Adjacent Pile Soldier Piles Derivation

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Abstract:

In many cases, soil is soft, and driving is possible on the upper surface. Shoring can be done without drilling equipment with two driven adjacent soldier piles. For example, a farmer can use a sludge hammer or a jackhammer to build a 5 ft retaining wall using pipes. Third-world countries can build their walls similarly using tubes without heavy drilling equipment. First, we show the passive resistance soil mechanics of embedded two adjacent piles. Second, we show the derivation of a cantilevered pile—third, we show how to use equivalent pressures on the wall.

1 - The passive resistance soil mechanics of embedded two adjacent piles:

Figure 1 shows two adjacent piles with the passive wedge on the left side.

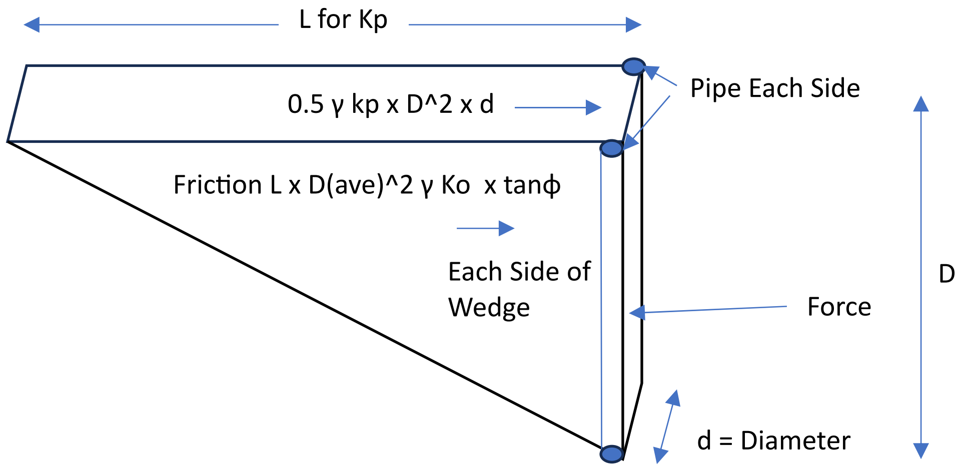
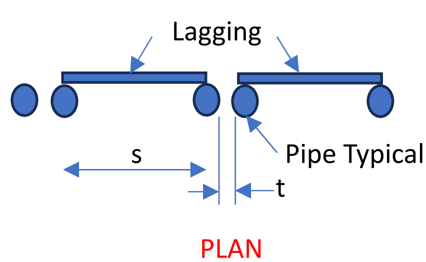


Figure 1

Adjacent Two Pipes Soldier Pile Shoring. Soil arch in the space between Pipes, no need for lagging. Install two pipes in drilled holes and fill them with concrete or drive pipes to proper embedment. Install lagging placed from Pipe to Pipe. Pipes can also be replaced by Wide Flange or H piles.



t can be 10 to 12 inches

s can be 8 ft

If the pipe diameter is 4 inches, then the passive diameter is (4"+4"+12")**N.*

A review of the how to calculate *N:*

Old Derivation from Retaining Wall Patent:

$$\text{N (for cohesiveless soil)} = 1 + \left(\frac{4K_0 \tan\phi}{3}\right)\left(\frac{D}{d1}\right)$$

$$\text{N (for cohesive soil)} = 1 + \left[\frac{2\left(\frac{c}{\gamma D}\right)}{1+4\left(\frac{c}{\gamma D}\right)}\right]\left(\frac{D}{d1}\right)$$

New Derivation:

$$N\ (For\ Cohesiveless\ soil) = 1 + \left(\frac{4\ K_0 \tan\varphi}{3}\right)\left(\frac{D}{d1}\right) + \left(\frac{2K_0 \tan\varphi}{3\sqrt{K_p}}\right)\left(\frac{D}{d1}\right)$$

Passive = W x tan(45+ϕ/2) = 0.5 x d1x L x D x tan(45+ϕ/2)

W = the weight of the effective wedge.

L = D x tan(45+ϕ/2)

The line equation is $x = (\frac{L}{D})(D\text{-}y)$

We take the resultant friction at tan(45+ϕ/2) at the bottom of the wedge; on each side, it increases W Because the wedge tries to move upward.

