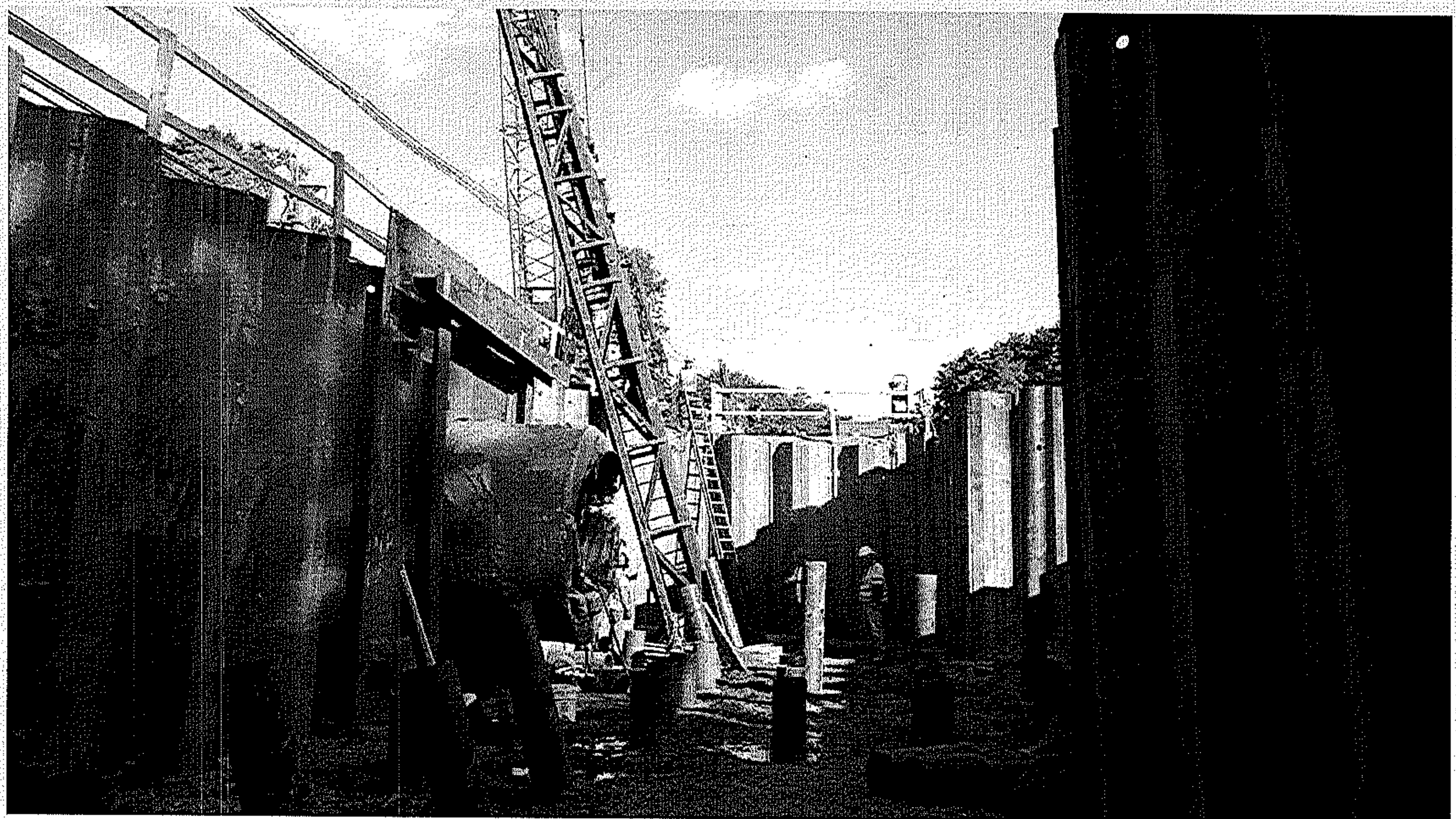
Design of Cantilevered, Non-Gravity, SSP Wall (ASD)
Conventional and Simplified Methods



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B. Design of cantilever sheetpiling in granular soils. A cantilever sheetpiling to be driven to granular soils may be designed by the conventional method in accordance with the principles just discussed, or by an approximate method based on further simplifying assumptions. These methods are illustrated in Fig. 12-9 where the subsoil is assumed to consist of one layer of

