Erzincan Üniversitesi
Fen Bilimleri Enstitüsü Dergisi
2020, 13(3), 1362-1373
ISSN: 1307-9085, e-ISSN: 2149-4584
Araştırma Makalesi

Erzincan University
Journal of Science and Technology
2020, 13(3), 1362-1373
DOI: 10.18185/erzifbed.750662
Research Article

Investigating The Effects of Waters Collected From Different Basins In Turkey on Clays' Consistency And Strength Properties

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Geliş / Received: 10/06/2020, Kabul / Accepted: 07/10/2020

Abstract

The engineering behavior of clay soils, vary depending on the amount of water they contain. These variations depend on the crystal structure of the clay mineral and the chemical structure of the water in the voids of the soil. In this study, on the geotechnical properties of high plasticity (CH) and low plasticity (CL) clays the effects of waters with different chemical structures were investigated. Within the scope of the study, some geotechnical experiments were carried out on two different clays from Erzurum with high plasticity and low plasticity and, tap water and water with different chemical structures obtained from three different basin in Eastern Anatolia (Fırat Basin, Çoruh Basin and Aras Basin) were used. The consistency limits, standard proctor and unconfined compression tests were carried out on clays, and the experiments were repeated using different basin waters and, the results were compared with the test results with tap water. The test results showed that different waters significantly changed the consistency and compaction properties of high and low plasticity clays and that they did not cause a significant change in unconfined compression strength. Çoruh Basin reduced the liquid limit of the CH and CL clays of the water by 33% and 20%, respectively. With the effect of the Çoruh Basin, the optimum moisture content of the CH clay decreased by 41.2%, while the optimum moisture content of the CL clay increased by 52.7% with the effect of the Fırat Basin.

Keywords: Clay, basin waters in Turkey, consistency limits, unconfined compressive strength

Farklı Havza Sularının Killerin Kıvam ve Mukavemet Özellikleri Üzerindeki Etkisinin Araştırılması

Öz

Kil zeminlerin mühendislik özellikleri içerdikleri su miktarına bağlı olarak değişiklik göstermektedir. Bu değişiklikler, kil mineralinin kristal yapısına ve zeminin boşluklarında yer alan suyun kimyasal yapısına bağlıdır. Bu çalışmada, farklı kimyasal yapıda suların, yüksek plastisiteli (CH) ve düşük plastisiteli (CL) killerin geoteknik özelliklerine olan etkisi araştırılmıştır. Çalışma kapsamında, Erzurum'dan temin edilen yüksek plastisiteli ve düşük plastisiteli iki farklı kil üzerinde bazı geoteknik deneyler gerçekleştirilmiş ve deneylerde çeşme suyu ile Doğu Anadolu Bölgesi'nde bulunan üç farklı su havzasından (Fırat Havzası, Çoruh Havzası ve Aras Havzası) temin edilen farklı kimyasal yapılara sahip sular kullanılmıştır. Killer üzerinde kıvam limitleri, standart proktor ve serbest basınç deneyleri yapılmış, deneyler farklı havza suları kullanılarak tekrarlanmış ve sonuçlar çeşme suyu ile yapılan deney sonuçları ile karşılaştırılmıştır. Deney sonuçları, farklı suların, yüksek ve düşük plastisiteli killerin kıvam ve kompaksiyon özelliklerini belirgin olarak değiştirdiğini, serbest basınç mukavemetlerinde ise belirgin bir değişim meydana getirmediğini göstermiştir. Çoruh Havzası suyu CH ve CL killerinin likit limitini sırasıyla %33 ve %20 oranlarında azaltmıştır. Çoruh Havzası suyunun etkisiyle CH kilinin optimum su içeriği% 41.2 oranında azalırken, CL kilinin optimum su içeriği Fırat Havzası suyunun etkisiyle % 52.7 oranında artmıştır.