Integral increase weight = $2\tan(45 + \frac{\varphi}{2}) \int_0^D 2\tan\varphi\ k_0 y \left[\frac{L}{D}(D-y)\right] dy = \frac{2}{3} k_0 D L^2 \tan\varphi$

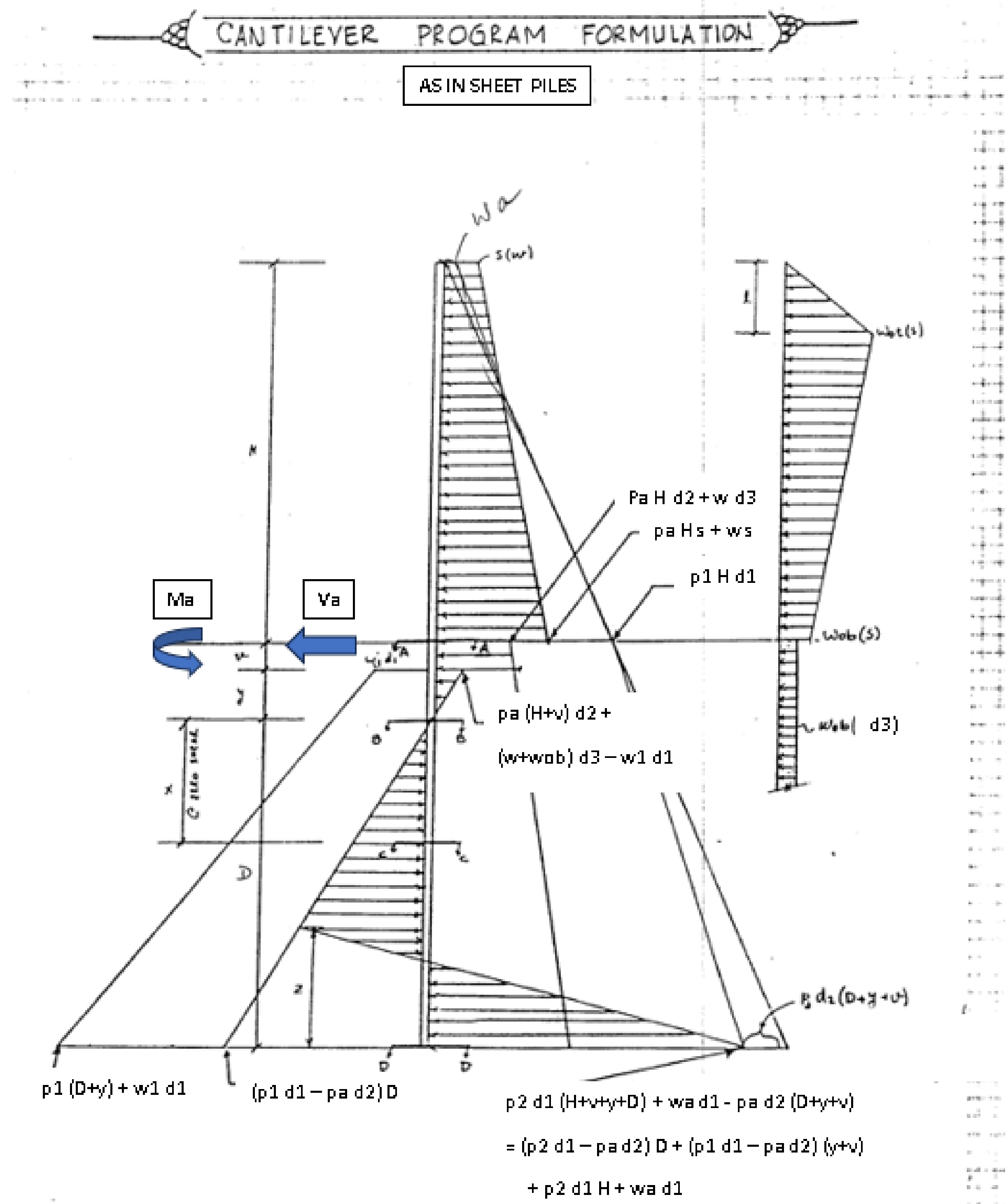
Integral increase side friction = $\int_0^D 2\tan\varphi\ k_0 y \left[\frac{L}{D}(D-y)\right] dy = \frac{1}{3} k_0 D^2 L \tan\varphi$

$$N(For\ Cohesiveless\ Soil = \frac{\frac{1}{2} d1\ LD\tan\left(45 + \frac{\varphi}{2}\right) + \frac{2}{3} K_0 D L^2 \tan\varphi + \frac{1}{3} K_0 D^2 L\tan\varphi}{\frac{1}{2} d1\ LD\tan\left(45 + \frac{\varphi}{2}\right)}$$

