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Aquacast Theory and Principles Structural Calculations

Project: Aquacast

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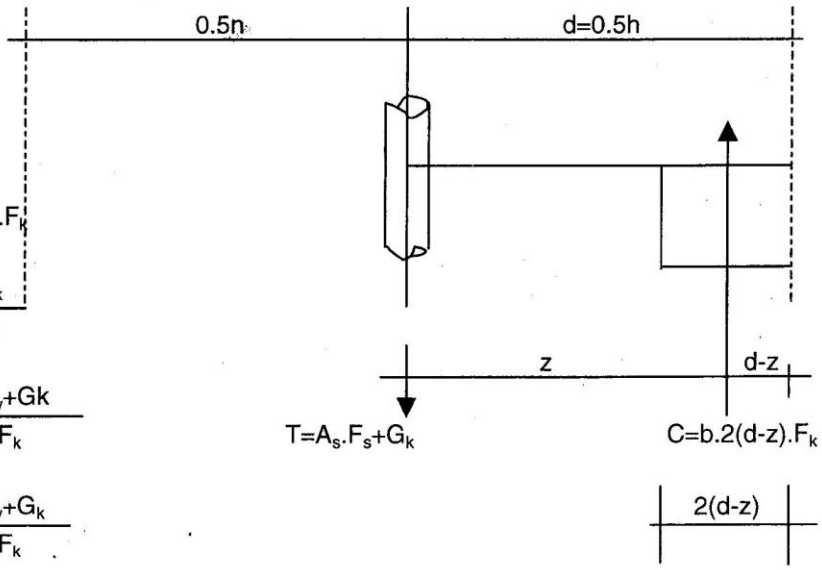
Theory and Design

1.0 Moment Resistance



1.1 Basic Theory

T=C

$A_s.F_y + G_k = b.2(d-z).F_k$

$$d-z = \frac{A_s.F_y+G_k}{2.b.F_k}$$

$$z = d - \frac{A_s.F_y+Gk}{2.b.F_k}$$

$$z/d = 1 - \frac{A_s.F_y+G_k}{2.b.d.F_k}$$

$Mrc = Mr_{s+w}$

$= Tz$

$= (A_s.F_y+G_k)z$

$$= (A_s.F_y+G_k)\left|1 - \frac{(A_s.F_y+G_k)\ d}{2.b.d.F_k}\right|$$

M = Flexural Resistance (Equation in N and mm).

1.1.1 Apply Partial Factors of Safety

$= Tz/Y_m$ N.mm

$= (A_s.F_y/Y_{ms}+G_k.Y_{mw})\ z$

$$\left|\frac{A_s.F_y + G_k.Y_{mw}}{Y_{ms}}\right|\left|1 - \frac{(A_s.F_y/Y_{ms}+G_k.Y_{mw})Y_{mm}\ d}{2.b.d.F_k}\right|$$

Where :

8 N° Bullivant Piles
Casing 100x3th CHS
C35 Concrete (or equivalent)
32 diameter HT Rebar
A_s = 804/2 = 402 mm^2 / m run of wall
F_y = 460 N/mm^2 Steel stress for HT rebar

G_k = Deadload
b = 1000 mm Width of wall
F_k = 14 N/mm^2 Compressive strength of Units
or Fk = 0.4 Fcu = 0.4. 35 = 14 N/mm2

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1.2 Flexural Resistance due to Reinforced Section

$$M_s = \left| \frac{A_s.F_y}{Y_{ms}} \right| \left| 1 - \frac{A_s.F_y.Y_{mm}}{2.b.d.F_k.Y_{ms}} \right| d$$

$$= \left| \frac{402.460}{1.15} \right| \left| 1 - \frac{402.460.2}{2.b.500.14.1.15} \right| 500$$

$$= 160{,}800 \,.\, 0.977 \,.\, 500 = 78.55 \,.\, 10^6$$

$$= \mathbf{78.55} \text{ Kn.m}$$

Partial Factors of Safety
Units $Y_{mc} = 1.5$ (BD21/01)
or $Y_{mm} = 2.0$ (BS5628)
Use Ymm as Units are defined by manufacture
Steel $Y_{ms} = 1.15$ (BD21/01 and BS5628)
Deadload $Y_{mw} = 0.9$ (BS8110)

