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Study of Erodability of Cemented Sand

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Abstract. Erodability is a measure which indicates whether the soil is stable against water impact due to rainfall and run off. Earthen dams, embankment and drainage ditches are highly susceptible to the risk of erosion. Cement stabilization mainly improves the strength of the soil but reduces durability with aging which further gets affected by the high flow of water during heavy rainfall. Hence, this paper mainly focuses on the study of erodability characteristics of cemented sand stabilized with different percentage of cement (2.5 %, 5 % ,7% and 10 % of weight of sand) and for different curing periods (3, 7, 14 and 28 days). The pinhole test was conducted as per ASTM D4647 to predict the erodability characteristics of the cemented sand. The eroded mass was also measured for its turbidity which shows that the turbidity gets decreased with respect to the curing period. The erosion of cemented sand gets decreased for increment in cement percentage as well as curing period. The unconfined compressive strength of the cemented sand gets enhanced upon increasing cement percentage and curing period.

Keywords: Erodability, Cement stabilization, percentage of cement, curing period and Pin-Hole test

1 Introduction

Soil erodability is the factor which represents the susceptibility of the soil to soil erosion. It is an extensively used factor to calculate the intensity of soil erosion both theoretically and experimentally. Earthen dams, Embankments, drainage ditches, bridges are some of the geotechnical structures which are affected by erosion due to rainfall and run off. Unlike clayey soils, where there is a cohesive bond, erosion in coarse sands is high due to lose particle arrangement and hence high erodability. In clayey soils, the time taken for detachment of particles is more, once the detachment occurs; the soil starts to erode as against sand, where the erosion is almost instantaneous. Apart from these natural causes, readability of stabilized soil is seen as a chal-

lenge in soil improvement techniques like jet grouting. Jet grouting majorly uses cement as an additive for the improvement of sandy soil. These techniques require a considerable curing period to attain the target strength. If during this curing phase, the stabilized soil site is exposed to a rainfall and runoff, it is observed that there is a loss of soil from the stabilized soil cement column. This results in lower strength improvement than the targeted strength and it should be considered in the geotechnical design. The factors that affecting soil erodability are soil texture, climate, soil structure, soil water contain and surface cover, size and shape of the soil grains.
Several studies were conducted in the past to understand the erodability mechanism and its dependability on different factors such as soil properties, and the properties of pore and eroding fluids.

2 Background

Wan and Fell (2004) performed erodability tests by applying hydraulic gradient across a 6-mm soil hole to investigate the erodability characteristics of soil in cracks of embankment dams. They concluded that the erosion rate is directly influenced by the degree of compaction and placement water content. Sherard et al. (1976) developed the standard pinhole test to study the erosion characteristics of soil by pushing eroding fluid through a 1-mm crack.. Buddhima et al (2008) studied about erosion behavior of chemically stabilized erodible soils. In this study erodability of soil are measured using two chemical stabilizers, namely lignosulfornate and Portland cement. Two different soils such on silty sand and dispersive clay were used for erodability studies. Four dosages of lignosulfornate, 0.1%, 0.2%, 0.4%, and 0.6% by dry weight of soil were selected to treat both soils. However, 0.5%, 1.0%, 1.5%, 2.0%, and 3.0% of cement were chosen to stabilize the silty sand, while 0.2%, 0.4%, and 0.6% dosages were selected to treat the dispersive clay. The erodability of soil was measured using pin-hole test. Each soil was mixed with the selected chemical additives and then it was compacted inside a 72 mm diameter by 100mm log copper mould. After a seven-day curing, the samples were immersed in the eroding fluid (tap water) until they absorbed the maximum amount of water to become saturated. It was observed that the variation of erosion rate with the hydraulic shear stress is linear for all treated and untreated soil samples compacted at 95% and 90% of the maximum dry density It was reported that increase in the critical shear stress of the silty sand with only 0.6% lignosulfornate treatment was equivalent to that with around 2.5% cements treatment variation. However, the stabilization of the dispersive clay with 0.6% cement was more effective than 0.6% lignosulfornate. The findings of this research also indicated that the coefficient of soil erosion decreased as a power function of the critical shear stress.

In this study, an extensive laboratory investigation was conducted on cemented sand stabilized with different percentages of cement (2.5 %, 5 %, 7% and 10 % of weight of sand) and for different curing periods (3, 7, 14 and 28 days). The erodability characteristics of the cemented sands, were found using a pin hole test as per ASTM standards

3 Materials and Methods

. The sand in this experiment is taken from Paalar river basin, Tamil Nadu. The dominant component of the sand is the particle with size between 0.5 and 0.1 mm (80%). The properties of soil are tabulated below. (Table 1)

