International Journal of Research and Review
Vol. 10; Issue: 8; August 2023
Website: www.ijrrjournal.com
Research Paper E-ISSN: 2349-9788; P-ISSN: 2454-2237

Effect of Zeolite Mixture Percentage on the Free Compressive Strength Test Value of Clay Soil in Pulo Padang Village in Mandailing Natal Regency

Darlina Tanjung[1], Jupriah Sarifah[1], Nurmayanti[2]

[1]Lecturers, Department of Civil Engineering, Faculty of Engineering, Universitas Islam Sumatera Utara, Medan, Indonesia
[2]Student, Department of Civil Engineering, Faculty of Engineering, Universitas Islam Sumatera Utara, Medan, Indonesia

Corresponding Author: Nurmayanti (yantinurma55@gmail.com)

DOI: https://doi.org/10.52403/ijrr.20230893

ABSTRACT

High plasticity clay soils which are often encountered in field construction work have low bearing strength and large volume changes (shrinkage expansion). Soil will expand when the pores are filled with water and will shrink in dry conditions. This makes the soil unstable, and it is unable to support a building construction. Therefore, soil improvement efforts are needed to increase this soft clay soil. Soil stabilization is a soil improvement effort to strengthen soil that has low bearing capacity. In this research, the soil stabilization method is carried out using mixed materials to reduce or eliminate the unfavorable properties of the soil to be used. To improve the quality of the soil, zeolite is used. In its utilization, zeolite is able to withstand high heat and can increase the bearing capacity of clay soil. This research was conducted to determine the effect of zeolite addition on the compressive strength value of clay soil. In this study, the percentage of zeolite mixture used was 0%, 2%, 4%, 6%, 8%, and 10%. Based on the research results, the addition of zeolite mixture percentage in clay soil can increase the compressive strength value of the soil where the compressive strength value of the soil increases. However, the increase in soil compressive strength value occurred only until the addition of zeolite by 8% with a compressive strength value of 12.208 kg/cm2. At the time, at the addition of zeolite at 10%, the compressive strength value of the soil decreased to 9.928kg/cm2. Thus, the addition of zeolite can increase the compressive strength value of soil at the maximum addition limit of 8%. So, zeolite can be used as an alternative material for soil stabilization for subgrade layers.

Keywords: Clay, Stabilization, Zeolite, Soil compressive strength

INTRODUCTION

The use of soil as a building material is commonly found in road works, earthfill dams, embankments among others. An introduction to the type, physical and mechanical properties of the soil used is helpful in the design of the soil and in the work success. Similarly, familiarity with the behavior of the soil under the planned load and water flow (for example, if the soil is to be used as a filter) greatly assists the success of the work. Soft soils often create problems for the structures above them due to weak bearing capacity and slow consolidation. High plasticity clay soils that are often encountered in construction work in the field have low bearing strength and high-volume change (shrinkage growth). Therefore, soil improvement efforts are needed to improve these soft clay soils.

Soil stabilization refers to soil improvement effort to the soil that has a low bearing capacity to be better. Stabilization can be done mechanically by using mechanical tools and chemically by mixture by adding additives such as cement, lime, gravel, zeolite, and granular soil. In this research, the mixing material is zeolite--a crystalline silica-alumina material that has a three-dimensional polymer arrangement structure consisting of SiO4 and AIO4 tetrahedral units. The units are joined by sharing oxygen, acidic and molecular-sized pores. Zeolites have a high capacity as absorbents because zeolites can separate molecules based on the size and configuration of the molecules.[1]

In its utilization, zeolite is able to withstand high heat and can increase the bearing capacity of clay soil. In addition, the level of zeolite consumption is increasing, especially in the industrial sector.[2] In this study, to stabilize the soft soil (clay soil), a mixture of zeolite was applied. Samples of clay soil and mixed with zeolite are tested in the laboratory. This aims to determine the effect of using zeolite on the stabilization of soft soil (clay) and also on its free compressive strength.

