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ARTIFICIAL INDUCEMENT OF DISPERSIVITY IN NON DISPERSIVE CLAY SOILS

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Abstract— **Dispersive clay soils under certain conditions deflocculate, rapidly erode and flow with water. These soils may have disastrous consequences for earth fill dams or other hydraulic structures. In nature, dispersive soil forms in old landscapes by leaching and illuviation process over a long period of time. Ground water containing carbonate / bicarbonate of sodium is one of the contributing factors in the formation of sodic soil/dispersive soil in many regions. Dispersion of soil is a complex physical, chemical and mechanical process. It has been established by authors that in laboratory also it is possible to produce dispersive soil from non-dispersive clay soil in short duration of time. Artificial synthesis of dispersive soil is possible only, if exact and actual cause of dispersivity is known. Once the reason could be identified, detailed studies can be taken up for various possible geotechnical remedies for dispersive problem.**

Non dispersive clay soil of CI group was treated with soda activated multani mitti (, a commonly available ordinary grade bentonite soil, activated with soda (Na2CO3) by wet method). The XRD analysis of the of the sample revealed that clay soil contains montmorrilonite mineral. Clay soil sample was blended with soda activated multani mitti in various proportions and mixed with distilled water and placed in mechanical shakers for 36 hours to ensure maximum possible exchange reactions. The resulting composite product was subjected to soil dispersity tests such as crumb test, double hydrometer test and pin hole test. Chemical pore water extract test was not conducted because soda activated multani mitti was already rich with excess sodium carbonate. All the three dispersive tests responded positive results indicating soil has become dispersive. These test results were compared with similar tests conducted on normal soil samples where no dispersion was observed.

In the other technique, non-dispersive clay soil (CI group) of soil was activated with soda in various proportions by keeping soda in low and controlled concentration. The clay soil contains montmorrilonite mineral (which is one of the necessary condition for dispersivity) was revealed by XRD analysis. Clay soil sample was blended with 1% soda and 2% soda (% by wt) thus keeping soda in low and controlled concentration and mixed with distilled water and placed in mechanical shakers for 36 hours to ensure maximum possible exchange reactions. To see the effect of soda concentration, soil was mixed with excess soda by wet method. The resulting composite product was subjected to soil dispersivity tests i.e., crumb test, and pin hole test. For 1% and 2% blended soda composite samples responded positive results indicating soil has become dispersive. For 20% blended composite sample showed no dispersivity. It has been concluded based on these studies that the presence of exchangeable sodium, calcium and montmorillonite are necessary for phenomenon of dispersitvity

Keywords— **Non dispersive CI soil, dispersive soil, soda, montmorillonite , multani mitti, soda activated multani mitti, XRD, crumb test, double hydrometer test, pin hole test**

I. INTRODUCTION

Dispersive soils occur in many parts of the world. These are easily erodible and segregate in water pose serious problems of stability of earth and earth retaining structures. Dispersive clays have not been associated with any specific geological origin but mostly have been found as alluvial clays in the form of slope wash, lake bed deposits, loess deposits, and flood-plain deposits. These soils are found extensively in United States, Australia, Greece, India, Latin America, South Africa and Thailand. These soils are erodible in nature and have tendency to segregate in presence of water and erode under small seepage velocity leading to problems of stability of earth and earth retaining structures. [1](2011). The erosion due to dispersion of soil depends on mineralogy and clay chemistry and the dissolved salts in pore water. Under saturated conditions, the attractive forces are less than the repulsive forces, and this helps the particle to segregate and to move in suspension. The dispersive mechanism have been reported by various researchers such as Sherard et al [2] (1976) Heinzen and Arulalandan [3] (1977), Holmgren and Flanagan [4]

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(1977), Bruce Carey[5] (2014). Many slope and earth dam failures, foundation and pavement failures have been observed in these types of soils [6] (2007). Most of the failures in embankments, earth dams and slopes were composed of clays with low-to- medium plasticity (CL and CL-CI) that contain montmorillonite. The principal difference between dispersive clays and ordinary erosion resistant clays appears to be the nature of the cations in the pore water of the clay mass. Dispersive clays have a preponderance of sodium cations, whereas ordinary clays have a preponderance of calcium, potassium, and magnesium cations in the pore water [7] (2011).

