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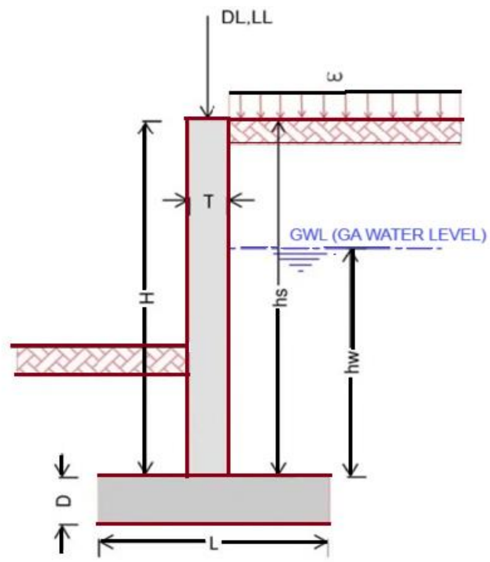
DESIGN OF CANTILIVER RETAINING WALL (ACI 318)

INPUT DESIGN PARAMETERS

Material Properties

Compressive Strength f'c	32	Mpa
Reinforcement Yield Strenght, fy	460	Mpa



SOIL PARAMETERS

Soil Bearing Capacity, q_{all}	100	Mpa
Unit weight of Soil, Ysoil	18	kN/m3
Unit weight of Water, Ywater	10	kN/m3
Coefficient of Soil Friction, ϕ	30	degrees

RETAINING WALL GEOMETRY

Base width of Footing, L	1500	mm
Thickness of Footing, D	250	mm
Thickness of Wall, T	250	mm
Height of Wall, H	2	m
diameter of rebars	10	mm
concrete cover, cc	75	mm
Height of Soil, hs	2	m
Height of Water, hw	1	m
Height of Surcharge	0.8	m

LOADING DATA

Surcharge, w	12	kPa
un-factored Dead Load DL	5	kN
un-factored Live Load, LL	10	kN
External Moment Dead Load	0	kN,m
External Moment Live Load	0	kN,m
Dead Load Factor	1.2	
Live Load Factor	1.6	
Lateral Load Factor	1.6	

WALL REINFORCEMENT

Vertical	10	@	250	mm both sides
Horizontal	10	@	250	mm both sides

RET. WALL FOOTING REINFORCEMENT

Main	10	@	250	mm both sides
Secondary	10	@	250	mm both sides

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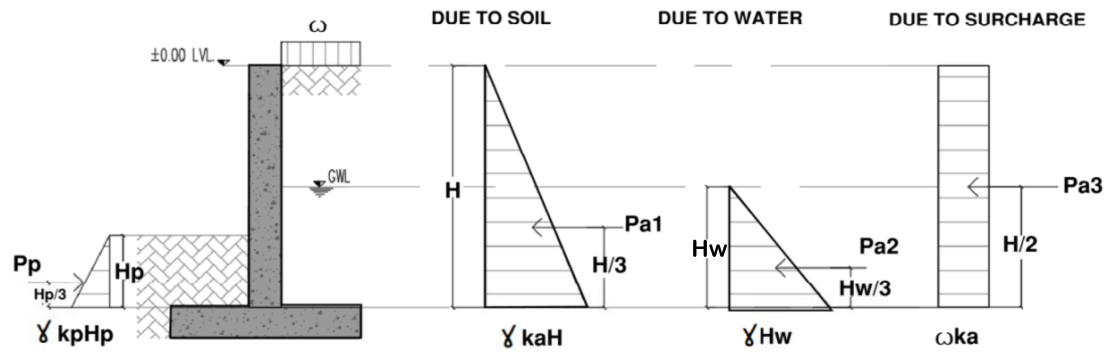
Design of Cantiliver Retaining Wall (ACI318)



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Solve for Retaining Wall Forces

ka = $\frac{1-\sin\phi}{1+\sin\phi}$ 0.3333

Lateral Forces from Soil

$Pa1 = 1/2\ \Upsilon soil\ ka\ h^2$ = 1/2 x 18.0 x 0.33333 x 2.0^2 = 12 KN

Level arm from base = 1/3 height of soil = 1/3 x 2.0 = 0.6667 m

Force from Water

$Pa2 = 1/2\ \Upsilon soil\ h^2$ = 1/2 x 10.0 x 1.0 ^2 = 5 KN

Level arm from base = 1/3 height of water = 1/3 x 1.0 = 0.3333 m

Force from Surcharge

Pa3 = w ka h = 12 x 0.33333333 x 0.8 = 3.2 KN

Level arm from base = 1/2 height of surcharge = 1/2 x 0.8 = 0.4 m

Check the Wall Thickness for Shear

Nominal Shear = 12 + 5 + 3.2 = 20.2 KN

Ultimate Shear = 1.6 x 12 + 1.6 x 5 + 1.6 x 3.2 = 32.32 KN

Allowable Shear, ϕ Vc = ϕ 0.17 √ f'c bw d = 0.75 x 0.17 x √ 32.0 x 1000 x 170 = 122.61 KN

