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The Use of the Crumb Test as a Preliminary Indicator of Dispersive Soils

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Abstract. Dispersive soils are prevalent in many areas around the world and the presence of these soils has always posed a serious problem on potential construction sites. The use of dispersive soils in hydraulic and other engineering structures such as roadway embankments can also lead to serious failures if the problem is not properly identified and addressed appropriately. Although the causes and consequences of dispersion are well understood, one of the main problems is the inability to positively identify such soils and thereby to reduce the potential for failure of many engineering structures. Many identification methods have been proposed but none has been completely successful. The primary test methods that are currently used for the identification of dispersive soils are the Pinhole Test; the SCS Double Hydrometer test; the crumb test and various chemical analyses of the soils with the crumb test being the most basic and unsophisticated test to perform. No single test and even the use of a combination of methods are reliable and it is possible that the reason lies in the actual testing procedures. A study involving the collection of various samples and execution of a single standard dispersive laboratory test, namely the crumb test, has identified some shortcomings. This paper discusses some of the various problems identified in the crumb test method and suggests some solutions to overcome them.

Keywords: Dispersive soils, dispersion, failure, identification, crumb test, shortcomings

Introduction

Dispersive soils are those soils, which when immersed in relatively pure and still water will deflocculate causing the clay particles to go into suspension. These soils are prevalent in many areas around the world and their presence has always posed a serious problem on potential construction sites. The use of dispersive soils in hydraulic and other engineering structures such as roadway embankments can also lead to serious failures if the problem is not accurately identified and appropriately compensated for. Although the causes and consequences of dispersion are well understood, one of the main problems is the inability of existing test methods to positively identify such soils and thereby assist in reducing the potential for failure of many engineering structures.

Many identification methods have been proposed but none has been completely successful. The primary test methods that are currently used for the identification of dispersive soils are the Pinhole Test; the Soil Conservation Service (SCS) Double Hydrometer test; the crumb test and various chemical analyses of the soils with the crumb test being the most basic and unsophisticated test to perform. No single test and even the use of a combination of methods are reliable and it is possible that the reason lies in the actual testing procedures.

A study involving the collection of four materials of differing dispersivity and execution of a single standard dispersive laboratory test, namely the crumb test, has identified some inconsistencies in the test method. The effect of different variables on the results of the crumb test was, therefore, investigated and modification of the test procedure to improve test reliability proposed.

1. Background

The crumb test, as an indicator for dispersive soils, is the simplest and easiest of the physical tests and was first described by Emerson in 1967 [1]. Emerson [1] found the interaction of clay-sized particles in water to be a major determining factor in the stability of a soil in an agricultural context. Based on this deduction, simple physical tests were devised to qualitatively divide soils into eight different classes. Remoulded soil crumbs were also used in one of the tests to simulate the effect of cultivation on the soil. Samples from a variety of soils were tested and their chemical properties determined for comparative purposes. **Figure 1** illustrates the flow chart developed by Emerson for the classification of soils.

