CHEMICAL ENGINEERING TRANSACTIONS

VOL. 59, 2017

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Zhuo Yang, Junjie Ba, Jing Pan

ISBN 978-88-95608- 49-5; **ISSN** 2283-9216

DOI: 10.3303/CET1759068

Study on Influencing Factors of Cohesive Soil Dispersion Based on Gray Relational Analysis

Liwu Xin

Shen Kan Engineering & Technology Corporation, MCC, Shenyang 110016, China
liwuxin@163.com

Dispersed soil is one of the special soils in geotechnical engineering. Its erosion resistance is very low. In the environment of low salinity water or pure water, the cohesive force between the fine particles of clay is mostly or even all disappeared, and the particles are dispersed into cohesive soil particles.
It is very harmful to the project. In recent years, although the dispersion mechanism and test methods have made great progress, it is not enough to guide the engineering application of dispersive soil. Based on the grey relational analysis method of grey system theory, the pinhole test and the fragment test method are expounded, and the physical, chemical and mineral composition factors affecting the dispersion of clay are analyzed theoretically. In the chemical, physical and mineralogical composition of the soil, the chemical properties are greater than the mineralogical and physical properties. Among them, the degree of correlation between pH and sodium ion concentration is relatively high in chemical properties.
Through the gray correlation analysis method, the dispersion mechanism of dispersive soil is further revealed, that is, the soil contains more sodium ions, and the pH is high.

1. Introduction

Cohesive soil refers to clay and silty soil. Its liquid limit is greater than 25%, and the plasticity index is greater than 10 (Chen, et al., 2016; Lim et al., 2017). The properties of cohesive soil and sand are different. Cohesive soil has a certain cohesive force between fine particles. Permeability coefficient is K<1×10-4cm/s, and the permeability is relatively poor. Therefore, it is the most commonly used material for earth rockfill dam seepage control (Gao and Wei, 2016). According to the osmotic stability, the clay is divided into two types: non-dispersive clay and dispersive clay. The permeability stability of the dispersed soil is poor. In the environment of low salinity water or pure water, the cohesive force between the fine particles of clay is mostly or even all disappeared, and the particles are dispersed into cohesive soil particles. Its erosion resistance is very low, which is likely to cause dam diversion and roadbed instability (Güneyli and Rüşen, 2016).
In the plastic soil classification, the dispersion of soil is mostly low liquid limit clay (Kurlenya, et al., 2016). According to particle size classification, it belongs to light silty loam. When water infiltrating into the soil, the clay particles are easily dispersed into primary particles. The soil structure is relatively uniform and the pore channel is extremely fine. Permeability is generally less than 1×10-7cm/s, and it has good impermeability (Kimiaghalam, et al., 2015).
However, the corrosion resistance of dispersive soil is very low. If the water with low salinity is dispersed into the dispersive soil, the soil particles on the soil surface will gradually fall off. In case of flowing water, soil particles are taken away, erosion is very serious (Liu, et al., 2016).
The results of laboratory tests show that the erosion rate of non - dispersive soils in the north of China is about 100cm/s, and the general erosion hydraulic ratio is J>2.0 (Navarro, et al., 2016). Based on knowledge of soil mechanics, soil chemistry and soil physics, the dispersed soil is studied.

Please cite this article as: Liwu Xin, 2017, Study on influencing factors of cohesive soil dispersion based on gray relational analysis, Chemical Engineering Transactions, 59, 403-408 DOI:10.3303/CET1759068

2. Dispersion mechanism of cohesive soil

2.1 The experiment method

Viscous soil dispersibility was identified by pinhole test and fragment test. These two test methods are developed by the American Society for Materials and Testing (ASTM) (Nguyen, et al., 2017). The following are the main methods and criteria of the fragment test and pinhole test.

