DISPERSIVE SOIL AND ITS MANAGEMENT – A BRIEF INTRODUCTION

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ABSTRACT

When a saline-alkali (sodic) soil comes in contact with rain water, water molecules in between the clay platelets cause the clay to dislodge and platelets are detached from the soil aggregate,this phenomenon is known as dispersion. It causes serious complications to stability of earthretaining structures or any water retaining structure due to dispersive characteristics of soil. Structures like embankments, channels and other areas are at risk of serious erosion because it is easily erodible and deflocculated in water. Therefore, in these applications it is important tocheck for erosion especially during high flow conditions. Dispersive soil persists high swelling and shrinking potential and in intact sate possesses low resistance to erosion and low permeability. The present paper attempts to examine the prime characteristics of dispersive soil, methods for identification, problems due to dispersive soil and their remedies.

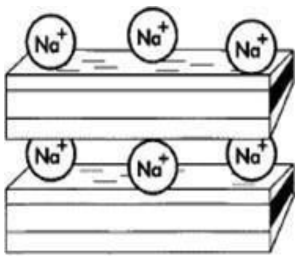
Keywords: *sodic soil, erosion, deflocculation, high swelling and shrinking potential. erosion, challenging & problematic soils*

INTRODUCTION:

Although it is found that clay is highly erosive soil in the nature, but the past studies revealedthat it was referred as non-erosive and highly resistant to water erosion. The nature of soils thatdisperse or de-flocculate depends on the soil chemistry and clay mineralogy along with dissolved sodium in the eroding and pore water. Due to the existence of the dispersive soils earth retaining structures, hydraulic structures, road embankments etc. have faced serious erosion problems and have failed also. Minute soil particles in dispersive clay are more repulsive in nature because dispersive clays possess the difference in the electrochemical forces between particles. As per the Classification System of Unified Soil, dispersive clays are of low to medium plasticity and classify as CL. However, ML, CL-ML and CH category may also contain dispersive clays. The cation characteristics of the clay mass in the pore water are the basic principal difference between ordinary and dispersive clay. The ordinary clays compriseof excess potassium, calcium or magnesium cations (K^+, Ca^{2+}, Mg^{2+}) whereas the dispersiveclays comprise excess of sodium cations (Na^+). Although simple methods are available to determine the dispersity of the soils but it is quite difficult to quantify. Fell et al. (1992) discussed that in piping failure of embankments dams, dispersive soils contribute its major role, specifically for small dams constructed without filters. The statistical research revealed by Foster et al. (2000), Rosquoet (2005) that among 11,192 hydraulic structures in the ground, 136 have undergone disorders with 48% by overflow, 46% by internal erosion and 6% by landslide. Anand et al. (2015) provides the fact that the dispersive soils which is available in so many places of world having erodible and deflocculated characteristics results serious stability failures of earth and earth retaining structures. Earth dams which are constructed onthe dispersive soils have exhibited surface and internal erosion. Dinesh et al. (2011) differentiates between dispersive clays and ordinary clays and found that particle size distribution, visual classification and Atterberg limits are not enough to distinguish the soil. The best methods to identify the dispersive soils are Pinhole and double hydrometer test. Bhuvaneshwari et al. (2007) demonstrated the micro structural modification and stabilizationof dispersive soils. The soil selected for the experiment was highly dispersive. The mixtion oflime + fly ash with lime provides substantial decrease in the dispersive characteristics of the soil. The % of dispersion tested by double hydrometer method for the soil was 71% which islater decreased to 9.5% after the addition of lime. At first the soil was classified as ND4 by the pin hole test, however the addition of optimum proportion of additives transformed it to ND1.The same result was also observed in both the crumb test and chemical tests. Also, the mineralogical and micro-structural changes examined by SEM analysis show the alteration in material and void spaces due to the chemical reactions initiated by the additives. Umesh et al. (2011) demonstrated for non-cohesive soils; the submerged weight of the deposit (gravity forces) provides resistance to erosion. While the interaction between eroding fluids and soil structure at the surface is mainly responsible for soil erosion in case of cohesive soil erosion.The researcher also examined the factors like type and quantity of clay, p^H of soil, quantity of organic matter, temperature variation, thixotropy, moisture content and ionic concentration in the voids and eroding fluids are going to affect the shear stress which is essential to initiate the process of erosion.

