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SOIL RETENTION TESTS FOR DETERMINING DISPERSION OF CLAYEY SOILS

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ABSTRACT: The essential nature of dispersive clays was first noticed by U.S. Dams' soil scientists and agricultural engineers. Highway embankments and natural formations of high sodium dispersive clay were recorded as severely damaged by internal (tunnel) erosion of water flowing in the form of concentrated leaks within cracks. These dispersive clays, which cannot be differentiated from ordinary erosion-resistant clays by the routine civil engineering tests, erode rapidly in slow-moving (or even quiet) water by individual colloidal particles going into suspension. In Iraq, few studies were interested in such types of soils; that's why the present study takes into consideration dispersion of Baghdad clayey soil brought from three different Zones in Baghdad; the first soil is brought from Al. Kazaliyah district Zone (A), This Soil is classified as (CH) according to the Unified Soil Classification System (USCS). The second soil is brought from Al. Qadisiya District Zone (B) is classified as (CH), while the third Soil is Al. Dora region Zone (C) is classified as (CL). The conventional testing and interpretation are found to be inapplicable to analyze and identify the Dispersion soils due to the existence of Na+. The effect of water content was studied in two different tests for each soil; the pinhole test and soil retention test. The behavior of dispersive soil is not affected by water content, but water content may change the time to failure. This fact gives a good and new indicator of the maximum time to failure.

Keywords: Dispersion, Retention, Soil Security, Pinhole

1. INTRODUCTION

Some natural clay soils disperse or deflocculate in the presence of relatively pure water and are, therefore, highly susceptible to erosion and piping. The tendency for dispersive erosion in a given soil depends upon such variables as the mineralogy and chemistry of the clay and dissolved salts in the soil pore water and the eroding water. Standard tests for classifying for engineering purposes don't identify this property of a fine-grained soil [1]**.**

Dispersive clay soils can be a problem for many practices or structures. In appearance, they are like normal clays that are stable and somewhat resistant to erosion, but in reality, they can be highly erosive and subject to severe damage or failure. It is important to understand the nature of these soils and to be able to identify them so they can be treated or avoided [2].

Ordinary clays have a flocculated or aggregated structure because of the electrochemical attraction of the particles to each other and water. This accounts for these soils' cohesive, non-erosive behavior. Dispersive clays have an imbalance in the electrochemical forces between particles. This imbalance causes the minute soil particles in a dispersive clay to be repulsed rather than attracted to one another. Consequently, dispersive clay particles tend to react as single-grained particles and not as an aggregated mass of particles. Dispersive clays are most easily eroded by low ion concentration water, such as rainwater. Runoff water has the opportunity to attain ions from land surface contact, making it more in ionic balance with the dispersive clays and less erosive [3]. Typically, dispersive clays are low to medium plasticity and classify as CL in the Unified Soil Classification System (USCS). Other USCS classes containing dispersive clays are ML, CLML, and CH. Soils classified as MH rarely contain dispersive clay fines [4-5].

The natural tendency of some fine-grained soils to deflocculate and disperse in the presence of water under certain circumstances creates problems when excessive removal and transport of the soil material cause erosion and piping. The dominant feature of such soils, which are generally identified as dispersive clays, is the presence of individual separate submicron-size particles or deflocculated small flocs where net repulsive forces characterize the interaction between the particles or flocs [6-7].

