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Matric suction effect on the soil stability in unsaturated soil

N. Soleimanian[1], A. Ekrami Fard[2], A.A. Riyahikhou[3] A. Akhtarpour *[4]

Abstract

In recent years, high-rise buildings have widely increased in cities, and there is an increasing need to excavate deep tranche to use the available space efficiently. One of the ways to stabilize the tranche is to use metal piles and an anchorage system. In many cases, tranche failure is due to rains, the burst of water pipes, absorbing wells, and artesian layers. Due to these factors, matric suction decreases, and pore water pressure increases. As a result, parameters of the shear strength of the soil weaken, and instability occurs. In this study, using numerical simulation through SEEP/W and Slope/W software, the effects of a water pipe burst, the existence of an absorbing well and artesian layer are investigated on the stability of a tranche stabilized by anchorage and metal pile over time. Also, the effects of the position of the water pipe, absorbing well, and the artesian layer are studied on the tranche's safety factor. The results show that as the distance of both water pipe and absorbing well increases from the failure zone, the safety factor increases. In addition, the safety factor increases by increasing the distance of the artesian layer from the tranche floor.

Keyword: *Unsaturated Soil, Stabilized Analysis, Water Pipe burst, Absorbing Well, Artesian Layer*

Extended Abstract:

1. PhD Student, Department of Civil Engineering, Ferdowsi University of Mashhad
2. PhD Student, Department of Civil Engineering, Ferdowsi University of Mashhad
3. PhD Student, Department of Civil Engineering, Ferdowsi University of Mashhad
4. Associate Professor, Department of Civil Engineering, Ferdowsi University of Mashhad, Akhtarpour@um.ac.ir

*** Corresponding Author**

1. Introduction

To study the hydromechanical behavior in three-phase porous media such as unsaturated soils, a complete understanding of the properties of materials such as the relationship between water content and matric suction and shear strength of soils is required. The soil-water characteristic curve (SWCC) indicates the relationship between water content and matric suction in unsaturated soils. In this regard, several researchers using experimental equations have presented the characteristic curve of water and soil (Fredlund and Xing, 1994, Ning and William, 2004, Vanapalli and Fredlund, 1999).

Researchers have developed models in SEEP/W and Slope/W software to investigate the effect of the SWCC curve of the soils on the distribution of pore pressures and the stability of unsaturated trenches during rainfall and increase the water content of the soil (Ng and Pang, 2000, Ahmadi et al., 2007). The results have shown that with increasing water content, soil stability is sharply reduced. For this purpose, methods are generally used to increase the stability of the trenches.

One of the methods of stabilizing the trenches is nail and anchor, which is widely used today. Therefore, researchers have researched the parameters affecting their performance, such as the angle of position to the horizon, their length, and distances (Marchal, 1984, Fan and Luo, 2008).

2. Numerical models

In this research, SEEP/W and Slope/W software have been used to model the stability of the trenches. In the following, the modeling process in each of these software is discussed.

2.1. Modeling in SEEP/W software

In order to analyze the effect of a pipe burst, drilling absorption wells, and the presence of an artesian layer on the stability of the trenches, the transient analysis should be used in the SEEP package. In this study, two types of coarse-grained and fine-grained soils have been used, the characteristics of which are presented in Table 1. The SWCC curve is considered using the default software curves according to the soil type. It should be noted that the permeability function was computed using Gardner's proposed formula (Lu and Likos, 2006).

Table 1. The characteristics of each soil (Carsel and Parrish, 1988)

Soil type	Saturated Kx (m/s)	Saturated water content	Residual water content (θ_r)
Sand	10^{-6}	0.35	0.027
Clay	10^{-8}	0.5	0.1

2.2. Modeling in Slope/W

The soil characteristics modeled in this section are shown in Table 2. In this study, the anchors were designed in accordance with ASTM regulations, and the specifications of the anchors designed in sandy and clay soils are presented in Tables 3 and 4, respectively. The design of piles used in numerical models has been done using the tenth topic of national building regulations. In this study, the dead load of gravity applied to the study trench has been calculated assuming the location of a 9-story building with the sixth point of the national building regulations. In Slope software, the Morgenstern-Price method was used for stability analysis. Figure 1 shows the numerical model made in Slope software and the dimensions of the model.

