CHAPTER 7
WASTEWATER TREATMENT PLANT CONSTRUCTION PROJECT (PACKAGE E)

7.1

Civil Design

7.1.1

Design Standard

1. Design Standard

(1) Permanent Structure

(a) Unit Weight

Reinforced concrete γc = $2.5t/m^3$

Backfill sand γs = $1.8t/m^3$ (under Ground water $0.8t/m^3$)

(b) Design Stress

• Concrete

Concrete	
Bending compressive stress σca	$210(kg/cm^2)$

• Reinforcement

Reinforcement	deformed bar
Tensile and compressive stress τsa	$3,000(kg/cm^2)$

(c) Allowable Stress

• Concrete

Concrete	$210(kg/cm^2)$
Bending compressive stress σca	$70(kg/cm^2)$
Shearing stress τca	$3.6(kg/cm^2)$

• Reinforcement

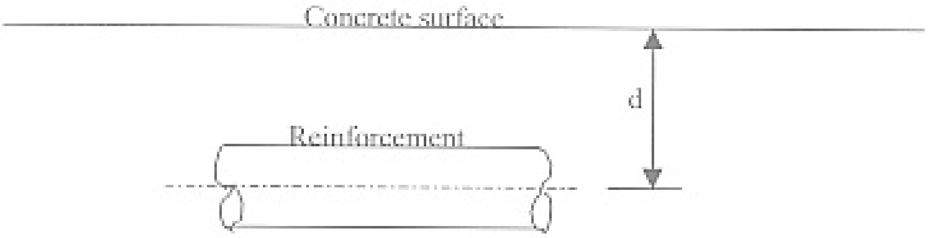
Reinforcement	deformed bar
Tensile and compressive stress τsa	$1,600(kg/cm^2)$

(d) Reinforcement Arrangement

• Diameter (mm)

6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 25, 28, 30, 32, 36

• Cover (d mm)



Underside of bottom slab d = 120 mm (with pile structure)
d = 100 mm (without pile structure)
Other slab and wall d = 70 mm (h≧300mm)
d = 50 mm(h <300mm)
Beam and Columnd = 70mm

・Minimum space between two bars of reinforcement (face to face)
For slab and wall t0 = 100mm
(In this calculation, the space between two bars (center to center) should be taken following two cases, 125mm or 250mm.)
For beam and column t0 = 50mm

・Minimum amount of reinforcement
Deformed bar

Beam	As =	0.002 b·d ≦ As ≦ 0.02 b·d
Column	As =	0.0015 A ≦ As ≦ 0.06 A

・Lap length
Plain bar and Deformed bar L = 35d (d = diameter of reinforcement)

(e) Design Load

・Basic parameters

Unit weight of soil	γ	=	$1.8(t/m^3)$, friction angle $\phi = 30°$
Under ground water	γ'	=	$0.8(t/m^3)$
Vehicle load	H30 (30T)		

・Vertical load
Soil load p1 = $h \times \gamma$
Vehicle load p2 = $(n \times P)/A$

Back axle weight = 12T
One tire weight P = 12/2 = 6T (The space of tire Is 1.6m)
Loading area
$A = (0.2+2 \times h \times \tan 30°) \times (0.6+2 \times h \times \tan 30°)$
n : over load factor 1.3

(If depth of upper slab is more than 1.4m, two tire loads should be considered)

Under ground water load Pw (unit weight is 1.0t/m^3)

• Horizontal load

Soil pressure P = (vertical soil load) × Ko

Ko = 0.5 (Earth pressure at rest)

Horizontal load pressure Pv = (Vertical load) × Ko

(For calculation of Box Culvert. Vertical vehicle load and horizontal vehicle load are not loaded at the same time.))

Axial load Pa = 1.0 t/m^2 (For calculation of under ground wall. If there is no road near the structure, axial load is 0.5t/m^2))

Under ground water pressure Pw

• Inside of structure

Vertical water load

Horizontal water pressure

• Equipment weight

Mechanical equipment load (activity load)

Electrical equipment load

• Building load

• Uplift strength

(2) Temporary structure

(a) Sheet Pile : Stress for calculation

Tensile Stress	2,700 kg/cm^2
Bending Compressive Stress	2,700 kg/cm^2
Shearing Stress	1,300 kg/cm^2

(b) H section steel

Tensile Stress	2,100 kg/cm^2
Bending Compressive Stress (*)	2,100 kg/cm^2
Shearing Stress	1,200 kg/cm^2

* Bending Compressive Stress is according to length of H section

$l/r \leqq 20$ 2,100 kg/cm^2

$20 < l/r < 93$ $\{1{,}400 - 8.4(l/r - 20)\}$

$93 \leqq l/r$ $\{12{,}000{,}000 / (6700 + (l/r)^2)\} \times 1.5$

Here l : length of H section
r = radius gyration of H section

(c) Stress Iron Weld Connection

Allowable stress of Shop Welding is same as the above.
Allowable stress of Field Welding is 80 % of Shop welding.

(d) Stress for Bolt Connection

Shearing Stress	1,300 (kg/cm^2)
Surface Compressive	2,900 (kg/cm^2)

2. Design Method of Pile Foundation

(1) Allowable Bearing Capacity of Pile

(a) Allowable vertical bearing capacity of pile

Allowable vertical bearing capacity of pile is calculated by following equation.

$$Ra = r/n \ (Ru - Ws) + Ws - W$$

Here

Ra : Allowable vertical bearing capacity of pile at pile head (t/pile)

n : Safety factor for point - bearing pile n = 3

for friction pile n = 4

r : Revise coefficient of safety factor

In case of ultimate bearing capacity is estimated r = 1.0

In case of ultimate bearing capacity of pile is calculated according to vertical load carrying test r = 1.2

Ru : Ultimate bearing capacity of pile decided from soil condition (t/pile)

Ws : Effective soil weight which permute by pile (t)

W : Effective weight of pile and soil in the pile (t)

(b) Assuming of ultimate bearing capacity of pile

$$Ru = qd \times A + U \times \Sigma \ Li \times Fi$$

Here

Ru : Ultimate bearing capacity of soil decided from soil condition (t/pile)

A : Area of tip of pile (m^2)

qd : Unit ultimate bearing capacity of pile at tip of pile (t/m^2)

U : The girth of pile (m)

Li : Thickness of layer which consider a friction (m)

Fi : Maximum friction ratio of layer which consider a friction (t/m^2)

- Assuming of unit ultimate bearing capacity of pile (qd t/m^2)
  (In case of driven pile)
  Unit ultimate bearing capacity of pile is assumed according to the ratio of N value of soil of pile tip and ratio of depth to width (embeded depth to bearing layer / pile width)
  Refer to Fig.3.3. and Fig. 3.3. .

- Assuming of maximum friction ratio which affect to pile surface
  Maximum friction ratio which affect to pile surface is calculated by following Table. (t/m^2)

	Driven pile	Cast in - situ diaphragm pile
Sandy soil	0.2 N (≦ 10)	0.5 N (≦ 20)
Cohesive soil (Clayer soil)	C or N (≦ 15)	C or N (≦ 15)

(2) Allowable Tensile Capacity of Pile

$$Pa = 1/n \times Pu + W$$

Here

Pa : Allowable tensile capacity of pile at pile head (t/pile)

n : Safety factor n = 6

Pu : Ultimate tensile capacity of pile decided from soil condition (t/pile)

W : Effective weight of pile (t)

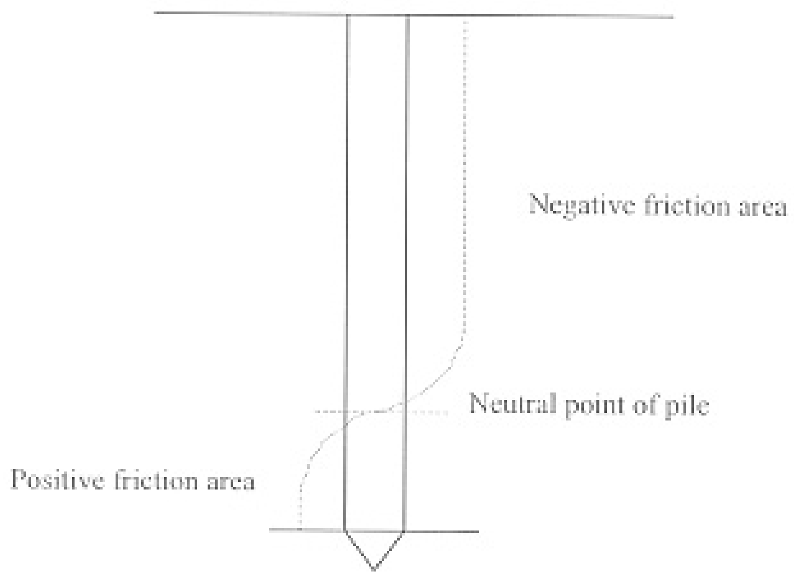
* Maximum friction ratio which affect to pile surface is decided according to calculation of bearing capacity of pile.

(3) Investigation of negative friction

It is necessary to consider a negative friction for pile, when pile is set in a settlement Soil condition.

