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Response of Retaining Wall to Support Mine Ob Dump under Passive Earth Pressure Using Limit Equilibrium Method

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Abstract:-- **Retaining walls are the most common structures which are used support the backfill. These structures are often seen at road and railway embankments, construction of residential and civil buildings and etc. In recent days, retaining walls are also constructed to hold back the soil of mine over burden dumps. In the present study, a retaining wall is analyzed over passive earth pressure. The wall is assumed to be vertical with rough surface. Soil parameters like cohesion, adhesion, angle of internal friction of soil are considered. Normally the density of OB dumps is noticed to be higher than that of regular density of soil what is considered in traditional analysis of the retaining wall. Hence, an augmented weight portions are considered in the present analysis. Failure surface is varied by changing the values of rupture surface angles. Using limit equilibrium method, equations to determine passive earth pressure is derived. Simplex iteration technique is used to optimize the equation of passive earth pressure. A detailed parametric study shows the variation of coefficient of passive earth pressure against the variation of parameters like friction angle, cohesion, and adhesion and unit weight of soil. A sensitivity analysis is also done for the behavior of rupture surface by changing different soil parameters.**

Key Words- Over Burden Dumps, Retaining walls, Limit equilibrium method, Optimization.

INTRODUCTION

Calculation of passive resistance is tremendously significant and the level of status of the passive earth pressure rises. Hence to study the retaining wall under passive condition under the overburden dumps, the basic theory is very amalgamated and the several scholars have deliberated on the related topics. Okabe(1926) and Mononobe and Matsuo(1929) given the profusions related to active earth pressure and passive resistance using pseudo static analysis. Davis et al.(1986) Morrison and Ebeling(1995), soubra(2000) and Kumar(2001) had evaluated the seismic passive resistance by considering Ø-backfill. Kumar(2001) derived seismic passive resistance coefficients for sands using limit equilibrium method. Kumar and Chitikela(2002) analyzed the seismic passive earth pressure using method of characteristics Choudhary Nimbalkar et. al(2006) established the behavior of seismic earth pressure for different soil friction, wall friction angle, shear and primary wave velocity for both active and passive pressure coefficients. Recently, Jadar and Ghosh(2017) applied the concepts of retaining wall to solve problem of seismic bearing capacity. Trusting the above facts in view, an approach has been progressed in this paper to obtained more definite values of passive earth resistance using limit equilibrium method.

Also, the result of cohesive resistance of soil mass and adhesive capacity of wall surface have been taken into consideration to optimize the values of assumed soil mixture with mining's having varying density 1.1, 1.2, 1.3 times of natural density of soil.

ANALYTICAL SOLUTION:

A vertical retaining wall is considered of H meters height for the study. The wall is assumed to be supporting soil mixed with mining having varying density 1.1, 1.2, 1.3 times of natural density of soil. Soil parameters like cohesion, adhesion, angle of internal friction of soil and angle of wall friction are accounted. Rupture angle to the vertical are considered as 90-θ. Equivalent coefficient of passive earth resistance is to be determined under different density cases.

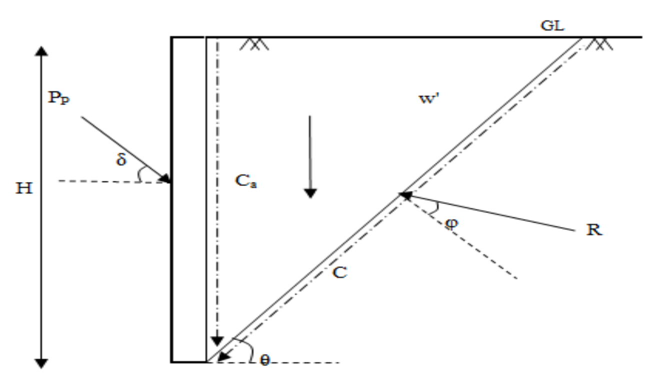

Figure 01. Various forces acting on retaining wall

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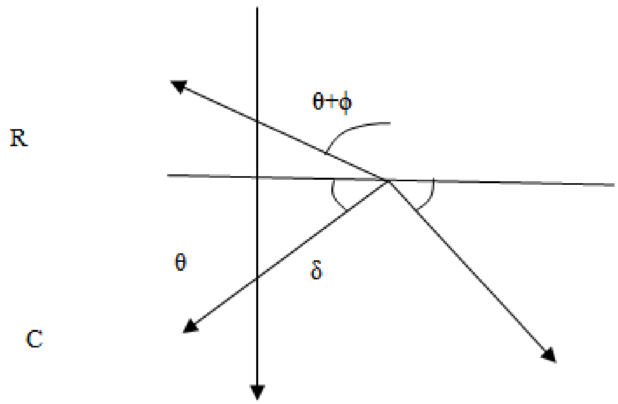