Table 2. The characteristics of each soil that modeling in Slope/W

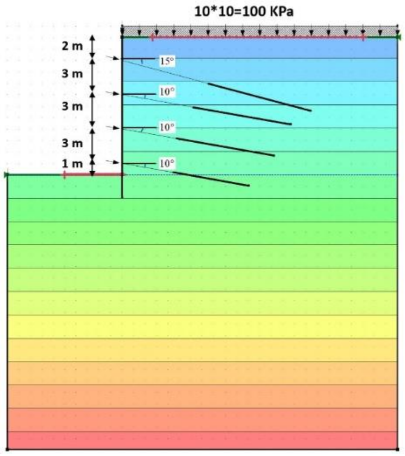
Soil type	Phi	Cohesion (kPa)	Unit weight (kN/m^3)
Sand	38	0	18
Clay	20	30	17

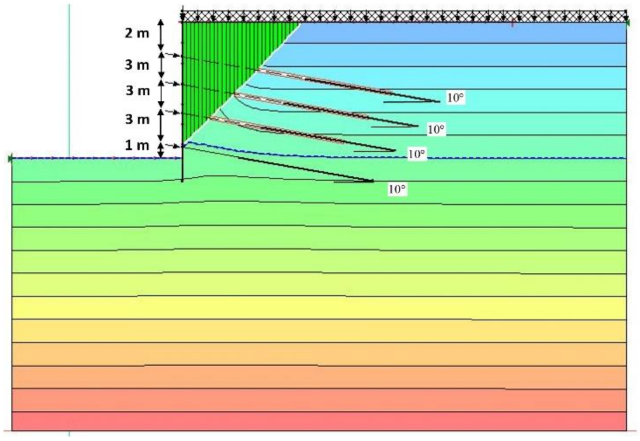
Table 3. The characteristics of anchors in sandy soil

Anchore No.	Bounded length (m)	Unbounded length (m)	Tensile capacity (kN)	Anchor angle with the horizon (degree)	Pullout resistant (F/A) (kPa)
1	9.23	7.75	669.76	15	220
2	8.65	6.26	627.25	10	187.67
3	8.65	4.79	627.25	10	187.67
4	6.69	4.5	485.27	10	182.02

Table 4. The characteristics of anchors in clay soil

Anchore No.	Bounded length (m)	Unbounded length (m)	Tensile capacity (kN)	Anchor angle with the horizon (degree)	Pullout resistant (F/A) (kPa)
1	12	11	450	10	100
2	12	9	450	10	100
3	12	**7**	450	10	100
4	12	**5**	600	10	132





