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THE COMBINED EFFECTS OF SOIL, WATER AND SURCHARGE LOADS ON THE STRUCTURAL BEHAVIOURS OF CANTILEVER RETAINING WALL

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ABSTRACT

Retaining walls are engineering structures constructed to resist lateral forces imposed by soil movement and water pressure; they are used as protection against the erosive forces of water and as a method of slope stabilization along highways, railroads and construction sites. This Study modeled the combined effects of soil, Surcharge loads and Hydrostatic pressure on the structural behaviours of cantilever retaining wall under varying geometric conditions. The limit state requirements for overturning, sliding and bearing pressure were studied under different geometric properties. The use of computer programming (Java) was employed for quick analyses of the conditions. This research therefore minimized the stress associated with the iterative process of design and analyses of these structures. The deductions gave range of satisfactory dimensions with respect to the height of the wall for the preliminary dimensioning state of design. This study also answered the remained unanswered question of the effects of an increasing load being supported by retaining wall. The results revealed that Cantilever retaining wall will perform satisfactorily based on the factors of safety of 1.5 ***and*** 2.0 ***as against sliding and overturning respectively if soil is ignored in front of the wall with following values of Base width: For wall supporting full submerged soil, the Base width,*** $B = (1.25 + 0.005q)$***; wall supporting submerge soil up to 0.6 of its Height, Base width,*** $B = (0.881 + 0.00805q)$ ***and for wall with submerge soil up to 0.2 of wall height, Base width,*** $B = (0.7093 + 0.0091)$***. Results also showed that safety factors against sliding and overturning increase at a decreasing rate with constant decrease in water level. This gives an indication that water level greatly affects the stability of the retaining wall, that is, the higher the water level the greater the sliding and overturning effects. Results also revealed that sliding safety factor increases constantly with Base width while factor of safety against overturning increases at an increasing rate. This also shows the severity of sliding as against overturning. Both safety factors also increase at a decreasing rate with Wall height giving an indication that the stability of cantilever retaining wall increases with its Height under the same load. For an increasing surcharge values, sliding safety factor decreases constantly while overturning decreases at a decreasing rate. This also explains why overturning is less critical as compared to sliding effect.***

Keywords: Retaining Wall, Hydrostatic Force, Stability, Loadings, Sliding, Overturning

INTRODUCTION

Retaining walls are permanent or temporary structures used to provide lateral support to the soil, liquid and other materials. These structures are used to retain earth fill or any other materials, which would not be able to stand vertically unsupported so that the ground surface at different elevations are maintained on either side of the retaining walls (Raju, 1990). Dismuke and Cornfield (1991) also described Retaining Walls as engineering structures constructed to resist lateral forces imposed by soil movement and water pressure; they are used as protection against the erosive forces of water and as a method of slope stabilization along highways, railroads and construction sites. Retaining walls are useful within the built up environment especially at bridge site, riverbank areas and even within the house in a sloppy terrain (Oyenuga, 2001). If unrestrained, a soil embankment will relapse to its angle of repose. Some soil, such as clays have cohesion that enables vertical and near- vertical faces to remain partially intact, but even these may slump under the softening influence of groundwater. Retaining walls must adequately support its backfill without detrimental lateral movement and the surface of the backfill must not settle unduly. If water is trapped behind the retaining structure, this may also reduce the adhesion and the bearing resistance. They are often designed with great heights and length to retain the movement of the soil and the rocks in ways that are both attractive and economical. The stability of these retaining structures is vital to reduce structural failures, earthquake losses and post-earthquake emergency response (Green and Cameron, 2004)

As a result of the dynamic nature of developments in engineering design and product development, different types of retaining walls have evolved in quick succession. Cantilever retaining walls constructed of reinforced of Portland cement concrete was the predominant type of rigid retaining walls used from about the 1920s to the 1970s. Due to superior economics in the use of material and support backfill up to 7.5m high it largely displaced the traditional gravity wall constructed of stone or unreinforced cement concrete, which may prove to be uneconomical for height above 3m (Oyenuga, 2005). According to Oyenuga (2005) and Morgenstern and Sangrey (1982), Retaining walls are broadly classified into major types as Gravity, Cantilever and Revetment walls. Delattre (2001) gave the general overview various methods used in analyzing retaining walls used over the centuries from predecessors of Coulomb to Boussinesq and the limitation of a method led to the development of another which was a continuation of work done in (Delattre,1999). The safety factor against overturning must be greater or equal to 1.5 if the soil in front of the wall is ignored and greater or equal to 2.0 if the soil is allowed in front of the wall (Alam, 1992) and Ranjan and Rao (2007). Mosley et al (1999) said that critical conditions for stability are when a maximum horizontal force acts with a minimum vertical load and when the Overturning moment is greater than Resisting moment. To guard against a stability failure, it is usual to apply conservative factors of safety to the force and loads with a value of $\gamma_f = 1.6$ or higher. Ranjan and Rao (2007) also made the following recommendations that Base width, B to be 0.4H to 0.7H, Projection of toe from the base of stem to be 0.2B to 0.4B and Unit weight of granular soils may range from 16.5 to 17kN/m^2 and 17 to 19kN/m^2 for cohesive soils.