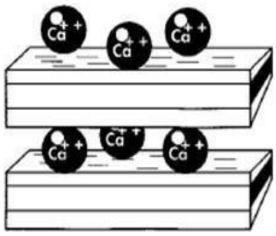
BEHAVIOR OF SODIC AND NON- SODIC SOILS IN WATER:

The dispersive clays are highly erosive rather the ordinary clays because they contain high value of dissolved cations of sodium in their pore water. The repulsive forces are exceeded the forces of attraction for which the particle went into the suspension quickly in the presence of water. And the reason of this suspension is the presence of sodium which increases the thickness of diffused double layer of water available adjacent to each of the clay particle.



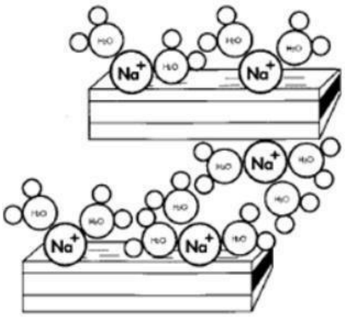
sodium adsorbed on the surface of sodic soil

(SODIC SOIL)



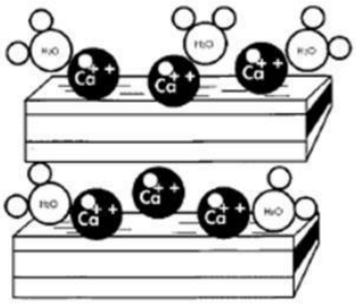
calcium adsorbed on the surface of clay

(NON-SODIC SOIL)



water is attracted towards sodium when water is added to a sodic soil

(SODIC SOIL+WATER)



swelling is due to the interaction of water and the platelets in the non-sodic soil

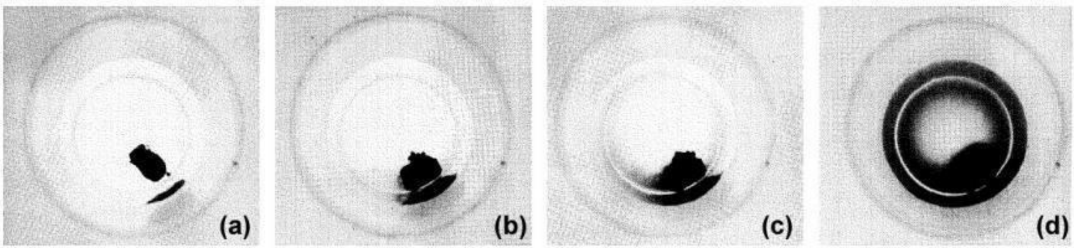
(NON-SODIC SOIL+WATER)

Figure 1: Interaction of water with sodic soil

DETERMINATION OF DISPERSION OF SOIL

To differentiate the dispersive and ordinary resistant clays, the factors like Atterberg's limits,visual classification like specific gravity and grain size distribution are not enough. So, there are many more effective laboratory tests are being performed to evaluate the characteristics of dispersive clays. These tests are named like the test of dissolved salts in the pore water and the SAR (sodium absorption ratio), double hydrometer test, pinhole test and the crumb test.

1) **CRUMB TEST:** To analyze the dispersive characteristics, the crumb test is referred as the simplest method for the detection of dispersive clay and a good positive indicator. The test is executed by lightly placing a lump of clay about 0.6 cm to 0.9 cm in diameter which is placed in a transparent plastic glass (250 ml) and filled with distilled water partially. To avoid misleading test results, the other substitutes or dematerialized water must not be used. The lump or crumb must be at natural moisture until unless the soil becomes very wet. The crumb is dropped on the edge of the bottom of the glass and left there for minimum 60 minutes.
After that, the crumb and water are checked and the presence of any colloidal cloud in the water is checked. A second look is also recommended after leaving the clod in the glass overnight because some soils have no reaction after 60 minutes rather than significant reaction after the longer waiting time.



