ตัวอย่างรายการคำนวณ

SHEET PILES DESIGN AND CALCULATION

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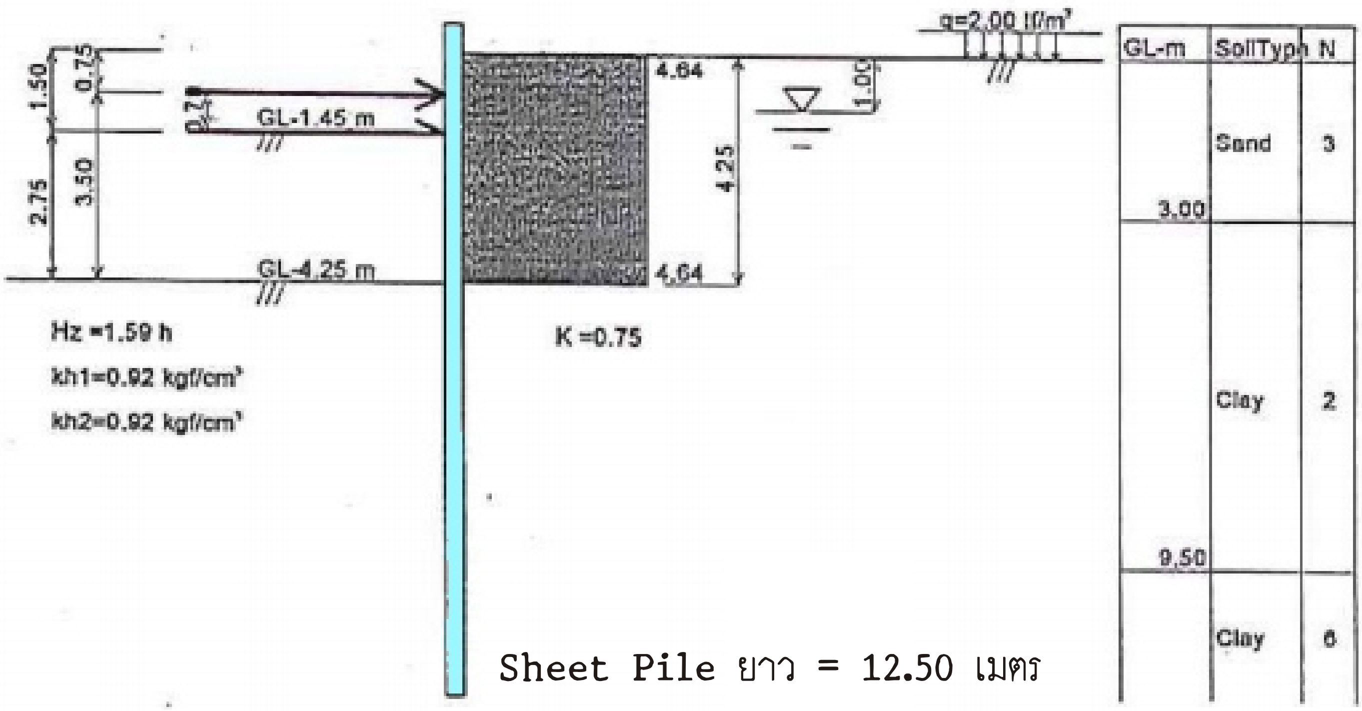
SHEET PILES DESIGN
And CALCULATION

1.ตัวอย่างข้อมูลในการออกแบบ Sheet Piles

1-1 . Figure of Section



1-2 . Wall Type

Wall : Sheet Pile

FSP-4 L=12.50 m Efficiency80 %

Props

Row	Wale	Strut
1	YH350*350	YH350*350

1-3 . Soil Parameter

Soil No.	SoilType	Depth (GL-m)	Thick. (m)	N	Unit Weight (tf/m^3)	Friction (deg)	Cohesion (tf/m^2)
1	Sand	3.00	3.00	3.0	1.50 (0.50)	28.0	0.00
2	Clay	9.50	6.50	2.0	1.55 (0.55)	0.0	1.35
3	Clay	14.50	5.00	6.0	1.70 (0.70)	0.0	3.10
4	Clay	18.50	4.00	15.0	2.00 (1.00)	0.0	7.00

2. การคำนวณและผลลัพธ์

2-1 . Wall Length

	Excavation Depth (m)	Balanced Depth (m)	Rooting Depth (m)	Required Length (m)
Self-Standing Stage	1.45	-----	5.77	7.22
Final Excavation Stage	4.25	6.38	7.66	11.91

Rooting Depth on Self-Standing Stage $Ld = \frac{2.5}{\beta}$ $(\beta=0.43\ m^{-1})$

$L=\Delta H+H+Ld=0.55+4.25+7.66=12.46$ m   Wall Length=12.50 m

2-2 . Wall Stress

	Depth (GL-m)	Bending Moment (tf*m)	Shear Force (tf)	Deflection (cm)
Excav.Stage-1	1.45 m	7.99	2.83	2.34
Final Excav.	4.25 m	17.74	12.83	1.55
Remov.Stage-1	1.50 m	0.82	1.65	0.01

USE : FSP-4 $Zx=1,816\ cm^3$ $Aw=131.75\ cm^2$

$\sigma b = \frac{Mmax}{Zx} = 977\ kgf/cm^2 < 2,700\ kgf/cm^2$

$\tau s = \frac{Smax}{Aw} = 97\ kgf/cm^2 < 1,500\ kgf/cm^2$

2-3 . Reaction Force

Row	Excav.Stage (tf/m) (Half)	Remov.Stage (tf/m) (Simple-Beam)
1	11.60	-----

2. การคำนวณและผลลัพธ์(ต่อ)

2-4 . Props

(1) Wale

Row	R (tf/m)	Lb (m)	Lb' (m)	Lc (m)	ΔN (tf)	M (tf*m)	N (tf)	S (tf)
1	11.60	4.50	4.50	3.15	0.00	23.49	36.54	26.10

Row	USE	σb (kgf/cm^2)	σc (kgf/cm^2)	τs (kgf/cm^2)	Comb.-1 <1.00	Comb.-2 <1.00
1	YH350*350	1,175	236	697	0.717	N.A.

