

# The SCS Double Hydrometer Test in dispersive soil identification

## Essai SCS de double hydrométrie pour l'identification des sols dispersifs

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**ABSTRACT:** The standard testing procedures for the Soil Conservation Service (SCS) Double Hydrometer test, the Pinhole Test, Crumb test and chemical analyses for the identification of potentially dispersive soils have recently been studied and problems/anomalies identified. Recent testing suggests that many of the shortcomings related to testing of dispersive soils may have been overlooked during past routine investigations. A comparative study involving the testing of three samples using one standard laboratory test, namely the SCS double hydrometer test was carried out and some potential means of overcoming the problems have been identified. The investigation has highlighted the differences that can be obtained on a single soil as a function of the variation in test procedures. The variability of the results obtained from the double hydrometer test in particular appears to be the cause of many of the ambiguities and discrepancies in the classification systems studied during this research. Problems related to the double hydrometer tests pose the potential for misleading results since the test has been used as the basis for identifying the potential dispersiveness of soils during the development of rating systems.

**RÉSUMÉ :** Les procédures de test standard pour le Soil Conservation Service (SCS) test hydromètre double, le test sténopé, le Crumb test et des analyses chimiques pour l'identification des sols potentiellement dispersifs ont récemment été étudiés et des problèmes ou anomalies identifiés. Des tests récents indiquent qu'un bon nombre de défauts liés à l'analyse des sols dispersifs peut avoir été négligé au cours des enquêtes de routine conduites dans le passé. Une étude comparative entre l'essai de trois échantillons à l'aide d'un test de laboratoire standard, à savoir le test SCS hydromètre double, a été effectué et des moyens possibles de surmonter les problèmes ont été identifiés. L'enquête a mis en évidence les différences qui peuvent être obtenues pour un sol unique en fonction de la variation dans les procédures de test. La variabilité des résultats, obtenus à partir du test SCS hydromètre double en particulier, semble être la cause de bien des ambiguïtés et des incohérences dans les systèmes de classification étudiés au cours de cette recherche. Les problèmes liés aux tests hydromètre double présentent le potentiel pour des résultats erronés, puisque le test a été utilisé comme base pour déterminer la dispersivité potentielle des sols lors de l'élaboration des systèmes de notation.

**KEYWORDS:** Dispersive soils ; hydrometer ; soil testing

### 1 INTRODUCTION

The failure of dams and embankments as a result of the use of dispersive clays has been recognized by engineers and geologists in South Africa and internationally for many years. A serious problem, however, still lies in the early identification of dispersive soils (Paige-Green, 2008). Despite all the information gained over the years, there is still no quick, simple and reliable means of conclusively identifying dispersive soils. Many methods have been proposed including the pinhole, double hydrometer, crumb and chemical tests, either individually or in combination. These, however, have not always been entirely reliable and it was considered possible that the reason lay in the actual testing procedures.

The standard testing procedures for the Soil Conservation Service (SCS) Double Hydrometer test, the Pinhole Test, Crumb test and chemical analyses have recently been studied and problems/anomalies identified. Although no discussion regarding these anomalies has been found in the literature, the recent testing suggests that many of these shortcomings may have been overlooked during past routine investigations. This paper summarizes a comparative study involving the testing of three samples using one standard laboratory test, namely the SCS double hydrometer test and discusses some potential means of overcoming the problems identified. The other tests have been discussed separately (Maharaj, 2010a: 2010b: 2011: 2012).

### 2 HISTORY OF THE SCS DOUBLE HYDROMETER TEST

The Soil Conservation Service (SCS) double hydrometer or dispersion test has been identified as one of the most appropriate tests for classifying dispersive soils. The test evaluates the dispersibility of a soil by measuring the natural tendency of the clay fraction to go into suspension in water. The procedure involves the determination of the percentage of particles in the soil that are finer than 0.005 mm using the standard hydrometer test. A parallel test is also carried out, in which no chemical dispersant is added and the solution is not mechanically agitated. The quantity of particles finer than 0.005 mm in the parallel test is expressed as a percentage of this fraction determined in the standard test, which is defined as the dispersion ratio or dispersivity of the soil (Walker, 1997). Dispersion ratios greater than 50% are considered highly dispersive, between 30 and 50% are moderately dispersive, between 15 and 30% are slightly dispersive and less than 15% are non-dispersive (Elges, 1985). Similar systems with different limits were utilized by Gerber & Harmse (1987) and Walker (1997).

