European Online Journal of Natural and Social Sciences 2014; www.european-science.com
Vol.3, No.3 Special Issue on Environmental, Agricultural, and Energy Science
ISSN 1805-3602

The Effect of Mixing Method on the Permeability Changes of Cement—Bentonite

Mohsen Farzi[1*], Javad Ahadian[2]
[1]Islamic Azad University, Iran
[2]School of Water Sciences, Shahid Chamran University
*Email: Mohsen.Farzi@gmail.com

Abstract

In researches conducted on various materials to stabilize soils, different factors have been investigated but none of the researches conducted has focused on method of incorporation or mixing. Hence, in this study the effect of cement—bentonite incorporation method with both wet and dry methods in 14.7 and 28 curing time will be studied to show its effect on the permeability coefficient changes. The results obtained in this study showed that the effect of incorporation is visible in all samples, so that most of the samples, which were prepared dry, the slope of their e-Log k curve is less than the wet samples which shows the sensitivity of wet samples to dry samples due to permeability coefficient changes .The results of this study can be used in preparing the underground waste storage tanks.

Keywords: method of incorporation, consolidation, cement, permeability, landfill

Introduction

The permeability coefficient is an important factor in the field of hydrology, this parameter can be used in groundwater management, supporting and maintaining groundwater and groundwater source management, Therefore the behavior of stabilized soils in terms of permeability of water in soil is significantly important. If the mixed stabilized soil has high permeability to water, where it is used for excavation or construction projects, the movement of water in the soil increases. Scrolling wheel and continuous loading and unloading of the traffic in the soil will have a performance similar to the pump .The movement of water in soil breaks the interlocks between stabilized soil seeds and resistance to speed decreases. If there is water, silicates and calcium aluminates of cement form hydrated compounds that in itself create hardened cement paste with high strength, which retain in themselves the materials mixed with cement. The hydration reaction, due to moving from cement particle surface, is slow and even the center of the particle may not get hydrated, Therefore the hydration process is constantly reducing which shows the reason for rapid reduction in the strength acquisition process by time in the materials stabilized with cement. Formation or lack of bond between hardened cement structure and particles of stabilized materials depend on chemical composition of the materials (Castelbaum and Shackelford, 2009). In addition to silicates and hydrated calcium aluminates, calcium hydroxide is another product of hydration of Portland cement that if pozzolanic materials were present in the stabilized soil, it could react with them and form additional cemented materials.

Several researches have indicated that cemented materials, taken during the process of soil-cement hardening, are different from the cement hardened paste in terms of composition. In these types of compositions, strong bases form during the cement hydration, small amounts of silica and surface clay alumina are resolved and then the present calcium ions react with silica and solvent alumina and form cemented materials (Consoli et al, 2010; Fred and Maureen, 2012). Consoli et. al conducted a research on the effect of water -cement ratio on the soil- bentonite -cement composition. It showed that by decreasing the ratio of water to cement, permeability coefficient also decreases. Of course, this research reached this conclusion that if cement is added to the soil-bentonite composition, it leads to an increase in permeability coefficient, one of the reasons for these behaviors may be the change in soil- bentonite structure and another reason for this could be very small pores in soil-bentonite structure leading to micro passageways for water passage (Giti Pour and Beayd Hendi, 2004)

In another research which was conducted by Maher et. al, concerning the effect of cement on soil-cement composition, was implemented on Atterberg limits, the result was that if the liquid limit of natural soil is more than 40%, the effect of adding cement in decreasing the liquid limit of soil is lower, but if the liquid limit is less than 40%, more effect of adding cement will be seen (Harty and Thompson, 1973).