ϕ shear = 0.75

Actual Ultimate Shear < Allowable Shear OK for Shear

Design the Wall Stem for Flexure

Nominal Moment = 12 x 0.67 + 5 x 0.33 + 3.2 x 0.4 = 10.947 KN-m

Ultimate Moment = 1.6 x 12 x 0.67 + 1.6 x 5 x 0.33 + 1.6 x 3.2 x 0.4 = 17.515 KN-m

$M_u = \phi\ fc'\ bd^2\omega\ (1 - 0.59\omega)$ = 17.514667 x 10^{6} = 0.9 x 32.0 x 1000 x 170^2 ω 1 - 0.59 q)

ϕ flexure = 0.9

ω = 0.0213

ρ = ω f'c / fy = 0.021311 x 32.0 / 460.0 0.0015

ρmin = 0.002

As = ρ b d = 0.001483 x 1000 x 170 = 252.0 mm^2

As min = ρmin b t = 0.002 x 1000 x 250 = 500.0 mm^2

Required Main Vertical Bars

Try 10 - 250 mm spacing both sides, As act = 628.3 mm^2

Required Horizontal Bars

Try 10 - 250 mm spacing both sides, As act = 628.3 mm^2

Required Reinforcements < Actual Reinforcements OK

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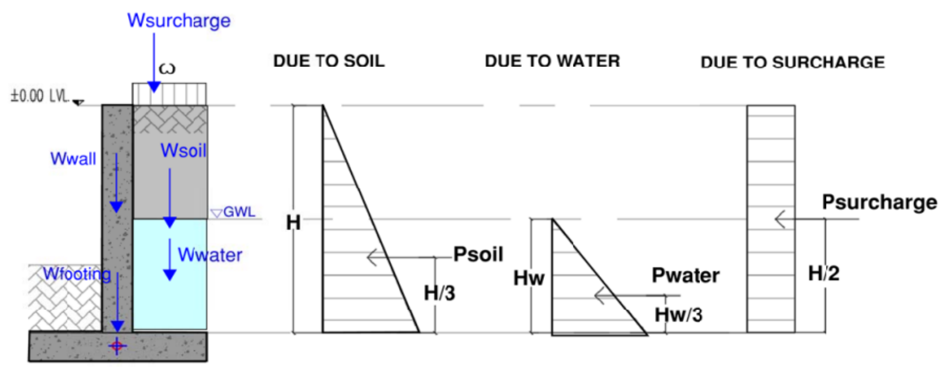
Stability Checks:



Check for Overturning:

When Surcharge is present

Overturning Moment =		12	x	0.67	+	5	x	0.333	+	3.2	x	0.4	=	10.95	KN-m
Righting Moment															
From Wall	=	0.9	x	25	x	0.25	x	2.0	x	1	x	0.75	=	8.44	KN-m
From Footing	=	0.9	x	25	x	1.5	x	0.25	x	1	x	0.75	=	6.33	KN-m
From Soil	=	18.0	x	0.63	x	2.0	x	1	x	1.19			=	26.72	KN-m
From Water	=	10.0	x	0.63	x	1.0	x	1	x	1.19			=	7.42	KN-m
From Surcharge	=	12.0	x	0.63	x	1	x	1.188					=	8.91	KN-m
Total Righting Moment														57.81	KN-m

Factor of Safety = RM / OM > 2.0

= 57.8 / 10.9467 **5.281**

OK for Overturning

Check for Sliding:

When Surcharge is present

Sliding Force =		12	+	5	+	3.2				20.2	KN
Resisting Force											
From Wall	=	0.9	x	25	x	0.25 x	2.0	x	1	11.25	KN
From Footing	=	0.9	x	25	x	1.5 x	0.25	x	1	8.44	KN
From Soil	=	18.0	x	0.63	x	2.0 x	1			22.50	KN
From Water	=	10.0	x	0.63	x	1.0 x	1			6.25	KN
From Surcharge	=	12.0	x	0.63	x	1				7.50	KN
Total Resisting Force										55.9	KN

