EVALUATION OF VOLUME COMPRESSIBILITY COEFFICIENT VARIATIONS INCEMENT STABILIZED BENTONITE CLAY USING(WET & DRY)

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ABSTRACT

According to the constituent materials of soil layers in the project area, different Sites exhibitdifferent behaviorstowards compressibility. Mechanical and hydraulic behaviors of layers composed of coarse aggregates such as sand and gravel are very more predictable than those of layers composed of fine aggregates, especially clay. The settlement in such soilsinvolve time parameters and it is possible to calculate and evaluatethe parameters using the common tests in geotechnical engineering. The coefficient of volume compressibility is an important parameter for calculating the consolidation settlement of clay layers, which can be calculatedby means of the one-dimensional consolidation test device. In this study, 2,4,6,8 and 10% of cement at treatment times of 7,14 and 28 days were used to stabilize the bentonite clay. All samples prepared by wet and dry method hadthe same moisture contents in the mentioned levels equal to the liquid limit moisture of the original soil. The studied soil falls in the group CH with the liquid limit of 132% based on the unified classification system. The results obtained in this study indicated that the changes in pressure applied on the soil exhibited a significant impact on the performance of stabilizers and generally, the effects of wet and dry mixing methods on the coefficient of volume compressibility, and consequently,on the settlement could be seen.

Keywords: Stabilization, Cement, Consolidation test, Bentonite, Coefficient of volume compressibility

1. INTRODUCTION

Soils are generally classified, according to different methods, as fine-grained and coarse-grained ones. The major fine-grained soils are grouped into silts and clays that are mainly differentin terms of cohesive and plastic properties of the clay. Clay is composed of a variety of minerals, and different research has been done on the specific characteristics of the soil(Grabowska-Olszewska,2003)(Retnamony et al.,2003).

In terms of clay minerals in the soil, the values of exchangeable cations may change. The more the monovalent exchangeable cations in the clay soils, the higher the distribution of crystals, and as a result, the particles become smaller and their Specific Surface Area (SSA) rises (Tie Lan et al., 1995). Increase in the SSAand fineness of soil causes the changes in its hydraulic and mechanical propertiesincluding the plasticity ones, such as liquid and plastic limits, coefficient of permeability, and thickness of the double layer water around the clay particles (Mitchell et al., 2005).As different methods and materials are used for soil stabilization, for example lime in deep mixture or dry lime in surficial mixture, but so far no study has addressed the effect of mixing on different types of soils. So this study tried to investigate the performance and impact of mixing.

Traditional additives such as cement, lime and some additives like bentonite (Kalkanet al., 2004)and silica (Kumar Mishra et al.,2006)in researchesrepresented the effective role of these additives in reducing the permeability coefficient of clay mechanical and hydraulic parameters of soils stabilized with the stabilizing materials.

Montmorillonite is one of clay minerals which due toits special properties, such as the strong affinity to water absorption that increases its plasticity range,is widely usedin geotechnical, environmental studies compared to another two common clay minerals(Franciscaet al.,2010). It is the main constituting part of bentonite.

Soil compaction and inflation does not change linearly or constantly and depends on the applied stress and current soil conditionwhichby changing the stress, these parameters will also change(Atkinson.2007). Another clay soil stabilization material is the rice husk ash which by increasing the level of this material, the decrease in the volume compressibility coefficientof these soils could be seen(Jain et al.,2013)

Calculating the settlement is among the first phases in the design of structures. Calculating the settlementis further manifested when the soil needs to be modified. The coefficient of volume compressibility (m_v) can help to obtain the settlement.

$$H = M_v \times H_0 \times \qquad\qquad (1)$$

According to Eq. (1), the consolidation settlement can be calculated using the volume compressibility coefficient. Given that in this study, the values of H_0 and   have been set as fixed in all samples, the consolidation settlement could be obtained by calculating m_v at any (wet and dry) mixing and a good comparison could be made on the effects of mixing methods.

