ACTIVE AND PASSIVE EARTH PRESSURE ACTING ON SMOOTH CIRCULAR SHAFTS USING NUMERICAL APPROACH

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ABSTRACT :

Several researchers have studied the lateral earth pressures acting on the vertical, rigid and circular shaft using experimental, theoretical and numerical methods of analysis. In this study, a new retaining wall model under ax-isymmetric conditions with outward pressure is considered and can be widely used in the design of grain silos, buildings and road construction. This paper presents a detailed evolution of the distribution of earth pressure on a smooth cylindrical wall filled with granular material and subjected to radial displacement by using the computer code FLAC-2D. Apart from the axisymmetric retaining wall, the analysis covered a wall under plane strain condition.

A parametric study is carried out to evaluate the distribution of the active and passive pressure on the wall as a function of the radius, the friction angle of the granular material. The numerical study found that: for the out-ward wall, increasing (r) has no effect on the active and passive earth pressures coefficients and is similar to plane strain conditions, for the inward wall, increasing (r) has a fully clear effect on the active and passive earth pressures coefficients and is similar to plane strain conditions when r/f =33.33. Numerical results are discussed and compared with recent experimental results and theoretical solutions. This study helps to know the difference between the two models (outward and inward mechanisms) and to know when to apply the two methods (ax-isymmetric and plane strain) when studying the lateral earth pressures acting on the vertical, rigid and circular shaft.

KEYWORDS : *Passive earth pressure, Active earth pressure, Numerical analysis, Finite difference method, Circular shaft.*

1. INTRODUCTION

Several attempts have been made to study the lateral earth pressure distribution for cylindrical shafts in non-cohesive media. Westergaard [2] and Terzaghi [4], proposed analytical solutions; Prater, [7] used the limit equilibrium method; and Berezantzev [5], Liu and Wang [12], Liu et al. [13] used the slip line method. In contrast to classical earth pressure theory, where active and passive earth pressures are calculated using Coulomb,[3] or Rankine [1]. Coulomb first proposed the limit equilibrium method by assuming a plane failure surface, and this method can be used to determine the lateral earth pressure in general cases for cohesionless soil. Rankine's solution could potentially explain cohesive-friction backfill material bounded by a horizontal line, when the walls are vertical and there is no wall friction. Many experimental studies on tunnel face stability have also been performed. Various techniques have been developed to simulate lining installation and radial soil movement during construction. (a) shaft sinking (Walz [6]); (b) temporary stabilization of the

excavation using fluid pressure (liquid or gas) (Lade et al. [8]); and (c) the use of a mechanically adjustable lining (Herten and Pulsfort [9]).
Walz [6] used a model shaft equipped with a cutting edge ring to investigate lateral active earth pressure on a circular vertical manhole. Lade et al.[8] perform physical modeling by replacing excavated soil with flexible rubber bag filled with liquid or gas.
In contrast, Herten and Pulsfort [9] conducted numerical analyses to simulate the construction of a laboratory scale shaft in granular material using the discrete element method (DEM). Distributions obtained in axisymmetric conditions can vary significantly depending on the analysis method chosen. Xianfeng Mg et al [16] provided valuable knowledge on earth pressure distribution for the construction of circular deep shafts (e.g. 100m) in composite geological strata. Martin et al. [17] concluded that the vaulting effect that develops in the ground and in the support makes circular shafts quite special with respect to the verifications classically defined for plane walls.

