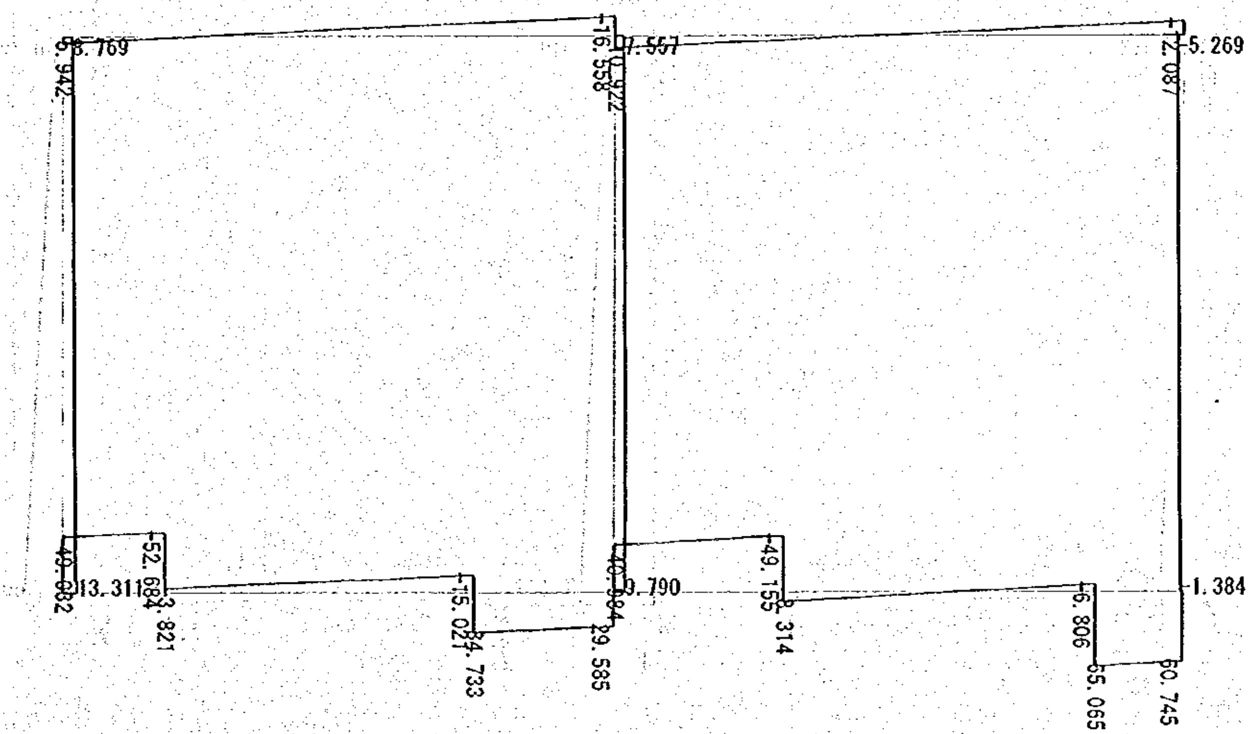
Baru-pumping station (D-D)

Case 6: D-D seismic rw

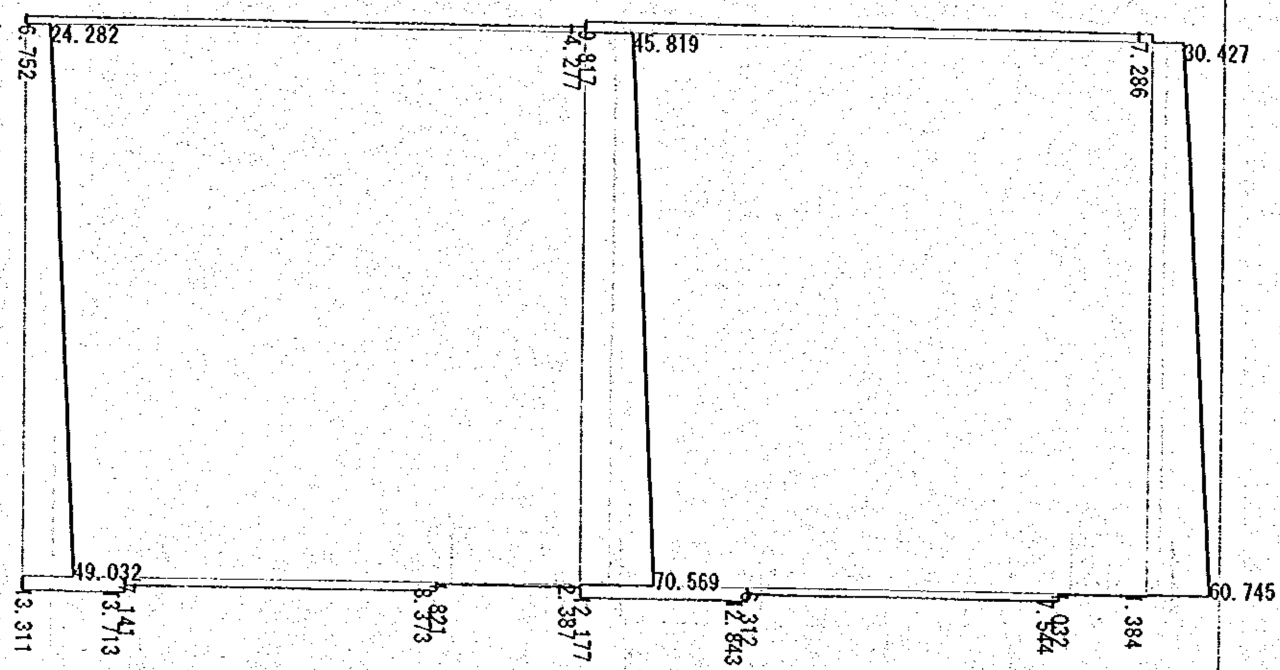
Shear Stress Scale ├───┤ : 65.09tf max. : 65.07 tf



Baru-pumping station (D-D)

Case 6: D-D seismic rw

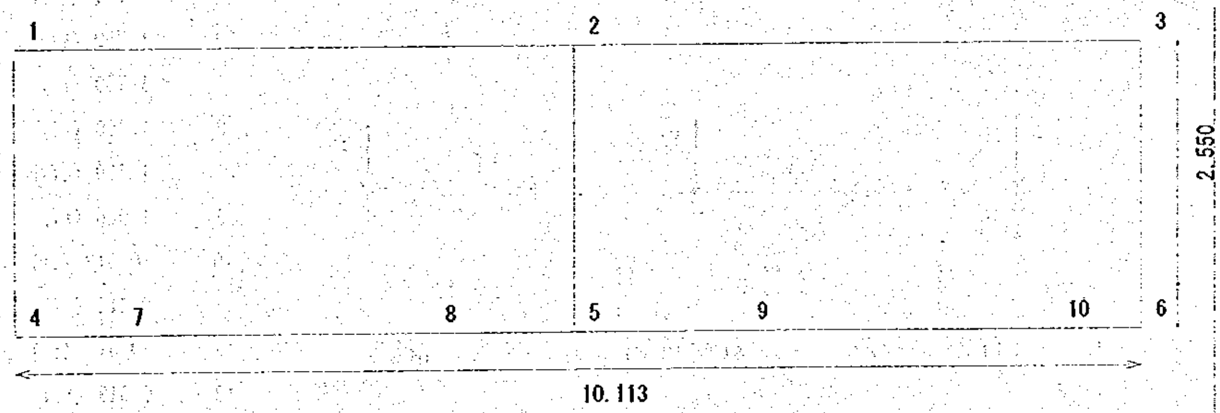
Axial Stress   Scale : 70.59tf   max. : 70.57 tf



Baru-pumping station (E-E)

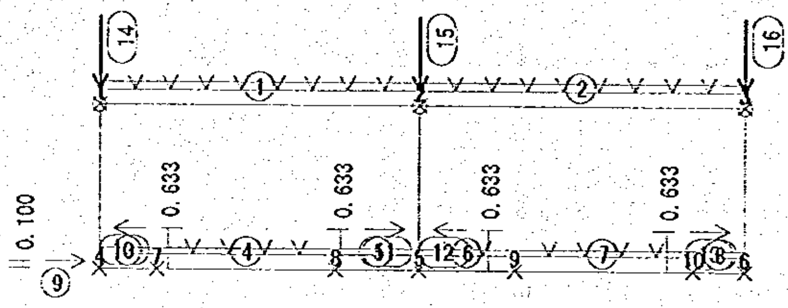
縮尺 1/ 66

骨組図



Baru-pumping station (E-E)

Case 1 : E-E Normal w



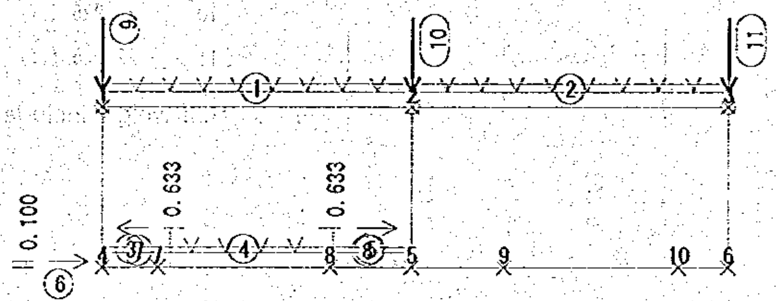
Load

①	2.500 (tf/m)
	2.500 (tf/m)
②	2.500 (tf/m)
	2.500 (tf/m)
③	1.750 (tf/m)
	1.750 (tf/m)
④	1.750 (tf/m)
	1.750 (tf/m)
⑤	1.750 (tf/m)
	1.750 (tf/m)
⑥	1.750 (tf/m)
	1.750 (tf/m)
⑦	1.750 (tf/m)
	1.750 (tf/m)
⑧	1.750 (tf/m)
	1.750 (tf/m)
⑨	1.925 (tf)
(10)	-0.613 (tf)
(11)	0.613 (tf)
(12)	-0.613 (tf)
(13)	0.613 (tf)
(14)	22.925 (tf)
(15)	22.925 (tf)
(16)	22.925 (tf)

Self-weight included

Baru-pumping station (E-E)

Case 2 : E-E Normal lw



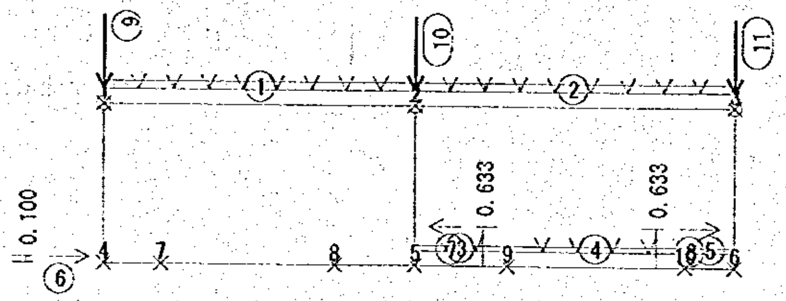
Load

- ① 2.500 (tf/m)
  2.500 (tf/m)
- ② 2.500 (tf/m)
  2.500 (tf/m)
- ③ 1.750 (tf/m)
  1.750 (tf/m)
- ④ 1.750 (tf/m)
  1.750 (tf/m)
- ⑤ 1.750 (tf/m)
  1.750 (tf/m)
- ⑥ 1.925 (tf)
- ⑦ -0.613 (tf)
- ⑧ 0.613 (tf)
- ⑨ 22.925 (tf)
- ⑩ 22.925 (tf)
- ⑪ 22.925 (tf)

Self-weight included

Baru-pumping station (E-E)

Case 3 : E-E Normal rw



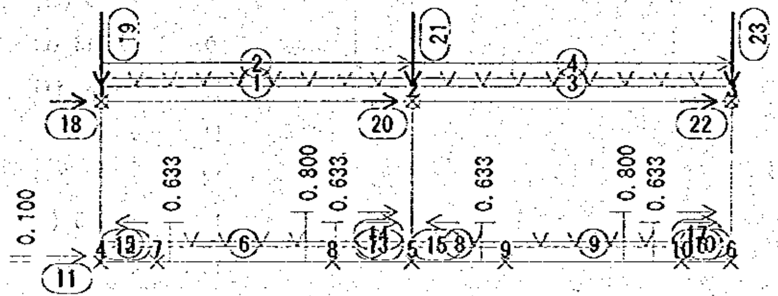
Load

①	2.500 (tf/m)
	2.500 (tf/m)
②	2.500 (tf/m)
	2.500 (tf/m)
③	1.750 (tf/m)
	1.750 (tf/m)
④	1.750 (tf/m)
	1.750 (tf/m)
⑤	1.750 (tf/m)
	1.750 (tf/m)
⑥	1.925 (tf)
⑦	-0.613 (tf)
⑧	0.613 (tf)
⑨	22.925 (tf)
⑩	22.925 (tf)
⑪	22.925 (tf)

Self-weight included

Baru-pumping station (E-E)