a) Non dispersive b) Intermediate c) Dispersive d) Highly dispersive

Figure 2: different result from crumb test

2) **PINHOLE TEST:** This test is a direct method to checking the dispersibility of compacted fine-grained soils and water flow through forming a hole by inserting a needle in the centre of that soil sample. Also, the test is used to find the amount of treatment rate is required to reduce the erodibility of soil specimen. Under the specified heads, distilled water flows into the sample hole. Water is cautiously monitored for turbidity, and the flow rate is observed to determine whether the hole in the sample size is increasing with erosion. Pinhole test also helps to determine the effectiveness of chemical adjustments for dispersive clays. Different soil samples are prepared with varying treatment rates of a chemical additive and check at which rate of treatment the erodibility reduces.

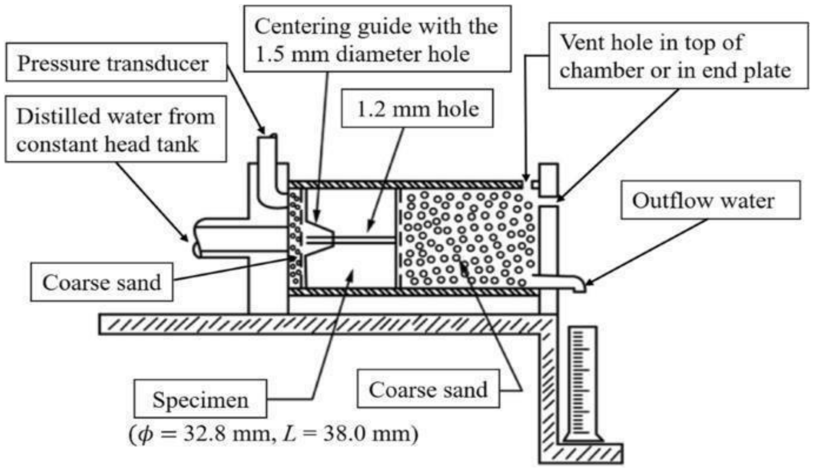


Figure 3: Pinhole Test Apparatus

Table 1: Interpretation of data from pinhole test

Rating	Nature of soil
D-1 / D-2	Dispersive but require special designs
ND-1	not dispersive
ND-2, ND-3 or ND-4	slightly or moderately dispersive

3) **DOUBLE HYDROMETER TEST or SCS TEST:**

Soil conservation service (SCS) dispersion test or commonly known as Double hydrometer test is one of the tests to check the dispersiveness of clay soil. Basically, two samples are prepared and compared in the laboratory by using this test. Grain size analysis is first done by using standard hydrometer in which soil sample is artificially dispersed in distilled water with the help of a chemical dispersant. Another sample is prepared in the same manner but without adding any chemical dispersant and the results of both the sample is compared.

Table 2: Interpretation of degree of dispersion from double hydrometer test

% of dispersion	degree of dispersion
greater than 60 %	probably dispersive
30 % - 60 %	considered dispersive for design purposes
Less than 30 %	not dispersive

4) **<u>CHEMICAL TEST:</u>**

This test is done in laboratory to check the dispersion in soil which is often least performed. In this test, a sample of pore water is taken out from saturated slurry from a soil sample for the analysis of cations. Chemical analysis like Exchangeable Sodium Percent and Sodium Absorption Ratio (SAR) can be performed to know the relative abundance of exchangeable cations.

Table3: Interpretation of degree of dispersion fromchemical test at normal salt concentration

% of dispersion	**degree of dispersion**
more than 60 %	Dispersive
40 % - 60 %	Intermediate
Less than 40 %	not dispersive

a) Exchangeable Sodium Percent (ESP) test is commonly used to analyse the dispersive soils.

$$ESP = \frac{Na^{+}}{Na^{+} + Mg^{2+} + K^{+} + Ca^{2+}} \times 100$$

b) SAR method is generally used to enumerate the role of sodium with respect to calcium and magnesium to check the dispersion in soil.

