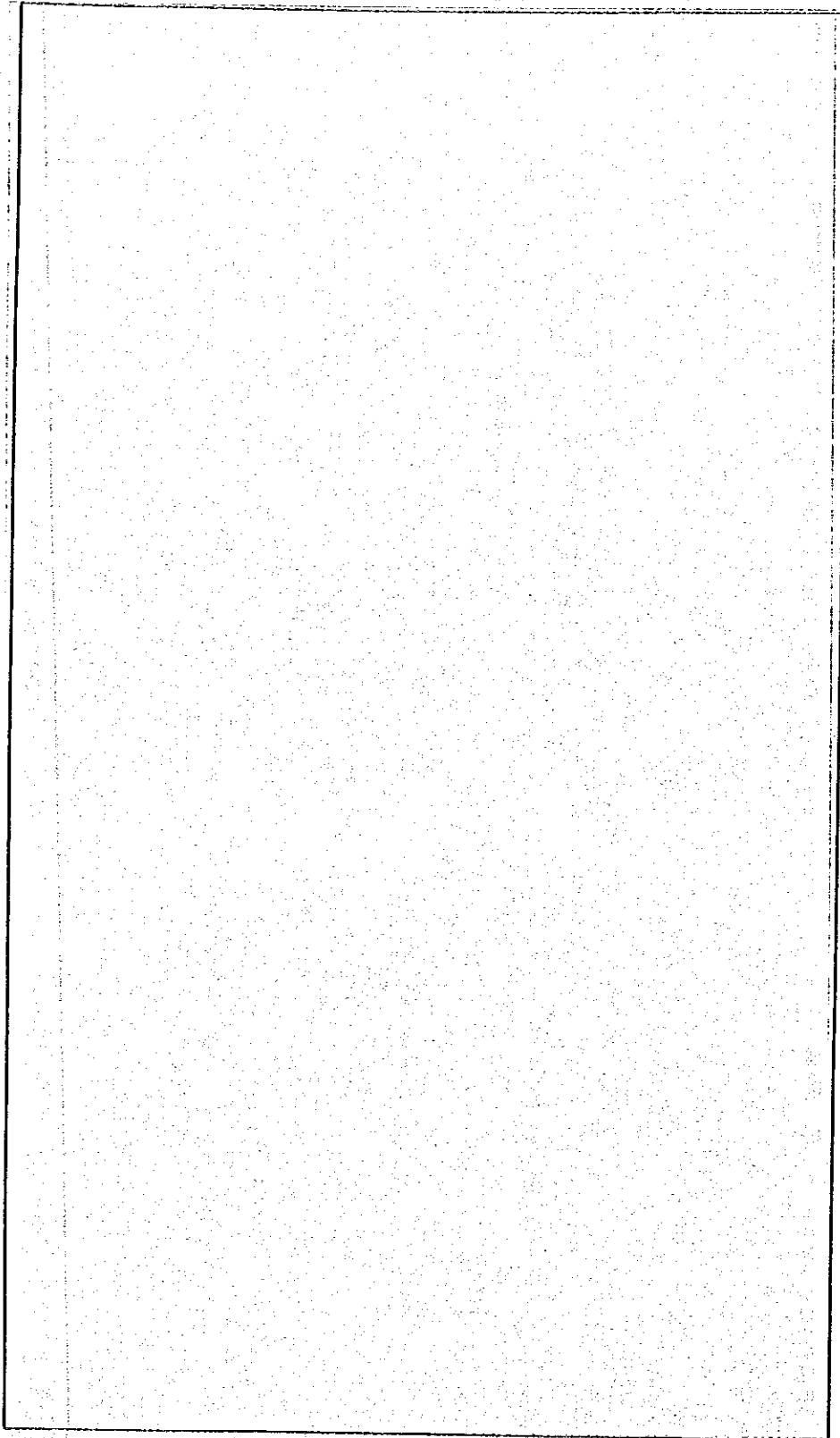
Axial Stress      Scale : 64.52tf      max. : 64.52 tf