(a) Investigation of negative friction for pile

- Neutral point of pile



- Investigation of negative friction

$$Pa' = 1/1.5 \ (Ru' - Ws') + Ws' - (Rnf + W)$$

Here

Ra' : Allowable vertical bearing capacity of pile at pile head in case of negative Friction affecting (t/pile)

Ru' : Ultimate bearing capacity of pile under the layer of neutral point (t/pile)

Rnf : Negative friction
Sum of maximum friction for pile upper layer of neutral point

Ws : Effective soil weight which permute by pile under the neutral point

W : Effective weight of pile and soil in the pile

(4) Investigation of pile stress

$$1.2 \times (Po + Rnf + W') \leqq \sigma y \times Ap$$

Here

Po : All the load affect to the pile head (t)

Rnf : Negative friction (t)

W' : Effective weight of pile upper side of neutral point (t)

σy : Yield stress of pile concrete (t/m^2)

Ap : Pure area of pile

(5) Axial modulus of spring of pile

Axial modulus of spring of pile is calculated by following equation.

$$Kv = \alpha \times (Ap \times Ep / l)$$

Here

Kv : Axial modulus of spring of pile (kg/cm)

Ap : Area of pile (cm2)

Ep : Modulus of elasticity of pile (2.3×10^5 kg/cm2)

L : Length of pile (cm)

$\alpha = 0.013 \times (l/D) + 0.61$

D : Diameter of pile (cm)

Comparison of standard

(1) Permanent structure

	Vietnam Standard	British Standard	Japanese Standard
1. Unit Weight			
Reinforced Concrete	2.5t/m3	2.5t/m3	2.5t/m3
Sand(backfill)	1.8t/m3	1.8 – 2.0t/m3	1.8t/m3
2. Allowable Stress			
Concrete (Compressive Stress)	110kg/cm2 (Grade250)	112kg/cm2 (fcu=250 rm=1.5 0.67fcu/rm=112)	70kg/cm2
Concrete (Shearing Stress)	7.92kg/cm2 (Checked by tensile stress)	Max4.6kg/cm2	3.6kg/cm2
Reinforcement (Deformed bar)	Domestic product 2600kg/m2(slab) 2100(Beam, Column) Import bar 2800kg/m2(slab) 2200(Beam, Column)	3390kg/cm2 (SD390/rm=3700 rm = 1.15)	1800kg/cm2 (1600kg/cm2) (Direct face to water)
	Consider a safety Factor calculation Of design loads. (Fs = 1.1 - 1.3)	Consider a safety Factor calculation Of design loads. (Fs = 1.0 - 1.6)	No safety factor
3. Bar arrangement			
Diameter	6 – 32 mm (by 2mm)	6 – 40mm (by 2mm – 8mm)	10 – 32 mm (by 3mm)
Cover	Cover to bar surface 15mm(Slab and wall thickness more than 100mm) 70mm(Bottom slab)	More than 20mm (Usual structure) More than 35mm (Direct face to soil)	Cover to bar surface Usual structure Slab 25mm Beam 30mm Column 35mm Corrosion condition Slab 40mm Beam 50mm Column 60mm
Space	Beam More than30mm Column More than 50mm	Horizontal (Maximum coarse Aggregate + 5mm) Vertical (maximum coarse aggregate × 2/3)	Beam More than 20mm or Aggregate × 4/3 Column More than 40mm or Aggregate × 4/3
Minimum amount Of reinforcement	More than 0.05%	Compressive side 0.4% Tensile side 0.24 – 0.13%	More than 0.2 %

Lap length	35D	35D	35D
Pile foundation design Spread foundation design		BS8004	Road bridge Substructure design Standard
Design load			
Track weight	T - 30	HA(Track) HB(Tank)	T - 25
Design soil pressure	Rankin earth pressure	Rankin earth pressure	Earth pressure At rest （same as rankin pressure φ 20° ）

(2) Temporary structure

	Vietnam Standard	British Standard	Japanese standard
Sheet pile			
Allowable tensile and compressive stress	CT3 2100kg/cm2 CT5 2300kg/cm2	43 2750-2450 50 3550-3150	SS41 2700kg/cm2
Shearing stress	CT3 1300kg/cm2 CT5 1400kg/cm2	0.6Py 43 1650-1470 50 2130-1890	SS41 1300kg/cm2
H section steel			
Allowable tensile and compressive stress	Same as sheet pile	Same as sheet pile	SS41 2100kg.cm2
Shearing stress	Same as sheet pile	Same as sheet pile	SS41 1200kg/cm2
Allowable Displacement of Temporary earth retaining structure			30 cm

4.1.2 Conclusion

In comparison of standard, British Standard is high and Japanese standard is low and Vietnam Standard is middle at compressive stress of concrete and tensile stress of reinforcement.

If British Standard is applied, tensile stress of reinforcement should be critical design.

Vietnam Standard has safety factors in calculation of design loads, such as earth pressure, vertical loads and etc.

Coefficient of factors are 1.1 ~1.3.

Japanese Standard is most strict for structure design.

The difference between Japanese Standard and Vietnam Standard is not so much, but if concrete structures are designed according to Japanese Standard, structures will be strong.

To consider the Wastewater Treatment Plant is important facility and it should be use more than 50 years, Japanese Standard is most applicable Standard.

Japanese Standards can applied without written agreement from Ministry of Construction.

(CIRCULATION OF MOC MINISTER on the application of standard, procedure and regulations on construction technique. Hanoi, April 24 1995)

7.1.2

Lift Pumping Station

Calculation for lift pumping station

1. Material property and soil condition

Ground water level	GWL =	± 0,00
Concrete: Grade 250,	Rn =	70 kg/cm^2
	Rs =	3.60 kg/cm^2
Reiforcement type JIS:	Ra =	1.600 kg/cm^2
Backfill sand:	γs	1.80 T/m^3
Coeficient of earth pressure at rest	K_o =	0.5
Internal friction		20°

2. Loading and calculation scheme

2.1 Self load

Weight of bottom

W1 = 2.5 x 1 x 341.36 = 853.4T

W2 = (25.1 + 17.1)/2x 4.25x 2.5x 1 = 224.19 T

W3 = 17.1x 14.3x 1.3 x 2.5 = 794.72 T

Total : 1872.31 T

Weight of Slab at elevation -1.5m

-Thickness of slab is 0.30m

Ar = 15.5x 13.5 + (23.5+ 15.5)/2x 3+ 23.5x = 479.25 m^2

Asb = Ar- A (holes) =479.25-104.36 = 375.02 m^2

Wsb = 375.02x 0.4x 2.5 = 374.89 T

-Thickness of slab is 0.60m

Asb = (3.65x 6.4 +(4.5+ 8.5)x 0.5x 3.5+ 4.5x 6.5)x 2 97.62 m^2

$W_{(0.6)}$ = 97.62x 0.6x 2.5 = 146.43 T

Slap at elevation = -3.1m, thickness = 0.6m

$W_{(-3.1)}$ = 4.5x 13.6x 0.6x 2.5x 2 = 183.6 T

Slap at elevation = +2.5m, thickness = 0.3m and 0.7m (0.4m is sinder concrete)

Area =(17.1x 13.15+ 3.1x 13.25) - [(2.5x 0.8)x 4+
(2.05x 3.5x 4)+(3.2x 2.2)x 3+ (2.25x 1.65)x 3 = 566.55 m^2

$W_{(0.3)}$ = (224.86 - 36.7)x 0.3x 2.5 = 141.12 T

W_{07} = (410.75 - 21.12 - 11.14)x 0.7x 2.5 = 662.36 T

Slap at elevaton = +10.0m, thickness 0.4m

Wsb = 4.6x 25.1x 0.4x 2.5 = 115.46 m

ΣW of slab = 1872.31+ 374.89+ 141.66+183.6+
. 141.12+ 662.36+ 115.46 = 3491.4T

Weight of wall (out side)

W1 = 6.4x 15.5x 0.8x 2.5 = 193.28 T

W2 = 2.3x 15.5x 0.5x 2.5 = 44.56 T

W3 = 3.7x 15.5x 0.4x 2.5 = 57.35 T

W4-5= 16.8x 23.5x 0.8x 2.5x 2 = 1579.2 T

W6 = 6.4x 0.5x 3.8x 2x 2.5 = 60.8 T

W7 = 0.5x 2.65x 2.1x 2x 2.5 = 13.9 T

W8 = 0.6x 3.95x 0.9x 2x 2.5 = 10.66 T

Weight of wall (in side)

W1 = 13.0x 6.0x2 0.8x 2.5 = 312 T

W2 = 9.5x 9x 2x0.8x 2.5 = 342 T

W3 = 4.6x 16.8x(2x 0.8x 2.5) = 309.12 T

W4 = 3x 16.8x 0.5x 2.5 = 63 T

W5 = (5.4+ 8.4)/2x 5.3x 2x 0.8x 2.5 = 146.28 T

W6 = 11x 2.3x 0.5x 3x 2.5 = 94.87 T

W7 = 7x 5.3x 0.5x 3x 2.5 = 231.87 T

W8 = 3.15x 3.8x 0.5x 2x 2.5+ 17.45x 1.9x 0.4x 2x 2.5 96.25 T
W9 = 17.45x 0.6x 3.7x 2x 2.5 = 193.69 T
ΣWeight of wall = 3748.83 T

Weight of beam

At elevation -1.5m = 0.4x 0.7x 6.1x 2.5x 5 = 21.35 T
At elevation +2.5m =(6.1+ 6.55)x 0.7x 0.4x 2.5x 5 44.27 T
7.1x 0.4x 0.7x 2.5x 3 = 14.9 T
5.05x 0.4x 0.4x 2.5x 3 = 6.06 T
0.2x 0.4x 3.5x 6x 2.5x 2 = 8.4 T

Weight of colunm

0.4x 0.4x 3.6x 16x 2.5 = 23 T

Total 117.98 T
ΣWeight = 7358.21 T

Weight of buiding

Q1 = 11.59x 7+ 23.27x 7+ 7.25x 7 = 294.77 T
Q2=2.61x 2+ 23.41x2+ 19.03x 2+ 9.03x 2 = 128.16 T

Total load of building = 422.93 T
Load of mechanical equipment = 285 T
Load of electrical equipment = 68.8 T
Total(W of structure + Wbuilding + Wmechan. + Welectr.) = 8134.94 T
Load of water when water full inside