II. MECHANISM OF DISPERSION IN COHESIVE SOIL

There exist three theories to explain the behaviour of dispersive soils viz mineral theory, cationic theory, and pH theory [8] (2017). The mineral theory states that dispersion is caused by presence of montmorillonite. As per cationic theory, soil is dispersed due to presence of sodium ions in excess quantity thereby making double layer of soil particles thicker. pH can affect the surface of the soil charge. The susceptibility of a soil to dispersion is related to the relative amounts of sodium and calcium ions between the montmorillonite clay platelets. If the layer between clay platelets is dominated by calcium then dispersion will not occur. Calcium ions are relatively small with two positive charges which attached to negative particles on the clay surface binding them together. When these soils become wet, the calcium ions are hydrated, they become larger in size and some expansion and swelling of the soil occurs. However the expansion is not great enough to disrupt the electrostatic binding [5] (2014). After exchange of some calcium ions by exchangeable sodium ions and if water is added to the system, the swelling of the soil begins, but in this case the binding between the platelets is overcome, significant swelling occurs. With further increasing of the amount of water between platelets, the soil disperses with water, the soil structure breaks down. Fig. 1

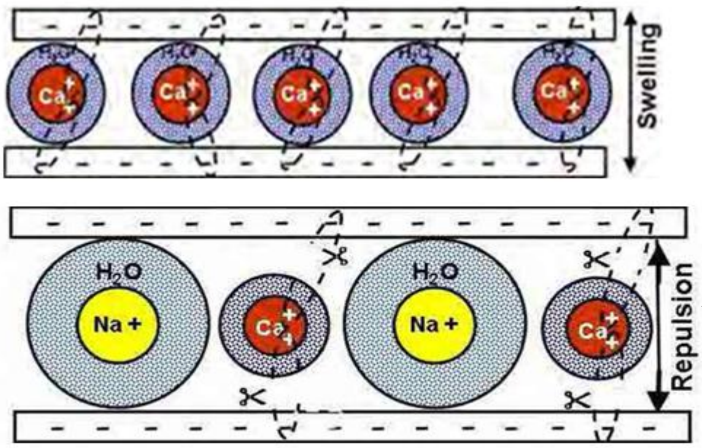

Fig. 1 Mechanism

III. COLLECTION OF MATERIALS

(i) Non Dispersive clay soil with medium compressibility (CI) of Wain Ganga Nal Ganga Project, Maharasthra was selected for the study. Reason behind choosing a CI soil was because there is high probability of presence of montmorrilonite in such kind of clay (ii) Multani mitti (soil rich in bentonite) and Sodium carbonate was sourced locally.

IV. ENGINEERING AND INDEX PROPERTIES OF THE CLAY MATERIALS

Liqid limit (LL), plastic limit (PL) and plasticity index (PI) of clay soil and Multani mitti were 46.5, 25.7, 20.2 and 165, 85, 80 respectively. Maximum dry density (MDD) and optimum moisture Content (OMC) of soil were 1.75g/cc and 18.5% respectively. Clay and silt of multani mitti were 86.7% and 13.3% respectively. Free swell index of multani mitti was 227%.

V. (METHOD 1)

A. **Soda activation of multani mitti** [9] (1999)

250 g of multani mitti was treated with 20% sodium carbonate (AR), mixed with distilled water and kept in mechanical shaker for 48 hours for shaking. The resulting product was then kept in bowl in air for drying. After drying the product was crushed with hammer and sieved to get it in powdered form. Both original multani mitti and the product were analysed by XRD. It was revealed from the XRD analysis that the reaction of soda activation was successful and the original multani mitti which was calcium bentonite dominated was converted into sodium bentonite dominated multani mitti.

B. **Treatment of CI soil with various proportions of soda activated multani mitti –**

300g each CI soil was blended with 2.5% and 5% soda activated multani mitti respectively and mixed with distilled water. The mixtures kept in reagent bottle and shook for 36 hours. The end product kept in bowel for air drying. After crushing the products shieving done to get 2mm passing material and 425μ passing material. The resulting products were subjected to Atterberg Limits test, free swell index, crumb test, double hydrometer test and pin hole test. The samples were not subjected to chemical analysis because the blended soils were already contained excess soda.