3.1 Properties of soil

Table 1. Properties of soil

Properties	Values
specific gravity (Gs)	2.6
maximum dry density (ρd_{max})	1.65 g/cm^3
minimum dry density (ρd_{min})	1.51 g/cm^3
maximum void ratio (e_{max})	0.72
minimum void ratio (e_{min})	0.58
Effective grain size (D_{10})	0.52 mm
Coefficient of curvature (C_c)	1.24
uniformity coefficient (C_u)	2.37

3.2 Sample preparation

Four dosages of Portland pozzolona cement (2.5 %, 5 %, 7% and 10 % of weight of sand) will mix sand. The cemented sand was mixed thoroughly with 10% water based standard proctor test and then filled in the PVC mould (33 mm dai and 38 long) using undercompaction method. The sample was punched at its center using 1 mm diameter rod. Prepared sample was allowed to set for 24 hrs and then separated specimen on the mould. After that the cemented sand were cured under humid conditions for 3,7,14 and 28 days.

4 Experimental Investigation

4.1 Pinhole test

The pinhole test device is an instrument for direct measurements of the dispersibility and erodability of soil, using a flow of water passing through a small hole (1 mm diameter in a specimen), under hydraulic heads (H) ranging between 50 and 1020 cm. Erodability is assessed by observing effluent color and flow discharge through the hole, by visual inspection of the hole after the completion of the test. Pinhole test

Procedure as follows:
The compacted Cemented sand 38 mm long and 1mm hole at center of the specimen. The cured specimen was inserted in a mould of 100mm height. Before the insertion of the cured specimen, pea gravel was filled up to 52mm length of the mould. Two circular wire meshes were kept on the top and bottom of the specimen. The space

above the specimen is also filled with gravel. The inlet and outlet of the mould is checked for any leakages before the commencement of the tests. Constant head is maintained at 380mm height. Water was collected from the sample for every 60 neglecting the first 120 seconds in accordance to ASTM. Test was stopped when clean water came out of the outlet. The pin hole tested specimens were subjected to turbidity tests to known the erodability range.

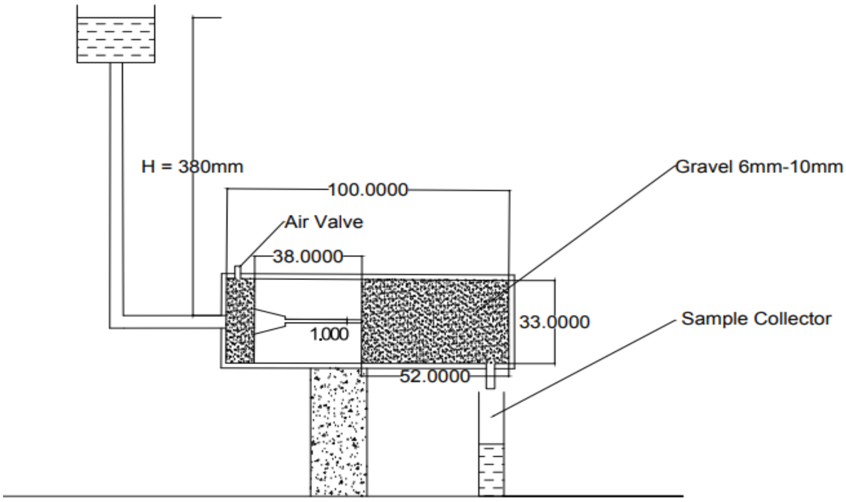

Fig.1. Schematic diagram of pin hole test.

4.2 Unconfined compressive test

Unconfined compressive tests can determine the strength of cemented soils without the need to apply the confining stress, while maintaining the soil cementation or bonding prior to shearing. To know the strength of the cemented sand with different percentage of cement content, a unconfined compression program was devised. The unconfined compressive strength tests were carried out for cemented sand samples with an sand- cement ratio of 2.5%, 5%, 7%, 10% and curing period of 3, 7,14, and 28days , for a total of16 samples .In order to ensure more accuracy in the determination of strength, three samples were tested for each sand-cement ratio and the average was considered. The axial strain rate of the unconfined compressive strength test was 0.800mm/min.

Before starting the test, the sample that has been cured is measured, the diameter (D) of the upper, middle and lower parts of the sample were measured respectively, the height (H) of the sample was measured in three different directions, and the average value of the three data was taken for the diameter (D) and height (H) of the sample. The unconfined compressive strength of the sample is taken as the peak strength of the stress curve or the strength corresponding to 15% of the strain.

5 Results and Discussions

5.1 Unconfined compressive strength

The unconfined compressive strength of the studied percentage cemented sands before erodability testing are presented in the following section. The relationship between the curing period and the unconfined compressive strength of artificially cemented sand is shown in figure 2. Figure 2, shows that, for 2.5%, 5%, 7% and 10% cemented sands, the unconfined compressive strength increases 2.07, 2.15, 2.20, 2.80 times respectively for 28 days curing period when compared to 3 days curing period.