Ordinary clays have a flocculated or aggregated structure because of the electrochemical attraction of the particles to each other and toter [8]. This aunts for these soils' cohesive, non-erosive behavior [9]. Dispersive clays have an imbalance in the electrochemical forces between particles[10]. Consequently, dispersive clay particles tend to react as single-grained particles and not as an aggregated mass of particles. Dispersive clays are most easily eroded by low ion concentration water, such as rainwater [11]. Runoff water has the opportunity to attain ions from land surface contact, making it more in ionic balance with the dispersive clays and less erosive [12]. Typically, dispersive clays are low to medium plasticity and classify as CL in the Unified Soil Classification System (USCS). Other USCS classes containing dispersive clays are ML, CLML, and CH. Soils classified as MH rarely contain dispersive clay fines. Clay loss is common in bare soils subjected to rainfall or sprinkler irrigation. In a dispersed state, clays can be easily transported by the surface runoff [13] reported that anions interact with 1:1 clay minerals, where kaolinite is the most dominant clay mineral. In recent years, the dispersion properties of the pure clay minerals under the influence of anions have received much attention [14]. However, the effect of anions on making surface charge more negative and dispersion properties of such kaolinite-rich soil clays has been neglected [15]. Organic anions originate from the exudation of plant roots and microorganisms, and the decomposition of soil organic matter is ubiquitous in soils, especially in the rhizosphere [16]. Inorganic anions such as sulfate and chloride may enter into soils through the degradation of soil organic matter and the application of mineral fertilizers. At acidic conditions, positively-charged edge sites of the clay minerals might favor the formation of edge-to-face structures, the so-called "card house," which facilitates coagulation. Adsorption of inorganic anions (SO4 2 − and Cl−) onto these positively charged edge sites may counteract clay coagulation [17].

Similarly, low-molecular-weight organic anions such as acetate, oxalate, and citrate can also associate with positively-charged edge sites and decrease the clay particle's zeta potential [18]. However, the effects of these organic anions on dispersion properties have not been studied systematically. The Test-tube experiments [19wwhich have been utilized tcollothe colloidal properties of clay minerals, but this technique requires a highly concentrated suspension of clay. In contrast, dynamic light [19]. Scattering is known as a suitable technique for investigating clay coagulation at lower clay concentrations[20]. However, few comparable investigations on the dispersion of clay particles using both methods have been reported. In the present work, a combination of dynamic light scattering and test-tube experiments has been employed to investigate the dispersion state of the clay fraction under the influences of anions (Cl−, SO4 2−, acetate, oxalate, and citrate) as a function of both pH and ionic strength was also investigated to provide more information on the adsorption of anions on clay minerals [21].

In general, the net repulsion between particles occurs when double-layer repulsion overwhelms Van der Waals attraction. Although this phenomenon is largely attributed to situations where an excessive amount of sodium ions exists about the total salt concentration in the pore water, two other events can contribute to the development of net repulsion. These two other circumstances are [22]:

1. The Low salt concentration of the pore fluid results from the desorption of the ions'.
2. The presence of potential determining anions such as bicarbonates, carbonates, hydroxides, phosphates, etc.

The various tests used to aid in the identification and characterization of dispersive clays generally involve two basic parameters:

1. The force required detaching particles.
2. The floc size and double-layer interactions between various particles and floc, i.e., between various micro fabric units.

2. AIMS AND SCOPE OF THE STUDY

To analyze the effect of availability of dispersive characteristics and the property of soil of these zones in Baghdad city: Zone(A), Zone (B), and Zone (C). All samples are disturbed samples and taken from a depth between 3.5 to 5m below the ground.

This study is concerned with the following:

1- Classifying Soil of Baghdad Region as dispersive or not.
2- Introducing a new Laboratory test to identify the dispersion

3. RESEARCH SIGNIFICANCE

Dispersion is a process that occurs in soils that are particularly vulnerable to erosion by water. In soil layers where clays are saturated with sodium ions ("sodic soils"), soil can break down very quickly into fine particles and wash away. This can lead to a variety of soil and water quality problems, including:

- significant soil losses by gully erosion and tunnel erosion
- Soil structural degradation, clogging, and sealing where dispersed particles settle[1]
- Suspended soil causes turbidity in water and transporting nutrients off the land

Laboratory tests used to diagnose a soil as dispersive focus on the cation exchange capacity of a soil sample and its cation breakdown. Soil cations are dominated by Ca2+, Mg2+, K+, and Na+, as well as H+ in acidic soils. The exchangeable sodium percentage s a key indicator derived from these measurements. Where ESP exceeds 5%, dispersive behavior becomes possible and is highly likely where ESP exceeds 15%. Specifically for the soil underneath hydraulic structures, e.g., earth and concrete Dams and embankments

4. DISPERSION OF CLAYEY SOILS

Clay is an assemblage of microscopic platelets formed by the chemical decomposition of rock minerals. These platelets are held together by various forces. A high exchangeable sodium percentage (ESP) causes the platelets to be loosely bonded [3].

