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Effects of plastic fines on the instability of sand

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ABSTRACT

The effects of plastic fines on the instability of sand were studied in this article. For this purpose, the results of undrained monotonic triaxial compression tests conducted on specimens of sand with variation in fines content from 0% to 30% are presented. The specimens were prepared in two different initial dry unit densities and were subjected to two different confining pressures. The results of the tests are shown in four groups. They demonstrate that an increase in plastic fines leads to an increase in the instability, followed by a decrease with a further increase in fines content. It is also seen that the slope of the steady-state lines in p'-q space increases with increase in fines content, but after certain fines content, it begins to decrease. A reverse trend is observed for the slope of instability lines; it decreases at lower fines content, followed by an increase with a further increase in fines content.

1. Introduction

Numerous studies have been performed to examine the effects of fines on the undrained behavior and liquefaction potential of sands. The effects of non-plastic fines on the undrained behavior of sands were studied well in both cyclic and monotonic manner (Thevanayagam et al. [1], Lade and Yamamuro [2], and Polito and Martin [3]). In sands and non-plastic fine mixtures, fines content and interactions between the two materials with different sizes are considered for assessing the effects of non-plastic fines on the behavior of sands. However, in the case of plastic fines, more parameters than non-plastic fines, such as plasticity of fines, fines content, clay mineralogy, pore water chemistry, influence the undrained behavior of sands. Numerous studies were conducted to examine the different parameters (Gratchev et al. [4], Prakash and Sandoval [5], Georgiannou et al. [6,7]). However, there remains a great deal of research to be done in this area [8].

One of the most important effects of fines on the undrained behavior of sands is their effects on the instability of sands. Sladen et al. [9] termed the locus of peak strengths of samples with the same initial void ratio in effective stress space as a collapse surface. Others defined this surface as instability line [10,11]; the only difference is whether there is a cohesion-like intercept to the instability line [12]. Instability is a kind of pre-failure flow in which large plastic strains are generated rapidly [13], and is different from failure [14].

The objective of this article is to investigate the effects of plastic fines on the instability of sand and to assess the instability potential of these soils. For this purpose, the results of undrained tests conducted on sand and plastic fines with different percentages ranging from 0% to 30% are presented. The specimens in this study were prepared in two different initial dry unit densities of 1.45 and 1.5 g/cm^3, and two confining pressures of 100 and 400 kpa were used to consolidate the specimens during the tests.

2. Materials tested

All the tests in this experimental program were performed using the standard 161 sand. Individual sand particles are angular and predominant minerals are silica. The sand is classified as poorly graded sand (SP) according to the unified soil classification system. The properties of the sand used in this study are shown in Table 1. The fines used in this study were a mixture of natural fines and bentonite in a proportion of 75% to 25%, respectively. The natural fines consisted of particles collected from the natural Darongar resources of Mashhad, which is situated in northern Iran, and passed through sieve No. 200. The properties of the fines are shown in Table 2. Fig. 1 also shows the grain size distribution of materials.

3. Method of sample preparation

All the specimens in this study were constructed by the moist-tamping method, which is performed by compacting moist soil in

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layers to a selected percentage of the required dry unit density of the specimen. The specimens were prepared in two initial dry unit densities of 1.45 and 1.5 g/cm^3. The water content of the soil during specimen preparation was 8% by weight. All the specimens were compacted in eight layers.

4. Test procedure

On the basis of initial dry unit density of the specimens and confining pressure, which was sustained during consolidation, the specimens were categorized into four groups, namely 1.45–100, 1.5–100, 1.45–400, and 1.5–400. The first number represents the initial dry unit density and the second number represents the confining pressure that the specimens sustained during consolidation. The specimens were 50 mm in diameter and 100 mm in height, and they were prepared with seven values of fines content (Fc=0%, 5%, 10%, 15%, 20%, 25%, and 30%) in each group. After preparing the specimens, their caps were placed and sealed with o-rings, and a partial vacuum of 20 kpa was applied to the specimens to reduce disturbances. When the chamber was filled with water, the partial vacuum was removed, and a confining pressure of 20 kpa was applied to the specimens. Saturation was performed by purring the specimens with carbon dioxide before adding de-aired water. Back-pressure equal to 120 kpa was applied in four steps to ensure complete saturation of the specimens. A minimum *B*-value of 0.98 was obtained for all the specimens. After saturation, the specimens were isotropically consolidated to a confining pressure of 100 or 400 kpa according to their groups and were subsequently subjected to undrained monotonic triaxial loading with a constant strain rate of 0.5 mm/min.

