TYPAR® GEOCELLS

STABILITY CALCULATIONS WITH SAND BALLAST

Scenario 1: Two stacked sand-filled T1 TYPAR GEOCELLS units:

A free-body diagram of the forces acting on the Scenario 1 arrangement is shown in Figure 1.0 below. The cells are analyzed as a monolithic system.

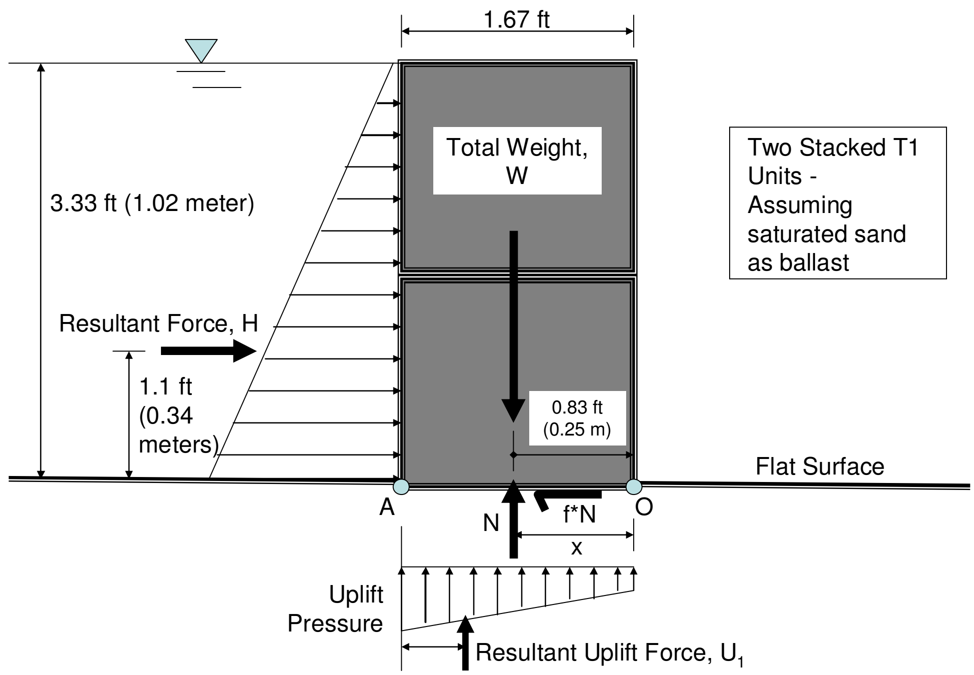

Figure 1.0 – Sand-Filled T1 TYPAR GEOCELLS – Two 0.5-meter Units Stacked Together

Total weight of saturated sand inside two T1 units = $110\frac{lb_f}{ft^3}*(1.67)*(3.34) = 614\frac{lb}{ft}$

d_w = distance below headwater = 3.34 ft

Δh = differential head = 3.34 ft

L_{A-O} = length from point A to point O = 1.67 ft

L_T = total length from water elevation to point O = 3.34 + 1.67 = 5 ft.

Uplift pressure at point A = $(d_w - \frac{\Delta h*(d_w)}{L_T})$*(unit weight of water)

Uplift pressure at point A = $[3.34ft - \frac{3.34*(3.34)}{(3.34+1.67)}]*(62.4\frac{lb_f}{ft^3}) \cong 69.5\frac{lb_f}{ft^2}$

Uplift pressure at point O = $(d_w - \frac{\Delta h*(d_w + L_{A-O})}{L_T})$*(unit weight of water)

Uplift pressure at point O = $[3.34ft - \frac{3.34*(5)}{(5)}]*(62.4\frac{lb_f}{ft^3}) \cong 0\frac{lb_f}{ft^2}$

Resultant Uplift Force, U_1 = $(0.5*(69.5)*1.67 = 58\frac{lb_f}{ft}$ acting at 1.11 ft from Point O

The resultant force due to hydrostatic pressure, H: $(0.5*207.8*3.34) = 347\frac{lb_f}{ft}$

The resultant hydrostatic force, H, is acting at a distance $(\frac{1}{3}*3.34) = 1.1$ ft up from point A

Resistance to sliding:

Coefficient of friction, f

Normal Force = N

Resulting force acting to resist sliding = f*N (neglecting adhesion)

Summation of Forces:

