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THE INVESTIGATION OF SALINITY EFFECTS ON BEHAVIORAL PARAMETERS OF FINE-GRAINED SOILS

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ABSTRACT

The present paper aims at investigating the effect of water salinity on engineering properties of fine-grain soil. Saline water used in this study was obtained from half saline water of Ajichay River (with TDS more than 1877 ppm) and saline branch of Korchay (with TDS more than 97000 ppm) located in Northwestern of Iran. Fine-grain soil studied is from Korchay dam core. Due to the high hardness of water in this river, the feasibility of using saline water as the water required in clay core of the dam process has been studied in this research. The experiments were performed including Atterberg limits, standard compaction, consolidation, direct shear and dispersion. These tests were performed by using distilled water, half saline water and saline water on reservoir materials. Due to low percentage of clay minerals in the soil, the changes in engineering soil properties as salinity increases are negligible. However, the use of saline water reduces Atterberg limits, compression index (Cc), swell index (Cs), coefficient of compressibility (av), coefficient of volume compressibility (mv) and causes slight increase in soil shear strength parameters. Despite the high percentage of sodium in half saline and saline water, dispersion degree of soil is ND2 in pinhole test.

INTRODUCTION

Characteristics of the water used in some of the construction activities such as concrete has been clearly presented by regulations and international standards. However, there is no specific standard about characteristics of water used in structures associated with soil such as construction of earthen dam. As opposed to soil structures, therefore concrete structure are not affected by the water in contact with them, effects of pore water characteristics on body materials of these dams especially fine grained materials of core may be significant in special conditions.
Generally, geotechnical behavior of fine grain soils depends on chemistry of pore fluid since they have a high percentage of clay minerals. However, still the drinking water is usually used in order to supply the needed moisture of soil in the laboratory. This makes it incorrect to interpret the engineering properties when specific water is used in construction. So when non-drinking water in situ is used in order to supply the needed moisture in processing of earthen dam core, behavioral characterization of materials should be considered with the same water.
This paper, therefore, studied the effect of water salinity on geotechnical characteristics of fine grained soil. The case study of this research has been done on Ajichay project in Northwestern Iran. The project consists of a main dam named Vaniar that is going to be constructed on Ajichay River. Since the water is saline and hard in some branches of this river, a number of earthen dams are going to be constructed to transfer the saline water to adjacent area therefore prevent the saline water from entering to reservoir of Vaniar dam. It is done in order to improve the quality of water in main reservoir in the upstream of the river. Korchay dam with clay core is one of dams which is constructed on branch with same name to prevent saline water enter to Vaniar reservoir. Since there is a large distance between dam site and the location of fresh water, it is suggested that the processing of clay core of dam be done using the same saline water. This study, therefore, tried to investigate the unknown effects of water with high hardness and TDS (97000 ppm) on caly core. In order to do so, water of Korchay branch was used as saline water and water of Ajichay River was used as half saline water and in laboratory, the effect of three types of saline, half saline and distilled water on geotechnical properties of fine grain soil used in Korchay dam core, has been investigated.

REVIEW OF STUDIES

Atterberg limits are one of the tests that are done on dam construction materials. Atterberg limits can be useful indicators of clay behavior. The liquid limit and plastic limits of a type of soil can be correlated with various engineering properties, such as permeability, shrinking and swelling behavior, shear strength, and compressibility of the soil. Consequently if the consistency limits are determined, some other geotechnical properties whose determination may take a long time can be estimated easily with an acceptable accuracy. In addition the evolution of consistency limits provides some very basic mechanical data about the soil and also gives a first insight into the chemical reactivity of clays (Arasan and Yetimoglu, 2008; Shariatmadari et al., 2011).

Alamdar, 1991; Arasan and Yetimoglu, 2008; Mahasneh, 2004; Mansour et al., 2008; Shariatmadari et al., 2011 and Yukselen-Aksoy et al, 2008 have studied the effect of salt solutions on the consistency limits of soil. The results have shown the liquid limit and plastic limit of soil decrease as the salinity of pore fluid increases. Sivapullaiah and Manju, 2005 have investigated the effect of NaOH solution on some geotechnical properties of the soil with low plasticity (LL=38%). The results of their studies have shown that the liquid limit of the soil increases as NaOH solution concentration increases. The reason behind that is the formation of a new swelling compound created by reaction of alkali solution with clay. The effect of four salt solutions including NH_4Cl, KCl, $CuSO_4$ and $FeSO_4$ on consistency limits of CL clay and CH clay have been investigated by Arasan and Yetimoglu, 2008. Their experimental results indicate the liquid limit of CL clay increases as the slat concentration increases whereas the liquid limit of CH clay decreases as the slat concentration increases.