Factor of Safety = RF / SF > 1.5

= 55.9 / 20.2 **2.769**

OK for Sliding

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Check Wall Footing

Maximum soil pressure (considering 1m strip)

$$q_{max} = \frac{P}{A} + \frac{6M}{bd^2} \leq q_{all}$$

$$q_{max} = \frac{70.9}{1 \times 1.50} + \frac{6 \times 10.95}{1 \times 1.50^2} = 76.48 \text{ Kpa} < 100.0 \text{ Kpa}$$

OK for Soil Bearing

Maximum ultimate soil pressure (considering 1m strip)

$$qu = -\frac{P}{A} \pm \frac{6M}{bd^2}$$

$$qu_{max} = \frac{103.6}{1 \times 1.50} + \frac{6 \times 17.5147}{1 \times 1.50^2} = 115.8 \text{ Kpa}$$

$$qu_{min} = \frac{103.6}{1 \times 1.50} - \frac{6 \times 17.5147}{1 \times 1.50^2} = 22.38 \text{ Kpa}$$

if qu_{min} is in tension (+), solve for the required Length, L (ignore when q_{min} is in compression(-))

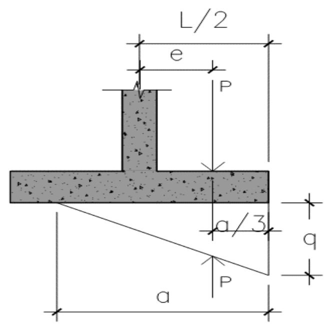
e = M/P = 17.5147 / 103.6 = 0.1690197 m

P = 1/2 a qe b

a = length of pressure

qe = qu_{max}

b = 1 meter strip



$$a = \frac{2P}{qu_{max}\, b} = \frac{2 \times 103.6}{115.8 \times 1} = 1.790 \text{ m}$$

L = 2 (e + a/3) = 2 x(0.1690197 + 1.790 / 3) = 1.5313 m **1.60** m

Check Footing Thickness for Shear

When qu_{min} is in Compression

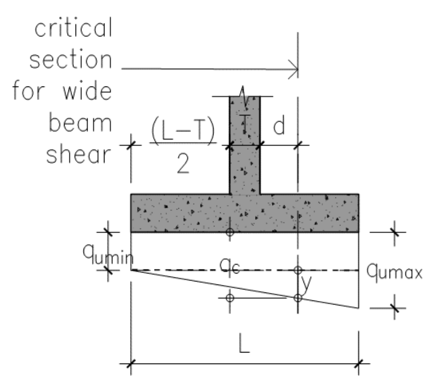
$q_c = qu_{min} + y$

Solving for y by similar triangles

$$\frac{y}{1.045} = \frac{93.41}{1.5}$$

y = 65.076717 Kpa

q_c = 22.377556 + 65.0767 = 87.454273 Kpa



$V_u = 1/2\,(q_c + qu_{max})\, L'\, b$

L' = 0.455 m

b = 1 m strip

V_u = 1/2 x(87.45427 + 115.789111)x 0.455 x 1

V_u = 46.23787 KN

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When qu_{min} is in Tension

$q_c = y$

Solving for y from similar triangles

$$\frac{y}{1.28489} = \frac{116}{1.7899}$$

y = 83.120379 Kpa

q_c = 83.120379 Kpa

$V_u = 1/2\ (q_c + qu_{max})\ L'\ b$

L' = 0.505 m

b = 1 m strip

V_u = 1/2 x(83.12038 + 115.789111)x 0.505 x 1

V_u = 50.224646 KN

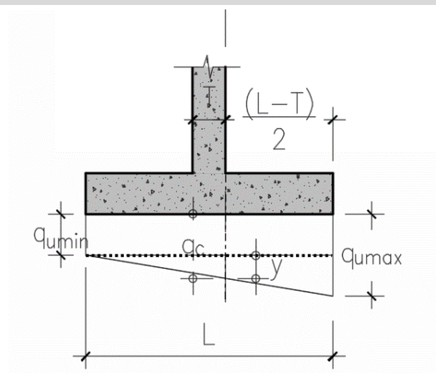
V_u govern = 46.23787 KN

Allowable Shear, ϕ Vc = ϕ 0.17 √ f'c bw d = 0.75 x 0.17 x √ 32.0 x 1000 x 170 = 122.61 KN