(2) Strut

Row	R (tf/m)	W (tf/m)	Lc (m)	Ly (m)	Lz (m)	ΔN (tf)	M (tf*m)	N (tf)
1	11.60	0.50	4.50	5.06	5.06	22.00	1.60	74.20

Row	USE	σb (kgf/cm^2)	σc (kgf/cm^2)	Comb.-1 <1.00	Comb.-2 <1.00
1	YH350*350	80	479	0.357	0.298

3. การคำนวณความยาวผนัง Sheet Piles

3-1 . Self-Standing Stage

(1) Active Pressure

Rankine Formula

$Pa=(q+\gamma*H)*Ka-2*c\sqrt{Ka}$ $Ka=\tan^2(45-\varphi/2)$

$q=2.00\ tf/m^2$

GL-m	SoilType	γ*H (tf/m²)	Ka	Pressure (tf/m²)
0.00 1.00	Sand	0.00 1.50	0.36	0.72 1.26
1.00 3.00	Sand	1.50 2.50	0.36	1.26 1.62
3.00 3.76	Clay	2.50 2.92	1.00	1.80 2.22

*Active Water Pressure

GL-m	Water Pressure (tf/m²)
1.00 3.76	0.00 2.76

(2) Passive Pressure

Rankine Formula

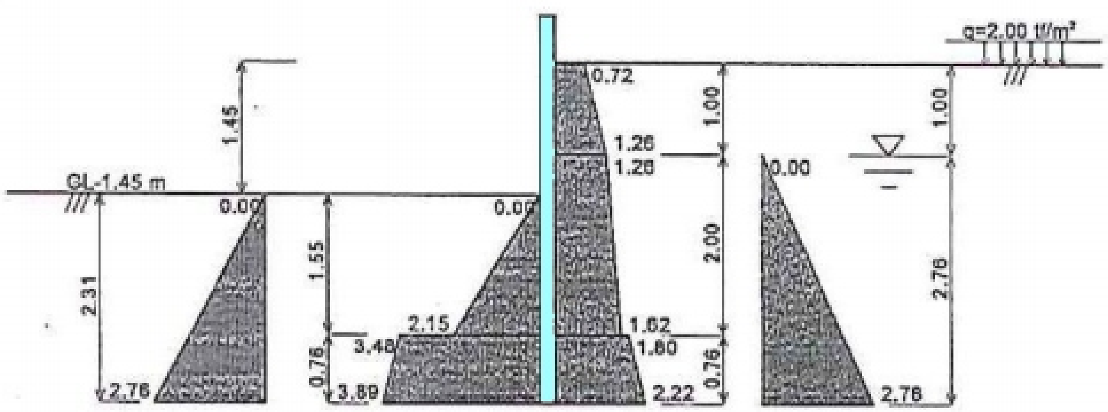
$Pp=Kp*\gamma*H+2*c\sqrt{Kp}$ $Kp=\tan^2(45+\varphi/2)$

GL-m	SoilType	γ*H (tf/m²)	Kp	Pressure (tf/m²)
1.45 3.00	Sand	0.00 0.78	2.77	0.00 2.15
3.00 3.76	Clay	0.78 1.19	1.00	3.48 3.89

*Passive Water Pressure

GL-m	Water Pressure (tf/m²)
1.45 3.76	0.00 2.76

(3) Figure of Soil Pressure



(4) Wall Character

$k_h=0.92\ kgf/cm^3$ $B=1.00\ m$ $E=2.1*10^6\ kgf/cm^2$ $I=38{,}600\ cm^4*0.80=30{,}880*10^{-8}\ m^4$

$$\beta=\sqrt[4]{\frac{k_h*B}{4*E*I}}=0.433\ m^{-1}$$

(5) Rooting Depth

$$Ld=\frac{2.5}{\beta}=5.77\ m$$

(6) Required Wall Length

$L=\Delta H+H+Ld=0.55+1.45+5.77=7.77\ m$

3. การคำนวณความยาวผนัง Sheet Piles(ต่อ)

3-2 . Final Excavation Stage

(1) Active Pressure

Rankine Formula

$P_a=(q+\gamma*H)*K_a-2*c\sqrt{K_a}$ $K_a=\tan^2(45-\varphi/2)$

$q=2.00$ tf/m²

GL-m	SoilType	γ*H (tf/m²)	Ka	Pressure (tf/m²)
0.00 0.75	Sand	0.00 1.13	0.36	0.72 1.13
0.75 1.00	Sand	1.13 1.50	0.36	1.13 1.26
1.00 3.00	Sand	1.50 2.50	0.36	1.26 1.62
3.00 9.50	Clay	2.50 6.08	1.00	1.80 5.38
9.50 10.63	Clay	6.08 6.87	1.00	1.88 2.67