Anahtar Kelimeler: Kil, farklı havza suları, kıvam limitleri, serbest basınç mukavemeti

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1. Introduction

It is known that the engineering properties of clays vary depending on the characteristics of their water content. Such variations, which occur depending on the properties of the water, depend on the crystal structure of the clay minerals and the chemical and physical properties of the water in voids. Clays are natural secondary minerals that generally consist of hydrated aluminosilicates due to the decomposition of coarse grains of the main rock after washing. They are available in the form of particles or granules in colloidal size. Soils whose volume increases or decreases are swelling soils depending on the water content. The main reason for the variation in the water content in the soil, is seasonal changes. The swelling of clay leads to changes in the clay volume. Clay minerals mostly consist of negatively charged surfaces and layered particles with positive electrical charge on the end faces. Because of these negative charges, electrostatic forces exist between the negative surface and exchangeable cations. When clay particles come into contact with water, an ionic counter charge accumulates on the surface of the clay particles, in order to maintain electrical neutrality. Accordingly, an electrostatic surface occurs, which is referred to as a diffuse double layer of the clay particle. The diffuse double layer influences the geomechanical properties of clays (Shcmitz, 2006).

There are certain studies in the literature that examine the effects of waters with different chemical structures on the engineering characteristics of clays. Sridharan et al. (1986) investigated the mechanisms that affect the compressibility and Atterberg limits of bentonite saturated with monovalent, divalent and trivalent cations. They emphasized that any increase in the cationic value decreases the liquid limit and compressibility of clay, while each increase in the hydrate diameter of the cation increases the liquid limit and compressibility of clay. In their studies, Dexter and Chant (1991) examined the mechanical properties of soils such as shear strength as a function of exchangeable cations. According to the results of the investigation, the shear strength increased with increasing content of exchangeable sodium, while it decreased with increasing content of exchangeable calcium. The shear strength in wet soils increased with increasing levels of exchangeable calcium, potassium and sodium. By saturating sodium bentonite clay with K, Na, Ca and Mg chloride salt solutions prepared in various concentrations (0.01, 0.10 and 1.00 mol / l), Studds et al. (1996) examined the variation in the consistency limits of clay. They reported that any increase in the saline concentration resulted in a decrease in the liquid limit of the clay. Kinuthia et al. (1999) examined in their studies the effects of calcium, magnesium, sodium and potassium sulfates on the consistency and compressibility characteristics of kaolinite clay. The results showed that the addition of lime generally increased the liquid limit, plastic limit and plasticity index of kaolinite clay; However, high lime additions reduced the liquid limit and the plasticity index. Ören and Kaya (2003) investigated in their site studies the physicochemical properties of a clay mixture that was produced using montmorillonite, illite and kaolinite clay minerals. In the study, the clay mixture was saturated with the ions of Na^{+}, Ca^{+2} and Al^{+3} and then, their engineering features like consistency limits, compressibility behaviours and hydraulic conductivity were investigated. The results showed that the liquid, plastic, and shrinkage limits of the clay mix increased as the cation valency increased. In addition, the hydraulic conductivity of the soil increased with increasing cation valence. Yilmaz and Marschalko (2014) investigated the effects of liquids with different chemical contents on the swelling behavior of clays. They reported that increasing the salinity of water decreased the swelling percentage and swelling potential of clay, while there was an inverse relationship between the sodium content of the liquid and swelling according to the results of the experiments with seawater, lake and river water with different salt concentrations. Elmashad and Ata (2014) compared the consistency limits of clays with the consistency limits of sea water with different salt concentrations and found that the liquid limit value of high plasticity montmorillonite decreased from 497% to 112% when the amount of salt in the mixture increased while an insignificant increase occurred in plastic limit. Abu Zeid and Abd El-Aal (2017) examined in their studies how the technical characteristics of clay differed with clay, distilled water and salt solutions with different concentrations. In the study, the liquid limit, plastic limit, and plasticity index gradually decreased with increasing salinity. In addition, the maximum dry density decreased with increasing salinity.