[13.5x 15.5x 0.74+ (23.5+ 15.5)/2x 3x (0.74+ 3.54)/
2+ 9.5x 3.54x 23.5]x 1 = 1070.34 T
23.5x 3x 15.41x 1 = 1086.4 T

2.2 Vehicle Load

Vehicle type : H30
Horizontal vehicle load from both sides

$P_v = 1(T/m^2) \times k_o = 1 \times 0.5$ = $0.5\ T/m^2$
Where: 1(T/m2) is vertical uniform load due to vehicle

2.3 Soil load

In case of ground water level at ± 0.00
Soil load for wall calculation
At elevation -7.2m
Horizontal distributed load due to ground water

$P_w = (GWL - BL) \times 1 = 7.7 \times 1$ = $7.7\ T/m^2$

Horizontal distributed load due to soil earth from both sides
under ground water level

$P_{-7.2} = (\gamma s - 1) \times (GWL - BL) \times ko + (GWL - BL) \times 1 =$
$(1.8 - 1) \times 7.7 \times 0.5 + 7.7 \times 1$ = $10.78\ T/m^2$

Horizontal distributed load due to earth from both sides
above ground water level

$P_s = \gamma s(GL - GWL) \times ko = 1.8 \times 2.2 \times 0.5$ = $1.98\ T/m^2$

At elevation - 4.2m

$P_w = 1 \times 4.7$ = $4.7\ T/m^2$
$P_s = 2.2 \times 1.8 \times 0.5 + 4.7 \times 0.8 \times 0.5$ = $3.86\ T/m^2$

At elevation -3.1m

$P_w = 1 \times 3.4$ = $3.4\ T/m^2$
$P_s = 2.2 \times 1.8 \times 0.5 + 3.4 \times 0.8 \times 0.5$ = $3.18\ T/m^2$

At elevation -1.5m

$P_w = 1 \times 1.8$ = $1.8\ T/m^2$
$P_s = 2.2 \times 1.8 \times 0.5 + 1.8 \times 0.8 \times 0.5$ = $2.7\ T/m^2$

2.4 Live load

Loading for slab at elevation +2.5m

$P_l = 2\ T/m^2$ (electrical room)

Pl =0.5 T/m^2 (other rooms)

Loading for slab at elevation -1.5m

Pl = 0.5T/m^2

3 Checking uplift that due to ground water

In case of water level at +2.20 inside is empty

Uplift force at bottom

Pupl = Pw x Abottom

Pupl = 10.4x 341.36+ 7.7x 244.53+(10.4+7.7)/2x

73.85+ 94.44x 4.3+ 122.4x 5.9 = 7951.63 T

Total(W of structure + Wbuilding + Wmechan. + Welectr.)= 8134.94 T

So Pupl < ΣWeight **Satisfied**

4 Checking presure to base soil

When inside is water (the most dangerous case)

Ps = Total weight/ A = 10291.68 / 876.56 = 11.74 T/m^2

Allowable capacity of 400x 400 RC pile as calculated P: = 45 T

It means that 1RC pile(400x 400) can be used for the area as calculation below

F = 45 / 11.74 = 3.83 m^2

5 Calculation sheme for lift pump

In case no water inside

In case of full water inside

Refer to attached result sheet for calculation value of stress, steel area for sheet, beam and colunm elements

Calculation for bar arrangement:

Base on attached results of shell forces analised by SAP2000, choosing the most dangerous forces for calculation:

$A_o = M/R_n b h_o^2$ Where, M: Maximum bending moment(T.m)

h_o: Effective depth of bearing area(cm)

h_o= (Element thickness-Cover thickness)

b: Width of calculated area(cm)

Required area of reinforcement:

$Fa = M/\gamma Raho$ Where: $\gamma = 0.5 + ((1-2Ao)^{1/2})/2$

Beams

AREA m2	Values (T.m)	Ao	γ	Fa (cm^2)	Bar arrangement ϕ(mm)	Bar arrangement quantity
b=0.40	-32.200	0.1330	0.928	23.31	28	4
h=1.00	22.310	0.0921	0.952	15.76	28	4
	-15.800	0.0652	0.966	10.99	28	2
	9.510	0.0393	0.980	6.52	28	2
	-30.450	0.1257	0.933	21.94	28	4
	32.240	0.1331	0.928	23.34	28	4
	-26.440	0.1092	0.942	18.86	28	4
BEAM	-16.300	0.0673	0.965	11.35	28	2
bxh=40x100	32.430	0.1339	0.928	23.49	28	4
	33.320	0.1376	0.926	24.19	28	4
	-27.140	0.1121	0.940	19.39	28	4
	-12.260	0.0506	0.974	8.46	28	2
	15.090	0.0623	0.968	10.48	28	2
	14.940	0.0617	0.968	10.37	28	2
	23.790	0.0982	0.948	16.86	28	4
b=0.40	-6.360	0.1228	0.934	9.89	22	3
h=0.50	5.190	0.1002	0.947	7.97	20	3
BEAM	3.410	0.0659	0.966	5.13	20	2
bxh=40x50	-4.430	0.0856	0.955	6.74	22	2

COLUMNS

I.MATERIAL PROPERTIES

Concrete	Grade	250	Rn	=	70 (Kg/cm2)
			Eb	=	230000 (Kg/cm2)
Reinforcement	Type	All	Ea	=	2E+06 (Kg/cm2)
			Ra = Ra'	=	1600 (Kg/cm2)

II.CALCULATION:

NAME OF COLUMN	l (cm)	b (cm)	h (cm)	a=a' (cm)	h0 (cm)	l0 (cm)	l h	mb	Rn* (Kg/cm2)	a 0	A0	m gt (%)	Ja (cm4)	Jb (cm4)	M (Kg.m)
55	400	40	40	7	33	280	7	1.00	70	0.62	0.43	0.6	1338	213333.3	1.99E+03
54	400	40	40	7	33	280	7	1.00	70	0.62	0.43	0.6	1338	213333.3	2.39E+03
79	400	40	40	7	33	280	7	1.00	70	0.62	0.43	0.6	1338	213333.3	2.42E+03

N (Kg)	e0 (cm)	e0/h	S	Mdh (Kg.m)	Ndh (Kg)	Kdh	Nth (Kg)	η	h.e0 (cm)	e0gh	e (cm)	x (cm)	αo.ho	x' (cm)	Fa=Fa' (cm2)	Seme orrangement Fa=Fa'
8.36E+04	4.4	0.110	0.63	1.99E+03	8.36E+04	2.00	1.48E+06	1.060	4.64	11.82	17.6	29.9	20.5	32.9	-1.2	3D22
7.75E+04	5.1	0.127	0.58	2.39E+03	7.75E+04	2.00	1.40E+06	1.059	5.38	11.82	18.4	27.7	20.5	31.7	-2.3	3D22
7.85E+04	5.1	0.127	0.58	2.42E+03	7.85E+04	2.00	1.40E+06	1.059	5.38	11.82	18.4	28.0	20.5	31.7	-1.9	3D22

Checking shear forces:

-Height of hand for supporting coverslab s, so the section need to be checked shear bearing capacity is [c/2+(h+s)/2]

- In case Q >= Rsxbxd so the below case is to be considered
- In case concrete is not enough to bear shearing force, stirrups will be considered

Sc/2 + Ss >= Q (shearing force at section calculated)

Where Sc: shearing bearing capacity of concrete (kg)

Ss: shearing bearing capacity of reinforcement (kg)

Ss=AsxRaxjxd/a = Q - Sc/2

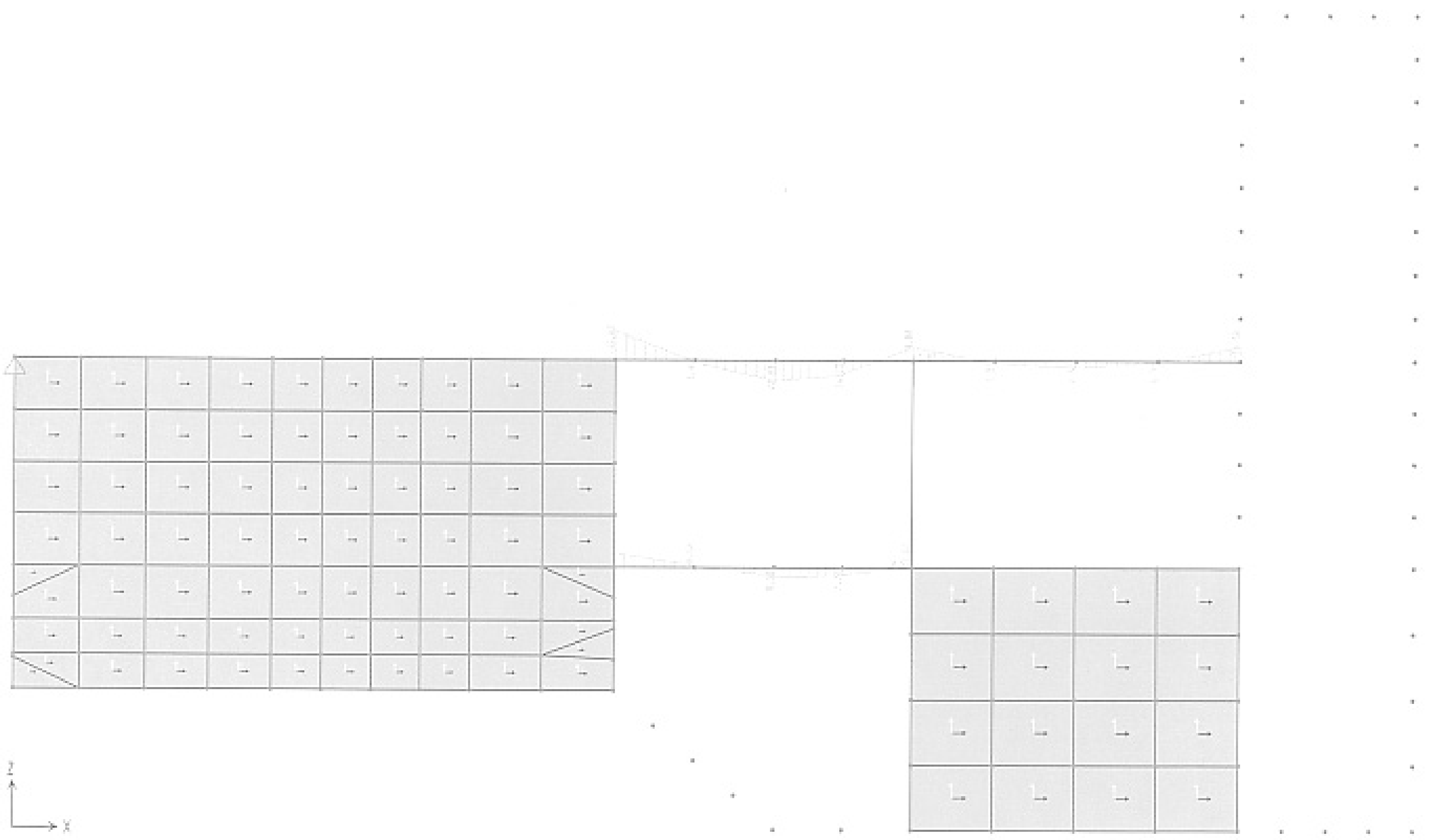
As: area of all stirrup in section considered