baru-1.0-seismic

Case 6: Baru-seismic-close-1.0 + Baru-seismic force-close-1.0

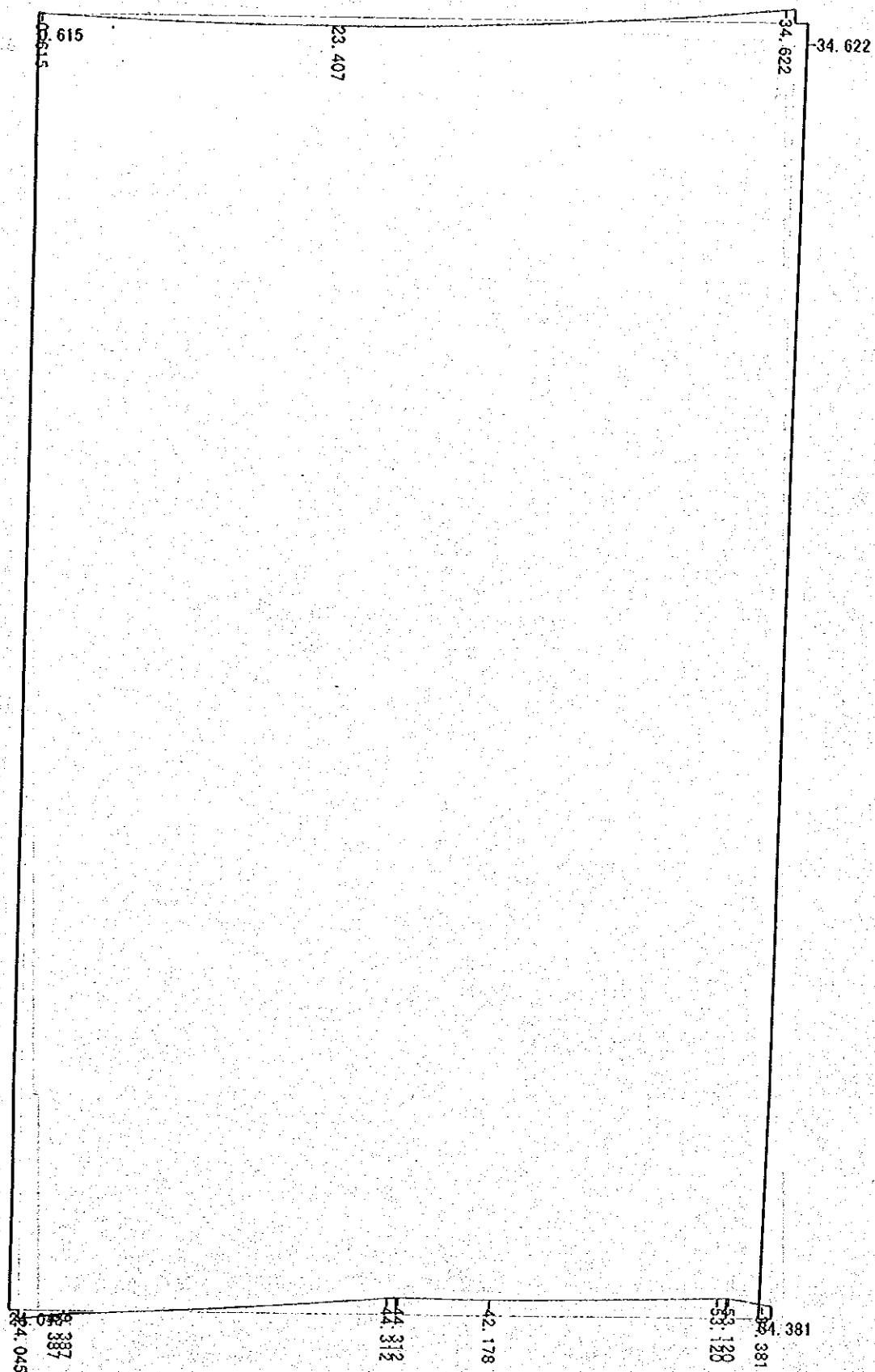
Deformation Scale : 7.266cm max. : 1.420 cm