In the present study, the effects of water from various basins in the Eastern Anatolian region of Turkey on the geotechnical properties of clays with high plasticity and low plasticity were examined. Therefore, consistency limits, standard proctor and unconfined compressive strength test results that were performed with tap water were compared with the test results that were performed with water from various basin waters in Turkey (collected from the Firat Basin, the Coruh Basin and the Aras basin).

2. Materials and Methods

2.1. Clays

In High plasticity clay and low plasticity clay from Erzurum, Turkey, were used in this study. Certain geotechnical properties of the clays are given in Table 1. The content of clay minerals was determined by X-ray analysis tests on the soil samples (Table 2). According to the test results of the X-ray analysis, the clay sample with high plasticity contains smectite, serpentine, quartz, calcite and amorphous silica mineral. Minerals from the amphibole, feldspar and chlorite groups were also found in small quantities. On the other hand, the clay sample with low plasticity contains calcite, chlorite group clay mineral, illite, feldspar and quartz, dolomite mineral in large quantities and amorphous materials in small quantities.

2.2. Waters used in the experiments

The The experiments carried out on CH and CL clays with tap water were repeated using different basin waters. Water from the Firat, Coruh and Aras basins was used for this purpose. The chemical analysis was carried out on the water used in the experiments. The analysis results are shown in Table 3.

2.3. Experiments

The clays used in the experiments were dried in a drying oven at 105 ° C after being placed in the laboratory and then grounded using a Los Angeles abrasion device. Consistency limits, standard proctor and unconfined compressive strength test were carried out on the clays using tap water and water from different basins. The liquid limits of the clays were determined using the Casagrande method. Liquid limit and plastic limit tests were performed according to BS 1377 and ASTM D 4318, respectively. The compaction parameters of the clays were determined in accordance with ASTM D 698 by a standard proctor experiment. Unconfined compressive strength tests were carried out according to ASTM D 2166.

Table 1. Some properties of clays

Soil Classification (USCS*)	Optimum Moisture Content (%)	Specific Gravity
CH	27.8	2.64
CL	14.1	2.67

* Unified Soil Classification System

Table 2. The mineral contents of clay minerals

Clay	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	Fe_2O_3
CH	0.1	16.4	3.3	44.1	0.5	0.25	3.8	0.35	0.2	14.6
CL	0.6	3.2	11.5	40.56	0.35	2.5	15.3	0.4	0.26	5.3

Table 3. Analysis of waters

Water	Anion Analysis (mg/l)						Cation Analysis (mg/l)			COD (mg/l)	pH	Conductivity (µs/cm)
	Ca	Mg	Na	K	Fe	Al	HCO_3	Cl	SO_4			
Tap Water	78.38	21.88	6.12	1.62	<0.01	<0.01	420.90	7.26	23.54	5	7.33	691
Firat Basin	84.84	4.6	9.42	2.11	0.62	0.48	388.23	9.91	7.75	>5	8.23	25.4
Coruh Basin	87.36	6.31	9.29	11	0.16	0.22	520.39	7.33	10.87	>5	8.64	390
Aras Basin	84.79	23	7.32	10.29	0.037	0.097	300.68	7.75	16.08	>5	8.44	254

*Chemical oxygen demand

3. Results and Discussion

3.1. Test results of consistency limits

Water from the basins was added to the two clay soils to perform liquid limit and plastic limit tests. Consistency limits tests performed with tap water showed that the clays were CH and CL. Table 4 shows the results of liquid limit and plastic limit tests performed on CH and CL clays with water from different basins. Figures 1, 2 and 3 show the variation of the liquid limit, the plastic limit and the plasticity index of CH and CL clays, which are caused by different basins waters respectively.

