Pattern Associates Ltd

Structural Engineering Consultants

Structural Calculations Report

20.593

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STRUCTURAL CALCULATIONS

Proposed Extension & Alterations to:

St Mary's Pavilion

Dilly Lane

Hartley Wintney

Hook

Hampshire

RG27 8RQ

Ms Reid

20.593

January 2021

Project Address: St Mary's Pavilion, Dilly Lane, Hartley Wintney, Hook, Hampshire, RG27 8RG

Project Reference: 20.593

Date: January 2021

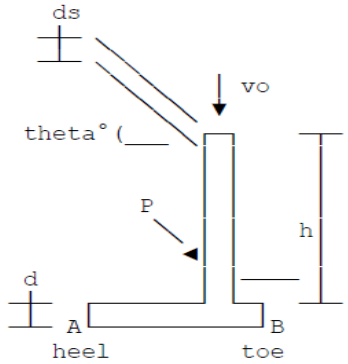
Client: Ms Reid

Brief:

Pattern Associates Ltd were appointed by Ms Reid to undertake the structural design of the structural elements to the following:

- *Retaining wall and ramp details.*

Location: Retaining Wall



RC retaining wall to BS8002

Using either Rankine or Coulomb theory, the following assumptions are made:

- surface of rupture is a plane
- point of resultant pressure P on back back of wall is at one third of the distance up from the base of the wall.

Small unbattered mass-concrete wall with no heel is considered.
Both Rankine and Coulomb give formula for resultant earth pressure on back of wall as P = Ce.w.h^2/2 where Ce is a pressure coefficient.

Weight/unit vol.of retained soil	w=18.8 kN/m³
Height of wall s any toe prov.	h=1 m
Pressure due to surcharge	press=5 kN/m²
Equivalent depth of surcharge	ds=press/w=5/18.8=0.26596 m
Load above wall supported on stem	vo=0 kN/m
Angle of slope of soil (if any)	theta=0°
Internal friction angle of soil φ	phi=45°
Angle of wall-to-soil friction δ	delta=30°
Friction factor on underside base	fb=0.4
Thickness of wall	t=.215 m
Density of wall (stem)	dt=24 kN/m³

Pressure from retained soil

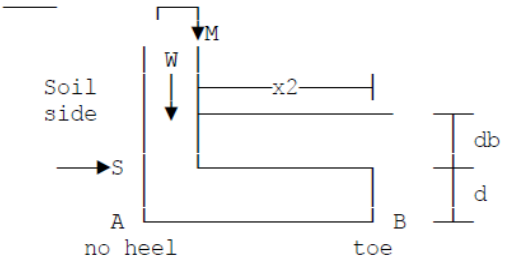
Cosine of surcharge angle (theta)	ct=COS(RAD(theta))=1
Sine of friction angle (phi)	sp=SIN(RAD(phi))=0.70711
Cosine of friction angle (phi)	cp=COS(RAD(phi))=0.70711
Cosine of wall-soil friction (δ)	cd=COS(RAD(delta))=0.86603
Sine of (phi + delta)	ss1=SIN(RAD(phi)+RAD(delta)) =SIN(RAD(45)+RAD(30)) =0.96593
Sine of (phi - theta)	ss2=SIN(RAD(phi)-RAD(theta)) =SIN(RAD(45)-RAD(0)) =0.70711
Coulomb theory:	
Factor	f=cd*(1+SQR(ss1*ss2/(cd*ct)))^2 =0.86603*(1+SQR(0.96593*0.70711 /(0.86603*1)))^2 =3.0872
Pressure coefficient	Cec=cp^2/f=0.70711^2/3.0872 =0.16196
Rankine theory:	
Factor	f=SQR(ct^2-cp^2)=SQR(1^2-0.70711^2) =0.70711

Pressure coefficient	Cer=ct*(ct-f)/(ct+f) =1*(1-0.70711)/(1+0.70711) =0.17157
Rankine pressure coefficient is chosen.	
Resultant earth force (active)	P=Ce*w*h^2/2=0.17157*18.8*1^2/2 =1.6128 kN/m run
Horiz.component of this force	Ph=P*COS(RAD(theta)) =1.6128*COS(RAD(0)) =1.6128 kN/m run
Vertical component of this force	Pv=P*SIN(RAD(theta)) =1.6128*SIN(RAD(0)) =0 kN/m run
Pressure coefficient (surcharge)	Ca=(1-sp)/(1+sp) =(1-0.70711)/(1+0.70711) =0.17157
Resultant earth force (surcharge)	Ps=Ca*w*ds*h=0.17157*18.8*0.26596*1 =0.85786 kN/m run
Horiz.component of this force	Psh=Ps*COS(RAD(theta)) =0.85786*COS(RAD(0)) =0.85786 kN/m run
Vertical component of this force	Psv=Ps*SIN(RAD(theta)) =0.85786*SIN(RAD(0)) =0 kN/m run