baru-1.0-seismic

Case 6: Baru-seismic-close-1.0 + Baru-seismic force-close-1.0

Bending Moment Scale : 160.18 tf·m max. : -53.12 tf·m

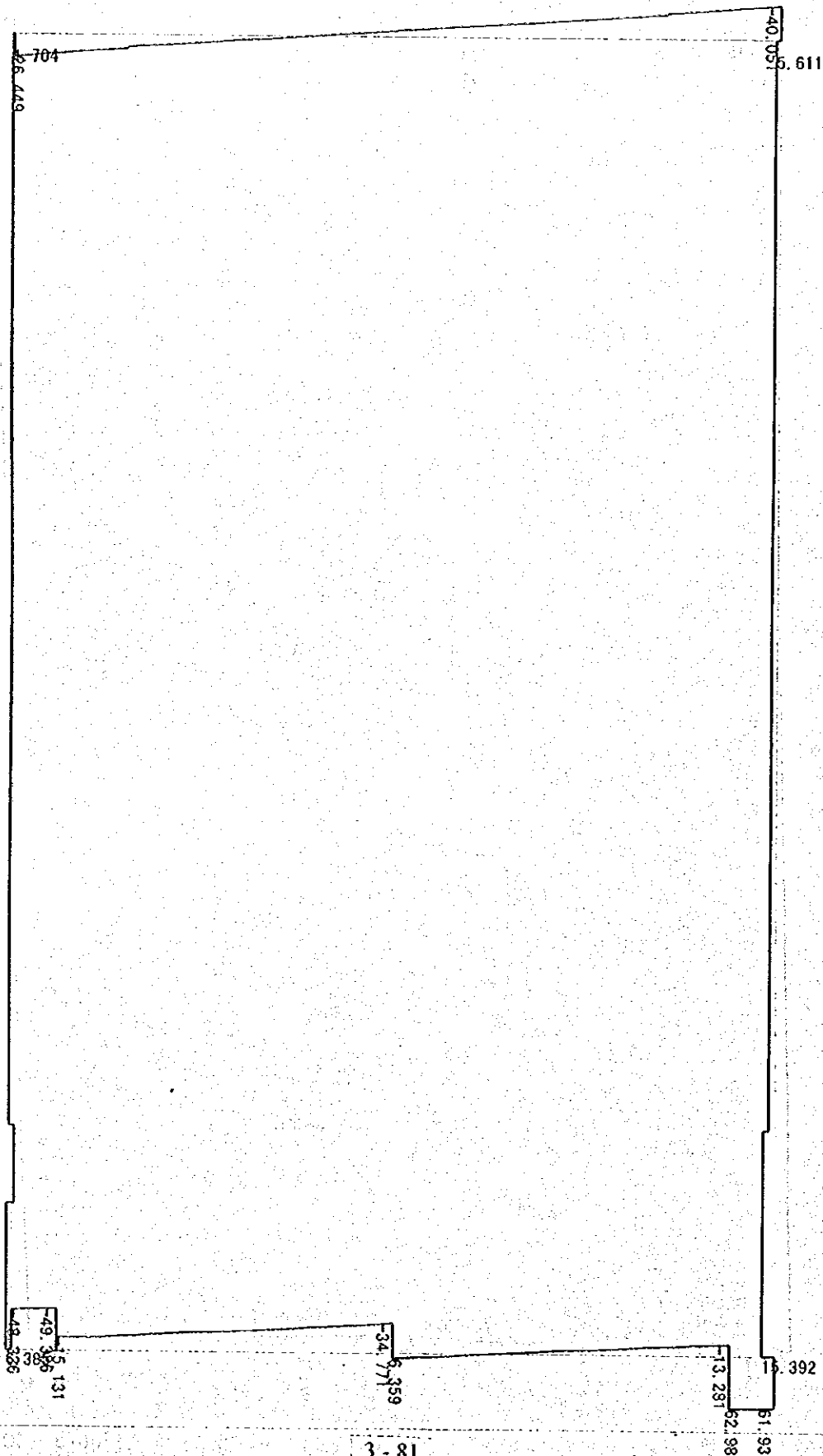


baru-1.0-seismic

Case 6: Baru-seismic-close-1.0 + Baru-seismic force-close-1.0

Shear Stress

Scale : 72.81tf max. : 62.99 tf





baru-1.0-seismic

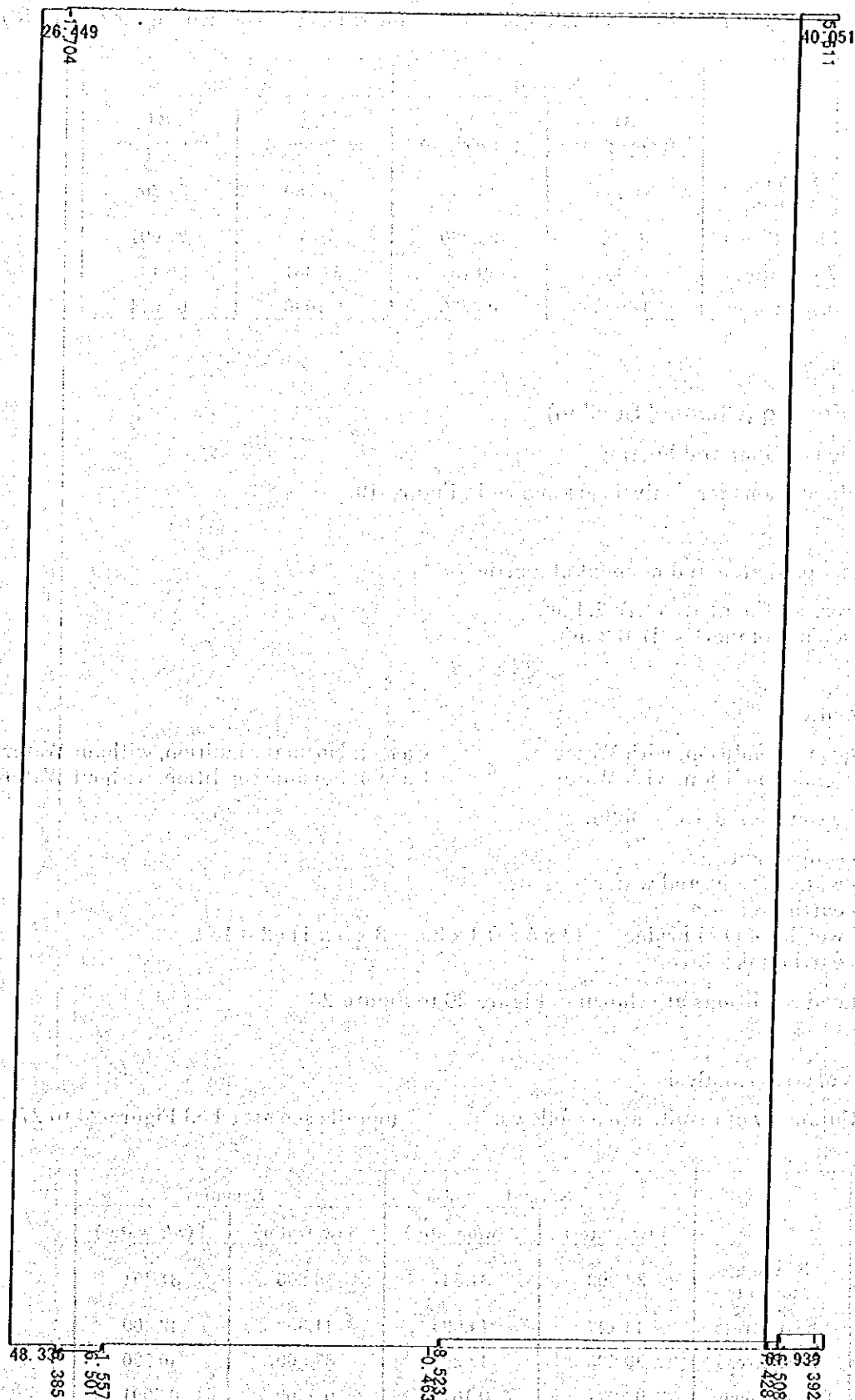
Case 6: Baru-seismic-close-1.0 + Baru-seismic force-close-1.0

Axial Stress

Scale

: 64.52tf

max. : 61.94 tf



Name of Structure	Baru Gate	Category of calculation	Stress Analysis	Page	24/77
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Load conditions are shown in Figure-11 to Figure-14.

#### 4) Results of stress analysis

Summary of results are as follows:

(details, see attached Figures-15 to 18)

	Normal		Seismic	
	B1 (gate open)	B3 (gate close)	B2 (gate open)	B4 (gate close)
Bending Moment	31.535	43.648	38.750	57.300
Shear Stress	3.710	25.360	5.763	27.691
Axial Stress	52.387	50.137	52.387	30.137
Displacement	0.0903	0.0756	0.1036	0.1074

## 2. Pier & Footing (Channel Section)

### 1) Dimensions of Pier and Footing.

Assumed dimensions for analysis are shown in Figure-19.

### 2) Cross sectional area and moment of inertia

cross sectional area (A): 2.4 m<sup>2</sup>

moment of inertia (I): 0.2 m<sup>4</sup>

### 3) Load condition

Case-1: Normal condition, with Water

Case-3: Seismic condition, with Water

Case-2: Normal condition, without Water

Case-4: Seismic condition, without Water

Loads to be considered are as follows:

- self-weight
- water weight and water pressure
- earth pressure
- weight of O/M bridge  $(3 \times 5 \times 0.4 \times 2.5 + 3 \times 5 \times 1) / 2 = 15 \text{ t}$
- earthquake force

Load conditions are shown in Figure-20 to Figure-23.