In a study on atype of peat having high settlement,moderate to low permeability and stabilized by cement, a consolidation test was done and the initial moisture content and void ratio was 668 and 9.33%, respectively. Comparing the results, the following can be noted: the coefficient of volume compressibility for the disturbed peatranges from 0.665 to 7.807 m^2/MN, but after the stabilization, the range is reduced to 0.079 to 0.042 m^2/MN, representing the effect ofstabilizing the peat with cement(Haji ali et al., 2010)

In a study on the peat soil of Orumieh (Iran) it was observed that for a fixed vertical effective stress, the volume compressibility is increased by increasing the organic matter contents. On the other hand, the compressibility of the soil is reduced by increasing the vertical effective stress and the reduction level for soils with more organic matter content and is found to be higher(Sayadian et al., 2011)

In another study on a clay soil known as CL in the unified classification system, it was concluded that increasingthe moisture content of samples from 27.20 to 51%, the coefficient of compressibility is also increased, which it indicates the increased compressibility of the samples as a result of increasingthe sample moistures, but the rangeis declining by increasing the vertical stress(Abasy et al., 2004).

In another study carried out on a clay with high plasticity and stabilized with the rice husk ash, the results showed that in the samples with a fixed level of stabilizer, increasing the vertical effective stress reduces the coefficient of volume compressibility, but by increasing the stabilizer, a clear trend in variations of this coefficient could not be seen, so that in some cases, this coefficient is increased and in some other cases, it is reduced(Jain et al .,2013).

In another study on a peat stabilized with concrete columns, the result obtained from this study showed that by increasing the pressure and level of the stabilizer, the coefficient of compressibility is declined(Setyo et al .,2002)

Furthermore, in a study on the impact of adding lime and rice husk ash on clay, it was found that increasing the stabilizer added to the clay may reduce the compressibility of the soil (Kazemian et al.,2009).

In the study conducted on the CL clay stabilized with rice husk ash in which the samples were prepared at three different moisture content (optimum moisture, 2% less than the optimum

moisture and 2% higher than the optimum moisture content), the optimum moisture range of the study is from 16 to 24%. The stabilizers used in this study were first passed the sieve No. 200, then they added to the considered soil in different levels. The results obtained from this research showed that the variations in the coefficients of compressibility of samples were more regular than the increased pressure in the samples prepared in the optimum and less than optimum moisture contents, so that increasingthestabilizerscan reduce the coefficient of volume compressibility, but by increasing themoisture content and exceeding the optimum moisture,no regular trendinthe coefficient changes can be seen in respect to the pressure(Adrian et al .,2011).

In another study on the CL and ML soils stabilized with cement, some soil samples were mixed with different levels of cement and then, they weretreated in 7, 14 and 21 days. It was concluded that as the stabilizersare increased, the coefficient of compressibility is dropped(Firas et al .,2011).

In another study carried out on the sodium and calcium bentonite soils mixed with silt, as part of the results emphasizes the highly dependent coefficient of volume compressibility to the applied load, and the higher the value of plasticity index IP, the more the coefficient of volume compressibility(Paramita Das,2015).

MATERIALS AND METHODS

The soil that was used in this study consisted of a mixture of 60% commercial bentonite (wl = 255%, Ip = 122%) used in drilling and 40% local wind blown sand (D10 = 0.074 mm, D60 = 0.2 mm, CU =2.4). The reason for using sand in the mixture is to reduce the time for primary consolidation of soil samples in the laboratory. The time for 90% consolidation (t90) untreated mixture varied between 30 and 600 min depending on the stress level. The end of primary consolidation for untreated bentonite without sand was not measured. Liquid limit and plastic limit of the soil mixture were 132 and 70% respectively. All the samples prepared with initial water content equal to the base soil liquid limit. The reason for selecting initial water content of all samples as the liquid limit of the mixture tend to have similar initial condition.

Another advantage of this combination is having a soil which in the Unified Classification System (USCS) is named CH, and the reason to use wind blown sand in this combination is decreasing the liquid limit of bentonite and bringing the liquid limit of the soil to the desired level, another reason to use wind blown sand is the availability of this wind blown sand and the fact that it is very cheap.

It is realized that in practice,during wet method application higher initial water content than during dry method application before setting time may be achieved. The cement that was used was type II cement manufactured in Karoon factory in Khuzestan.