In another research which was conducted by Onitsuka and Kouno on a sample of clay with characteristics of liquid and paste limit of 133% and 71.4% which has a close similarity with the soil under study, one of the results of this research is the slope of porosity ratio changes to permeability coefficient which decreases by an increase in lime percentage (Klug and Alexander,1974). In a research that examined the effect of clay content in sandy and clay soils on permeability coefficient, the result was that there is a direct relationship between the present clay content in soil composition and permeability coefficient, in a way that with an increase in clay, permeability coefficient decreases (Maher et al, 2005). In another research studying the effect of tree localization and root formation region on bulkheads and dykes on permeability coefficient done by numerical method, The result was that in the root regions of trees, trees have a significant influence on hydraulic gradient and permeability coefficient (Onitsuka and Kouno, 2001).

In another research conducted on the effect of leachate on permeability coefficient and bentonite clay structures showed that with a 4 to 6 percent increase of bentonite to sand soil with bad aggregation (SP) prepared the permeability coefficient value according to the standards of America to create a levee wall around the landfill (ASTM, 1990).Another study conducted on the effect of bentonite slurry mixed with sand on permeability coefficient showed that while sample characteristics were in such a way that the range of porosity ratio changes were between 0.67 to 3.94, the amount of added bentonite in volume was between the range of 0.61 to 7.65. The effective contribution of bentonite slurry composition in reducing permeability coefficient is seen (Transport Road Research Board, 1987).In another research which was conducted on the effect of adding salt water to crushed bentonite on permeability coefficient, the result was that if the dry density of bentonite is low, permeability coefficient increases by adding water-soluble salts.

In this research consolidation test was used to obtain soil parameters in order to calculate permeability. In this test, a sample of soil which is laterally enclosed is loaded axially with total stress steps, which these stresses start from 0.25 kg/ cm2 and continue till 4 kg/ cm2. Each loading step is kept until additional pore water pressure is fully amortized. During consolidation process, the amount of sample deposition is read and this information is used to determine the relationship between effective stress and pores ratio or strain. The consolidation process is generally done on the grain soil virgin samples which in nature are deposited in water environment. But, this experiment is conductible on compacted soils or virgin samples which have been formed during such processes as weathering or chemical changes. The results of this study are significantly influenced by sample disturbance and so, adequate sample preparation is necessary for reducing the disturbance.

Materials and Methods

The desired soil is prepared by mixing 60% of bentonite and 40% of wind sand, the reason for using this compound primarily is this issue that there was more control on the factors affecting permeability coefficient. The permeability coefficients depend on several factors including the initial porosity ratio, the amount of clay content present in the composition, position of the desired soil in the ground, the history of loading and unloading, the constituent minerals, the quality of the constituent minerals, the soil exposure, and so on. 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 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 sand is the availability of this sand and the fact that it is very cheap.The soil profile under investigation is shown in table (1).

Table 1. Eprofil soil primary.

LL	PL	Porosity ratio		
		days 7	**days 14**	28 days
132**%**	70**%**	5.33	4.64	4.3

Due to this fact that liquid limit of the soil was %132 and all the samples are prepared in liquid limit, so due to the high sensitivity of bentonite to absorbing moisture, in order to prepare all the samples in the desired moisture without any lapse, first, we pass bentonite, wind sand and cement (as stabilizers) through a size 40 sieve and then we put it in a hothouse for about 24 hours to completely lose its moisture, then we bring them out and after cooling, by adding water we give the desired moisture percentage to the compound and in order to have a homogeneous mix, we blend it for about 15 to 30 minutes and make sure that the soil has a unified form. After the primary soil was prepared, we add type 2 cement in weights of 2,4,6,8,10 to it and blend it for about 15 to 30 minutes to have a unified mixture. In this research, two methods of wet and dry were used to prepare the samples. The dry method is in this way that after mixing the primary soil, with respect to the mentioned percentages, dried cement is added and then the sample is blended. 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. Then we add the two acquired cement slurry to the unified soil mixture, after that until getting to the unified mixture again, the moisture of the two samples from the two cement percentages is kept constant.