Case 4 : E-E seismic w



Load

①	2.500 (tf/m)
	2.500 (tf/m)
②	0.275 (tf/m)
	0.275 (tf/m)
③	2.500 (tf/m)
	2.500 (tf/m)
④	0.275 (tf/m)
	0.275 (tf/m)
⑤	1.750 (tf/m)
	1.750 (tf/m)
⑥	1.750 (tf/m)
	1.750 (tf/m)
⑦	1.750 (tf/m)
	1.750 (tf/m)
⑧	1.750 (tf/m)
	1.750 (tf/m)
⑨	1.750 (tf/m)
	1.750 (tf/m)
(10)	1.750 (tf/m)
	1.750 (tf/m)
(11)	2.275 (tf)
(12)	-0.613 (tf)
(13)	0.613 (tf)
(14)	0.075 (tf)
(15)	-0.613 (tf)
(16)	0.613 (tf)
(17)	0.075 (tf)
(18)	2.522 (tf)
(19)	22.925 (tf)
(20)	2.522 (tf)
(21)	22.925 (tf)
(22)	2.522 (tf)
(23)	22.925 (tf)

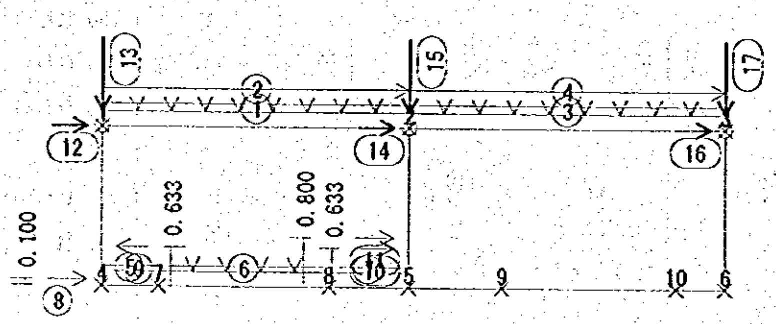
Self-weight included

Seismic Force

KH = 0.11

Baru-pumping station (E-E)

Case 5 : E-E seismic lw



Load

①	2.500 (tf/m)
	2.500 (tf/m)
②	0.275 (tf/m)
	0.275 (tf/m)
③	2.500 (tf/m)
	2.500 (tf/m)
④	0.275 (tf/m)
	0.275 (tf/m)
⑤	1.750 (tf/m)
	1.750 (tf/m)
⑥	1.750 (tf/m)
	1.750 (tf/m)
⑦	1.750 (tf/m)
	1.750 (tf/m)
⑧	2.275 (tf)
⑨	-0.613 (tf)
(10)	0.613 (tf)
(11)	0.075 (tf)
(12)	2.522 (tf)
(13)	22.925 (tf)
(14)	2.522 (tf)
(15)	22.925 (tf)
(16)	2.522 (tf)
(17)	22.925 (tf)

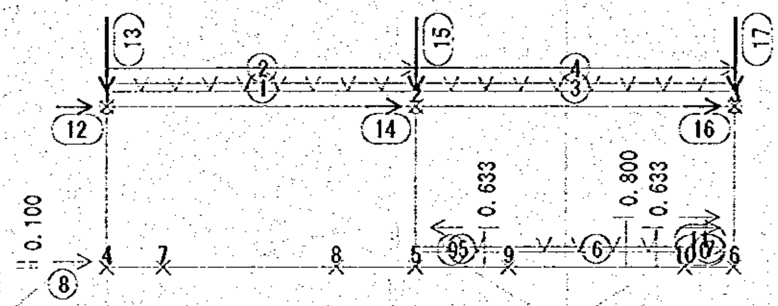
Self-weight included

Seismic Force

KH = 0.11

Baru-pumping station (E-E)

Case 6 : E-E seismic rw



Load	
①	2.500 (tf/m)
	2.500 (tf/m)
②	0.275 (tf/m)
	0.275 (tf/m)
③	2.500 (tf/m)
	2.500 (tf/m)
④	0.275 (tf/m)
	0.275 (tf/m)
⑤	1.750 (tf/m)
	1.750 (tf/m)
⑥	1.750 (tf/m)
	1.750 (tf/m)
⑦	1.750 (tf/m)
	1.750 (tf/m)
⑧	2.275 (tf)
⑨	-0.613 (tf)
(10)	0.613 (tf)
(11)	0.075 (tf)
(12)	2.522 (tf)
(13)	22.925 (tf)
(14)	2.522 (tf)
(15)	22.925 (tf)
(16)	2.522 (tf)
(17)	22.925 (tf)

Self-weight included

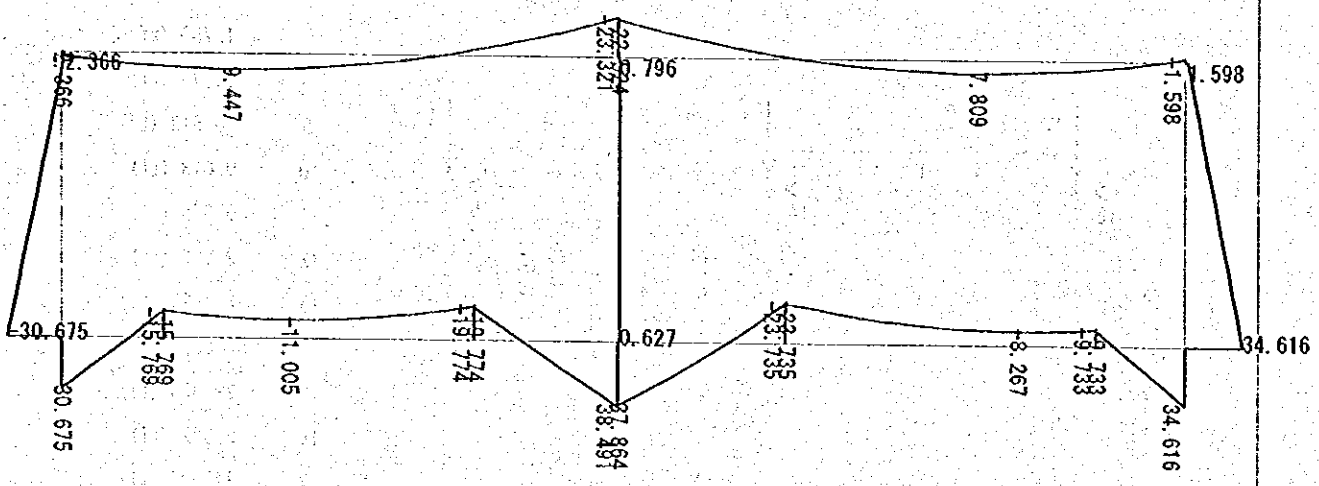
Seismic Force

KH = 0.11

Baru-pumping station (E-E)

Case 1: E-E Normal w

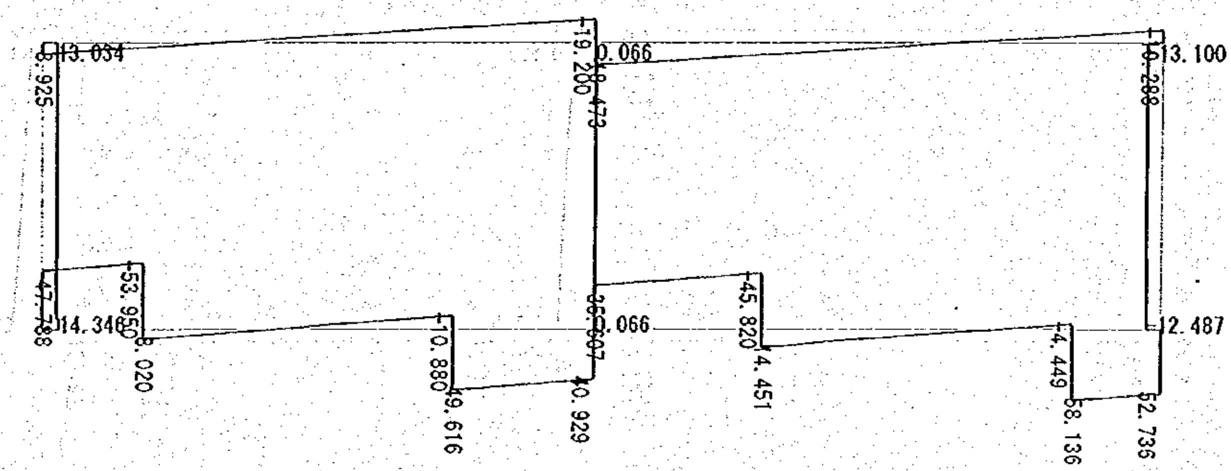
Bending Moment Scale : 43.92tf·m max. : 38.49 tf·m



Baru-pumping station (E-E)

Case 1: E-E Normal w

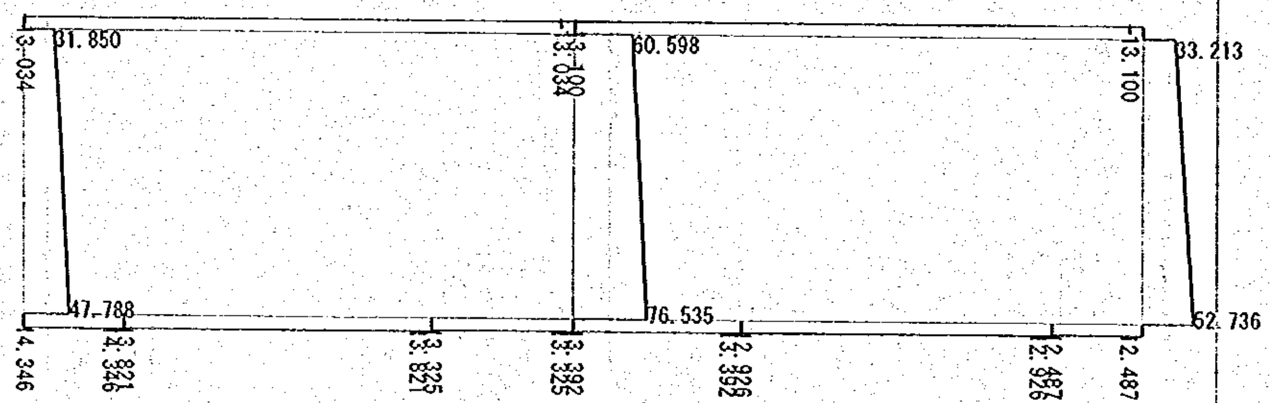
Shear Stress Scale ⊢—⊣ : 60.89tf max. : 58.14 tf



Baru-pumping station (E-E)

Case 1: E-E Normal w

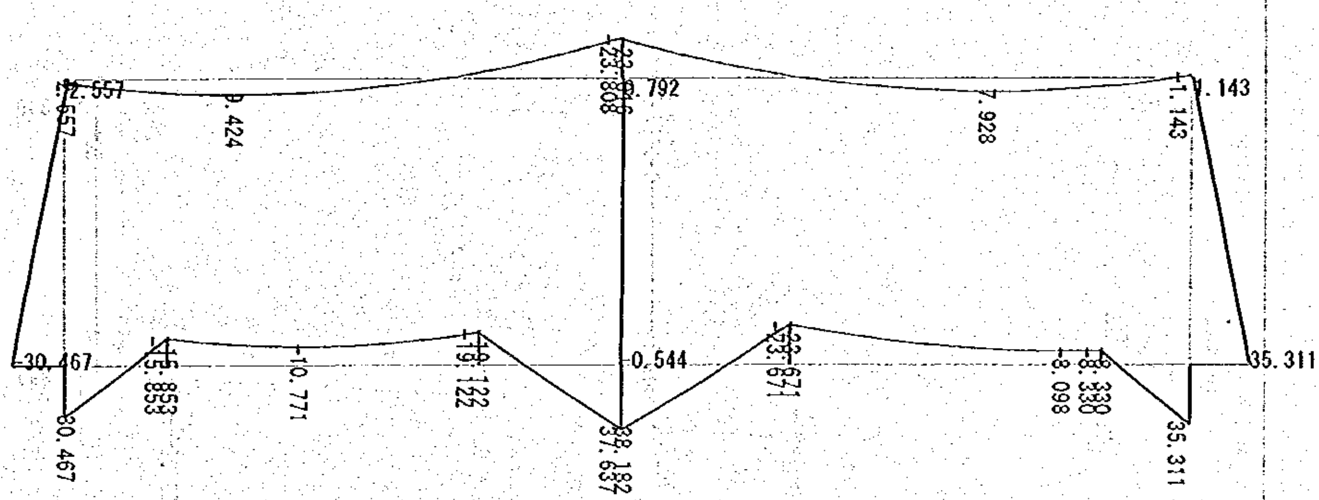
Axial Stress Scale : 76.86tf max. : 76.54 tf



Baru-pumping station (E-E)