The sodium acts to increase the thickness of the diffused double water layer surrounding individual clay particles, and hence, to decrease the attractive force between the particles, making it easier for individual particles to be detached from the mass [4]

The degree of dispersion is one of the best measures for predicting clay material erosion and piping potential. However, their nature, dispersive clay particles being unable to form stable aggregates, are easily detached from other soil materials, and thus, are easily suspended and carried away by the movement of water. Because of this characteristic, the presence of critical dispersion is sometimes easily detectable in the field, particularly in areas of strong relief [5].

5. RECOGNITION OF DISPERSIVE CLAY

Clays are said to be dispersive when the interparticle forces are such that there is a net repulsion between the clay platelets. Some efforts to recognize the dispersive properties of clay specimens utilize laboratory experimentation in which the field behavior is simulated to varying degrees, depending upon the type of test performed. In other procedures, the chemical constituents of the soil are determined. These are extrapolated empirically to predict dispensability based on previous experience with similar materials. No single test provides results that have a satisfactory level of reliability. In general, several different types of tests have to be performed before a confident recognition of clay dispensability can be made [6].

The various methods used to identify the dispersive nature of clays can be categorized as (a) qualitative methods and (b) quantitatmethodoThe Soil Conservation Service (SCS) developed the dispersion ratio testsSCS), the crumb test, and the pinhole test developed by Sherard [22]. Are qualitative free swell test, the rotating cylinder, and the flume test provide quantitative criteria for the determination of the dispersive nature of clays. In 1977, predictive criteria based on the amount and type of clay, SAR (Sodium Adsorption Ratio), the concentration of pore fluid, and the shear stress required to initiate erosion had been proposed [7].

6. GEOLOGIC ORIGIN AND TOPOGRAPHY OF DISPERSIVE SOILS

The various origins of dispersive clay are not well known. Most of them encountered alluvial clays in the form of flood-plain deposits, slope wash, lake bed deposits, and loess deposits. In some areas, it has been found that claystone and shales laid down as marine deposits have the same pore water salts as dispersive clay, and their residual soils are dispersive.

Dispersive clays have been red, brown, gray (some nearly white), yellow, and all transitions among these. No black-colored soils, with obviously high organic content, have tested dispersive.

Many deposits of dispersive clay studied are situated in flat flood plains or gentle rolling topography with low relief and smooth, relatively flat slopes. Usually, there are no manmade excavations or embankments in the area, and there is little or no evidence from the surface appearance that the soil is highly erodible. The ground surface is covered with a thin layer of protective silty sand from which the dispersive clay particles have been removed or has a protective layer of topsoil and vegetation.

Where steep topography and dispersive clay coexist, the peculiar ground surface topography is easily recognized by deep, rapidly forming channels and tunnels.

It was indicated that dispersive soils in nature, causing trouble with agriculture and hydraulic structures, were found most commonly in arid and semiarid regions and commonly had alkaline pore water (pH greater than about 8.5). Studies (including studies of damaged dams) have found many dispersive soils in humid areas, and many have pH well on the acid side [1].

7. LABORATORY TESTS

7.1 General

To distinguish the behavior and the properties of dispersion. The soil was brought from three different locations in Baghdad City. Al.Kazalia (Zone A), Al.Qadisiyah (Zone B) and Al.Dora (Zone C) Zones. All disturbed samples were taken from depths between 3.5m to 5.0m.below the ground surface was transported tSoile soil Mechanics Laboratory, Civil Engineering department, and collage of engineering Al.Mustansiria University [23] and [24] . The physical properties of soil for each Zones are shown in Table 1. There are four laboratory tests for identifying dispersive clays, and another one is recommended here, according to tottrading25].