$+\uparrow \sum F_y = W - N - U_1 = 0;$

614 – N –58 = 0

$N = 556\frac{lb_f}{ft}$

$\overset{+}{\rightarrow} \sum F_x = H - f*N = 0;$

347– f*(556)= 0;

f must be $\geq$ 0.62 for stability against sliding – **Marginal stability based on published interface data**

$\circlearrowleft + \sum M_o$ = summation of moments about point O:

Overturning Moment (OM) = 58*(1.1) +347*(1.1)
Resisting Moment (RM) = 614*(0.83)

Factor of Safety (FS) = RM/OM = 510/445.5 = 1.14

Solving for FS: FS is less than 1.5- **Considered unstable**.

Scenario 2: Two stacked sand-filled T2 TYPAR GEOCELLS units:

A free-body diagram of the forces acting on the Scenario 2 arrangement is shown in Figure 2.0 below. The cells are analyzed as a monolithic system.

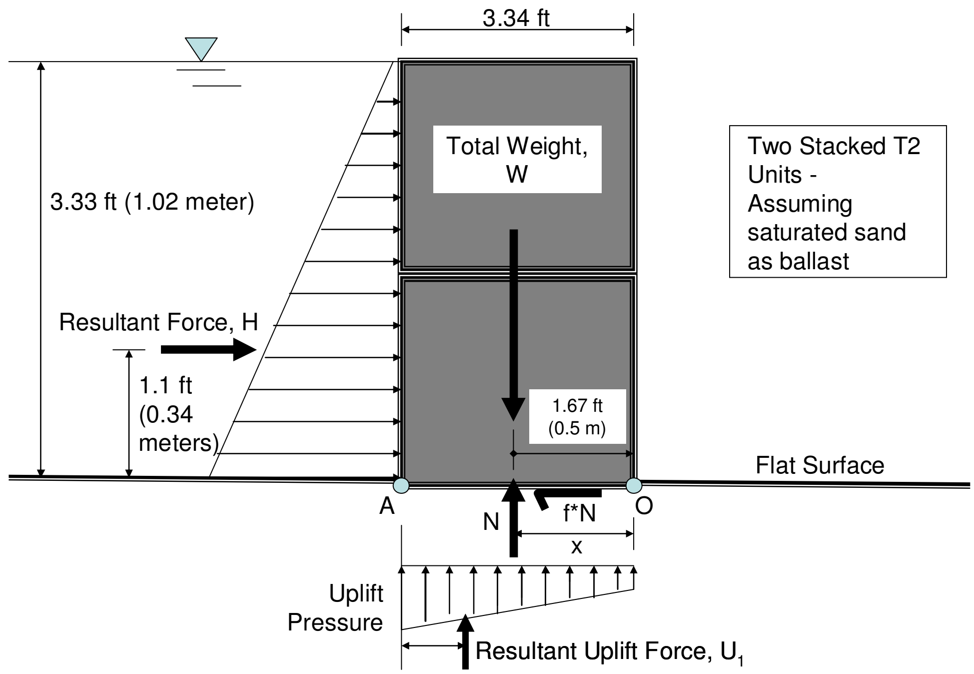

Figure 2.0 – Sand-Filled T2 TYPAR GEOCELLS – Two 0.5-meter Units Stacked Together

Total weight of saturated sand inside two T2 units = $110\frac{lb_f}{ft^3}*(3.34)*(3.34) = 1227.1\frac{lb}{ft}$

d_w = distance below headwater = 3.34 ft

Δh = differential head = 3.34 ft

L_{A-O} = length from point A to point O = 3.34 ft

L_T = total length from water elevation to point O = 3.34 + 3.34 = 6.68 ft.

Uplift pressure at point A = $(d_w - \frac{\Delta h*(d_w)}{L_T})$*(unit weight of water)

Uplift pressure at point A = $[3.34ft - \frac{3.34*(3.34)}{(3.34+3.34)}]*(62.4\frac{lb_f}{ft^3}) \cong 104.2\frac{lb_f}{ft^2}$

Uplift pressure at point O = $(d_w - \frac{\Delta h*(d_w + L_{A-O})}{L_T})$*(unit weight of water)

Uplift pressure at point O = $[3.34ft - \frac{3.34*(6.68)}{(6.68)}]*(62.4\frac{lb_f}{ft^3}) \cong 0\frac{lb_f}{ft^2}$