Another test performed on dam construction materials is compaction test. Soil compaction improves strength characteristics of soil and consequently increases bearing capacity of foundations constructed on it. Alainachi and Alobaidy, 2010; Emami, 2008; and Mansour et al., 2008 have studied the effect of salinity on the compaction test results. Their results show that optimum moisture content decreases and maximum dry unit weight of soil increases as the salinity of water increases.

The other important test is the one-dimensional consolidation. This test indicates soil compressibility amount that is one of the important properties of the soil. The test results performed by Yukselen-Aksoy etal, 2008 show seawater has limited effect on the compressibility of clayey soils with liquid limit less than 110%. In clayey soils with liquid limit more than 110% (Na-bentonites), seawater effect becomes significant. Rao and Mathew, 1995 have studied the effect of monovalent, divalent and threevalent cations on the test results of consolidation. This study has indicated the replacement of monovalent cations by higher order valency cations can change the particle arrangement from dispersion to flocculation due to reduction in double layer thickness. Siddiqua et al., 2011 have investigated the effect of NaCl and $CaCl_2$ solutions on light and dense backfill materials. In light backfill, compression and swell indexes decrease noticeably as pore fluid salinity increases. In dense backfill, the mechanical behavior of these materials is not strongly dependent on pore fluid chemistry. Shariatmadari et al., 2011 have shown that as the salt concentration increases, the Cc value decreases. The reason of such tendency might be the reduction in diffuse double layer thickness.

The effects of water chemistry on shear strength of soil have been evaluated by Alamdar, 1999; Ayininuola et al., 2009; Chattopadhyay, 1972; Di Maio and Fenelli, 1994; Naeini and Jahanfar, 2011; Siddiqua et al., 2011 and Tiwari et al., 2005. In these studies, shear strenght of soil has increased as concentration of water increased.

Soil dispersibility is a phenomenon during which, clay particles separate from each other by water moving slowly due to the fact that the attractive force between them decreases. Using dispersive soils in hydraulic structures, embankment dams and other engineering structures can causes serious problems if they are not identified and used appropriately. The tendency for dispersive erosion in a given soil depends on mineralogy and chemistry of clay and disolved salt on water in soil pores and in erodingwater (Knodel 1991). In the study conducted by Chaudhari 2007, dispersive index of soil has increased as SAR increased and concentration of water decreased. Ayenu-Prah, 2004 used SAR (sodium adsorption ratio) method and double hydrometer test for evaluating effect of water chemistry on soil dispersibility. His results have shown water with high value of SAR had no effect on dispersibility of compacted soil. Abbasi, 2011, have investigated the role of anions in the dispersion potential of clayey soil. His results show that soil dispersion, which is a physic-chemical phenomenon, was caused by combination of existing anions and cations in the soil, both in type and quantity. In study performed by Alamdar 1999, a noticeable difference in dispersibility of soil with saline water and distilled water has not been observed.

MATERIALA AND METHODS

To study the effect of salt water on the behavioral parameters of fine-grained soil, the basic characteristics of the soil and water samples were measured. Then laboratory tests of Atterberg limits, standard compaction, consolidation, direct shear test and dispersion (pinhole test and chemical method) were done with all three types of water according to procedures referred to in this section:

Atterberg Limits. The tests were performed according to ASTM D 4318 on soil passing no. 100 sieve. For half saline and saline water, this test was performed at 0, 24 and 48 hours after soil and water exposure.

Compaction Test. In order to investigate the type of water on optimum moisture content and maximum dry density, the standard compaction test was performed by using all three types of water according to ASTM D698-70 and A method on soil passing no. 5 sieve (4 mm). For saline water, this test was also done at 24 and 48 hours after soil and water exposure.

1 D Consolidation Test. This test was performed according to ASTM D2435 on soil passing no. 60 sieve. To do so, the soil compacted at optimum moisture content in consolidation ring had a diameter of 70 mm and thickness 20 mm. Then the mold of consolidation was left under loading equipment and the first load of apparatus (1 kPa) was applied on it and the sample was immersed during 24 hours. Thereafter, the sample was loaded with the stresses of 0.25, 0.5, 1, 2 and 2.5 kg/cm^2.

Direct Shear Test. This test was carried out according to ASTM D3080 on soil passing no. 5 sieve (4 mm). For this purpose, soil was compacted at optimum water content in mold of apparatus (10×10 mm). The using stresses were 0.5, 1 and 2 kg/cm^2 and shearing velocity was 0.35 mm/min. Before shearing at each stress, the sample was immersed and consolidated during 24 hours under the same stress.

Dispersion tests

Pinhole Test. This test was done according to ASTM 4647 and A method on soil passing no. 60 sieve. In order to do, the soil was compacted with optimum moisture content in the mold of the apparatus in three layers and 25 impacts on any layer. Applied water heads were 50, 180, 380, 1020 mm and the first head and other heads were applied for 10 and 5 minutes respectively. The criteria for evaluation of soil dispersion in A method are consistent with the rate of flow discharge, water clarity and final size of hole.