Table 4. The test results of consistency limits

Clay	Water	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Soil Classification
CH	Tap Water	58	23	35	CH
	Firat	54.2	20	34.2	CH
	Coruh	38.7	12	26.7	ML
	Aras	39.4	9	30.4	ML
CL	Tap Water	37	17	20	CL
	Firat	32	15	17	CL
	Coruh	29.6	14	15.6	CL
	Aras	30.1	11	19.1	CL

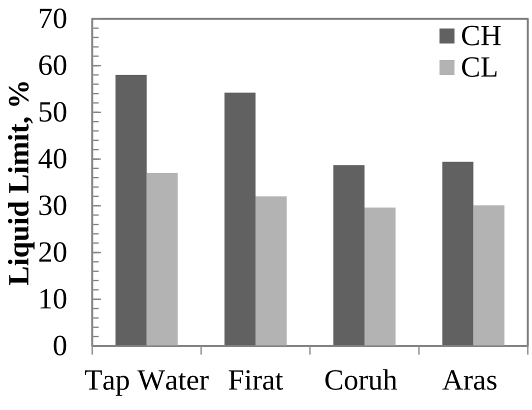

Fig. 1. The effects of different basin waters on the liquid limits of clays

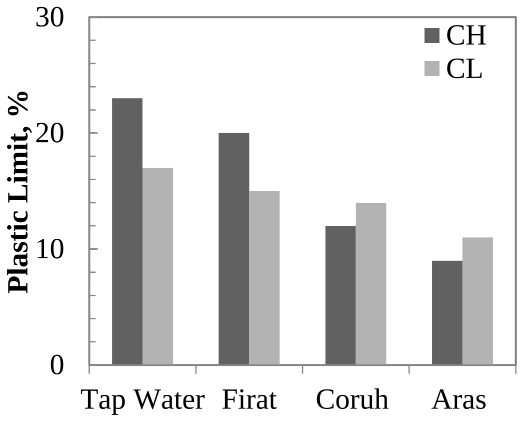

Fig. 2. The effects of different basin waters on the plastic limits of clays

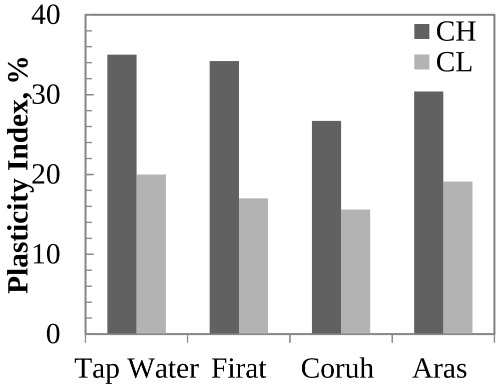

Fig. 3. The effects of different basin waters on the plasticity indexes of clays

When the results of consistency limit tests performed on CH clay with water from different basins are compared to the results of consistency limit tests performed on tap water, it can be seen that the liquid limit, the plastic limit and the plasticity index decreased (Table 4). Taking liquid limit tests into account, it was found that the greatest decrease occurred in the test carried out with the water collected from the Coruh basin. The liquid limit value, which was determined as a result of the experiment carried out with water from the Coruh basin, is 33% lower than the liquid limit value, which was determined as a result of the experiment carried out with tap water (Fig. 1). At plastic limit values for CH clay, the greatest decrease occurred in the result of the experiment with water from the Aras basin with a ratio of 60.8% (Fig. 2).

When the results of consistency limit tests performed on CL clay with water from different basins are compared with the results of consistency limit tests performed on tap water, it can be seen that the liquid limit, the plastic limit and the plasticity index decreased (Table 4). Taking liquid limit tests into account, it was found that the highest decrease occurred in the test carried out with the water collected from the Coruh basin. The liquid limit value determined as a result of the experiment carried out with water from the Coruh basin is 20% lower than the liquid limit value determined as a result of the experiment carried out with tap water (Fig. 1). At plastic limit values for CL clay, the greatest decrease occurred as a result of the experiment with water from the Aras basin with a ratio of 35.3% (Fig. 2).

The variation in the soil classes of CH and CL clays was shown in the Casagrande plasticity chart (Fig. 4 and Fig. 5). In Figure 4 it was found that due to the effects of different chemical structures of water there were changes in the soil classes of CH Clay, which were determined according to the Unified Soil Classification System (USCS). The water collected from the Firat basin did not change the soil class, while the water collected from the Coruh and Aras basins changed the soil class from CH clay to CL. According to Figure 5 it can be seen that different chemical structures of water have not changed the soil class of CL clay and remain in the CL class.