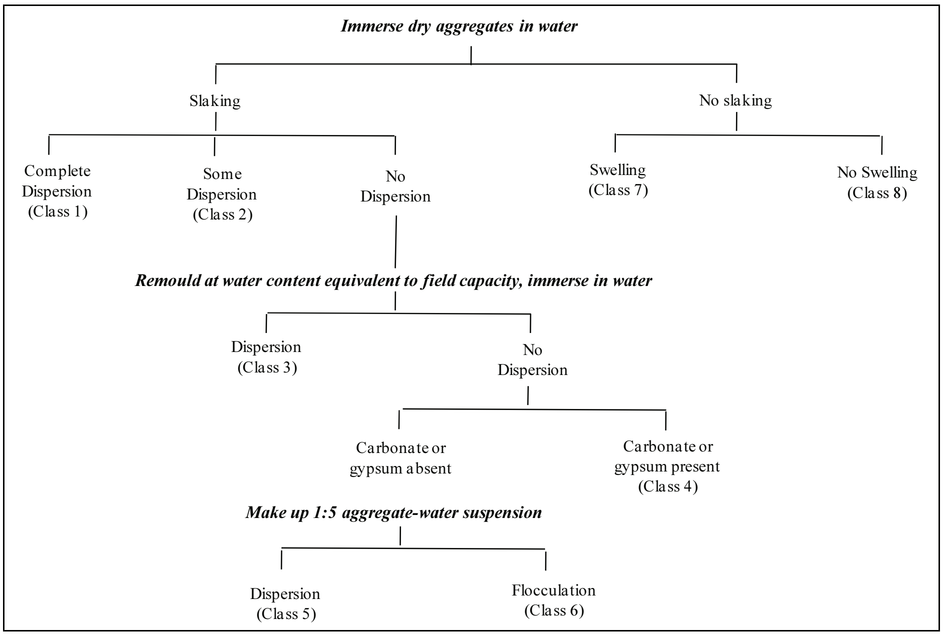

Figure 1: Flow chart for the classification of soil crumbs (Adapted from Emerson, 1967)

An evaluation of the existing literature has indicated that many researchers appear to misquote Emerson's work and use his findings incorrectly. There have been many cases in which the method has been misinterpreted with regard to variables such as moisture content and dispersing medium [2],[3],[4],[5]. An ASTM standard is also available for the crumb test (ASTM D6572-00) [6]. The standard, however, takes other variables such as temperature, which has no effect on the dispersivity of a soil, into account. The standard also calls for remoulding of the sample into a specific size, which again has no effect on the dispersivity.

The method mostly followed currently, which can be carried out in the field or a laboratory, involves placing a crumb of soil in a beaker of solution and observing the reaction as the crumb begins to hydrate. The test is primarily used as a visual assessment of the behaviour of the soil as it indicates the tendency of the particles to deflocculate in solution. After a certain time, usually 5-10 minutes, the soil crumb and the solution in the beaker are observed and the soil is classified according to the quantity of colloids in suspension [4],[5]. The soil can be at its *in situ* moisture content, air dried, oven dried or remoulded before being immersed in the beaker. The solution in which the crumb is immersed is commonly distilled water but a dilute sodium hydroxide solution is also known to be used instead of water. Four grades of dispersivity can be noted ranging from no reaction to strong reaction (**Table 1**).

Table 1: A table depicting the description of grades for a crumb test (Walker, 1997).

Grade	Reaction	Description
1	No reaction	Crumbs may slake, but no sign of cloudiness caused by colloids in suspension
2	Slight reaction	Bare hint of cloudiness in water at surface of crumb.
3	Moderate reaction	Easily recognisable cloud of colloids in suspension, usually spreading out in thin streaks on bottom of beaker.
4	Strong reaction	Colloid cloud covers nearly the whole bottom of the beaker, usually as a thick skin.

A literature search has found that one of the main problems associated with this test is the inconsistency of results. It was also found that no standard protocol regarding variables like immersion solution and condition of crumb is employed. Tests are carried out using dilute NaOH or distilled water and samples are either air dried, oven dried, remoulded or in situ. All of these variables can have significant effects on the outcome of the test and thus the classification of the dispersivity of the soil. **Figure 2** illustrates the difference in results obtained when the crumb test was carried out on the same material but with different variables. The first test was carried out on a remoulded crumb in dilute 0.001N NaOH solution (a), the second was carried out on an air dried crumb in distilled water (b) and the third on a remoulded crumb in distilled water (c).

One of the consistent observations, however, that has come up many times is the time taken to “run” the test. It is most commonly stated that observations on the dispersivity (or suspension cloud) should be taken 5 to 10 minutes after the crumb is immersed in water. It should, however, be noted that if a soil is dispersive, the colloidal suspension will not settle and will still be present after a few hours. **Figure 3** gives an idea of what the colloidal suspension of a dispersive soil should look like after more than an hour.

Figure 2: Comparison of results for same material based on different variables

Figure 3: Colloidal suspension of a highly dispersive soil- Grade: 4- strong reaction

2. Methodology

For this study, the crumb test was carried out on four samples, two of unknown classes, one highly dispersive (based on previous work and field performance) and one non-dispersive sample (also based on previous work). The test was carried out on each sample using different variables. These variables include condition of the crumb or moisture content and immersion medium.

Six tests were carried out on each sample. Two solutions were used, namely distilled water and dilute 0.001N NaOH. For each solution, three conditions of crumbs were tested. The condition of the materials included air dried, oven dried and remoulded crumbs. For the remoulded specimens, air dried samples were crushed and distilled water added until the soil was at a consistency to mould into approximately spherical “crumbs” about 3cm in diameter.