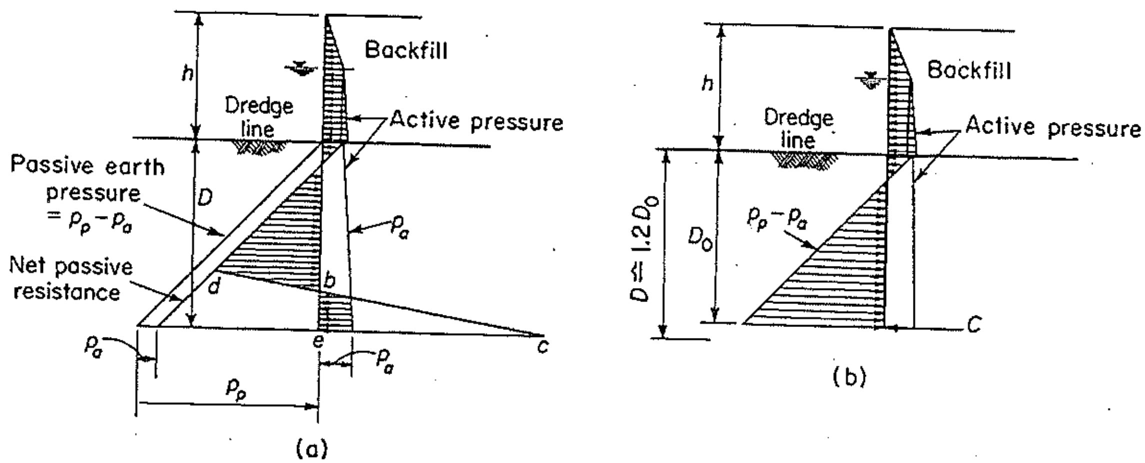


Fig. 12-9 Design of cantilever sheetpiling in granular soils: (a) conventional method; (b) simplified method.

Ref. Foundation Design, Wayne C. Teng, Prentice-Hall, 1962

Design of Cantilevered, Non-Gravity, SSP Wall (ASD) Conventional Method

be a spiral surface. Since the application of the wedge theory is laborious, the Coulomb theory is often used instead. The passive pressure obtained by the Coulomb theory should be used conservatively because it is somewhat greater than the actual values.

The conventional method of design generally consists of the following steps:

1. Sketch a profile of the piling with a trial depth of penetration. Approximate depth of penetration may be taken as follows:

Soil	*Depth of penetration**
Dense	$0.75h$
Firm	$1.0h$
Loose	$1.5h$
Very loose	$2.0h$

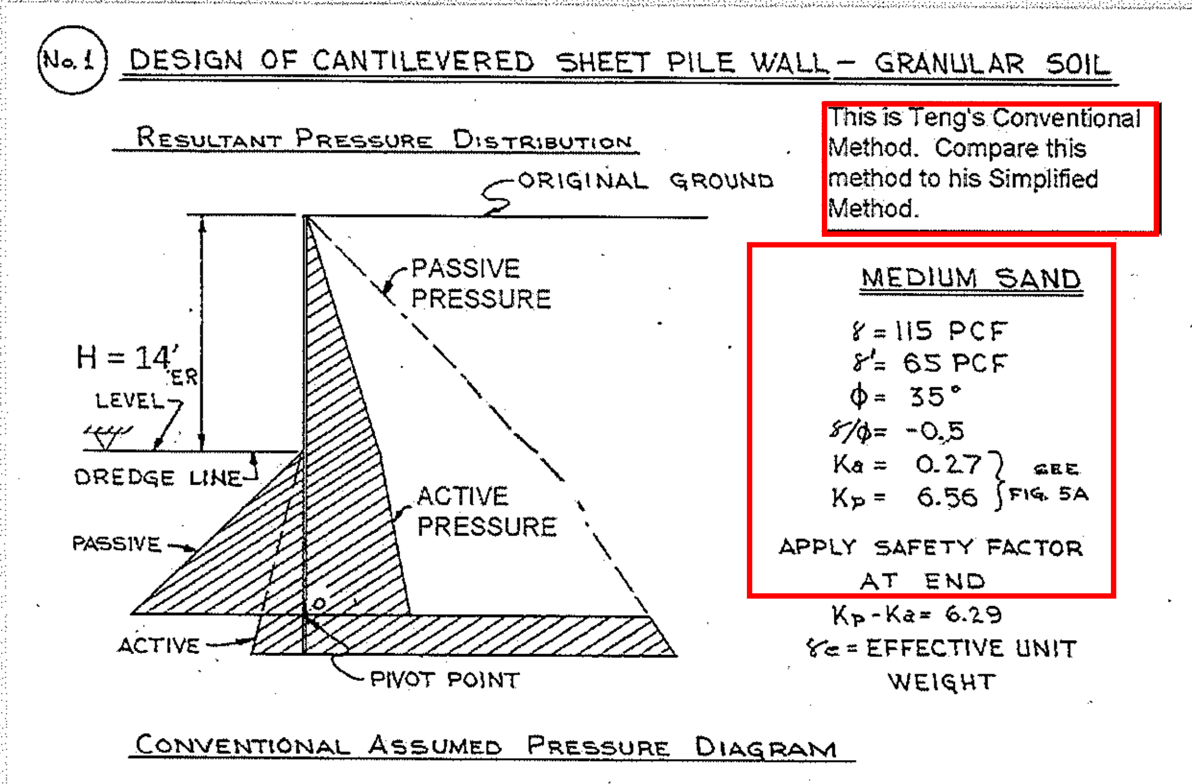
* h = height of piling above the dredge line.