It is known that as the amount of Ca ions in water increases, the liquid and plastic limits of CH and CL clays decrease (Ören and Kaya, 2003). Taking into account the anion analysis results of the basin water, it can be seen that the Ca ion content of the basin water is higher than that of the tap water. The highest Ca level is present in the water from the Coruh Basin, and it is believed that the results of liquid limit tests performed on CH and CL clays with the water from the Coruh Basin are lower than the results of liquid limit tests done with water from other Basins for this reason. Studds et al. (1996) investigated saturated sodium bentonite clay with K, Na, Ca and Mg chloride salt solutions in various concentrations and examined the consistency limits of the clay. As the salt solution increased, liquid limit values decreased. Abu Zeid and Abd El-Aal

(2017) reported that the reason is the fact that free ions were replaced with Na^+, Al^{+3}, Mg^{+2}, K^+ ions in the salt solution. Similarly, Jayasekera and Hall (2007) reported that the liquid limit and the plastic limit of the soil increased as the amount of Na decreased. Accordingly, it can be said that the water from the Coruh basin reduced the liquid limit values and plastic limit values of CH and CL clays, since the Na content of the basin water was higher than that of tap water. Furthermore, Bakhshipor et al. (2016) reported in their study that, low pH value caused an increase in liquid limit value. Considering the fact that, pH value of the basin waters was higher than that of tap water, it may be said that, pH had an effect on the fact that, liquid limit values are low.