Chemical Test. In this method, water was added to soil in liquid limit. After soil and water exposure during 24 hours, saturated extract was taken by vacuum pump. Then cations concentration of Ca^{2+}, Mg^{2+}, Na^{+} and k^{+} were determined in saturated extracts.

BASIC CHARACTERISTICS OF SOIL AND WATER

Figure 1 shows grain size distribution of construction materials of dam core. According to this graph the soil has 37% gravel and sand, 35% silt and 28% clay. In order to identify the clay minerals in the soil, XRD analysis was done on soil passing 75 µm (no. 200) sieve. The result of this analysis has been shown in table 1. Based on XRD analysis, the fine grains of soil mainly consists of quartz, calcite, dolomite and gypsum and its clay mineral was only 5% montmorillonite.

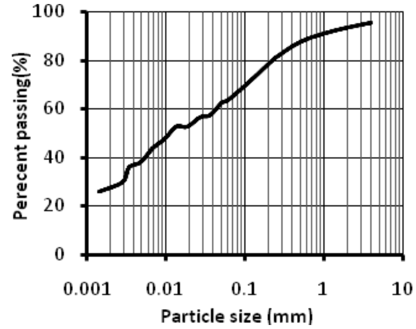

Fig. 1. Particle size distribution curve of the soil

Table 1. XRD analysis of fine grained of soil

Compound Name	Concentration(%W/W)
Quartz	12.9
Calcite	18.9
Montmorillonite	5.2
Albite, ordered	9
Dolomite	19.3
Muscovite	5.8
Clinochlore	5.8
Gypsum	23.1

The concentration of four main cations in the waters used in this research was specified by atomic adsorption method. The results of this analysis are shown in table 2. The total amount of these cations in half saline and saline water is 1877 and 97020 ppm respectively. In saline water, sodium constitutes more than 99 percent of all cations. So this cation plays important role in increasing double layer thickness and decreasing interparticle attractive force and finally causing behaviors such as dispersibility, it seems necessary to perform tests with this water on the soil before constructing the dam.

Table 2. Chemical analysis Results of water studied (ppm)

	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Total
Distilled water	0.82	0.4	3	0.08	4.3
Half saline water	92	42	1739	4.6	1877.6
Saline water	678	648	95652	42	97020

RESULTS AND DISCUTION

The laboratory tests were done on samples affected by saline water. The results of these tests are shown separately according to the characteristic parameters of soil.

Atterberg Limits

Table 3 shows the average of plastic and liquid limits and plastic index by using three types of water. Plastic limits with distilled, half saline and saline water are 21.31, 20.43 and 20.12 respectively. Marginal effect of salinity on plastic limit can arise little moisture of soil in this condition which can lead to decreasing the interaction between soil and solute in water. But in liquid limit, in which soil moisture is higher, the effects of the type of water will be higher. The liquid limit has decreased 5 and 17 percent with half saline and saline water respectively. Mahasneh, 2004, has attributed the decrease in liquid limit and plastic index by using saline water of Dead Sea to substitution of water molecules by salts that led to the decrease of the double layer thickness and water content and subsequently it stiffened the soil. Mansour et al., 2008 have indicated that the presence of high valence exchangeable cations in Dead Sea brine decreases the distance between particles by decreasing the repulsive forces in the soil microstructure. This causes the Vander Waals attractive force to be dominant, hence increasing of capillary stress that is formed between particles boundaries and finally forming the aggregation. The aggregation reduces the available surface for interaction with water which negatively reflected on the Atterberg limits. In present study, lower part of changes of Atterberg limits are attributed to decrease in the double layer thickness and most of the changes can be attributed to sediment salt in the pores of soil which subsequently increases the mass of soil solid. That is because on one hand, the XRD analysis showed montmorillonite content in the soil was approximately 5% and on the other hand, salt crystals were seen in the soil after drying it. Hence when the mass of salt added to soil was removed, and then the moisture content was calculated, it was said with certainty that saline water has decreased the liquid limit and activity of soil. Due to reduction of liquid limit with increase in salinity water, plastic index also has decreased and it is not certainly indication of decrease in soil activity.

Table 3. Results of Atterberg limits by using three types of water

	Distilled water	Half saline water			Saline water		
Time	0	0	24 hr.	48 hr.	0	24 hr.	48 hr.
Plastic limit	21.31	20.43	19.09	20.09	20.12	20.87	19.39
Liquid limit	29.98	28.37	28.31	28.1	24.89	25.3	26.47
Plastic index	8.67	7.94	9.22	8.01	4.77	4.43	7.08

In fig 2, limits of liquid and plastic against water construction is shown. This figure shows that these limits decrease as salinity water increases, but there is not a linear relationship between them and decrease rate of these limits reduced as concentration increased. However concentration of saline water is 50 times more than that of half saline water, but it has reduced liquid limit alone 12 percent in comparative half saline water.