(1) Fragment test

In the fragment test, the test soil was made into a beaker of about 1 cm^3 , placed in a beaker containing distilled water, and immersed for 5 to 10 minutes to observe the dispersal properties of the colloidal particles. After the immersion of soil block soil, soil particles quickly collapse phenomenon and soon covered the bottom of the beaker, the water was mist, it is scattered soil. After the soil is disintegrated, there is turbidity around it, but the extent is small and the range of diffusion is small. Then, it is judged as transitional soil. After the soil is disintegrated, the clay particles react at the bottom of the cup. If it is a fine particle type heap, it is considered non-dispersive soil.

(2) Pinhole test

In the special pinhole test device, the soil samples were divided into 5 layers, and the compaction degree was 0.95. An axial fine pinhole with a diameter of 1.0 mm passes through the middle of the specimen. Then, distilled water was used to carry out the sample erosion test. The head is 50,180,380 and 1020 mm in turn. During the erosion process, we should carefully observe the erosion of the pinhole. After the erosion of the sample, the head is no longer continue to increase. The pinhole test is an effective way to simulate the erosion environment and condition of the soil under the action of seepage. Compared with other methods, it is considered to be a higher reliability method.

2.2 Mechanism method

(1) Physical properties and dispersibility

When the correlation between the physical property index and the cohesive soil is less than 0.5, the correlation is not significant. However, according to the degree of correlation, the relative density and the composition of the particles are the physical permeation conditions and the path of the dispersed soil, the correlation between the particle content and the sand content is close to 0.5. The apparent physical property index is only the external manifestation of chemistry and mineralogy composition. It can predict the decentralized trend from a certain angle, but it is not the essential reason and cannot be used as a measure of the dispersion of soil samples. The results show that the model cannot be used to reflect the real situation, and it is not recommended to include the index in the calculation model.

(2) Chemical indicators and dispersibility

The correlation between pH and cohesive soil was the highest, CO_3^{2-} and HCO_3^- were the next, and followed by Na+. These chemical properties are directly related to the dispersion of cohesive soil, that is, the alkaline environment and Na + content have a decisive influence on the dispersion of cohesive soil. There was a positive correlation between the content of Na + and the dispersibility of cohesive soil, that is, the higher the Na + content, the higher the dispersibility of the clay. The correlation between CO_3^{2-} and HCO_3^- and the dispersivity of cohesive soil is high. HCO_3^- is hydrolyzed in aqueous solution, resulting in a significant increase in OH^- in the solution, and the solution is alkaline. The increase in pH provides a favorable alkaline environment for the dispersion of cohesive soils. Strong acid ions do not occur hydrolysis in water, which does not affect soil pH, so it does not affect the cohesive soil dispersibility. The correlation between high valence cation and cohesive soil is high. Ca^{2+} and Mg^{2+} exchange with Na + on the surface of cohesive soil particles, which reduces the number of Na + on the surface of the clay particles and affects the thickness of the double layer of soil particles, thus weakening the tendency of cohesive soil dispersion to achieve the inhibitory effect.

(3) Clay minerals and dispersibility

Common clay minerals are kaolinite, montmorillonite and illite, which are substances that are active in physical and chemical properties in the soil and have a significant effect on the engineering properties of cohesive soils. Kaolinite belongs to the 1: 1 type clay minerals, and the oxygen in the silicon tetrahedron and the OH-oxide in the aluminum oxide octahedron form hydrogen bonds, so that the two ions are just together. Its crystal layer is firm, lattice is non-expandable, and it has no dispersibility and shrinkage. Montmorillonite belongs to the 2: 1 type of mineral. The water can enter between the layers, so that the crystal produces a large volume change. The interlayer bonding of montmorillonite is weak, and the lattice is extensible and dispersible. Illite is a 2: 1 type mineral. The main difference between the two is that the combination of illite crystals is not water but K + or Na +. As a result, the illite crystal is solid, and its dispersion and expansion and contraction is smaller than montmorillonite. From the mineralogical point of view, it is generally believed that the dispersed soil contains more montmorillonite. However, if the cations adsorbed by montmorillonite are different, their engineering properties are very different, such as calcium montmorillonite, which is not obvious, and it inhibits dispersibility.