2.1. Sample preparation

All specimens were prepared in the pvc molds of 5 cm in diameter and 16 cm in height.

After curing of samples, specimens for consolidation tests were cut and prepared from original cured samples using wire saw (diameter= 5 cm height=3 cm). In order to eliminate any sample disturbance during the removal of the samples from the molds, the molds were cut longitudinally into two halves and the two halves were then taped back together stiffly before placing the soil samples into them. Before placing the soil samples into the molds, the bottom of the molds were sealed tightly with a thick plastic. In order to prevent the soil from sticking to the molds a plastic lining was placed inside the molds.

The soil samples after proper mixing were placed into the molds with spatula in four stages. In each stage, after placing the soil into the mold to a height of about 4 cm, the mold was tapped 40 times against the surface of the table from a height of about 10 cm. This was done in order to ensure removal of any air bubbletrapped within the samples. The samples were then sealed and wrapped with a thick plastic and placed into a water tab for curingAfter the curing period, each consolidation test specimen was cutand prepared from the original sample using wire saw. (Pakbaz et al ., 2015)

2.2. Dry mixing method

In dry mixing method 2, 4, 6, 8 and 10% by drymass of cement (in equal amount)were added dry to the soil samples prepared at thewater content of 132% equal to the liquid limit of the soil and mixed thoroughly with spatula for 10 min before the soil mixture was placed into the mold. The samples were then cured for 7, 14 and 28 days before testing . For each group one consolidation test on the soil samplewithout admixture was also performed for comparison purposes. (Pakbaz et al ., 2015)

2.3. Wet mixing method

In wet mixing method cement (equal amount) in slurry form were added to the already wet soil in percentages of 2,4,6,8 and 10 by dry mass. The initial water content of mixtures were 132% the same as those for dry method. The samples for this series were also cured for the periods of 7, 14 and 28 days before testing.

In the wet method, the ratio of 1 to 3 of water-cement is used, a small amount of the primary water which must be added to the sample in order to make it reach the desired moisture, is deducted and added to the cement in order to make the cement slurry. (Pakbaz et al ., 2015)

3. Results and discussion

After doing the consolidation test(ASTM- D-2435:1990) and calculating the coefficient of volume compressibility for 1 and 2kg/cm^2 pressure, the values of volume compressibility coefficient were plotted versus the different treatment time stepsof 7, 14 and 28 days for this study to better control and evaluate the changes in the behavior ofstabilizers and the mixture method, and the results are shown in Figures 3 and 4. The coefficient of volume compressibility for the initial soil is shown in Table 1.