ϕ shear = 0.75

Actual Ultimate Shear < Allowable Shear OK for Shear

Check Wall Thickness for Flexure



When qu_{min} is in Compression

$q_c = q_{min} + y$

Solving for y from similar triangles

$$\frac{y}{0.875} = \frac{93.41}{1.5}$$

y = 54.490074 Kpa

q_c = 22.377556 + 54.4901 = 76.86763 Kpa

Mu = 76.87 x 0.625 x 1/2 x 0.625 + 1/2 x 38.921 x 0.625 x 2/3 x 0.625

Mu = 20.08 KN-m

When qu_{min} is in Tension

$q_c = y$

Solving for y from similar triangles

$$\frac{y}{1.11489} = \frac{116}{1.7899}$$

y = 72.122984 Kpa

q_c = 72.122984 Kpa

Mu = 72.12 x 0.675 x 1/2 x 0.675 + 1/2 x 43.666 x 0.675 x 2/3 x 0.675

Mu = 23.06 KN-m

Mu govern = 20.08 KN-m

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$M_u = \phi\ fc'\ bd^2 \omega\ (1 - 0.59\omega)$ = 20.1 x 10^6 = 0.9 x 32.0 x 1000 x 170 ^2 q (1 - 0.59 ω)

ϕ flexure = 0.9

ω = 0.0245

ρ = q f'c / fy = 0.02448 x 32.0 / 460.0 0.0017

ρmin = 0.002

As = ρ b d = 0.001703 x 1000 x 170 = 289.5 mm^2

As min = ρmin b t = 0.002 x 1000 x 250 = 500.0 mm^2

Required Main Bars

Try 10 - 250 mm spacing both sides, As act = 628.3 mm^2

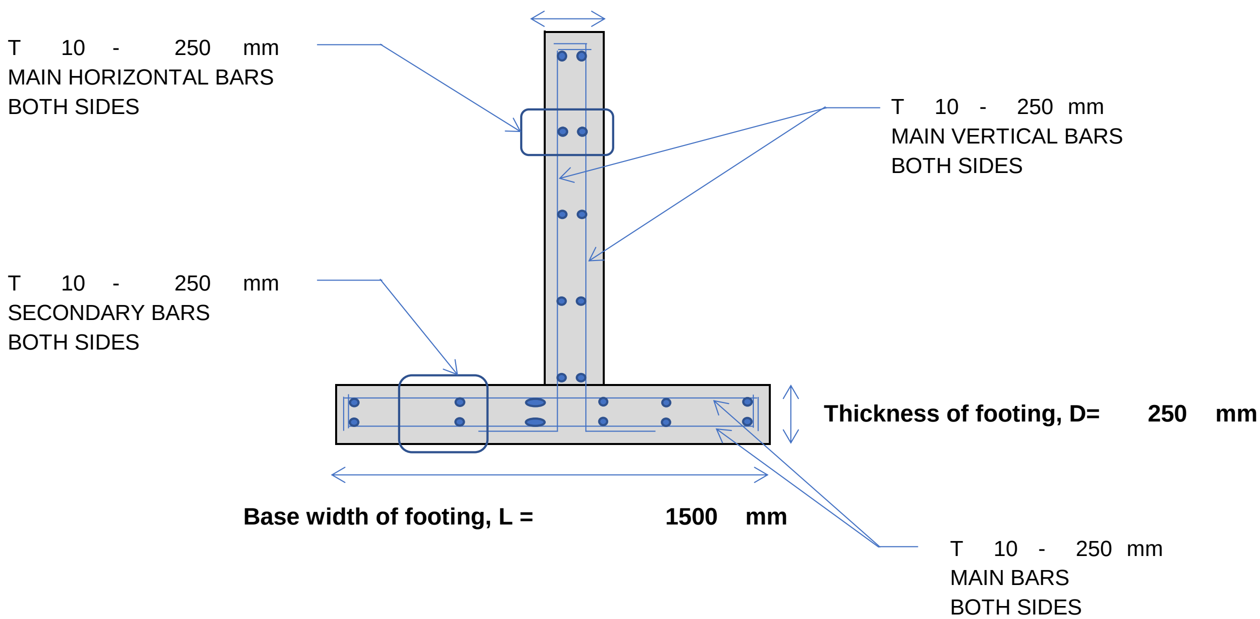
Required Secondary Bars

Try 10 - 250 mm spacing both sides, As act = 628.3 mm^2

Required Reinforcements **<** **Actual Reinforcements** **OK**

SUMMARY OF RETAINING WALL DESIGN

Thickness of wall, T = 250 mm



Base width of footing, L = 1500 mm