*Active Water Pressure

GL-m	Water Pressure (tf/m²)
1.00 10.63	0.00 9.63

(2) Passive Pressure

Rankine Formula

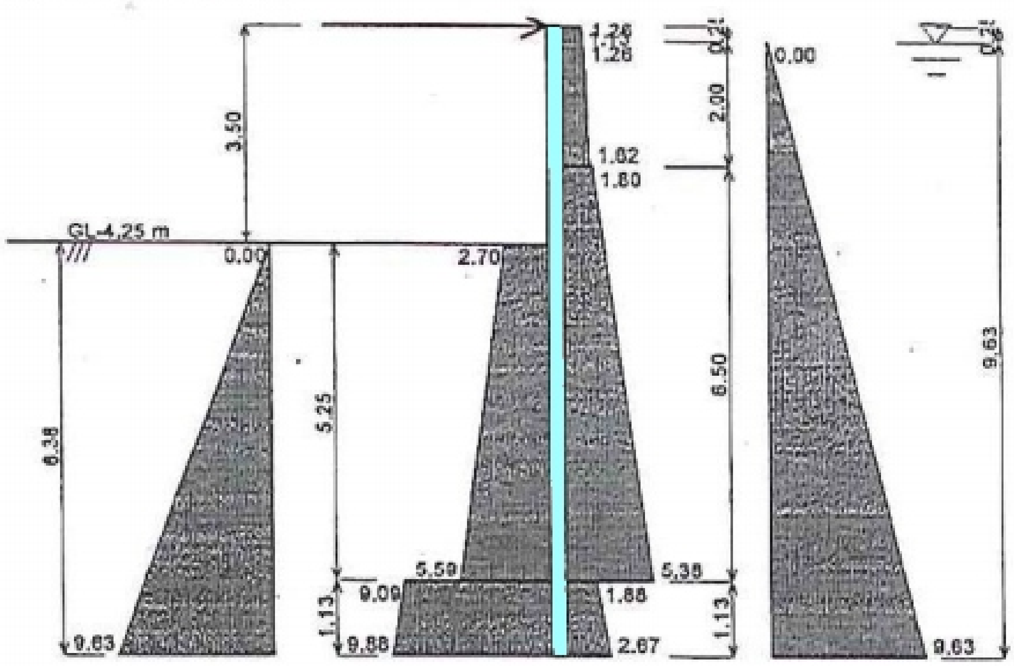
$P_p=K_p*\gamma*H+2*c\sqrt{K_p}$ $K_p=\tan^2(45+\varphi/2)$

GL-m	SoilType	γ*H (tf/m²)	Kp	Pressure (tf/m²)
4.25 9.50	Clay	0.00 2.89	1.00	2.70 5.59
9.50 10.63	Clay	2.89 3.68	1.00	9.09 9.88

*Passive Water Pressure

GL-m	Water Pressure (tf/m²)
4.25 10.63	0.00 9.63

(3) Figure of Soil Pressure



4.คำนวณหาโมเมนต์ Equilibrium

Balanced Depth Lx=6.38

Rotary Moment by Active Pressure

GL-m~GL-m	ΣP (tf)	l (m)	M (tf*m)
0.75~1.00	0.30	0.13	0.04
1.00~3.00	2.89	1.29	3.73
3.00~9.50	23.32	6.04	140.84
9.50~10.63	2.57	9.35	23.99
Total	29.07	-----	168.60

Rotary Moment by Water Pressure

GL-m~GL-m	ΣP (tf)	l (m)	M (tf*m)
1.00~10.63	46.37	6.67	309.29
Total	46.37	-----	309.29

Resisting Moment by Passive Pressure

GL-m~GL-m	ΣP (tf)	l (m)	M (tf*m)
4.25~9.50	21.75	6.43	139.88
9.50~10.63	10.72	9.32	99.92
Total	32.47	-----	239.80

Resisting Moment by Water Pressure

GL-m~GL-m	ΣP (tf)	l (m)	M (tf*m)
4.25~10.63	30.72	7.75	238.19
Total	30.72	-----	238.19

Hence Mr-Md=(168.60+309.29)-(239.80+238.19)=0.00

5. คำนวณหา Rooting Depth

Ld=1.2*Lx=1.2*6.38=7.66 m

6. Required ความยาวของผนัง Sheet Piles

L=ΔH+H+Ld=0.55+4.25+7.66=12.46 m

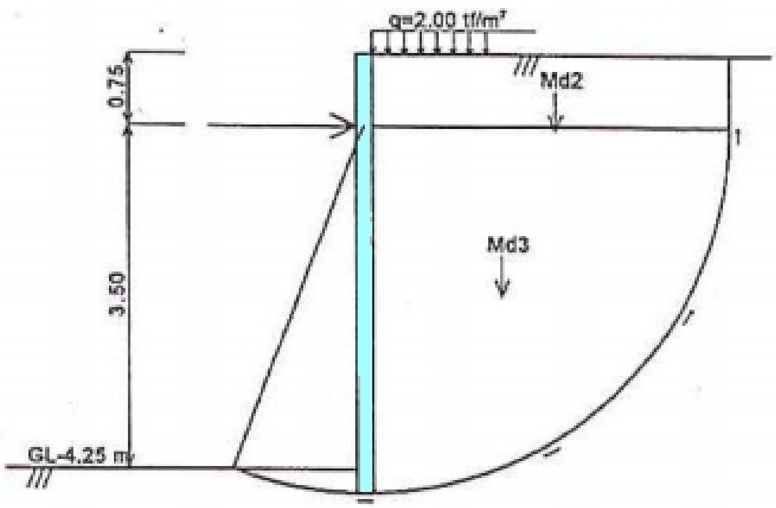
7. Virtual Supporting Point

Moment : Mr=239.80 tf*m(/m) Total Forces : Pp=32.47 tf(/m)