The dispersion test was first described by Volk (1937) as a means of determining the potential dispersiveness of soils. The test has since been used extensively in this regard with minor modifications. Volk's test compared the weight of soil grains, 0.005 mm or smaller that slaked free when air-dried lumps of soil were soaked in quiet, distilled water, with that of the entire soil. This was expressed as the percentage dispersion. Measurements of the clay in the soil-water suspension were made by the pipette method (Volk, 1937).

The pipette method itself was introduced by Middleton in 1930 as a means of determining the erosion potential of a soil. The difference in the methods was that the samples collected in the pipette consisted of particles of a maximum diameter of 0.05mm (Middleton, 1930). Volk's method was, however, preferred because studies in the southwest of the United States indicated that the dispersion of the clay fraction (< 0.005 mm diameter), was more significant in assessing the piping potential of soils (Decker and Dunnigan, 1977).

The SCS involvement in earth dam construction in the United States increased in the 1940's and early 1950's. The dispersion test was employed as a routine procedure for all samples submitted to SCS Laboratories. It was during this period that the test procedure was adapted to use a hydrometer instead of a pipette (Decker and Dunnigan, 1977). The procedure is specified in ASTM standard D422-63 for Particle Size Analysis of soils (ASTM International, 2007a & b).

With the increased use of the dispersion test and the growth of the SCS testing facilities in the 1950's and 1960's, a few Table 1: Difference in testing procedures used for the determination of the clay fraction of a soil.

Property	ASTM- D422-63	BSi- BS 1377-2: 1990	TMH1- 1986 (A6)
Amount of dry soil required for the test:	100g of sand sized particles (i.e.: particles less than 2mm in size) or 50g of soil fines if material has a high percentage of silt/ clay.	Depends on type of soil, i.e.: 100g for sandy soil, 50g for silty soil and 30g for clayey soil.	100g of soil fines (i.e.: particles less than 0.425mm in size) or 50g of soil fines if material has a high percentage of silt/ clay.
Pre-treatment	None	With hydrogen peroxide if organic matter present.	None
Dispersing agent	125ml sodium hexametaphosphate solution at 40g/l.	100ml sodium hexametaphosphate solution comprising 33g Na-hexa. + 7g Na-carbonate in distilled water to make 1 l of solution. NB: If soil does not disperse completely, allow soil to settle, decant as much of the water as possible and then add a further 100ml of dispersant.	5 ml each of sodium silicate and sodium oxalate solutions.
Soaking	Samples soaked for minimum of 16 hrs.	Soak in solution for min of 4hrs or overnight.	Minimum period of 2 hrs but preferably overnight.
Hydrometer readings	Taken at 2min; 5min; 15min; 30min; 1h; 4h and 24h.	Taken at 8min; 30min; 2h; 8h & 24h.	Taken at 18s, 40s & 1h.
Analysis	Equations used to calculate maximum diameter of particles in suspension	Equations used to calculate maximum diameter of particles in suspension.	Maximum particle size calculated. At 1h, max size is 0.005mm, at 40s max size is 0.05mm and at 18s, max size is 0.075mm.
Temperature	Constant temperature at or near 20°C is required.	Constant temperature bath of 25°C, to an accuracy of $\pm 0.5^\circ\text{C}$ .	20°C when readings are taken or a temperature correction has to be applied.

Close observation of these test procedures illustrates little variation in the method of determination of the dispersion ratio, except with regard to the types of dispersing agents used. The ASTM and BSi standards specify that sodium hexametaphosphate be used as a dispersing agent. However, the solution is prepared differently and at different proportions in each standard. The volume required to disperse the sample in the test is also very different.