LITERATURE REVIEW

Land

In civil engineering, soil is a relatively loose set of minerals, organic matter, and sediments lying on top of bedrock. The relatively weak bonds between grains can be caused by carbonates, organic matter, or oxides deposited between the particles. The spaces between the particles can contain water, air, or both. Weathering of rocks or other geological processes occur near the earth's surface form soil.[3] The terms sand, clay, silt, or mud are used to describe particle sizes at predetermined grain size limits. However, the same terms are also used to describe specific soil properties, for example, clay is a cohesive and plastic soil type, while sand is described as non-cohesive and non-plastic.

Soil classification

Three kinds of soil classification systems are cited from Soedarmo[4]:

- Textural classification system is based on the percentage of soil grain composition. In nature soil consists of grains including sand, silt, and clay with different percentages. Its texture has been classified by the U.S. Department of Agriculture (USDA) which also describes the boundaries of soil grain arrangement under the USDA. system. It was further developed and used for highway work, which is better known as soil classification based on percentage of soil grain arrangement by U.S. Public Roads Administration.
- There is unified soil classification system and the most widely used classification system based on the results of laboratory experiments is the unified soil classification system. The laboratory experiments used are grain size analysis and Atterberg limits. All soils are assigned two letter designations based on the results of these experiments. There are two broad classes of coarse-grained soils, <50% through a No. 200 sieve and fine-grained soils >50% through a No. 200 sieve. Fine-grained soils are then classified on the basis of their plasticity and organic compound content. In this case, grain size is not the determining basis for classification. This system, originally developed for airfield construction, was elaborated by Casagrande.[5] It has been in use since 1942, but was slightly modified in 1952 to make it applicable to dam construction and other constructions.
- Concerning AASHTO classification system, soil classification system was developed in 1929 by the Public Road Administration Classification System. With several changes, it is now used and recommended by the Committee on Classification of Materials for Subgrade and granular types of Roads of the Highway Research Board in 1945 (ASTM uses code D- 3282 and AASHTO method M 145).

Clay minerals

Clay minerals are alumina and silica which are quite complex and are composed of two main components, namely silica tetrahedron which consists of four oxygen atoms circling one silicon atom. The combination of silica tetrahedron produces silica sheets and the alumina octahedron contains six hydroxyls circling one aluminium atom. This aluminium hydroxyl combination forms octahedral sheets which are often referred to as gibbsite sheets.[6]

Soil stability

Soil stabilization is a method to increase the strength of the bearing capacity of a soil layer with special treatment to the soil layer. The direction of soil stabilization is at least able to increase the bearing capacity of the soil, to minimize the decline of the soil layer, to improve (maintain) the potential permeability and swelling of the soil, and to maintain (maintain) the potential of the existing soil (existing strength).[7] The type of stabilization in this research is chemical stabilization in which stabilization uses chemicals that allow chemical reactions to occur, and produce new compounds that are more stable than the compounds contained in the soil mass before stabilization is carried out.

Chemical stabilization can provide increased bearing capacity, improved settlement, and permeability properties of the soil layers. However, care must be taken in its selection, as not all chemical stabilization measures are capable of simultaneously improving the three characteristics mentioned above, for example, stabilization with cement, lime, chemical solutions, zeolites among others.

Zeolite

Zeolites consists of hydrated aluminosilicate minerals, like alkali or alkaline earth cations in a three-dimensional framework. The structure of zeolite includes tetrahedral units of AIO_4 and SiO_4 interconnected through O atoms and in the structure Si^{4+} which can be replaced by A*l*3+. There are two types of zeolites, such as, natural and synthesized and both types of zeolites have similar physical and chemical properties even though they have some differences. Synthesized zeolite is more pure when compared to natural zeolite which is obtained by open and mechanical addition and found in Indonesia as in the Cipatujuh, Bayan, Nagrek, and South Malang areas and its types are mordenite, clipnotilolite, plagioplast.

