

## Characterization of Dispersive Soils

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**Abstract.** The concept of dispersive soils is particularly significant with reference to earthen dams, embankment, canals etc. The comparatively less explored role of surface chemistry in understanding dispersive phenomenon leads to a state of doubt and confusions amongst various researchers. Dispersive soils are those with unique properties which under certain conditions deflocculates and are rapidly eroded and carried away by water flow. These soils are highly prone to erosion often leading to tunnel and gully erosion. 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. Using dispersive clay soils in hydraulic structures, embankment dams, or other structures such as roadway embankments can cause serious engineering problems if these soils are not identified and used appropriately. The tendency for dispersive erosion in a given soil depends on variables such as mineralogy and chemistry of the clay, as well as dissolved salts in the water in soil pores and in the eroding water. the presence of exchangeable sodium as a main contributing chemical factor to dispersive clay behavior .

The laboratory tests generally performed to identify dispersive clays are the crumb test, double hydrometer test, pinhole test, test of dissolved salts in the pore water and the SAR (sodium absorption ratio) . The extracted soil pore water is tested using routine chemical tests to determine the amounts of the main dissolved cations; calcium, magnesium, sodium, and potassium, in terms of milliequivalents per liter (mEq/L). The percent sodium and TDS (sum of the four metallic cations) are determined. This article discussed the characterization and identification of dispersive soils based on chemical methods . The mineralogical characterization of soils were also studied using X-ray diffraction ( XRD ).

The soil samples from different projects were compared for dispersive behavior based on slandered tests. The results shows that soils with higher concentration of exchangeable sodium and presence of typical clay mineralogy are responsible for dispersive behavior.

**Keywords:** Dispersive Soil; Earthen Dams; Surface Chemistry; Exchangeable Sodium; Mineralogical Characterization; X-ray Diffraction.

### 1 Introduction

Dispersive soils are highly susceptible to erosion and piping phenomenon and undergo deflocculation in the presence of flowing water. It rapidly erode forming tunnels and deep gullies by a process in which the individual clay particles go into sus-

pension in slow-moving water (colloidal erosion), damaging earth dams, canals, and other hydraulic structures.

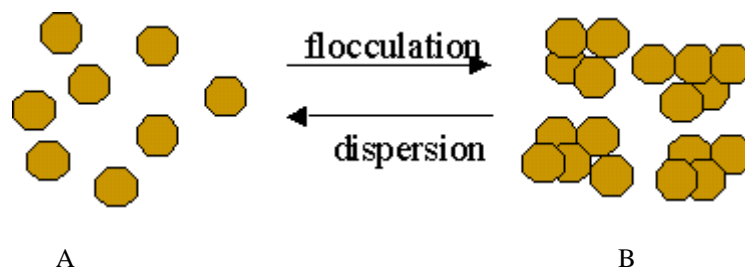
The failure initiated by piping makes the embankments constructed on dispersive soil susceptible. Dispersive piping in dams has occurred either on the first reservoir filling or, less frequently, after raising the reservoir to highest level.

Dispersive soils contains higher content of dissolved sodium ions in pore-water than ordinary soils, The tendency for dispersive erosion in a given soil depends on variables such as mineralogy and chemistry of the clay, as well as dissolved salts in the water in soil pores and in the eroding water.

Dispersive soils cannot be differentiated from ordinary soils by conventional soil mechanics tests. An investigation in which four different laboratory tests for dispersion were performed on a considerable number of soils of diverse origins and properties has provided improved understanding of the properties of dispersive soil and strengthened identification criteria.

### 1.1 Mechanism of clay dispersion

Clay particles are negatively charged as the result of isomorphous substitution or broken edges so they naturally repel each other (like charges repel). However, the presence of adsorbed cations tends to mask this negative charge (repulsion) to varying degrees, depending on the type of cation. Small multi-charged cations (i.e.,  $Al^{+3}$ ,  $Ca^{+2}$ ,  $Mg^{+2}$ ) are strongly adsorbed by colloids (unlike charges attract), greatly reducing the negative charge. If the negative charge of the colloid is sufficiently reduced, flocculation will occur as represented shown in Figure 1A. If, on the other hand, the colloids are saturated with large weakly charged cations (i.e.  $Na^+$ ,  $K^+$ ), dispersion will occur as represented in Figure 1B. Sodium, a weakly charged cation that encourages dispersion and calcium, a multi-charged cation that encourages flocculation, provide an example of the intricate relationship between soil chemistry and the physical condition of a soil. The importance of the physical condition and the influence of sodium, creates the situation where knowing the concentration of this cation in a soil is essential



**Fig. 1.** Soil Particles in a Dispersed and Flocculated Condition

The flocculation and dispersion reactions are the result of cation exchange. Cation exchange is the interaction between a cation in solution and another cation on the surface of any surface-active material, such as clay or organic matter. The cation exchange that occurs between sodium and calcium on clay mineral surfaces.