The main objective of this study is to investigate the combined effects of soil, surcharge loads and water on the structural behaviors of cantilever retaining wall under varying geometric properties by proportioning the dimensions of the wall to allow for iterative design process to study the effect of the variations on the stability against forward sliding, overturning and bearing capacity failure.

METHODOLOGY

The major method employed in this research is numerical method and a computer program(Java) was developed to ease the analysis of cantilever retaining wall under varying application of loads based on the model advanced for the purpose. The project is also comparative in nature with the comparison of the changes in two or three parameters on the structural properties of the cantilever retaining walls. The types of loads allowed by the program to act on the structure (retaining walls) are hydrostatic pressure, backfill soil pressure and the self weight of the retaining walls (wall and footing). The backfill soil pressure is the pressure exerted on the structure by the retained soil which was calculated internally by the program as a function of structure lateral displacement. Self weight of the abutment was also calculated internally by the program.

A structure model shown in figure 1 was used to develop a program for the calculation of the overturning moment and sliding forces on the wall under varying application of loads and geometric dimensions. The procedures followed are explained below under stability and bearing pressure analyses:

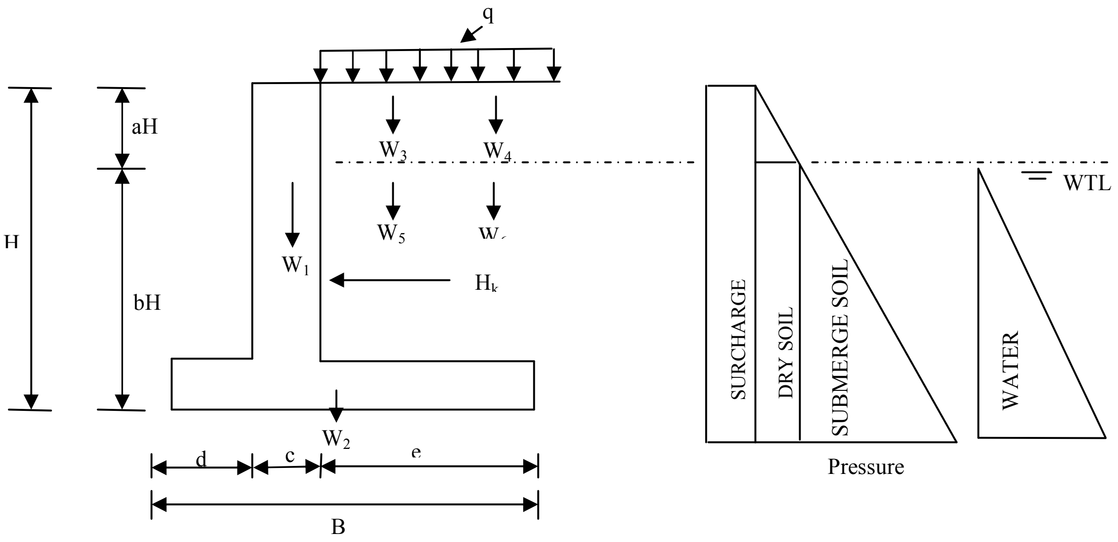

Figure 1: A Model of Cantilever Retaining Wall

Stability analysis

The steps used are as follows:

i. The height of the retaining wall was taken to be H=3m, 5m, 7m and 9m and Width of the footing (B) was taken to be in the range of 0.5 to 1.4 of wall height, Wall thickness, $c = B/x$ where x is a dividing factor taken as 6 in the analysis, toe width as $d = B/y$, y was taken to be 3 as suggested by Raju (1990) and width of heel, d was also used as $e = B/z$, where z is also a dividing factor to allow for varying values of e and z was used as 2 (in this study) to make heel to be half of the entire Base width. A value of angle of internal friction (ϕ) was also taken to be 30° as stated by Smith and Smith (1990) as the average value for the soil and all these are inputted into the computer program.

ii. Coefficient of active pressure, K_a was determined from the equation 1:

$$K_a = (1 - Sin\phi)/(1 + Sin\phi) \quad \text{-------------} \quad 1$$

It was assumed that the effect of passive earth pressure is zero because the wall is not retaining soil in front of the stem (at toe side).

iii. Lateral/horizontal earth pressure induced on the wall by the backfill soil (P_a), hydrostatic load (P_w) and surcharge load (P_s) were calculated from equations 2 below:

Submerge Unit Weight, $\gamma' = \gamma_{sat} - 9.81$, where $\gamma_{sat}(G_{sat})$ is the saturated unit weight of the soil aken to be $20 kN/m^3$ as practical value for most soils.

$$\left.\begin{array}{l} P_a = K_a H(a\gamma + b\gamma'), \\ P_w = 9.81bH \text{ and} \\ P_s = K_a q, \end{array}\right\} \quad \text{----------} \quad 2$$

where a and b are multiplying factors of the wall height which demarcate the submerge portion from the dry portion. $\gamma(G)$ is the unit weight of the dry soil taken to be $18 kN/m^3$ for well-drained soil, q is the surcharge load.