Hz=Mr/Pp-h=239.80/32.47-3.50=3.88 m

4. ตรวจสอบ Ground Stability

4-1 . Study of Heaving (Slipping)



GL-m	SoilType	N	?	c	?
3.00	Sand	3	1.50	0.00	28
	Clay	2	1.55	1.35	0

(1) Calculation of Safety Factor

$$Fs = \frac{Mr}{Md}$$

Mr : Total Resisting Moment=Mr1+Mr2

Mr1 : Resisting Moment(Passive-Arch)=$R^2 \int c(z) d\theta$

Mr2 : Resisting Moment(Active-Arch)=$R^2 \int c(z) d\theta$

Md : Total Slipping Moment=Md1+Md2+Md3

Md1 : Slipping Moment due to Surcharge=$R^2/2*q$

Md2 : Slipping Moment due to Soil Weight=$R^2/2*\Sigma\gamma*H$

Md3 : Slipping Moment due to Soil Weight=$R'^2/2*\Sigma\gamma*H$

(2) Safety Factor depend on Rooting

R (m)	Z (m)	Md (tf*m)	Md1	Md2	Md3	Mr (tf*m)	Mr1	Mr2	Fs
9.25	10.00	349.99	85.56	48.13	216.29	388.59	186.08	202.52	1.11
9.75	10.50	390.06	95.06	53.47	241.53	477.64	230.20	247.44	1.22
10.25	11.00	432.25	105.06	59.10	268.09	565.54	273.75	291.79	1.31
10.75	11.50	476.55	115.56	65.00	295.98	655.35	318.25	337.09	1.38
11.25	12.00	522.95	126.56	71.19	325.20	749.39	364.87	384.52	1.43
11.75	12.50	571.47	138.06	77.66	355.75	845.22	412.38	432.84	1.48
12.25	13.00	622.10	150.06	84.41	387.62	947.46	463.09	484.37	1.52
12.75	13.50	674.83	162.56	91.44	420.83	1,051.63	514.77	536.86	1.56
13.25	14.00	729.67	175.56	98.75	455.36	1,162.76	569.92	592.84	1.59

5. Soil Pressure โมเดล

5-1 . Soil Unit Weight

$\gamma = \Sigma\gamma * D/L = 6.44/4.25 = 1.51$ tf/m^3

5-2 . Extra Soil Pressure due to Surcharge

Coefficient of Soil Pressure :K=0.75

$P_0 = q * K = 2.00 * 0.75 = 1.50$ tf/m

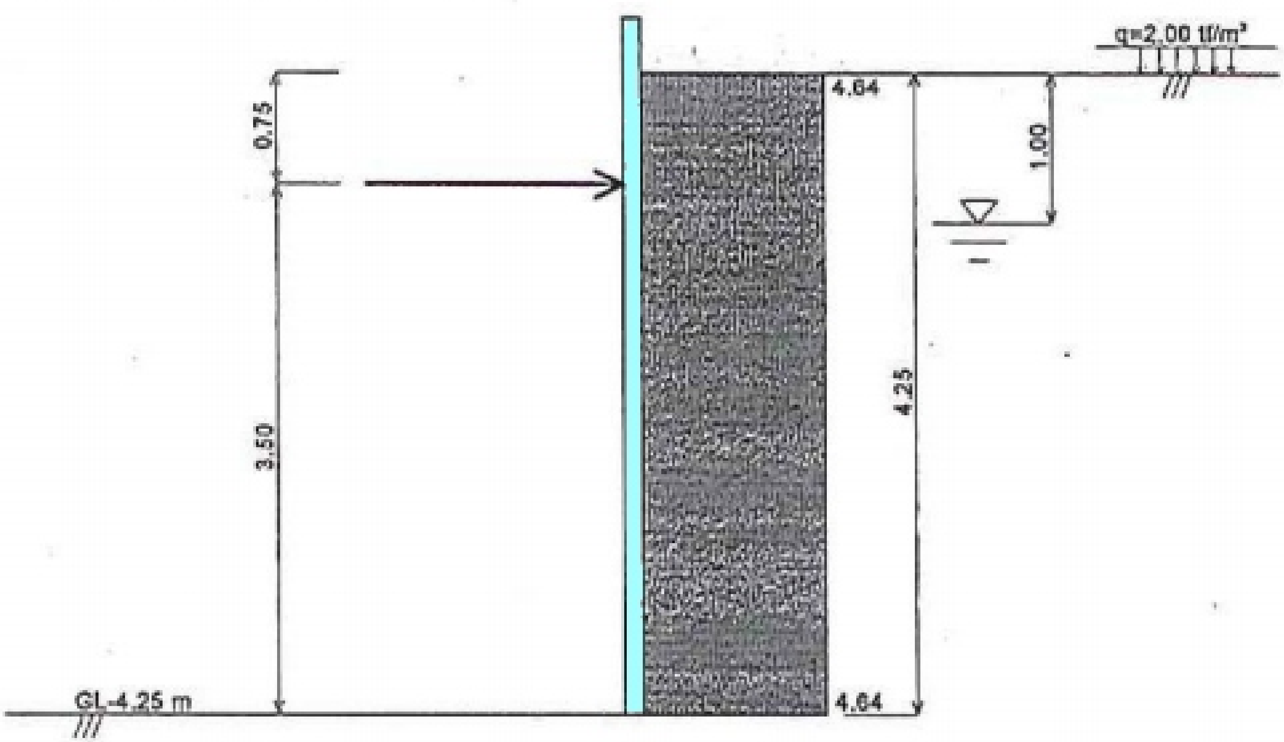
5-3 . Soil Pressure Model

Sand:

$P' = 0.65 * K * \gamma * H = 0.65 * 0.75 * 1.51 * 4.25 = 3.14$ tf/m

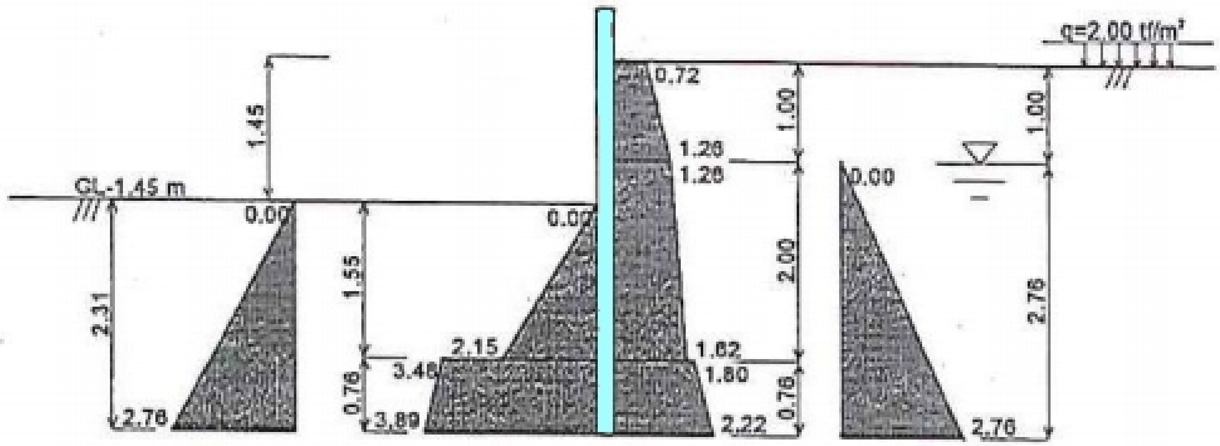
$P = P_0 + P' = 1.50 + 3.14 = 4.64$ tf/m

5-4 . Figure of Soil Pressure Model



6. คำนวณหาค่า Wall Stress

6-1 . Self-Standing Stage



(1) Horizontal Force and Arm Length

Supporting Point : Hz=h*1.59=2.31 m

Horizontal Force : P_0=2.83 tf(/m) <- Shearing force

Moment : M_0=7.08 tf*m(/m)

Arm Length : $H_0=M_0/P_0$=2.50 m

(2) Wall Character

k_h=0.92 kgf/cm³

B =1.00 m

E =2.1*10⁶ kgf/cm²

I =38,600 cm⁴ *0.80=30,880*10⁻⁸ m⁴

$$\beta = \sqrt[4]{\frac{k_h*B}{4*E*I}} = 0.433\ m^{-1}$$

(3) Bending Moment

$$M=P_0*H_0*\frac{\sqrt{(1+2*\beta*H_0)^2+1}}{2*\beta*H_0}*exp\left(-tan^{-1}\frac{1}{1+2*\beta*H_0}\right)$$

=7.99 tf*m(/m)

(4) Deflection

$$\delta_1 = \frac{(1+\beta*H_0)}{2*E*I*\beta^3}*P_0*@ = 0.56\ cm$$

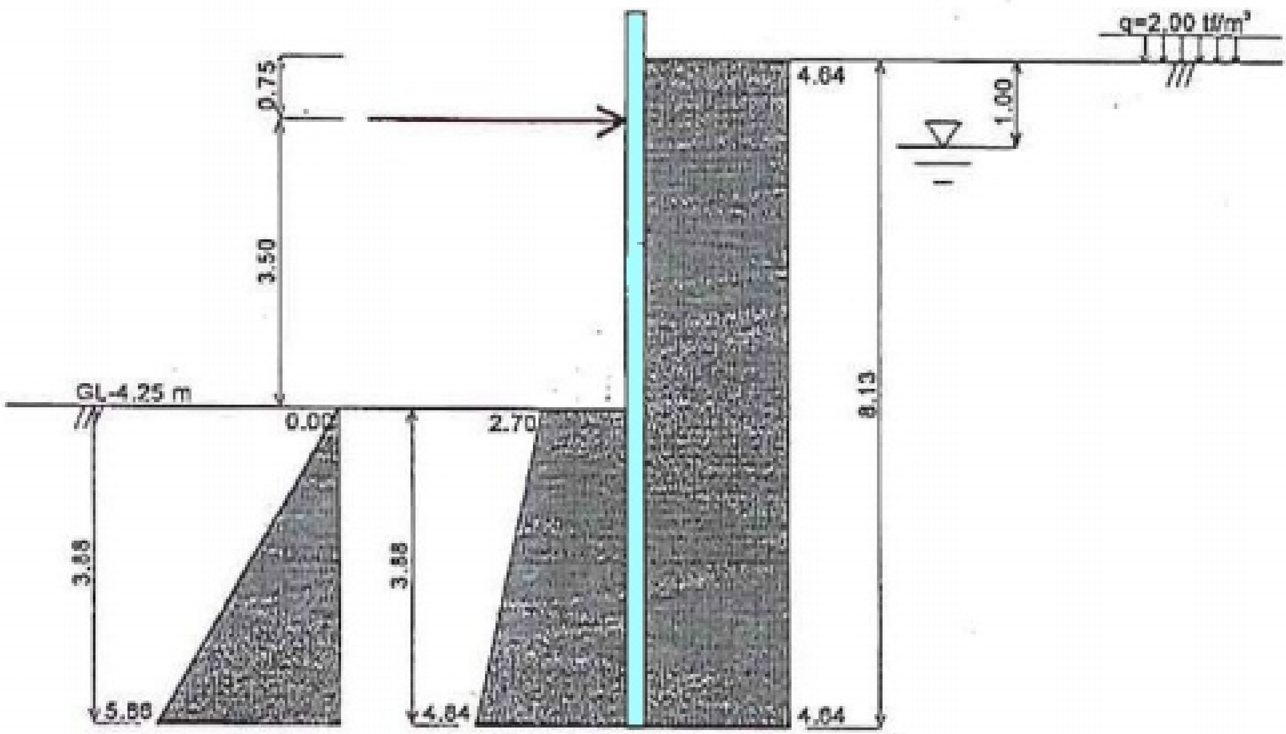
$$\delta_2 = \frac{(1+2*\beta*H_0)}{2*E*I*\beta^2}*P_0*H*@ = 1.38\ cm$$