Case 2: E-E Normal lw

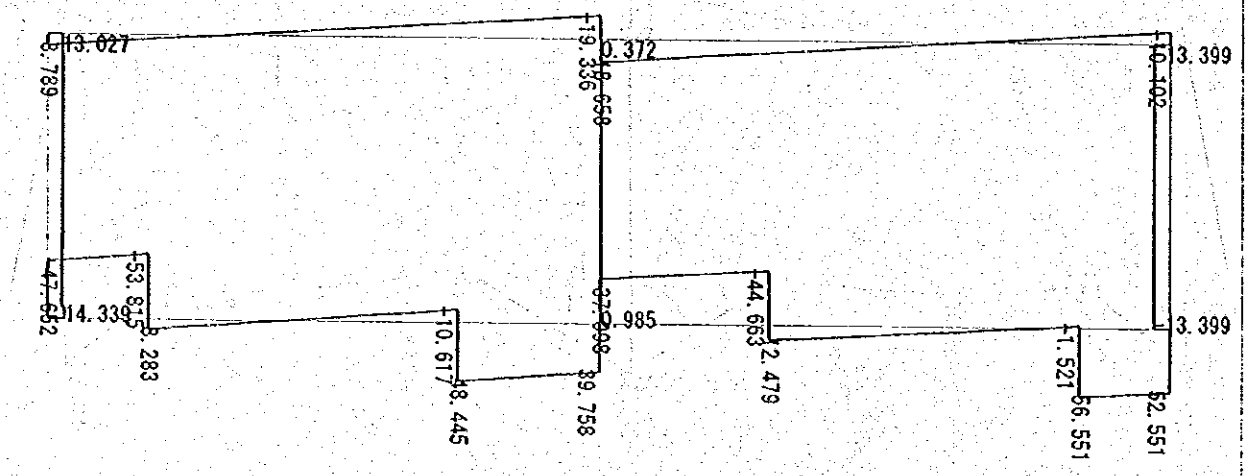
Bending Moment Scale : 43.92tf·m max. : 38.18 tf·m



Baru-pumping station (E-E)

Case 2: E-E Normal lw

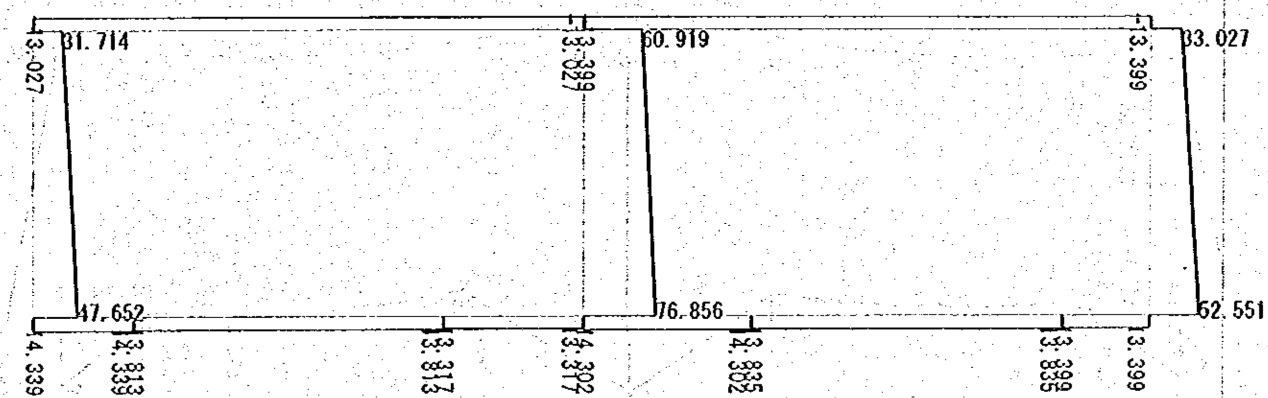
Shear Stress Scale ├───┤ : 60.89tf max. : 56.55 tf



Baru-pumping station (E-E)

Case 2: E-E Normal lw

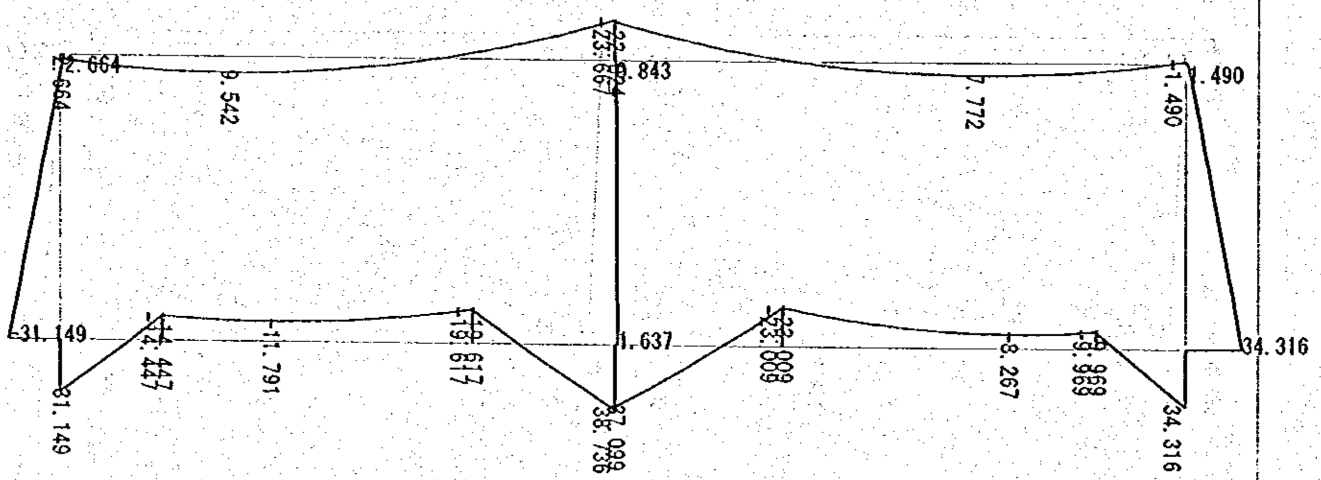
Axial Stress Scale : 76.86tf max. : 76.86 tf



Baru-pumping station (E-E)

Case 3: E-E Normal rw

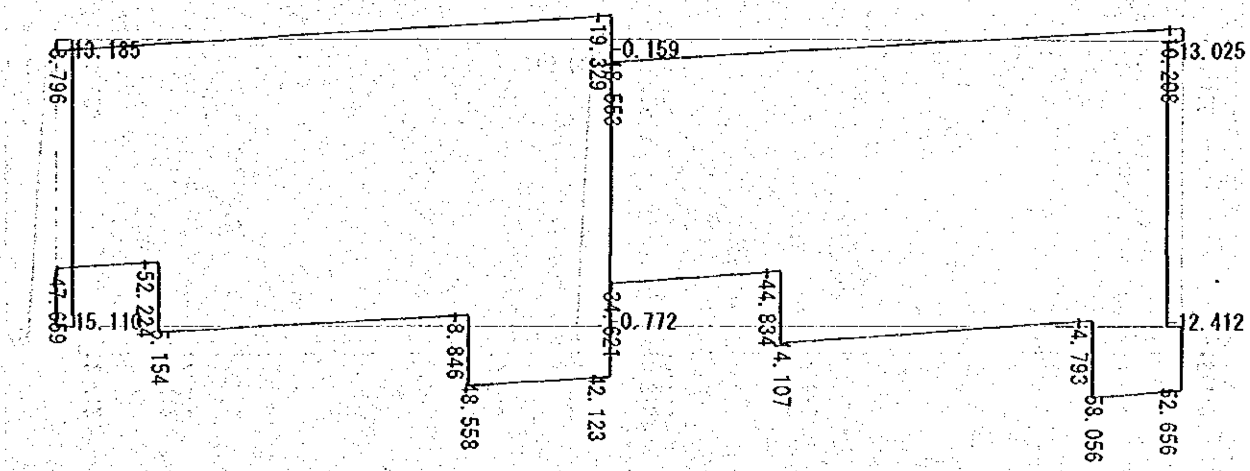
Bending Moment Scale ------ : 43.92tf·m max. : 38.74 tf·m



Baru-pumping station (E-E)

Case 3: E-E Normal rw

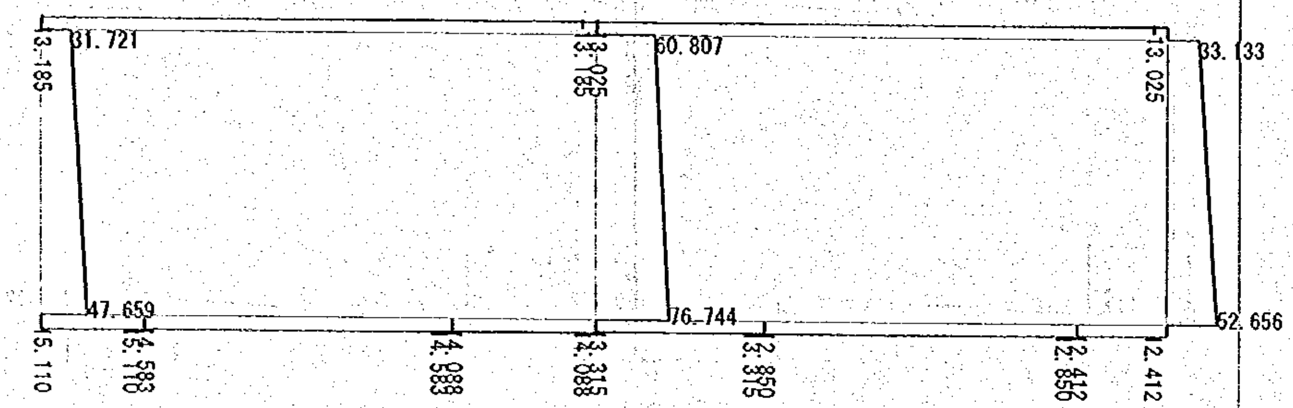
Shear Stress Scale : 60.89tf max. : 58.06 tf



Baru-pumping station (E-E)

Case 3: E-E Normal rw

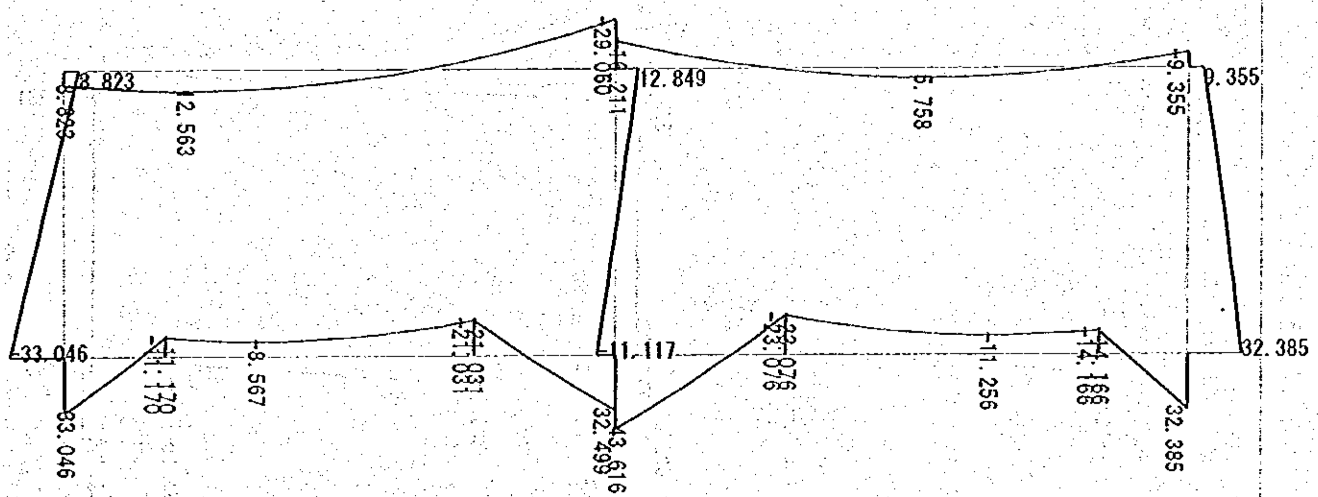
Axial Stress Scale : 76.86tf max. : 76.74 tf



Baru-pumping station (E-E)

Case 4: E-E seismic w

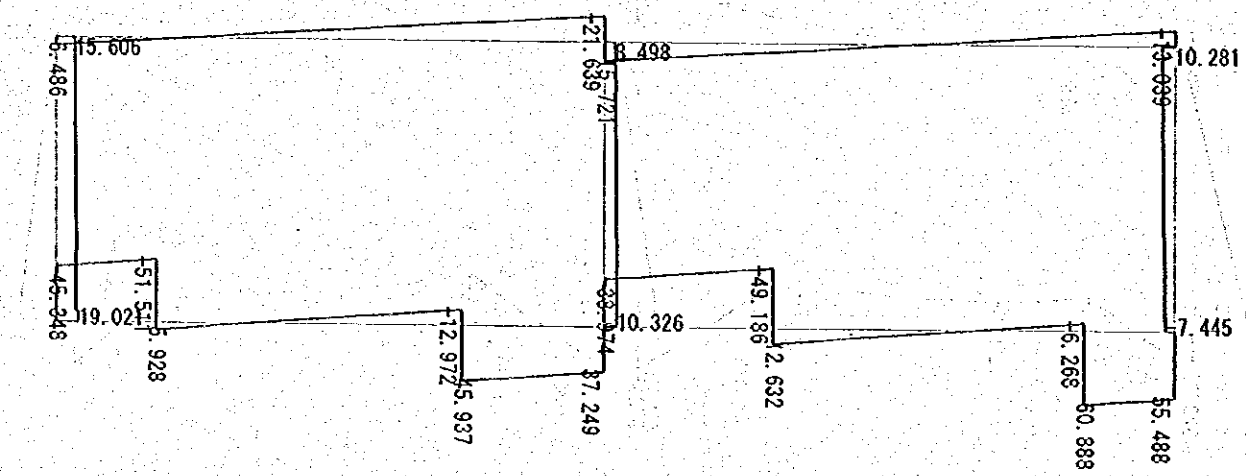
Bending Moment Scale : 43.92tf·m max. : 43.62 tf·m