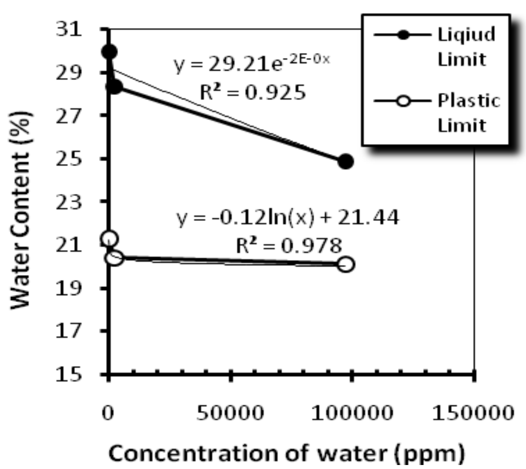

Fig. 2 Changes liquid and plastic limits with water concentration

For half saline and saline water, consistency limits results in 0, 24 and 48 hours after soil and water exposure are nearly identical. So it seems the time of exposure is not a determining factor for changing atterberg limits.

Figure 3 shows liquid limit with saline water against liquid limit with fresh water for several studies. As seen, the effect of salinity is low in the soils with LL lower than 120 percent. As a result, the samples are located on the diagonal line. But in the very active soil (high LL), the liquid limit decreases more than 60 percent. So it seems that influence of salinity on the liquid limit increases as the percentage of active clay minerals in the soil increases.

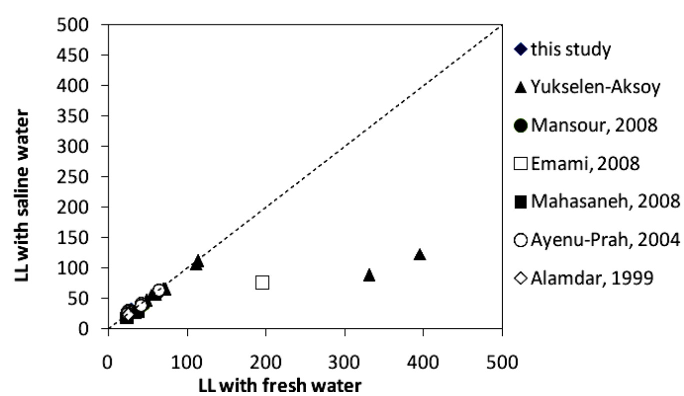

Fig. 3. Liquid limit with saline water versus Liquid limit with fresh water

Regarding performance facility of atterberg limits, many studies have been performed on the effect of chemical solutions on these limits in comparison to other engineering properties of soil. Almost all studies have shown the decrease of atterberg limits of CH soils as water salinity increases. But there is no agreement on the influence of water chemistry on atterberg limits of CL soil. Some of researchers have shown decrease of these limits with an increase in water concentatrion and some of them have shown an increase of them. Sridharan 1991 has attributed increase in the consistency limits of kaolinitic soils to capped water between edge-to-face soil aggregates. Sivapullaiah and manju, 2005, have claimed formation of a new swelling compound in the soil is the reason of increase in liquid limit of CL soil with NaOH solution. Supposing the behavior of CH soils with chemical solutions is different from CL soils. Since clay mineral in the soil is montmorillonite type, in the present study it behaves similar to CH soil, i.e. its atterberge limits have decreased as increase in water salinity.

<u>Maximum Dry Density and Optimum moisture</u>

This test was performed three times with all three types of water. These results have been shown in table 4. As seen in this table, the effect of water type on compaction properties of soil is relatively small. In the studies of Alainachi and Alobaidy, 2010; Emami Azadi, 2008; Mansour et al., 2008 and Shariatmadari, et al., 2011 optimum moisture content and maximum dry density decreases and increases respectively with increase in salinity of water. The reason of these changes in these studies has been attributed to the reduction of double layer thickness and increasing of attractive force between particles as pore fluid concentration increases. But in the present study, like the one performed by Alamdar 1999, there was little changes in compaction characteristics as salinity increases. These results can be for the reason that the soil is not saturated and particles are not immersed in water. Because in this condition the soil particles cannot interact freely with salts in water to reduce the thickness of double layer. Also according to one of the theories of the influence of double layer on properties of clay, the diffuse double layer influences on clay in suspension but it doesn't influence the geomechanical properties of compacted clay (Schmitz 2006). On the other hand since there is low percent of active clay minerals in the soil, small changes in optimum moisture content and maximum dry density with an increase in pore water salinity seems reasonable. As mentioned the apparent decreasing of liquid limit was due to the deposition salts of water in the soil pores, but since in the compaction test, water added to soil is little, the added salt to soil are not sufficient to cause the apparent increase and decrease in dry density and optimum moisture respectively.