$$\delta_3 = \frac{P_0*H_0^2*(3*H-H_0)}{6*E*I}*@ = 0.40\ cm$$

$\delta=\delta_1+\delta_2+\delta_3$=2.34 cm

6. คำนวณหาค่า Wall Stress (ต่อ)

6-2 . Final Excav.



(1) Stress

Ra=12.83 tf(/m)   Rb=4.32 tf(/m)

M=17.74 tf*m(/m)

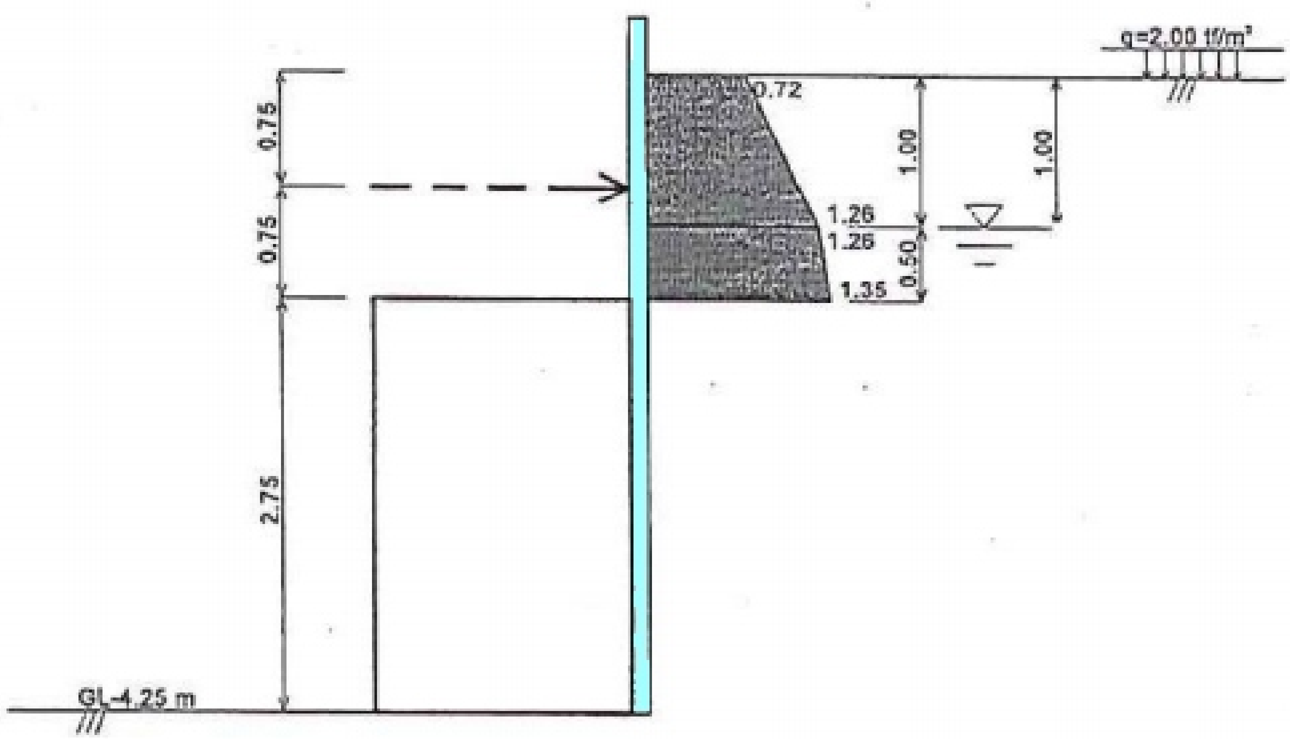
S=12.83 tf(/m)

(2) Deflection

$$\delta = \frac{5*M*L^2}{48*E*I}*@ = \frac{5*(17.74*10^5)*(7.38*10^2)^2}{48*(2.1*10^6)*(38,600*0.80)}*1.00 = 1.55\ cm$$

6. คำนวณหาค่า Wall Stress (ต่อ)