#### 4) Results of stress analysis

Summary of results are as follows:

(details see attached Figure-24 to 27)

	Normal		Seismic	
	1 (w. water)	2 (w/o water)	3 (w. water)	4 (w/o water)
Bending Moment	38.303	31.537	38.806	31.491
Shear Stress	43.147	44.095	41.352	42.300
Axial Stress	39.295	42.295	37.500	40.500
Displacement	0.2077	0.1618	0.3309	0.2991

Baru Gete

Case 1 : Baru-normal-open

Load

- ① 3.710 (tf)
- ② 30.500 (tf)

Self-weight included

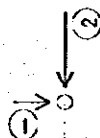
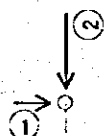


Figure - 11

Baru Gete

Case 2 : Baru-seismic-open



Load

- ① 3.355 (tf)
- ② 30.500 (tf)

Self-weight included

Seismic Force

 $KH = 0.11$ 

Figure -12

Baru Gete

Case 3 : Baru-nomal-close

Load

- |   |             |
|---|-------------|
| ① | 22.620 (tf) |
| ② | 2.740 (tf)  |
| ③ | 28.250 (tf) |

Self-weight included

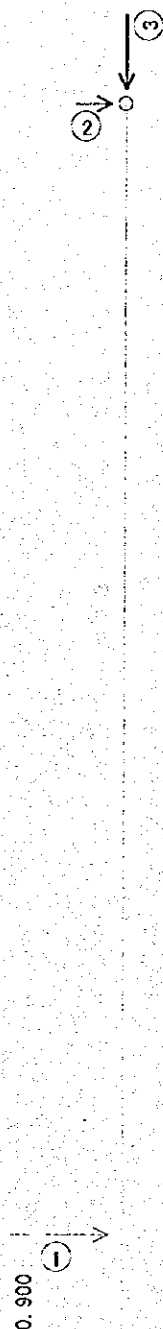
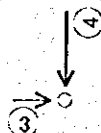


Figure - 13

## Baru Gete

Case 4 : Baru-seismic-close



## Load

- ① 21.785 (tf)
- ② 0.660 (tf)
- ③ 3.108 (tf)
- ④ 28.250 (tf)

Self-weight included

Seismic Force

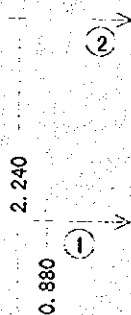
 $KH = 0.11$ 

Figure - 14

Baru Gete

Case 1: Baru-nomal-open

Deformation Scale : 0.107cm max. : 0.090 cm

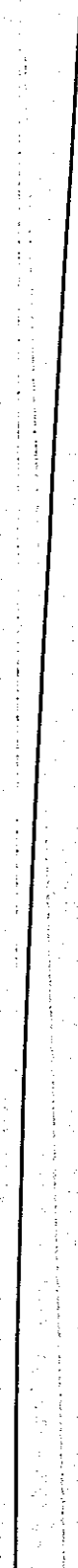


Figure - 15 (1)

Baru Gete

Case 1: Baru-normal-open

Bending Moment Scale : 57.30tf·m max. : -31.53 tf·m

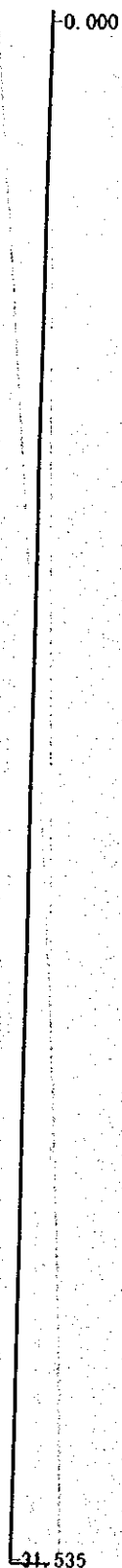


Figure -15 (2)



Baru Gete

Case 1: Baru-normal-open

Shear Stress      Scale : 27.96tf      max. : 3.71 tf

3.710

3.710

Figure -15(3)