VI. RESULTS OF METHOD 1

A. **Atterberg Limits** [10] (1985)

Liquid limit and plasticity index of soda activated multani mitti were 176 and 98 respectively whereas for untreated multani mitti the values were 165 and 80 respectively showing increasing trend in values for soda activated multani mitti. For plasticity index there was a decreasing trend. When CI soil was treated with 2.5% and 5% soda activated multani mitti there were increase in Atterberg Limits values with increase of

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blending material i.e., soda activated multani mitti. The results of Atterberg Limits are shown in Figure 2 and Figure 3

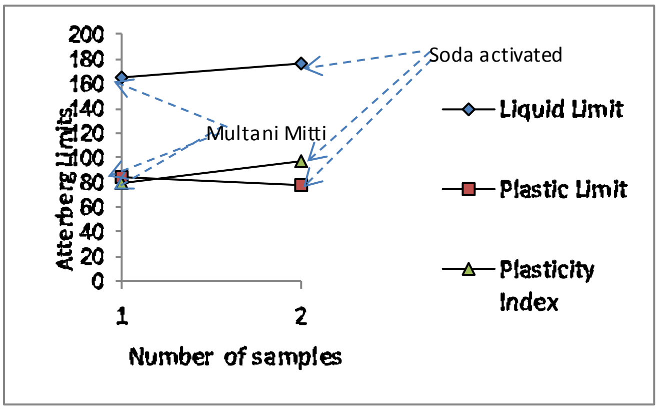

Fig. 2 Atterberg Limits of Multani Mitti and Soda activated Multani Mitti

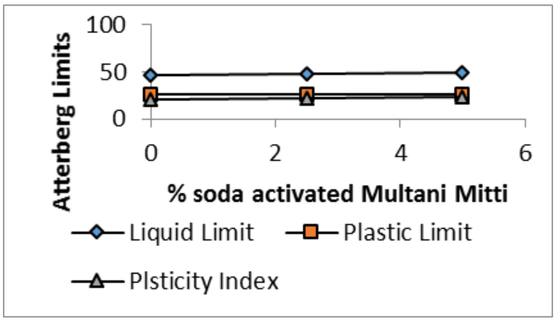

Fig. 3 Atterberg Limits of 0%, 2.5%, 5% Soda activated Multani Mitti

***B*. Free swell index test** [11] (1977)-

There was an increase in free swell index when untreated CI soil mixed with 2.5% and 5% soda activated multani mitti. The blended soils took 8-10 days for settling in cylinder containing distilled water. The results are shown in Figure 4

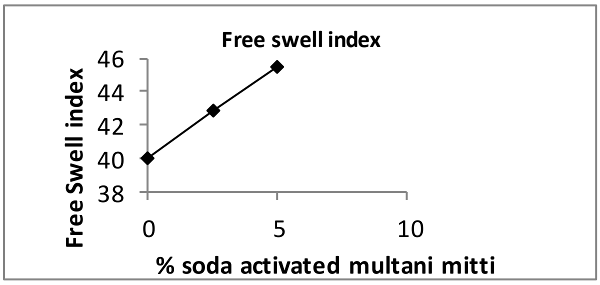

Fig. 5 Free swell index vs %Soda activated Multani Mitti

***C*. Double Hydrometer test** [12] (1994)

SCS double hydrometer test were done for 2 mm passing CI soil and 2.5%, 5% soda activated multani mitti blended CI soil. % dispersion for untreated CI soil was26.38%, for 2.5% and for 5% soda activated multani mitti blended CI soil were 50.16% and 71.05% respectively showing the blended soils had been converted into dispersive soil. The results are shown in Figure 6.

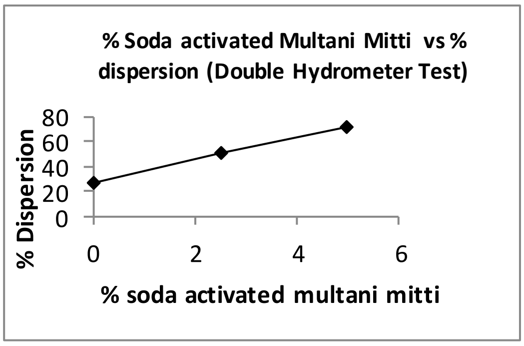

Fig. 6. % Dispersion in Double Hydrometer test vs %Soda activated Multani Mitti

***D*. Crumb Test** [13] (1966)

Small crumbs of 6-10mm dia were prepared with 2 mm passing untreated CI soil and 2,5% 5% soda activated multani mitti blended CI soil. Crumbs were dropped distilled water containing beaker. Moderate to strong reaction occurred as cloud of colloids appeared at the bottom for the blended soils (Grade 3).(Figure 7). Untreated CI soil was non dispersive as no cloud appeared**.**