6-3 . Remov.Stage-1



(1) Shear Force

Convert equivalent area to Trapezoid Load Pressure

w1=0.00 tf/m² w2=2.20 tf/m²

R=(w1+w2)*L/2=1.65 tf/m <- Shear force

(2) Bending Moment

$$M = \frac{(2*w1+w2)*L^2}{6} = 0.82\ tf*m(/m)$$

(3) Deflection

$E = 2.1*10^6\ kgf/cm^2$

$I = 38{,}600\ cm^4 *0.80 = 30{,}880*10^{-8}\ m^4$

$$\delta = \frac{(11*w1+4*w2)*L^4}{120*E*I} *@ = 0.01\ cm$$

7. ตรวจสอบค่า Stress

7-1 . Stress

	Depth (GL-m)	Bending Moment (tf*m/m)	Shear Force (tf/m)	Deflection (cm)
Excav.Stage-1	1.45 m	7.99	2.83	2.34
Final Excav.	4.25 m	17.74	12.83	1.55
Remov.Stage-1	1.50 m	0.82	1.65	0.01

Maximum Moment : Mmax=M*@=17.74 tf*m

Maximum Shear Force : Smax=S*@=12.83 tf

7-2 . Allowable Stress

Bending Stress : σba=2,700 kgf/cm^2 (SY295,TIS1390-1996,Extra Factor=1.50)

Shear Stress : σsa=1,500 kgf/cm^2 (SY295,TIS1390-1996,Extra Factor=1.25)

7-3 . Wall Type

USE : FSP-4

Aw=131.75 cm^2

Zx=2,270*0.80=1,816 cm^3

Ix=38,600*0.80=30,880 cm^4

7-4 . Wall Stress

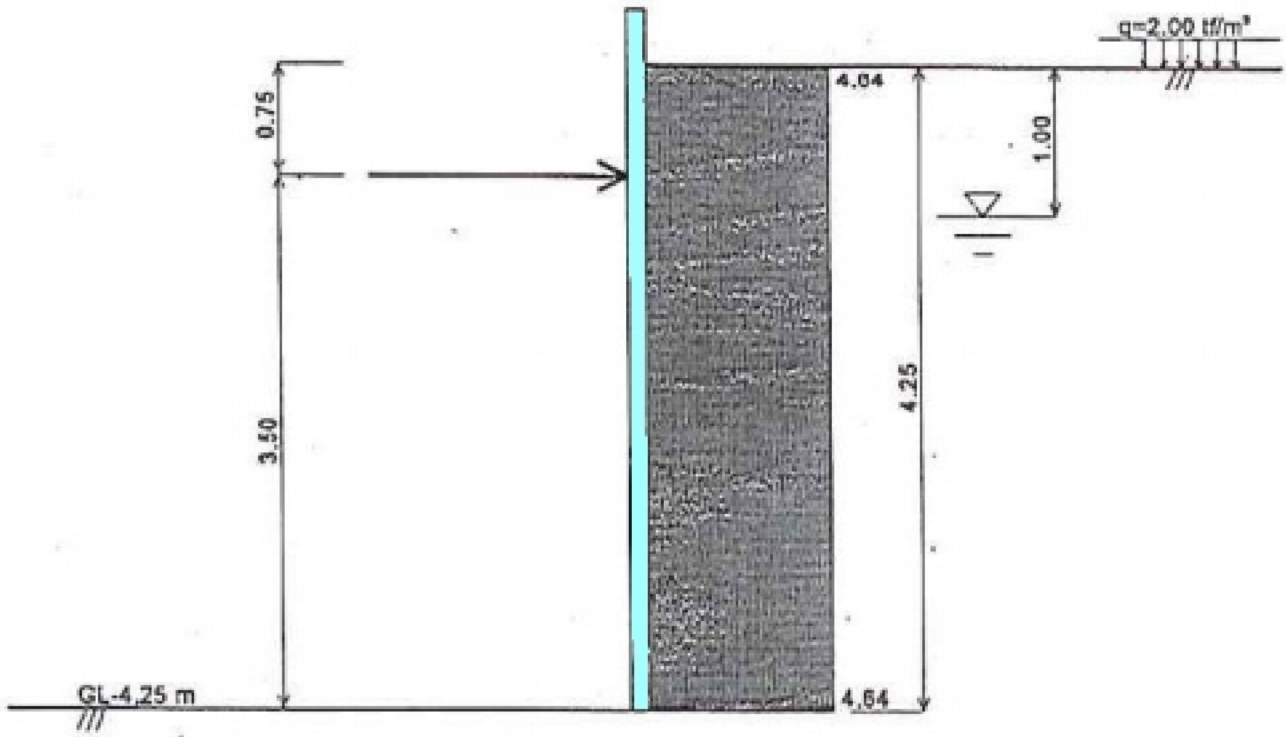
(1) Bending Stress

$$\sigma b = \frac{Mmax}{Zx} = 977\ kgf/cm^2 \quad < \quad \sigma ba = 2{,}700\ kgf/cm^2$$

(2) Shear Stress

$$\tau s = \frac{Smax}{Aw} = 97\ kgf/cm^2 \quad < \quad \sigma sa = 1{,}500\ kgf/cm^2$$