Table 1. Specifications of compressibility coefficient of initial soil

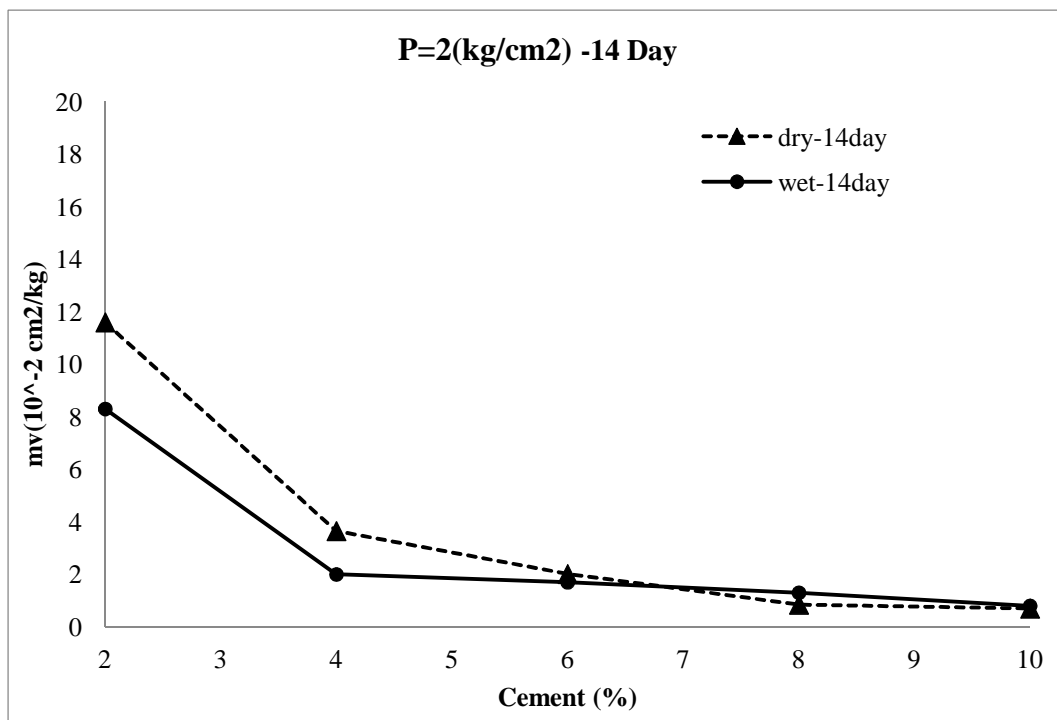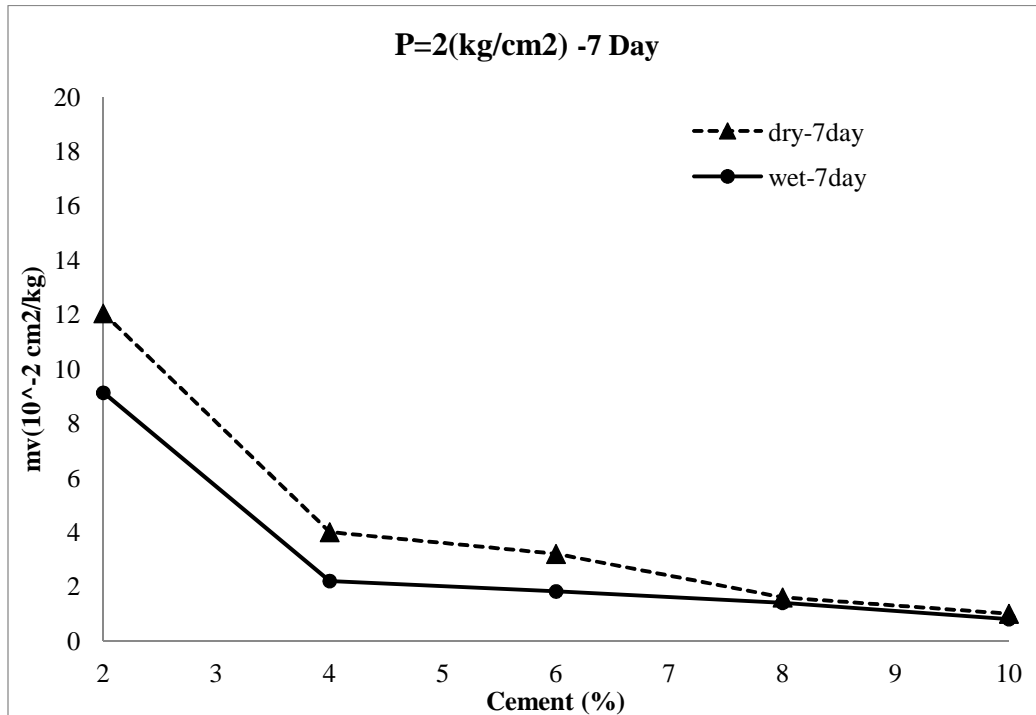| P(kg/cm2)	mv(10^-2 cm2/kg)
1	21
2	15
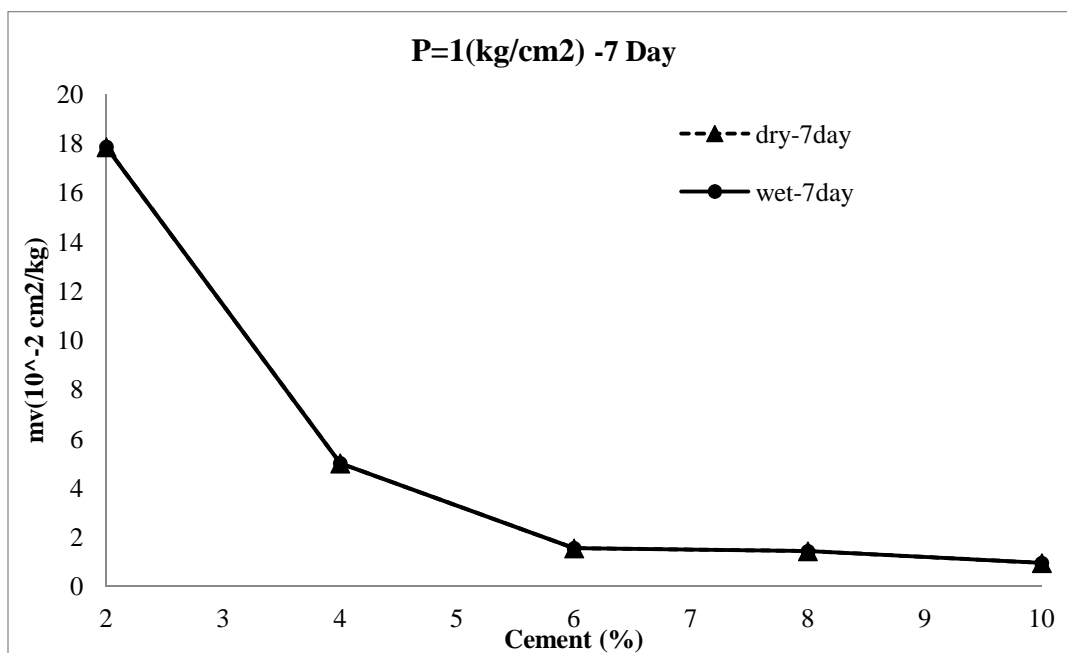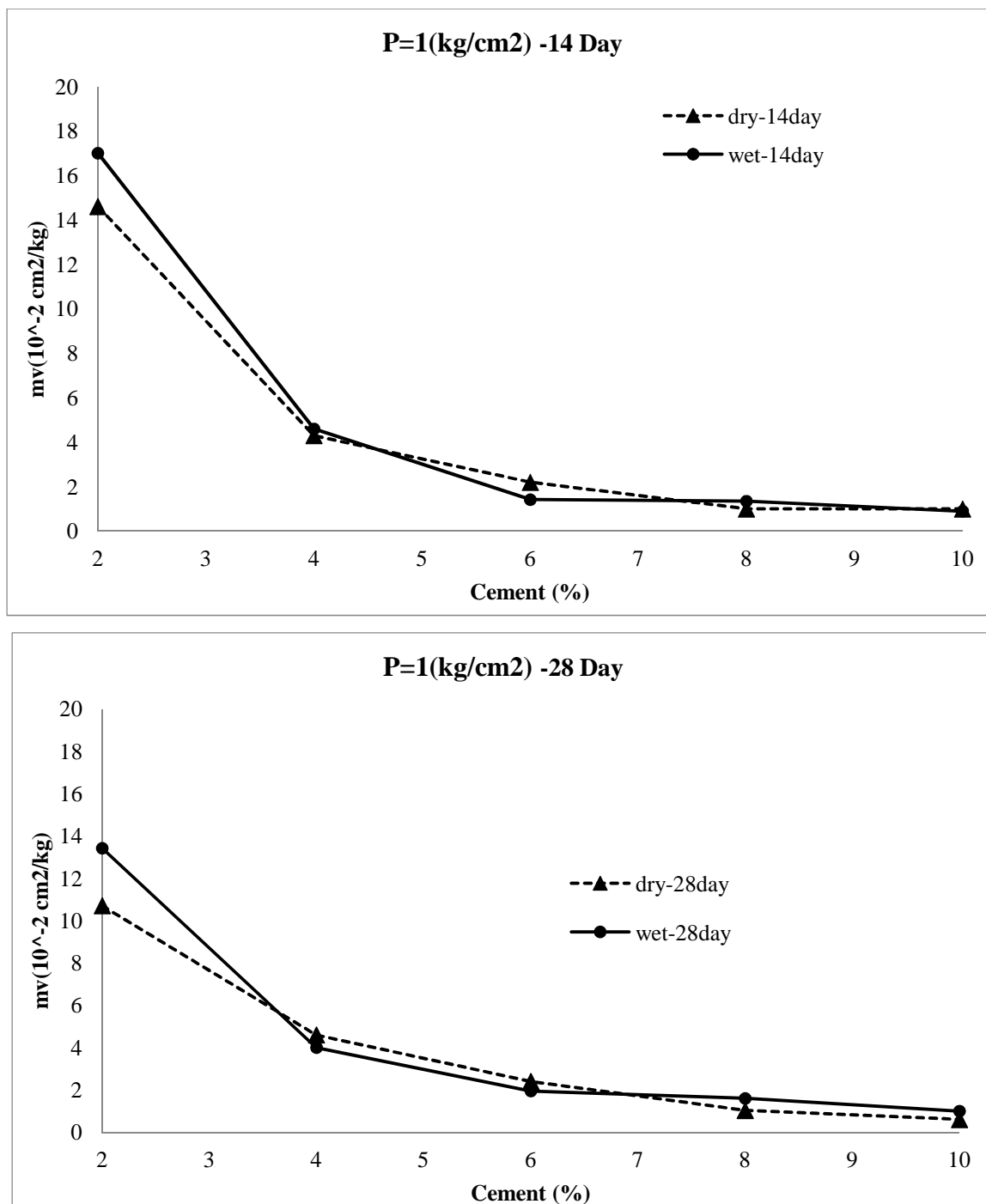
