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Studying the effects of considering dilation angle over the performance of geotechnical elements using numerical methods

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ABSTRACT

Applying geo textile and nail elements adjacent to structures like: shallow foundations, dams, tunnels, slopes, retaining walls, etc is a very important and inevitable case in most geotechnical projects. In other hand, installing these elements truly and precisely, needs the distinction of geological and geotechnical condition in project site. Among the countless mechanical soil parameters, dilation angle is one the most effective and also controversial parameters, so that any highly over/under estimation of this parameter could result to irrecoverable structural and economical consequences. In this paper the effects of considering the dilation angle over performance of above elements in soil are studied, using the finite element code FLAC.2D. Also further to considering a great variation of quantities for dilation angle and gaining a reasonable trend, comprehensive results are acquired. It is observed that variation of dilation angle between φ/3 up to φ/2(φ is the soil internal friction angle) has a great effect on geo textile elements, so that increasing of dilation angle leads to a more stable condition in geotechnical structures containing elements like geo textiles or nails.

Keywords: Dilation angle, Geo textile, Nailing, FLAC 2.D

1. INTRODUCTION

If the adjacent soil of a geotechnical structure does not have proper condition and durability/ resistance, various ways such as inserting geo synthetic layers, soil stabilization, and nailing can be used. In addition, among the geo synthetics, geo textiles are the best and most useful ones. These plates are similar to fabric layers which instead of cotton, wool and silk, synthetic materials are used in their textures. At least 80 specific uses are defined for geo textiles, but their basic application can be summarized in five cases: Separation, reinforcing, filtration, drainage and sealing membrane[1]. By entering geo synthetics to geotechnic engineering, a lot of research was done by researchers such as Seki (1986), Korner (1994), Basarest (1998), sheen and Das (1998). They studied different kinds of geotechnical structure buried in reinforced soil by geo textile material. Furthermore in recent years other studies about geo synthetic behavior available in shallow were done by shookla and yeen (2006), Chang and kasekant(2007) and Sawav(2007).
Three decades ago, nailing was introduced as a technique for trench stability and protection of excavation, wall nailing means reinforcing existing soil in the form of in situ and installing adjacent steel bars in a sloppy area or dug in ground. In this way the bars usually are put in to holes created in soil walls and are controlled in their own place by cement grout. This process has passive performance and applies its effect by soil-bar interaction. The issue of soil interaction with reinforced elements has been in the focus of many researchers. Clearly, true understanding of this problem necessitates information about soil mechanic parameters and their effect on interaction between soil and elements. One of the most important parameters is dilation angle. As we know, in general, five parameters are needed in Mohr-Coulomb behavioral model which are as follows: Young modules, void ratio, friction angle, cohesion and dilation Angle. Dilation angle has a unit of degree. For heavily-over consolidated clay, the dilation angle is counted zero. On the other hand the amount of dilation in sands depends on compaction and friction angle. for quartz sand is approximately φ-30 and for φ<30 it's amount can be considered zero. Additionally negative amount of ψ can only be applied for very loose sands. By using finite element program Afena, Varaiean[2] calculated bearing capacity coefficients of shallow foundations in wide spectrum of parameters including dilation angle. Fahimifar and Javaheri[3], examined shear behavior and dilation of two sliding surfaces on each other by modeling direct shear test. Rabi'ee & Shahkarami[4] by examining the effect of various parameters on bearing capacity of foundation on the slope, found that by increasing dilation angle from zero to φ, the amount of bearing capacity increased such that they recorded the effect of dilation angle on less slope, in a clearer and better way. Fredman and Burd(1997)[5] examined the changes of bearing capacity coefficients (N_γ) for dilation angle between zero to φ in the smooth and rough foundations and came to the conclusion that in smooth foundations and for internal frication angle under 35º, changing the dilation angle, significant difference is not observed in N_γ amount, but for amount of friction angle plus 35º and change of dilation angle between 0.0 to φ significant changes is observed in bearing capacity coefficient N_γ. Shahbarkhordar & et.al)[6] examined the