$$SAR = \frac{Na^{+}}{\sqrt{0.5\,(Ca + Mg)}}\ meq/l$$

ENGINEERING PROBLEMS RELATED WITH DISPERSIVE SOILS

Due to presence of dispersive clay soil many engineering problems may arise such as structural failure, construction problems and internal erosions.

a) riling and gullying on the slopes due to erosion
b) failure in Dam embankment
c) erosion in tunnel
d) failure in canal
e) Collapse of fill
f) Failure in pipes and cables
g) Breaching Septic trenches
h) poor compaction around conduits

REMEDIATION PROCESS OF DISPERSIVE SOIL

It is very important to make dispersive soils worthy for the construction by maximizing its strength, durability and minimizing compressibility, swelling or shrinkage by altering the engineering properties of soil by stabilization. In general replacement of soil is considered as a remedy for dispersive soil which is expensive, so alternative solution is adopted to treat dispersive soil such as Chemical stabilization, unique compaction techniques, using sand filters and sand blocks etc.

1) **Chemical Stabilization:** This is a method in which original structure of minerals breaks into a new stabilized mineralogical arrangement. The following materials can be used as stabilizing material to make the dispersive soil useful for construction.

a) **Hydrated lime or, calcium hydroxide:** To prevent piping in earth dams, Lime is used widely. Depending on the soil and degree of compaction, rate of application has varied. To prevent dispersion, nearly 0.5 –1.0% hydrated lime is required. Though, higher rates of application are required when difficulties with application and mixing. The strength of the clayey soil depends on clay content and reactive silica and increases with increase in lime percent up to a particular range which is called optimum lime percent. It is seen that the lime treatment with dispersive soil improves the strength of soil by reducing the settlement.

b) **Gypsum / calcium sulphate di-hydrate:** To treat the dispersive soils, it is considered as more effective than the lime treatment as it increases displacing sodium with calcium and the electrolyte concentration in the soil solution. Due to lower solubility and higher rate, gypsum is used in fewer amounts than hydrated lime in the construction of dam and other construction works. From different studies it is observed that at least 2% by weight of gypsum should use in construction.

c) **Aluminum Sulphate or Alum:** It is used for prevention of dam failure and protection of embankments from erosion. From the limited study, it can be suggested that mixtures of 0.6to 1.5% of total dry weight of soil is suitable for mixture. As alum is highly acidic in nature (p^H 4 to 5), so soils treated with alum have to be capped with topsoil for the establishment of vegetation. To get idea about application rates, soil testing is required.

d) **Sulphuric Acid:** It is an oily liquid material which is corrosive in nature and about 95 % pure. Soils which contain calcium carbonate, after application of sulphuric acid, it reacts immediately and form calcium sulphate which indirectly gives soluble calcium.

e) **Pozzolanic Materials:** Natural pozzolana material from different geographical locations shows different properties due to their chemical compositions which gives different results when treated as an additive material. Different test results show that adding 5% pozzolana material to the soil has highest reduction in dispersion percentage.

2) **Compaction:** According Ritchie (1965), degree of compaction is the most significant aspect to reduce failure of dam from piping or, tunnel erosion. From different studies it can be stated that a high degree of compaction decreases the severity of dispersion and it also helps to reduce permeability of soil and restricts the movement of water and dispersed clay in the soil structure. According to Elges (1985), Bell & Bryun (1997) and Bell & Maud (1994), in order to achieve MDD (maximum dry density) dispersive soils should be compacted at water content from 1.5 to 2% above the OMC (optimum moisture content) which helps in preventing piping failure. So, in order to achieve that density excavator, bull-dozers and graders do not provide satisfactorily compaction effort. Hence a sheep-foot roller of approximate weight (pressure 9.3kg/cm^2) is needed to compact dispersive soil.

3) **Sand blocks and sand barriers:** Dam failure can be prevented with the use of sand filters. The mechanism of sand filter is at the exit, it traps sand and silt which will block the tunnel and prevents additional development of tunnel. The sand blocks are slightly different from the sand filters. Through the sand particles the free water rises to the surface in sand blocks.