The tests were run for approximately 16hrs with observations made at 10 minutes, 2 hours and 16 hours to evaluate changes in the colloidal suspension over time. In the case of a truly dispersive soil, the colloidal suspension should not settle over time.

3. Results

The results of the testing are summarised in Table 2.

Table 2: Results obtained for crumb test under different variables.

Solution	Crumb condition	Time	Sample			
			ZT114	**DD**	**KNP**	**ND**
Distilled Water	Air dried	10 min	4	2	1	2
		2 hrs	4	2	1	1
		>16 hrs	4	1	1	1
	Oven dried	10 min	4	3	1	1
		2 hrs	4	2	1	1
		>16 hrs	4	2	1	1
	Remoulded	10 min	4	3	3	2
		2 hrs	4	3	3	1
		>16 hrs	4	2	2	1
0.001N NaOH	Air dried	10 min	3	2	2	1
		2 hrs	4	1	1	1
		>16 hrs	4	1	1	1
	Oven dried	10 min	1	2	2	1
		2 hrs	3	1	1	1
		>16 hrs	3	1	1	1
	Remoulded	10 min	4	4	2	2
		2 hrs	4	4	1	1
		>16 hrs	4	4	1	1

Results show that after 10 minutes most samples observed would be classified as being dispersive to some degree (Grade 2-4). Settlement of particles began after approximately 30 minutes and the maximum settlement was attained after 2 hours. **Figures 4** and **5** graphically illustrate the variation in results obtained at the 10 minute and 16 hour readings.

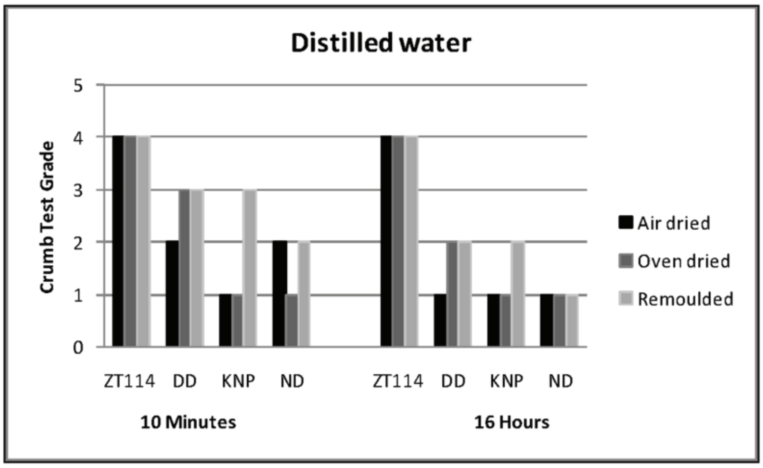

Figure 4: Variation in classification at 10 minutes and 16 hours in distilled water.

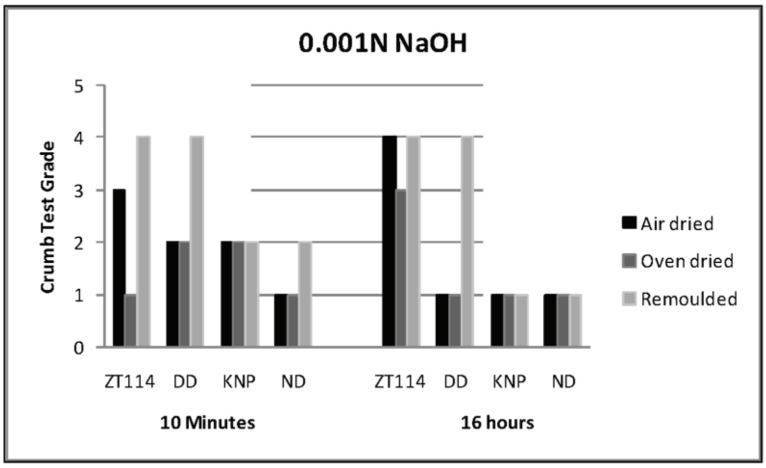

Figure 5: Variation in classification at 10 minutes and 16 hours in dilute NaOH solution.