Sodium montmorillonite is swollen with water and has a strong dispersibility. Therefore, the difference between the clay minerals of different groups and the dispersibility of cohesive soil is very different, and it cannot be quantified and compared. It can also be seen from the calculation and analysis results that the correlation between the mineralogical indicators and the dispersibility of the cohesive soil is small, that is, the correlation is not significant.

(4) A comparative analysis of three kinds of property

The order of correlation between the three kinds of property indexes and the dispersibility of the cohesive soil is: the chemical property index is larger than the physical property index and the mineralogical property index. The microscopic chemical composition is the main factor to determine the properties of soil, so it has the highest correlation degree. The high content of Na+ and high pH are the key factors of soil dispersion. Clay minerals are the main components of macroscopic clay. However, due to the complex mineral composition and the variable structure, different types of montmorillonite on the dispersion of the soil has a diametrically opposite effect, and it cannot be generalized, so the correlation analysis results have a certain deviation. Physical properties of the chemical and mineralogy composition are the combined effect of the external performance, so the correlation with the decentralization is also smaller.

3. Analysis of chemical factors and mechanism of dispersion of cohesive soil

Dispersed soil is a complex physical, chemical and mechanical process. At present, the dispersion mechanism of dispersed soil is mineral theory, cationic theory and pH theory (Pezowicz and Chomamoryl, 2015). Mineral theory argues that the dispersion of the soil is caused by montmorillonite; the cationic theory holds that the soil is dispersed due to the large amount of Na + in the soil that makes the double layer of the soil particles thicker. PH can affect the surface of the soil charge, and the pH theory explains the dispersion. These theories have a certain theoretical basis, but each theory has imperfect composition. Practice also proves that these single theories often cannot explain the causes of the dispersion of certain soils. Based on the method of pinhole test and fragment test, the effects of chemical factors such as pH and sodium ion, mineral composition and mineral composition on the dispersion of cohesive soil were studied by artificial preparation of soil samples. We try to further clarify the dispersion mechanism of cohesive soil, and provide theoretical basis for the design, construction and management of distributed soil engineering.

3.1 Test materials and methods

The materials incorporated in the soil are calcium-based montmorillonite bentonite, sodium-based montmorillonite bentonite and sodium carbonate. The contents of the above two kinds of montmorillonite bentonite were 10.0%, 20.0%, 30.0%, 40.0% and 50.0% respectively. According to the preliminary test, the soil samples with the mass fraction of sodium carbonate above 0.12% were dispersive soil. Therefore, in the experiment of the influence of different groups of montmorillonites on the dispersibility of dispersal soil, the mass fraction of sodium carbonate was 0.32% (disperse soil referred to as F1). The sodium and calcium montmorillonite single factor soil samples were dispersed by pinhole and fragmentation test, in order to obtain the influence of single factor sodium and calcium montmorillonite on the dispersion of clay. The two kinds of montmorillonite montmorillonite samples were mixed with F1 soil samples according to the mass ratio of 1: 1, and 5 groups of calcium-F1 mixed soil samples and 5 groups of sodium-F1 mixed soil samples were obtained. The mass fraction of montmorillonite bentonite was 5.0%, 10.0%, 15.0%, 20.0% and 25.0%, respectively, and the mass fraction of sodium carbonate was 0.16%. The effects of montmorillonite species and content on the dispersibility of dispersal soil were studied, and then the pinhole and the fragment test were used to identify the dispersibility.

In the experiment of studying the influence of Na + on the dispersion of cohesive soil, 7 groups of sodium carbonate were 0.04%, 0.08%, 0.12%, 0.16%, 0.20%, 0.40% and 1.00% respectively. Soil samples were 8 soil samples. The relationship between Na + and the dispersion of cohesive soil was explored and identified by pinhole and fragment test. In the study of the effect of pH on the dispersibility of cohesive soil, the soil concentration and the concentration of the reagent in the soil sample are complicated, and the pH in the soil sample is measured and identified by pinhole test and fragment test. The soil moisture content of the tested soil is the optimum moisture content, and the compaction degree is 0.95. This study was carried out using pinhole test and fragment test method, and referenced the American Society of Materials and Testing Association of pinhole test (ASTM D4647-93), fragment test (ASTM D6572-00) and other two test procedures.