a. Natural zeolite

Natural zeolite is formed due to the process of natural change (zeolitization) of volcanic tuff rock. Zeolite minerals have been known since 1756 by a Swedish mineralogist named F.A.F Cronsted. In nature many zeolites are found in lava rock pits, and in sedimentary rocks, especially fine-grained pyroclastic sediments. More than 40 types of natural zeolite minerals are known and of these, only 20 types are found in sedimentary rocks, especially pyroclastic sediments.[1] In the process of forming zeolite minerals, the clinoptilolite and philipsite minerals are formed first, because these two are the predecessor minerals / seed minerals or mineral derivatives for other zeolite minerals, such as analsim minerals, heulandite, laumontite and mordenite. [1]

b. Synthetic zeolite

Synthesized zeolites are engineered by humans in a chemical process and due to the unique nature of zeolites, namely their atomic arrangement, composition, and modification, researchers try to make synthetic zeolites that have special properties according to their needs, and as a result, various synthetic zeolites can be engineered.

Sieve analysis

The properties of soil are highly dependent on its grain size which becomes the basis for soil naming and classification; therefore, grain analysis test is very frequent.[3]

Water content

The method to analyze soil moisture content is gravimetric water content and the ratio of the weight of soil water to the weight of air-dry (moist) soil. [3]

Specific gravity

The specific weight of soil grains (solid part) is often required for various calculations in soil mechanics, and the weight can be determined accurately in the laboratory. [3]

Liquid limit

Liquid limit (LL) is defined as the moisture content of the soil at the boundary between the liquid state and the plastic state, i.e. the upper limit of the plastic region. [9]

Plastic limit

Plastic limit (PL), can be defined as the moisture content at the position between the plastic and semi-solid regions, consisting of the percentage of moisture content at which the soil with a cylinder diameter of 3.2 mm begins to crack when rolled. [3]

Soil compaction

As described the soil stabilization by compaction is basically an attempt to increase soil density by using mechanical energy to produce particle compression. [3]

MATERIALS & METHODS

Research methods

The research is quantitative method using primary data which is obtained through direct testing in the soil mechanics laboratory at Universitas Islam Sumatera Utara and at Universitas Negeri Medan. As for some tests carried out this research includes testing sieve analysis, water content, specific gravity, liquid limit, plastic limit, compaction, and unconfined compression test. Then, from the results of the study, the compressive strength value of clay soil is taken from Mandailing Natal on the percentage of zeolite mixture.

Field study

The research began in January 2023 in which its implementation involved three tests; testing soil characteristics and soil physical properties was carried out at the Soil Mechanics Laboratory, Department of Civil Engineering, Universitas Islam Sumatera Utara. The test for the mechanical properties of soil, namely the unconfined compression test, was carried out at the Soil Mechanics Laboratory of the Civil Engineering Department, Universitas Negeri Medan.

The material for the study was a type of clay soil taken from Pulo Padang village, Mandailing Natal regency. Taking undisturbed soil was done by using a sample tube 1.5 meters deep, while for disturbed soil is applied by digging the soil using shovel and hoes of 1-1.5 meters deep in order to remove the remnants of soil dirt. The zeolite additive materials were taken from Indah Sari Windu w Company which is located at Sutomo street, Medan, North Sumatra. This zeolite itself was brought from the coast of South Lampung, and it was originally in the form of rocks which were then fabricated and then broken into very small sizes up to 100 mesh.

Laboratory testing

The experiments were carried out in the following procedures: sieve analysis, soil water content, specific gravity, plastic and liquid limit, weight content (density test), compaction test, and unconfined compression test.

Stages of data collection and processing

The data collection and processing were done in five steps: first was literature study to seek research location, and to provide materials (clay samples and zeolite mixture materials), in the second step, soil was dug between 1-1.5 meters deep to remove residual soil debris and soil sampling was taken from undisturbed and disturbed soil conditions, for the third step, the soil was put into a barrel or bucket of paint and then covered for testing the original soil characteristics, the fourth step was related to testing of physical and mechanical properties of soil, where each test was given a mixture of zeolite clinoptilolite additives, and in the last step, data analysis was carried out from the test results.

RESULT AND DISCUSSION

Testing the results of native soil characteristics

All testing steps to determine the physical and mechanical properties of clay soil are carried out in the laboratory with zeolite as a stabilizing material, both in original conditions and after mixing with zeolite.