Figure 02. Free body diagram

DERIVATION OF FORMULATIONS CONSIDERING PASSIVE STATE OF EQUILIBRIUM

$\sum \boldsymbol{H}$**=0**

$P_a \cos\delta - R\sin(\theta+\varphi) - c\sin\theta = 0$

$R = \frac{P_p \cos\delta - c\cos\theta}{\sin(\theta+\varphi)}$ ……………………Equation (1)

$\sum V = 0$

$P_p \sin\delta - R\cos(\theta+\varphi) + c\sin\theta + W' + c_a = 0$ ……………Equation (2)

Solving equation (1) & equation (2),

$P_p \sin\delta - \left(\frac{P_p\cos\delta - c\cos\theta}{\sin(\theta+\varphi)}\right)\cos(\theta+\varphi) + c\sin\theta + W' + c_a = 0$

$P_p \sin\delta \sin(\theta+\varphi) - P_p\cos\delta\cos(\theta+\varphi) + c\cos\theta\cos(\theta+\varphi) + c\sin\theta\sin(\theta+\varphi) + W'\sin(\theta+\varphi) + c_a\sin(\theta+\varphi) = 0$

$-P_p\cos(\delta+\theta+\varphi) + c\cos\varphi + W'\sin(\theta+\varphi) + c_a\sin(\theta+\varphi) = 0$

$P_p = \frac{W'\sin(\theta+\varphi) + c_a\sin(\theta+\varphi) + c\cos\varphi}{\cos(\delta+\theta+\varphi)}$

$C = \frac{c*h}{\sin\theta}$, $C_a = c_a*h$, $W' = 1.1W = \frac{11}{10}\left(\frac{1}{2}\gamma h^2 \cot\theta\right)$

$P_p = \frac{\frac{11}{10}\left(\frac{1}{2}\gamma h^2\cot\theta\right)\sin(\theta+\varphi) + c_a*h\sin(\theta+\varphi) + \left(\frac{c*h}{\sin\theta}\right)\cos\varphi}{\cos(\delta+\theta+\varphi)}$

$P_p = \frac{1}{2}\gamma h^2\left[\left(\frac{11\cot\theta\sin(\theta+\varphi)}{10\cos(\delta+\theta+\varphi)}\right) + \left(\frac{2c_a\sin(\theta+\varphi)}{\gamma h\cos(\delta+\theta+\varphi)}\right) + \left(\frac{2c\cos\varphi}{\gamma h\sin\theta\cos(\delta+\theta+\varphi)}\right)\right]$

$K_P = \left(\frac{11\cot\theta\sin(\theta+\varphi)}{10\cos(\delta+\theta+\varphi)}\right) + \left(\frac{2c_a\sin(\theta+\varphi)}{\gamma h\cos(\delta+\theta+\varphi)}\right) + \left(\frac{2c\cos\varphi}{\gamma h\sin\theta\cos(\delta+\theta+\varphi)}\right)$

Similarly, for W'=1.2W and W'=1.3W we get,

$P_p = \frac{1}{2}\gamma h^2\left[\left(\frac{6\cot\theta\sin(\theta+\varphi)}{5\cos(\delta+\theta+\varphi)}\right) + \left(\frac{2c_a\sin(\theta+\varphi)}{\gamma h\cos(\delta+\theta+\varphi)}\right) + \left(\frac{2c\cos\varphi}{\gamma h\sin\theta\cos(\delta+\theta+\varphi)}\right)\right]$

$K_P = \left(\frac{6\cot\theta\sin(\theta+\varphi)}{5\cos(\delta+\theta+\varphi)}\right) + \left(\frac{2c_a\sin(\theta+\varphi)}{\gamma h\cos(\delta+\theta+\varphi)}\right) + \left(\frac{2c\cos\varphi}{\gamma h\sin\theta\cos(\delta+\theta+\varphi)}\right)$

$P_p = \frac{1}{2}\gamma h^2\left[\left(\frac{4\cot\theta\sin(\theta+\varphi)}{3\cos(\delta+\theta+\varphi)}\right) + \left(\frac{2c_a\sin(\theta+\varphi)}{\gamma h\cos(\delta+\theta+\varphi)}\right) + \left(\frac{2c\cos\varphi}{\gamma h\sin\theta\cos(\delta+\theta+\varphi)}\right)\right]$