Baru-pumping station (E-E)

Case 4: E-E seismic w

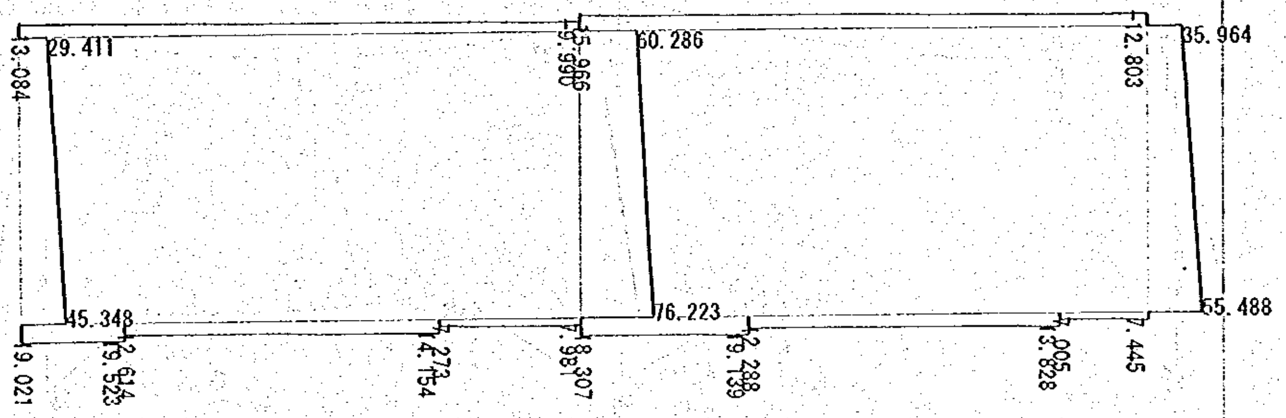
Shear Stress Scale : 60.89tf max. : 60.89 tf



Baru-pumping station (E-E)

Case 4: E-E seismic w

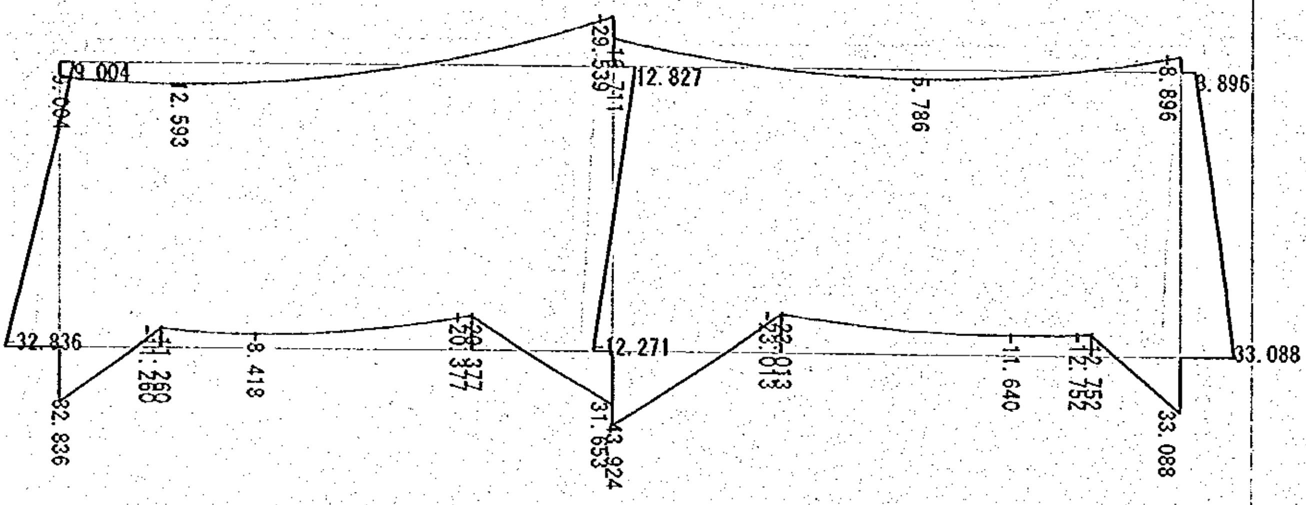
Axial Stress   Scale : 76.86tf   max. : 76.22 tf



Baru-pumping station (E-E)

Case 5: E-E seismic lw

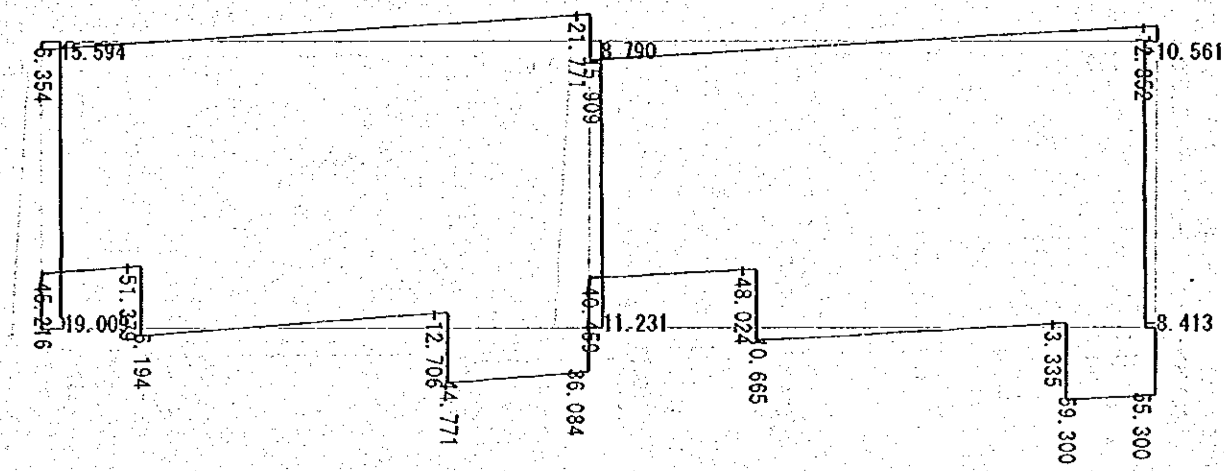
Bending Moment   Scale : 43.92tf·m   max. : 43.92 tf·m



Baru-pumping station (E-E)

Case 5: E-E seismic lw

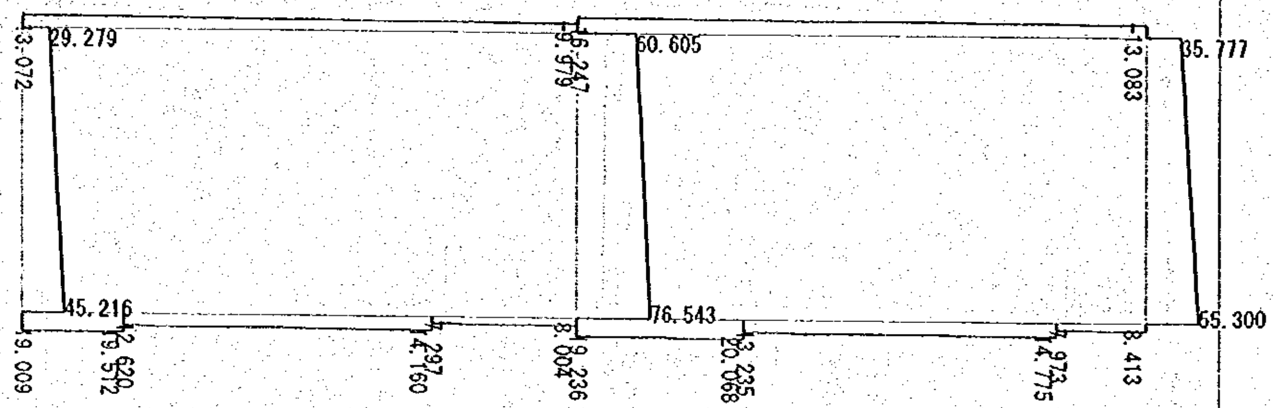
Shear Stress Scale : 60.89tf max. : 59.30 tf



Baru-pumping station (E-E)

Case 5: E-E seismic lw

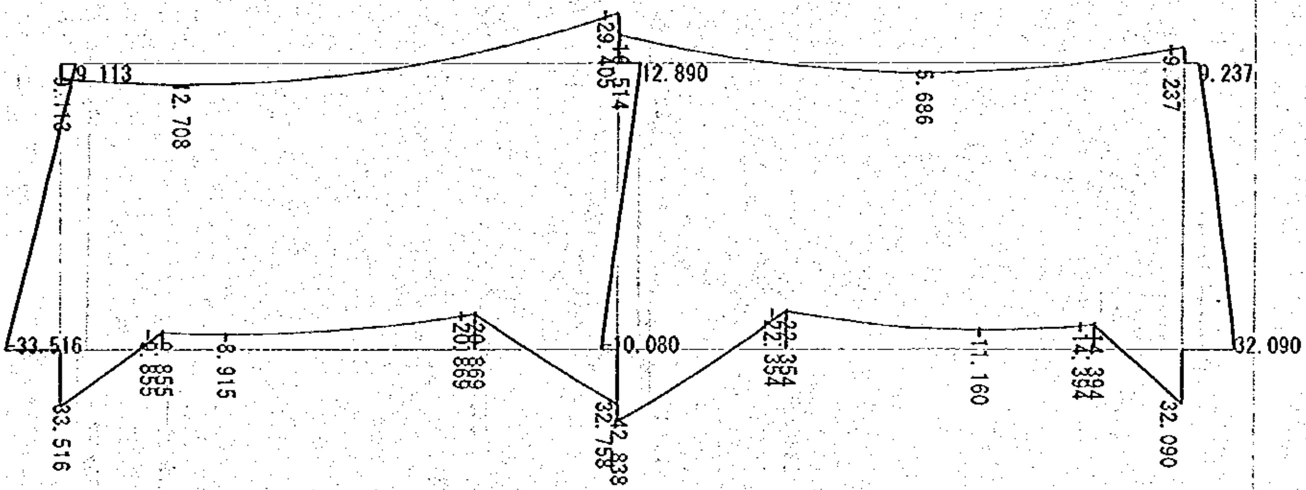
Axial Stress Scale : 76.86tf max. : 76.54 tf



Baru-pumping station (E-E)

Case 6: E-E seismic rw

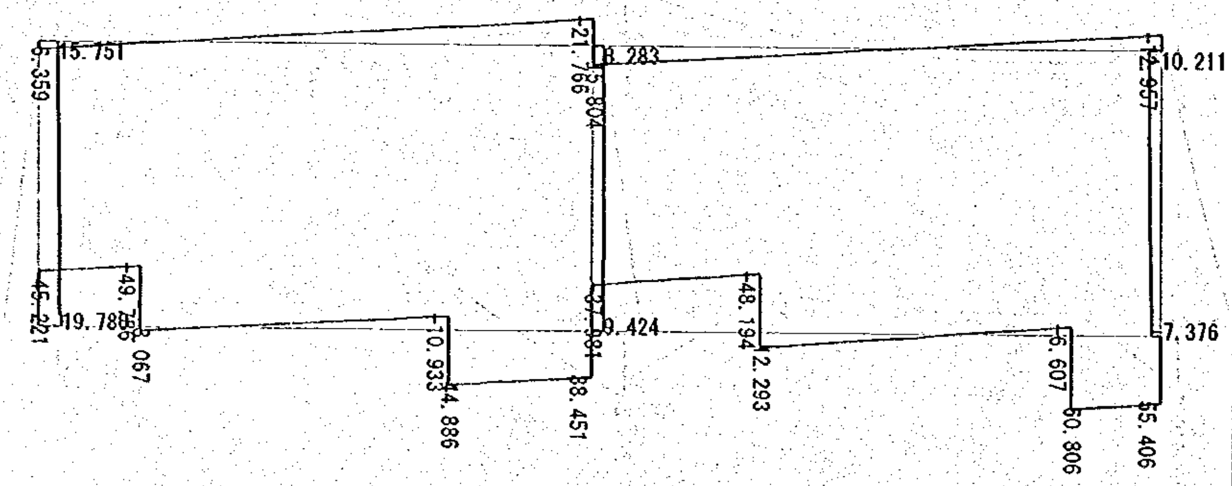
Bending Moment Scale : 43.92tf·m max. : 42.84 tf·m



Baru-pumping station (E-E)