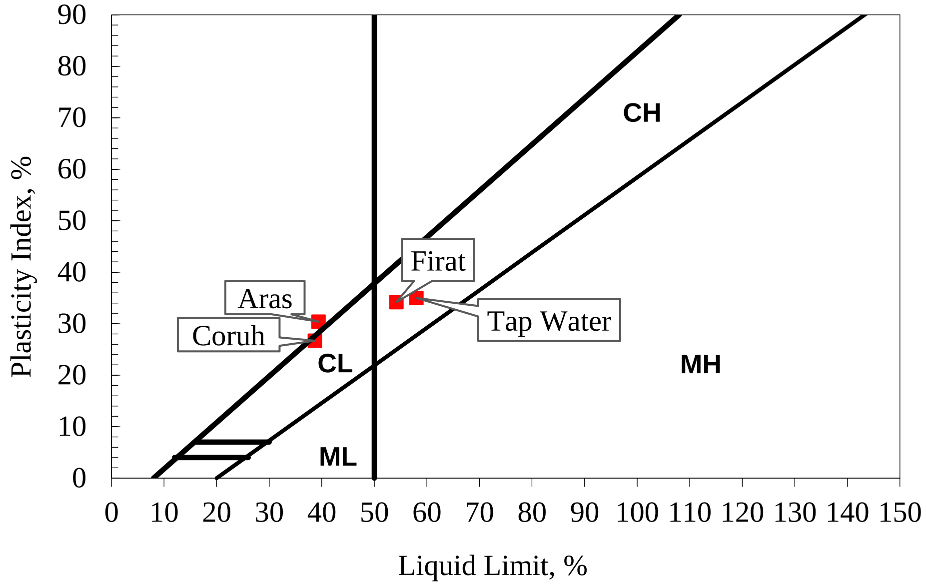

Fig. 4. Soil classifications of CH clay affected with different basin waters

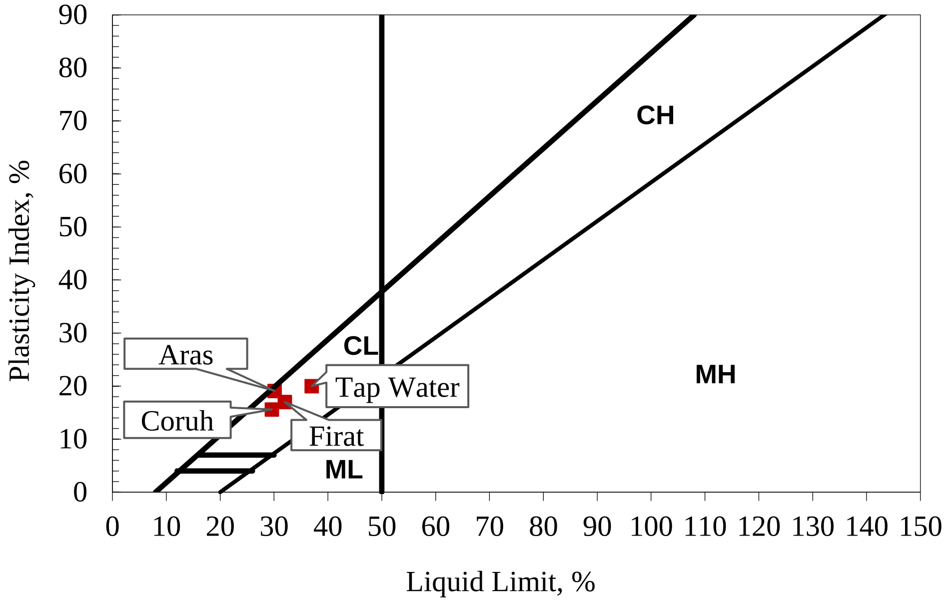

Fig. 5. Soil classifications of CL clay affected with different basin waters

3.2. Standard Proctor Test Results

Compaction tests conducted by adding water from different basins to CH and CL clays were performed at standard proctor energy. The compression curves created for CH clay as a result of standard proctor tests are shown in Figure 6, while the compression curves created for CL clay as a result of standard proctor tests are shown in Figure 7.

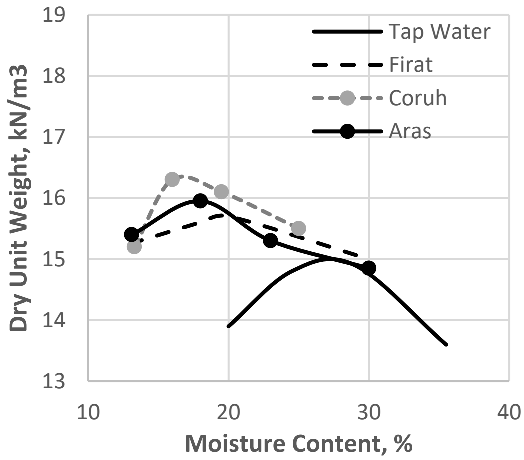

Fig. 6. Compaction curves of CH clays affected with different basin waters

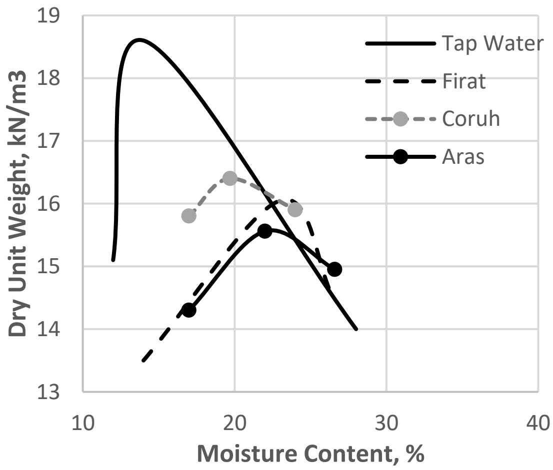

Fig. 7. Compaction curves of CL clays affected with different basin waters

Table 5. Compaction parameters of clays

Clay	Water	Maximum Dry Unit Weight (kN/m^3)	Optimum Moisture Content (%)
CH	Tap Water	15	28.9
	Firat	15.80	20
	Coruh	16.30	17
	Aras	15.98	18
CL	Tap Water	18.6	14.5
	Firat	16.08	22.67
	Coruh	16.32	20
	Aras	15.56	22.14

The optimum moisture content and maximum dry unit weight of the clays, which was obtained using different basin waters, is shown in Table 5. Figure 8 shows the variation in the optimum moisture content of the clays caused by different basin waters, while Figure 9 shows the variation caused by it in the maximum dry unit weight of the clays.