1.2.1 Add the effects of Gk, the Deadload

$G_k = 24$ Kn/m^3. 1. 2.6 = 62.4 Kn/m run of wall

$$M_d = \left| G_k.Y_{mw} \right| \left| 1 - \frac{(As.Fy./Y_{ms} + G_k.Y_{mw})Ymm}{2.b.d.F_k} \right| d$$

$$= \left| 62.4.0.9 \right| \left| 1 - \frac{(245.47.460/1.15 + 62.4.0.9)\,2}{2.b.500.14.} \right| 500$$

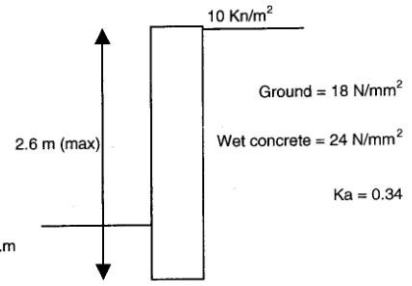
$$= 56.16.0.977.0.50 = \mathbf{27.43} \text{ Kn.m}$$

1.2.2 Total Flexural Resistance

M = Ms + Md = 78.55 + 27.43 = **105.98** Kn.m

1.3 Applied Bending Moment

$$M = \left| \frac{Y.h^3}{6} + \frac{S.h^2}{2} \right| Ka$$



1.3.1 Temporary loadcase H=2.6m

$$M_t = \frac{24.2.6^3}{6} = 70 \text{ Knm}$$

and 70. 1.6 = **112** Kn.m Factored > 105.98 Kn.m

FOS =0.95 < 2.0 Not okay.

Backfill concrete must be poured in two layers.

1.3.2 Permanent loadcase H=2.6m

$$M_p = \left| \frac{18.2.6^3}{6} + \frac{10.2.6^2}{2} \right| 0.34$$

$$= \left| 53 + 34 \right| 0.34 = \mathbf{30} \text{ Kn.m}$$ Overturning Moment (unfactored)

and $\left| 1.4 \,.\, 53 + 1.6 \,.\, 34 \right| 0.34 = 128.0.34$

= **44** Kn.m Factored < **105.98** Kn.m

FOS = 2.41 > 2.0 Okay.

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1.3.3 Permanent loadcase H=2.1m

$= \left| \frac{18.2.1^3}{6} + \frac{10.2.1}{2} \right| 0.34$

$= | 28 + 11 | 0.34 = 13$ Knm

and $| 1.4 . 28 + 1.6 .11 | 0.34$

$= 57. 0.34 =$ **19** Kn.m Factored < **105.98** Kn.m Okay.

2.0 Overturning Resistance

by Deadload only assuming
no contribution from passive pressure.

$= 0.5 (Y.h.b.d^2)$

$= 0.5 (24. 2.6. 1. 1^2) = 0.5. 62.4$

= **31** Kn.m Unfactored > Overturning Moment (30)

FOS = 1.03 < 2.0 Not okay. Provide Pile Restraining Moment = 29 Kn.m

3.0 Base Pressure

$= \frac{P}{A} +/- \frac{M}{Z}$

$= \frac{62.4}{1.1} +/-$ Zero NB: Overturning Moment (30) < Restraining Moment (31)

= **62** Kn/m2 Unfactored Provide Ground Bearing Capacity = 65 Kn/m^2

4.0 Horizontal Restraint

4.1 Coefficient of friction = 0.35 for cohesionless soil

$= 0.35 G_k = 0.35. 62.4 =$ **22** Kn

4.2 Passive Pressure Kp=3.4

$= \frac{Kp.Y.h^2}{2} = 3.4. 0.5 .18 .1^2 =$ 31 Kn say **0** Not allowed for

4.3 Total Horizontal Restraint

$= 0 + 22 =$ **22** Kn

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4.4 Sliding Force

$$= \left| \frac{Y.h^2}{2} + S.h \right| Ka$$

$$= \left| 0.5.18.2.6^2 + 10.2.6 \right| Ka = 87.0.34$$

= **30** Kn Unfactored > 22 (Horizontal Restraint)

FOS = 0.73 < 2.0 Not okay Provide Pile Resistance = 38 Kn.