Resultant Uplift Force, U_1 = $(0.5*(104.2)*3.34 = 174\frac{lb_f}{ft}$ acting at 2.2 ft from Point O

The resultant force due to hydrostatic pressure, H: $(0.5*207.8*3.34) = 347\frac{lb_f}{ft}$

The resultant hydrostatic force, H, is acting at a distance $(\frac{1}{3}*3.34) = 1.1$ ft up from point A

Resistance to sliding:

Coefficient of friction, f

Normal Force = N

Resulting force acting to resist sliding = f*N (**neglecting adhesion**)

Summation of Forces:

$+\uparrow \sum F_y = W - N - U_1 = 0;$

1227.1 – N – 174 = 0

$N = 1053.1 \frac{lb_f}{ft}$

$\overset{+}{\rightarrow} \sum F_x = H - f*N = 0;$

347 – f*(1053.1)= 0;

f must be ≥ 0.33 for stability against sliding – **stable based on published interface friction coefficients for sand to rock and sand to soil interface conditions (>0.60) and need for safety factors of 1.5 or greater.(SF= 1.8).**

$\circlearrowright + \sum M_o =$ summation of moments about point O:

Overturning Moment (OM) = 174*(2.2) +347*(1.1)
Resisting Moment (RM) = 1227.1*(1.67)

Factor of Safety (FS) = RM/OM = 2049/765 = 2.67

Solving for FS: FS is greater than 1.5- **Considered stable**.

Scenario 3: One sand-filled T2 TYPAR GEOCELLS unit stacked on top of one sand-filled T3 unit:

A free-body diagram of the forces acting on the Scenario 3 arrangement is shown in Figure 3.0 below. The cells are analyzed as a monolithic system.

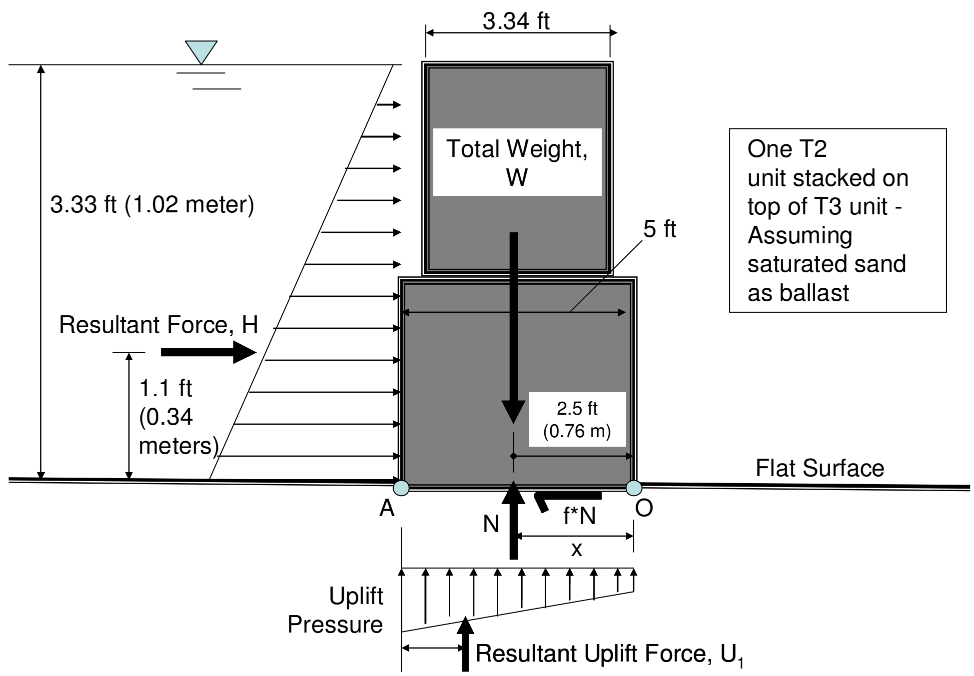

Figure 3.0 – Sand-Filled T2 TYPAR GEOCELLS Stacked Atop T3 TYPAR GEOCELLS Unit

Total weight of saturated sand two units =

$$110\frac{lb_f}{ft^3}*[(3.34)*(1.67)+(5)*(1.67)]=1532.1\frac{lb}{ft}$$

d_w = distance below headwater = 3.34 ft

Δh = differential head = 3.34 ft

L_{A-O} = length from point A to point O = 5.0 ft

L_T = total length from water elevation to point O = 3.34 + 5.0 = 8.34 ft.