The Surcharge values of $0,10,20,30$ and $40 kN/m^2$ (Fethi, 2000) and Dicleli (2001) were used as design practical values for uniform loads (roadway, building and stock goods) or dynamic load (traffic) and based on minimum design surcharge of $10 kN/m^2$ recommended by code of practice. After this, total horizontal force/load (H_k) was determined from the express

$$H_k = 0.5H^2(a^2\gamma + b^2\gamma')K_a + abH^2K_a\gamma + P_sH + 0.5P_wbH \quad \text{----------------} \quad 3$$

(If the wall supports the surcharge load together with the backfill soil), otherwise the surcharge effect becomes zero and for this condition, horizontal force reduces to

$$H_k = 0.5H^2(a^2\gamma + b^2\gamma')K_a + abH^2K_a\gamma + 0.5P_wbH \quad \text{------------} \quad 4$$

iv. Calculation of vertical loads

The vertical loads acting on the wall are loads from surcharge (W_4), backfill soil (W_3), self weight of the stem (W_1), submerge soil (W_5), water (W_6), and self weight of the footing (W_2). These loads are calculated from the expression:

$$W_1 = c(H - c)\gamma_m$$

$$W_2 = \gamma_m Bc$$

$$W_3 = aeH\gamma$$

$$W_4 = eq$$

$$W_5 = e(bH - c)\gamma'$$

$$W_6 = e(bH - c)\gamma$$

Where $\gamma_m(G_m)$ is unit weight of concrete which was taken to be $24 kN/m^3$

Total vertical load, $V_k = W_1 + W_2 + W_3 + W_4 + W_5 + W_6$ --------- 5

v. Checking for sliding

The structure will only be stable against sliding when the frictional resisting force is greater than sliding force. These forces were calculated from:

Frictional resisting force $F = \mu V_k$ ---------- 6

Where μ is the coefficient of friction and its value was taken to be 0.5 in the program. Safety factor against sliding,

$$F_s = F/H_k \quad \text{--------------------------} \quad 7$$

vi Checking for overturning effect

For the wall to resist the overturning moment that may be developed at the toe, overturning moment must be less than resisting moment, that is

Resisting moment (R) ≥ Overturning moment (M_o)

$$M_o = \tfrac{1}{6}H^3(a^2\gamma + b^2\gamma')K_a + 0.5abH^3K_a\gamma + 0.5P_sH^2 + \tfrac{1}{6}P_wb^2H^2 \quad \text{---------} \quad 8$$

$$R = W_1(0.5c + d) + 0.5W_2B + (W_3 + W_4 + W_5 + W_6)(0.5e + d + c) \quad \ldots\ldots\ldots\ldots\ldots \quad 9$$

The safety factor against overturning, $F_o = R/M_o$

Bearing Pressure Analysis

The bearing pressures underneath retaining walls were assessed on the basis of serviceability limit state when determining the size of the base that is required. The analysis was based on foundations subjected to vertical load and horizontal (vertical load applied eccentrically) loads, coupled with an overturning moment. By considering a unit length of the cantilever wall, the resultant moment about the centroidal axis of the base was calculated as:

Moment about base centre-line M

$$M = \tfrac{1}{6}H^3(a^2\gamma + b^2\gamma')K_a + 0.5abH^3K_a\gamma + 0.5P_sH^2 + \tfrac{1}{6}P_wb^2H^2 + W_1(0.5B - 0.5c - d) - (W_3 + W_4 + W_5 + W_6)(0.5B - 0.5e)$$

-------- 10

The maximum bearing pressure was calculated from the program by the expression:

$$P_1 = \frac{V_k}{B} + \frac{6M}{B^2} \quad \text{----------------} \quad 11$$

$$P_2 = \frac{V_k}{B} - \frac{6M}{B^2} \quad \text{------------} \quad 12$$

RESULTS AND DISCUSSION

Program Structure

```
import javax.swing.*;
public class stability
{public static void main (String args [])
{ String hi,Bi,ai,bi,µi,fi,Gi,Gisat,Gim,xi,yi,zi,qi;
        float H,B,a,b,µ,f,G,Gsat,Gm,x,y,z,q;
        double
c,d,e,Gp,Pa,Ka,Ps,Pw,m,n,r,l,Hk,W1,W2,W3,W4,W
5,W6,Vk,F,Fs,Mo,R,Fo,M,P1,P2;
hi=JOptionPane.showInputDialog ("Enter the value
of H=");
Bi=JOptionPane.showInputDialog ("Enter the value
of B=");
ai=JOptionPane.showInputDialog ("Enter the value
of a=");
bi=JOptionPane.showInputDialog ("Enter the value
of b=");
fi=JOptionPane.showInputDialog ("Enter the value
of ø= ");
µi=JOptionPane.showInputDialog ("Enter the value
of µ=");
Gi=JOptionPane.showInputDialog ("Enter the value
of G=");
Gisat=JOptionPane.showInputDialog ("Enter the
value of Gsat=");
Gim =JOptionPane.showInputDialog ("Enter the
value of Gm=");
xi=JOptionPane.showInputDialog ("Enter the value
of x=");
yi =JOptionPane.showInputDialog ("Enter the value
of y=");
zi=JOptionPane.showInputDialog ("Enter the value
of z=");
H=Float.parseFloat (hi);
B=Float.parseFloat (Bi);
a=Float.parseFloat (ai);
b=Float.parseFloat (bi);
f=Float.parseFloat (fi);
µ=Float.parseFloat (µi);
G=Float.parseFloat (Gi);
Gsat=Float.parseFloat (Gisat);
Gm=Float.parseFloat (Gim);
x=Float.parseFloat (xi);
y=Float.parseFloat (yi);
z=Float.parseFloat (zi);
// Processing
  c=B/x;
  d=B/y;
  e=B/z;
// submerge Unit weight, G
//   Gp=Gamma prime, Gsat=Gamma Sat,
Gm=Gamma m
   Gp=Gsat-9.81;
        Ka= (1 - Math.sin (3.142*f /180)) / (1
+Math.sin (3.142*f /180));
        // Testing for Surcharge, q
        qi =JOptionPane.showInputDialog ("if the
soil contains Surcharge, enter value for q=? else enter
0 (if not). Enter the value of q= ");
        q=Float.parseFloat (qi);
        n=Math.pow (H, 2);
            m=n*H;
            l=Math.pow (a, 2);
            r=Math.pow (b, 2);
        If (q!=0)
         {
                Pa=Ka*H*(a*G+b*Gp);
                Ps= Ka*q;
                Pw=9.81*b*H;
                        // Therefore
                Hk=0.5*Ka*n*(l*G+r*Gp)
+a*b*n*G*Ka+Ps*H+0.5*Pw*b*H;
                W1=c*(H-c)*Gm;
                W2= Gm*B*c;
                W3=a*e*H*G;
                W4=e*q;
                W5=e*(b*H-c)*Gp;
                W6=9.81*e*(b*H-c);
                Vk=W1+W2+W3+W4+W5+W6;
                F=µ*Vk;
                Fs=F/Hk;

        Mo=m*Ka*(l*G+r*Gp)/6+0.5*a*b*m*G*
Ka+0.5*Ps*n+Pw*r*n/6;
                R=W1*(0.5*c+d)    +0.5*W2*B+
(W3+W4+W5+W6)*(0.5*e+c+d);
                Fo=R/Mo;
M=m*Ka*(l*G+r*Gp)/6+0.5*a*b*m*G*Ka+0.5*Ps
*n+Pw*r*n/6+W1*              (0.5*B-0.5*c-d)-
(W3+W4+W5+W6)*(0.5*B-0.5*e);
                }//End of if when there is
surcharge
        else
                {
                Pa=Ka*H*(a*G+b*Gp);
                Pw=9.81*b*H;
```

```
                Hk=0.5*n*Ka*(l*G+r*Gp)
+a*b*n*G*Ka+0.5*Pw*b*H;
                W1=c*(H-c)*Gm;
                W2= Gm*B*c;
                W3=a*e*H*G;
                W5=e*(b*H-c)*Gp;
                W6=9.81*e*(b*H-c);
                Vk= W1+W2+W3+W5+W6;
                F=µ*Vk;
                Fs=F/Hk;

        Mo=m*Ka*(l*G+r*Gp)/6+0.5*a*b*m*G*
Ka+Pw*r*n/6;
//Displaying Result
System.out.println ("Output Results");
System.out.println (" Ka = " +Ka);
System.out.println (" Hk = " +Hk);
System.out.println (" Vk = " +Vk);
System.out.println (" F = "  +F);
System.out.println (" R = "  +R);
System.out.println (" Mo = " +Mo);
                R=  W1*(0.5*c+d)  +0.5*W2*B+
(W3+W5+W6)*(0.5*e+c+d);
                Fo=R/Mo;
M=m*Ka*(l*G+r*Gp)/6+0.5*a*b*m*G*Ka+Pw*r*
n/6+W1*            (0.5*B-0.5*c-d)            -
(W3+W5+W6)*(0.5*B-0.5*e);
                }//end of else
                P1=Vk/B+ (6*M)/ (Math.pow (B,
2));
                P2=Vk/B-(6*M)/(Math.pow(B,
2));


System.out.println (" M = " +M);
System.out.println (" Fs = " +Fs);
System.out.println (" Fo = " +Fo);
System.out.println (" P1 = " +P1);
System.out.println (" P2 = " +P2);
System.exit (0);
 }
}
```