8. ตรวจสอบ Strut Reaction Force



Row	Excav.Stage (tf/m) (Half)	Remov.Stage (tf/m) (Simple-Beam)
1	11.60	-----

9. Calculations for Props.

9-1 . Wale

(1) 1Row

Reaction Force : R =11.60 tf/m

Bending Span : Lb=4.50 m   Lb'=4.50 m

Axial Force Width : Lc=3.15 m

USE : YH350*350

$A = 154.90\ cm^2$ $Af = 57.00\ cm^2$ $Aw = 37.44\ cm^2$

$Zx = 2{,}000\ cm^3$ $B = 35.00\ cm$

ry(ix)=15.10 cm   rz(iy)=8.99 cm   i=9.93 cm

a.Calculation of Stress

$$Mmax = \frac{R*Lb^2}{10} = \frac{11.60*4.50^2}{10} = 23.49\ tf*m$$

Nmax = R*Lc = 11.60*3.15 = 36.54 tf

$$Smax = \frac{R*Lb}{2} = \frac{11.60*4.50}{2} = 26.10\ tf$$

b.Allowable Stress

*Allowable Bending Stress

$$h/tw = 29.2 < 3.76*\left\{1-3.74*\left(\frac{\sigma c}{Fy}\right)\right\}*(E/Fy)^{0.5} = 71.0$$

$$L1 = 0.45*bf*(E/Fy)^{0.5} = 4.56m\ ,\ L2 = \frac{0.69*Af*E}{h*Fy} = 9.44m\ ,Lb' < Min(L1,L2)$$

$bf/2tf = 9.2 < 0.38*(E/Fy)^{0.5} = 11.0$, Hence $fb = 0.66*Fy*1.25 = 2{,}063\ kgf/cm^2$

*Allowable Compresive Stress

$\lambda x = 29.8$, $\lambda y = 50.1$, $Max(\lambda x, \lambda y) < Cc = (2*\pi^2*E/Fy)^{0.5} = 128.8$

$$fc = \left\{1-\left(\frac{\lambda^2}{2*Cc^2}\right)\right\}*Fy\ /\ \left\{\frac{5}{3} + \frac{3*\lambda}{8*Cc} - \frac{\lambda^3}{8*Cc^3}\right\}*1.25 = 1{,}600\ kgf/cm^2$$

*Allowable Shear Stress

$fs = 0.4*Fy*1.25 = 1{,}250\ kgf/cm^2$

c.Stress Check

$$\sigma b = \frac{Mmax}{Zx} = \frac{23.49*10^5}{2{,}000} = 1{,}175\ kgf/cm^2 < 2{,}063\ kgf/cm^2$$ -OK-

$$\sigma c = \frac{Nmax}{A} = \frac{36.54*10^3}{154.90} = 236\ kgf/cm^2 < 1{,}600\ kgf/cm^2$$ -OK-

$$\tau s = \frac{Smax}{Aw} = \frac{26.10*10^3}{37.44} = 697\ kgf/cm^2 < 1{,}250\ kgf/cm^2$$ -OK-

d.Buckling Check

$$\frac{\sigma c}{fc} + \frac{\sigma b}{fb} = 0.717 < 1.00$$ -OK-

9. Calculations for Props.(ต่อ)

9-2 . Strut

(1) 1Row

Reaction Force : R =11.60 tf/m

Self-Weight + α : W =0.50 tf/m

Axial Force Width : Lc=4.50 m

Buckling Span : Lx=5.06 m   Ly=5.06 m

USE   : YH350*350

$A = 154.90\ cm^2$ $Af = 57.00\ cm^2$

$Zx = 2{,}000\ cm^3$ $B = 35.00\ cm$

ry(ix)=15.10 cm   rz(iy)=8.99 cm   i=9.93 cm

a.Calculation of Stress

$$Mmax = \frac{W*Lx^2}{8} = \frac{0.50*5.06^2}{8} = 1.60\ tf*m$$

$$Nmax = R*Lc+\Delta N = 11.60*4.50+22.00 = 74.20\ tf$$

ΔN = 22.00tf Due to Temperature Changing

b.Allowable Stress

*Allowable Bending Stress

$$h/tw = 29.2 < 1.51*(E/Fy)^{0.5} = 44.0$$

$$L1 = 0.45*bf*(E/Fy)^{0.5} = 4.56m\ ,\ L2 = \frac{0.69*Af*E}{h*Fy} = 9.44m$$

Ly > Min(L1,L2) , Hence Noncompact

Hence $fb = 0.6*Fy*1.25 = 1{,}875\ kgf/cm^2$

*Allowable Compresive Stress

$$\lambda x = 33.5\ ,\ \lambda y = 56.3\ ,\ Max(\lambda x,\lambda y) < Cc = (2*\pi^2*E/Fy)^{0.5} = 128.8$$

$$fc = \left\{1-\left(\frac{\lambda^2}{2*Cc^2}\right)\right\}*Fy / \left\{\frac{5}{3} + \frac{3*\lambda}{8*Cc} - \frac{\lambda^3}{8*Cc^3}\right\}*1.25 = 1{,}553\ kgf/cm^2$$

c.Stress Check

$$\sigma b = \frac{Mmax}{Zx} = \frac{1.60*10^5}{2{,}000} = 80\ kgf/cm^2 < 1{,}875\ kgf/cm^2$$

$$\sigma c = \frac{Nmax}{A} = \frac{74.20*10^3}{154.90} = 479\ kgf/cm^2 < 1{,}553\ kgf/cm^2$$

d.Buckling Check

$$\frac{\sigma c}{fc} + \frac{\sigma b}{\left\{1-\left(\frac{\sigma c}{fe}\right)\right\}*fb} = 0.357 < 1.00$$

$$\frac{\sigma c}{0.6*Fy*1.25} + \frac{\sigma b}{fb} = 0.298 < 1.00$$