4) **Other necessary measures:** If possible, the top soil and vegetation should not be removed and the dispersive soil is covered with satisfactory layer of top soil. Those construction techniques which cause the exposure of dispersive subsoil should be avoided. Safe areas should be created for discharge of runoff and the water should not be discharged in to the areas with dispersive soils. Culverts and drains constructed in the dispersive sub soils should be properly capped with non-dispersive clays mixed with top-soil, vegetation and gypsum.

CONCLUSION:

Dispersive Soils mainly affect the structural stability of earth and earth retaining structures. The mechanism of dispersion can be well understood from the above discussion. It can be concluded that only visual classification, Grain size distribution, Atterberg's limit is not enough to distinguish between ordinary erosion resistant clay and dispersive clay. For the determination of dispersive soil special tests like crumb test, pinhole test, double hydrometer test, chemical test is required. This paper illustrates the interaction of sodic soil with water, different methods to identify the dispersive soil, engineering problems created due to dispersive soil and different methods to overcome from these problems.

To develop the engineering properties & strength characteristics methods like chemical stabilization, degree of compaction and use sand barriers considered to be effective methods. And due to which high value of dissolved cations of sodium in their pore water can be reducedand the strength can be maximized. For the construction of dam, roads, culverts and tunnels in the dispersive soil, one or a combination of accurate degree of compaction, chemical improvement, capping with non-dispersive clays, sand filters and satisfactory top soiling canbe adopted.

REFERENCE:

1) Singh, B., Gahlot P., and Purohit D. G. M. (2018) "Dispersive soils-characterization, problems and remedies." Int. Res. J. Eng. Technol 5.6: 2478-2484.
2) Hardie, M. (2009) " Dispersive Soil and their Management", Technical Reference Manual, Sustainable Land Use Department of Primary Industries and Water.
3) Richley, L.R. (2000) Treatment of tunnel erosion in Tasmania. Natural Resource Management 3, 31–34.
4) Richley, L.R. (1992) Minimising erosion hazard due to installation of an optical fibre cable through dispersible clay soils. Australian Journal of Soil and Water Conservation 5, 35–38.
5) Sherard, J. L., and Decker, R. (1977). “Dispersive clays, related piping, and erosion in geotechnical projects.” ASTM Special Technical Publication 623, ASTM, Philadelphia
6) Sherard, J. L., Dunnigan, L. P., Decker, R. S., (1976), "Identification and Nature of

Dispersive Soils", Journal of Geotechnical Engineering Division, ASCE, Vol. 102, GT4, pp. 284-301.

7) Sherard, J. L. (1975). Discussion of "Pore and eroding fluid influences on surface erosion of soils," by K. Arulanandan, P. Loganathan, and R. B. Krone. J.Geotech. Engrg. Div., ASCE, 101(GT12), 1299-1300.
8) Knodel, P. C. (1991) "Characteristics and problems of dispersive clay soils" United States Department of the Interior, Colorado.
9) Umesha, T. S., Dinesh, S. V. and Sivapullaiah, P. V. (2011) "Characterization of Dispersive Soils" Materials Sciences and Applications 2, pp 629-633
10) V.R. Ouhadi and A.R. Goodarzi (2006) "Assessment of the stability of a dispersive soil treated by alum" Eng. Geol. 85, 91–101. doi: 10.1016/j.enggeo.2005.09.042
11) Vakili et al. (2012) "Stabilization of Dispersive Soils by Pozzolan", Forensic Engineering 2012.
12) Krishnankutty, S. V. and Keerthi, S. (2021) "Chapter 31 Feasibility Study on Dispersivity of Lignosulphonate-Treated Clay Using Pinhole Test", Springer Science and Business Media LLC, 2021
13) Reddy, N. G., Rao B. H. and Reddy K. R. (2019) "Chapter 3 Chemical Analysis Procedures for Determining the Dispersion Behaviour of Red Mud", Springer Science and Business Media LLC, 2019
14) Gidday B. G. and Satyendra M. (2020) "Improving the characteristics of dispersive subgrade soils using lime", Heliyon, 2020
15) Mohanty et al (2019) "Effect of industrial by-products on the strength of stabilized dispersive soil", International Journal of Geotechnical Engineering, 19