OR

$$N\ (For\ Cohesiveless\ soil) = 1 + \left(\frac{4\ K_0 \tan\varphi}{3}\right)\left(\frac{D}{d1}\right) + \left(\frac{2K_0 \tan\varphi}{3\sqrt{K_p}}\right)\left(\frac{D}{d1}\right)$$

2- The derivation of a cantilevered pile



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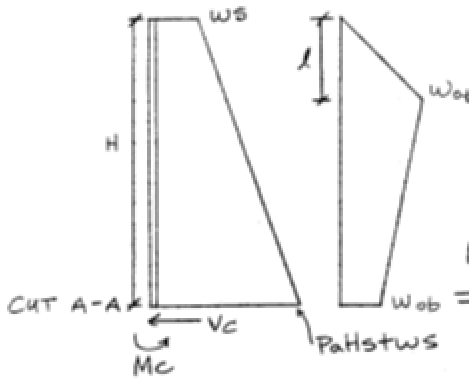


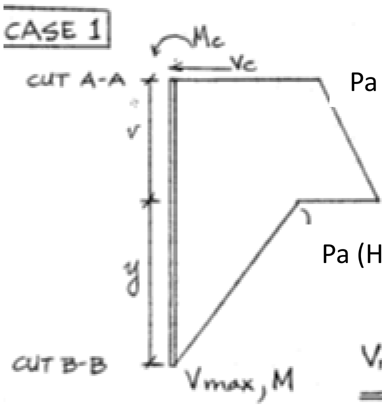
$\Sigma F = 0$ at cut A-A:

$$V_c = wsH + \tfrac{1}{2}H^2 p_a S + \tfrac{1}{2} w_{ot}\, l\, S + \tfrac{1}{2}(H-l)(S)(w_{ot}+w_{ob}) + V_a$$

$\Sigma M = 0$ at cut A-A:

$$M_c = \frac{wsH^2}{2} + \frac{H^3 p_a S}{6} + \frac{w_{ot} S l}{2}\left(H - \frac{2l}{3}\right) + \frac{S}{6}(H-l)^2(w_{ob} + 2w_{ot}) + M_a$$

CASE 1



zero pressure at y:

$$y = \frac{p_a(H+v)d_2 + (w+w_{ob})d_3 - w_1 d_1}{p_1 d_1 - p_a d_2}$$

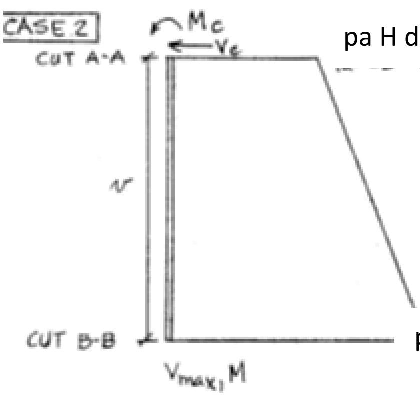
$\Sigma F = 0$ at cut B-B

$$V_{max} = V_c + v\left[p_a H d_2 + (w+w_{ob})d_3 + \frac{p_a v d_2}{2}\right] + \tfrac{1}{2} y\left[p_a(H+v)d_2 + (w+w_{ob})d_3 - w_1 d_1\right]$$

$\Sigma M = 0$ at cut B-B

$$M = M_c + V_c(v+y) + v\left(y+\frac{v}{2}\right)\left[p_a H d_2 + (w+w_{ob})d_3\right] + \frac{v}{2}\left(y+\frac{v}{3}\right)(p_a v d_2) + \frac{y^2}{3}\left[p_a(H+v)d_2 + (w+w_{ob})d_3 - w_1 d_1\right]$$