Baru Gete

Case 1: Baru-normal-open

Axial Stress      Scale : 52.39tf      max. : 52.39 tf

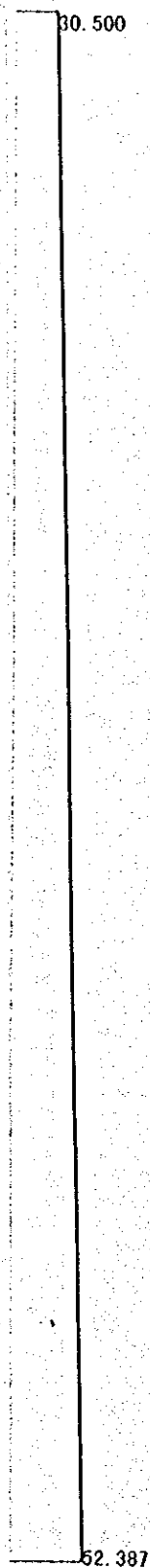


Figure -15 (4)

Baru Gete

Case 2: Baru-seismic-open

Deformation

Scale

: 0.107cm

max. : 0.104 cm



Figure - 16 (1)

Baru Gete

Case 2: Baru-seismic-open

Bending Moment      Scale : 57.30tf·m      max. : -38.75 tf·m

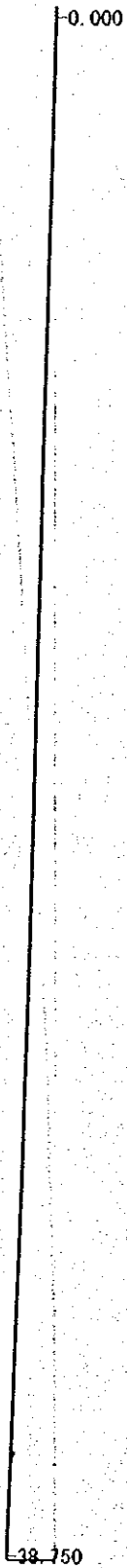


Figure -16(2)

Baru Gete

Case 2: Baru-seismic-open

Shear Stress

Scale

: 27.96tf

max. : 5.76 tf

3.355

-6.763

Figure -16 (3)

Baru Gete

Case 2: Baru-seismic-open

Axial Stress      Scale : 52.39tf      max. : 52.39 tf

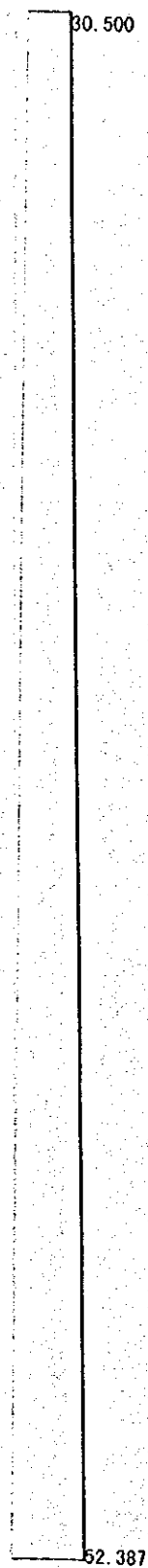


Figure - 16 (4)

Baru Gete

Case 3: Baru-normal-close

Deformation Scale : 0.107cm max. : 0.076 cm

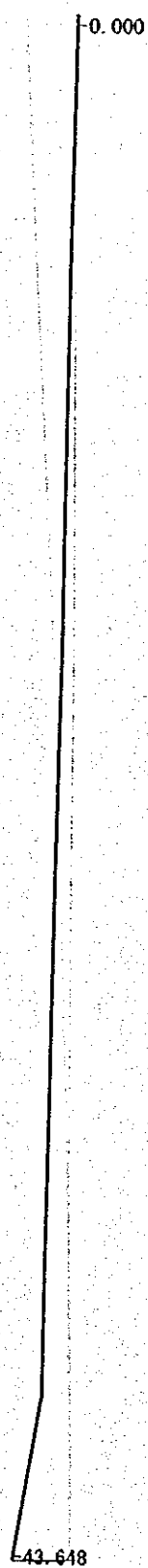


Figure - 17 (1)

Baru Gete

Case 3: Baru-normal-close

Bending Moment Scale : 57.30tf·m max. : -43.65 tf·m



(1) 1 - 00001

Figure-17(2)



Baru Gote

Case 3: Baru-normal-close

Shear Stress

Scale ----- : 27.96tf

max. : 25.36 tf

2.740

25.360

Figure - 17 (3)