Case 6: E-E seismic rw

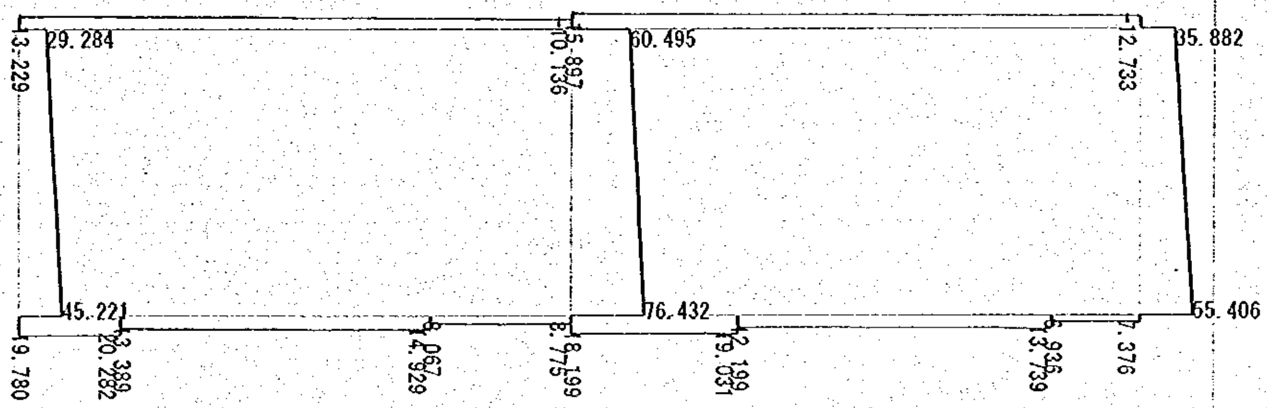
Shear Stress Scale : 60.89tf max. : 60.81 tf



Baru-pumping station (E-E)

Case 6: E-E seismic rw

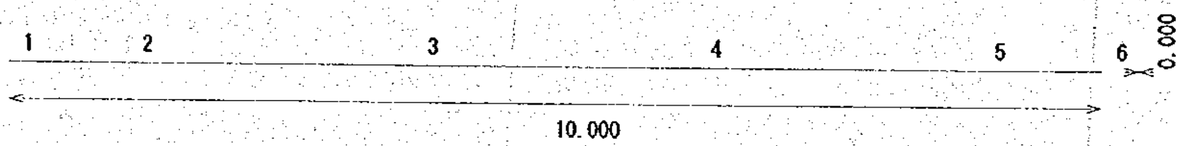
Axial Stress Scale : 76.86tf max. : 76.43 tf



Baru pumping station (F-F)

縮尺 1/ 66

骨組図



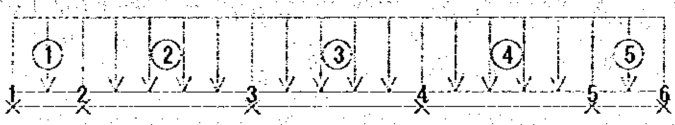
Baru pumping station (F-F)

Case 1 : F-F nomal

Load

①	7.750 (tf/m)
	7.750 (tf/m)
②	7.750 (tf/m)
	7.750 (tf/m)
③	7.750 (tf/m)
	7.750 (tf/m)
④	7.750 (tf/m)
	7.750 (tf/m)
⑤	7.750 (tf/m)
	7.750 (tf/m)

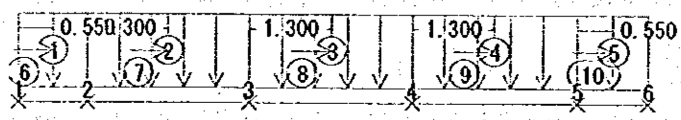
Self-weight included



Baru pumping station (F-F)

Case 2 : F-F Seismic

Load	
①	7.750 (tf/m)
	7.750 (tf/m)
②	7.750 (tf/m)
	7.750 (tf/m)
③	7.750 (tf/m)
	7.750 (tf/m)
④	7.750 (tf/m)
	7.750 (tf/m)
⑤	7.750 (tf/m)
	7.750 (tf/m)
⑥	0.853 (tf)
⑦	0.853 (tf)
⑧	0.582 (tf)
⑨	0.853 (tf)
⑩	0.853 (tf)



Self-weight included

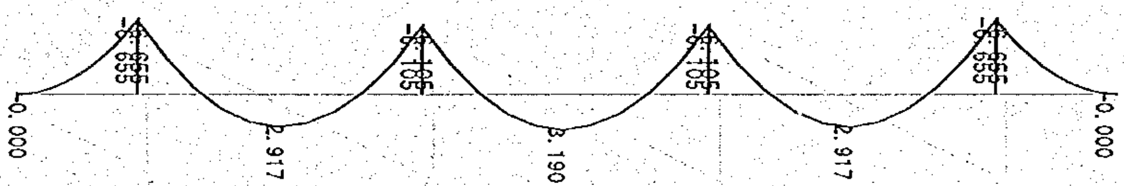
Seismic Force

KH = 0.11

Baru pumping station (F-F)

Case 1: F-F nomal

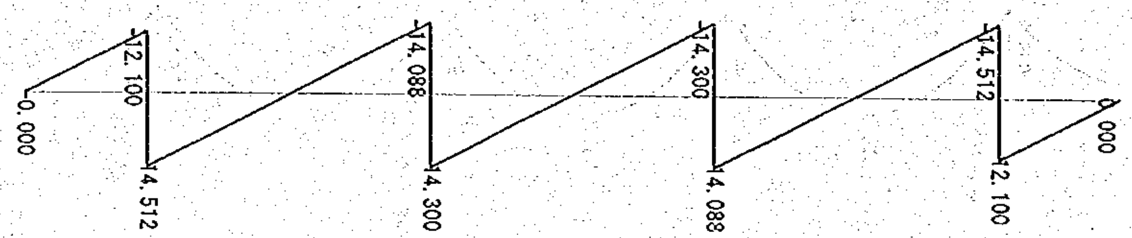
Bending Moment   Scale ├───┤ : 6.66tf·m   max. : -6.66 tf·m



Baru pumping station (F-F)

Case 1: F-F nomal

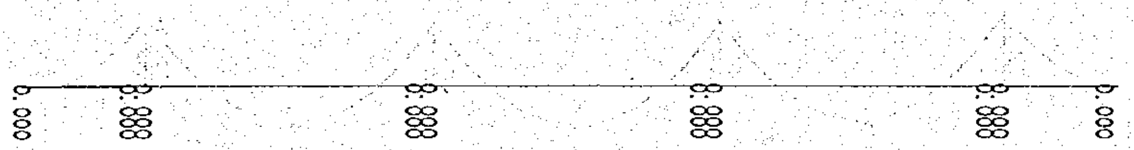
Shear Stress Scale : 14.51tf max. : -14.51 tf



Baru pumping station (F-F)

Case 1: F-F nomal

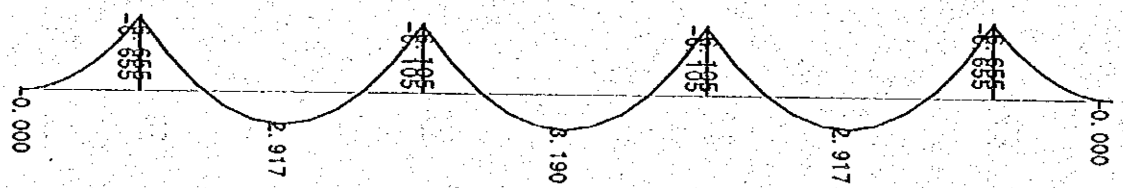
Axial Stress Scale ——: 6.32tf max.: 0.00 tf



Baru pumping station (F-F)

Case 2: F-F Seismic

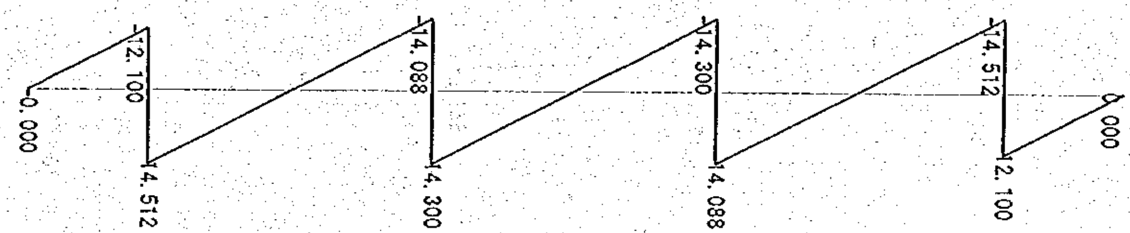
Bending Moment Scale ├──┤ : 6.66tf·m max. : -6.66 tf·m



Baru pumping station (F-F)

Case 2: F-F Seismic

Shear Stress Scale : 14.51tf max. : -14.51 tf



Baru pumping station (F-F)

Case 2: F-F Seismic

Axial Stress Scale : 6.32tf max. : -6.32 tf

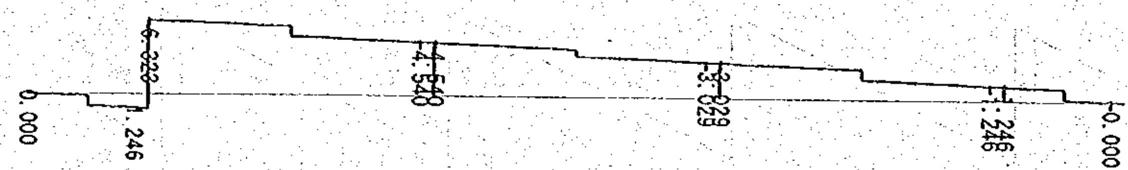
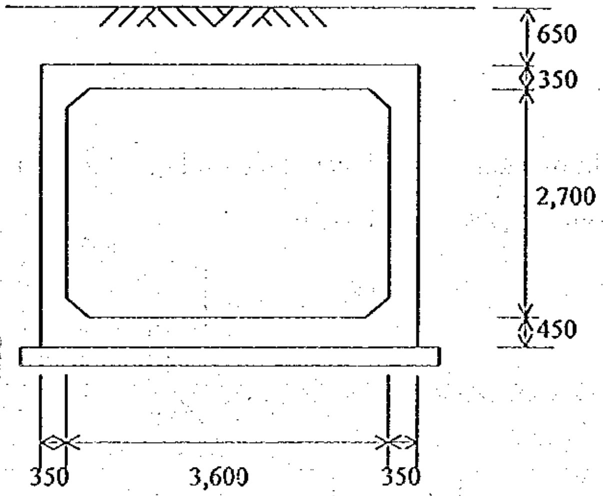