CASE 2



$y = 0$

$\Sigma F = 0$ at cut B-B

$$V_{max} = V_c + \frac{v}{2}\left[2 p_a H d_2 + 2(w+w_{ob})d_3 + p_a v d_2\right]$$

pa (H+v) d2 + (w+w0b) d3 $< w_1 d_1 \rightarrow y = 0$

$\Sigma M = 0$ at cut B-B

$$M = M_c + vV_c + \frac{v^2}{2}\left[p_a H d_2 + (w+w_{ob})\, d_3\right] + \frac{v^3}{6} p_a d_2$$

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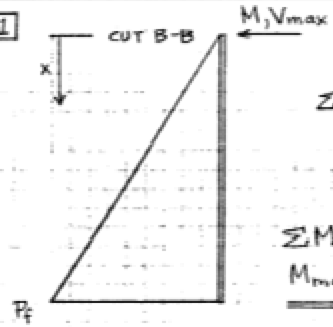
CASE 1



$w_f = 0$

$\Sigma F = 0$ at cut B-B

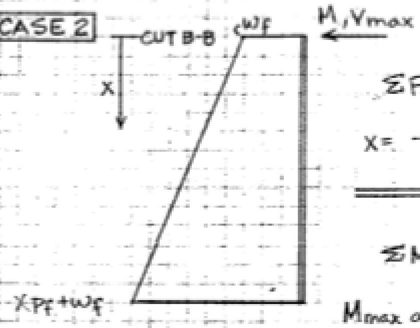
$$x = \sqrt{\frac{2V_{max}}{P_f}}$$

$$P_f = P_1 d_1 - P_a d_2$$

$\Sigma M = 0$ at x

$$M_{max} \text{ at } x = M + x V_{max} - \frac{P_f x^3}{6}$$

CASE 2



$$-w_f = p_a(H+v)d_2 + wd_3 - w_1 d_1 + W_o b d_3$$

$\Sigma F = 0$ at cut B-B

$$x = -\frac{w_f}{P_f} + \sqrt{\left(\frac{w_f}{P_f}\right)^2 + \frac{2V_{max}}{P_f}}$$

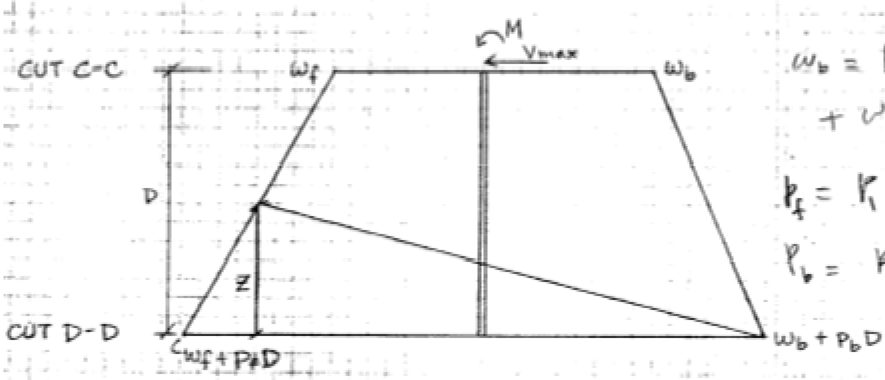
if $P_f = 0$

$$w_f x = V_{max}$$

$$x = \frac{V_{max}}{w_f}$$

$\Sigma M = 0$ at x

$$M_{max} \text{ at } x = M + x V_{max} - \frac{P_f x^3}{6} - \frac{w_f x^2}{2}$$



$$w_b = P_2 d_1 H + (P_2 d_1 - P_a d_2)(y+a) + v a d_1$$

$$P_f = P_1 d_1 - P_a d_2$$

$$P_b = P_2 d_1 - P_a d_2$$

from the force equation at cut D-D ($\Sigma F = 0$ at D-D) we obtain an equation for z (unknown)

$$z = \frac{2 w_f D + P_f D^2 - 2P}{w_f + w_b + D(P_f + P_b)}$$

$$P = V_{max}$$

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from the moment equation at cut D-D ($\Sigma M = 0$ at D-D) and the above equation for z we obtain an equation for D (unknown)