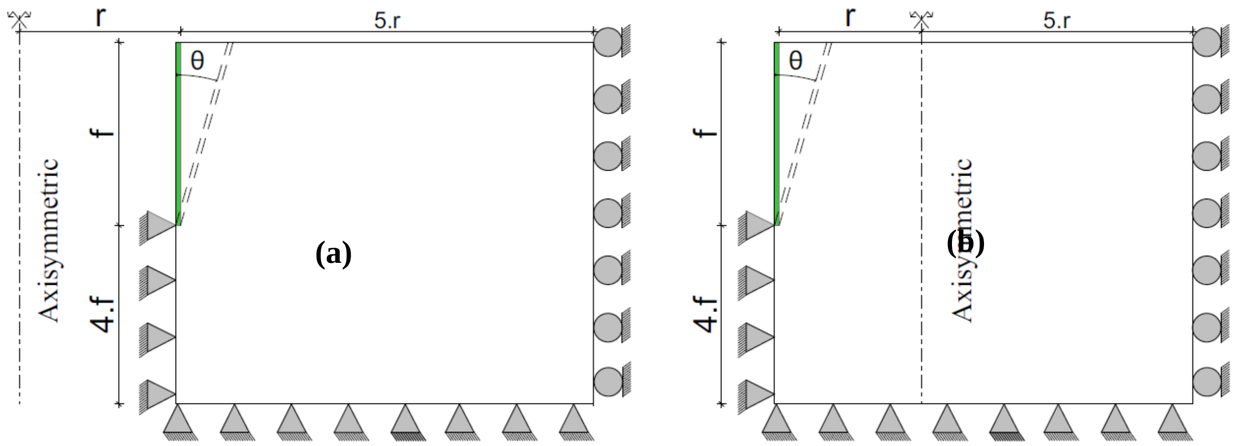

Figure 1. *The analysis model: (a) Axisymmetric problem of inward wall and (b) Axisymmetric problem of outward wall*

Fig. 1 show the geometry of the circular shaft problem in active and passive cases. The principle of boundary conditions assumes that the lower bound is fixed in both directions; the left and right lateral boundaries are fixed horizontally. The height of the model exceeds the sum of (4×f+f), and a length equal (5×f). Choosing models with these dimensions can minimize the effects of limits on circular shaft performance, this dimensions is based on previous studies in the literature.
Fig. 1(a) is used for vertical, circular excavation. However, the case in Fig. 1(b) is commonly used in the design of grain silos, buildings, road construction and different geotechnical structures.
The objective of this study is to evaluate the active and passive earth pressures on smooth circular shaft puted in cohesionless ground and the required displacement for establishing active/passive conditions by numerical approach using the explicit finite difference code FLAC [11] (Fast Lagrangian Analyses of Continua). The results are compared to published experimental results and many interesting conclusions are drawn.

2. DISCUSSION AND COMPARISON

The behavior of the ground is modeled by the elastic-perfectly plastic model of Mohr-Coulomb coded in FLAC code. The mesh size is fine near the wall where deformations are concentrated. All the following results are given for γ = 20 kn/m^3, bulk modulus K = 30 MPa , shear modulus G = 11.25 MPa, angle of internal friction φ = 20°, 25°, 30°, 35° and 40° and cohesion c = 0.

Tables 1, 2 and 3 compares the results of this study with those of other studies on plane strain and axisymmetric cases. For the active earth pressure coefficients ($K_{a\gamma}$) is shown in Tables 1, we compared our results with the both results of Liu & Wang [12] and Amin. K & Mohsen. E [1] for different values of radius (r_i) of 100 and 1000 m.

As can be observed, the results obtained in this study are in good agreement with those of Liu and Wang [12] and those of Amin. K and Mohsen. E [14]. Moreover, the results of this study for r_i = 1000 m are very close to those of Coulomb [3] and Abdul-Hamid Soubra, B. Macuh [10] for plane strain.

Similarly, for the passive earth pressure coefficients ($K_{p\gamma}$) is shown in Tables 2, and 3.

Table 2 is shown for the axisymmetric inward and Table 3 is shown for the axisymmetric outward. As can be seen, there is very good agreement between the results of this study and the two results of plane strain Abdul-Hamid Soubra, B. Macuh [10] and Coulomb [3]. Moreover, the results of this study and the axisymmetric cases of Amin. K and Mohsen. E [14] are different.

Table 1. A comparison between the active earth pressure coefficients ($K_{a\gamma}$) in this study and other studies for the plane strain and axisymmetric inward cases (δ = 0°, r = 1000m, c = 0, γ = 20 kn/m^3 and f = 3 m).