Fig.3. Coefficient of volume compressibility for 7, 14 and 28-day treatments versusadditive levels for 1 kg/cm^2 pressure
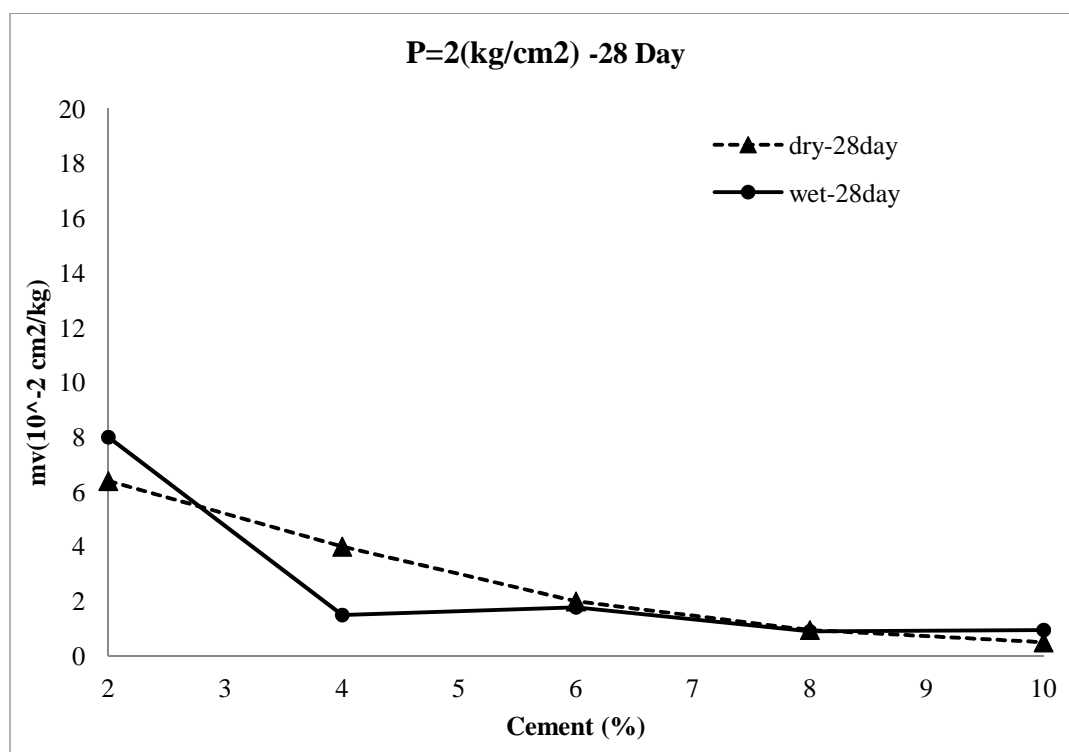
According to the results from the consolidation test in the pressure of 1 kg/cm^2, the dry mixing method showed better results in reducing the coefficient of compressibility than the wet method, so that by adding 2% cement in the dry method 28 days after the mixing period, a 30% decline in the coefficient of compressibility could be seen with respect to the wet method, though by increasing the stabilizer levels, the difference is declining, but given that