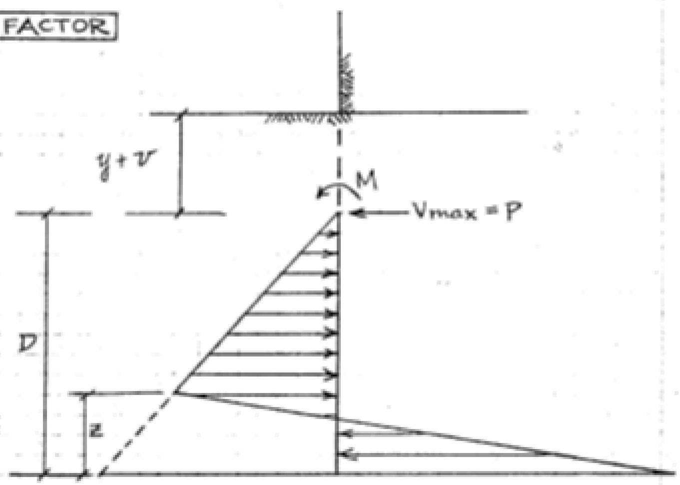
$$p_f p_b D^4 + (3w_f p_b + w_b p_f)D^3 + [(3w_b - w_f)w_f - P(6p_b + 2p_f)]D^2$$
$$-[6M(p_b + p_f) + P(6w_b - 2w_f)]D - 6M(w_f + w_b) - 4P^2 = 0$$

if $p_f p_b = 0$ its cubic

by solving this equation, D is found and thus the embedment is also found.

$$\text{Embedment} = D + y + v$$

SAFETY FACTOR



Assume $D_o > D$ req'd and determine new values for M • P

The equation becomes

$$p_f p_b D_o^4 + (3w_f p_b + w_b p_f)D_o^3 + [(3w_b - w_f)w_f - P(6p_b + 2p_f)]D_o^2$$
$$-[6M(p_p + p_f) + P(6w_b - 2w_f)]D_o - 6M(w_f + w_b) - 4P^2 = 0$$

or $4P^2 + k_1 P + k_2 M = k_3$

where $k_1 = (6p_p + 2p_f)D_o^2 + (6w_b - 2w_f)D_o$

$k_2 = 6(p_b + p_f)D_o + 6(w_f + w_b)$

$k_3 = p_f p_b D_o^4 + (3w_f p_b + w_b p_f)D_o^3 + (3w_b - w_f)w_f D_o^2$

Safety Factor on overturning: P remains the same; M is increased by ΔM

$$\therefore\ 4P^2 + k_1 P + k_2(M + \Delta M) = k_3 \longrightarrow \quad S.F.\ O.T. = \frac{M + \Delta M}{M} = \frac{k_3 - 4P^2 - k_1 P}{k_2 M}$$

Safety Factor on shear: M remains the same; P is increased by ΔP

$$\therefore\ 4(P + \Delta P)^2 + k_1(P + \Delta P) + k_2 M - k_3 = 0$$

$$S.F.\ shear = \frac{P + \Delta P}{P} = \frac{-\frac{k_1}{8} + \sqrt{\left(\frac{k_1}{8}\right)^2 - \frac{k_2 M - k_3}{4}}}{P}$$

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********* Definition Of Symbols *********

INPUT
-----

w   = Uniform surcharge ksf
a   = Spacing ft
H   = Cut height ft
p_a = Active triangular kcf
w_{ot} = Top surcharge due to point, line or strip load ksf
w_{ob} = Bop surcharge due to point, line or strip load ksf
l   = Distance where w_{ot} is from top of pile ft
v   = Distance where passive starts below cut ft
d_2 = Active dia. = (pile dia)x(# of dia) ft
w_1 = Uniform passive starting @ v ksf
d_1 = Passive dia. = (pile dia)x(# of dia) ft
p_1 = Passive triangular in front of pile kcf
p_2 = Passive triangular in back of pile kcf
w_f = $p_a\,(H+v)d_2 + (w+w_{ob})d_2 - w_1 d_1$, (=0 if $y \neq 0$)
p_f = $p_1 d_1 - p_a d_2$
p_b = $p_2 d_1 - p_a d_2$
w_b = $p_b\,(y+v) + p_2 d_1 H$

OUTPUT

Vc   = Shear @ sect A-A (bot of excav.) kips
Mc   = Moment @ sect A-A (bot of excav.) ft-k
y   = Distance where maximum shear occurs ft
Vmax= Maximum shear @ sect B-B kips
M   = Maximum moment @ sect B-B ft-k
x   = Distance where maximum moment occurs ft
Mmax= Maximum moment @ sect C-C ft-k
z   = Distance needed for equilibrium ft
D   = Distance needed for embedment
Embedment = v + y + D
D_s = Distance selected for req'd S.F.