Sampling was done using two methods, such as, undisturbed sampling using a tube and manual means, namely by hoeing the soil surface until the soil was obtained. After clay soil samples were obtained, the physical properties of the original soil were tested in the laboratory. Testing the physical properties of this soil was done as a consideration in planning and carrying out construction development and in order to know whether the soil can be used for construction on it. In this study, the test was carried out by mixing native soil with zeolite with different percentage mixture of 2%, 4%, 6%, 8%, and 10%. The results of laboratory testing of native soil samples can be seen in Table 1. According to the unified classification system, if the soil that passes the No. 200 sieve is more than 50% then the soil is classified as fine-grained soil (silt/clay) and for plasticity index >17, the soil is classified as pure clay with high plasticity (see Fig. 1).

Table 1. Test results of soil characteristics

Soil moisture content (%)	79,99
Soil specific gravity	2,38
Liquid limit (%)	73,14
Plastic limit %)	40,62
Plasticity index (%)	32,52
Passing sieve No. 200 (%)	88,72

(Source: Personal)

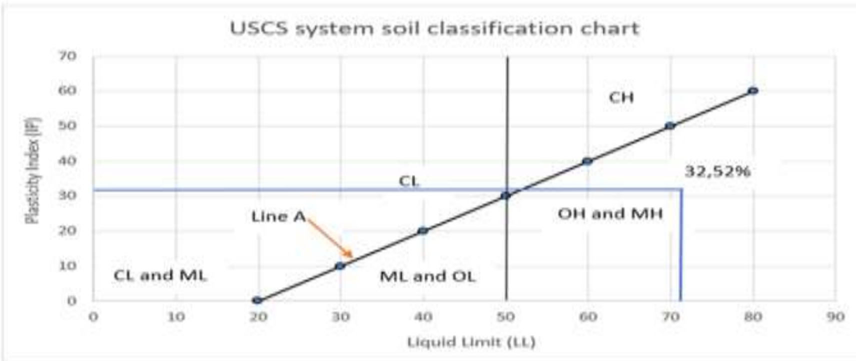

Figure 1. USCS system soil classification results
(Source: Personal)

The results of laboratory research show liquid limit is 73,14%, plasticity index is 38.792%, and sieve passing No.200 is 88,72%. When the percentage passing No. 200 sieve is 88.72% (greater than 50%), then, according to the unified classification table, the lower column of fine grains should be used. When the liquid limit value is greater than 50%, it consists of MH or CH, then, the plastic index number can be determined, namely, 32.52%. The values of plasticity index and liquid limit are then displayed on the plasticity diagram, so, the point above line A is obtained, which occupies the CH zone; the soil to be used in this study is classified as CH (inorganic clay with high plasticity).

Test results of clay soil characteristics mixed with zeolite

Soil water content

Table 2 shows that there is a decrease in water content towards the addition of zeolite mixture. For more details, Fig. 2 shows the relationship between water content and the percentage of zeolite mixture.

Table 2. Test results of water content mixed with zeolite

Mixed percentage of zeolite	Soil moisture content (%)
0% (native soil)	79,99
2%	50,02
4%	47,00
6%	44,24
8%	43,98
10%	43,48

(Source: Personal)

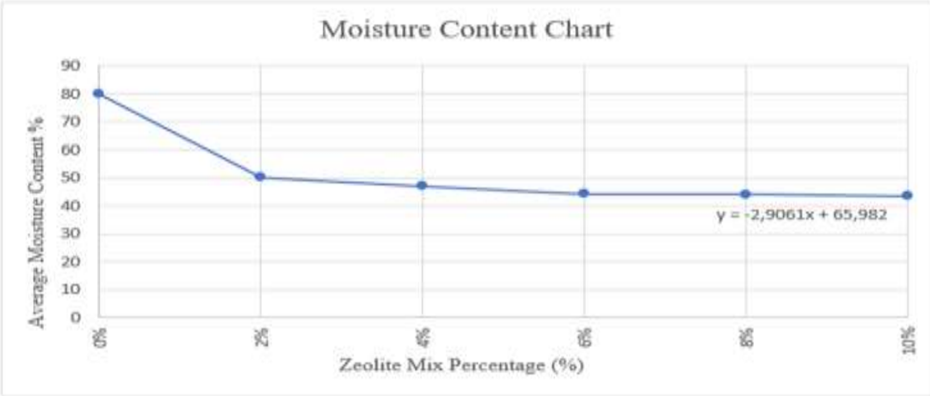

Figure 2. Relationship between moisture content and percentage of zeolite mixture.
(Source: Personal)

From Table 2 and Fig. 2 displays that the more addition of zeolite can reduce the water content of the soil sample, so, the soil is classified pure clay soil because zeolite can bind clay particles.