$K_P = \left(\frac{4\cot\theta\sin(\theta+\varphi)}{3\cos(\delta+\theta+\varphi)}\right) + \left(\frac{2c_a\sin(\theta+\varphi)}{\gamma h\cos(\delta+\theta+\varphi)}\right) + \left(\frac{2c\cos\varphi}{\gamma h\sin\theta\cos(\delta+\theta+\varphi)}\right)$

Optimization of the passive earth pressure coefficient K_a is finished for the different values of θ ie. θ_1 to θ_n satisfying the optimization criteria. The optimum value of K_a for W'= 1.1w, W'=1.2w, W'=1.3w are given in **Table.1, Table.2, Table.3**

Table-1
Passive earth resistance coefficients (K_p) for W'=1.1W

ϕ	δ	C_a	C=0.1 Kp	C=0.15 Kp	C=0.2 Kp
20	0	0	2.528	2.671	2.814
		C/2	2.599	2.776	2.953
		C	2.666	2.876	3.084
	ϕ/2	0	1.883	2.022	2.161
		C/2	2.009	2.212	2.414
		C	2.136	2.401	2.667
	ϕ	0	-	-	-
		C/2	-	-	-
		C	-	-	-
25	0	0	3.024	3.181	3.338
		C/2	3.101	3.296	3.491
		C	3.176	3.407	3.638
	ϕ/2	0	2.728	2.870	3.013
		C/2	2.806	2.987	3.166
		C	2.882	3.099	3.313
	ϕ	0	2.465	2.595	2.725
		C/2	2.546	2.714	2.882
		C	2.623	2.828	3.030
30	0	0	3.645	3.818	3.991
		C/2	3.731	3.946	4.161
		C	3.815	4.071	4.326
	ϕ/2	0	-	-	-
		C/2	-	-	-
		C	-	-	-
	ϕ	0	3.000	3.148	3.296
		C/2	3.045	3.215	3.386
		C	3.090	3.283	3.475
	0	0	4.443	4.635	4.827
		C/2	4.537	4.776	5.015

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35		C	4.631	4.916	5.199
	ϕ/2	0	2.935	3.065	3.194
		C/2	2.979	3.131	3.283
		C	3.024	3.197	3.371
	ϕ	0	2.954	3.108	3.262
		C/2	3.097	3.323	3.548
		C	3.241	3.538	3.835
40	0	0	5.485	5.700	5.914
		C/2	5.593	5.861	6.127
		C	5.698	6.015	6.332
	ϕ/2	0	-	-	-
		C/2	-	-	-
		C	-	-	-
	ϕ	0	-	-	-
		C/2	-	-	-
		C	-	-	-

DISCUSSION ON RESULTS:

A detailed parametric study has been conducted to encounter the difference of static passive earth resistance coefficients for W'=1.1w with various other parameters like cohesion(c=0.1,0.15,0.2), adhesion (c_a=0, c/2, c), for angle of internal friction (Ø=20°,25°,30°,35°,40°), wall frication (δ=0, Ø/2, Ø).

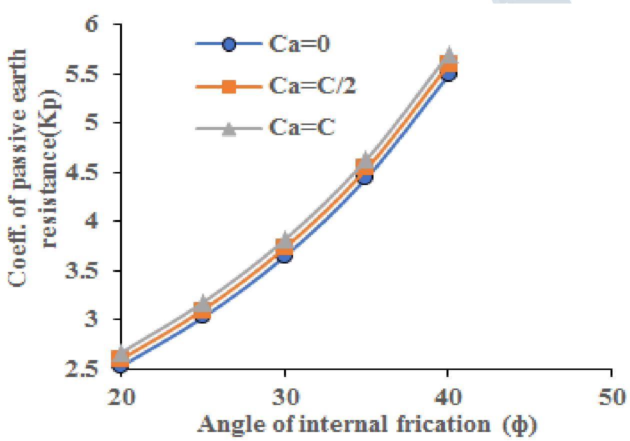

Figure 3 Shows the variation of passive earth resistance coefficients with respect to angle of internal frication at different ratio of adhesion parameters (c_a=0, c/2, c)

Figure 3 Demonstrates the variation of the passive earth resistance coefficient (K_p) with angle of internal friction (Ø), for different values of adhesion parameters(c_a). It shows that the value of passive earth resistance coefficient(K_p) increases with the rise of angle of internal friction (Ø). For example, the value of K_p for Ø=40, c_a=0, c/2, c and c=0.1, δ=0 are 5.485, 5.593, 5.698.