TMH1 specifies that a combination of sodium silicate and sodium oxalate be used as the dispersing agent. A study of the past revisions of the South African standards shows that the combination of sodium silicate and sodium oxalate was specified in the 1958 and 1986 test methods, whereas, sodium hexametaphosphate was specified as the standard dispersant in the 1970 version. There is no reason found as to why the combination of sodium silicate and oxalate is used instead of sodium hexametaphosphate or why there was a change in the standard in 1970.

It should also be noted that TMH1 states that the one hour hydrometer reading indicates the percentage of the clay fraction in the sample. Analyses using Stoke's Law show that at one

hour, particles in suspension in all samples are in the range of 0.006 – 0.007 mm, which is silt-sized and not clay-sized.

### 3 EVALUATION OF CURRENT TESTING METHODS

The test methods for hydrometer analysis currently in use are the American standards (ASTM International, 2007), the British standards (BSi, 1990) and the South African Technical Methods for Highways - TMH1 (NITRR, 1986). Table 1 summarizes procedures carried out for each test standard, focusing on the main aspects of the testing procedure.

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### 4 TESTING EQUIPMENT AND METHODS USED

A study was conducted to evaluate the effects of the different methods on the test results. For the study, testing procedures that were carried out were the South African standard (TMH1) and the American standard (ASTM), the primary difference in the procedures, being the variation in dispersing agents. The tests were carried out on three samples, one non-dispersive, one highly dispersive and a third that was presumed to be moderate to slightly dispersive (based on past experience and field observations).

The dispersing agents used were combinations of sodium hexametaphosphate (33g) plus sodium carbonate (7g) in a liter of water and a sodium silicate (5ml) plus sodium oxalate (5ml) solution. Samples were left to stand for approximately 16 hours after dispersion before being mechanically agitated and then the hydrometer readings were taken. Time intervals for the hydrometer readings were at 1 hour, 40 seconds and 18 seconds as specified in TMH1 Method A6. Duplicate samples were

prepared according to the parallel test procedure, with no chemical dispersant and mechanical agitation.

## 5 RESULTS

The one hour readings as well as the calculated dispersion ratios for the two dispersing agents are summarized in Table 2.

Table 2: Results obtained from 1 hour hydrometer readings and dispersion ratios

Sample	Control	Na silicate & oxalate	Dispersion ratio %	Na Hexameta-phosphate	Dispersion ratio%
ND309	1.9	7.9	17.7	13.9	10.1
UM108	2.6	11.6	22.4	16.6	15.7
ZT114	19.9	15.9	125.2	24.9	79.9

The test results show that there is significant variation in the apparent clay fraction between the two dispersants. The samples that were dispersed with sodium hexametaphosphate produced more realistic dispersion ratios than those of the other samples.

This could mean that the samples were not completely dispersed with this dispersing agent (sodium silicate + oxalate) or that there was some variation in sample preparation. However, as the samples were prepared together with utmost care to ensure ideal representatives, the latter is unlikely.

The maximum dispersion should occur when a chemical dispersant is added to the sample ensuring a total disaggregation of all flocs of soil. A high dispersion ratio indicates that the sample breaks down significantly without the use of a chemical dispersant and is thus dispersive. In theory, the 0.005 mm fraction for the parallel test cannot be higher than that of the standard test with the use of a chemical dispersant. This is only likely to occur if there are inconsistencies in the testing procedure or if the chemical dispersant does not act fully on the material. The dispersion ratio of 125.2% shown for the sodium silicate/oxalate dispersant (Table 2) indicates that the dispersant in the standard test did not completely disperse the particles or possibly caused some flocculation to occur.

An additional observation is that the classification obtained for the two dispersants do not correlate. Sample ND309 falls into two different categories of dispersivity based on the classification by Elges (1985). It is classified as being slightly dispersive using sodium silicate/oxalate and non-dispersive using sodium hexametaphosphate, which can lead to uncertainty regarding treatment requirements, should it be used for construction.