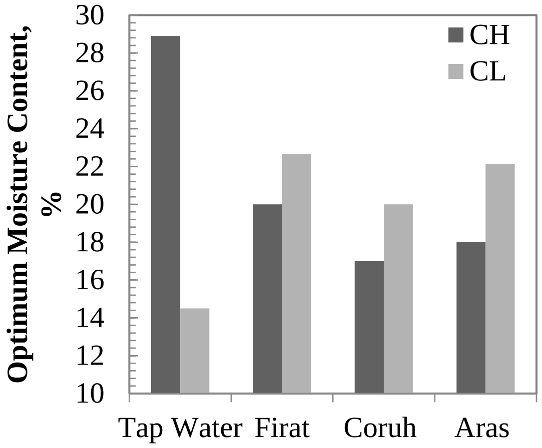

Fig. 8. The effects of different basin waters on the optimum moisture contents of clays

When the results of standard proctor tests performed on CH clay with different basin waters were compared to the results of the tests performed on tap water, it was found that the optimum moisture content decreased as the maximum dry unit weight value increased (Fig. 8 and Fig. 9). The lowest optimum moisture content and the highest maximum dry unit weight were obtained in the tests carried out with the water from the Coruh basin.

The water from the Coruh basin reduced the optimum moisture content of the clay with high plasticity by 41.2%. On the other hand, it increased its maximum dry weight volume weight value by 8%.

When comparing the results of standard Proctor tests performed on CL clay with different basin waters to the results of the tests performed on tap water, it was found that the optimum moisture content increased while the maximum dry unit weight value decreased. In the case of CL clay; The highest optimum moisture content was obtained in the test carried out with the water from the Firat basin. The water collected from the Firat basin increased the optimum moisture content of the clay with low plasticity by 56.3%. The water collected from the Aras Basin was determined to be the water that caused the greatest decrease in the maximum dry unit weight. The water collected from the Aras Basin reduced the maximum dry unit weight of the clay with low plasticity by 16.3%.

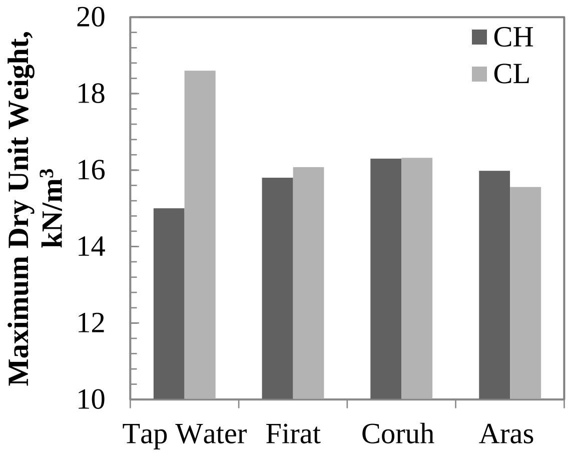

Fig. 9. The effects of different basin waters on the maximum dry unit weights of clays

3.3. Unconfined compressive strength test results

Unconfined compressive strength tests were carried out on CH and CL clays by adding water from different basins. The test results for the Unconfined compressive strength are given in Table 6. The variations in the unconfined compressive strength of CH and CL clays caused by different basin waters are shown in Figure 10.