Forces and moments on wall

Maximum B.M. at base of stem	M=Ph*h/3+Psh*h/2 =1.6128*1/3+0.85786*1/2 =0.96653 kNm/m
Maximum S.F. at base of stem	S=Ph+Psh=1.6128+0.85786 =2.4706 kN/m
Weight of wall	v=h*t*dt=1*0.215*24=5.16 kN/m run
Weight of wall plus load over	v=v+vo=5.16+0=5.16 kN/m run

Base



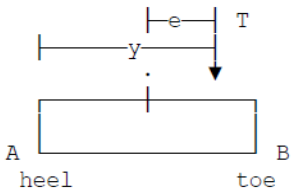
Distance from B to face of wall	x2=.39 m
Total length of base	L=t+x2=0.215+0.39=0.605 m
Depth of soil over base at toe	db=.5 m
Thickness of toe	d=0.3 m
Depth of soil for passive resist.	dp=.5 m
Allowable ground pressure	p=75 kN/m²
Self-weight of foundation	Sw=L*d*dt=0.605*0.3*24=4.356 kN/m run
Wt. of soil behind wall (earth)	wbe=(h+ds)*(x-t/2)*w =(1+0.26596)*(0.1075-0.215/2)*18.8 =0 kN/m run

Wt. of soil behind wall (slope)	wbs=w*(x-t/2)^2*TAN(RAD(theta))/2 =18.8*(0.1075-0.215/2)^2 *TAN(RAD(0))/2 =0 kN/m run
Total weight of soil behind wall	wb=wbe+wbs=0+0=0 kN/m run
Weight of soil at front of wall	wf=db*(x1-t/2)*w =0.5*(0.4975-0.215/2)*18.8 =3.666 kN/m run
Total earth pressure (active)	Pab=Ce*ct*w*(h+d)^2/2 =0.17157*1*18.8*(1+0.3)^2/2 =2.7256 kN/m run
Horiz.component of this force	Pabh=Pab*COS(RAD(theta)) =2.7256*COS(RAD(0)) =2.7256 kN/m run
Vertical component of this force	Pabv=Pab*SIN(RAD(theta)) =2.7256*SIN(RAD(0)) =0 kN/m run
Total earth pressure (surcharge)	Psb=Ca*w*ds*(h+d) =0.17157*18.8*0.26596*(1+0.3) =1.1152 kN/m run
Horiz.component of this force	Psbh=Psb*COS(RAD(theta)) =1.1152*COS(RAD(0)) =1.1152 kN/m run
Vertical component of this force	Psbv=Psb*SIN(RAD(theta)) =1.1152*SIN(RAD(0)) =0 kN/m run
Total load on soil beneath base	T=v+Sw+wb+wf+Pabv+Psbv =5.16+4.356+0+3.666+0+0 =13.182 kN/m run
Overturning moment due to earth pressure	Mt=Pabh*(h+d)/3+Psbh*(h+d)/2 =2.7256*(1+0.3)/3+1.1152*(1+0.3)/2 =1.906 kNm/m run
Force u/s base (earth pressure)	St=Pabh+Psbh=2.7256+1.1152 =3.8408 kN/m run
Clockwise moments about A due to weight of soil behind wall	Mcb=(3*wbe+2*wbs)*(x-t/2)/6 =(3*0+2*0)*(0.1075-0.215/2)/6 =0 kNm/m
Clockwise moments about A due to vert.component of earth pressure	Mcbv=(Pabv+Psbv)*(x-t/2) =(0+0)*(0.1075-0.215/2) =0 kNm/m

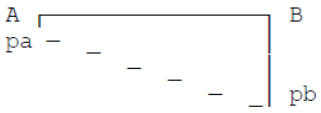
Total clockwise moments about A:

Mc=v*x+Mt+Sw*L/2+Mcb+Mcbv+wf*(L-(x1-t/2)/2)
=5.16*0.1075+1.906+4.356*0.605/2+0+0+3.666*(0.605
-(0.4975-0.215/2)/2)
=5.2814 kNm/m

Distance to centroid of load y=Mc/T=5.2814/13.182=0.40066 m



Eccentricity e=y-L/2=0.40066-0.605/2=0.098156 m
Centroid of load lies within middle third. Pressure varies from pa at A to pb at B.



Base area modulus z=1*L^2/6
=1*0.605^2/6
=0.061004 cu.m per metre run

Pressure at A pa=T/(L*1)-T*e/z
=13.182/(0.605*1)-13.182*0.098156
/0.061004
=0.57862 kN/m²

Pressure at B pb=T/(L*1)+T*e/z
=13.182/(0.605*1)+13.182*0.098156
/0.061004
=42.998 kN/m²

Maximum pressure is at B pmax=pb=42.998 kN/m²
As pmax does not exceed p (42.998 kN/m² ≤ 75 kN/m²), pressure beneath base is within specified limit.