Uplift pressure at point A = $(d_w - \frac{\Delta h*(d_w)}{L_T})$*(unit weight of water)

Uplift pressure at point A = $[3.34ft-\frac{3.34*(3.34)}{(8.34)}]*(62.4\frac{lb_f}{ft^3})\cong 125\frac{lb_f}{ft^2}$

Uplift pressure at point O = $(d_w - \frac{\Delta h*(d_w+L_{A-O})}{L_T})$*(unit weight of water)

Uplift pressure at point O = $[3.34\,ft - \frac{3.34*(8.34)}{(8.34)}]*(62.4\frac{lb_f}{ft^3}) \cong 0\frac{lb_f}{ft^2}$

Resultant Uplift Force, U_1 = $(0.5*(125)*5.0 = 312.5\frac{lb_f}{ft}$ acting at 3.34 ft from Point O.

The resultant force due to hydrostatic pressure, H: $(0.5*207.8*3.34) = 347\frac{lb_f}{ft}$

The resultant hydrostatic force, H, is acting at a distance $(\frac{1}{3}*3.34) = 1.1$ ft up from point A

Resistance to sliding:

Coefficient of friction, f

Normal Force = N

Resulting force acting to resist sliding = f*N (neglecting adhesion)

Summation of Forces:

$+\uparrow \sum F_y = W - N - U_1 = 0;$

1532.1 – N –312.5 = 0

$N = 1219.6\ \frac{lb_f}{ft}$

$\xrightarrow{+} \sum F_x = H - f*N = 0;$

347 – f*(1219.6)= 0;

f must be $\geq$ 0.28 for stability against sliding – **provides satisfactory stability based on published interface friction coefficients for sand to rock and sand to soil interface conditions (>0.6) with a safety factor of 2.1.**

$\circlearrowright + \sum M_o$ = summation of moments about point O:

Overturning Moment (OM) = 312.5*(3.34) +347*(1.1)
Resisting Moment (RM) = 1532.1*(2.5)

Factor of Safety (FS) = RM/OM = 3830/1425 = 2.68

Solving for FS: FS is greater than 1.5- **Considered stable**.

Scenario 4: Two sand-filled T3 TYPAR GEOCELLS units stacked on top of each other:

A free-body diagram of the forces acting on the Scenario 4 arrangement is shown in Figure 4.0 below. The cells are analyzed as a monolithic system.

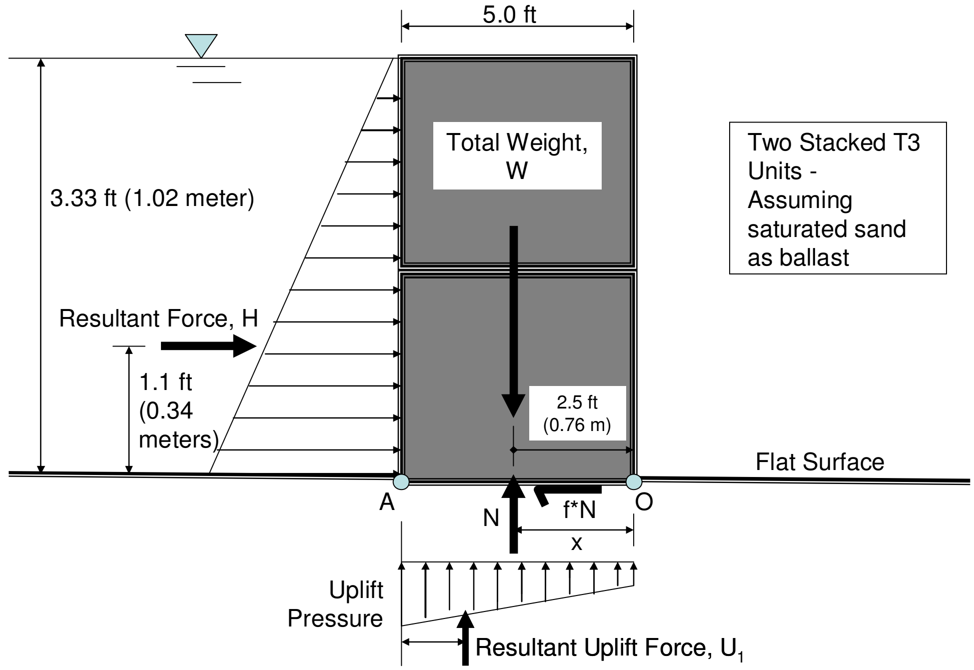

Figure 4.0 – Two Sand-Filled T3 TYPAR GEOCELLS Units Stacked Atop One Another

Total weight of saturated sand two units = $110\frac{lb_f}{ft^3} * [(5) * (3.34)] = 1837\frac{lb}{ft}$