reducing the coefficient of volume compressibility impacts directly on the reduction settlement, therefore, the impact on reducing this coefficient with regard to the type of mixing can be observed.

- lowest volume compressibility coefficient in dry mixing method for 10% cement additive is about 0.6 (10^{-2} cm^2/kg).

P=2(kg/cm2) -7 Day

P=2(kg/cm2) -14 Day

Fig.4. Variations of volume compressibility coefficient for 7, 14 and 28-day treatments versus additive levels for 2 kg/cm^2 pressure

According to the results of consolidation tests in the pressure of 2 kg/cm^2, different behavior could be seen in respect to 1 kg/cm^2 pressure, so that at the beginning of treatment, samples prepared by the wet method showed less volume compressibility coefficient, but by increasing the treatment time and after 28 days of treatment, in general, the samples prepared by the dry method have lower levels in terms of this parameter.

Generally, it can be said that the dry mixture outperforms the samples prepared by the wet method in terms of reducing the coefficient of volume compressibility. The lowest value of volume compressibility coefficient in dry mixing method for 10% added cement is about 0.55 (10^{-2} cm^2/kg).

CONCLUSION

In previous studies, as mentioned before like the one conducted on bentonite soil (Paramita Das, 2015), by increase of effective pressure on the stabilized sample, volume compressibility coefficient decreases. As in this study, bentonite clay with high humidity was studied, the results confirmed this trend. The method of mixture and its impact on volume compressibility coefficient has been neglected. In another study (Adrian .O Eberemu .2011) on clay with rice husk ash in low humidity (16-24%), it was revealed the irregular behavior of

this material in high percentages while in this study, by application of high-humidity cement (about 132%), we can see regular behavior of this stabilizer material. More importantly, different results can be observed in volume compressibility coefficient depending on the method of mixing. Another study (Jain et al., 2013) which investigated the impact of rice husk ash on high-plasticity clay, a definite trend can't be observed in compressible coefficient by increase of stabilizer percentage; while, by application of cement for stabilization of bentonite soil in high humidity, increase of cement percentage resulted in decrease of compressibility coefficient in both dry and wet samples. However, the results for method of mixing are different. This shows that for obtaining the optimized method for stabilization, in addition to application of different stabilizers, the method of mixing should also be considered.

In general, according to the obtained results, it can be stated that:

- the wet and dry mixing methods exhibit significanteffectson reducing the coefficient of compressibility, so that by adding 2% cement in the dry method after 28 days and in the pressure of 2 kg/cm^2, a 50% decline in the coefficient of compressibility could be seen.

-the samples prepared bythe dry method using cement outperform in terms of reducing the coefficient of volume compressibility.

-the effects of mixing method for lower levels is more visible than those for higher levels, so that by adding 2% stabilizer in the dry method 28 days after the treatmentin the pressure of 1 kg/cm^2, a 30% more decline in the coefficient of compressibility could be seen than the wet method, but by increasing the stabilizer levels, the difference between the mixing methods even reaches about 10%for 10% added cement.

-The lowest value of volume compressibility coefficient in dry mixing method for 10% added cement is about 0.55 (10^{-2} cm^2/kg) after 28 days of treatment and inthe pressure of 2 kg/cm^2.

-One of the important results of this study is that in addition to different percentage of stabilizer materials and their impacts on mechanical and hydraulic parameters of soil, the mixing method should also be closely investigated to reach the optimized method.

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