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# Experimental study on reduction of dispersion potential by adding nano $Al_2O_3$ and lime

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**Abstract**

Dispersive soils are among the most important problematic soils in earth structures, especially earth dam projects. Lime and aluminum sulfate are common and traditional additives for stabilization of dispersive soils due to the proper replacement of calcium or aluminum ions instead of sodium ions. Considering the progress of nanotechnology and using its in soil improvement, in this study, nano-sized aluminum oxide powder was used to improve dispersive soil. Five different nano material ratios (0, 0.2, 0.4, 0.8 and 1% by weight of dry clay) were mixed with a dispersive clay and four different lime contents (0, 2, 4 and 6% by weight of dry clay) and the dispersion potential of mixtures are obtained from double hydrometer test. The results show that increasing nano $Al_2O_3$ greatly reduced the percentage of dispersion. Adding 1% nano-$Al_2O_3$ in dispersive clay has diminished 64% the potential of dispersion. In samples with containing 2% lime, only 0.2% of the nano material has been able to place the soil in non-dispersive category.

***Key words***: *Dispersive soil, Soil stabilization, double hydrometer test, nano-$Al_2O_3$, Lime*

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**Extended Abstract:**

## 1. Introduction

Use of dispersive soils in embankment dams can cause major problem them in utilization. Considering that the needs of local material resources it is one of the most important concerns in the construction of earth dams,it is necessary to treat the available soils at the near site in the absence of suitable material resources. The major problems of dispersive soils are due to the significant percentage of sodium, which can be decomposed particles in the presence of water and consequently dissolve the soil. Lime and aluminum sulfate are common traditional additives in the treatment of dispersive soils. In this situation, the calcium ions contained in lime or aluminum contained in aluminum sulfate replace the sodium ions in the soil. On the other hand, the use of nanomaterials for improving the mechanical properties and geotechnical problems of soils has been considered in recent years. Among these studies, the use of a combination of lime and nano materials has been further recommended in treatment of clay soils. In this study, the combination of lime (as the traditional additive) and the novel material of nano-$Al_2O_3$ has been evaluated for the reduction of the dispersion potential. For this purpose, the double hydrometer test was used to determine the dispersion percentage.

## 2. Methodology

The double hydrometer test is one of four common methods for identifying dispersive soils. This test is generally a reliable test with high reproducibility that indicate the tendency of the soil to disperse. So the particle size distribution is measured with and without dispersing agent. By definition, the dispersion percentage is the ratio of the soil material less than 0.005 mm in the two tests. To evaluate the effect of nano $Al_2O_3$ on the dispersion potential of soil, as well as its role in lime stabilized soils, various combinations of additives were performed the hydrometer tests according to the ASTM D4221-17 standard. For this purpose, the stabilized clay with four different lime contents (0, 2, 4, and 6% of the weight of the dry soil) and five different nano- $Al_2O_3$ contents (0, 0.2, 0.4, 0.8, and 1% of the weight of the dry soil) was tested. The Sherard et al., (1976) and Bell and Maud (1994) criteria have been used to determine the dispersion percentage in the double hydrometer tests.

## 3. Results and conclusions

By performing the double hydrometer tests on samples prepared with different percentages of lime and nano $Al_2O_3$ were calculated the dispersion percentages that is shown the results in Table 1. Accordingly, variations in dispersion percentage versus nano $Al_2O_3$ values are demonstrated in Fig. 1. As shown in Fig. 1, the dispersion percentage for the lime-free clay by adding nano $Al_2O_3$ to dispersive soil has decreased with a significant slope. In other words, a small amount of nano-alumina has been able to significantly reduce the potential of dispersivity. The addition of 0.2% nano-alumina to clay leaded to reduce the dispersion percentage by 31%from 51% to 37%. However, the soil remains in the "Dispersive" state based on Sherard's criteria, but it is a significant decrease and is located on "Moderately Dispersive" state on the basis of Bell and Maud's criteria. By adding 1% of the nanomaterial is reduced the dispersion percentage to about 19.5%.

The effect of the addition of nano $Al_2O_3$ in the dispersive soil stabilization scheme using lime has been specifically evaluated in this study. Unlike lime-free samples, by adding only 0.1% aluminum oxide powder, even samples with low lime content (2% lime) are also classified as "Non-Dispersive" soils. The dispersion percentage in samples containing only 2% of lime has been reduced by adding 0.8% of the nano alumina by about 8%, which will ensure the conversion to a non-dispersive of the sample. Of course, the graphs in Figure 1 show that the decreasing trend of dispersion potentials in different mixtures is not continuous, thus by adding more nanomaterial, dispersion conditions will not necessarily be better. For samples containing 6% lime, adding 0.4% nano $Al_2O_3$ has provided optimum conditions. So the dispersion percentage is close to zero. Also, in other lime percentages, the addition of 0.4 to 0.8% nano material has created better conditions.