d_w = distance below headwater = 3.34 ft

Δh = differential head = 3.34 ft

L_{A-O} = length from point A to point O = 5.0 ft

L_T = total length from water elevation to point O = 3.34 + 5.0 = 8.34 ft.

Uplift pressure at point A = $(d_w - \frac{\Delta h * (d_w)}{L_T})$*(unit weight of water)

Uplift pressure at point A = $[3.34\,ft - \frac{3.34 * (3.34)}{(8.34)}] * (62.4\frac{lb_f}{ft^3}) \cong 125\frac{lb_f}{ft^2}$

Uplift pressure at point O = $(d_w - \frac{\Delta h*(d_w + L_{A-O})}{L_T})$*(unit weight of water)

Uplift pressure at point O = $[3.34\,ft - \frac{3.34*(8.34)}{(8.34)}]*(62.4\frac{lb_f}{ft^3}) \cong 0\frac{lb_f}{ft^2}$

Resultant Uplift Force, U_1 = $(0.5*(125)*5.0) = 312.5\frac{lb_f}{ft}$ acting at 3.34 ft from Point O.

The resultant force due to hydrostatic pressure, H: $(0.5*207.8*3.34) = 347\frac{lb_f}{ft}$

The resultant hydrostatic force, H, is acting at a distance $(\frac{1}{3}*3.34) = 1.1$ ft up from point A

Resistance to sliding:

Coefficient of friction, f

Normal Force = N

Resulting force acting to resist sliding = f*N (neglecting adhesion)

Summation of Forces:

$+\uparrow \sum F_y = W - N - U_1 = 0;$

1837 – N -312.5 = 0

$N = 1524.5\ \frac{lb_f}{ft}$

$\overset{+}{\rightarrow} \sum F_x = H - f*N = 0;$

347 – f*(1524.5)= 0;

f must be ≥ 0.23 for stability against sliding – **provides satisfactory stability based on published interface friction coefficients for sand to rock and sand to soil interface conditions (>0.6) with a safety factor of 2.6.**

(+ $\sum M_o$ = summation of moments about point O:

Overturning Moment (OM) = 312.5*(3.34) +347*(1.1)
Resisting Moment (RM) = 1837*(2.5)

Factor of Safety (FS) = RM/OM = 4593/1425 = 3.22

Solving for FS: FS is greater than 1.5- **Considered stable**.

Scenario 5: Three (3) sand-filled T3 TYPAR GEOCELLS units stacked on top of each other:

A free-body diagram of the forces acting on the Scenario 5 arrangement is shown in Figure 5.0 below. The cells are analyzed as a monolithic system.