Table 1 Physical properties of soil used

specs	Soil From		
Tests	ZONE A	ZONE B	ZONE C
Specific gravity	2.68	2.654	2.70
Liquid limit %	56.0	51.5	34.4
Plasticity Index	30.5	28.1	17.2
Unified classification	CH	CH	CL
Sand size fraction %	6.4	8.5	11.7
Silt size fraction %	41.6	40.5	48.3
Clay size fraction %	52.0	51.0	39.0
Activity	0.58	0.55	0.44
Maximum dry unit wt.(kN/m^3)	14.9	17.4	17.25
Optimum Moisture Content %	21.0	17.05	16.4

7.2 The Soil Conservation Service (Double Hydrometer) Test

This test was developed by Volk [26] and has been widely used by the U.S. Soil Conservation Service. The particle size distribution is first measured by using the standard hydrometer test, in which the sample is dispersed in the hydrometer bath with solid mechanical agitation and chemical dispersant. A second hydrometer test is made without strong mechanical agitation and chemical dispersant [8].

The ratio may express the degree of dispersion, degree of dispersion= percent finer than 0.005 mm without chemical dispersant or mechanical agitation divided by percent finer than 0.005 mm with chemical dispersant and mechanical agitation [7].

7.3 The Crumb Test

The crumb test, first applied in Australia by Emerson [27] and later introduced to SCS engineers by Sherard [22], is useful as a quick field identification test by geologists during site investigation or by inspectors during construction [5]. The test was described in detail by [9]. The procedure consists of preparing a cubical specimen of about 15mm on a side and is carefully placed in about 250ml of distilled water. As the soil crumb begins to hydrate, the tendency for colloidal-sized particles to deflocculate and go into suspension is observed.

As originally developed by Emersion (27), the crumb test was called the aggregate coherence test and had seven different categories of soil-water reactions. Sherard [8] later simplified the test by combining some soil-water reactions to use only four categories or grades of soil dispersion. The crumb test has some limitations on its usefulness as an indicator of dispersive clay. A dispersive soil may sometimes give a non-dispersive reaction in the crumb test. Soils containing kaolinite with known field dispersion problems have non-dispersive in the crumb test. However, if the crumb test indicates dispersion, the soil is probably dispersive [9].

7.4. Chemical test

This is a standard test of the agricultural soil scientist described briefly as follows:

1. Soil is mixed with distilled water to a consistency near the liquid limit.
2. A pore-water sample (saturation extract) is sucked out by vacuum using a filter.
3. The saturation extract is tested to determine the quantities of the four main metallic cations in solution The "total dissolved salts"(TDS) equals the total of these four cations, and "percent sodium" equals the quantity of sodium divided by the TDS, all in milliequivalents per liter [10].

7.5. Pinhole Test

The water running through samples of dispersive clay carries a cloudy colored suspension of colloidal particles, whereas the water running through erosion-resistant clays is crystal clear [8]. Sherard classified the dispersive nature of soils under three categories. Dispersive soils are considered to fail under a flow caused by a 50-mm head of distilled water. Intermediate soils erode slowly under 50 or 180-mm head of water, whereas non-dispersive soils are supposed to produce no colloidal erosion under 380 or 1020-mm head of water [7].

7.6. Soil water Retention Test

This test has been developed and applied in the Geo-mechanics laboratory of the New South Wales Public Works Department since 1979. This test is based solely on water-retention properties and has the advantages of simplicity reproducibility. The indication of multiple failure modes (not merely dispersive soil tunneling) the test involves filling a central hole in a compacted soil cylinder with water and measuring the time taken to fail; the mode of failure is also recorded. This test is repeated for a limited range of compaction moisture conditions to determine the optimal performance conditions and the range of acceptable behavior [11].

Depending on material type and compaction condition, failure occurs due to the following:

1. Extensive cracking of the cylinder wall.
2. Hole (tunnel) formation.
3. Seepage through the cylinder base or wall.
4. Complete or partial collapse of the cylinder wall.

These classifications depend on the results proposed by [11].

Several sosoilsnown to be dispersive, non-dispersive, or marginal by other tests, together with (for some of the dispersive soils) lime-modified samples of the same samples, were submitted to the test and toher test methods by [11].

These soils were also characterized by Sherard determinations.

Tadanier [28] showed that a more comprehensive soil security test for proposed water retaining structures could be operated simply and at least as effective as other tests. This test yields information on dispersity, slaking, and swelling (cracking) propensity simultaneously.