d: effective height of beam

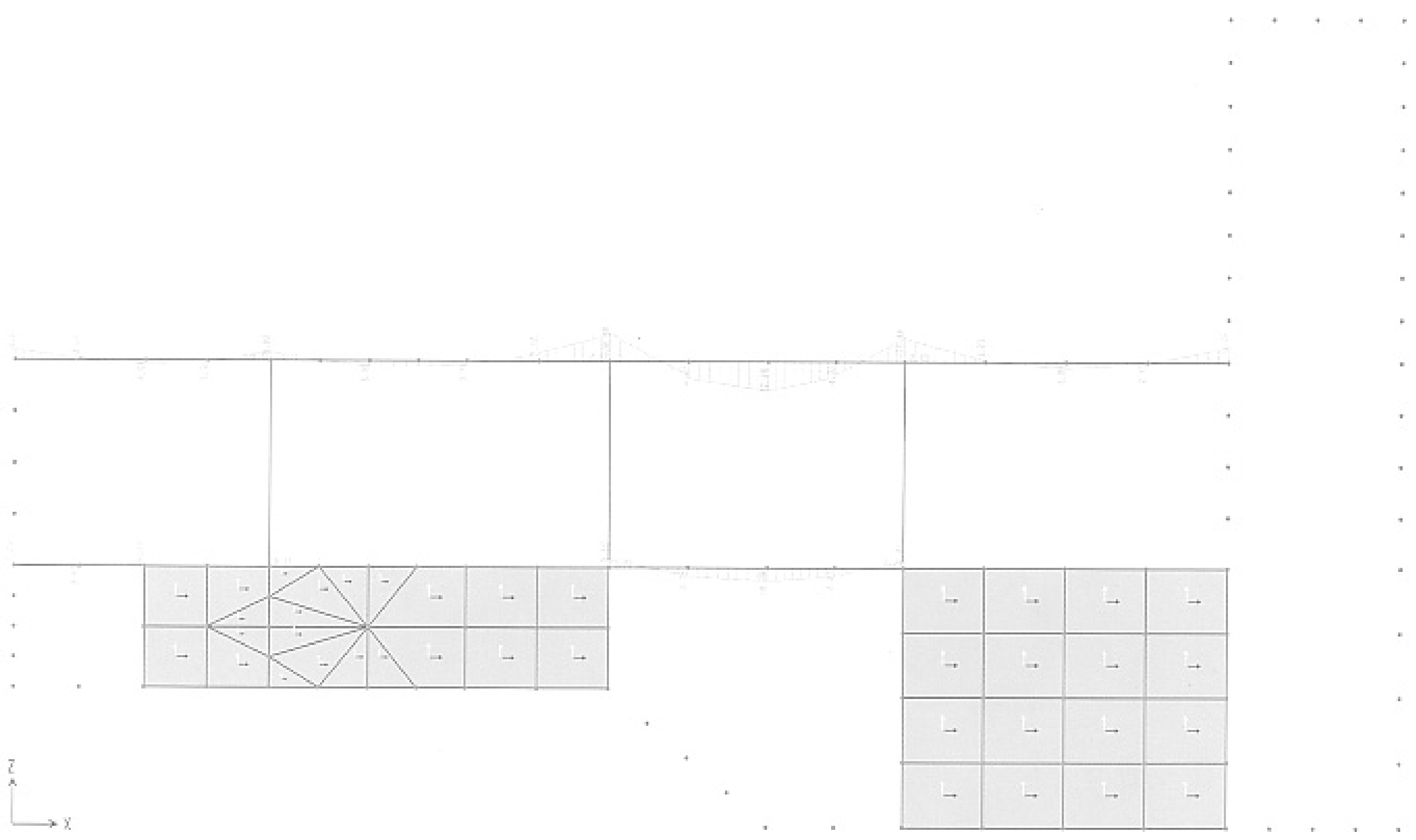
a: pitch of stirrup (distance between two stirrups)

j: coefficient that consider safety factor (=1/1.15) =0.87

Frame element	height of beam h (m)	Width of beam b (m)	height of hand s (m)	height of column c (m)	c/2+ +(h+s)/2	Values (T.m) (Q)	Capacity of concrete (ton)	Shearing stresses (Kg/cm2)	Degn Shearing stress (Sc) (Kg/cm2)	Compare &Conclude	Number of stirrup branches	Dia. Of stirrup (mm)	pitch of stirrup (cm)
40	1	0.4	0.2	0.4	0.80	26.60	13.39	7.15	3.6	NOT OK!	2	14	
65	1	0.4	0.2	0.4	0.80	28.29	13.39	7.60	3.6	NOT OK!	2	14	15.0
93	1	0.4	0.2	0.4	0.80	27.51	13.39	7.40	3.6	NOT OK!	2	14	15.0
112	1	0.4	0.2	0.4	0.80	20.55	13.39	5.52	3.6	NOT OK!	2	14	15.0
95	1	0.4	0.2	0.4	0.80	13.02	13.39	3.50	3.6	OK!!!			
109	1	0.4	0.2	0.4	0.80	18.79	17.11	5.05	4.6	NOT OK!	2	14	15.0
144	0.5	0.4	0	0.4	0.45	4.75	9.63	2.76	5.6	OK!!!			
147	0.5	0.4	0	0.4	0.45	3.45	11.35	2.01	6.6	OK!!!			



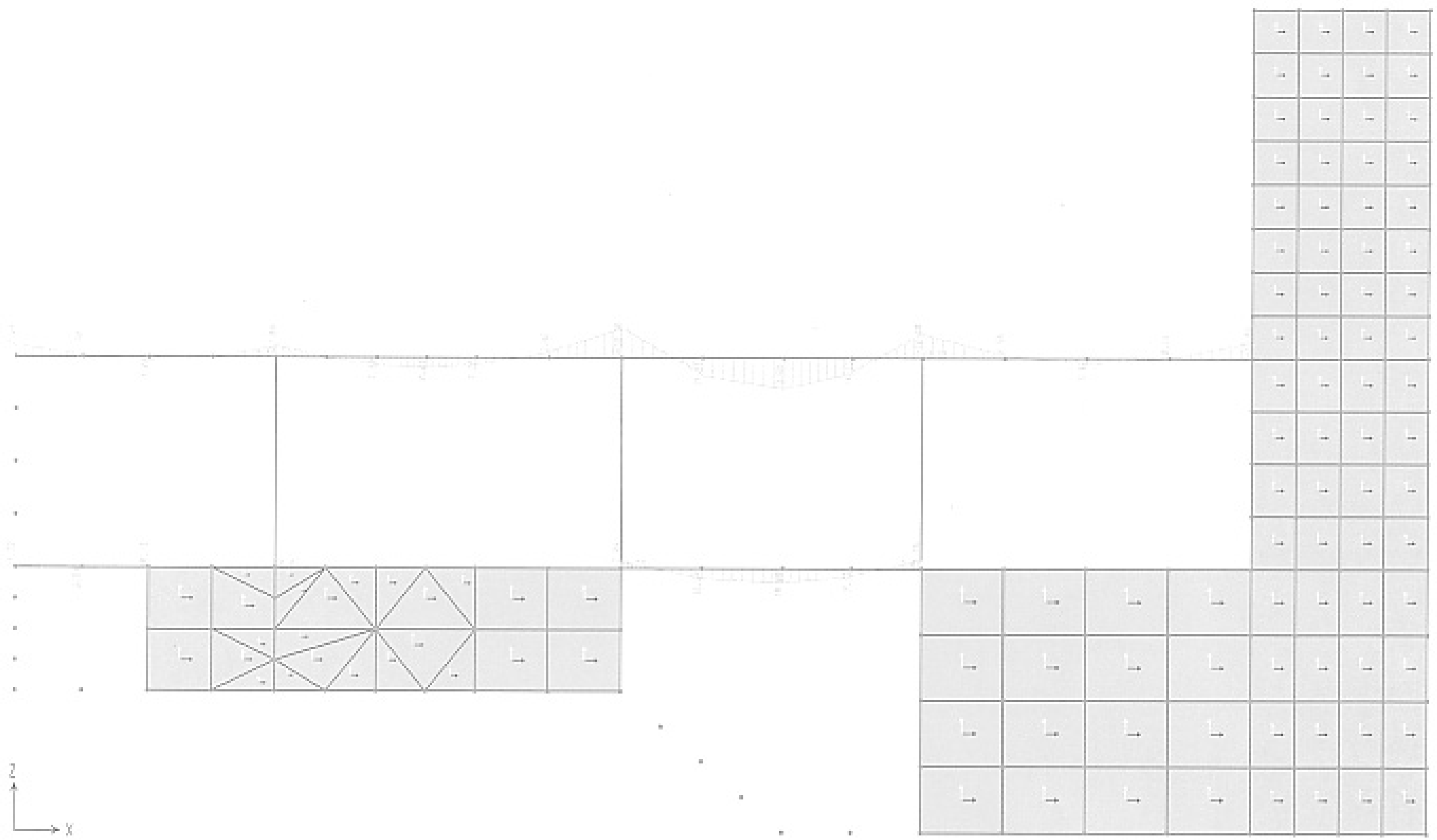
SAP2000 v6.11 - File:LIFTPUMP1 - Moment 3-3 Diagram (LOAD1) - Ton-m Units