Table 4. Results of three times of standard compaction test

Distilled water		Half saline water		Saline water	
W%	Y_d	W%	Y_d	W%	Y_d
	(gr/cm^3)		(gr/cm^3)		(gr/cm^3)
1.86	14	13.6	1.85	13.78	1.85
1.85	14.7	15.8	1.83	12.8	1.85
1.85	13.25	14	1.86	13	1.89

Figure 4 shows the compaction test results by using saline water at 0, 24 and 48 hours after soil and water exposure. As seen there aren't distinguished differences between these curves. So in compaction test, like atterberg test, the time of exposure is not an effective factor in changing the results.

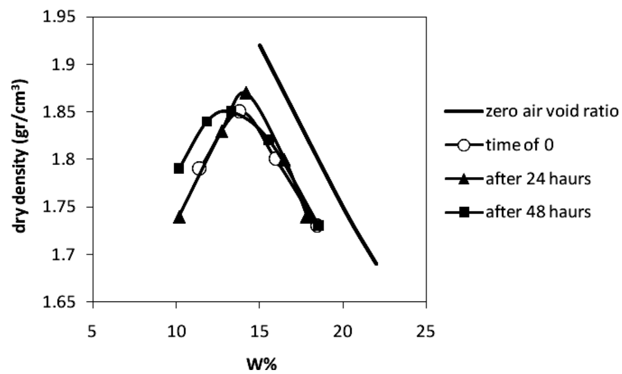

Fig. 4. Compaction curves with saline water

Fig. 5 shows maximum dry density with saline water versus maximum dry density with fresh water for five studies. All the studies used natural saline water. As shown in the figure, most of samples are located near diagonal line and slightly higher than that. This shows a low increase in maximum dry density with saline water. In study of Emami Azadi 2008, the liquid limit of the soils has not been cited. Among other studies, highest percentage of increasing in dry density belongs to Mansour, 2008. In this study, dry density has increased 8 percent with saline water of Dead Sea. But in the present study, the percentage for the change in dry density was 0.92% with saline water. Some probable reasons for this difference can be: 1) water concentration in the study of Mansour, 2008 (330000 ppm) was higher than this study (97000 ppm). If changes in maximum dry density are due to sedimentation of salt in the soil, high concentration of water in the study of Mansour, 2008 has caused apparent increase in maximum dry density. If increase of maximum dry density is due to decreasing thickness of double layer, high concentration of water in the study of Mansour, 2008 has caused high decrease in double layer thickness and high increase in maximum dry density in comparison to the present study. 2) Soil liquid limit in the study of Mansour, 2008 (46) is higher than present study (29.98). It may be due to the difference in soil liquid limit.

In fig. 6 optimum moisture with saline water versus optimum moisture with fresh water is drawn from five studies. As seen, most of the samples are located under diagonal line that shows optimum moisture decreases as water salinity increases. In the present study and Alamdar, 1999 the percentage of change in optimum moisture is lower than other studies. The reason may be the lower liquid limit of the soils in these two studies.

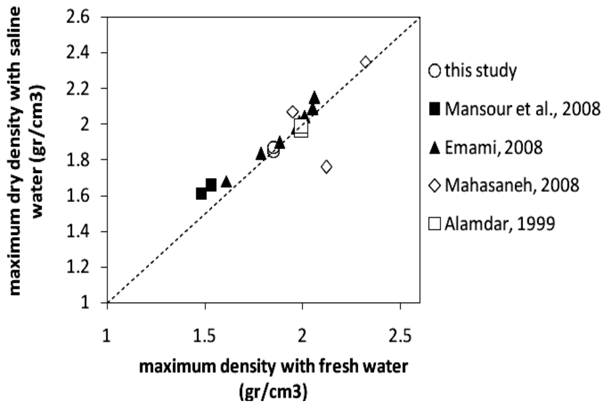

Fig. 5. Maximum dry density with saline water versus maximum dry density with distilled water

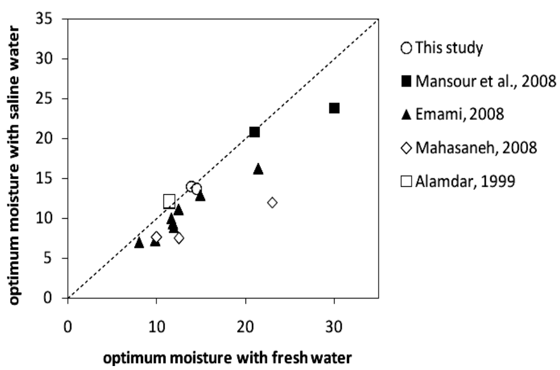

Fig. 6. Optimum moisture with saline water versus optimum moisture with distilled water