sensitivity of bearing capacity coefficients N_γ toward changes of dilation angle and by using finite element method. By calculating bearing capacity coefficients, Griffiths [7] observed that in the case of dilation angle equal zero, Significant instability is created in calculation process (trends). Owlaapour & Fakhradini [8] worked on the effects of various parameters such as dilation angle and emphasized numerical analyses the effect of clay layer on bearing capacity of sandy soil by using finite element program PLAXIS. Amir Hossein & Ali shaffiee[9], also calculated bearing capacity coefficient of a shallow strip foundation for wide variety of changes in dilation angle. In the present paper, modeling and examining the performance of geo technical elements, geo textile and nailing operation by using finite difference program (FLAC.2D) was emphasized. The performance of these two geo technical elements is calculated for different amounts of soil dilation angle and by following a reasonable trend, general results are achieved.

2. Introducing FLAC.2D software

Flac is a two-dimensional finite difference program that is exclusively used for geotechnical calculations. by using this software, we can model the behavior and performance of any construction (structure) on soil , stone or any building materials which may undergo a kind of plastic flow during the yield limit. in a general view, materials are defined in FLAC by help (means) of elements or Zones, And by forming a network, the geology shape of the object or structure to be modeled, is formulated. Both elements in this software are defined based on a linear or non-linear stress-strain rule and react against applied boundary conditions. Another feature of FLAC is yielding and flowing of materials in parallel to changes in network form in the case of large-strain mode. Accurate calculation of Langrage along with techniques based on definition of behavioral zones and availability of wide variety of materials in this software, makes the modeling of failure and flowing more exact (accurate). On the other hand, since no matrix will be formed in FLAC, it is possible to do two-dimensional calculations without the need for extra memory. Also formulating (existing limitation in the given time to run the problem or definition of needed damping) have been lifted in this virtual space especially by automatic scaling inertia capability and defining automatic damping (this problem has no effect on failure situation). Although FLAC has exclusively been designed to solve geo technical and mining engineering problems, it has also great capability in analyzing complex mechanical problems. Such that by means of various defined behavioral models in it we can model and simulate many of geologic non-linear and irreversible behaviors.

3. statement of the problem

3.1. soil (ground) space

The target soil in the problem site, was mono layer sand and had the following specifications:

Table 1: constant parameters used in the modeling trend of soil space.

Resistance cohesion (C) kPa	Internal friction angle(φ)	Bulk modulus kPa	Shear modulus kPa	Unit weight KN/m^3
0.0	35	2×10^8	1×10^8	10

We know that, introducing the parameter of dilation angle in the position of internal friction angle which is greater than or equals 30 is meaningless and can be ignored. Therefore in order to have a realistic modeling the degree of internal friction angle of target sandy soil in this study is 30 to 40 and to be more exact it is 35. It must be noted that the target failure criterion in this modeling was Mohr-Coulomb criteria.

3.2. Geo textile Element

In order to have a much better and effective geo textile element, two parameters should be taken into account. First, the question of flexibility of texture of geo textile and second, the question of the interaction of inserted geo textile with its own upper and lower soil surface. Performing this task in finite difference program FLAC.2D, is possible through connecting beam element to its upper and lower network lines. In this way by putting moment of inertia of modeled beam to zero in the FLAC.2D consider its performance as equal to geo textile elements. furthermore, one of the major problem of soil profiles reinforced with geo textile element, is the possibility of sliding on both sides of installed geo textile plates and consequently is the happening of pull out and eventually paying the way for large strain.