Figure 6 illustrates the difference in colloidal suspension observed at 10min, 2 hours and 16 hours for a non-dispersive sample. At 10 minutes, the sample can be classified as dispersive, with a classification grade of 3-4. The suspension, however, settles after some time and the 2 hour reading classifies the sample as being non-dispersive. This illustrates that the results of a crumb test after 10 minutes are not reliable as some of the fine particles, which are not necessarily dispersive, can still be in suspension. As discussed before, the colloidal suspension of a dispersive soil should not settle over time. It is likely that the inconsistency of results associated with the crumb test is primarily due the time of observation and it is recommended that a minimum waiting period of 1 hour be practiced.

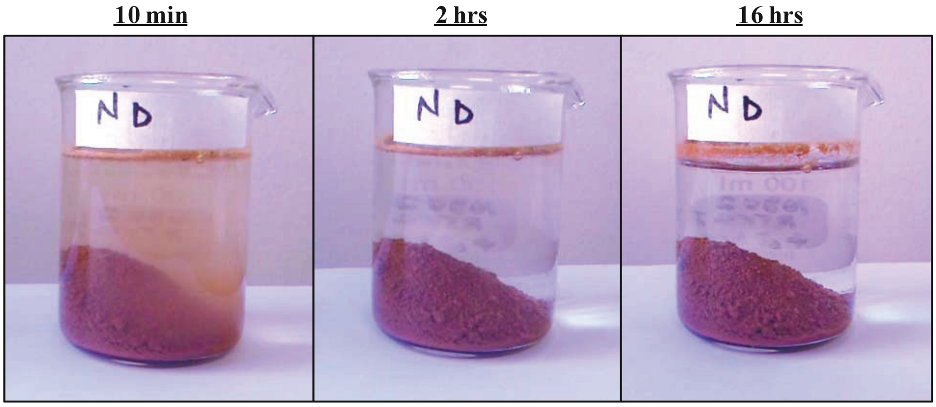

Figure 6: Illustration of the difference in colloidal suspension observed at 10 minutes, 2 hours and 16 hours.

There are slight differences between the results of samples immersed in distilled water and dilute NaOH. The significant difference occurred between the remoulded crumbs and those that were dried. Remoulding the samples appeared to have the effect of enhancing the dispersive behaviour of the soil. Sample DD demonstrated dispersive behaviour when remoulded and slight or non-dispersive behaviour when dried. The known dispersive sample, ZT114, gave a less dispersive reaction when oven dried and immersed in NaOH solution. Remoulded sample KNP classified as dispersive when immersed in distilled water, as opposed to being non-dispersive in the other tests.

4. Discussion

Results obtained from the 6 crumb tests on each of the samples illustrates the variations that can occur due to the lack of a standard protocol for testing dispersivity of soils and leading to differences in classifications. A variety of factors affects the dispersive behaviour of soils resulting in contradictory results, which are likely to pose a problem when faced with the task of treating the soil for construction purposes. Changing the solution in which the crumb is immersed has a significant effect on the results. It is likely that the different solutions have different effects on various soils and carrying out the test using both solutions should provide more useful results. Oven dried samples demonstrated the most inconsistent results. This is due to the fact that the physiochemical properties of the soil pore-water and adsorbed water may be changed when exposed to high temperatures. Remoulded samples showed relatively consistent results since remoulding the samples appears to enhance the dispersive behaviour in the soil. Remoulding the samples also simulates the action of the working and compaction processes on the soil in the field, and is likely to give more realistic results. All samples showed some variation in results due to the different variables. The only sample, however, that was not affected by the different variables was the totally non-dispersive sample (ND).

5. Conclusions

Investigations into the crumb test method most commonly used for the identification of dispersive soils have highlighted some of the differences that can be obtained on a single soil, as a function of variations in test procedures. This is due to the numerous variables in the test procedures resulting in different interpretations of the test methods, and consequently misleading results. Research and experience show a number of ambiguities in the test procedures which can be interpreted differently by different laboratories. The major problems observed with the crumb test method have been discussed in this paper and suggestions to overcome them proposed.

In light of the results of this study, the current procedures for the identification of dispersive soils by the use of the crumb test should be reviewed and the need for a detailed, simple and repeatable test protocol acknowledged. In order to reduce the variation/inconsistencies in results, it is essential that the test method is reviewed and the optimum procedure developed. The procedure should be simple and have as few ambiguities as possible so that no misinterpretations can occur.

Work to improve and standardise the test protocol is currently being extended to include more materials.

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