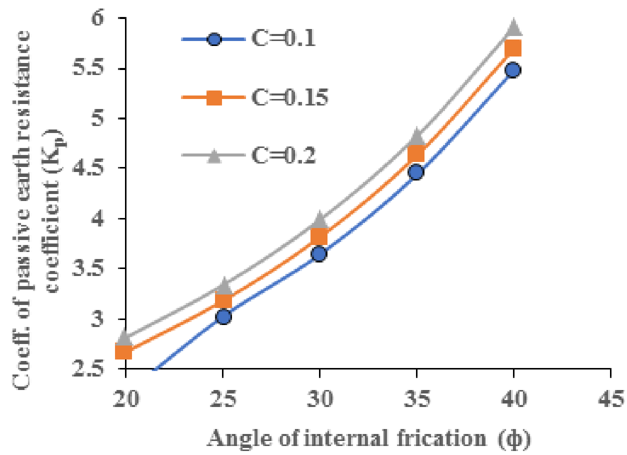

Figure 4 Shows the variation of passive earth resistance coefficients with respect to angle of internal frication at different cohesion parameters. (C=0.1, 0.15, 0.2)

Figure 4 Demonstrates the variation of the passive earth resistance coefficient (K_p) with angle of internal friction (Ø), for different values of cohesion parameters(c). It shows that the value of passive earth resistance coefficient(K_p) increases with the rise of angle of internal frication(Ø). For example the value of K_a for Ø=40, c=0.1, 0.15, 0.2 and c_a=,0 δ=0 are 5.485, 5.7, 5.914.

Table-2

Passive earth resistance coefficients (K_p) for W'=1.2W

ϕ	δ	C_a	C=0.1 Kp	C=0.15 Kp	C=0.2 Kp
20	0	0	2.732	2.875	3.018
		C/2	2.803	2.980	3.157
		C	2.871	3.080	3.289
	ϕ/2	0	2.029	2.168	2.307
		C/2	2.155	2.358	2.560
		C	2.282	2.547	2.813
	ϕ	0	-	-	-
		C/2	-	-	-
		C	-	-	-
25	0	0	3.270	3.427	3.584
		C/2	3.347	3.543	3.737
		C	3.423	3.654	3.885
	ϕ/2	0	2.950	3.092	3.235
		C/2	3.029	3.209	3.389
		C	3.105	3.322	3.537
	ϕ	0	2.666	2.796	2.926
		C/2	2.746	2.915	3.083
		C	2.824	3.029	3.232
30	0	0	3.945	4.118	4.291
		C/2	4.032	4.247	4.462
		C	4.115	4.371	4.627
	ϕ/2	0	-	-	-
		C/2	-	-	-

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Vol 3, Issue 5, May 2018

		C	-	-	-
	ϕ	0	3.246	3.394	3.542
		C/2	3.291	3.461	3.632
		C	3.336	3.528	3.721
35	0	0	4.810	5.004	5.196
		C/2	4.906	5.145	5.384
		C	5.000	5.286	5.568
	ϕ/2	0	3.178	3.308	3.437
		C/2	3.223	3.374	3.526
		C	3.267	3.441	3.615
	ϕ	0	3.295	3.348	3.502
		C/2	3.338	3.563	3.789
		C	3.481	3.778	4.076
40	0	0	5.945	6.160	6.374
		C/2	6.052	6.320	6.588
		C	6.158	6.476	6.793
	ϕ/2	0	-	-	-
		C/2	-	-	-
		C	-	-	-
	ϕ	0	-	-	-
		C/2	-	-	-
		C	-	-	-

DISCUSSION ON RESULTS:

A detailed parametric study has been conducted to encounter the difference of static passive earth resistance coefficients for W'=1.2w with various other parameters like cohesion(c=0.1,0.15,0.2), adhesion (c_a=0, c/2, c), for angle of internal frication(Ø=20°,25°,30°,35°,40°), wall frication (δ=0, Ø/2, Ø).