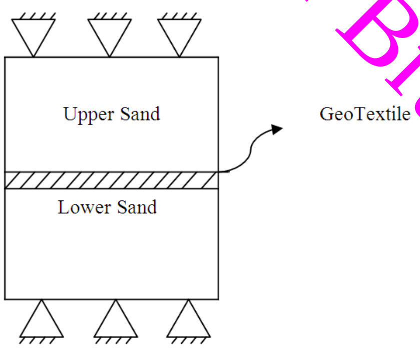

Fig 1: schematic drawing of investigated geo textile model

According to fig(1) the used numerical model is a rectangle network in the dimensions of 5(m)*7(m) [5 meter width 2 & 7 meter depth). The boundary conditions on this model are regarded in such a way That the bottom and the upper part of the model is supported in both directions, and its left and right ends are free in both directions. The reason for leaving free support conditions in both ends, as to facilitate the modeling of sliding phenomenon. In this way by inserting geo textile element in the center of target profile, It is possible to observe the effect of pull out happening on it Directly. In order to apply loading in the case of strain control, the load has been introduced as application of velocity vectors. The amount of these velocity vectors in vertical loading equals 0.5×10^{-4} and the case of loading it is regarded 1×10^{-4} m for each step of loading. The amount of velocity vector in both states, is considered in such a way that, it prevents an initial shock to system and to neutralize and modify the initial and temporary effect of the loading.

3. 3. Nailing Operation

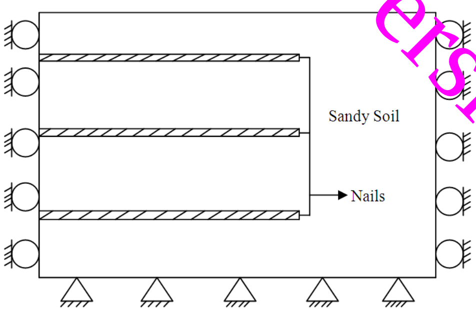

Fig 2: schematic drawing of nailing model.

Modeling of nailing operation in ELAC.2D has been done by cable element According to figure (2), the applied model is a rectangle network with the dimensions of 11m×11m(11 meter width * 11 meter depth). In this model border lines are considered in such a way that model bottom is supported in both directions but its left and right end(s) has reactions only in horizontal direction or(X axis). In this situation three layers of nailing are predicted for protection of a vertical deposit. In this case the behavior and reaction of nail elements are analyzed against the force of deposit weight. In order to make real the modeling of nail elements, we can show the effects of grout injection around the nails by considering a friction resistance among the nail and sand soil. This resistance force is regarded as a friction angle between nail and soil and its amount, is determined 20 according to reference[10]. On the other hand, by regarding support conditions by maintaining more consistency in nail performance, the effect of shotcrete performance has been taken into account.

4. Modeling and analyzing the results

4.1 geo textile element

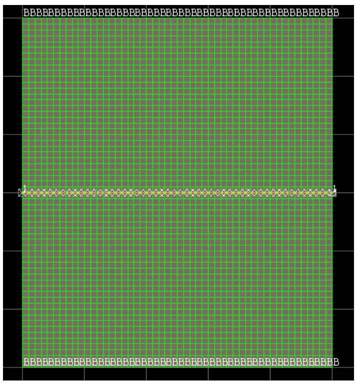

Fig 3. Element network of geo textile problem in FLAC.2D

Element network for geo textile modeling is based on fig 3. Having done the modeling, the problem for dilation angles equals Zero, φ-30(5 degree), φ/3 (about 12 degree), φ/2 (about 18 degree) and φ (equals 35 degree), is solved. It should be noted that the assumption of equality between amounts of dilation and internal friction means that soil follows an associated flow rule which is not a correct assumption. But in the present article, to compare with the result of other targeted amounts, for dilation angle and examining the effect of increasing the amount of ψ, we have taken this assumption. Based on Table 2 and Fig 4, we can see that by increasing dilation angle, the amount of bearable axial force on part of geo textile element is increasing, in other words its bearing capacity is rising.