2. Determine the passive earth pressure in front of the piling. This is the gross passive resistance due to the weight of soil. Buoyant weight should be used for soil below water level.
3. Determine the active earth pressure due to surcharge load, the backfill, and the soil layers below.
4. Determine the net passive resistance which is equal to the gross passive pressure (step 2) minus the active earth pressure (step 3).
5. Determine the maximum net passive resistance *ce* which is equal to the passive pressure due to the backfill and soil below, minus the active earth pressure at the foot of the piling due to the soil in front of the sheetpiling.
6. Draw a trial line *cd* and check the statical equilibrium of the entire sheetpiling under the action of the lateral forces. The position of point *d* is correct if the total moment is zero about any point of the piling. When it is impossible to maintain equilibrium with any location of point *d*, the trial penetration is too small.
7. Add 20 to 40 per cent to the calculated depth of penetration. This will give a safety factor of 1.5 to 2.0 approximately. An alternate and more desirable method is the use of a reduced value of passive earth pressure for design. In this method, the maximum allowable earth pressure is limited to $\frac{1}{2}$ to $\frac{2}{3}$ the ultimate passive resistance.
8. Compute the maximum bending moment which occurs at the point of zero shear prior to increasing the depth by 20 to 40 per cent.

Iteration required!

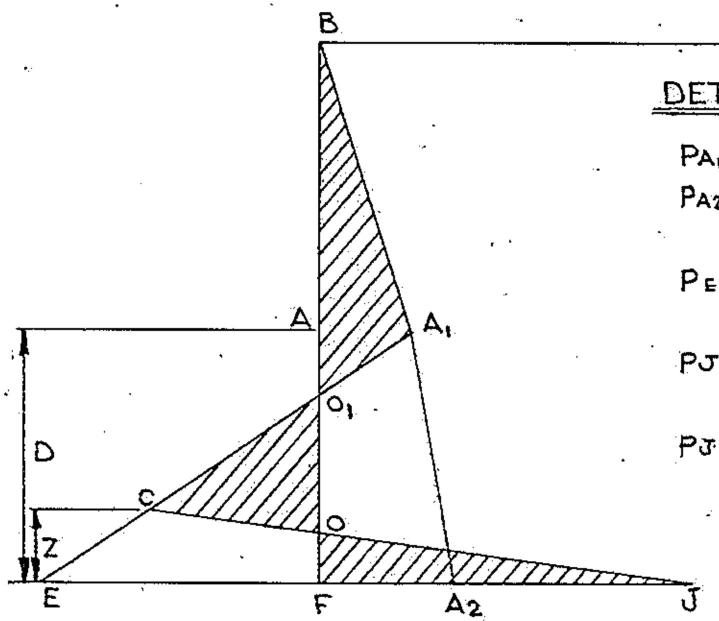
Ref. Foundation Design, Wayne C. Teng, Prentice-Hall, 1962

Design of Cantilevered, Non-Gravity, SSP Wall (ASD)
Teng's Conventional Method



Ref: Steel Sheet Piling Design Manual, United States Steel, 1970, Ex. No. 1, Pg. 86

Design of Cantilevered, Non-Gravity, SSP Wall (ASD)
Teng's Conventional Method



DETERMINE WALL PRESSURES

$P_{A_1} = \gamma_e H K_a = (115)(14.0)(0.27) = 435$ PSF

$P_{A_2} = P_{A_1} + \gamma_e' D K_a = 435 + (65)(0.27) D$

$= 435 + 17.6 D \approx 620$

$P_E = \gamma_e' D (K_p - K_a) - P_{A_1} = 65 D (6.29) - 435$

$= 408.9 D - 435 \approx 3858$

$P_J = \gamma_e' D (K_p - K_a) + \gamma_e H K_p = 65D(6.29) + 115(14)(6.56)$

= 14,855

$P_J = 408.9 D + 10{,}562$

= 14,855

Ref: Steel Sheet Piling Design Manual, United States Steel, 1970, Ex. No. 1, Pg. 86

Design of Cantilevered, Non-Gravity, SSP Wall (ASD)
Teng's Conventional Method

FROM STATICS, THE FOLLOWING CONDITIONS MUST BE SATISFIED

(1) $\Sigma F_H = 0$ IN TERMS OF AREAS:

AREA (BAA_1) + AREA (AA_1A_2F) + AREA (ECJ) − AREA $(EA_1A_2) = 0$

OR

$$\frac{1}{2}(H)PA_1 + (PA_1 + PA_2)\frac{D}{2} + (P_E + PJ)\frac{Z}{2} - (P_E + PA_2)\frac{D}{2} = 0$$

SOLVING FOR Z:

$$Z = \frac{(P_E - PA_1)D - H\,PA_1}{P_E + PJ}$$

(2) ΣM ABOUT ANY POINT IS ZERO

$$\Sigma M_F = \left[\frac{1}{2}(H)PA_1\left(D + \frac{H}{3}\right)\right] + \left[(PA_1)\frac{D^2}{2}\right] + \left[(P_E + PJ)\frac{Z^2}{6}\right] - \left[(P_E + PA_2)\frac{D^2}{6}\right] + \left[(PA_2 - PA_1)\frac{D^2}{6}\right] = 0$$

METHOD OF SOLUTION:

1. ASSUME A DEPTH OF PENETRATION, D
2. CALCULATE Z
3. SUBSTITUTE Z INTO ΣM_F AND CHECK IF ZERO. ADJUST D AND RECALCULATE IF NECESSARY.

TRY D = 10.5 FT.

This is an iterative process.

Design of Cantilevered, Non-Gravity, SSP Wall (ASD)

Teng's Conventional Method

$PA_1 = 435 \text{ PSF} \quad PA_2 = 620 \text{ PSF.} \quad P_J = 14{,}855 \text{ PSF.} \quad P_E = 3858 \text{ PSF}$

$$Z = \frac{(3858-435)(10.5)-(14)(435)}{14{,}855 + 3858} = \frac{29852}{18713} = 1.60 \text{ FT.}$$

$$\Sigma M_F = \left[\tfrac{1}{2}(14)(435)(10.5+4.67)\right]_{(1)} + \left[(435)\frac{(10.5)^2}{2}\right]_{(2)} + \left[(620-435)\frac{(10.5)^2}{6}\right]_{(5)}$$

$$+\left[(3858+14{,}855)\frac{(1.60)^2}{6}\right]_{(3)} - (3858+620)_{(4)}\frac{(10.5)^2}{6}$$

$$\Sigma M_F = \overset{(1)}{46{,}193} + \overset{(2)}{23{,}979} + \overset{(5)}{3399} + \overset{(3)}{7984} - \overset{(4)}{82{,}283}$$

$\Sigma M_F \neq 0$

$\Sigma M_F = -728$ FT.-LB. ~~SAY O.K.~~ ~~USE~~ D = 10.5 FT.

D is NOT 10.5'

Ref: Steel Sheet Piling Design Manual, United States Steel, 1970, Ex. No. 1, Pg. 87

Design of Cantilevered, Non-Gravity, SSP Wall (ASD)
Teng's Conventional Method

This will give a bigger bending moment. No good!

CANTILEVERED SHEET PILE WALL / 1. Granular Soil

TO ASSURE A MARGIN OF SAFETY, D MAY BE INCREASED BY 20 TO ~~40~~ % OR, ALTERNATELY, A REDUCED PASSIVE EARTH PRESSURE COEFFICIENT COULD BE USED.

10.5' X 120% = 12.6'

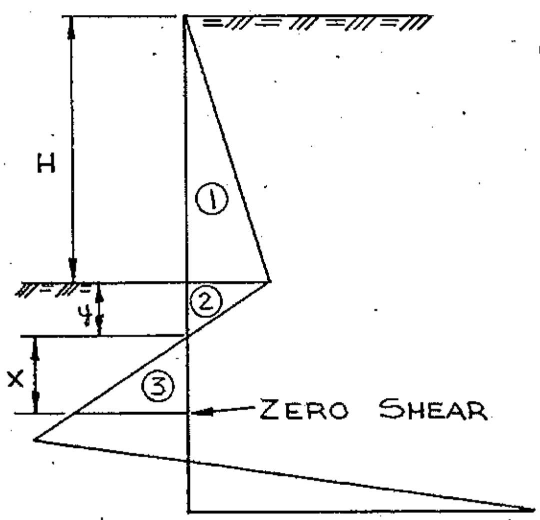
~~USE D = 13.5 FT. (INCREASE = 28.5 %)~~ Remember, US Steel sells steel!