Table 11 Reinforcing Bar Arrangement

Section Name	Member Name	direction	surface	type	cover (mm)	t (m)	L (m)	normal M (tm)	normal N (t)	earthquake M (tm)	earthquake N (t)	reinforcing bar(main) diameter (mm)	pitch (mm)	reinforcing bar (distribution) diameter (mm)	pitch (mm)	Normal C σ (kg/cm2)	Earthquake S σ (kg/cm2)	C σ (kg/cm2)	S σ (kg/cm2)
allowable stress																225	1,600 - 1,800	338	2,400 2,700
A-A	wall no.1	-z	water	wall	100	0.975	10	37	133	107	133	D16	250	D13	500	4	21	18	814
		+z	water	wall	50	0.975	10	37	133	107	133	D16	250	D13	500	4	25	17	776
	wall no.2	-z	water	wall	50	0.975	10	37	133	107	133	D16	250	D13	500	4	25	17	776
		+z	water	wall	50	0.975	10	37	133	107	133	D16	250	D13	500	4	25	17	776
	wall no.3	-z	water	wall	50	0.975	10	0	133	0	133	D16	250	D13	500	-	-	-	-
		+z	soil	wall	100	0.975	10	106	133	171	133	D16	250	D13	500	18	799	30	1,763
	bottom slab	+y	water	slab	50	0.8	10	79	0	134	0	D16	125	D16	125	14	716	23	1,215
		-y	pile	slab	150	0.8	10	106	0	171	0	D16	125	D16	125	23	1,115	37	1,798
B-B	wall no.1	-z	water	wall	100	1	8.2	81	136	210	136	D19	250	D16	500	13	366	38	1,939
		+z	water	wall	50	1	8.2	81	136	210	136	D19	250	D16	500	13	354	35	1,836
	wall no.2	-z	water	wall	50	1	8.2	81	136	210	136	D19	250	D16	500	13	354	35	1,836
		+z	water	wall	50	1	8.2	81	136	210	136	D19	250	D16	500	13	354	35	1,836
	wall no.3	-z	water	wall	50	1	8.2	0	136	0	136	D19	250	D16	500	-	-	-	-
		+z	soil	wall	100	1	8.2	158	136	224	136	D19	250	D16	500	23	1,289	41	2,109
	bottom slab	+y	water	slab	50	1.3	8.2	191	0	284	0	D16	125	D16	125	18	1,247	27	1,854
		-y	pile	slab	150	1.3	8.2	158	0	224	0	D16	125	D16	125	17	1,124	24	1,593
C-C	wall no.1	-z	water	wall	100	1	7.8	19	140	36	140	D16	250	D13	500	3	9	5	16
		+z	water	wall	50	1	7.8	19	140	36	140	D16	250	D13	500	3	7	5	21
	wall no.2	-z	water	wall	50	1	7.8	19	140	36	140	D16	250	D13	500	3	7	5	21
		+z	water	wall	50	1	7.8	19	140	35	140	D16	250	D13	500	3	7	5	21
	wall no.3	-z	water	wall	50	1	7.8	0	140	0	140	D16	250	D13	500	-	-	-	-
		+z	soil	wall	100	1	7.8	75	140	126	140	D16	250	D13	500	13	374	26	1,282
	bottom slab	+y	water	slab	50	0.92	7.8	240	0	263	0	D19	125	D19	125	36	1,680	40	1,841
		-y	soil	slab	100	0.92	7.8	163	0	197	0	D19	125	D19	125	27	1,213	33	1,466
D-D	wall no.1	-z	water	wall	100	1	2.7	8	37	8	37	D16	250	D13	500	3	3	3	3
		+z	water	wall	50	1	2.7	8	37	8	37	D16	250	D13	500	3	5	3	5
	wall no.2	-z	water	wall	50	1	2.7	1	43	1	43	D16	250	D13	500	2	2	2	20
		+z	water	wall	50	1	2.7	1	43	1	43	D16	250	D13	500	2	2	2	20
	wall no.3	-z	water	wall	50	1	2.7	0	32	0	32	D16	250	D13	500	-	-	-	-
		+z	soil	wall	100	1	2.7	7	32	7	32	D16	250	D13	500	3	3	3	3
	bottom slab	+y	water	slab	50	0.8	2.7	27	0	27	0	D16	125	D16	125	17	907	17	907
		-y	pile	slab	150	0.8	2.7	28	0	28	0	D16	125	D16	125	23	1,090	23	1,090
	box culvert top	+y	air	beam	50	0.5	2.7	7	0	9	0	D16	250	D16	250	13	779	17	1,001
		-y	air	beam	50	0.5	2.7	5	0	5	0	D16	250	D16	250	10	556	10	556
E-E	wall no.1	-z	water	wall	100	1	7	67	107	67	107	D16	250	D13	500	14	511	14	511
		+z	water	wall	50	1	7	0	107	53	107	D16	250	D13	500	-	-	10	257
	wall no.2	-z	water	wall	50	1	7	0	147	14	147	D16	250	D13	500	-	-	3	15
		+z	water	wall	50	1	7	3	147	14	147	D16	250	D13	500	2	27	3	15
	wall no.3	-z	water	wall	50	1	7	0	94	0	94	D16	250	D13	500	-	-	-	-
		+z	soil	wall	100	1	7	60	94	63	94	D16	250	D13	500	13	471	14	529
	bottom slab	+y	water	slab	50	0.8	7	51	0	49	0	D16	125	D16	125	10	580	10	558
		-y	pile	slab	150	0.8	7	80	0	83	0	D16	125	D16	125	25	1,202	26	1,247
	box culvert top	+y	air	beam	50	0.5	7	44	0	46	0	D19	250	D19	250	28	1,325	29	1,385
		-y	air	beam	50	0.5	7	21	0	21	0	D19	250	D19	250	20	821	20	821
F-F	bottom	+y	air	slab	50	0.5	10	26	0	26	0	D16	250	D16	250	13	781	13	781
		-y	pile	slab	150	0.5	10	12	0	12	0	D16	250	D16	250	9	467	9	467

3.1 Baru Pumping Station

3.1.7 Structural Calculation of Fuel Tank Box



DESIGN SECTION

I. STRUCTURE DESIGN CALCULATION

Concrete box for fuel tank designed as the barrel. The calculation to be adopted per meter length to longitudinal section direction, the thickness of frame are:

Top slab	=	35 cm
Side walls	=	35 cm
Bottom slab	=	45 cm

1) The acting forces, in case under construction when vehicle pass over the barrel, the tank empty/no fuel and the uplift are acting.

2) The soil data, there are no data form laboratory test. According to the Design Criteria, the soil data will be assumed soft clay.

- Unit weight, the soil to be compacted and wet condition unit weight $\gamma s = 1.80\ t/m^3$.
- Cohesion, to be estimate by using "N" value

$$C = \frac{N}{8} \approx \frac{N}{11} (N \text{ for soft clay, } N < 10)$$

$$\text{assume} \quad C = \frac{N}{9.5},\ N = 5 \sim 10 \rightarrow N = \frac{5+10}{2} = 7.5$$

$$C = \frac{7.5}{9.5} = 0.80\ kg/cm^2 = 8\ t/m^2$$

- Internal Friction Angle.

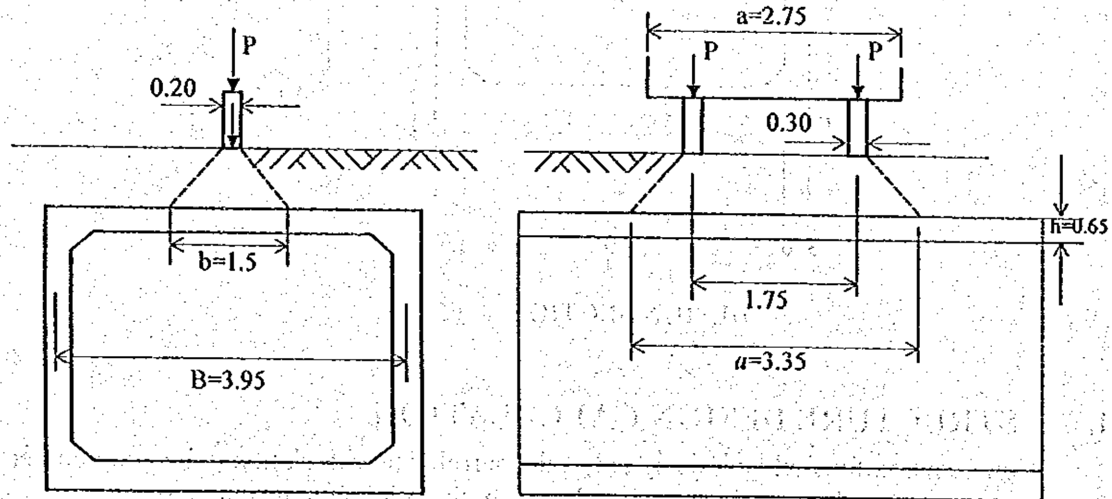
$$\phi = 15 + \sqrt{15N} \leq 45^\circ \text{ (for N > 5)}$$

$$\varphi = 15 + \sqrt{15 \times 75} = 25.6° \sim 25°$$

3) Loading

a. Top Slab loading

- Weight of saturated soil over the barrel $q_s = 0.65 \times 1.8 = 1.170\ t/m^2$.
- The vehicle pass over the barrel



$$W_e = \frac{2P(1.0+i)}{a} \times \frac{2B-b}{B^2} \quad for\ b < B$$

where, We = Distributed load (t/m^2)

a = Width of Truck (m), a = 2.75 m

a = width of distributed load to longitudinal direction (m), $a = 2h + (1.75 + 0.3) = 3.35$ m.

B = width of structure

P = rear wheel load of vehicle (t), P = 10 t

h = height of earth covering about top slab (m)

i = impact coefficient, determined as follows:

$i = 0.30$ for $h \leq 3.5$ m

$i = 0.00$ for $h > 3.5$ m

$$W_e = \frac{2 \times 10\ (1.0 + 0.3)}{3.35} \times \frac{2 \times 3.95 - 1.5}{3.95^2} = 3.184\ t/m^2$$

- Loading over top slab = $q_{ts} = q_s + W_e = 1.17 + 3.184 = 4.354\ t/m^2$
- Weight of Top Slab = $W_{ts} = 0.35 \times 2.5 = 0.875\ t/m^2$
- Total loading of top slab = $q_1 = 4.354 + 0.875 =$ <u>5.229 t/m²</u>

b. Bottom slab loading

(i) Loading for down direction (assume as uniform load).

- Estimation weight of tank

  Tank thickness = 7 mm; unit weight of steel = 7.80 t/m³

  $Wt = \{(2\times\pi\times1^2)+(2\times\pi\times1\times4.7)\}\times0.007\times7.80 = 1.955\ t$

- Weight of concrete tank support

  $$Ws = \left\{(0.2\times3.2)+\left(\frac{2.4+3.2}{2}\times1\right)-\left(\frac{\pi\times1^2}{2}\right)\right\}\times0.2\times5\times2.5 = 4.673\ t$$

- Loading of over bottom slab

  $Wobs = Wt + Ws = 1.955+4.673 = 6.628\ t$

- Uniform load of over bottom slab = $q_{obs} = \frac{6.628}{3.2\times4.2} = 0.493\ t/m^2$

- Weight of bottom slab = $W_{bs} = 0.45\times2.5 = 1.125\ t/m^2$

- Total uniform load of over bottom slab

  $q_{bst} = q_{obs} + W_{bs} = 0.493+1.125 = 1.618\ t/m^2$

(ii) Loading for Up direction.

- Weight of concrete box

  $Wb = [(7\times4.3\times0.35)+(7\times4.3\times0.45)+\{(3.6+6.3)\times2\times2.7\times0.35\}]\times2.5$

  $= 106.978\ t$

- Total weight of concrete box without live load

  $Wb_{tot} = (q_s\times4.3\times7)+W_{obs}+Wb$

  $= (1.17\times4.3\times7)+6.628+106.978$

  $= 148.823t$

- Uplift force = Uf = 4.3 x 7 x 3.5 x 1.00 = 105.35 t

  $Wb_{tot} > Uf = 148.823t > 105.35t \rightarrow$ *no buoyancy (OK)*

- Pressure to base slab

  $q_{bs} = \frac{W_{btot}}{area} = \frac{148.823}{4.3\times7} = 4.944\ t/m^2$

  $W_e = \underline{3.184\ t/m^2}$ +

  $Q_{bs\ tot} = 8.124\ t/m^2$

- Total Pressure to base slab

$$q_2 = q_{b,tot} + \frac{Uf}{4.3\times 7} - q_{b1}$$

$$= 8.124 + \frac{105.35}{4.3\times 7} - 1.618 = 10.006\ t/m$$

c. **Side wall loading**

Active earth pressure by clayey soil.

$$Pa = Ka\cdot\gamma s.h\ -2c\sqrt{Ka} + Ka\times q$$

c value not include calculated, more save.

$$Pa = Ka.\gamma a\ + Ka\times q$$

Active earth pressure coefficient Ka

$$Ka = \frac{\cos^2(\phi-\theta)}{\cos^2\theta\cdot\cos(\theta+\delta)\cdot\left[1-\sqrt{\frac{\sin(\theta+\delta)\cdot\sin(\theta-\alpha)}{\cos(\theta-\delta)\cdot\cos(\theta-\alpha)}}\right]^2}$$

for θ, δ, α = 0°

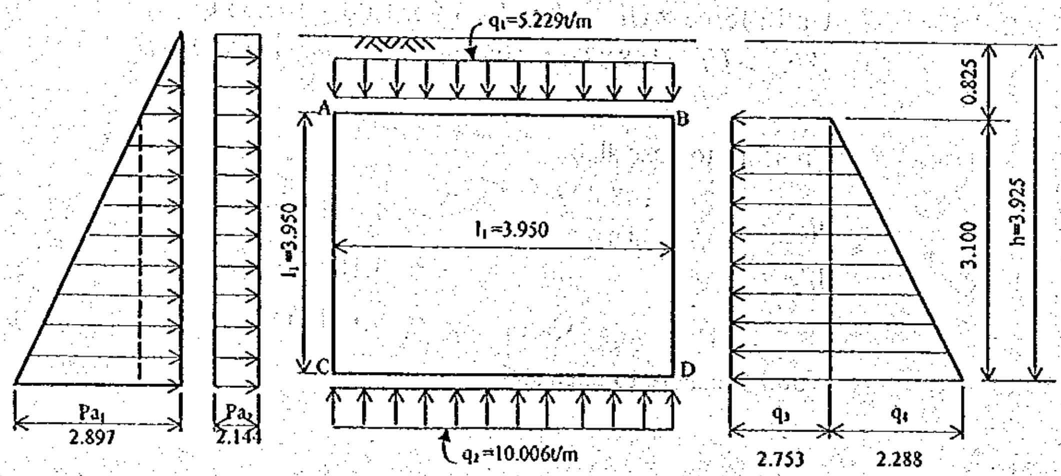
$$Ka = \frac{\cos^2\phi}{(1+\sin\phi)^2} = \frac{\cos^2 25°}{(1+\sin 25)^2} = 0.41$$

$$Pa_1 = Ka\cdot\gamma s\ \cdot h = 0.41\times 1.80\times 3.925 = 2.897 t/m$$

$$Pa_2 = Ka\cdot q_1 = 0.41\times 5.229 = 2.144 t/m$$

$$q_3 = 2.144 + \frac{0.825}{3.925}\times 2.897 = 2.753 t/m$$

$$q_4 = \left(1-\frac{0.825}{3.925}\right)\times 2.897 = 2.288 t/m$$



4) **Moment Calculation (with Hardy Cross method)**

a. **Fixing moment**

$$MfAB = \frac{q_1 l_1^2}{12} = \frac{5.229 \times 3.95^2}{12} = 6.799tm[+]$$

$$MfBA = 6.799tm[-]$$

$$MfCD = \frac{q_2 l_1^2}{12} = \frac{10.006 \times 3.95^2}{12} = 13.010tm[-]$$

$$MfDC = 13.010tm[+]$$

<u>**on member AC**</u>

Rectangular load, $MR = \frac{q_3 \times l_2^2}{12} = \frac{2.753 \times 3.10^2}{12} = 2.205tm$