Baru Gete

Case 3: Baru-normal-close

Axial Stress

Scale ---

: 52.39tf

max. : 50.14 tf

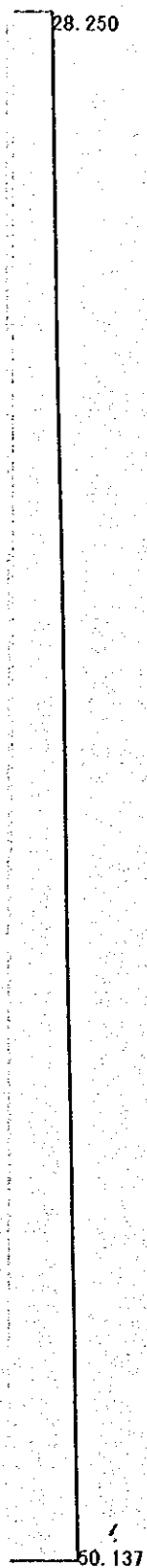


Figure -17 (4)

Baru Gete

Case 4: Baru-seismic-close

Deformation

Scale : 0.107cm max. : 0.107 cm



Figure-18 (1)

Baru Gete

Case 4: Baru-seismic-close

Bending Moment Scale : 57.30 tf·m max. : -57.30 tf·m

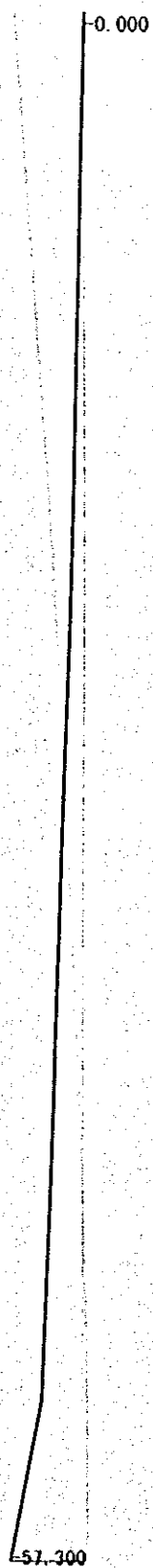


Figure - 18(2)

Baru Gete

Case 4: Baru-seismic-close

Shear Stress Scale : 27.96tf max. : 27.96 tf

3.108

27.961

Figure -18(3)