<u>Parameters of Consolidation</u>

The 1D consolidation test was preformed three times with all types of water. Compression index (Cc) and swell index (Cs) were determined from the curve of stress logarithmic against void ratio. The average of compression index (Cc) with distilled water, half saline water and saline water is 0.109, 0.088 and 0.077 respectively. These results are in agreement with those in other studies which were done by Shariatmadari et al., 2011; Siddiqua et al., 2011 and Yukselen-Aksoy etal, 2008. In these studies, the reason of decrease in compression index has been attributed to the reduction of double layer thickness and increase of attractive force between particles as pore fluid concentration increases. Since in this study high percentage of fine grained soil is formed from inactive minerals such asquartz, calcite, dolomite and gypsum, small reduction of consolidation parameters seems to be reasonable as salinity increases. Further, since the soil has a few percentage of montmorillonite, a smaller amount of the changes is concerned with reduction of double layer. It can be said that high concentration of salt in water has increased attractive forces between particles and has established bonding among them. Consequently flocculation structure has formed in the soil. Also salt crystals may sediment in the pores of soil and play role of cement. In this condition, subsidence of soil and compression index will be lower. Alamdar 1999, also belived the main reason of decrease of compression index was propagation of salt into the soil.

The swell index (Cs) also has decreased as water salinity increased. The average of swell index (Cs) with distilled water, half saline water and saline water is 0.035, 0.03 and 0.019 respectively. These changes can be justified with the difference in osmotic pressure. Regarding the high concentration of half saline and saline water, osmotic pressure difference between water within layers of clay and water in the pores of soil is lower in comparison with the distilled water. So after unloading, less water enters to space between layers of clay to balance osmotic pressure. Hence Cs has decreased as salinity of water increases. Also formed bonding between particles by solute in water and sedimentation of salt crystal in pores of the soil has not allowed the soil is expanded due to water adsorption.

In fig. 7, the changes of Cc and Cs against concentration of water have been shown. The relations with high determination coefficient (R^2) between these indexes and concentration of water show there is a hard dependence between them. This figure show Cc and Cs decrease as salinity of water increases. But here, similar to atterberg limits, there is not linear relation between them. The average of compression index with half saline water is 0.088. The use of saline water has lessened it to 12 percent, while concentration of saline water is 50 times more than that of half saline water.

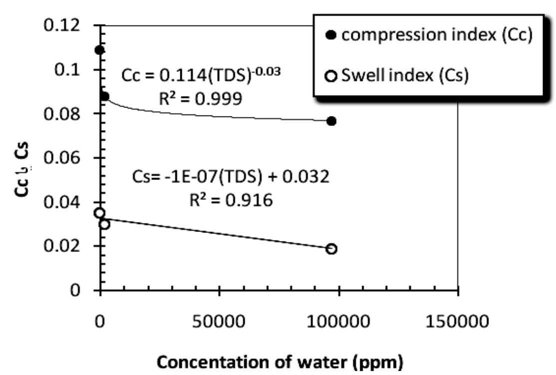

Fig. 7. Compression and swell indexes versus concentration of water

Since coefficient of compressibility (av) and coefficient of volume compressibility (mv) were not constant during consolidation pressures, we spotted two quantities for them. The reason is shown in the figure 8. In this figure, the graph of stress versus strain for one of the tests performed with saline water has been plotted. As it is clear, the slop of graphs has decreased as consolidation pressure increased. So coefficient of volume compressibility (mv) is not constant and decreases as consolidation pressure increases. In figure 5 it is shown that most changes in curve slop is in the pressure of 1 kg/cm^2. So the slope of the first part and the second part of the curves was used as average of mv in stress ranges from 0.25 to 1 and 1 to 2.5 kg/cm^2 respectively.

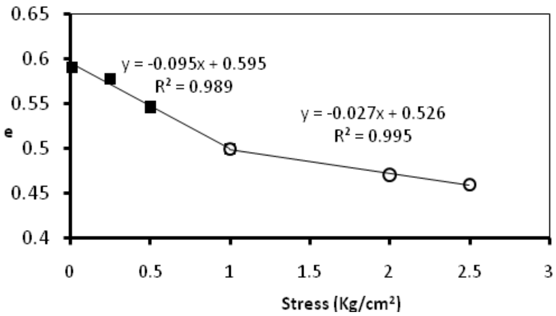

Fig. 8. The curve of stress versus strain (related to test with saline water)

In figs 9 and 10, the average of coefficient of volume compressibility (mv) and coefficient of compressibility (av) versus water concentration has been drawn. As seen significant decrease in the coefficients occurred concurrently with the increase in water salinity as long as the concentration of half saline water in stress ranges from 0.25 to1 kg/cm^2. So the coefficients of mv and av have decreased to 38 and 42 percent respectively by using half saline water rather than distilled water. But then a further increase in water concentration has not caused significant changes in the coefficients. If these changes are due to decrease in double layer thickness as concentration of water increases, fig. 11 shows that the effects of double layer in geomechanical engineering decreases as concentration of cations in the percolating fluid increases (Smithz, 2006). In high concentration, the cations in water may prefer combination with anions and form salt while they interact with surface of clay minerals. These salts deposit in pores of the soil and on particle surface. So in this condition, interaction between soil particles and solute in water decreases. So, it can be concluded that in very high concentration, noticeable changes have not been caused in engineering characteristics of soil.