Use SSP length = 14.0' + 12.6' = 26.6'

Ref: Steel Sheet Piling Design Manual, United States Steel, 1970, Ex. No. 1, Pg. 88

Design of Cantilevered, Non-Gravity, SSP Wall (ASD)

Teng's Conventional Method



$$y = \frac{P_{A1}}{\gamma'(K_P - K_a)} = \frac{435}{65(6.29)} = 1.06 \text{ FT.}$$

SAY 1.0 FT.

$$P_1 = \tfrac{1}{2} P_{A1} H = \tfrac{1}{2}(435)(14) = 3040 \text{ LB}$$

$$P_2 = \tfrac{1}{2} P_{A1} y = \tfrac{1}{2}(435)(1.0) = 218 \text{ LB.}$$

Locate Point of Zero Shear in order to calculate the Maximum Moment in SSP

$$\tfrac{1}{2} \gamma' (K_P - K_a) X^2 = P_1 + P_2$$

$$X^2 = \frac{2(P_1 + P_2)}{\gamma'(K_P - K_a)}$$

Ref: Steel Sheet Piling Design Manual, United States Steel, 1970, Ex. No. 1, Pg. 88

Design of Cantilevered, Non-Gravity, SSP Wall (ASD)
Teng's Conventional Method

$$X^2 = \frac{2(3040+218)}{65(6.29)} = \frac{2(3258)}{407} = 16$$

$$X = 4.0 \text{ FEET}$$

MAXIMUM MOMENT

$$P_3 = \tfrac{1}{2}\ \gamma' \ (K_p - K_a)\ 4^2 = P_1 + P_2 = 3280 \text{ LB.}$$

$$M_{MAX} = P_1 \ell_1 + P_2 \ell_2 - P_3 \ell_3$$

$$\ell_1 = \left(\frac{H}{3} + y + X\right)$$

$$\ell_2 = \left(\frac{2y}{3} + X\right)$$

$$\ell_3 = \frac{X}{3}$$

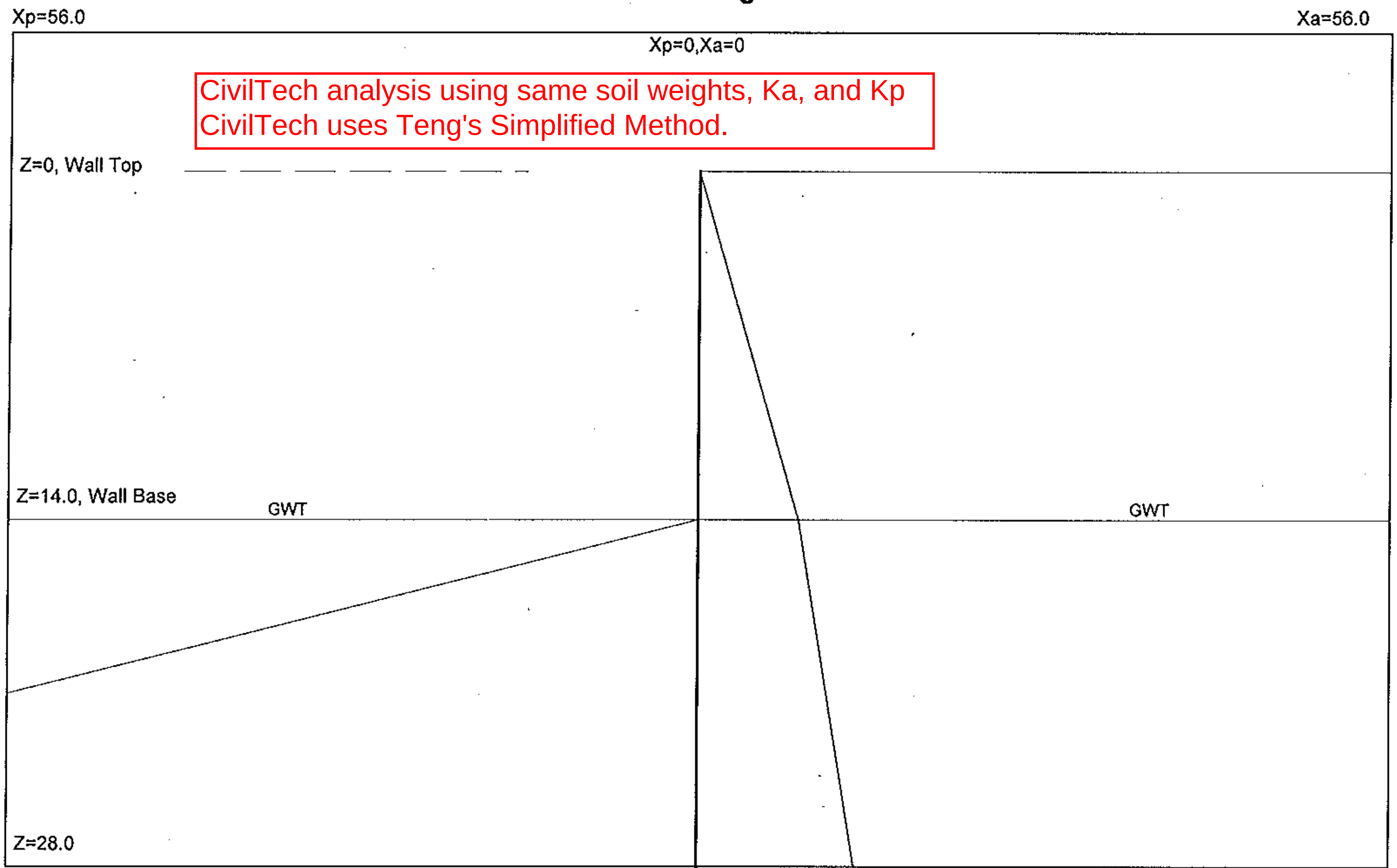
$$M_{MAX} = 3040\left(\frac{14}{3} + 1.0 + 4.0\right) + 218\left(\frac{2(1)}{3} + 4.0\right) - 3280\left(\frac{4.0}{3}\right)$$