Table 1
Properties of the standard 161 sand.

Sand 161	G_s	e_{max}	e_{min}	D_{50} (mm)
	2.67	0.928	0.583	0.26
	Cu	Cc	F (%)	K (cm/s)
	1.8	1.19	0	0.0125

Table 2
Properties of the fines used in tests.

Fines name	Gs	LL	PL	PI
Drongar fines	2.70	28	18	10
Bentonit	2.74	144	46	98
Mixture of bentonit and Darongar (25%–75%)	2.72	51	21	30

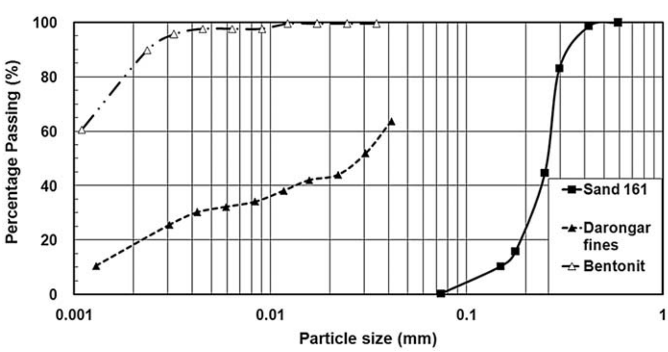

Fig. 1. Particle-size distribution for the tested materials.

5. Test results

A total of 28 undrained monotonic triaxial compression tests were conducted on the specimens of standard sand with different fines content. For being certain about the results, each test was repeated two times. The summary of the laboratory tests is presented in Table 3. In this table, e_0 shows the initial void ratio of the specimens, which is determined by calculating the volume of solids as follows:

$$V_s = \frac{M_d}{G_s} \tag{1}$$

$$e_0 = \frac{V_0 - V_s}{V_s} \tag{2}$$

where V_0 is the initial volume of specimen, V_s is the volume of solids, M_d is the dry mass of the specimen, and G_s is the specific gravity of solids. The variations in the values of e_0 of the specimens derive from the small variations of G_s of the mixtures owing to the varied proportions of sand and fines. Moreover, e_f in Table 3 shows the final void ratio of the specimens, which is determined by considering the change in volume of the specimens during consolidation and saturation as follows:

$$V_f = V_0 - \Delta V \tag{3}$$

Table 3
Summary of the laboratory tests.

Group name	Fc	σ_3	e_0	e_f	Group name	Fc	σ_3	e_0	e_f
1.45–100-H	0	100	0.842	0.830	1.45–400-H	0	400	0.842	0.788
	5	100	0.845	0.821		5	400	0.845	0.770
	10	100	0.849	0.819		10	400	0.849	0.762
	15	100	0.850	0.801		15	400	0.850	0.738
	20	100	0.853	0.753		20	400	0.853	0.693
	25	100	0.856	0.751		25	400	0.856	0.675
	30	100	0.859	0.741		30	400	0.859	0.673
1.5–100-H	0	100	0.782	0.775	1.5–400-H	0	400	0.782	0.736
	5	100	0.783	0.769		5	400	0.783	0.727
	10	100	0.786	0.766		10	400	0.786	0.719
	15	100	0.789	0.758		15	400	0.789	0.697
	20	100	0.792	0.714		20	400	0.792	0.641
	25	100	0.794	0.708		25	400	0.794	0.622
	30	100	0.797	0.670		30	400	0.797	0.587