The mold that is used in this research is of PVC and with 12 cm height and a diameter of 5.5 cm which a talc has been placed within it not to stick to the mold after the soil was placed within the mold and to be brought out easily. The reason for using these dimensions in selecting the mold is that the device mold has been consolidated which according to 6932 standard recommendation of Institute of standards and industrial research of Iran, the minimum sample diameter to height ratio should be two and a half. Therefore, the consolidation device mold has a diameter of 5 cm and a height of 2 cm.

Here, mentioning this point is necessary, because, in this research, optimum moisture content is not used. Therefore, samples are not as dense in the mold, but with the help of a process which includes first adding 4 cm of the mixture into a mold and then releasing the mold from a height of 10 cm on the ground and repeating the process 40 to 50 times to make sure that there are no pores left, this cycle continues until the mold is complete. The prepared samples by wet and dry method in the above mentioned was all together 33 which 11 (were wet and dry, 5 each and the one left in the form of soil without any fixative materials) of the samples were cured for about 7 days and 11 other samples for 14 days and the remaining 11 samples for about 28 days were cured. In the above mentioned time frame of curing, the samples were put in sealed molds in order to make sure the moisture exchange with the environment.

After the curing session was over, the mold is removed from water. First, dry it completely, and with the help of a surgery razor, cut the adhesive around the mold and slowly extract the sample from the mold and with the help of a jigsaw, cut 3 cm of it and put it in a nylon and put the obtained sample based on ASTM- D-2435 standard recommandations under consolidation test. In the primary information analysis of consolidation test, reflow time method has been used (Shevnin et al, 2007).

As was expressed in the descriptions above, to obtain soil parameters to calculate permeability coefficient, consolidation tests have been used, with the information obtained from the consolidation test, e-Logp chart was outlined and then with the help of the information obtained, the value of Mv and Cv and permeability coefficient in each step of loading is calculated and to get the slope graph of permeability coefficient versus the porosity ratio, the e-Logk diagram is drawn, and then the best fitting between the points within the chart is done and the slope of the graph can be achieved with this process.

Results

After testing the consolidation and gaining cavity ratio changes process and gaining other consolidation parameters, permeability coefficient is calculated by equation (1) and permeability coefficient changes chart versus cavity ratio changes is drawn. In equation number 1, consolidation coefficient is calculated by t 50. In figures of (1) to (4) charts are shown.

$$K = cv \times \gamma \times mv$$

In Equation number (1), the parameters from left to right include permeability coefficient, consolidation coefficient, the specific gravity of the water and the coefficient of volumetric compression capabilities.

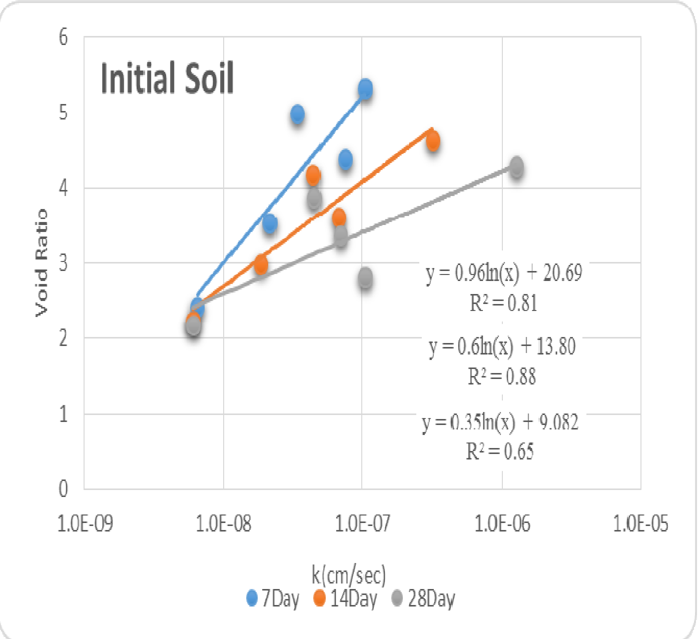

Figure 1. Diagram of permeability coefficient versus porosity ratio for the original soil sample