**Table 1.** Results of double hydrometer tests on samples

| Test No. | Sample Name | Lime (%) | Nano (%) | % passing 5-µm in Test Method D 422 | % passing 5-µm in Test Method D 4221 | Dispersion (%) | Soil Dispersion Potential |
|---|---|---|---|---|---|---|---|
| 1 | C+0.0N+0.0L | 0 | 0.0 | 31.34 | 16.78 | 53.56 | H. D |
| 2 | C+0.2N+0.0L | 0 | 0.2 | 31.84 | 11.70 | 36.73 | M. D. |
| 3 | C+0.4N+0.0L | 0 | 0.4 | 36.99 | 10.69 | 28.91 | S. D. |
| 4 | C+0.8N+0.0L | 0 | 0.8 | 37.25 | 8.77 | 23.55 | S. D. |
| 5 | C+1.0N+0.0L | 0 | 1.0 | 32.60 | 6.34 | 19.45 | S. D. |
| 6 | C+0.0N+2.0L | 2 | 0.0 | 33.33 | 9.29 | 27.87 | S. D. |
| 7 | C+0.2N+2.0L | 2 | 0.2 | 29.02 | 4.39 | 15.12 | S. D. |
| 8 | C+0.4N+2.0L | 2 | 0.4 | 35.00 | 3.40 | 9.71 | N. D. |
| 9 | C+0.8N+2.0L | 2 | 0.8 | 30.89 | 2.38 | 7.70 | N. D. |
| 10 | C+1.0N+2.0L | 2 | 1.0 | 29.77 | 2.41 | 8.10 | N. D. |
| 11 | C+0.0N+4.0L | 4 | 0.0 | 31.02 | 6.29 | 20.29 | S. D. |
| 12 | C+0.2N+4.0L | 4 | 0.2 | 22.97 | 2.43 | 10.57 | N. D. |
| 13 | C+0.4N+4.0L | 4 | 0.4 | 27.03 | 0.99 | 3.66 | N. D. |
| 14 | C+0.8N+4.0L | 4 | 0.8 | 27.00 | 1.44 | 5.32 | N. D. |
| 15 | C+1.0N+4.0L | 4 | 1.0 | 23.94 | 2.43 | 10.14 | N. D. |
| 16 | C+0.0N+6.0L | 6 | 0.0 | 29.02 | 4.40 | 15.18 | S. D. |
| 17 | C+0.2N+6.0L | 6 | 0.2 | 23.70 | 1.40 | 5.92 | N. D. |
| 18 | C+0.4N+6.0L | 6 | 0.4 | 29.06 | 0.43 | 1.47 | N. D. |
| 19 | C+0.8N+6.0L | 6 | 0.8 | 33.74 | 0.83 | 2.46 | N. D. |
| 20 | C+1.0N+6.0L | 6 | 1.0 | 21.81 | 0.99 | 4.53 | N. D. |

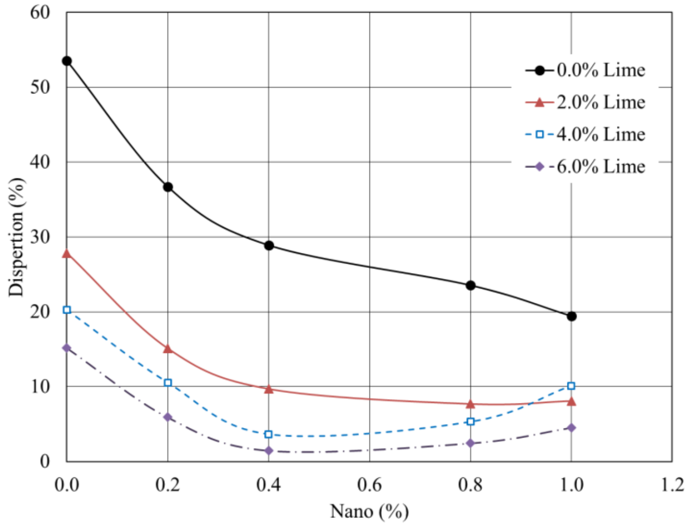


**Fig.1**. Effect of the nano $Al_2O_3$ additive on the dispersion percentage

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