Specific gravity and weight content (density test)

From Table 3 and Fig. 3, it can be assumed that the greater the percentage of zeolite mixture addition, the value of soil specific gravity in this study becomes increase, namely, at the addition of 2%, 4%, 6%, and 8% zeolite mixture. But, at the addition of 10% zeolite, the value of soil specific gravity decreased. Thus, in this study the maximum limit of zeolite mixture addition is 8%.

Table 3. Test results of specific gravity content of zeolite-mixed soil

Number	Mixed percentage of zeolite	Specific gravity	Soil bulk density (gr/cm3)	Dry bulk density (gr/cm3)
1	0%	2,38	2,22	1,57
2	2%	2,38	2,31	1,57
3	4%	2,41	2,39	1,54
4	6%	2,42	2,30	1,56
5	8%	2,66	2,43	1,56
6	10%	2,48	2,38	1,62

(Source: Personal)

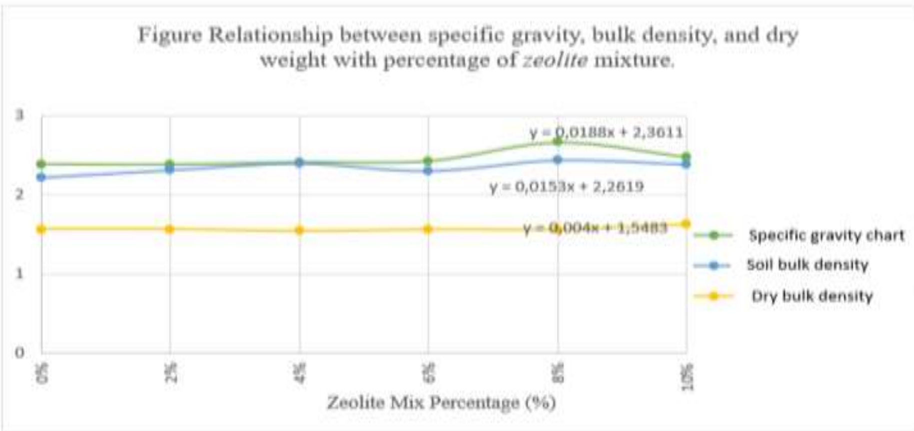

Figure 3. Relationship between specific gravity, bulk density, and dry weight with zeolite mixture percentage
(Source: Personal)

Plastic limit and liquid limit

Table 4 shows that the greater the percentage of zeolite mixture is, the plasticity index value decreases. Fig. 4 displays that the greater percentage of zeolite addition to the original soil can reduce the plasticity index (PI) value. The PI value determines the classification of soil development potential. The greater the PI value of the soil mixture is, the development of the soil is potentially greater. The lower the PI value of the soil mixture is, the less potential is the development. All this indicates that the addition of zeolite can increase the stability of the soil.

Table 4. Test results of liquid limit and plastic limit mixed with zeolite

Number	Mixed percentage	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
1	0% zeolite	73,34	40,62	32,72
2	2% zeolite	54,39	35,61	18,78
3	4% zeolite	53,58	35,69	17,89
4	6% zeolite	52,82	35,41	17,41
5	8% zeolite	50,85	34,31	16,54
6	10% zeolite	47,71	33,35	14,35

(Source: Personal)