Figure 9 and 10 show that concentration of water does not have a significant effect on coefficients of mv and av in the stress ranging from 1 to 2.5 kg/cm^2. As it is shown in fig. 11. This figure also shows the double layer effects decrease as the density of the clay (< e) or exterior compressive stress perpendicular to the double layers (> σ_v) increases (Smithz, 2006). Also it seems that high pressure overcomes on the bounding between particles of soil.

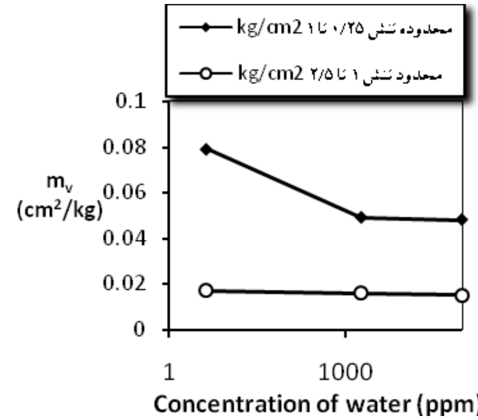

Fig. 9. Changes of coefficient of volume compressibility versus concentration of water

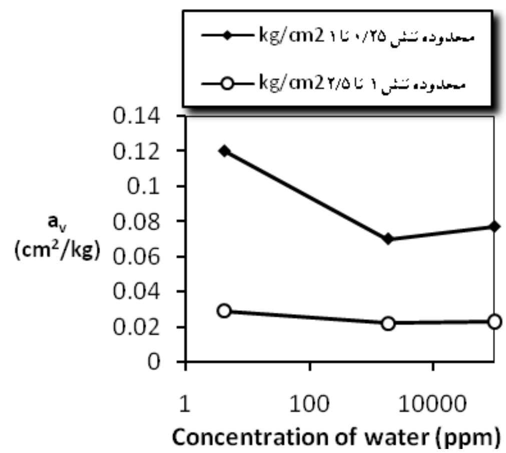

Fig 10. Changes of coefficient of compressibility versus concentration of water

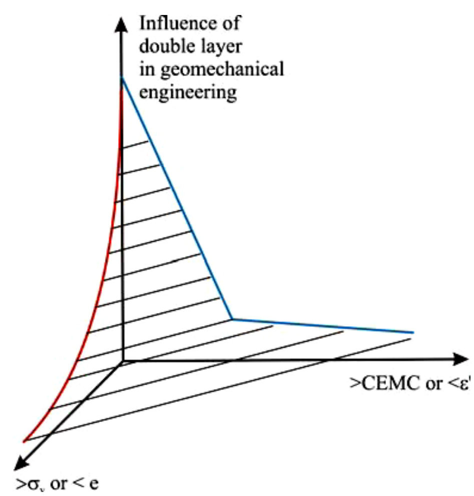

Fig. 11. The effects of fluid concentration and stress on influence of double layer in geomechanical engineering (Schmitz, 2006)

Shear Strength

This test was performed two times using each kind of water and the results are shown in table 5. The average of cohesion and friction angle with distilled, half saline and saline water are 0.078, 0.108 and 0.107 kg/cm^2 and 14.8, 15.8 and 15.2 degrees respectively. The results indicate that salinity does not have a significant effect on shear strength parameters. However cohesion and friction angle have increased with half saline and saline water. This result is compatible with studies performed by Tiwari et al., 2005; Di Maio and Fenelli, 1994; and Alamdar 1999.The reason for the low changes in cohesion and friction angle may be the low clay content in soil and the low increase of these parameters with salinity of water can be due to increasing attractive force between particles and establishing bounds between them.