$$M_{MAX} = 29{,}300 + 1030 - 4360 = 26{,}000 \text{ FT. LBS.}$$

Ref: Steel Sheet Piling Design Manual, United States Steel, 1970, Ex. No. 1, Pg. 88

Compare US Steel Conventional Method

Ex. No. 1 Page 86



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UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf
Date: 2/23/2017 File: O:\CivilTech\USS Conv. vs. Simplified\14.0'.ep8

* INPUT DATA *

Wall Height=14.0 Total Soil Types= 1

Soil No.	Weight	Saturate	Phi	Cohesion	Nspt	Type	Description
1	115.0	127.4	35	0.0		4	Sand

Ground Surface at Active Side:

Line	Z1	Xa1	Z2	Xa2	Soil No.	Description
1	0.0	0.0	0.0	800.0	1	Sand

Water Table at Active Side:

Point	Z-water	X-water
1	14.0	0.0
2	14.0	800.0

Ground Surface at Passive Side:

Line	Z1	Xp1	Z2	Xp2	Soil No.	Description
1	14.0	0.0	14.0	800.0	1	Sand

Water Table at Passive Side:

Point	Z-water	X-water
1	14.0	0.0
2	14.0	800.0

Wall Friction Options: 3. Both sides (for formulary solution)
Wall Friction = 17.5
Wall Batter Angle = 0
Apparent Pressure Conversion: 1.* Default (Terzaghi and Peck)*

* OUTPUT RESULTS *

Multiplier to force CivilTech to use the same Ka as USS

Total Force above Base= 3.04 per one linear foot (or meter) width along wall height
Total Static Force above Base= 3.04

Driving Pressure above Base - Output to Shoring - Multiplier of Pressure = 1.0971

Z1	Pa1	Z2	Pa2	Slope	Coef.
0.00	0.00	14.00	0.43	0.0311	0.2700

Same as used by USS SSP Design Manual Ex. No. 1

Driving Pressure below Base - Output to Shoring - Multiplier of Pressure = 1.0971

Z1	Pa1	Z2	Pa2	Slope	Ka or Ko
14.00	0.43	28.00	0.68	0.0176	0.2700

Passive Pressure below Base - Output to Shoring - Multiplier of Pressure = 0.8917