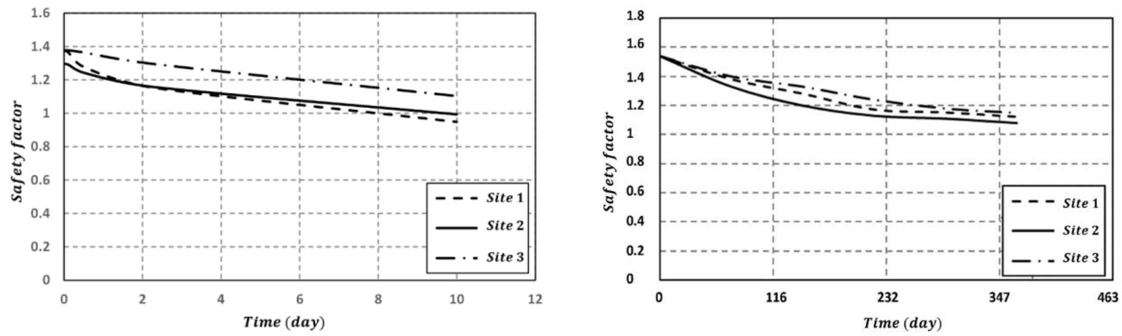
(a) **(b)**

Figure 1. Numerical model in Slope/W in a) sand and b) clay

3. Conclusion and results

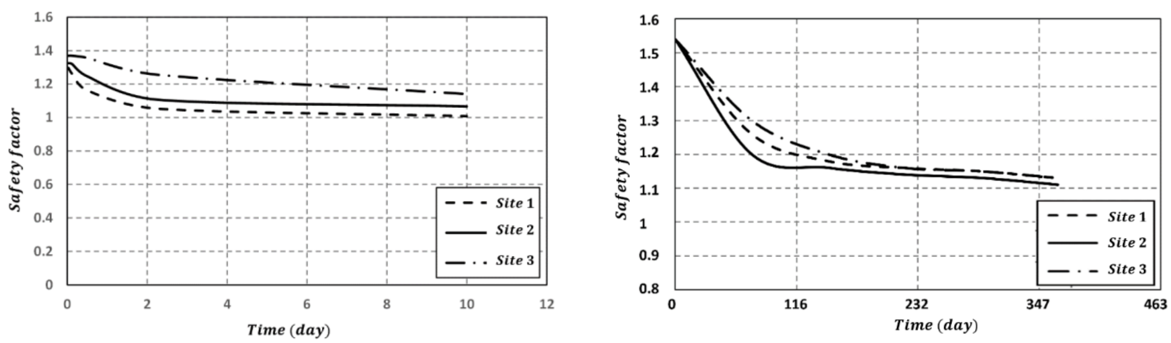
Today due to the increase of urban constructions, excavation operations in high-rise buildings area are inevitable. Pipe burst under the building, drilling absorption wells, and the presence of an artesian layer are some of the factors that can affect the stability of the trenches and ultimately lead to intense damages. Therefore, in this study, the effect of these factors on the stability of the trench has been investigated. Three different positions are assumed to examine the water pipe and absorbing well. The first position is inside the failure line, the second position is on the failure line, and the third position is outside the failure.

The condition of the artesian layer is considered in three different coordinates. In the first, second, and third positions, the artesian layer has been assumed to be at a distance of 8 meters, 4 meters, and 1 meter below the bottom of the trenches, respectively. Figures 2 to 4 show the results of this research.



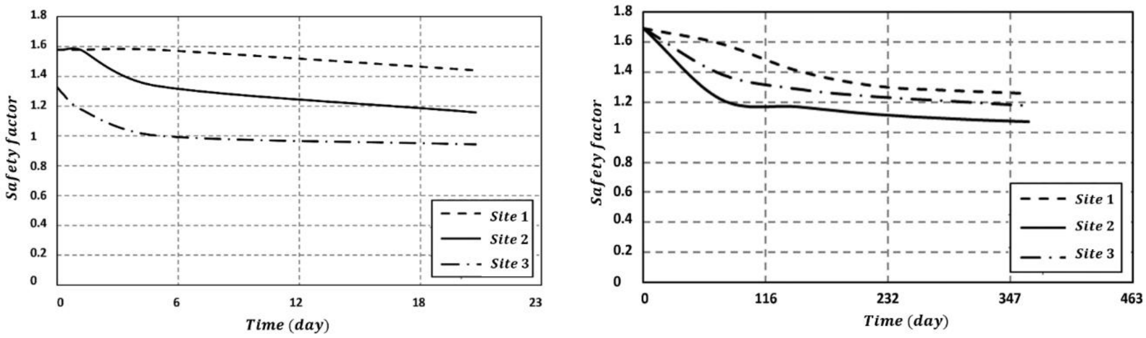
(a) **(b)**

Figure 2. Investigation of safety factor by changing the position of water pipe in a) sand and b) clay



(a) **(b)**

Figure 3. Investigation of safety factor by changing the position of absorbing well in a) sand and b) clay



(a) **(b)**

Figure 4. Investigation of safety factor by changing the position of the artesian layer in a) sand and b) clay

The results of this research are explained below:

1. In general, the results of studies show that depending on the type of soil, the time to reach failure is different, so that failure occurred in coarse-grained soils much faster than fine-grained soils.

2. The results showed that the duration of failure in soils strongly depends on the position of the water pipe, absorption well, and artesian layer relative to the failure line. The most critical case occurred when the failure line passed the burst water pipe, absorption well, and artesian layer.

3. In clay soils, a higher percentage of matric suction is converted to suction stress. Accordingly, with the unsaturation of soil, shear strength in clay soils has increased more than sandy soils. As a result, at the same matric suction, suction stress, and failure reliability were higher in clay soils than in sandy soils.

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