Conclusions

Concrete backfill will need to be placed in two layers (1.3m)

The Aquacast Wall will cater for bending moments from permanent loads

Overturning of the wall will be resisted by a Pile Restraining Moment = 29 Kn.m

Minimum Ground Bearing Capacity = 62 Kn/m^2

Piles are required to resist a Sliding Force = 38 Kn

Piles shall be C35 concrete (or equivalent) reinforced with 1 N° T32 steel bar, with a permanent casing of 100x3th CHS

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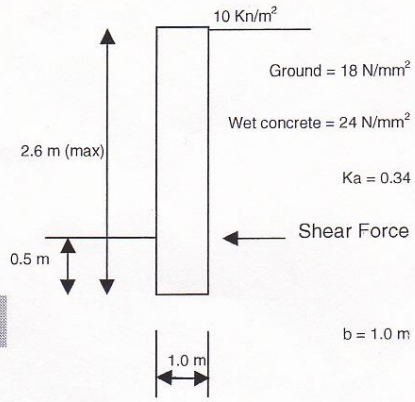
5.0 Applied Shear Force

$$F = \left| \frac{Y.h^2}{2} + S.h \right| \quad Ka$$



5.1 Temporary loadcase H=1.3m

$$F_t = \frac{24.2.1^2}{2} = 53 \text{ Knm}$$

and 53. 1.6 = **85** Kn Factored

Reduce by pouring concrete in layers

5.2 Permanent loadcase H=2.1m

$$F_p = \left| \frac{18.2.1^2 + 10.2.1}{2} \right| 0.34$$

$$= \left| 37 + 21 \right| 0.34$$

= **20** Kn Unfactored

and $\left| 1.4 . 37 + 1.6 . 21 \right| 0.34 = 85.4. 0.34$

= **29** Kn Factored

5.3 Frictional Shear Resistance

NB: The are no published values for friction coefficients between concrete interfaces. This value would be affected by the finish of the contact faces, and also the presence of water.

If the coefficient of friction is assumed to be = 0.3 between Units

= $0.3\ G_k$ = 0.3. 62.4 = 18.72 Kn < 20

Take friction into account for FOS only.

5.3 Shear Resistance of Pile

= $P_v = 0.6\ F_y 0.9\ A_v$ Where $A_v = 0.9A_s$

$= 0.6 .460. 0.9 .402 / 10^3 =$ 100 Kn > 29

FOS = 3.44 > 2.0 Okay

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6.0 Force on individual Units

Pushing out Unit from wall.

= 20. 0.5 = 10 Kn Unfactored

= 29. 0.5 = 14.5 Kn Factored

6.1 Frictional Resistance

Assume Coefficient of Friction = 0.3

Area = 2 (1. 0.75) = 1.5 m2 / Unit

= $0.3\ G_k$ = 0.3 (24. 2.5) 1.5

= 27 Kn Unfactored

Take friction into account for FOS only

6.2 Shear Resistance of Core

Assume F_c = 0.9 N/mm^2

Area = 3.142 .150^2 / 4 = 17673.75 mm^2

= $0.9 .17673.75 / 10^3$

= 15.9 Kn Unfactored > 10 Okay

6.3 Shear Resistance of Unreinforced Unit

= 27 + 15.9 = 42.9 Kn

FOS = 4.29 > 2.0 Okay

Conclusions

The concrete core in Grade C35 (or equivalent) will resist the push out force on each unit.

The unreinforced core together with friction will provide an adequate factor of safety.

By inspection the shear resistance of the piles are satisfactory.