### **1.2 Diffuse double layers**

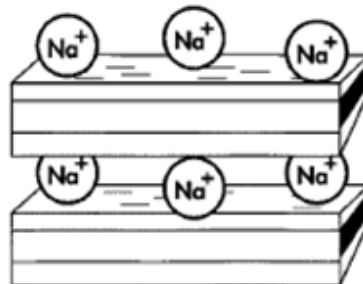
Clay particles some times behave as a colloidal particles in suspension. The diffuse double layer occurs at the interface between the clay surface and the soil solution. It is made up of the permanent negative charge of the clay and the cations or counter-ions in the soil solution that balance the negative charge. The counter-ions are influenced by two equal but opposing forces – the electrical force attracting the positive ion to the negative surface, and the diffusive or thermal forces (responsible for Brownian motion) which tend to move the cations away from the surface. The balance of these two forces gives rise to a distribution of cations in water adjacent to the clay surface. This distribution, described as a diffuse electrical double layer or simply diffuse double layer, is made up of the negative clay surface and the spread-out (diffuse) distribution of the counter-ions.

When the electrical diffused double layers of the two clay particles carrying similar outer charge come close to each other, they repel due to electrostatic repulsion and thus initiated colloidal dispersion phenomenon.

### **1.3 Dispersivity due to Sodic soils**

When two clay particles with a high concentration of sodium counter-ions sit close to one another, their double layers overlap or interact as presented in figure.2.

As a consequence, the total concentration of the ions at the plane mid-way between the two particles is greater than that in the soil solution in which the particles are immersed. This creates a difference in osmotic pressure which will draw water between the particles, causing them to move further apart – this is the swelling associated with sodic soils. In the presence of free water (eg, excess rainfall or low electrolyte irrigation water) at a soil surface, a sodic soil may move a stage further in disruption so that the particles become dispersed in this water. Dispersion can be decreased to a considerable extent in the presence of high concentrations of electrolytes.



**Fig.2.** Showing Negatively Charged Clay Particle with Adsorbed Sodium CounterIons

Most studies reported in the literature have shown that failures of structures built of dispersive clay soils occurred on first wetting. All failures were associated with the presence of water and cracking by shrinkage, differential settlement, or construction deficiencies. These failures emphasize the importance of early recognition and identification of dispersive clay soils; otherwise, the problems they cause can result in sudden, irreversible, and catastrophic failures.

The common soil classification index tests do not distinguish between dispersive and non dispersive clay soils. The recommended tests for the identification of dispersive clay soils are pinhole test, crumb test, double hydrometer test and chemical analysis of pore water extract.

The objectives of this study is to established a confirmatory test for identification of soil dispersivity by chemical analysis of pore water extract and mineralogical identification. Conducting different test on soil samples and correlating the results it was observed that the chemical test including determination of total dissolved salts (TDS, Percent sodium and mineralogical examinations are very important parameters which need to be conducted properly which is also going to helps us in understanding their influence on other engineering tests.

## **2 Experimental**

### **2.1 Material and Methodology**

The four different types of soil samples were selected for this study based on engineering tests conducted on these soil samples.

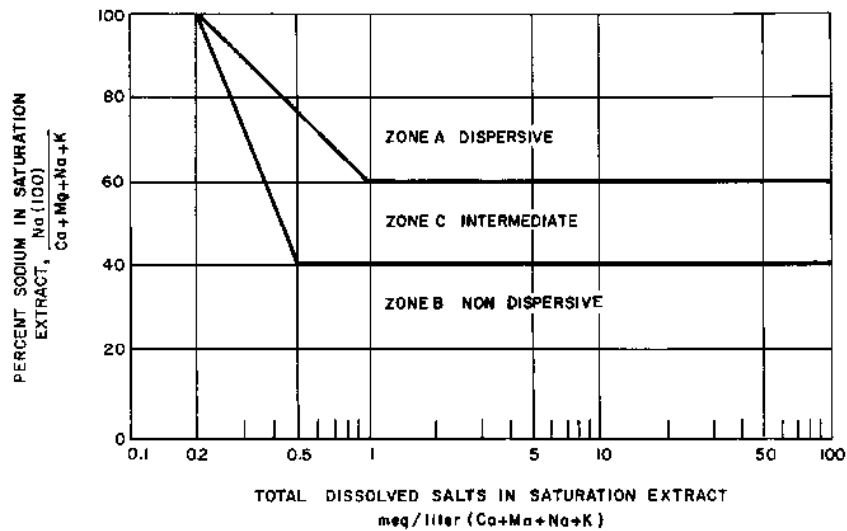
### **2.2 Chemical tests**

The chemical analysis of soils pore water extract was seems to the most reliable methods for characterizing soil dispersivity. The phenomenon of dispersivity is due to the presence of dissolved sodium content in pore water and therefore its percentage was calculated by estimating total dissolved cations ( Na, K, Ca & Mg) present in soils pore water extract. To obtain saturation extract, soil is mixed with distilled water until a saturated soil paste with water content near the liquid limit is obtained. The paste is allowed to set for a number of hours until equilibrium is attained between the salts in the pore water and those on the cation exchange complex. Subsequently, a small quantity of pore water is filtered from the soil paste using a vacuum. This extracted pore water is tested using EDTA titration method (For Ca & Mg) and using flame photometer( For Na & K).( Fig.3)