Z1	Pp1	Z2	Pp2	Slope	Kp
14.00	0.00	28.00	5.97	0.426	6.5600

Multipler to force CivilTech to use the same Kp as UUS

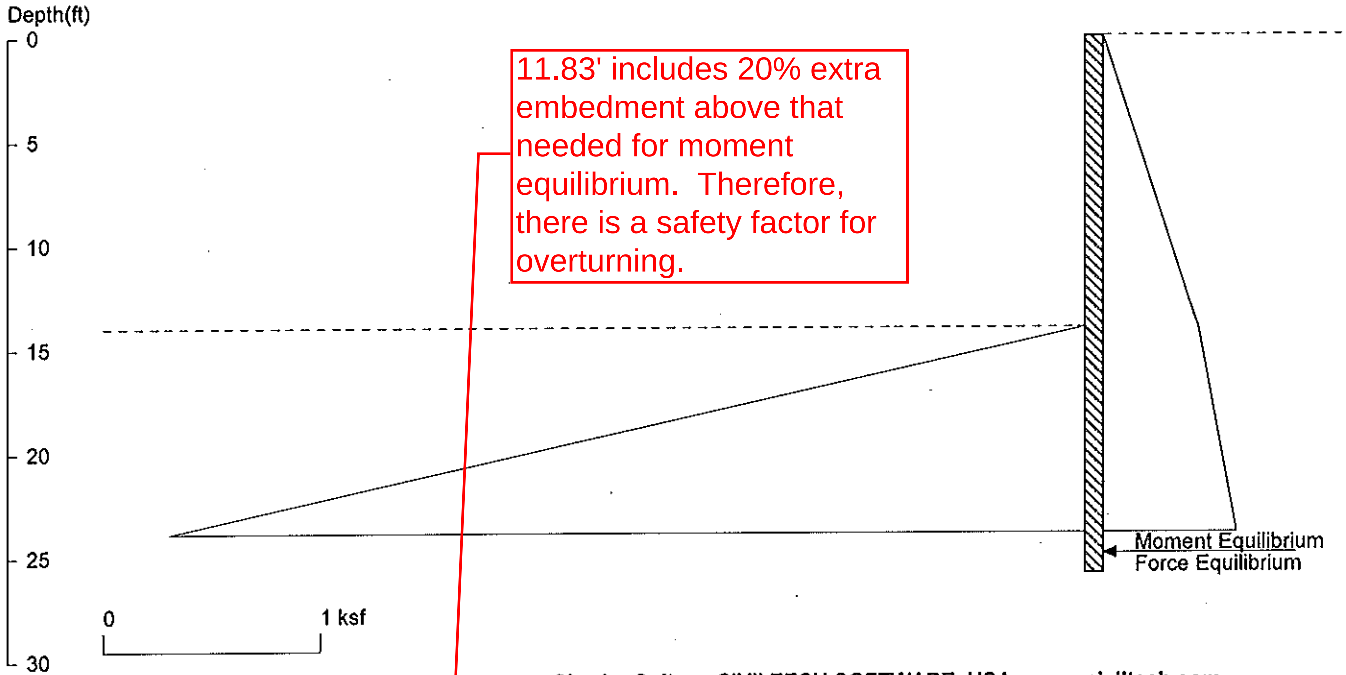
UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

Date: 2/23/2017 File Name: O:\CivilTech\USS Conv. vs. Simplified\14.0'.ep8

CivilTech calculated slightly different Ka and Kp than what USS got from a chart. Therefore, I added the earth pressure multipliers to adjust Civiltech's coefficients to be the same as those used by USS, Ex. No. 1.

Compare US Steel Conventional Method

Ex. No. 1 Page 86



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Wall Height=14.0 Pile Diameter=1.0 Pile Spacing=1.0 Wall Type: 1. Sheet Pile

PILE LENGTH: Min. Embedment=11.83 Min. Pile Length=25.83

MOMENT IN PILE: Max. Moment=26.34 per Pile Spacing=1.0 at Depth=19.06

vs. USS's L = 26.6' (< 3% difference)

vs. USS's M = 26.0 ft-kips/lf (1.3% difference)

DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE):

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	14.000	0.435	0.031052
*	Below	Base		
14.000	0.435	126.000	2.400	0.017551

PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		
14.000	0.000	126.000	47.757	0.426398

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	1.00
2	14.00	1.00

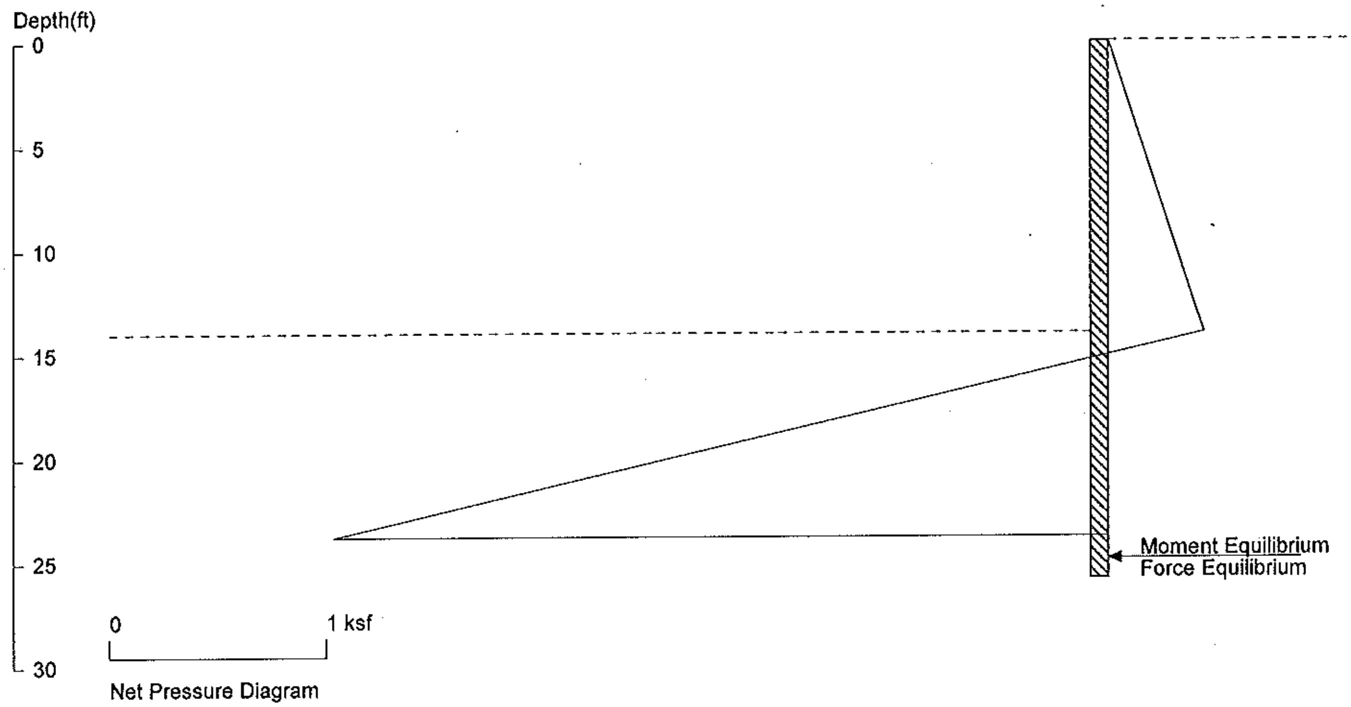
PASSIVE SPACING:

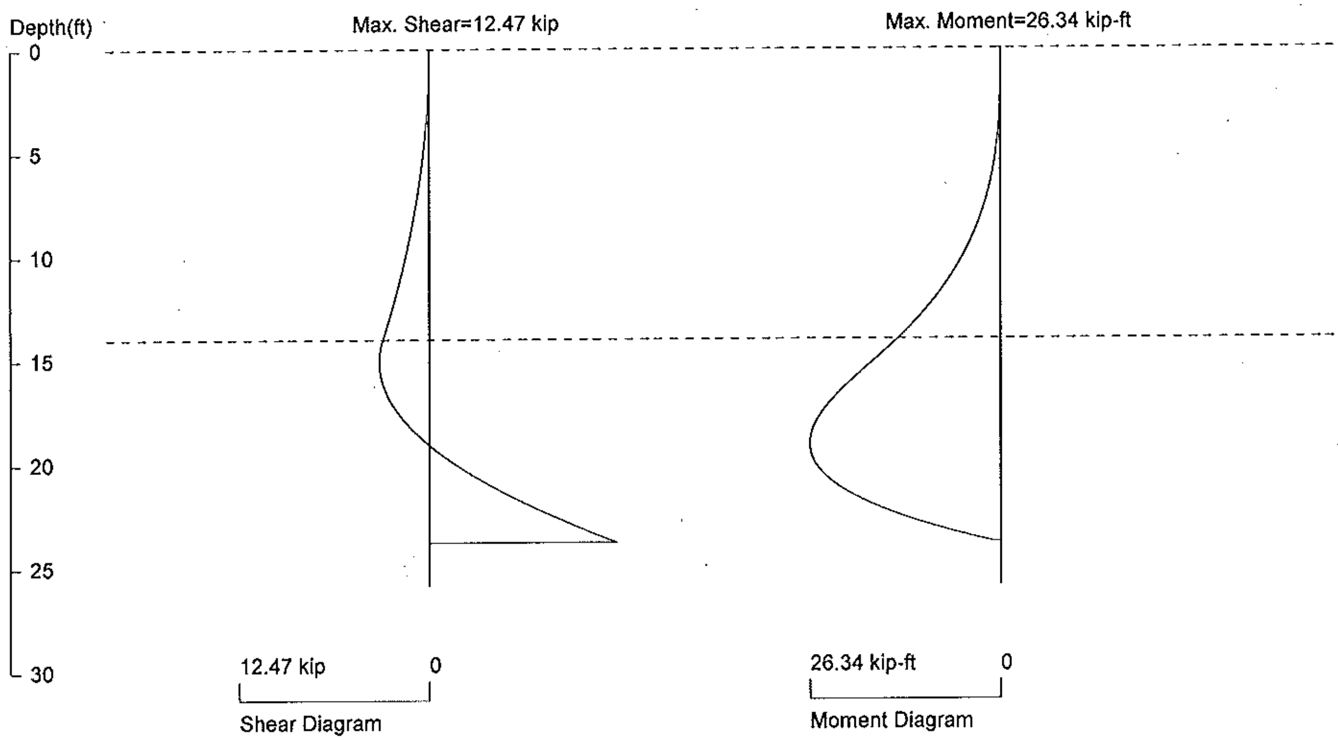
No.	Z depth	Spacing
1	0.00	1.00

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft3; Deflection - in

Compare US Steel Conventional Method

Ex. No. 1 Page 86





PRESSURE, SHEAR, AND MOMENT DIAGRAMS

Based on pile spacing: 1.0 foot or meter

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