Triangular load

$$AC = \frac{q_4 \times l_2^2}{30} = \frac{2.288 \times 3.10^2}{30} = 0.733tm$$

$$CA = \frac{q_4 \times l_2^2}{20} = \frac{2.288 \times 3.10^2}{20} = 1.099tm$$

$$MfAC = MR + AC = 2.205 + 0.733 = 2.938tm[-]$$

$$MfCA = MR + CA = 2.205 + 1.099 = 3.304tm[+]$$

$$MfBD = 2.938tm[+]$$

$$MfDB = 3.304tm[-]$$

b. **Moment distribution factors**

$$\mu = \frac{4EI}{l}$$

– **Joint A**

$$\mu ab : \mu ac = \frac{4(EI)ab}{l_1} : \frac{4(EE)ac}{l_2} = \frac{1}{3.95} : \frac{1}{3.10} = 0.253 : 0.323$$

$$\mu ab = \frac{0.253}{0.253 + 0.323} = 0439$$

$$\mu ac = \frac{0.323}{0.253 + 0.323} = 0.561$$

– **Joint C**

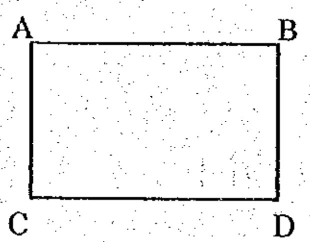
$$\mu cd \div \mu ca = \frac{4(EI)cd}{l_1} : \frac{4(EE)ca}{l_2} = \frac{(hcd)^4}{l_1} : \frac{(hca)^4}{l_2}$$

$$= \frac{(0.45)^4}{3.95} : \frac{(0.35)^4}{3.10} = 1.038 : 0.484$$

$$\mu cd = \frac{1.038}{1.038 + 0.484} = 0.682$$

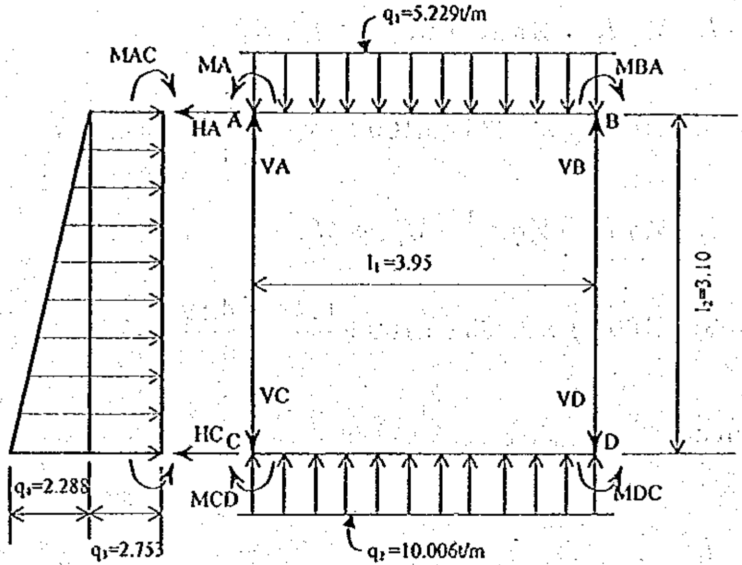
$$\mu ca = \frac{0.484}{1.038 + 0.484} = 0.318$$

c. Distribution of moment



Joint	C		A		B		D	
Member	CD	CA	AC	AB	BA	BD	DB	DC
μ	0.682	0.318	0.561	0.439	0.439	0.561	0.318	0.682
Mf	-13.010	+3.304	-2.938	+6.799	+6.799	+2.938	-3.304	+13.010
M0	-9.706		+3.861		-3.861		+9.706	
	+6.619	+3.087	-2.166	-1.695	+1.695	+2.166	-3.087	-6.619
	-3.310	-1.083	+1.544	+0.848	-0.848	-1.544	+1.083	+3.310
	+2.996	+1.397	-1.342	-1.050	+1.050	+1.342	-1.397	-2.996
	-1.498	-0.671	+0.697	+0.525	-0.525	-0.697	+0.671	+1.498
	+1.479	+0.690	-0.686	-0.536	+0.536	+0.686	-0.690	-1.479
	-0.740	-0.343	+0.345	+0.268	-0.268	-0.345	+0.343	+0.740
	+0.739	+0.344	-0.344	-0.269	+0.269	+0.344	-0.344	-0.739
	-0.369	-0.172	+0.172	+0.135	-0.135	-0.172	+0.172	+0.369
	+0.369	+0.172	-0.172	-0.135	+0.135	+0.172	-0.172	-0.369
Mf0	-6.725	+6.725	-4.890	+4.890	-4.890	+4.890	-6.725	+6.725
	↺	↻	↺	↻	↺	↻	↺	↻

d. Shear Force (SF) and Normal Force (NF)



For free body:

MCD = 6.725 tm

MCA = 6.725 tm

MAC = 4.890 tm

MAB = 4.890 tm

MBA = 4.890 tm

MBD = 4.890 tm

MDB = 6.725 tm

MDC = 6.725 tm

Free body for member A-B

$$\Sigma MA = 0 \rightarrow \quad V_B \times l_1 - ½ q_1 l_1^2 - M_{BA} + M_{AB} = 0$$

$$V_B = ½ \times 5.229 \times 3.95 + \frac{4.890 - 4.890}{3.95} = 10.327t$$

$$\Sigma MB = 0 \rightarrow \quad V_A \times l_1 - ½ q_1 l_1^2 - M_{AB} + M_{BA} = 0$$

$$V_A = ½ \times 5.229 \times 3.95 + \frac{4.890 - 4.890}{3.95} = 10.327t$$

Free body for member C-D

$$\Sigma MC = 0 \rightarrow \quad V_D \times l_1 - ½ q_2 l_1^2 - M_{DC} + M_{CD} = 0$$

$$V_D = ½ \times 10.006 \times 3.95 + \frac{6.725 - 6.725}{3.95} = 19.762t$$

$$\Sigma MD = 0 \rightarrow \quad V_C \times l_1 - ½ q_2 l_1^2 - M_{CD} + M_{DC} = 0$$

$$V_C = ½ \times 10.006 \times 3.95 + \frac{6.725 - 6.725}{3.95} = 19.762t$$

Free body for member C-A

$\Sigma MC = 0 \rightarrow \quad H_A \times l_2 - \frac{1}{2} q_3 l_2^2 - \frac{1}{6} q_4 l_2^2 - M_{AC} + M_{CA} = 0$

$$H_A = \frac{1}{2} \times 2.753 \times 3.100 + \frac{1}{6} \times 2.288 \times 3.100 + \frac{4.890 - 6.725}{3.10} = 4.857t$$

$\Sigma MA = 0 \rightarrow \quad H_C \times l_2 - \frac{1}{2} q_3 l_2^2 - \frac{1}{3} q_4 l_2^2 - M_{CA} + M_{AC} = 0$

$$H_C = \frac{1}{2} \times 2.753 \times 3.100 + \frac{1}{3} \times 2.288 \times 3.100 + \frac{6.725 - 4.890}{3.10} = 7.223t$$

e. Maximum of moment

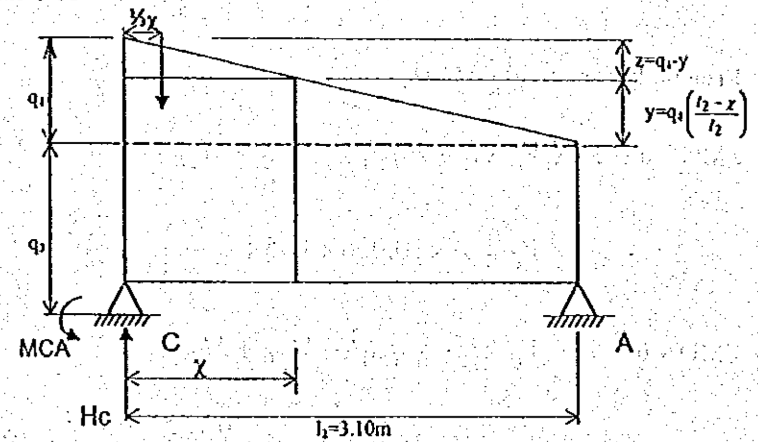
- Span A-B

$$M_{ABmax} = V_A \times \frac{l_1}{2} - \frac{1}{8} q_1 \times l_1^2 - M_{AB}$$
$$= 10.327 \times \frac{3.95}{2} - \frac{1}{8} \times 5.229 \times 3.95^2 - 4.890$$
$$= 5.308tm$$

- Span C-D

$$M_{CDmax} = V_C \times \frac{l_1}{2} - \frac{1}{8} q_2 \times l_1^2 - M_{CD}$$
$$= 19.762 \times \frac{3.95}{2} - \frac{1}{8} \times 10.006 \times 3.95^2 - 6.725$$
$$= 12.790tm$$

- Span C-A



$$M_\chi = H_C \times \chi - \frac{q_3 \times \chi^2}{2} - \frac{y \times \chi^2}{2} - \times \frac{Z}{6} \chi^2 - M_{CA}$$

2

$$\frac{dM_\chi}{d\chi} = 0$$

$$H_C - q_3\chi - y\chi - \frac{2}{3}Z\chi = 0$$

$$H_C - q_3\chi - \chi\left\{q_4\left(\frac{l_2-\chi}{l_2}\right)\right\} - \frac{2}{3}\chi\left\{q_4 - q_4\left(\frac{l_2-\chi}{l_2}\right)\right\} = 0$$

$$H_C - q_3\chi - q_4 + \frac{q_4\chi^2}{l_2} - \tfrac{2}{3}q_4\chi + \tfrac{2}{3}q_4\chi - \tfrac{2}{3}\frac{q_4\chi^2}{l_2} = 0$$

$$H_C - \chi(q_3 + q_4) + \tfrac{1}{3}q_4\frac{\chi^2}{l_2} = 0$$

$$7.223 - \chi(2.753 + 2.288) + \frac{2.288}{3\times3.10}\chi^2 = 0$$

$$0.246\chi^2 - 5.041\chi + 7.223 = 0$$

$$\chi_{1,2} = \frac{5.041 \pm \sqrt{5.041^2 - 4\times0.246\times7.223}}{2\times0.246} = 0$$

$$\chi_1 = \frac{5.041 + 4.278}{0.492} = 18.941m \rightarrow NO!$$

$$\chi_2 = \frac{5.041 - 4.278}{0.492} = 1.551m \rightarrow OK!$$

M_{CAmax}

$$= H_C\times\chi - \frac{q_3\times\chi^2}{2} - \frac{\chi^2}{2}\left\{q_4\left(\frac{l_2-\chi}{l_2}\right)\right\} - \tfrac{1}{3}\chi^2\left\{q_4 - q_4\left(\frac{l_2-\chi}{l_2}\right)\right\} - M_{CA}$$

$$= H_C\times\chi - \chi^2\left[\frac{q_3}{2} + \frac{1}{2}\left\{q_4\left(\frac{l_2-\chi}{l_2}\right)\right\} + \tfrac{1}{3}\left\{q_4 - q_4\left(\frac{l_2-\chi}{l_2}\right)\right\}\right] - M_{CA}$$

$$= H_C\times\chi - \chi^2\left[\frac{q_3}{2} + \tfrac{1}{2}q_4\left(\frac{l_2-\chi}{l_2}\right) + \frac{q_4}{3} - \frac{q_4}{3}\left(\frac{l_2-\chi}{l_2}\right)\right] - M_{CA}$$

$$= H_C\times\chi - \chi^2\left[\frac{q_3}{2} + \tfrac{1}{6}q_4\left(\frac{l_2-\chi}{l_2}\right) + \frac{q_4}{3}\right] - M_{CA}$$

$$= 7223\times1.551 - 1.551^2\left[\frac{2.753}{2} + \frac{2.288}{6}\left(\frac{3.10-1.551}{3.10}\right) + \frac{2.288}{3}\right] - 6.725$$

$$= +0.865tm.$$

f. Summary of Forces

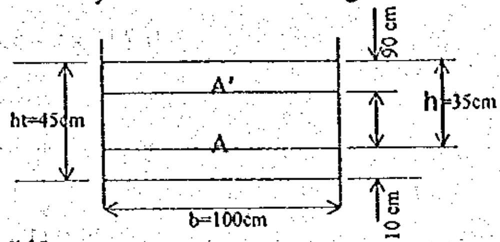
Member	CD	CA	AC	AB	BA	BD	DB	DC
M_{fo} (kgm)	-6.725	+6725	-4890	+4890	-4890	+4890	-6725	+6725
M_{max} (kgm)	+12790	+865	-865	-5308	+5308	+865	-865	-12790
NF (kg)	7223	19762	10327	4857	4857	10327	19762	7223
SF (kg)	19762	7223	4857	10327	10327	4857	7223	19762

5) Reinforcing Calculation

a. Member CD

M_{fo} = -6725 kg m
M_{max} = +12790 kg m

Determined M_{max} = 12790 kg m, to be used symmetrical reinforcing bar.