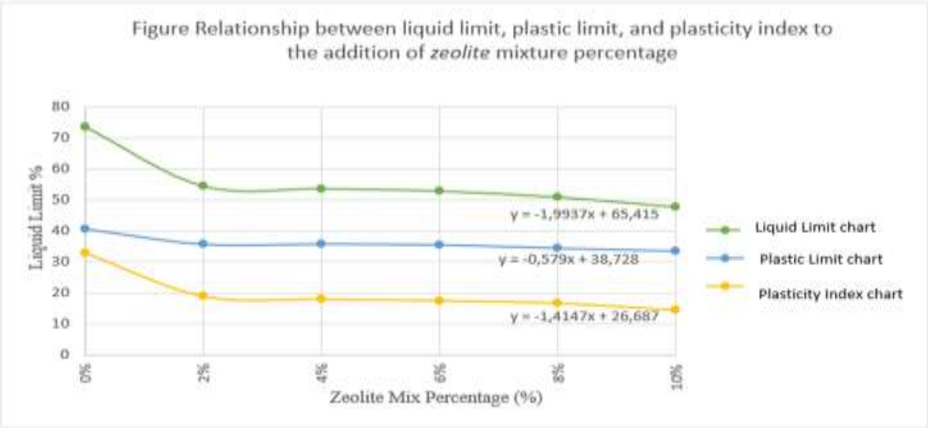

Figure 4. Relationship between liquid limit, plastic limit, and plasticity index to the addition of zeolite mixture percentage
(Source: Personal)

Compaction test

From table 5, it can be seen that the optimum moisture content value after the addition of zeolite mixture increases only at a mixture of 2%. Meanwhile, when adding zeolite at 4%, 6%, 8%, and 10%, the optimum water content value decreases (see also Fig. 5 for comparison).

Table 5. Test results of optimum moisture content and dry weight of blended contents zeolites

Mixed percentage of zeolite	W optimum (%)	Dry bulk density (gr/cm3)
0% (native soil)	33,40	1,56
2%	36,40	1,53
4%	35,90	1,54
6%	33,90	1,56
8%	32,60	1,60
10%	32,50	1,62

(Source: Personal)

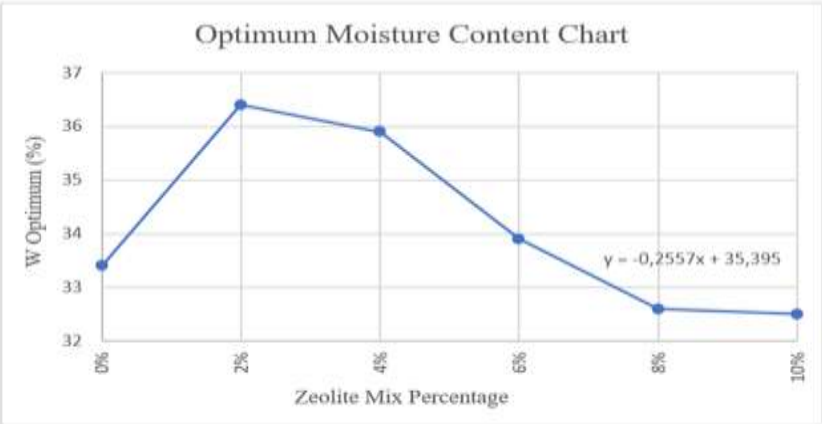

Figure 5. Relationship between moisture content and percentage of zeolite mixture.
(Source: Personal)

Unconfined compression test

Table 6 and Fig. 6 show that the higher the percentage value of zeolite addition is, the compressive strength value increases, but, the maximum increase is only until the addition of 8% with a compressive strength value of 12.208 kg/cm2. At the time, at the addition of 10%, the compressive strength value decreases to 9.928 kg/cm2. Thus, zeolite can increase the compressive strength value of the soil at the maximum limit addition of 8%.