SAP2000 v6.11 - File:LIFTPUMP1 - Moment 3-3 Diagram (LOAD1) - Ton-m Units

SAP2000

March 1,2001 15:20



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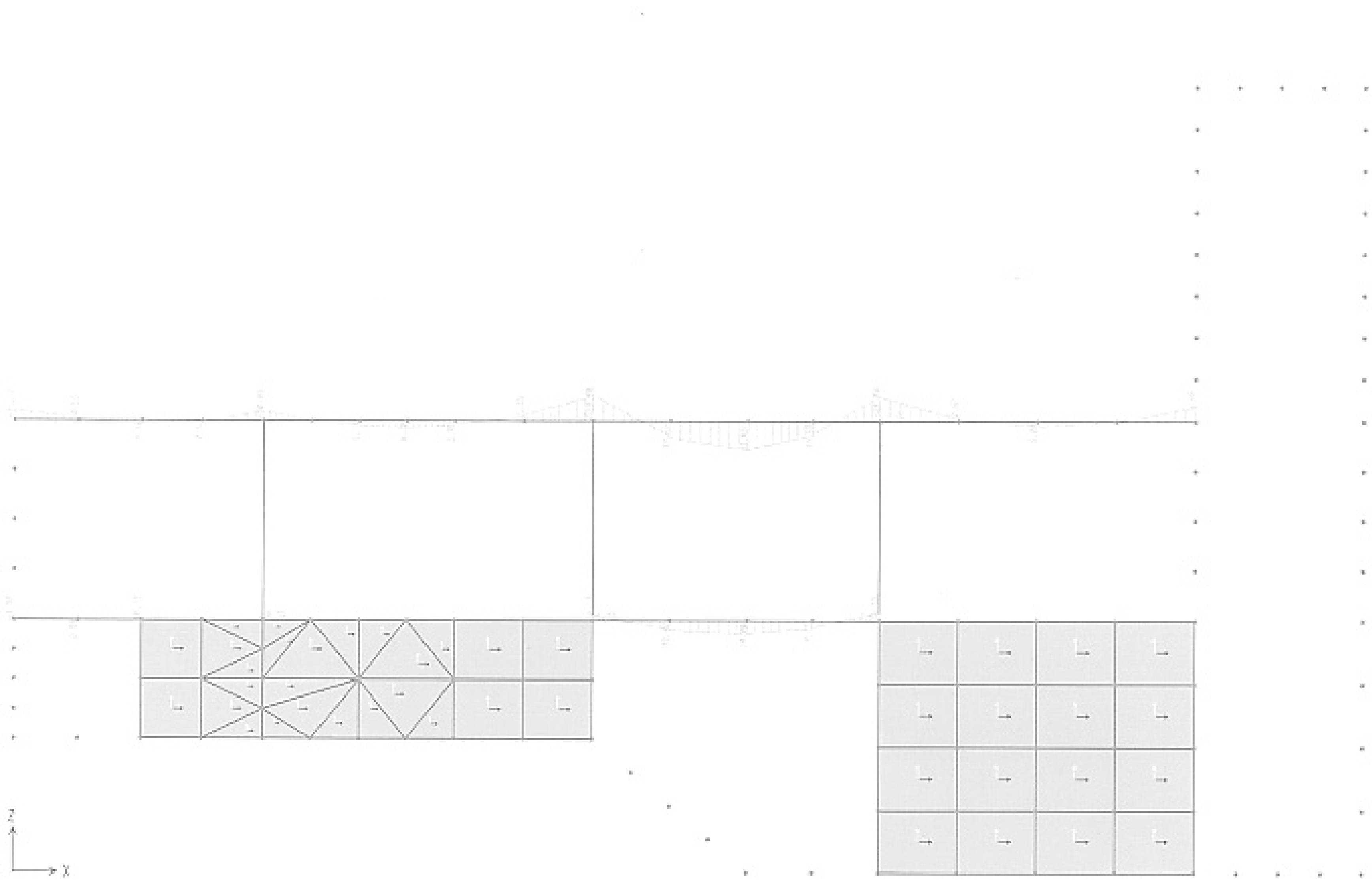

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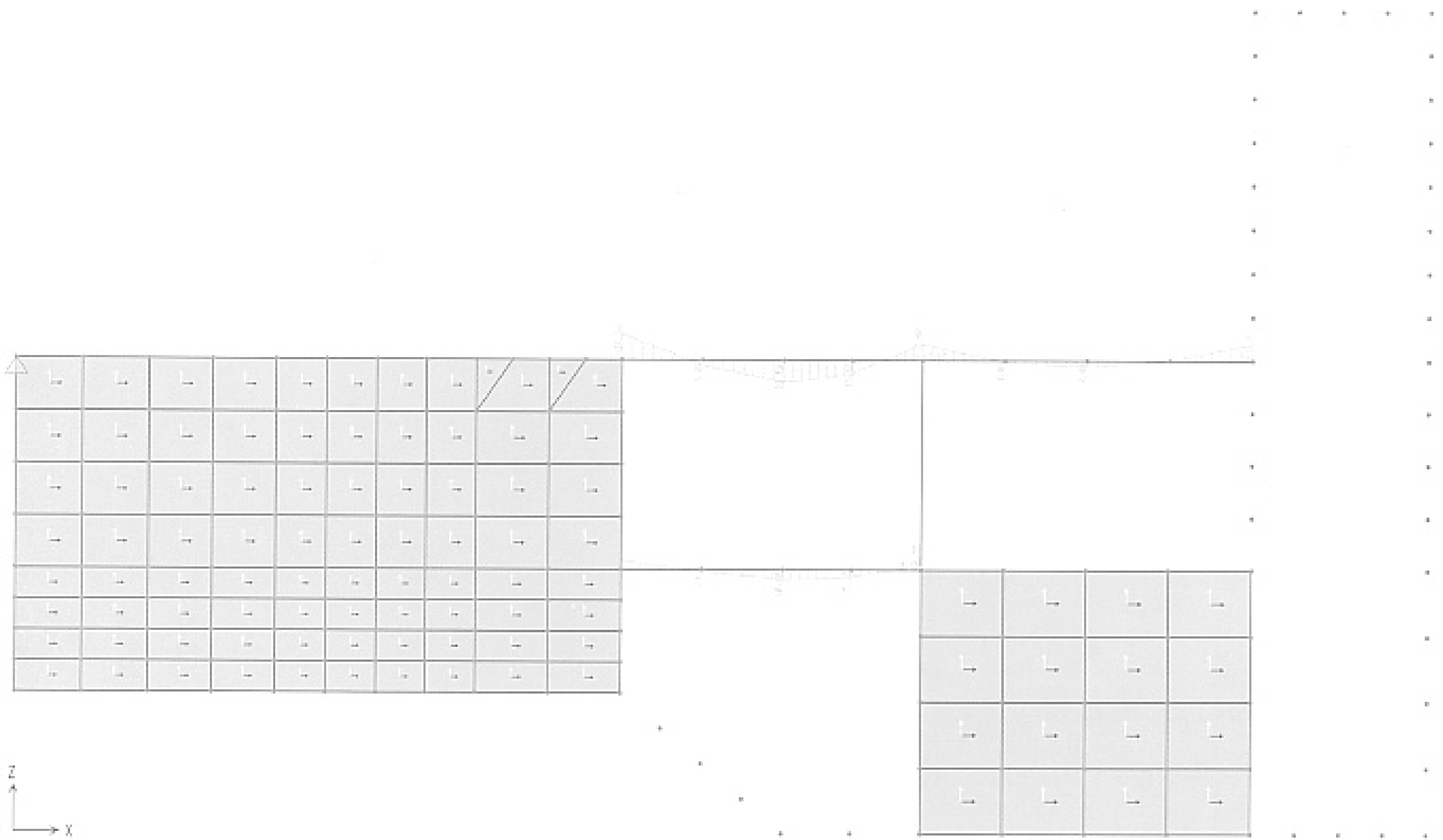
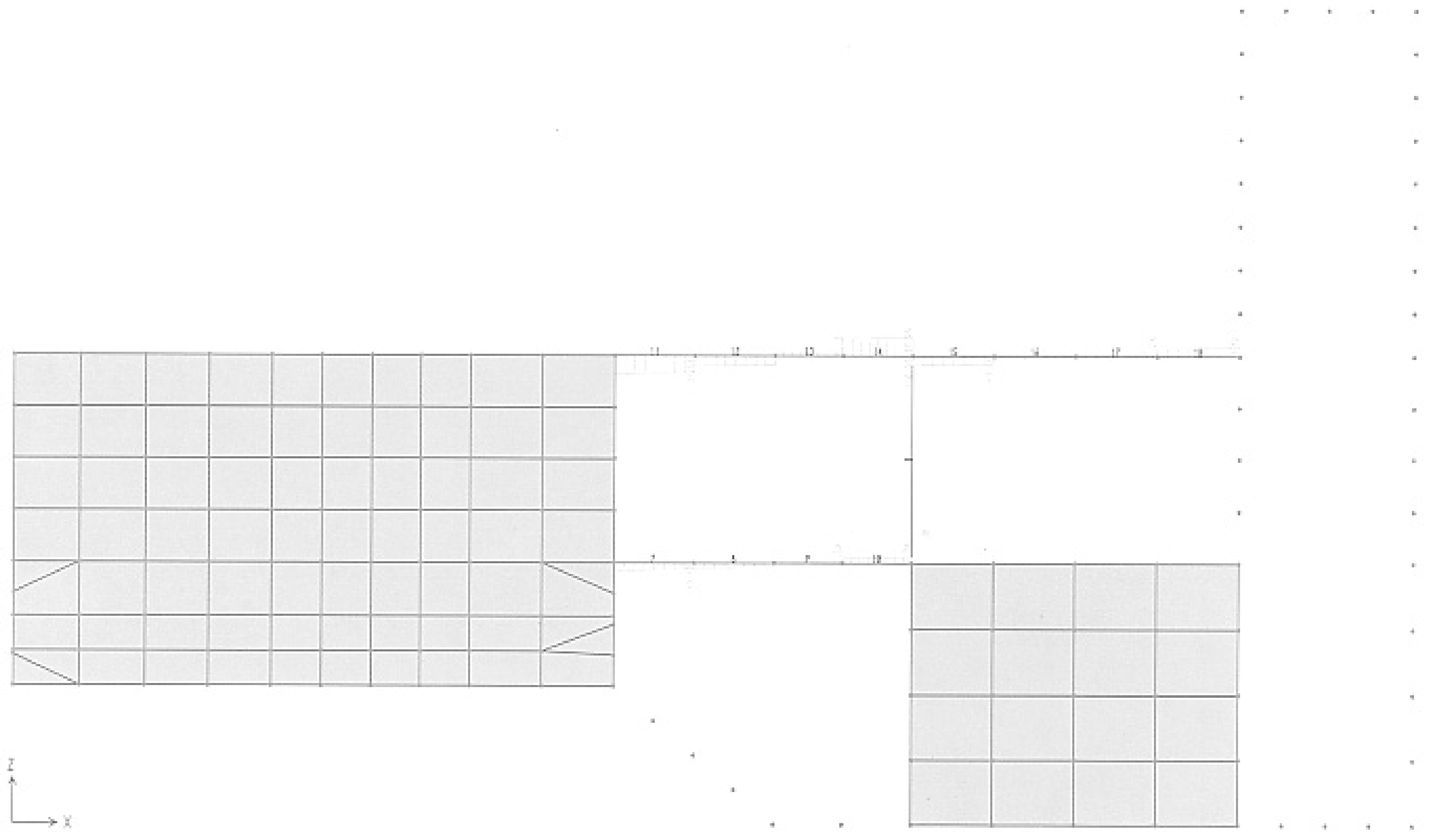