**Fig.3.** Determination of Sodium and Potassium using Flame Photometer.

The percent sodium and TDS (sum of the four metallic cations) are determined. The further interpretation were evaluated using graph presented in Figure.4



**Fig.4.** The Plot of Percent Sodium Verses Total Dissolved Cations.

After plotting the above graph for each samples the results were categorized as follows:-

- Zone A: Dispersive
- Zone B: Non Dispersive
- Zone C: Intermediate

### 2.3 Mineralogy study using X-ray Diffraction (XRD tests)

XRD is a technique used extensively in the geological sciences, materials, environmental science, chemistry, physics, metallurgy and other subjects. The instrumental setup is presented in figure.5



Fig. 5. Mineralogy study with XRD.

## 3 Results and Discussion

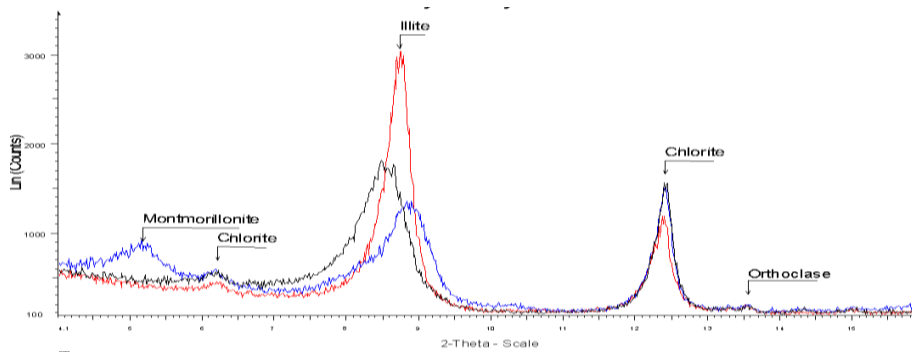
The results of chemical analysis of pore water extracts of all the four samples are presented in table-1.

Table 1. Test Results of Pore Water Analysis of Soil Samples

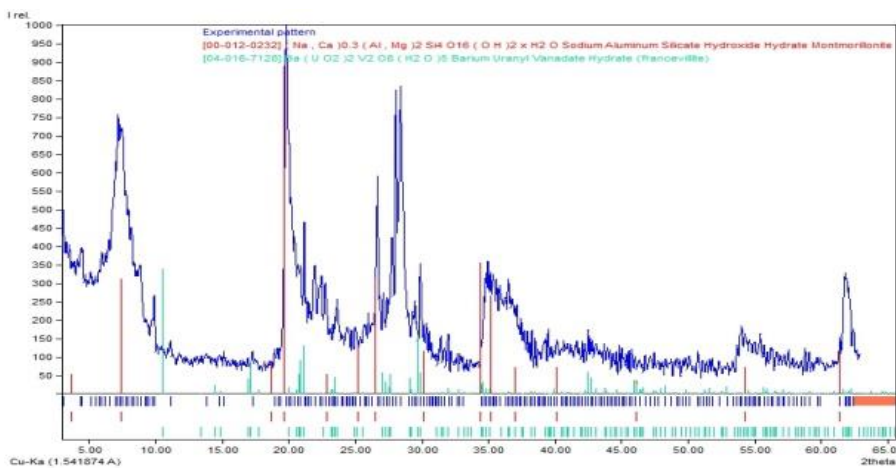
Sample No.	mEq/L				Total Cations	Sodium %	Remarks Grade
	Na	K	Ca	Mg			
1	2.19	0.47	0.8	0.4	3.86	56.73	C
2.	3.20	0.69	0.6	0.2	4.69	68.23	A
3.	4.12	1.01	1.0	0.6	6.73	61.21	A
4.	3.44	0.80	0.6	0.2	5.04	68.25	A

The first sample was fall in intermediate category( C) while all others samples were fall in category (A), which indicated their dispersive nature .

The XRD pattern of soil samples are presented in figure 6 & 7.



**Fig. 6.** XRD pattern of Dispersive and Intermediate soil samples.



**Fig. 7.** Typical XRD pattern of Dispersive soil.

The XRD pattern of soil samples shows that soil with dispersive and intermediate nature are rich in montmorillonite and illite clay minerals. Both of these clay minerals are having high colloidal activity and responsible for soil dispersion.

## **4 Conclusions**

The mechanism of dispersivity of soil is however based on surface chemistry and depends on types of cations present in soil pore water in dissolved state. Therefore the importance of chemical tests are of great concern, The results of Percent sodium, and TDS are need to be evaluate and correlate to clearly understand and designate a sample under the title of dispersive nature. The results of chemical analysis of pore water extract of soils and mineralogical examination with XRD clearly shows that soils with high sodium content and contains Montmorillonite minerals such as Smectite and illite are dispersive and intermediate in nature .

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