Table 2: The amount of axial force applied on geo textile on the moment of failure

35	**φ/2≈18**	**φ/3≈12**	**5.0**	**0.0**	**°Ψ**
103547	84954	59237	48657	42358	Fa(N)

In table (2) the amount ψ dilation angle is based on degree, and F_a is the amount of axial Force on geo textile element in terms of Newton at the moment of failure. As mentioned before, by increasing dilation angle, the bearing capacity of geo textile element is also increased. According to figures 4 and 5, The greatest amount of the increase has been recorded in ψ equals to 12 to 18 degrees.

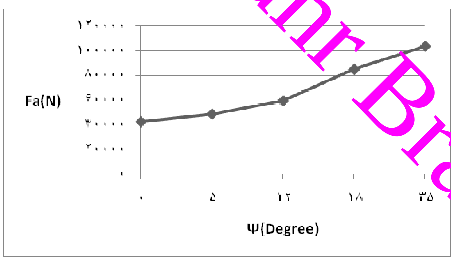

Fig 4: Changes of amounts of axial force according to dilation angle.

Table 3: The resultant increasing amounts in axial bearing capacity according to increasing the dilation angle

18-35	**12-18**	**5-12**	**0.0-5**	**Ψº**
22	**43**	**22**	**15**	**Δ(%)**

In table 3, Δ is increasing in amount of axial bearing capacity of geo textile element in term of percentage. As it can be seen, the greatest amount of this increase is in ψ within 12 to 18 degree which record in ψ/3 to ψ/2. Additionally It was seen that by increasing dilation angle, the depth of shear failure mechanism is also increased. In fig 5 and 6 we can easily see the progress of shear failure mechanism, particularly under inserted geo textile layers.

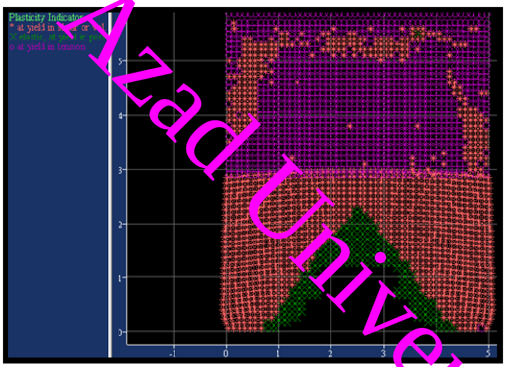

Fig 5: Shear failure areas (zones) under geo textile regarding ψ=12°

Based on fig 5 and 6, It can be seen that the depth of shear failure mechanism in dilation angle equals 12 degrees, is less than the situation in which dilation angle is 18 degrees. In other words in ψ=18°, bearing threshold of system is evaluated much greater than ψ=12 degrees , such that by forming greater failure zones, the system undergoes instability and failure.

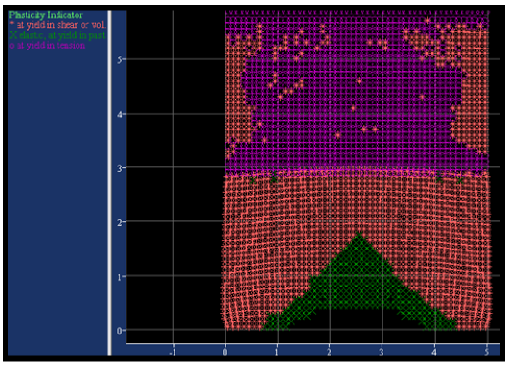

Fig 6: Shear failure zones under geo textile regarding ψ=18°

4.2. Nailing operation

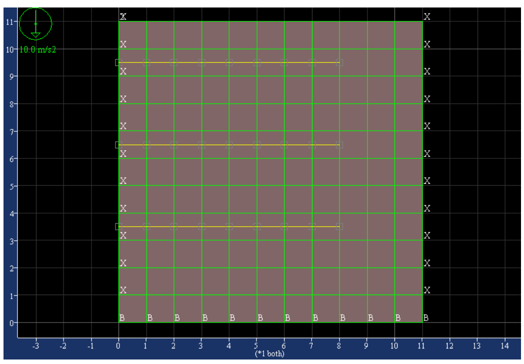

Fig 7: Element network for nailing problem in FLAC.2D

The applied element network for modeling of nailing operation is given in fig 7. After modeling, just like what was done before, the problem is solved regarding dilation angles equal to Zero, φ -30 (5 degrees), φ/3 (about 12 degrees), φ/2 (about 18 degrees) and φ (35 degrees). It must be noted once again that the assumption of equality the amounts of dilation angles and internal friction implies that soil acts as associated flow rule, which is not a true assumption, but in this paper it is accounted to compare with results of other targeted amount of dilation angle and assessing the effect of increasing the amount of ψ.