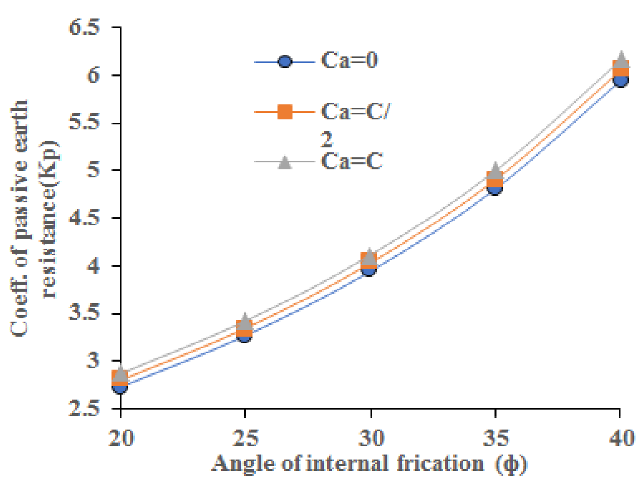

Figure 5 Shows the variation of passive earth resistance coefficients with respect to angle of internal frication at different ratio of adhesion parameters (c_a=0, c/2, c)

Figure 5 Demonstrates the variation of the passive earth resistance coefficient (Kp) with angle of internal friction (Ø), for different values of adhesion parameters(ca). It shows that the value of passive earth resistance coefficient(Kp) increases with the rise of angle of internal friction (Ø). For example the value of Kp for Ø=40, ca=0, c/2, c and c=0.1, δ=0 are 5.945, 6.052, 6.158.

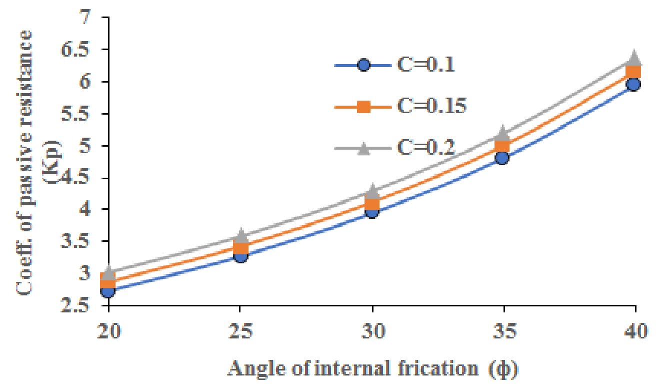

Figure 6 Shows the variation of passive earth resistance coefficients with respect to angle of internal frication at different cohesion parameters(C=0.1, 0.15, 0.2)

Figure 6 Demonstrates the variation of the passive earth resistance coefficient (Kp) with angle of internal friction(Ø), for different values of cohesion parameters(c). It shows that the value of passive earth resistance coefficient(Kp) increases with the rise of angle of internal frication(Ø). For example the value of Ka for Ø=40, ca=0 and c=0.1, 0.15, 0.2 δ=Ø/2 are 5.945, 6.16, 6.374.

Table-3
Passive earth resistance coefficients (K_p) for W'=1.3W

ϕ	δ	C_a	C=0.1 Kp	C=0.15 Kp	C=0.2 Kp
20	0	0	3.004	3.147	3.290
		C/2	3.075	3.252	3.429
		C	3.143	3.353	3.562
	ϕ/2	0	2.223	2.363	2.502
		C/2	2.350	2.552	2.755
		C	2.476	2.742	3.007
	ϕ	0	-	-	-
		C/2	-	-	-
		C	-	-	-
25	0	0	3.599	3.756	3.913
		C/2	3.676	3.871	4.066
		C	3.752	3.983	4.215
	ϕ/2	0	3.246	3.389	3.531
		C/2	3.325	3.506	3.686
		C	3.402	3.619	3.834
	ϕ	0	2.933	3.063	3.193
		C/2	3.014	3.183	3.351
		C	3.093	3.298	3.501
	0	0	4.345	4.518	4.691
		C/2	4.432	4.647	4.862

30		C	4.515	4.772	5.028
	ϕ/2	0	-	-	-
		C/2	-	-	-
		C	-	-	-
	ϕ	0	3.574	3.722	3.870
		C/2	3.619	3.789	3.960
		C	3.664	3.856	4.049
35	0	0	5.304	5.496	5.688
		C/2	5.398	5.637	5.876
		C	5.492	5.778	6.061
	ϕ/2	0	3.503	3.632	3.762
		C/2	3.547	3.699	3.850
		C	3.591	3.765	3.939
	ϕ	0	3.601	3.669	3.823
		C/2	3659	3.884	4.110
		C	3.802	4.099	4.396
40	0	0	6.558	6.773	6.987
		C/2	6.665	6.933	7.201
		C	6.772	7.089	7.407
	ϕ/2	0	-	-	-
		C/2	-	-	-
		C	-	-	-
	ϕ	0	-	-	-
		C/2	-	-	-
		C	-	-	-