Table 6. Free compressive strength test results

Mixed percentage of zeolite	Free compressive strength (kg/cm2)
0% (undisturbed soil)	1,156
0% (disturbed soil)	1,093
2%	4,085
4%	9,156
6%	11,417
8%	12,208
10%	9,928

(Source: Personal)

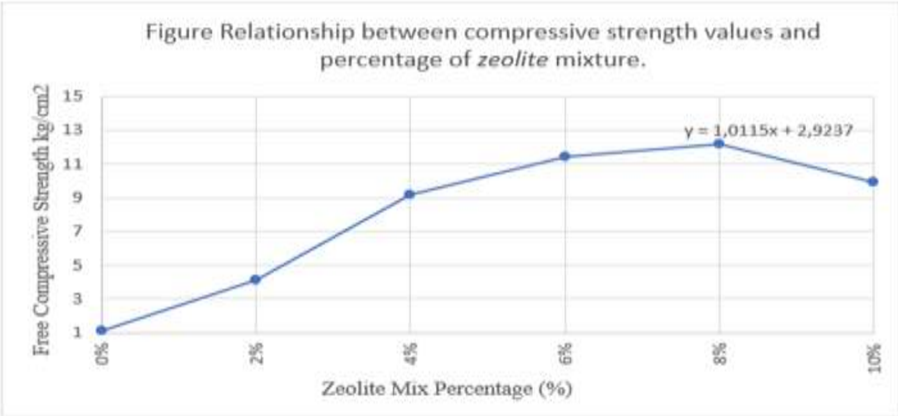

Figure 6. Relationship between compressive strength values and percentage of zeolite mixture
(Source: Personal)

CONCLUSION

Based on the results of research that has been carried out in the laboratories, conclusions can be drawn.

- The percentage addition of the zeolite mixture in clay soil can increase the compressive strength value of the soil in which the compressive strength value of the soil increases in every additional percentage of zeolite mixture. However, the increase in soil compressive strength value occurs only until the addition of zeolite reaches 8% with a compressive strength value of 12.208 kg/cm2. When zeolite increases at 10%, the compressive strength value of soil decreases to 9.928kg/cm2. Thus, the addition of zeolite can increase the compressive strength value of soil at the maximum addition limit of 8%.
- There was a decrease in compressive strength at the zeolite addition of 10%, while from some literature proves that the value of soil compressive strength increases when the percentage of zeolite increases caused by the density of the sample soil when it is tested, and the type of zeolite.
- From the compressive strength tests, the clay soil has a low sensitivity value.
- The optimum water content value also affects the addition of zeolite mixture at 2%. At zeolite addition of 4%, 6%, 8%, and 10%, the optimum moisture content decreases. At optimum moisture content increase of 2%, the optimum moisture content value is 36.40% while the optimum water content value before being given additional zeolite mixture amounts to 33.40%.

- Zeolite can improve the physical and mechanical properties of clay soil and it can be used for alternative materials for soil stabilization for subgrade layers.

Declaration by Authors

Acknowledgement: None
Source of Funding: None
Conflict of Interest: We declare that no conflict of interest exists among us.

REFERENCES

1. Sutarti, Mursi. Zeolite. Jakarta: Documentation and Information Center; 1994.
2. Bowles, J. E. Physical and Geotechnical Properties of Soils. Jakarta: Erlangga; 1989.
3. Hardiyatmo, Hary Christady. Soil Mechanics. Vol. 1. Yogyakarta: Gajah Mada University Press; 2016.
4. Soedarmo, Djatmiko G. Soil Mechanics Practicum Manual. Malang: Universitas Merdeka Malang; 1985
5. Prapaga, T. R. Effect of Zeolite Addition on Shear Strength of Clayey Soil. Manado: Department of Civil Engineering, Faculty of Civil Engineering, Sam Ratulangi; 2018.
6. Hatmoko, John Tri. Soil Improvement Technology. Yogyakarta: Andi Publisher; 2020.
7. Panguriseng, D. Soil Stabilization. Makassar: University of 45 Makasssar; 2001.
9. Panguriseng, D. Basics of Soil Mechanics. Makassar: University 45 Makasssar; 2018.

How to cite this article: Darlina Tanjung, Jupriah Sarifah, Nurmayanti. Effect of zeolite mixture percentage on the free compressive strength test value of clay soil in Pulo Padang Village in Mandailing Natal Regency. *International Journal of Research and Review*. 2023; 10(8): 708-716.
DOI: *https://doi.org/10.52403/ijrr.20230893*

******