Shear forces and bending moments on toe

Pressure under back of wall pwa=pa+(pb-pa)*(x-t/2)/L
=0.57862+(42.998-0.57862)*(0.1075
-0.215/2)/0.605
=0.57862 kN/m²

Pressure under front of wall pwb=pa+(pb-pa)*(x+t/2)/L
=0.57862+(42.998-0.57862)*(0.1075
+0.215/2)/0.605
=15.653 kN/m²

Downward B.M. on toe Mbd=(dt*d*(x1-t/2)+wf)*(x1-t/2)/2
=(24*0.3*(0.4975-0.215/2)+3.666)
*(0.4975-0.215/2)/2
=1.2624 kNm/m

Total S.F. on toe (plus is up) Swb=((pwb+pb)/2-dt*d)*(x1-t/2)-wf
=((15.653+42.998)/2-24*0.3)
*(0.4975-0.215/2)-3.666
=4.9631 kN/m

Total B.M. on toe (plus is up) Mwb=(2*pb+pwb)*(x1-t/2)^2/6-Mbd
=(2*42.998+15.653)*(0.4975-0.215
/2)^2/6-1.2624
=1.3144 kNm/m

Tensile stress in top of toe ft=6*Mwb/d^2=6*1.3144/0.3^2
=87.626 kN/m²
=0.087626 N/mm²

Resistance to sliding

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Frictional resistance              F=fb*T=0.4*13.182=5.2728 kN/m run
Rankine coeff.of passive pressure  Kp=(TAN(RAD(45)+RAD(phi/2)))^2
                                     =(TAN(RAD(45)+RAD(45/2)))^2
                                     =5.8284
Passive resistance                 R=0.5*Kp*w*dp^2=0.5*5.8284*18.8*0.5^2
                                    =13.697 kN/m
FoS sliding (frict.resist.only)    FOSF=F/St=5.2728/3.8408
                                       =1.3728
FoS sliding (friction/cohesion + passive)  FOSF2=(F+R)/St
                                             =(5.2728+13.697)/3.8408
                                             =4.9389
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Resistance to overturning

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Rotation assumed to occur about lowest forward edge of base (i.e. toe).
Restraining moments:
Due to soil behind wall            Mre=wbe*(L-(x-t/2)/2)+wbs*(L-(x-t/2)
                                       /3)
                                     =0*(0.605-(0.1075-0.215/2)/2)+0
                                      *(0.605-(0.1075-0.215/2)/3)
                                     =0 kNm/m
Due to base,wall and soil on toe   Mrw=v*x1+Sw*L/2+wf*(x1-t/2)/2
                                     =5.16*0.4975+4.356*0.605/2+3.666
                                      *(0.4975-0.215/2)/2
                                     =4.5997 kNm/m
Due to vert.comp.of earth pres.    Mrv=(Pabv+Psbv)*(x1+t/2)
                                     =(0+0)*(0.4975+0.215/2)
                                     =0 kNm/m

Total restraining mt.(with Mrv)    Mr1=Mre+Mrw+Mrv=0+4.5997+0
                                     =4.5997 kNm/m
  ditto           (without Mrv)    Mr2=Mre+Mrw=0+4.5997=4.5997 kNm/m
Total overturning moment           Mot=Mt=1.906 kNm/m
Safety factors against overturning:
Including vert.comp.of pressure    FOSOT1=Mr1/Mot=4.5997/1.906
                                         =2.4133
Ignoring vert.comp.of pressure     FOSOT2=Mr2/Mot=4.5997/1.906
                                         =2.4133
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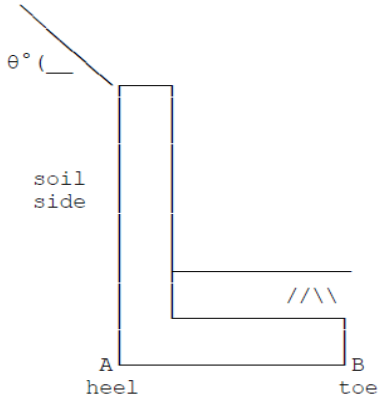

Design Summary

Moment at stem base	0.96653 kNm
Shear at stem base	2.4706 kN
Moment on toe	1.3144 kNm
Shear on toe	4.9631 kN
FoS for Overturning	
(1) With vertical component of earth pressure considered	2.4133
(2) Ignoring vertical component of earth pressure	2.4133
FoS for Sliding	
(1) Friction only	1.3728
(2) Friction+passive	4.9389
Pressure at A	0.57862 kN/m²
Pressure at B	42.998 kN/m²
Allowable GBP	75 kN/m²

NOTE: The sliding resistance calculation check assumes that a a heel beam/key will be provided to the underside of base.