According to figure(1), the point to mention is that slope decrease of e-Logk diagram is related to time increase, this point indicates that the decrease in ranges of permeability coefficient changes is associated with time, due to this fact that in samples under experimentation which the results are shown in figure(1) no fixative was used, but in the beginning of the experiment, substantial difference exists between 7 days sample and 28 days sample, in a way that the 28 days sample in the beginning of the experiment has 10 times more permeability than the 7 days sample, but at the end of the experiment, after reducing the amount of cavity ratio, the value of permeability in all the sample at all times of curing roughly will become the same value. Another reason that we can mention for the increase in the ranges of permeability coefficient changes is that when the sample is in the curing period, clay particles, by sticking to each other, form bigger particles, but the structure of these particles, due to samples being made in wet liquid limit, does not have high strength, which this leads to an increase in permeability value in the beginning of the experiment, but as mentioned before, due to the lack of sufficient strength, in consolidation test, after loading, the consolidation of the structures will break and the soil will be more dense by a decrease in porosity ratio value and so, after the experiment, the permeability coefficient value decreases.

Table 2. Permeability Changes Before and After the Loading for 7 Days Samples

Percent	Dry Mix-7Day	
	K in The 0.25 kg/cm^2	K in The 4 kg/cm^2
0	1.03E-07	6.40E-09
2	3.28E-07	1.11E-08
4	1.24E-07	2.82E-08
6	8.10E-08	5.50E-08
8	1.10E-07	2.55E-08
10	5.10E-08	1.57E-08
Percent	Wet Mix-7Day	
	K in The 0.25 kg/cm^2	K in The 4 kg/cm^2
0	1.03E-07	6.40E-09
2	1.50E-07	1.10E-08
4	2.90E-08	4.10E-08
6	4.10E-08	9.50E-08
8	9.50E-08	3.40E-08
10	9.80E-08	1.34E-08

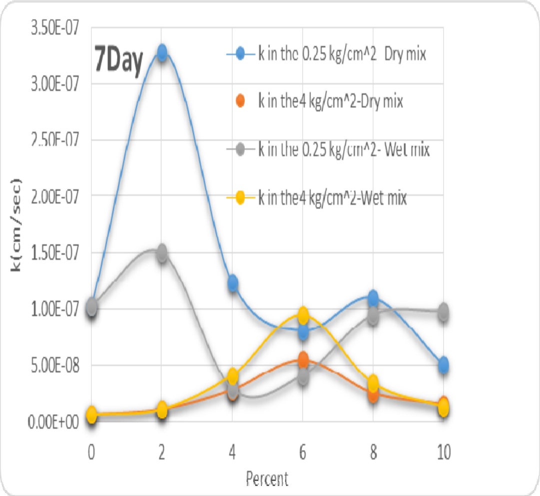

Figure 2. Chart of the permeability coefficient in the beginning and end of loading vs. the percentage of fixative materials for 7 days samples

According to table and figure number 2, in which permeability changes in the beginning and end of loading in 7 days samples are given, we can conclude that in all samples, except for samples of 4 and 6 percentage which were prepared wet, permeability coefficient reduced with loading increase, but the value of permeability coefficient reduction in samples which were prepared dry is more than the samples which were prepared wet, in a way that the maximum difference between permeability coefficient changes is seen in the 6 percent sample, this value is 3 times more. The least permeability coefficient is seen at the end of 10 percent sample loading which is seen dry.

Table 3. Chart of the Permeability Coefficient In The Beginning And End Of Loading Vs. The Percentage of Fixative Materials for 14 Days Samples

Percent	Dry Mix-14Day	
	K in The 0.25 kg/cm^2	K in The 4 kg/cm^2
0	3.20E-07	6.00E-09
2	4.25E-07	1.10E-08
4	6.90E-07	2.12E-08
6	3.10E-07	4.23E-08
8	3.60E-07	8.10E-08
10	4.30E-08	2.84E-08
Percent	Wet Mix-14Day	
	K in The 0.25 kg/cm^2	K in The 4 kg/cm^2
0	3.20E-07	6.00E-09
2	3.40E-07	1.20E-08
4	1.30E-07	2.90E-08
6	8.20E-08	5.20E-08
8	1.10E-07	2.60E-08
10	5.15E-08	1.60E-08