Table 6. Unconfined compressive strength test results of clays

Clay	Water	Unconfined Compressive Strength (kPa)
CH	Tap Water	91.52
	Firat	91.89
	Coruh	91.17
	Aras	89.27
CL	Tap Water	74.36
	Firat	74.30
	Coruh	74.60
	Aras	77.15

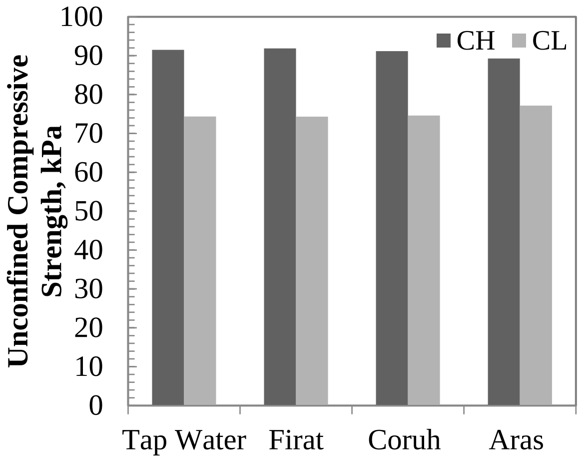

Fig. 10. The effects of different basin waters on the unconfined compressive strength of clays

Unconfined compressive strength tests carried out on CH and CL clays with different basin waters showed that there was no significant change in the unconfined compressive strength with the effect of different waters. In CH clay, the water from the Aras basin reduced the unconfined compressive strength by 2%, while the water from the Aras basin increased the unconfined compressive strength in CL clay by 3.7%.

4. Conclusions

In this study, the impact of the water collected from the Turkish basins such as Firat, Aras and Coruh on the consistency limit, the compression and the unconfined compressive strength of clays with high and low plasticity was examined. Accordingly, consistency limits, standard proctor and unconfined compressive strength tests were carried out on the clays with the water collected from the basins. The test results were compared to the results of the tests performed with tap water. Anion analysis, cation analysis, conductivity, pH and chemical oxygen demand analysis for tap water and basin water were performed and the results obtained as a result of the study are shown below.

-The consistency limits of CH clay decreased with the effect of different waters. The water collected from the Coruh basin was found to be more effective at consistency limits compared to the others. The water collected from the Coruh basin reduced the liquid limit, plastic limit and plasticity index of CH clay by 33%, 47.8% and 23.7%, respectively, compared to those performed with tap water.

- The soil class of CH clay was changed to CL in the tests carried out on the water collected from the Coruh and Aras basins. In the tests carried out with the water from the Firat basin, no change in the clay class was observed, while the plasticity decreased.

-The consistency limits of CL clay decreased with the effect of different waters. The water collected from the Coruh basin was found to be more effective at consistency limits compared to the others. The water collected from the Coruh basin reduced the liquid limit, plastic limit and plasticity index of CL clay by 20%, 17.6% and 22%, respectively, compared to those performed with tap water.

- In the case of CL clay, no significant change in the soil classes of the clays was observed depending on the type of water used.

-According to standard Proctor tests performed on CH clay, when comparing the tests performed on the water collected from the basins with that performed on tap water, it was found that the maximum dry unit weight values was higher, while the optimum moisture content values were lower. The highest maximum dry unit weight and the lowest optimum moisture content were obtained in the tests carried out with the water collected from the Coruh basin.

- According to standard Proctor tests performed on CL clay, the comparison of the tests performed on the water collected from the basins with that performed on tap water found that the maximum dry unit weight values was lower, while the optimum moisture content values were higher.

-As a result of tests for unconfined compressive strength, which were carried out on CH and CL clays with tap water and various basin waters, it was found that the unconfined compressive strength was not significantly influenced by different basin waters.

The present study showed that the water from different basins caused variations in the parameters of the consistency limits and the compression of CH and CL clays. It can be said that these variations occurred due to the different chemical content of the basin water. It was found that the unconfined compressive strength of the clays was not significantly influenced by different basin waters. The influence of different basin waters on the swelling, permeability and consolidation properties of the clays can be investigated in future studies. In addition, it is believed that when the nature of the changes that different waters cause in the mineralogical structure of the clays is determined by special analyze methods, the causes of changes in geotechnical features could be understood clearly.

Conflicts of Interest

The authors declare no known conflicts of interest associated with this publication.

Funding Statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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