3.2 Test results and analysis

(1) Effect of the kind and content of montmorillonite on the dispersibility of cohesive soil

According to the different adsorption of cations, montmorillonite is divided into calcium-based montmorillonite and sodium-based montmorillonite. The dispersibility test of montmorillonite with different kinds and contents was carried out in soil samples (non-dispersible soil) and F1 (dispersive soil). The types and contents of montmorillonite were studied. The test results are shown in Figure 1 and Figure 2. In the ordinate, N, T, and D represent non-dispersive soil, transitional soil and dispersive soil, respectively.

Figure 1 shows that a soil sample is non-dispersible soil, but with the incorporation of sodium-based montmorillonite bentonite content increases, the non dispersive soil has the characteristics of dispersive soil. In the process of fragment test, the swelling of the soil sample was significantly improved by adding sodium-based montmorillonite. When the amount of sodium montmorillonite bentonite in the soil sample is 50%, the volume expansion of the test piece of 1cm×1cm×1cm can be doubled. However, the dispersibility of the samples doped with calcium-montmorillonite in Yangling soil samples was almost unchanged, and the soil samples were stable during the test and the water stability was good. They all showed the characteristics of non-dispersive soil.

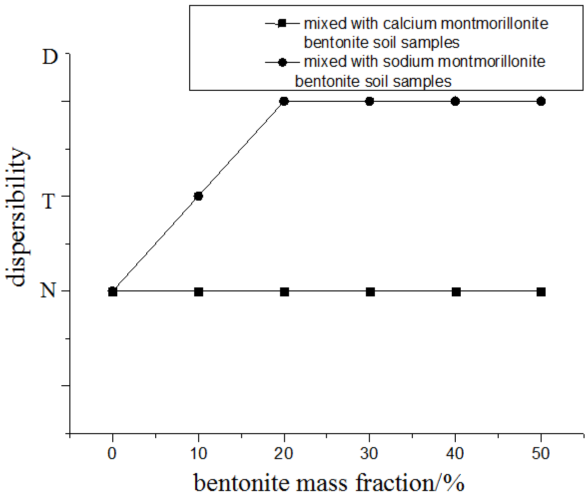

Figure 1: Changes of dispersion properties of montmorillonite bentonite in non - dispersive soil

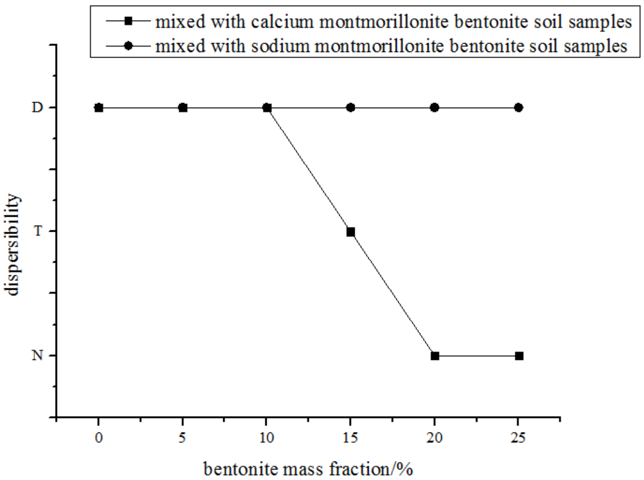

Figure 2: Changes of dispersion properties of montmorillonite bentonite in dispersed soil

As can be seen from Figure 2, in dispersive soils, as the content of sodium-montmorillonite bentonite increases, it is always expressed as a dispersive soil. However, with the increase of calcium-montmorillonite bentonite content, the soil samples were gradually changed from the dispersed soil to transitional soil, and then changed from transitional soil to non-dispersible soil. It can be seen that calcium-based montmorillonite and sodium-based montmorillonite have the opposite effect on the dispersion of soil samples.