## 6 DISCUSSION

Although the results of only limited testing is reported in this paper, it is clear that the incorrect classification of dispersive soils as a result of test variations appears to be common.

Inconsistencies noted in the available literature include the variations in test methods. Observations have found that different authors indicate different particle sizes for the clay fraction. TMH1 and ASTM use the 0.005 mm fraction as the boundary for the clay fraction, whereas BSI uses the 0.002 mm. Many authors quote the 0.005 mm fraction as the clay fraction

when determining dispersivity of a soil. A Dictionary of Geology (1972) defines the clay fraction as a mineral particle having a diameter less than 0.004 mm (1/256 mm). According to Reeves et al (2006), the ASTM standards define the clay fraction as being less than 0.005 mm and Japan defines the fraction as less than 0.006 mm. However, the majority of the countries listed define the clay fraction as particle sizes less than 0.002 mm. Once again there is no standard definition with regards to the unit size for clay particles although a scan of the literature shows that 0.002 mm is used more widely. As the 0.002 mm fraction is also the basis for classification of South African soils according to Brink and Bruin (2002), this size fraction should be taken as the upper limit of clay-sized particles for future studies in South Africa.

The literature also indicates that during studies of dispersive soils the initial indicator of dispersivity of the material is generally classified on the basis of the double hydrometer test by means of various indicator graphs/plots. Many workers (Gerber and Harmse, 1987; Bell and Maud, 1994; Walker, 1997) have then proceeded to indicate that no single test (including the double hydrometer test) can be used to identify dispersive soils, and then propose classification rating systems using a number of tests. It is postulated that many of the ambiguities (i.e., the inconsistencies of results among workers) are the result of the incorrect initial classification of the dispersivity of materials as a result of variations introduced in the double hydrometer test.

Most of the rating systems used currently in South Africa seem to have been based on the initial classification of dispersiveness by the double hydrometer test. Gerber and Harmse (1987) used the test as a primary parameter when developing the ESP-CEC chart. Walker (1997) included the ESP-CEC chart as a parameter in the rating system and studies carried out by Bell and Walker (2000) also make use of the double hydrometer test when initially classifying the dispersive soils.

This has resulted in the overlap of results within single classification bands. Although it is assumed that in these investigations, the materials have been tested following uniform and standard procedures, preliminary testing has indicated spurious results when sodium silicate/oxalate (the South African road standard) is used as the dispersant (NITRR, 1986). It is also noted that the dispersant standard in South Africa has changed over time, possibly affecting the results, if they were obtained from different laboratories over a prolonged period of time. It can thus be assumed that this would be particularly more so in projects carried out over short periods at various times related to the general use of different dispersants with time.

## 7 CONCLUSIONS

An investigation into the double hydrometer test method used for the identification of dispersive soils has highlighted differences that can be obtained on a single soil as a function of the variation in test procedures. This is due to the relatively ambiguous state of the test procedures resulting in different interpretations of the test methods, and consequently misleading results.

The double hydrometer test is a good example of misinterpretations due to ambiguities. Despite the test being an ASTM standard (ASTM D4221-99), many laboratories just duplicate the standard hydrometer analysis procedure (TMH1 and ASTM D422-63), which invariably produces incorrect results. The variability of the results obtained from the double hydrometer test appears to be the cause of many of the ambiguities and discrepancies in the classification systems studied during this research. The incorrect classification of the dispersiveness in the early stages of the investigations would influence the entire analysis process negatively.

Problems related to the double hydrometer tests pose the potential for misleading results since the test is associated with a number of different parameters in the rating systems. Inaccurate results from the double hydrometer test can significantly affect the correlation of the final rating, particularly when this test method is used as the reference methods for the preliminary classification of the dispersivity of soils (Gerber and Harmse, 1987; Bell and Maud, 1994; Walker, 1997).

It is therefore necessary to stress the importance of developing and following a standard protocol for the test. 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.

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