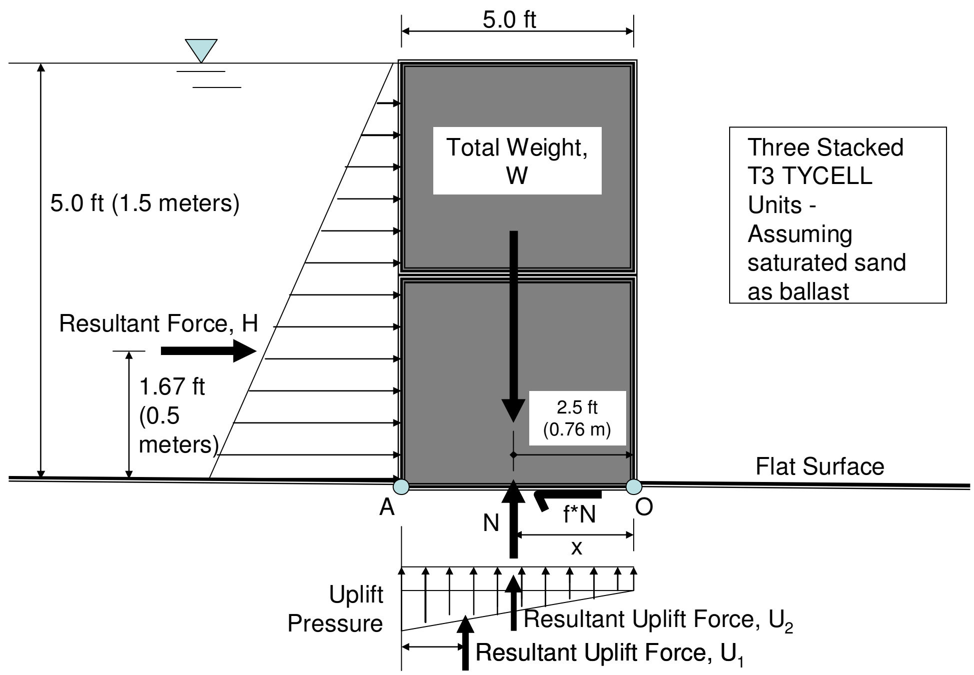

Figure 5.0 – Three (3) Sand-Filled T3 TYPAR GEOCELLS Units Stacked Atop One Another

Total weight of saturated sand three units = $110\frac{lb_f}{ft^3}*[(5)*(5)] = 2750\frac{lb}{ft}$

d_w = distance below headwater = 5.0 ft

Δh = differential head = 5.0 ft

L_{A-O} = length from point A to point O = 5.0 ft

L_T = total length from water elevation to point O = 5.0 + 5.0 = 10.0 ft.

Uplift pressure at point A = $(d_w - \frac{\Delta h*(d_w)}{L_T})$*(unit weight of water)

Uplift pressure at point A = $[5.0ft - \frac{5.0*(5.0)}{(10)}]*(62.4\frac{lb_f}{ft^3}) \cong 156\frac{lb_f}{ft^2}$

Uplift pressure at point O = $(d_w - \frac{\Delta h*(d_w + L_{A-O})}{L_T})$*(unit weight of water)

Uplift pressure at point O = $[5.0ft - \frac{5.0*(10)}{(10)}]*(62.4\frac{lb_f}{ft^3}) \cong 0\frac{lb_f}{ft^2}$

Resultant Uplift Force, $U_1 = (0.5*(156)*5.0) = 390\frac{lb_f}{ft}$ acting at 3.34 ft from Point O.

The resultant force due to hydrostatic pressure, H: $(0.5*312*5.0) = 780\frac{lb_f}{ft}$

The resultant hydrostatic force, H, is acting at a distance $(\frac{1}{3}*5.0) = 1.67$ ft up from point A

Resistance to sliding:

Coefficient of friction, f

Normal Force = N

Resulting force acting to resist sliding = f*N (neglecting adhesion)

Summation of Forces:

$+\uparrow \sum F_y = W - N - U_1 = 0;$

2750 – N -390 = 0

$N = 2360\ \frac{lb_f}{ft}$

$\overset{+}{\rightarrow} \sum F_x = H - f*N = 0;$

780 – f*(2360)= 0;

f must be ≥ 0.33 for stability against sliding – **provides satisfactory stability based on published interface friction coefficients for sand to rock and sand to soil interface conditions (>0.6) with a safety factor of 1.8.**

$\circlearrowright + \sum M_o =$ summation of moments about point O:

Overturning Moment (OM) = 390*(3.34) +780*(1.67)
Resisting Moment (RM) = 2750*(2.5)

Factor of Safety (FS) = RM/OM = 6875/2605= 2.63

Solving for FS: FS is greater than 1.5- **Considered stable**.

Scenario 6: Four (4) sand-filled T4 TYPAR GEOCELLS units stacked on top of each other:

A free-body diagram of the forces acting on the Scenario 6 arrangement is shown in Figure 6.0 below. The cells are analyzed as a monolithic system.