Table 5. Results of direct shear test

	C (kg/cm2)	φ
Distilled Water	0.065	14.9
	0.091	14.75
Half Saline Water	0.125	15.75
	0.092	16
Saline Water	0.109	15
	0.105	15.25

Dispersion

As mentioned, in order to determine the salinity effect on soil dispersion in this study, pinhole test and chemical method were used. In fig. 12 results of pinhole test have been shown. In this graph, pipe flow discharge through the specimen (Qw, ml/sec) against measured volume for all three types of water is drawn. Since Qw at the end of the1020 mm head for all three types of water was more than 3 ml/sec, the effluent was clear and size of hole was 1.5 to 2 mm, dispersion class of soil was called ND2. So the soil with distilled water was nondispersive and saline water has not created dispersion in the soil despite high percentage of sodium within them.
Location of saturated extracts obtained from soil with all three types of water is shown in sherard graph in fig. 13. Unlike pinhole test results, chemical method shows that the soil is dispersed with half saline and saline water. This difference between pinhole method and chemical method are also seen in the studies performed by Abbasi et al., 2010; Ayenu-Prah, 2004; Khamechian et al., 2005. Ayenu-Prah, 2004 has stated water with high SAR have no effect on dispersion of unsaturated compacted cohesive soils. Abbasi, 2011, has stated that the reason of this difference in chemical method is only based on concentration cations and role of anions are ignored. Because in the stances where concentration of sodium cation and chloride anion in their samples was high, in the pinhole test, dispersion has not been observed. Rahimi and Delfy, 1992 showed sherared graph is not accurate enough for the soils with solutes more than 50 mille equivalents per litter and has a noticeable error in the soils with more than 100 mille equivalents per litter. Ouhadi and Goodarzi, 2006 provided a set of soil – electrolyte artificial samples with mixing soil, bentonite and sodium salts and investigated changes in soil behavior. They found that sodium cation causes dispersive structure and flocculation structure in low concentration and high concentration respectively. In this study, the difference between the two methods can be attributed to low percent of clay in the soil. It is due to the fact that if percentage of active clay minerals in the soil were high, high sodium concentration might decrease attractive forces between particles and finally the soil would be dispersive.

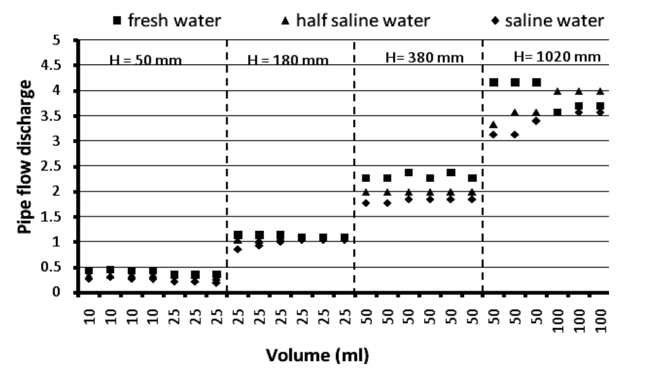

Fig. 12. Results of Pinhole Test

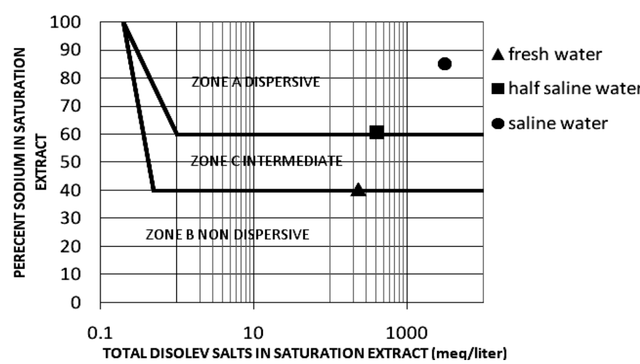

Fig. 13. Evaluation of dispersion potential by chemical method

CONCLUSION

In this study, the effect of saline water of Kochay branches and half saline water of Ajichay River on engineering properties of fine grained soil used in dam core of Korchay was investigated. Since cations percentage was nearly equal in the types of water studied, type of cation has not been a significant influence on the changes observed and most of changes are the result of the difference in water concentration. Tests results showed atterberg limits, compression index, swell index, coefficient of volume compressibility and coefficient of compressibility have decreased and consolidation of coefficient and shear strength parameters have increased as water salinity increased. The main reason of these changes has been attributed to an increase of attractive force between soil particles, establishment of bonding between them and formation of salt crystals in pores of soil and role of the cement. Regarding the low percentage of clay in the soil, small part of these changes is concerned with the reduction of double layer thickness. Although concentration of saline water is 50 times more than that of half saline water, the difference between soil properties is not noticeable with these two types of water. It seems that rate of variations on the soil properties decreases as water salinity increases. It can be said that excessive concentration of water causes cations in water to combine with anions to form salt before they influence on surface of clay minerals. The salt deposits on the surface of the soil particles and in the pores of soil and causes contact of particles with water decrease. So increase in concentration of water will not cause a significant difference in soil behavior. Consolidation test showed soil behavior with all three types of water is almost the same in high pressure. Its reason can be attributed to breaking interparticles bonding by high pressure. Although sodium concentration in half saline and saline water is high, but soil dispersion has not been observed with them. At the end, results indicated that saline water of Korchay branch has improved engineering properties of the core soil. So it can be used in processing of dam core and prevent the additional cost for transferring water.

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