Baru Gete

Case 4: Baru-seismic-close

Axial Stress

Scale

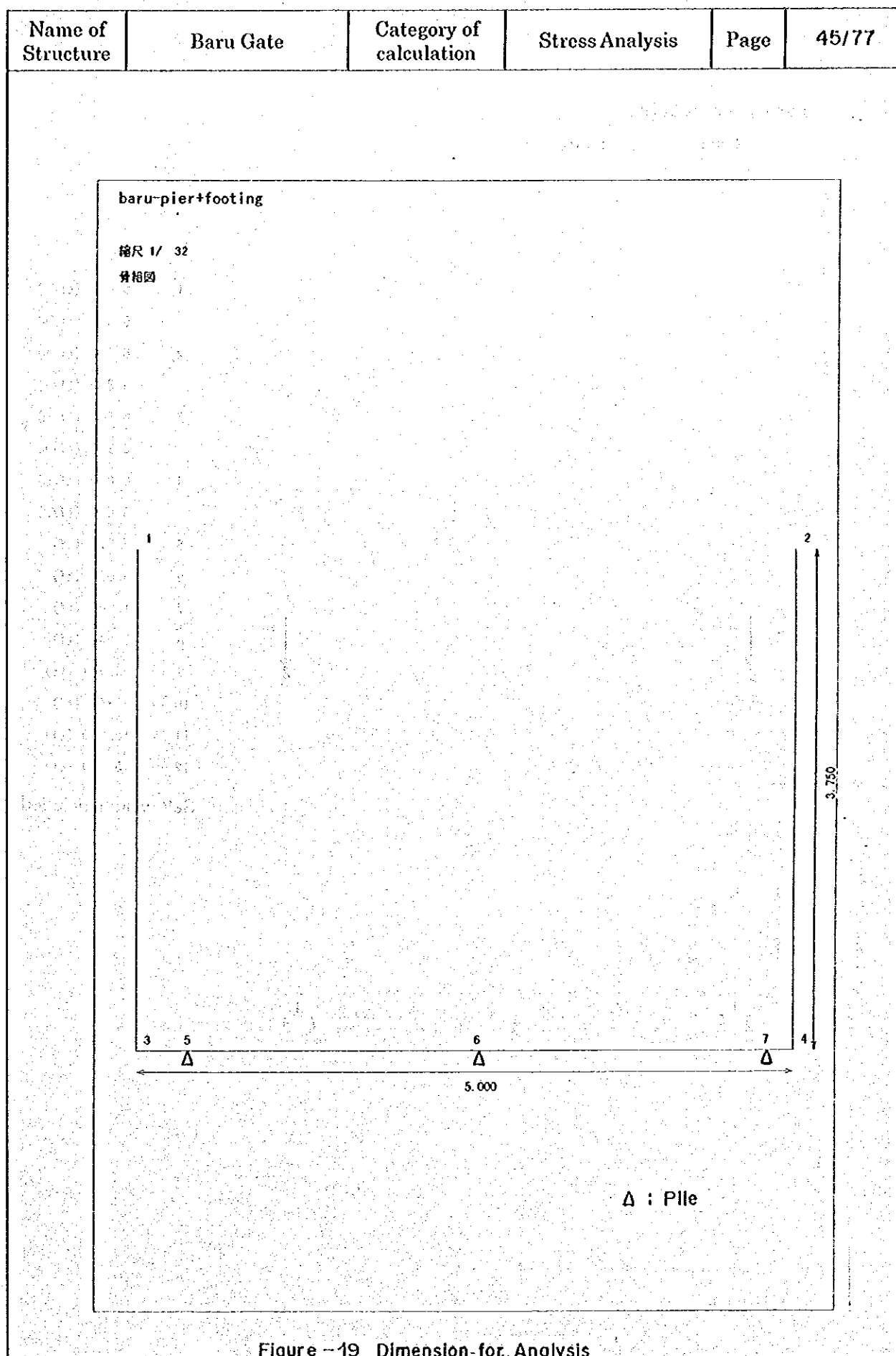
: 52.39tf

max. : 50.14 tf

28.250

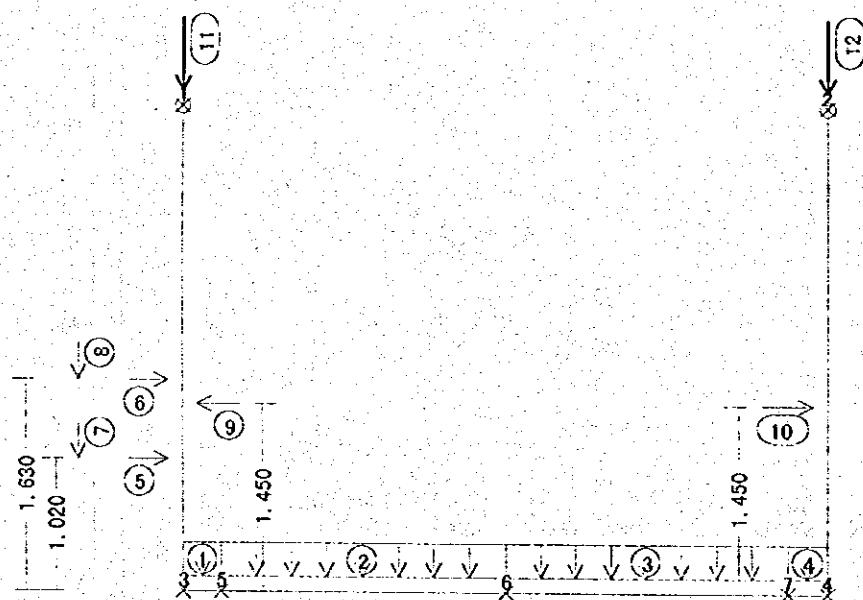
50.137

Figure - 18 ( 4 )



baru-pier+footing

Case 1 : Normal-water



Load

①	6.840 (tf/m)
	6.840 (tf/m)
②	6.840 (tf/m)
	6.840 (tf/m)
③	6.840 (tf/m)
	6.840 (tf/m)
④	6.840 (tf/m)
	6.840 (tf/m)
⑤	7.071 (tf)
⑥	3.092 (tf)
⑦	1.248 (tf)
⑧	0.547 (tf)
⑨	-9.747 (tf)
⑩	9.747 (tf)
⑪	15.000 (tf)
⑫	15.000 (tf)

Self-weight included

Figure - 20