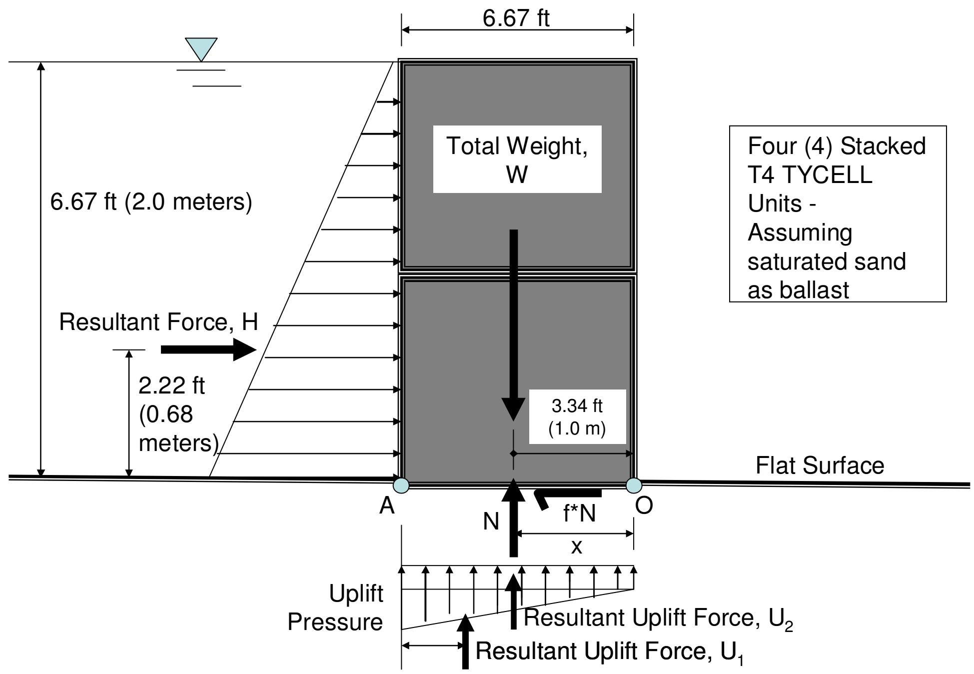

Figure 6.0 – Four (4) Sand-Filled T4 TYPAR GEOCELLS Units Stacked Atop One Another

Total weight of saturated sand three units = $110\frac{lb_f}{ft^3}*[(6.67)*(6.67)] = 4894\frac{lb}{ft}$

d_w = distance below headwater = 6.67 ft

Δh = differential head = 6.67 ft

L_{A-O} = length from point A to point O = 6.67 ft

L_T = total length from water elevation to point O = 6.67 + 6.67 = 13.34 ft.

Uplift pressure at point A = $(d_w - \frac{\Delta h*(d_w)}{L_T})$*(unit weight of water)

Uplift pressure at point A = $[6.67\,ft - \frac{6.67*(6.67)}{(13.34)}]*(62.4\frac{lb_f}{ft^3}) \cong 208.1\frac{lb_f}{ft^2}$

Uplift pressure at point O = (d_w - $\frac{\Delta h*(d_w + L_{A-O})}{L_T}$)*(unit weight of water)

Uplift pressure at point O = $[6.67\,ft - \frac{6.67*(13.34)}{(13.34)}]*(62.4\frac{lb_f}{ft^3}) \cong 0\frac{lb_f}{ft^2}$

Resultant Uplift Force, U_1 = $(0.5*(208.1)*6.67) = 694\frac{lb_f}{ft}$ acting at 4.45 ft from Point O.

The resultant force due to hydrostatic pressure, H: $(0.5*416.21*6.67) = 1388.1\frac{lb_f}{ft}$

The resultant hydrostatic force, H, is acting at a distance $(\frac{1}{3}*6.67) = 2.22$ ft up from point A

Resistance to sliding:

Coefficient of friction, f

Normal Force = N

Resulting force acting to resist sliding = f*N (neglecting adhesion)

Summation of Forces:

$+\uparrow$ $\sum F_y = W - N - U_1 = 0$;

4894 – N -694 = 0

$N = 4200\ \frac{lb_f}{ft}$

$\xrightarrow{+}$ $\sum F_x$ = H – f*N = 0;

1388.1 – f*(4200)= 0;

f must be ≥ 0.33 for stability against sliding – **provides satisfactory stability based on published interface friction coefficients for sand to rock and sand to soil interface conditions (>0.6) with a safety factor of 1.8.**

$\curvearrowright +$ $\sum M_o$ = summation of moments about point O:

694*(4.45) +1388.1*(2.22) -4894*(3.34) + 4200*(x) = 0

Overturning Moment (OM) = 694*(4.45) +1388*(2.22)
Resisting Moment (RM) = 4894*(3.34)

Factor of Safety (FS) = RM/OM = 16,346/6170 = 2.65

Solving for FS: FS is greater than 1.5- **Considered stable**.