Table 1. *A comparison between the active earth pressure coefficients ($K_{a\gamma}$) in this study and other studies for the plane strain and axisymmetric inward cases (δ = 0°, r = 1000m, c = 0, γ = 20 kn/m^3 and f = 3 m).*

φ (deg)	Inward wall						Plane strain		
	[12] r_i (m)		[14] r_i (m)		This study r_i (m)		This study	[3]	[10]
	100	1000	100	1000	100	1000			
10°	0.696	0.708	0.681	0.701	0.691	0.693	0.702	0.704	/
20°	0.461	0.491	0.458	0.487	0.461	0.464	0.483	0.490	0.333
30°	0.300	0.332	0.299	0.329	0.307	0.310	0.325	0.333	0.217

Table 2. *A comparison between the passive earth pressure coefficients ($K_{p\gamma}$) in this study and other studies for the plane strain and axisymmetric inward cases (δ = 0°, r = 1000m, c = 0, γ = 20 kn/m^3 and f = 3 m)*

φ (deg.)	Inward wall				Plane strain		
	[15] r_i (m)		This study r_i (m)		This study	[3]	[10]
	100	1000	100	1000			
30°	6.69	6.58	3.02	3.03	3.02	3.00	3.00
40°	19.61	18.91	4.57	4.62	4.60	4.60	4.60

Table 3. *A comparison between the passive earth pressure coefficients ($K_{p\gamma}$) in this study and other studies for the plane strain and axisymmetric Outward cases (δ = 0°, r = 1000m, c = 0, γ = 20 kn/m^3 and f = 3 m).*

φ (deg.)	Outward wall [15] ri (m)		Outward wall This study ri (m)		Plane strain This study	Plane strain [3]	Plane strain [10]
	100	1000	100	1000			
30°	6.74	6.59	3.00	3.00	3.02	3.00	3.00
40°	19.62	18.92	4.56	4.56	4.60	4.60	4.60

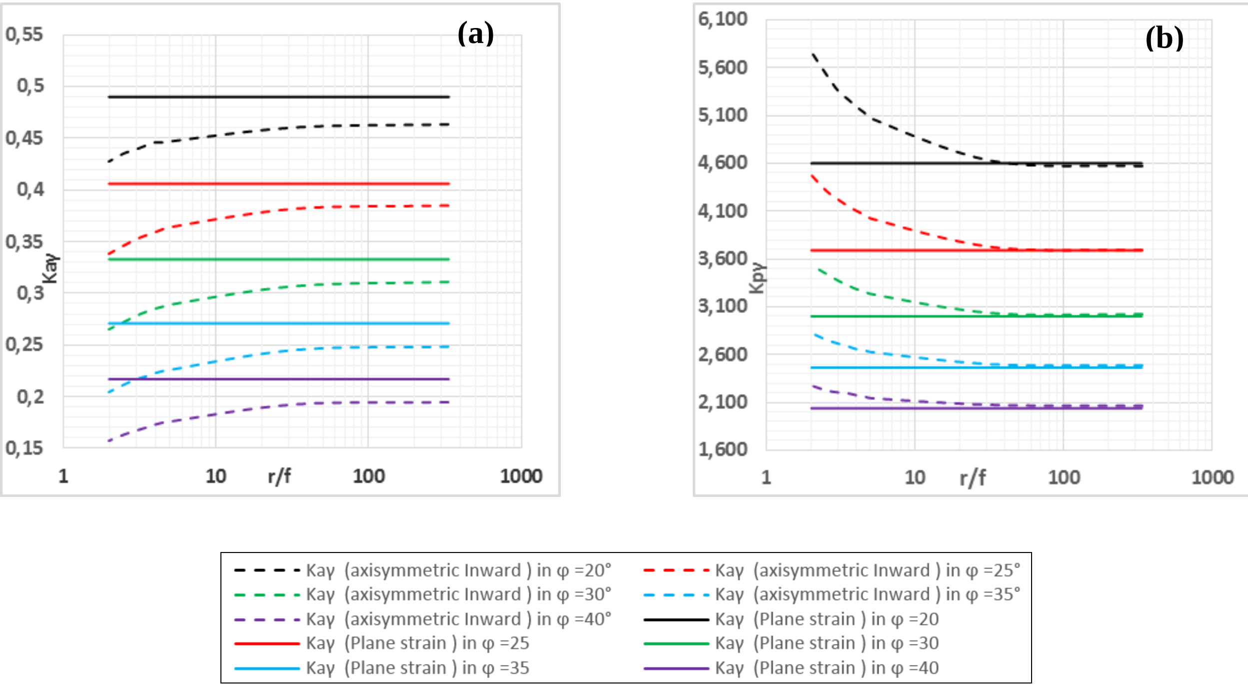

Figure 2. *(a) Active / (b) Passive earth pressure coefficients for Axisymmetric*