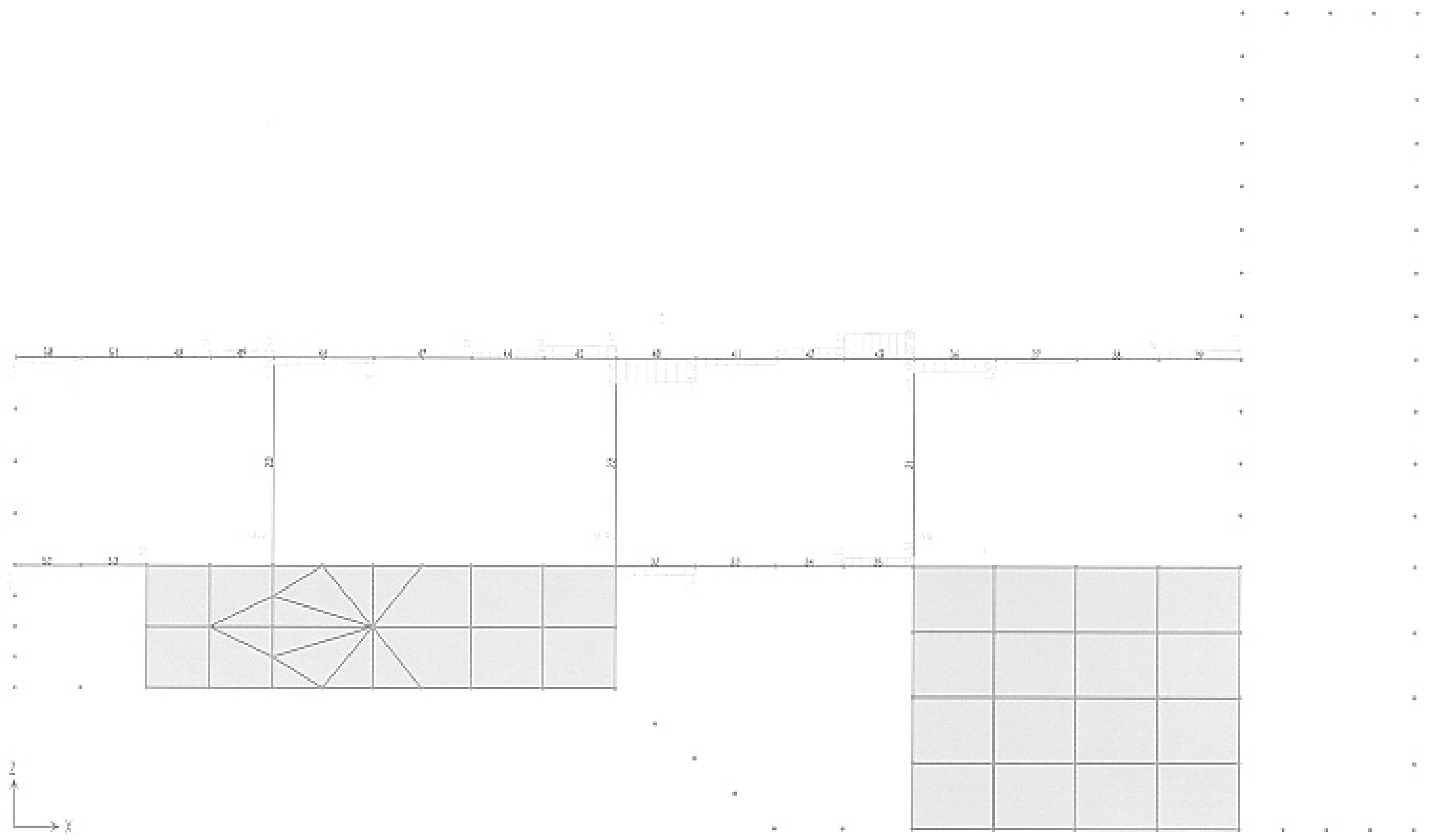
SAP2000 v6.11 - File:LIFTPUMP1 - Moment 3-3 Diagram (LOAD1) - Ton-m Units

SAP2000

March 9,2001 19:26



SAP2000 v6.11 - File:LIFTPUMP1 - Shear Force 2-2 Diagram (LOAD1) - Ton-m Units



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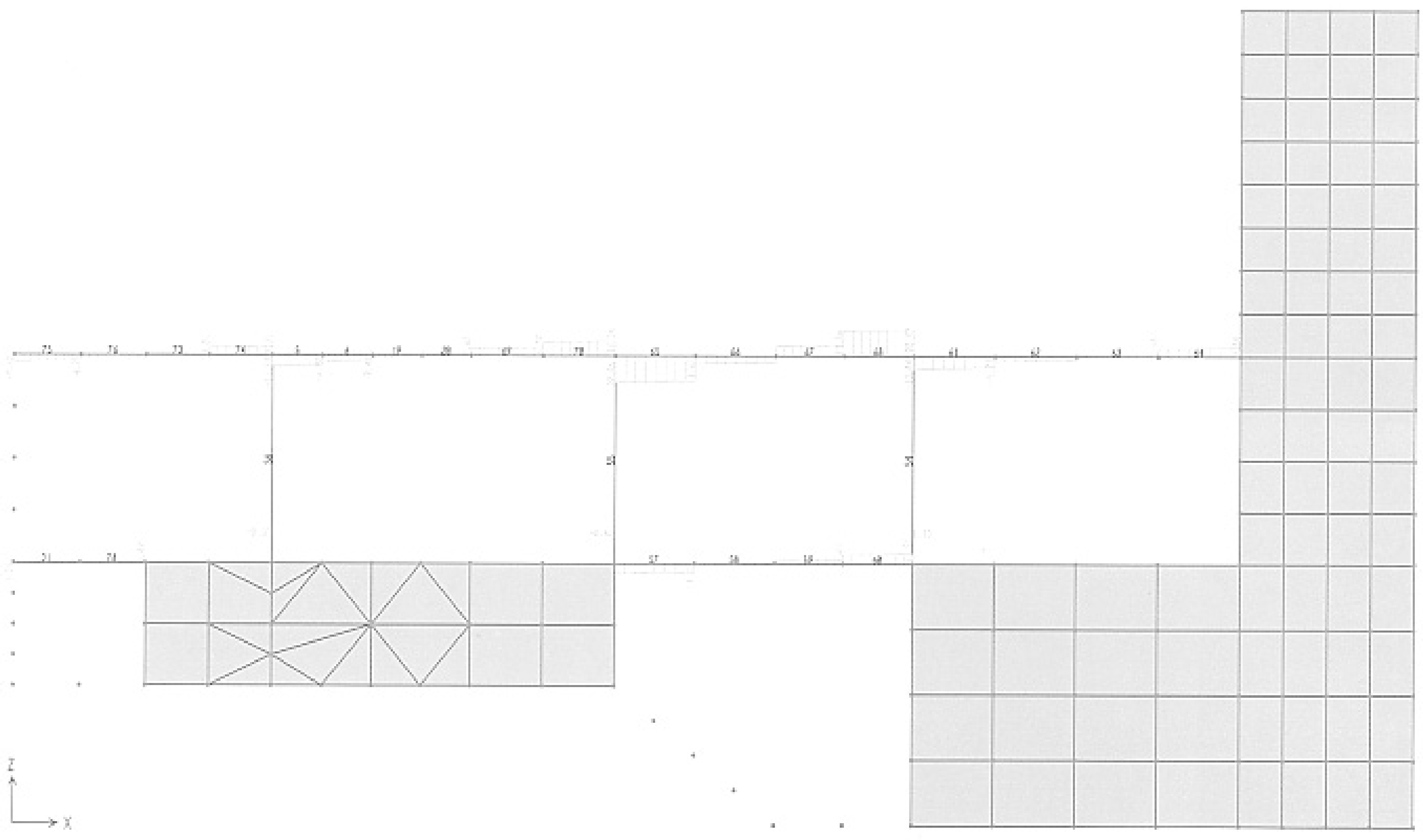
SAP2000