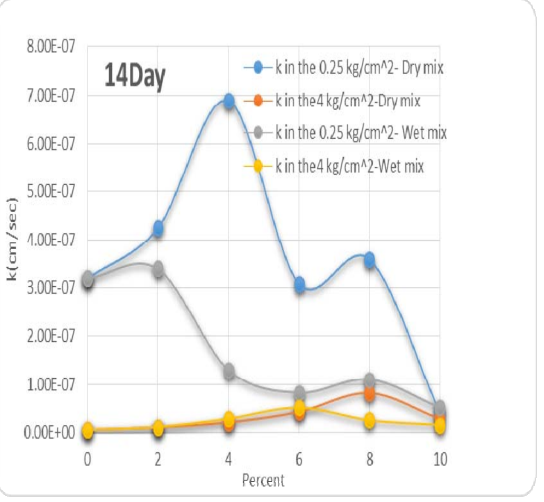

Figure 3. Graphs of Permeability Coefficient Before And after Loading Versus the Percentage Of The Fixative Materials For 14 Days Samples

According to Figure 3 and Table 3 in which permeability changes in the beginning and end of loading in 14 days samples is given, we can conclude that in the begging of loading those samples which were prepared dry, they have less permeability coefficient than those which were prepared wet, but at the end of loading the behavior of these two mixes become alike and no significant difference in respect to the value of permeability coefficient is not seen in them. The amount of permeability coefficient changes in samples which were prepared dry in all of the percentages, except in 10 percent sample, were more than those which were prepared wet.

Table 4. Permeability Changes in the Beginning and End of Loading for 28 Days Samples

Percent	Dry Mix-28Day	
	K in The 0.25 kg/cm^2	K in The 4 kg/cm^2
0	1.26E-06	6.00E-09
2	2.00E-07	2.60E-08
4	7.70E-08	3.80E-08
6	5.00E-08	8.50E-08
8	9.70E-08	3.80E-08
10	3.30E-08	2.00E-08
Percent	Wet Mix-28Day	
	K in The 0.25 kg/cm^2	K in The 4 kg/cm^2
0	1.26E-06	6.00E-09
2	1.45E-07	1.62E-08
4	1.40E-07	3.30E-08
6	8.60E-08	5.10E-08
8	8.60E-08	3.00E-08
10	4.10E-08	2.90E-08

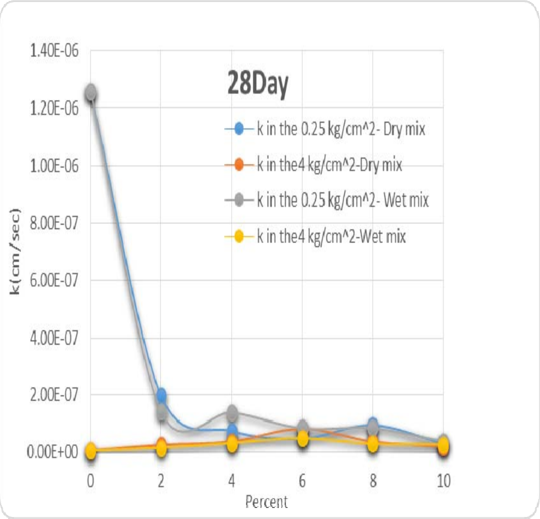

Figure 4. Chart of the permeability coefficient in the beginning and end of loading vs. the percentage of fixative materials for 28 days samples

According to figure(4) and table (4) in which permeability coefficient changes in the beginning and end of loading for 28 days samples is given, we can conclude that in all the percentages of fixative materials and in all the sample, the value of permeability decreases at the end of loading, another point to be expressed here of this information is this issue that the range of permeability coefficient changes compared to samples tested in 14 and 7 time frames has got very lower and by increasing the amount of fixative material, this range gets even smaller, in the study which was conducted on permeability coefficients, resulted in the fact that the lowest permeability coefficient obtained from the 10 percent sample which was prepared by the dry method, but at the end of loading this sample is 2 percent dry, which has the lowest value among the samples. According to permeability changes in both methods of incorporation, we can conclude that samples which were prepared wet have less permeability coefficient changes than the dry samples.