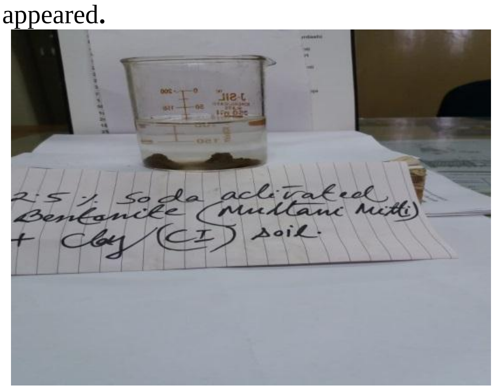

Fig. 7. Clouds formed by crumbs with 2.5% treated soda activated multani mitti

***E*. Pin Hole Test**

2 mm BIS sieve passing soil sample specimens packed in cylindrical pin hole apparatus. 38 mm long and 33 mm dia specimens were packed having moisture content at plastic limit and at 95% MDD. Distilled water at various heads were passed through 1 mm hole of the soil specimens. For untreated CI soil crystal clear water came out from the hole and no change in the hole was visible at the end of the test. The soil was non dispersive.(ND1) But for 2.5% and 5% soda activated

multani mitti treated soil there were severe cloudy discharge at even 50 mm head. The samples were dispersive (D1). Pin hole test is shown in Figure. 8

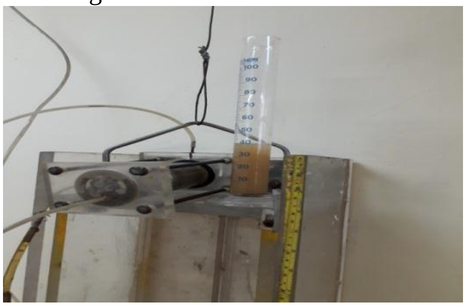

Fig. 8. Heavy Colloidal discharge at 50mm head in pin hole test

F. X Ray Diffraction Analysis

XRD analysis of multani mitti and sodactivated multani Mitti and clay sample are presented in Figure 9, 10 and 11 respectively. Presence of montmorillonite peaks can be seen in all the samples. Lower d(001) values were found for soda activated multani mitti than original multani mitti.