March 9,2001 19:27



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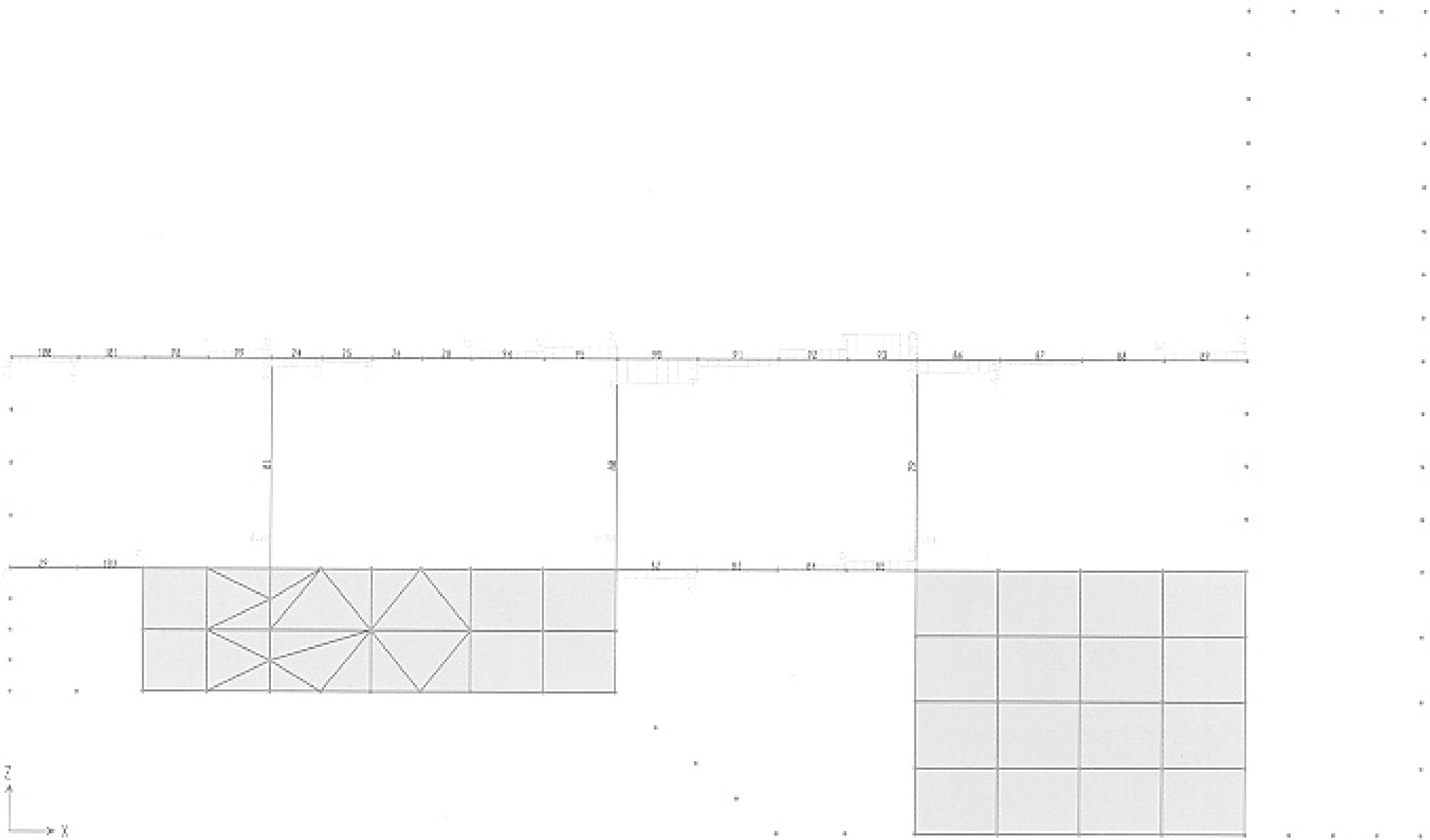

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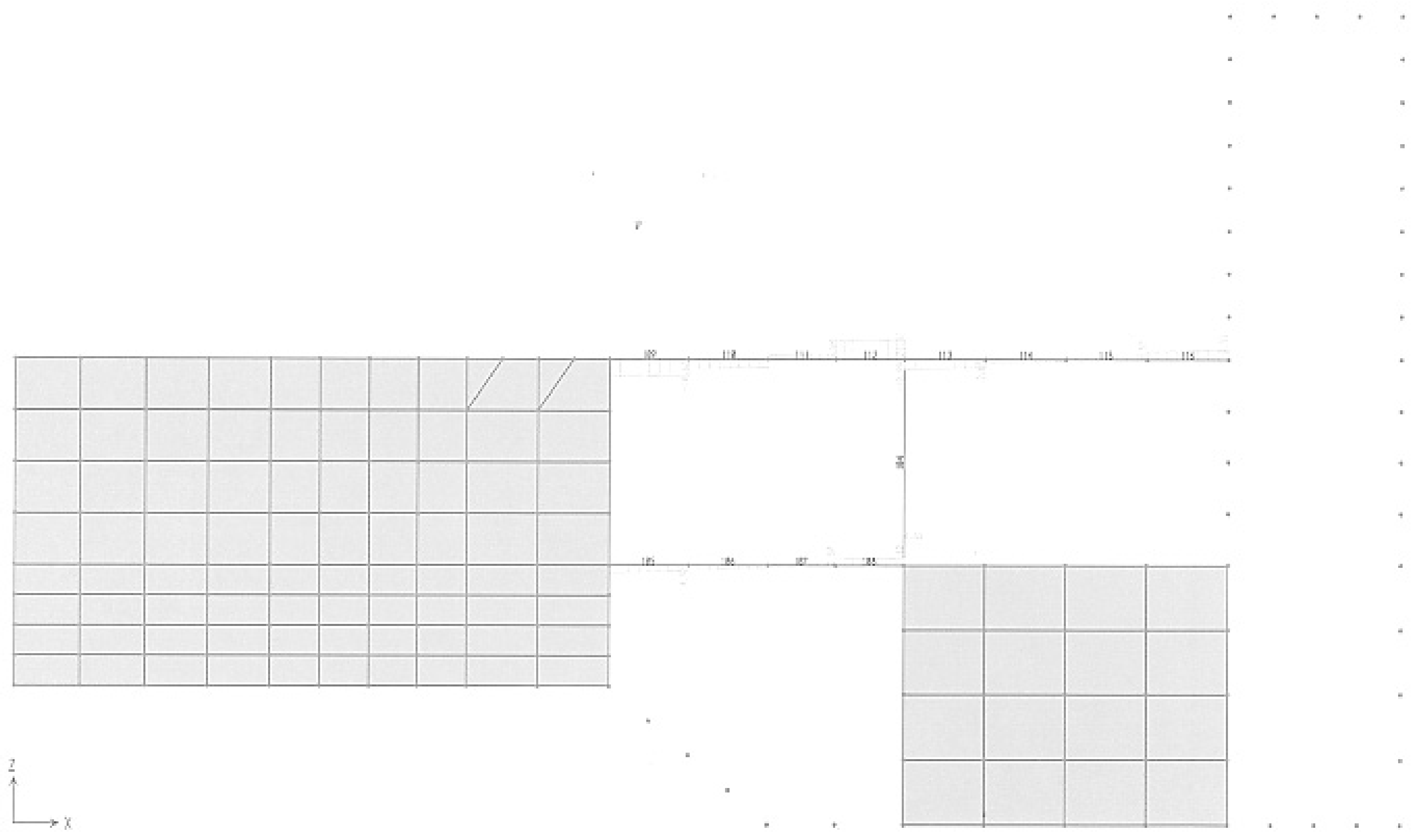