d3 = active diameter below A-A cut
Wa = ksf passive at top grade also is referred to as W2
Wf (revised) = pa (H+v) d2 + (w+w0b) d3 - w1 d1
Wb (revised) = pb (y+v) + p2 d1 H + wa d1

3- How to use equivalent pressures on the wall:

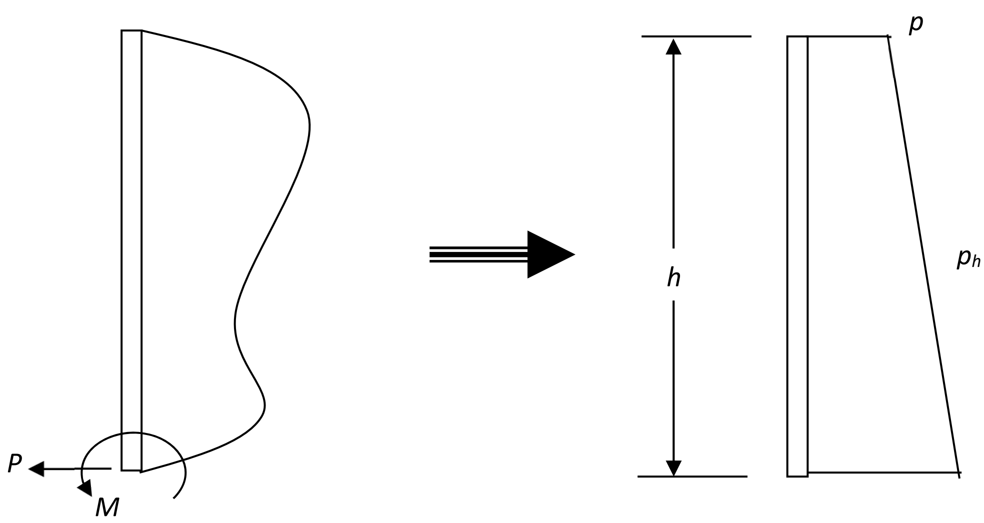

FIG 1

$$\begin{aligned} P &= ph + \frac{p_h h^2}{2} \\ M &= \frac{ph^2}{2} + \frac{p_h h^3}{6} \\ &\textit{thus} \\ p &= 6\frac{M}{h^2} - 2\frac{P}{h} \\ p_h &= -12\frac{M}{h^3} + 6\frac{P}{h^2} \end{aligned} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Equation 1 allows the conversion of any pressure into a trapezoidal pressure for active or passive pressure.

Seismic Active Load:

$$P = \frac{\gamma K_A h^2}{2} + \frac{\gamma (K_{AE} - K_A) h^2}{2}$$
$$M = \frac{\gamma K_A h^3}{6} + \frac{\gamma (K_{AE} - K_A) h^3}{3}$$

$$or$$

$$p = \gamma(K_{AE} - K_A)h$$

$$p_h = \gamma(2K_A - K_{AE})$$

……………………………………… (2)

For designing reinforcing with seismic, the load factor is 1.0E+1.6H. Since it is intended for 1.6H total, a reduction in the load is allowed for the seismic design, and Equation 2 becomes:

$$P = \frac{\gamma K_A h^2}{2} + \frac{\gamma(K_{AE} - K_A)h^2}{2(1.6)}$$
$$M = \frac{\gamma K_A h^3}{6} + \frac{\gamma(K_{AE} - K_A)h^3}{3(1.6)}$$
$$or$$
$$p = \frac{\gamma(K_{AE} - K_A)h}{1.6}$$
$$p_h = \gamma K_A - \frac{\gamma(K_{AE} - K_A)}{1.6}$$

………………………………………………………. (3)

Equations 2 and 3 are to help out, but Equation 1 is the main solution, and if it is necessary, add seismic divide by 1.6 as in Equation 3.

For at-rest pressure, replace by K0 instead of KA and K0E instead of KAE.

If there is water, recalculate the active pressures using Equation 1. For the passive pressure, adjust K_p in cell R9 to be $(\gamma - \gamma_w)K_p / \gamma$. Thus, change the formula to multiply by a factor close to ½.