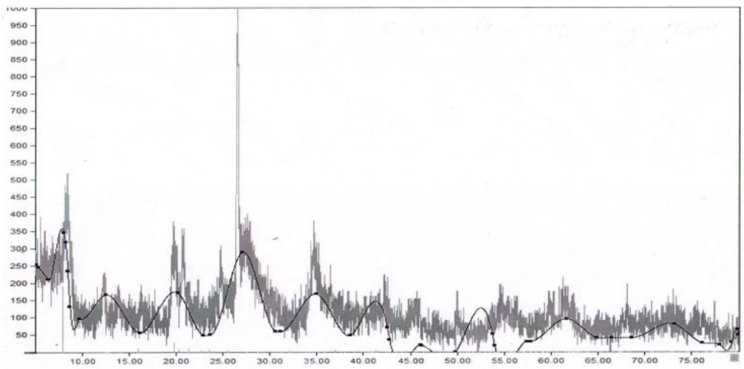

Fig 9. XRD of multani mitti

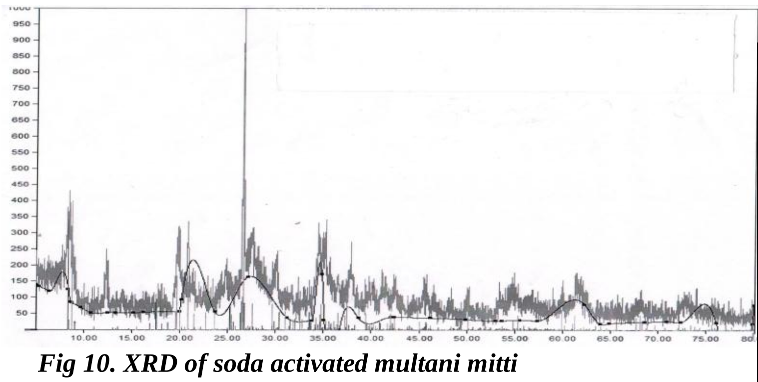

Fig 10. XRD of soda activated multani mitti

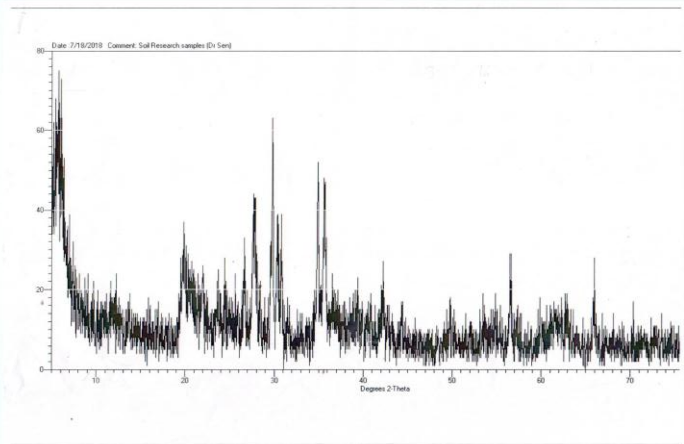

Fig. 11. XRD of clay soil under study

VII. METHOD 2

A. Soda activation of multani mitti

300g each CI soil was blended with 1% , 2% and 20% soda respectively and mixed with distilled water. The mixtures kept in reagent bottle and shook for 36 hours. The end product kept in bowel for air drying. After crushing the products shieving done to get 2mm passing material .The resulting products were subjected to crumb test and pin hole test.

VIII. RESULTS OF METHOD 2

A. Crumb Test [13] (1966)

Small crumbs of 6-10mm dia were prepared with 2 mm passing untreated CI soil and 1%, 2% and 20% sodium carbonate blended CI soil. Crumbs were dropped distilled water containing beaker. Moderate reaction occurred as cloud of colloids appeared at the bottom for the blended soils (Grade 3).Fig. 12

Fig. 12. Moderate reaction in LHS beaker and Middle beaker

Moderate reaction for crumb (LHS beaker)- colloidal suspension(1% treated Na2CO3 CI soil) spreading at bottom of beaker (Grade 3)Dispersive

Moderate reaction for crumb (Middle beaker)- colloidal suspension(2% treated Na2CO3 CI soil) spreading at bottom of beaker in lesser extent than 1% treated Na2CO3 CI soil (Grade 3)Dispersive

No reaction for crumb (RHS beaker) for 20% Na2CO3 treated CI soil (Grade 1)Non dispersive

A. Pin Hole Test

2 mm BIS sieve passing soil sample specimens packed in cylindrical pin hole apparatus. 38 mm long and 33 mm dia specimens were packed having moisture content at plastic limit and at 95% MDD. Distilled water at various heads was passed through 1 mm hole of the soil specimens.

For 1% sodium carbonate treated non dispersive CI soil there was heavy cloudy discharge at even 50 mm head. Thus soil was converted successfully into dispersive soil (D1). Fig. 13

Fig.13: 1% Na_2CO_3 treated/activated CI (ND) soil at 50mm head

Fig. 14: 2% Na_2CO_3 treated/activated CI (ND) soil at 50mm head

For 2% Na_2CO_3 treated/activated CI (ND) soil at 50mm head there was colloidal discharge but lesser turbidity than 1% Na_2CO_3 treated soil. Here also soil was converted to dispersive soil (D2) Fig. 14

Fig.15: 20% Na2CO3 treated/activated CI (ND) soil at 380mm head

When 20% Na2CO3 treated/activated CI (ND) soil was subjected to pin hole test, at even 380mm head – no colloidal discharge was observed. Thus for this case the soil was non dispersive. (ND3) Fig15.

IX. CONCLUSION

This paper presents artificial method to induce dispersion in non dispersive soil as well as it suggests that the presence of exchangeable sodium, calcium and montmorillonite are necessary for phenomenon of dispersitvity. The selected non dispersive clay soil (CI) contains montmorrilonite mineral as revealed from XRD. To ascertain the presence of both exchangeable sodium and calcium the experiments were conducted in such a controlled manner so that both exchangeable sodium and calcium are present in montmorrilonite mineral. And doing that it was observed that soil was dispersive when both sodium and calcium were present. When only exchangeable sodium is present soil was non dispersive.

X. ACKNOWLEDGEMENT

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