Samples of the Output for the Combined Effects of Soil, Surcharge and Water

```
Microsoft Windows [Version 6.0.6001]
Copyright (c) 2006 Microsoft Corporation.  All
rights reserved.
C:\Users\SOLOMON COMPUTERS>cd..
C:\Users>cd..
C:\>cd j2*
C:\j2sdk1.4.1_01>cd bin
C:\j2sdk1.4.1_01\bin>java stability
        ========Input Values=======
              H=             3.0
              B=             1.5
              a=            0.0
              b=            1.0
              x=            6.0
              y=            3.0
              z=            2.0
              °     =       30.0
              Á     =       0.5
              G     =       18.0
              Gm    =       24.0
              Gsat  =       20.0
              q     =       10.0

   ========Output Results=======
              Ka =       0.3332810738372141
              Hk =       69.42603585592187
              Vk =       74.25
              F =        37.125
              R =         71.90625
              Mo =        74.4252519634801
              M =         58.20650196348009
              Fs =        0.5347417513084658
              Fo =       0.9661539343566328
              P1 =       204.71733856928026
              P2 =       -105.71733856928026
```

```
C:\j2sdk1.4.1_01\bin>java stability
        ========Input Values=======
              H=             3.0
              B=             1.8
              a=            0.0
              b=            1.0
              x=            6.0
              y=            3.0
              z=            2.0
              °     =       30.0
              Á     =       0.5
              G     =       18.0
              Gm    =       24.0
              Gsat  =       20.0
              q     =       10.0
        ========Output Results=======
              Ka =       0.3332810738372141
              Hk =       69.42603585592187
              Vk =       89.99999607801442
              F =         44.99999803900721
              R =          104.00399112832565
              Mo =        74.4252519634801
              M =          51.421253442986554
              Fs =         0.6481717915220536
              Fo =        1.397428807891166
              P1 =        145.2245476037829
              P2 =        -45.22454931244937
```

```
C:\j2sdk1.4.1_01\bin>java stability
      ========Input Values=======
           H=                3.0
           B=                2.1
           a=               0.0
           b=               1.0
           x=               6.0
           y=               3.0
           z=               2.0
           °      =         30.0
           Á      =         0.5
           G      =         18.0
           Gm     =         24.0
           Gsat   =         20.0
           q      =         10.0
 ========Output Results=======
           Ka =         0.3332810738372141
           Hk =         69.42603585592187
           Vk =         106.0499956905842
           F =          53.0249978452921
           R =          142.1857400884332
           Mo =         74.4252519634801
           M =          43.592004264725965
           Fs =         0.7637624299237474
           Fo =         1.9104502347966879
           P1 =         109.80885496781349
           P2 =         -8.808854485299655
```

```
C:\j2sdk1.4.1_01\bin>java stability
      ========Input Values=======
           H=                3.0
           B=                2.4
           a=               0.0
           b=               1.0
           x=               6.0
           y=               3.0
           z=               2.0
           °      =         30.0
           Á      =         0.5
           G      =         18.0
           Gm     =         24.0
           Gsat   =         20.0
           q      =         10.0
      ========Output Results=======
           Ka =         0.3332810738372141
           Hk =         69.42603585592187
           Vk =         122.40000438690187
           F =          61.200002193450935
           R =          186.52801146411912
           Mo =         74.4252519634801
           M =          34.77724938283734
           Fs =         0.8815137064783273
           Fo =        2.506246287962142
           P1 =        87.22629836276582
           P2 =        14.7737012398699
```

```
C:\j2sdk1.4.1_01\bin>java stability
      ========Input Values=======
           H=                3.0
           B=                2.7
           a=               0.0
           b=               1.0
           x=               6.0
           y=               3.0
           z=               2.0
           °      =         30.0
           Á      =         0.5
           G      =         18.0
           Gm     =         24.0
           Gsat   =         20.0
           q      =         10.0
    ========Output Results=======
           Ka =         0.3332810738372141
           Hk =         69.42603585592187
           Vk =         139.05000440478327
           F =          69.52500220239163
           R =           237.10726372513193
           Mo =          74.4252519634801
           M =           25.035499954237302
           Fs =           1.0014254932641573
           Fo =         3.1858442863113003
           P1 =         72.10534975064526
           P2 =         30.894651693111687
```

```
C:\j2sdk1.4.1_01\bin>java stability
      ========Input Values=======
           H=                3.0
           B=                3.0
           a=               0.0
           b=               1.0
           x=               6.0
           y=               3.0
           z=               2.0
           °      =         30.0
           Á      =         0.5
           G      =         18.0
           Gm     =         24.0
           Gsat   =         20.0
           q      =         10.0
      ========Output Results=======
           Ka =         0.3332810738372141
           Hk =         69.42603585592187
           Vk =         156.0
           F =          78.0
           R =           294.0
           Mo =          74.4252519634801
           M =           14.425251963480093
           Fs =          1.123497820930918
           Fo =           3.9502721488166888
           P1 =           61.616834642320065
           P2 =           42.383165357679935
```

```
C:\j2sdk1.4.1_01\bin>java stability
     ========Input Values=======
          H=                5.0
          B=                2.5
          a=               0.0
          b=               1.0
          x=               6.0
          y=               3.0
          z=               2.0
          °     =          30.0
          Á     =          0.5
          G     =          18.0
          Gm     =         24.0
          Gsat    =        20.0
          q      =         10.0
     ========Output Results=======
          Ka =         0.3332810738372141
          Hk =         181.74073047187585
          Vk =         197.91666532556212
          F =          98.95833266278106
          R =          317.2742993156943
          Mo =         316.78792886301034
          M =          246.90945741689023
          Fs =         0.5445027782481304
          Fo =         1.001535318768078
          P1 =         316.1997452504395
          P2 =         -157.8664129899897
```