The test also defines the limits for soil moisture content or dry density, which must be achieved to obtain a safe structure.

8. RESULT AND DISCUSSION

8.1 Soil Retention Test

Soils of Zone (A), (B), and (C) are submitted to the soil retention test. The characteristic failure time is defined quite analogously to maximum dry density as that failure time which is a maximum (T_{max}) about variable moisture content. T_{max} can be determined from a plot of T_f (time to failure) versus moisture content.

In the present test, T_{max} for each Soil could be recognized in Figs. (1) (3) and (5) Ingles and wood proposed that any soil with T_{max}>420 $_{min}$ may be accepted without question. The maximum failure time for each soil in the present test is less than 420 minutes. For Soil (A), T_{max} occurs on the dry side of optimum, while T_{max} for Soil (B) and Soil (C) occurs at the wet side of optimum. Therefore the last two samples are in the operating range of 0-3% over optimum; on the other hand, soil (A) could be considered as a dangerous case, and treatment may change its result.

Concerning air voids, it is safer to say simply that more than 6% is acceptable (but remembering that less than 6% does not necessarily mean an acceptable resistance to failure, depending on soil type and moisture content). This absolute prohibition of air voids of more than 6% was suggested by Ingles and wood, 164 within their study for deflocculation phenomena in Earth Dams. This suggestion applies here as it is clear in figs. (2), (4), and (6Trainerer [28] agreed that more than 45 minutes could be accepted where adequate construction control is exercised. This seems okay with the results. T_{max} of soil (A) and Soil (B) seems to be satisfied, while T_{max} of Soil (C) is less than 45, and treatment may change its results

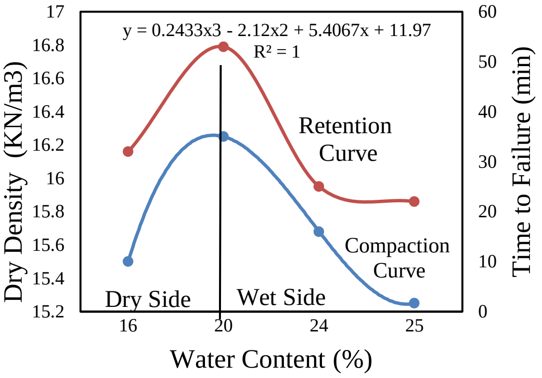

Fig. (1): Compaction and time to failure curves for a zone (A)

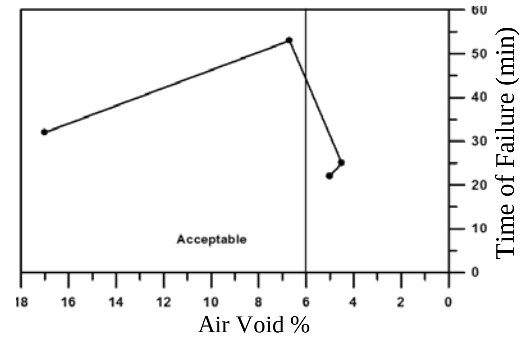

Fig. (2): Air voids versus time to failure curve for a zone (A)

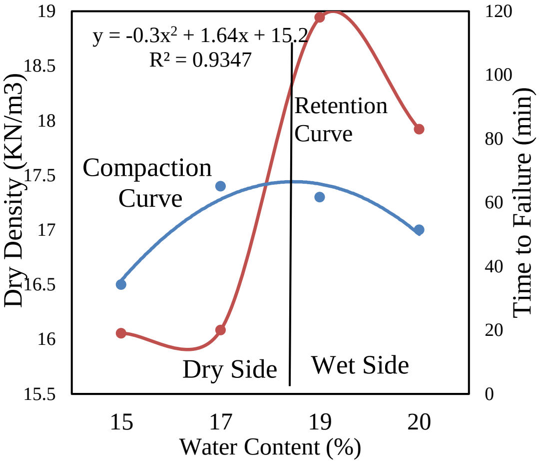

Fig. (3): Compaction and time to failure curves for a zone (B)

8.2 Pinhole Test

The test is applied to three soils Zone, and the results show that: Soil (B) shows high dispersion, while soil (A) and (C) are moderately dispersive.