Table 4. *Active earth pressure coefficients $K_{a\gamma}$ for axisymmetric outward cases*

	r/f								
φ (deg.)	333.33	33.33	5	4.50	4	3.5	3	2.5	2
20°	0.469	0.470						0.469	0.470
25°	0.385	0.384						0.385	0.385
30°	0.309	0.309						0.310	0.310
35°	0.247	0.247						0.247	0.247
40°	0.194	0.194						0.195	0.195

Table 5. *Passive earth pressure coefficients $K_{p\gamma}$ for axisymmetric outward cases*

	r/f								
φ (deg.)	333.33	33.33	5	4.50	4	3.5	3	2.5	2
20°	2.06	2.06						2.05	2.05
25°	2.48	2.47						2.45	2.46
30°	3.00	2.99						2.98	2.99
35°	3.68	3.67						3.66	3.66
40°	4.56	4.56						4.55	4.57

Table 6. *Active earth pressure coefficients $K_{a\gamma}$ for axisymmetric inward cases*

	r/f								
φ (deg.)	333.33	33.33	5	4.50	4	3.5	3	2.5	2
20°	0.464	0.461	0.447	0.446	0.446	0.443	0.439	0.435	0.427
25°	0.385	0.382	0.364	0.362	0.359	0.356	0.352	0.346	0.338
30°	0.311	0.307	0.289	0.287	0.285	0.282	0.278	0.272	0.265
35°	0.248	0.245	0.226	0.225	0.223	0.220	0.217	0.212	0.205
40°	0.195	0.193	0.176	0.175	0.173	0.170	0.167	0.163	0.157

Table 7. *Passive earth pressure coefficients $K_{p\gamma}$ for axisymmetric inward cases*

	r/f								
φ (deg.)	333.33	33.33	5	4.50	4	3.5	3	2.5	2
20°	2.07	2.08	2.15	2.17	2.18	2.20	2.21	2.23	2.28
25°	2.49	2.50	2.63	2.65	2.66	2.69	2.72	2.76	2.83
30°	3.02	3.03	3.23	3.26	2.28	3.32	3.37	3.44	3.53
35°	3.69	3.72	4.02	4.06	4.10	4.15	4.22	4.31	4.47
40°	4.57	4.62	5.07	5.13	5.19	5.27	5.36	5.53	5.76

3. IMPLICATION AND EXPLANATION OF FINDINGS

Tables 4 to 7 summarize the results of the parameter investigation by numerical investigation of the active and passive earth pressure coefficient inward and outward the wall. These tables show the effect of parameters such as soil friction angle (φ) and retaining wall radius (r_i) on the active and passive earth pressure coefficients.

Figure 3 and Fig. 4 compares the results of axisymmetric and those of plane strain.

Tables 4 to 7 and Figures 3 and 4 illustrate that:

- There is an effect of the circular shape of the wall on the active and passive earth pressures in axisymmetric inward case.
- Inward case, the active and passive earth pressures, are decreased and increase respectively with increasing radius and tend to approach Coulomb values for very large radii.
- Outward case, the results indicated that no effect of the circular shape of the wall on the active and passive earth pressures.

4. CONCLUSION

Circular retaining walls are often used in deep excavation due to their structural advantages. However, employing plane strain results when designing circular retaining walls can be conservative and inaccurate. This study evaluated the axisymmetric active and passive earth pressure coefficients of the retaining wall using the explicit finite difference code FLAC (Fast Lagrangian Continuum Analysis).

The results were presented and discussed in terms of earth pressures on the wall.

The following conclusions were drawn as follow.

- The results showed that the values of the lateral earth pressure for the outward and inward cases were very close to each other.
- In the outward case, the increasing (r_i) has not effect on the active and passive earth pressures coefficients and is similar to plane strain conditions.
- In the inward case, the increasing (r_i) a fully clear effect on the active and passive earth pressures coefficients and is similar to plane strain conditions.

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