Behaviour of Frictional Resisting Force with Base Width and Wall Height

The behaviour of Frictional resisting force with both Base width and Wall height is expressed graphically of Figures 2 to 4, which shows a linear relationship with Base width and non-linear relationship with Height of the retaining wall. This revealed that Frictional resisting force increases constantly with Base width but increases at an increasing rate with Wall height. For a particular wall height, Frictional resisting force increases constantly while Horizontal thrust remains unchanged but increases at an increasing rate with constant increase in Wall height. Figure 5 shows the behaviour of the Frictional resisting force both increase in surcharge values and water table levels; it is clearly shown that Resisting force decreases constantly with a constant decrease in water level but increases constantly with an increasing surcharge loads. This figure also revealed that the higher the load being supported by the retaining wall, the higher the value of the resisting force but the greater the horizontal thrust on the wall and thereby leads to greater tendencies of failure of the retaining wall.

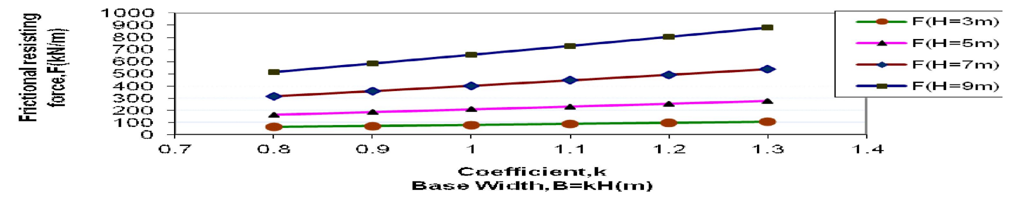

Figure 2: Frictional resisting force against Base width (for a= 0.0 and q=10kN/m^2)

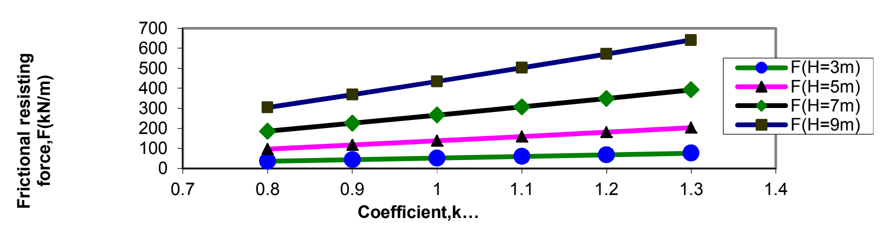

Figure 3: Frictional resisting force against Base width (for a= 0.4 and q=10kN/m^2)

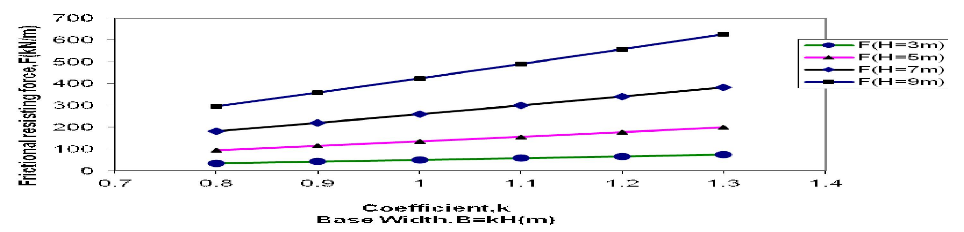

Figure 4: Frictional resisting force against Base width (for a= 0.8 and q=10kN/m^2)

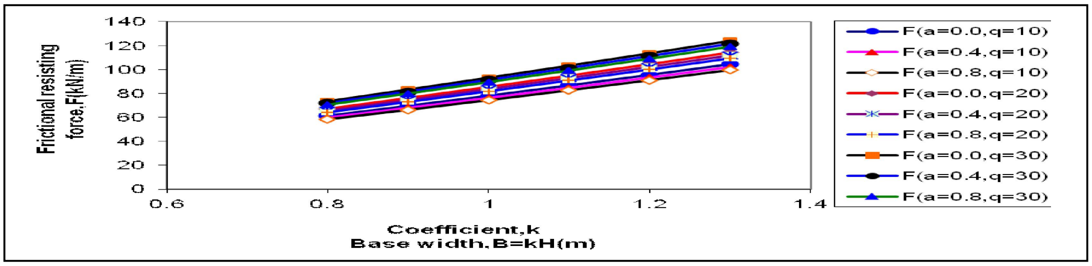

Figure 5: Behaviour of Resisting force against Base width (H=3m)