DISCUSSION ON RESULTS:

A detailed parametric study has been conducted to encounter the difference of static passive earth resistance coefficients for W'=1.3w with various other parameters like cohesion(c=0.1,0.15,0.2), adhesion(c_a=0, c/2, c), for angle of internal frication(Ø=20°,25°,30°,35°,40°), wall frication (δ=0, Ø/2, Ø).

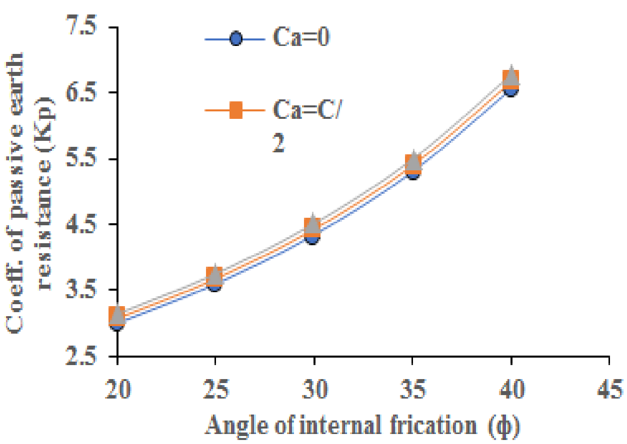

Figure 7 Shows the variation of passive earth resistance coefficients with respect to angle of internal frication at different ratio of adhesion parameters (c_a=0, c/2, c)

Figure 7 Demonstrates the variation of the passive earth resistance coefficient (K_p) with angle of internal friction (Ø), for different values of adhesion parameters(c_a). It shows that the value of passive earth resistance coefficient(K_p) increases with the rise of angle of internal friction (Ø). For example the value of K_p for Ø=40, c_a=0,c/2,c and c=0.1, δ=Ø/2 are6.558, 6.665, 6.772.

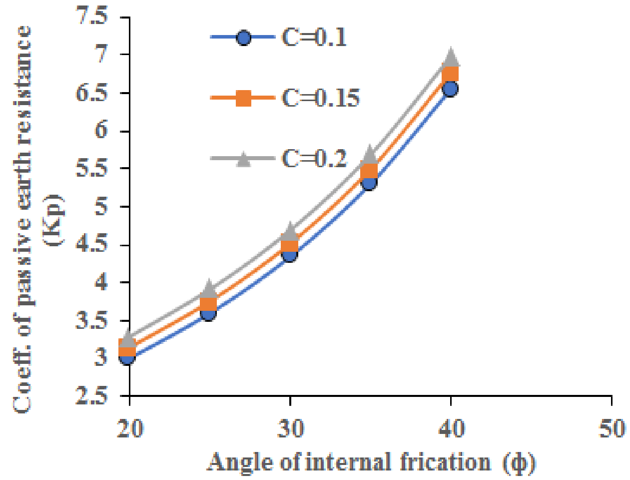

Figure 8 Shows the variation of passive earth resistance coefficients with respect to angle of internal frication at different cohesion parameters.(C=0.1, 0.15, 0.2)

Figure 8 Demonstrates the variation of the passive earth resistance coefficient (K_p) with angle of internal frication(Ø), for different values of cohesion parameters(c). It shows that the value of passive earth resistance coefficient(K_p) increases with the rise of angle of internal frication(Ø). For example the value of K_a for Ø=40, c_a=0, c/2, c and c=0.1, δ=Ø/2 are 6.558, 6.773, 6.987.

CONCLUSION:

The present analysis decorates an analytical formulation for the coefficients of all passive resistances on the back of the retaining wall supporting against C-Ø backfill along with weight of wedge, adhesion, cohesion and single rupture angle. From the obtained analysis, a detailed parametric study is completed for the variation of various density of soil and wall parameters. From the point of parametric learning it shows that passive earth resistances displays direct relation with the rise in angle of internal frication(Ø), cohesion(c) and adhesion(ca). For a certain sequence it may be negative. This shows that there should not be any weight acting on the retaining wall during passive state. On the other hand it rises with the increasing in the density of overburden dumps by 1.1, 1.2, 1.3 times of natural density of soil.

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