NF = 7223 kg
SF = 19762 kg
ht = 45 cm
h = 45 – 10 = 35 cm
b = 100 cm
lt = 3.95 m
lk = 0.7 lt = 0.7 x 3.95 = 2.765 m.

Concrete K_{225} → $\overline{\sigma}_b = 75 kg/cm^2$

$\overline{\tau}_b = 6.50 kg/cm^2$

n = 15

Steel U_{32} → $\overline{\sigma}_a = 1850 kg/cm^2$

$$\phi_0 = \frac{\sigma_a}{n\overline{\sigma}_b} = \frac{1850}{15 \times 75} = 1.644$$

$$e_{01} = \frac{M}{NF} = \frac{12790}{7223} = 1.771 \text{ m}$$

$$e_{02} = \frac{1}{30} ht = \frac{0.45}{30} = 0.015 \text{ m}$$

$$e_0 = e_{01} + e_{02} = 1.771 + 0.015 = 1.786 \text{ m}$$

$$\frac{l_0}{ht} = \frac{1.786}{0.45} = 3.969 > 1 \rightarrow C = 7.7$$

$$e_1 = C\left(\frac{l_k}{1000ht}\right)^2 \times ht = 7.7 \times \left(\frac{2.765}{100 \times 0.45}\right)^2 \times 0.45 = 0.013m$$

$$e_2 = 0.15 \text{ ht} = 0.15 \times 0.45 = 0.068 \text{ m}$$

$$e = e_0 + e_1 + e_2 = 1.786 + 0.013 + 0.068 = 1.867 \text{ m}$$

$e_a \quad = e + \frac{1}{2}ht - 0.05 = 1.867 + \frac{0.45}{2} - 0.05 = 2.042m$

NF x e_a = 7223 x 2.042 = 14757 kg m

$$Ca = \frac{h}{\sqrt{\frac{n \times NF \cdot e_a}{b \times \overline{\sigma}a}}} = \frac{35}{\sqrt{\frac{15 \times 14757}{1 \times 1850}}} = 3.200$$

$\delta \quad = 1 - \frac{1}{3} \times \frac{h}{ea} = 1 - \frac{1}{3} \times \frac{0.45}{3.200} = 0.876 \sim 0.80$

(Symmetrical reinforcing)

$\left.\begin{array}{ll} \delta & = 0.80 \\ Ca & = 3.200 \end{array}\right\} \rightarrow \begin{array}{ll} \phi' & = 2.931 > \phi' = 1.644 \rightarrow \text{OK.} \\ \zeta & = 0.893 \\ \omega & = 0.11200 \end{array}$

$\left.\begin{array}{l} \frac{e_a}{h} = \frac{2.042}{0.35} = 5.832 \\ \zeta = 0.893 \end{array}\right\} \rightarrow i = 1.21$

$iA \quad = \omega bh \quad = \frac{0.1120}{15} \times 100 \times 35 = 26.133 cm^2$

$A \quad = \frac{26.133}{1.21} = 21.600 cm^2$

to be used D22 @ 125 (A = 30.40 cm²)

$A' \quad = \delta \times iA = 0.876 \times 26.133 = 22.89 \text{ cm}^2 \sim A.$

Shear Stress Check

$\tau_b = \frac{SF}{\frac{7}{8} \times b \times h} = \frac{19762}{\frac{7}{8} \times 100 \times 35} = 6.453 kg/cm^2 < \overline{\tau}_b = 6.50 kg/cm^2 \rightarrow OK$

b. Member CA

M_{fo} = +6725 kg m
M_{max} = +1865 kg m

Determined M_{fo} = 6725 kgm,

NF = 19762 kg
SF = 7223 kg
ht = 35 cm

h = 35 – 9 = 26 cm

lt = 3.10 m

lk = 0.7 lt = 0.7 x 3.10 = 2.170 m.

$$e_{01} = \frac{M}{NF} = \frac{6725}{19762} = 0.340\ \text{m}$$

$$e_{02} = \frac{1}{30} ht = \frac{0.35}{30} = 0.012\ \text{m}$$

$$e_0 = e_{01} + e_{02} = 0.340 + 0.012 = 0.352\ \text{m}$$

$$\frac{l_0}{ht} = \frac{0.352}{0.35} = 1.006 \rightarrow C = 7.70$$

$$e_1 = C\left(\frac{l_k}{1000ht}\right)^2 \times ht = 7.7 \times \left(\frac{2.17}{100 \times 0.35}\right)^2 \times 0.35 = 0.010m$$

$$e_2 = 0.15\ ht = 0.15 \times 0.35 = 0.053\ \text{m}$$

$$e = e_0 + e_1 + e_2 = 0.352 + 0.010 + 0.053 = 0.415\ \text{m}$$

$$e_a = e + \tfrac{1}{2} ht - 0.05 = 0.415 + \frac{0.35}{2} - 0.05 = 0.540m$$

NF x la= 19762 x 0.540 = 10671 kg m

$$Ca = \frac{h}{\sqrt{\dfrac{n \times NF \cdot e_a}{b \times \overline{\sigma} a}}} = \frac{26}{\sqrt{\dfrac{15 \times 10671}{1 \times 1850}}} = 2.795$$

$$\delta = 1 - \tfrac{1}{8} \times \frac{h}{e_a} = 1 - \tfrac{1}{8} \times \frac{0.26}{0.540} = 0.579 \sim 0.60$$

$$\left.\begin{aligned} \delta &= 0.60 \\ Ca &= 2.795 \end{aligned}\right\} \rightarrow \begin{aligned} \phi' &= 2.333 > \phi' = 1.644 \rightarrow \text{OK.} \\ \zeta &= 0.883 \\ \omega &= 0.1463 \end{aligned}$$

$$\left.\begin{aligned} \frac{e_a}{h} &= \frac{0.540}{0.26} = 2.08 \\ \zeta &= 0.883 \end{aligned}\right\} \rightarrow i = 1.77$$

$$iA = \omega bh = \frac{0.1463}{15} \times 100 \times 26 = 25.359cm^2$$

$$A = \frac{25.359}{1.77} = 14.327 cm^2$$

to be used D16@125 (A = 16.08 cm²)

$A' = \delta \times iA = 0.579 \times 25.359 = 14.683\ cm^2 \sim A.$

Shear Stress Check

$$\tau_b = \frac{SF}{\frac{7}{8} \times b \times h} = \frac{7223}{\frac{7}{8} \times 100 \times 26} = 3.175 kg/cm^2 < \bar{\tau}_b = 6.50 kg/cm^2$$

c. Member AB

M_{fo} = +4890 kg m
M_{max} = -5308 kg m

Determined M_{fo} = 5308 kg m,

NF = 4857 kg
SF = 10327 kg
ht = 35 cm
h = 35 – 9 = 26 cm
lt = 3.95 m
lk = 0.7 lt = 0.7 x 3.95 = 2.765 m.

$$e_{01} = \frac{M}{NF} = \frac{5308}{4857} = 1.093 m$$

$$e_{02} = \frac{1}{30} ht = \frac{0.35}{30} = 0.012 m$$

$e_0 = e_{01} + e_{02} = 1.093 + 0.012 = 1.105$ m

$$\frac{e_0}{ht} = \frac{1.105}{0.35} = 3.157 \rightarrow C = 7.70$$

$$e_1 = C\left(\frac{l_k}{1000 ht}\right)^2 \times ht = 7.7 \times \left(\frac{2.765}{100 \times 0.35}\right)^2 \times 0.35 = 0.017 m$$

$e_2 = 0.15\ ht = 0.15 \times 0.35 = 0.053$ m

$e = e_0 + e_1 + e_2 = 1.105 + 0.017 + 0.053 = 1.175$ m

$$e_a = e + \frac{1}{2} ht - 0.05 = 1.175 + \frac{0.35}{2} - 0.05 = 1.300 m$$

$NF \times e_a = 4857 \times 1.300 = 6314$ kg m

$$Ca = \frac{h}{\sqrt{\frac{n \times NF \cdot e_a}{b \times \overline{\sigma}a}}} = \frac{26}{\sqrt{\frac{15 \times 6314}{1 \times 1850}}} = 3.634$$

$$\delta = 1 - \tfrac{7}{8} \times \frac{h}{e_a} = 1 - \tfrac{7}{8} \times \frac{0.26}{1.00} = 0.825 \sim 0.80$$

$\delta = 0.80$, $Ca = 3.634$ → $\phi' = 3.390 > \phi' = 1.644$ → OK.; $\zeta = 0.899$; $\omega = 0.08759$

$\frac{e_a}{h} = \frac{1.300}{0.26} = 5.000$, $\zeta = 0.899$ → $i = 1.22$

$$iA = \omega bh = \frac{0.08759}{15} \times 100 \times 26 = 15.182 cm^2$$

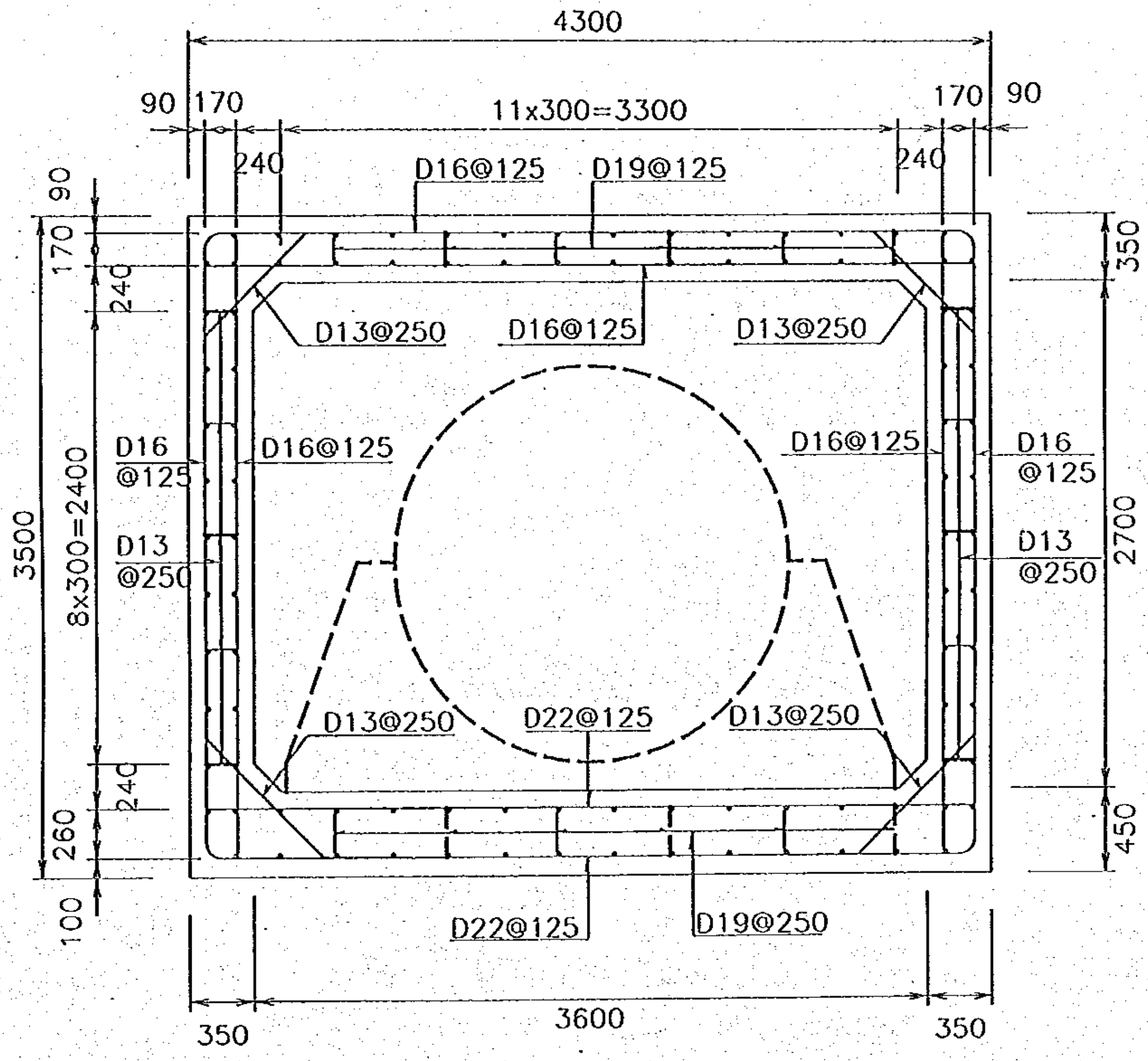
$$A = \frac{15.182}{1.22} = 12.44 cm^2$$

to be used D16@125 (A = 16.08 cm²)

$A' = \delta \times iA = 0.825 \times 15.182 = 12.53\ cm^2 \sim A.$

Shear Stress Check

$$\tau_b = \frac{SF}{\tfrac{7}{8} \times b \times h} = \frac{10327}{\tfrac{7}{8} \times 100 \times 26} = 4.54 kg/cm^2 < \overline{\tau}_b = 6.50 kg/cm^2 \rightarrow OK$$



REINFORCING BAR ARRANGEMENT