According to table 4 and fig 8, we can see that by increasing dilation angle, the amount of bearable axial force is increased on part of each of the nails.

Table 4: Resultant increasing amounts of axial bearing capacity of nails regarding to increasing the dilation angle

35	**18**	**12**	**5**	**0.0**	**Ψ°**	
21687	18553	14924	11761	9439	Cable 1	**Fa (N)**
27[illegible]79	22491	18325	15587	12325	Cable 2	
2995[illegible]	23284	20136	17693	16554	Cable 3	

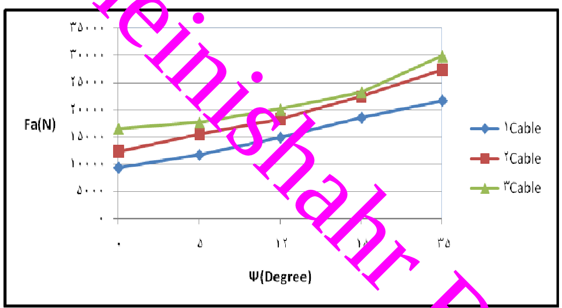

Fig 8: Variation in amounts of axial force of nails according to dilation angle

According to Table 4, the amount of increase in bearing capacity, has directly relationship with increasing dilation angle and the depth of buried nail element, such that nail or cable number 3 with the greatest amount of depth regarding dilation angle of 35 degrees experiences (bears) the greatest amount of axial force. [The nail are put in order of 1, 2 and3 from top to bottom]. According to Table 5, by increasing buried depth, the increase in bearing axial capacity of nails in ψ between φ/2 to φ is very conspicuous. put simply, the more the amount of surcharge soil is increased, the greater amount of dilation angle (with in φ/2 to φ) will have more effect on enhancing axial bearing capacity of nails. It is noted again that in Table 5, Δ is increasing in axial bearing capacity in each of nails in terms of percentage.

Table 5: Resultant increasing amount in axial bearing capacity regarding to increasing the dilation angle

18-35	**12-18**	**5-12**	**0.0-5**	**Ψ°**	
17	24	27	25	Cable 1	**Δ(%**

22	23	18	25	Cable 2	
28	16	14	7	Cable3	

However for lower amount of dilation angle, increasing of buried depth, not only did not cause the increase of bearing capacity of nails (relative to upper nail) but also bring about decreasing bearing capacity of nail elements in comparison with its upper elements.

5.CONCLUSION

In this paper the effect of dilation angle on the performance or function of geo technical elements like geo textiles and nailing operation was examined. Modeling of these two cases was done by finite difference code FLAC.2D and in the condition of Mohr-Coulomb criteria. Generally it was seen that by increasing dilation angle, the axial bearing capacity of geo textile and nails is also enhanced. In other words, by increasing dilation angle, the threshold of system failure and the width (extension) of shear failure zones are increased; meaning that by accounting greater amounts for dilation angle, the necessary condition for instability in system is forming and joining more failure zones. Furthermore, in modeling geo textile element, the greatest amount in bearing capacity occurs in dilation angle within $\varphi/2$ to $\varphi/3$. However the problem of increasing amount of bearing capacity in modeling the operation of nailing does not follow a specific rule or order. We come to conclusion that due to greater amount of dilation angle (within $\varphi/2$ to φ) as the amount of surcharge soil increases, the axial bearing capacity is also intensified.

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