Figure 5: Behaviour of Resisting force against Base width (H=3m)

Figures 6 to 7 showed that resisting moment behaves non-linearly with both Base width and Wall height, giving a positive curvature. Results showed that Resisting moment increases at an increasing rate with both Base width and Wall height. Overturning moment remains unchanged for a particular wall height despite an increasing value of Base width but increases an increasing rate with constant increase in Wall height. Figure 3.8 showed that resisting moment decreases constantly with constant increase in water table level but increases constantly with constant increase in surcharge loads. Result also revealed that the Overturning moment reduces at a greater decreasing rate with a constant decrease in water level and this shows that the higher the water table level the greater will the effect of Overturning on the retaining wall.

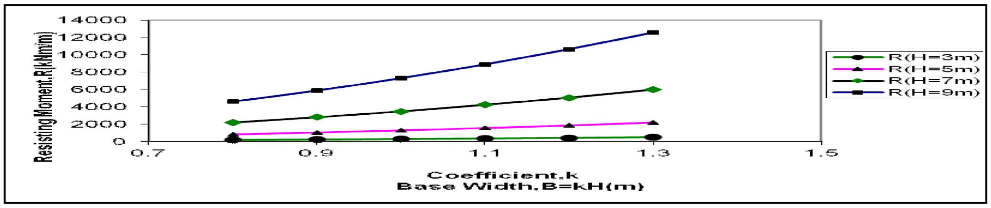

Figure 6: Resisting Moment versus Base width (for a=0.0 and q= 10kN/m^2)

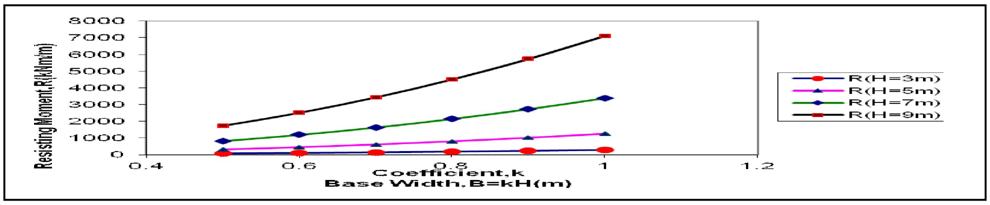

Figure 7: Resisting Moment versus Base width (for a=0.4 and q= 10kN/m^2)

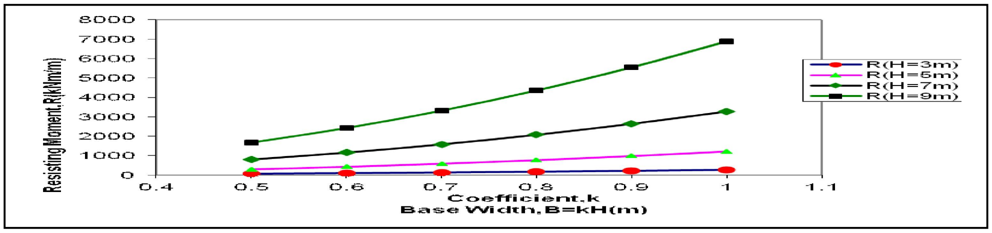

Figure 8: Resisting Moment versus Base width (for a=0.8 and q= 10kN/m^2)

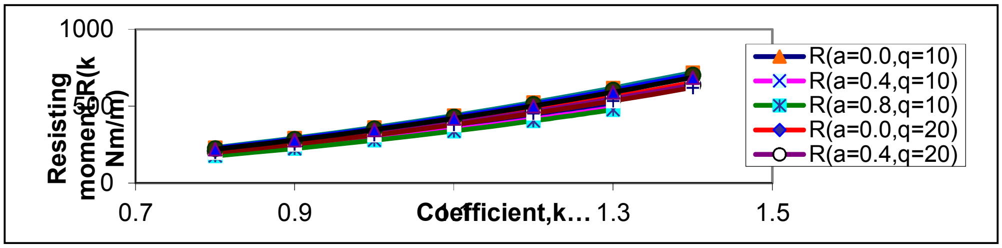

Figure 9: Behaviour of Resisting Moment against Base width (H=3m)

Figures 8 and 9 showed the behaviour of the Safety factors against Overturning and Sliding with Base width, it is revealed that the two Safety factors increases at a decreasing rate with constant decrease in water level. This gives an indication that water level greatly affects the stability of the retaining wall, that is, the higher the water level the greater the sliding and overturning effects. Results also revealed that sliding safety factor increases constantly with Base width while Factor of safety against overturning increases at an increasing rate. This also shows the severity of Sliding as against Overturning. Both safety factors also increase at a decreasing rate with Wall height giving an indication that the stability of cantilever retaining wall increases with its Height under the same load. For an increasing Surcharge values, Sliding safety factor decreases constantly while overturning decreases at a decreasing rate. This also explains why Overturning is less critical as compared to Sliding effect. The satisfactory values of these factors (the value of Base width at the safety factors of 1.5 and 2.0 for Sliding and Overturning respectively) are given below in figures 10 to 12: For wall supporting full submerged soil, the Base width, B= (1.25+0.005q) H; wall supporting submerge soil up to 0.6 of its Height, Base width, B= (0.881+0.00805q) and for wall with submerge soil up to 0.2 of wall height, Base width, B= (0.7093+0.0091q).