(2) Effect of Na + on the dispersibility of cohesive soil

In order to further verify the effect of Na + on the dispersibility of soil samples, different amounts of sodium carbonate were mixed in non-dispersive soils to study the relationship between Na + and the dispersibility of cohesive soils. The test results are shown in Figure 3 and Figure 4.

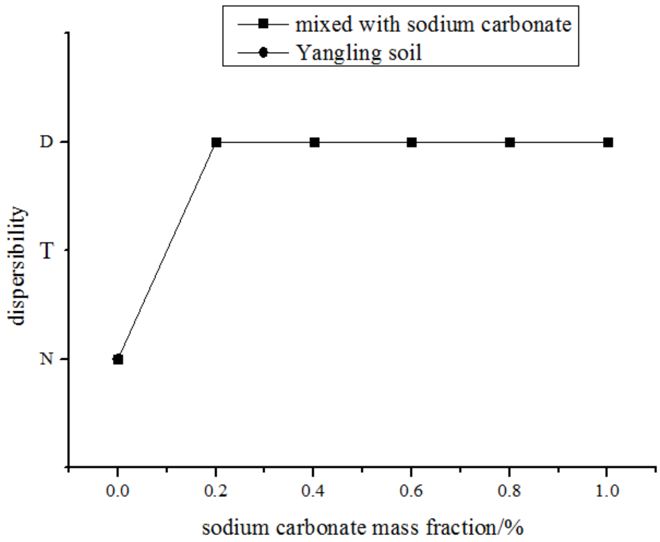

Figure 3: Relationship between Na + content and dispersibility of cohesive soil

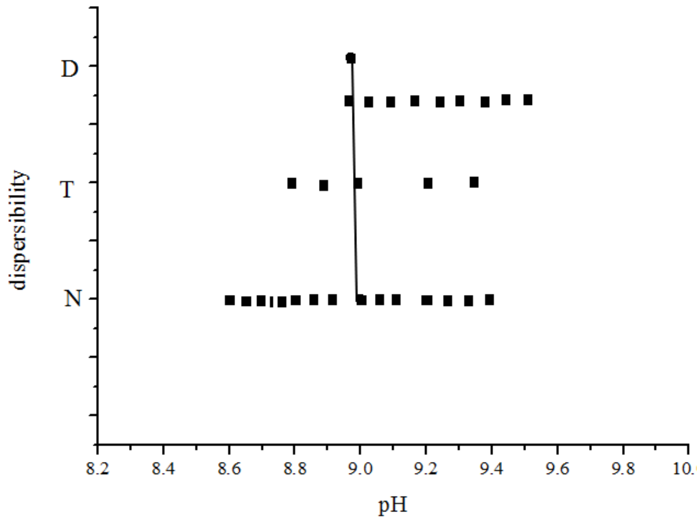

Figure 4: Relationship between soil pH and cohesive soil dispersibility

As can be seen from Figure 3, after dispersing sodium carbonate in non-dispersive soil, the dispersibility of soil samples is increased with the increase of Na + content. Sodium carbonate content is less than 0.08%, and the soil samples is non-dispersive soil. It is in the range of 0.08% to 0.12%, which belongs to transitional soil. When it is greater than 0.12%, soil samples are distributed soil. Sodium carbonate is a strong base weak acid salt, so the soil is mixed with sodium carbonate, it presents a strong alkaline.

(3) Effect of pH on the dispersibility of cohesive soil

The pH of soil can change the charge properties of the surface of soil particles, so it has a significant effect on the physical and chemical properties of cohesive soil. The pH of the soil sample was determined and the dispersivity of the soil sample was determined. The results were shown in Figure 4. Figure 4 shows that the soil sample pH is closely related to its dispersibility. PH is greater than 9.0, soil samples are identified as scattered soil; pH is less than 9.0, soil samples are mostly non-dispersible soil. Some of the soil samples were identified as non-dispersible soil pH higher. The reason is that the Na + content in the soil sample is relatively small, so it does not reach the degree of dispersion. This reflects that the dispersive soil needs to have two conditions of high pH and high Na+ concentration.