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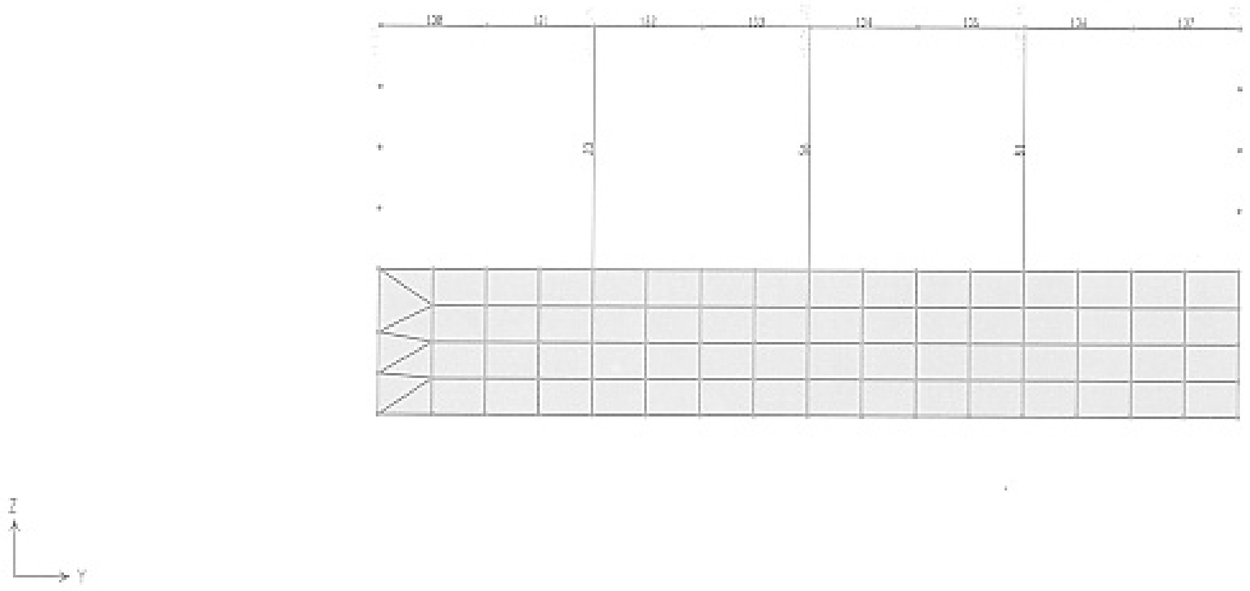
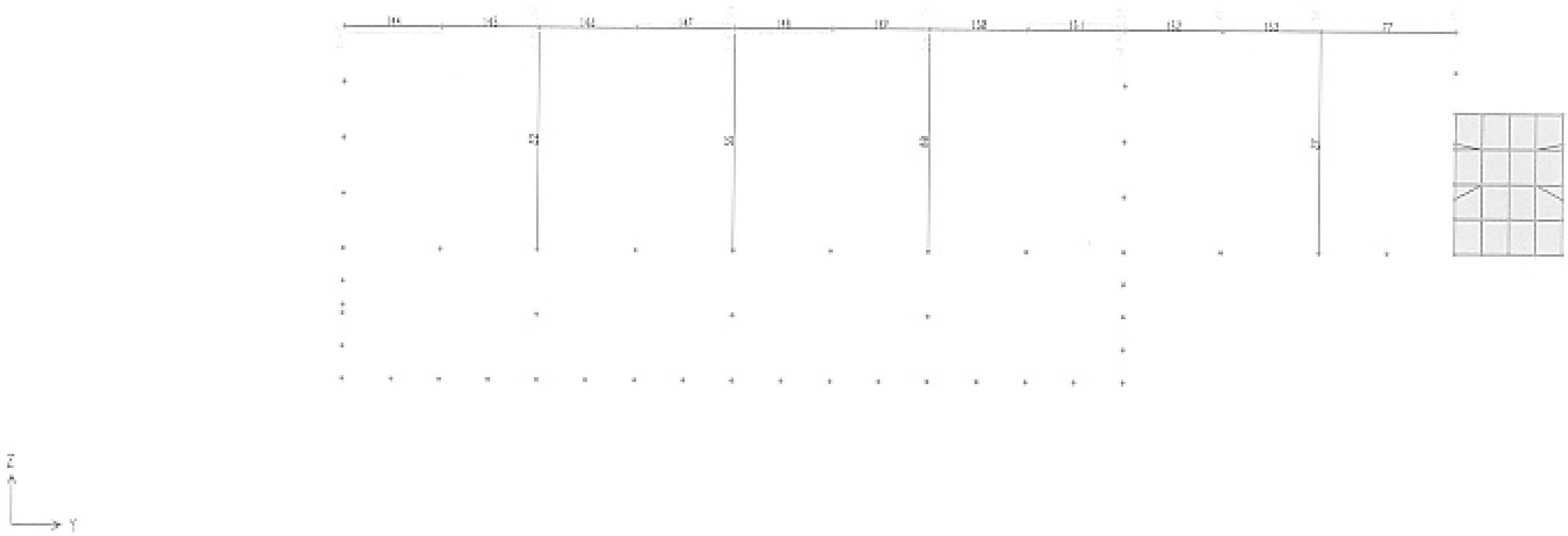


SAP2000 v6.11 - File:LIFTPUMP1 - Shear Force 2-2 Diagram (LOAD1) - Ton-m Units

X= 5,65



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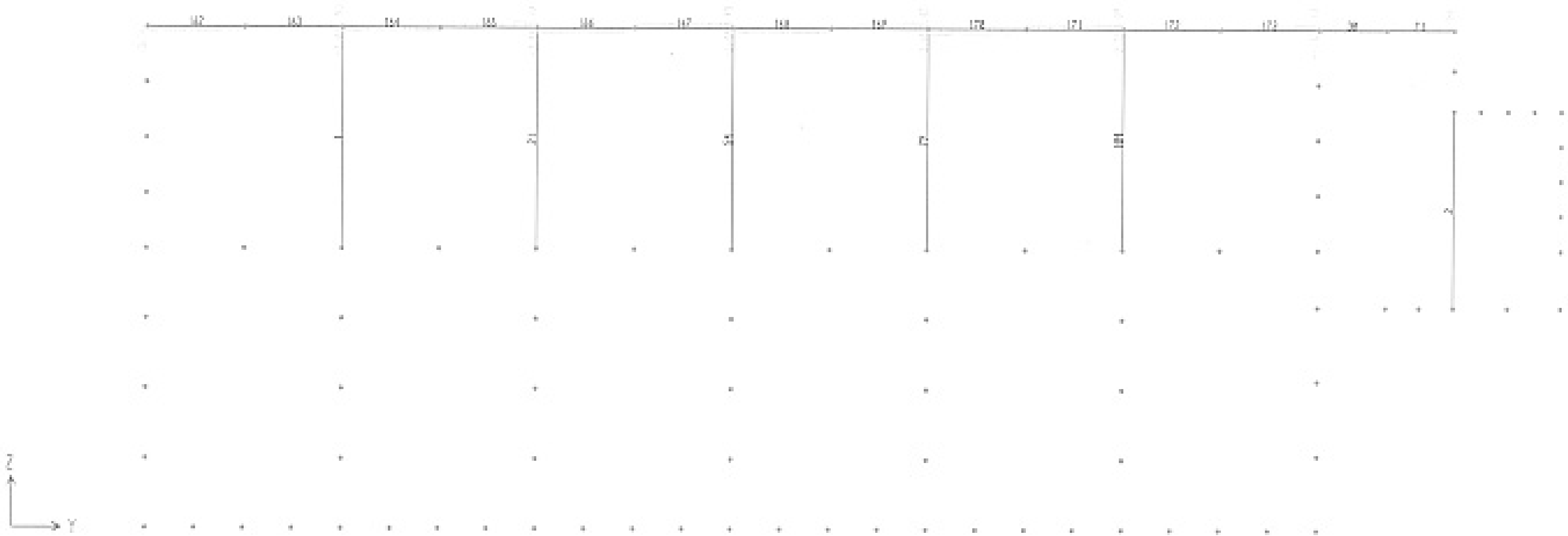

SAP2000 v6.11 - File:LIFTPUMP1 - Shear Force 2-2 Diagram (LOAD1) - Ton-m Units

Calculation for bar arrangement:

Factor related to Moment, bearing area and compress capacity:

$A_o = M/R_n bh_o^2$ Where, M: Maximum bending moment(T.m)

h_o: Effective depth of bearing area(cm)

h_o= (Element thickness-Cover thickness)

b: Width of calculated area(cm)

Required area of reinforcement:

Fa= M/γRaho Where: $\gamma = 0.5 + ((1\text{-}2Ao)^{1/2})/2$

h=0.6

Moments	Values (T.m)	Ao	γ	Fa (cm²)	Bar arrangement ϕ(mm)	Bar arrangement a(mm)
BOTTOM SLAB (Thickness 100cm)	22.290	0.0411	0.979	16.17	25	250
	20.730	0.0382	0.980	15.02	25	250
	44.830	0.0827	0.957	33.28	25	125
	40.000	0.0738	0.962	29.54	25	125
	17.360	0.0320	0.984	12.53	25	250
	14.100	0.0260	0.987	10.15	25	250
BOTTOM SLAB (Thickness 60cm)	10.900	0.0676	0.965	14.71	25	250
	5.740	0.0356	0.982	7.61	20	250
	4.810	0.0298	0.985	6.36	20	250
	17.100	0.1060	0.944	12.87	25	250
	12.510	0.0776	0.960	9.26	22	250
SLAB (Thickness 30cm)	1.870	0.0505	0.974	5.22	12	125
	1.260	0.0340	0.983	3.48	12	250
	3.470	0.0937	0.951	9.92	14	125
	3.070	0.0829	0.957	8.72	14	125
SLAB (Thickness 40cm)	7.390	0.0969	0.949	14.75	16	125
	6.450	0.0846	0.956	12.78	14	125
WALL (Thickness 80cm)	38.420	0.1030	0.946	34.79	25	125
	39.640	0.1063	0.944	35.96	25	125
	27.190	0.0729	0.962	24.20	25	125
	26.880	0.0721	0.963	23.91	25	125
	21.720	0.0582	0.970	19.17	22	125
x=26.8	16.200	0.0434	0.978	14.18	25	250
	17.680	0.0474	0.976	15.51	25	250
x=0	8.740	0.0234	0.988	7.57	22	250
y=26.75	31.560	0.0846	0.956	28.27	25	125
	23.290	0.0624	0.968	20.60	25	250
y=22.75	16.250	0.0436	0.978	14.23	25	250
	12.450	0.0334	0.983	10.84	20	250