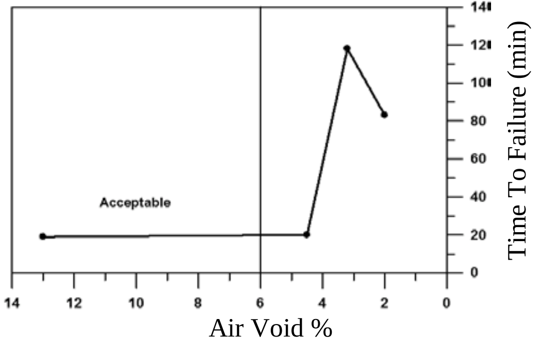

Fig. (4): Air voids versus time to failure curve for a zone (B)

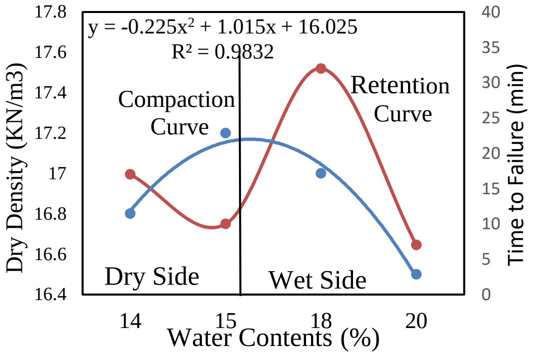

Fig. (5): Compaction and time to failure curves for a zone (C)

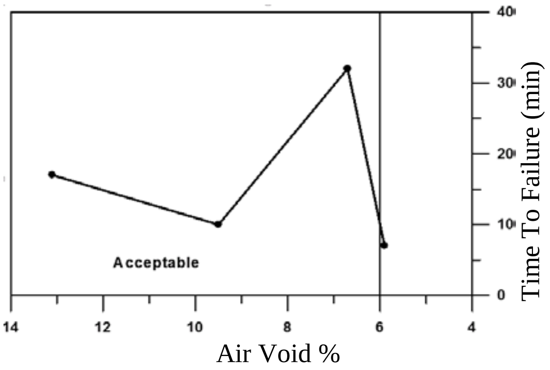

Fig. (6): Air voids versus time to failure curve for a zone (C)

9. INFLUENCE OF SAMPLE CURING AFTER COMPACTION

In the present investigation, a pinhole test is applied to dispersive and intermediate dispersive samples of soils after ten days of curing in a compacted state. Samples are stored in polythene bags and cured in a moist, humid environment to prevent drying show. Results show that the sample of grade ND4 has the same grade after ten days of curing, while a sample of grade D2 gets better resistance to dispersion by having grade ND3 instead of D2 after ten days of curing. Specimen(C) is of grade ND3 after ten days of curing instead of grade ND4.

10. INFLUENCE OF COMPACTION WATER CONTENT AND DENSITY

A series of pinhole tests are applied to soils, dry of optimum and wet of optimum water content.

On the dry side of optimum, Soil (A) is intermediate to highly dispersive, while Soil (B) and (C) are highly dispersive on the dry side of optimum water content. Thus, the three soils are recorded as highly dispersive soil on the dry side.

On the west side of optimum, soils (A) and (C) are intermediate to highly dispersive, while Soil (B) is highly dispersive. Thus, dry density and water content may increase the grade of depressiveness on the wet side.

11. CONCLUSIONS

1. Dispersion clays are distinguished in study regions of Baghdad city.
2. A soil security test should be carried out to evaluate soil due to dispersion.
3. The limits of soil moisture content or dry density could be reduced the effect of dispersion on a structure.
4. The results of dispersion soil in Baghdad City showed that the soil needs to cure before use.
5. Soil with high activity would be much erodible than other soils with low activity.
6. Dispersion could be eliminated or treated mainly by adding 4% of $Ca(OH)_2$.
7. Sampling and testing for dispersive soil should become a routine part of geotechnical investigation and testing programs in areas where dispersive soil is known to occur.
8. Adopting carrying out security tests as the main test provided for embankment

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