4. Conclusions

Dispersed soil is one of the special soils in geotechnical engineering. Its erosion resistance is very low. In the environment of low salinity water or pure water, the cohesive force between the fine particles of clay is mostly or even all disappeared, and the particles are dispersed into cohesive soil particles. It is very harmful to the project. In recent years, although the dispersion mechanism and test methods have made great progress, it is not enough to guide the engineering application of dispersive soil.

Based on the analysis of the existing data, this paper reveals the influencing factors of the dispersion of cohesive soil, and verifies it by experiment. Grey correlation analysis showed that in the soil physical and chemical and mineral components, the degree of closeness associated with the dispersion of cohesive soil is: chemical properties index is greater than the physical properties and mineralogical properties. Among them, the correlation between pH and Na+ concentration was relatively high in the chemical properties. Through the grey relational analysis method, the dispersion mechanism of the dispersed soil is further revealed, that is, the soil contains more Na+, and the pH is relatively high. The chemical factors that affect the dispersion of cohesive soil should have both high pH and high Na + content, but not related to the soil mineral composition. At the same time, the effect of montmorillonite on the dispersibility of cohesive soil is related to the type of montmorillonite, and the calcium-montmorillonite inhibits the dispersion of cohesive soil. Sodium-based montmorillonite can promote soil dispersion due to high pH content and high Na + content.

Reference

Chen J.G., Chen J., Wang Q.J., Zhang Y., Ding H.F., Huang Z., 2016, Retrieval of Soil Dispersion Using Hyperspectral Remote Sensing. Journal of the Indian Society of Remote Sensing, 44(4), 563-572.

Gao L., Wei Y., 2016, Fabrication of a novel hydrophobic/ion□exchange mixed□mode adsorbent for the dispersive solid□phase extraction of chlorophenols from environmental water samples, Journal of Separation Science, 39(16), 3186-3194.

Güneyli H., Rüşen T., 2016, Effect of length-to-diameter ratio on the unconfined compressive strength of cohesive soil specimens. Bulletin of Engineering Geology and the Environment (2), 1-14.

Kimiaghalam N., Clark S., Ahmari, H., & Hunt, J., 2015, Wave-current induced erosion of cohesive riverbanks in northern manitoba, canada. Proceedings of the International Association of Hydrological Sciences, 367, 134-140.

Kurlenya M.V., Serdyukov A.S., Chernyshov G.S., Yablokov A.V., Dergach P.A., Duchkov A.A., 2016, Procedure and evidence of seismic research into physical properties of cohesive soils. Journal of Mining Science, 52(3), 417-423.

Lim L.Y., Lee C.T., Lim J.S., Klemeš J.J., Ho C.S., Mansor N.N.A., 2017, Feedstock amendment for the production of quality compost for soil amendment and heavy metal immobilisation, Chemical Engineering Transactions, 56, 499-504, DOI: 10.3303/CET1756084

Liu S., Zou H., Cai G., Bheemasetti T.V., Puppala A.J., Lin J., 2016, Multivariate correlation among resilient modulus and cone penetration test parameters of cohesive subgrade soils. Engineering Geology, 209, 128-142.

Navarro V., Asensio L., Ángel Y., Morena G.D.L., Pintado X., 2016, Swelling and mechanical erosion of mx-80 bentonite: pinhole test simulation. Engineering Geology, 202, 99-113.

Nguyen M.N., Picardal F., Dultz S., Dam T.T.N., Nguyen A.V., Nguyen K.M., 2017, Silicic acid as a dispersibility enhancer in a fe-oxide-rich kaolinitic soil clay. Geoderma, 286, 8-14.

Pezowicz P., Chomamoryl K., 2015, Moisture content impact on mechanical properties of selected cohesive soils from the wielkopolskie voivodeship southern part. Studia Geotechnica Et Mechanica, 37(4), 37-46.