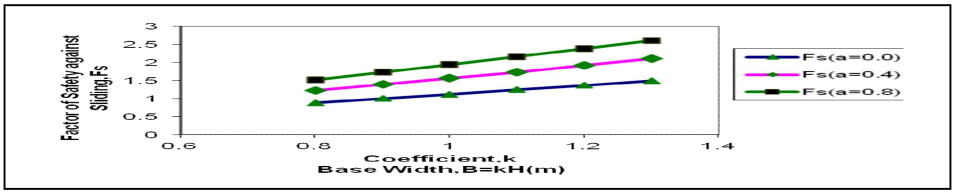

Figure 10: Factor of Safety against Sliding versus Base width (for q= 10kN/m^2)

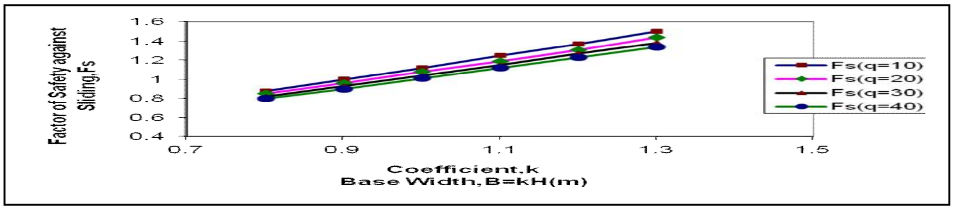

Figure 11: Factor of Safety against Sliding versus Base width (for H=3m)

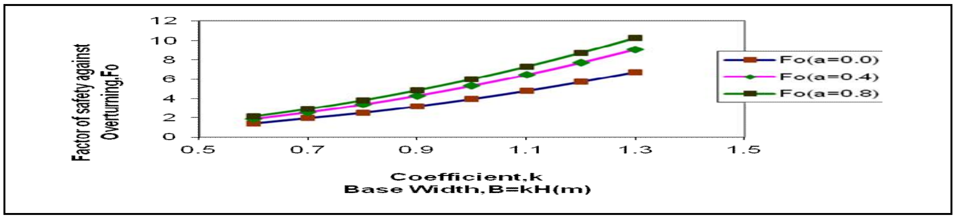

Figure 12: Factor of Safety against Overturning versus Base width (for q= 10kN/m^2)

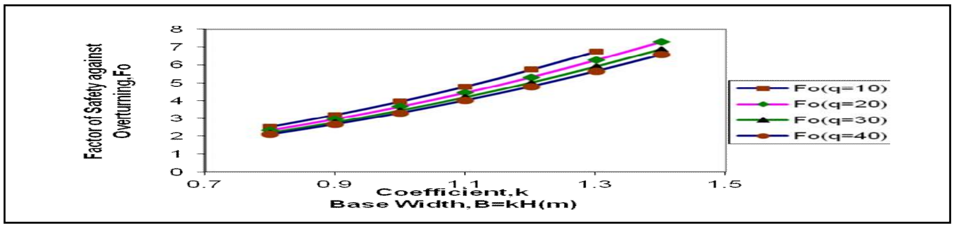

Figure 3.12: Factor of Safety against Overturning versus Base width (for H=3m)

CONCLUSION AND RECOMMENDATION

Results revealed that the higher the load being supported by retaining wall the lower the resistance offered against sliding and overturning. It also showed clearly that Frictional resisting force increases constantly with Base width but increases at an increasing rate with Wall height. This study also revealed that Resisting moment increases at an increasing rate with both Base width and Wall height. Overturning moment remains unchanged for a particular wall height despite an increasing value of Base width but increases at an increasing rate with constant increase in Wall height. Results also showed that Safety factors against sliding and overturning increase at a decreasing rate with constant decrease in water level. This gives an indication that water level greatly affects the stability of the retaining wall, that is, the higher the water level the greater the sliding and overturning effects. Results further revealed that sliding safety factor increases constantly with Base width while Factor of safety against overturning increases at an increasing rate. This also shows the severity of Sliding as against Overturning. Both safety factors also increase at a decreasing rate with Wall height giving an indication that the stability of cantilever retaining wall increases with its Height under the same load. For an increasing Surcharge values, Sliding safety factor decreases constantly while overturning decreases at a decreasing rate. This also explains why Overturning is less critical as compared to Sliding effect.

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