Conclusion

In the case of all the samples, it can be concludes that:

• The slope of the e-Log k curve with an increase in cement percentage is reduced in all samples.

• With an increase in the percentage of cement, permeability coefficient changes are placed in a smaller interval.

• The lowest range of change is seen in the 10% sample prepared by wetting method in the curing period of 28 days.

• The impact of incorporation method in all the samples is visible in such a way that in most of the samples which were prepared dry, the slope of e-Logk curve is less than those which were prepared wet, but in respect to permeability coefficient they are more than the dry samples.

• The lowest value of the permeability coefficient in 2 percent and dry sample with curing time of 14 days meaning 1.1 E -8 has occurred at the end of loading.

• The range of permeability coefficient changes decreases with an increase in curing time in both of the incorporations.

- The maximum coefficient of permeability changes between all the samples provided in wet and dry methods can be seen in 6% and 14 days samples which this amount of changes in the dry sample is 9 times more than the wet sample.
- According to the results of this research and the influence of incorporation on the soil properties under study, so it is recommended that researches with the main purpose of reaching specific permeability coefficient, pay more attention to incorporation.

References

ASTM- D-2435, 1990. Standard Test Method for One – Dimensional Consolidation Properties of Soils.

Castelbaum, D. & Shackelford, C. (2009). Hydraulic Conductivity of Bentonite Slurry Mixed Sands. J. Geotech. Geoenviron. Eng., 135(12), 1941–1956

Consoli N.C,,Karla S., Heineck,J.,Antonio ,& H.,Carraro.(2010). Portland Cement Stabilization of Soil-Bentonite for Vertical Cutoff Walls Against Piesel oil Contaminant.Geotech Geol Eng,28,361-371

Fred T. T., & Maureen K. (2012). Corcoran Effect OF Woody Vegetation On Hydraulic Conductivity at Various Levee Systems Using Numerical Models. XIX International Conference on Water Resources CMWR, University of Illinois at Urbana-Champaign June 17-22.

Giti Pour ,S.,& Nabi Beayd Hendi ,Gh. (2004). The Effect of leachate on the permeability coefficient of bentonite clays, Journal of Ecology33,15-9. Harty,J.R.& Thompson,M.R.(1973).Lime Reactivity of Tropical and Sugtropical Soils,Highway Research Record 442,102-112

Klug,H.P.& Alexander,LE.(1974). X-Ray Diffraction Procedures for Polycrystalline and Amorphous Materials.3rd.printing,John Wilev & Sons Inc.,New York.

Maher ,A., Najm ,H., Boile ,M.,(2005). Solidification Stabilization of Soft River Sediments Using Deep Soil Mixing, Federal Highway Administration,FHWA-NJ-2005-028

Onitsuka ,K., & Kouno ,M. (2001). Investigation on Mcrostructure and Strength of Lime and Cement Stabilized Ariake Clay, Report of the Faculty of Sicience and Engineering,Saga University,30,1.

Shevnin, V., Delgado-Rodríguez, O., & Mousatov ,A. (2006). Estimation of hydraulic conductivity on clay content in soil determined from resistivity data, Geofísica International, 45 (3), 195-207.

Transport Road Research Board,(1987)Lime Stabilization Reactions Properties and Construction, State of Art Report 5,Washington D.C

Won-Jin Cho, Jin Seop Kim & Jong Won Choi. (2011). Influence of Water Salinity on the Hydraulic Conductivity of Compacted Bentonite, J. of the Korean Radioactive Waste Society 9(4), 199-206.