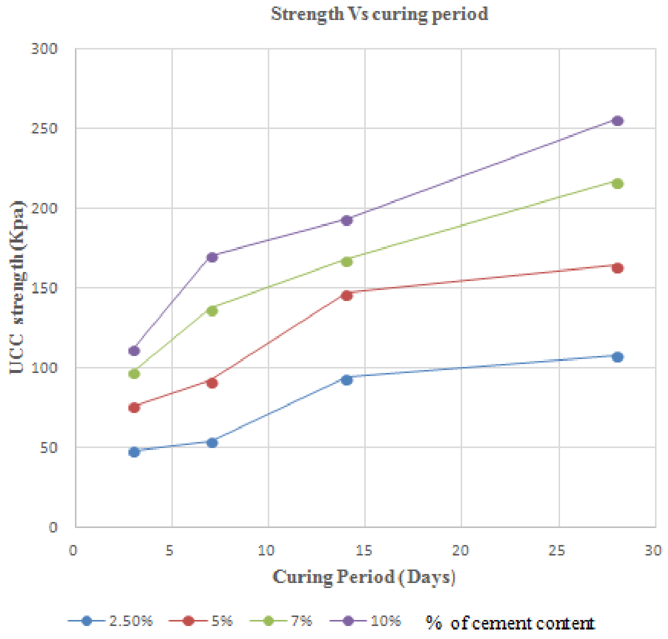

Fig. 2. Relationship between curing period and unconfined compressive strength.

The variation of unconfined compressive strength increases linearly with increase in curing periods and cement content for all the percentage of cemented sands studied.

5.2 Pinhole test results

At the end of the pinhole test, the eroding fluid was collected for all the cemented sands of different percentages and curing periods. The color of collected fluids was observed and classified by ASTM standards and listed in table 2.

Table 2. Criteria for evaluation of Pin –Hole test of cemented sand.

Curing period / %of cement content	3 days	7days	14 days	28 days
2.5 %	Slightly dark	Slightly dark	Barely visible	Clear
5%	Slightly dark	Slightly dark	Barely visible	Clear
7 %	Barely visible	Barely visible	Clear	Clear
10 %	Barely visible	Barely visible	Clear	Clear

From the table 2 it is observed that, for 2.5% and 5% cement content, the color of the eroded effluent for 3days and 7 days curing period is slightly dark and for 14days curing period it is almost transparent whereas for 28 days curing period it is clear. Then for 7% and 10% cemented sand the collected eroded effluent is almost transparent for 3days and 7 days curing period and clear for 14 days and 28days curing period.

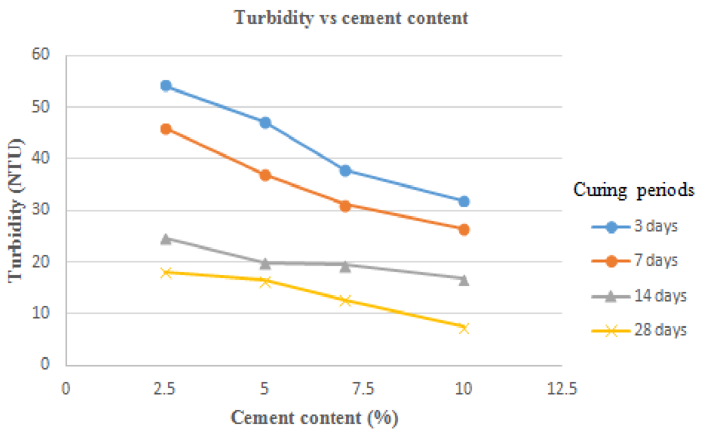

Fig. 3. Turbidity vs. Percentage of cement content.

The relations between turbidity and percent of cement content is shown in figure 3. Figure 3 shows that the turbidity decreases with incraese curing period and incraese in cement content . For 2.5 % cement content and 28 days curing period, the turbidity decreases 2.2 times when compared to 3 days cuirng period. Similarly for 5%,7% and 10% cement content and 28 days curing period, the turbitity decreases 2.8 times, 3 times and 4 times respectively when compared to 3 days curing period.

7 Conclusions

In this study the erodability of cement sands for different days of curing with also different percentage cement of cement content was studied using pin hole tests. The following conclusions were drawn from the study.

1. The unconfined compressive strength of the cemented sands increases linearly with increase in curing period and cement content. The increase is overall 1.3 times for the curing period and cement percentages studied.

2. Erodability of the cemented sands decreases with increase in cement content and increase curing period. This may be attributed to the fact that cemented sands reach 90% of their strength by 28 days of curing and their bond strength increases with increase in cement content decreasing the susceptibility to erodability.

These results are from the initial stages of an ongoing investigation on erodability of cemented sands and only the UCC strength of the cemented sands before erodability testing are presented. The testing of the eroded samples for strength is still underway. Further, a realistic characterization of the erodability of a stabilized soil is complex and difficult with many influencing factors. There is a wide scope of research in this aspect.

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