DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

AN INVESTIGATION OF EFFECTS OF BORON ADDITIVES ON THE PERMEABILITY AND SHEAR STRENGTH BEHAVIOR OF SAND BENTONITE MIXTURES UNDER HIGH TEMPERATURES

by
Şükran Gizem ALPAYDIN

July, 2019
İZMİR

AN INVESTIGATION OF EFFECTS OF BORON ADDITIVES ON THE PERMEABILITY AND SHEAR STRENGTH BEHAVIOR OF SAND-BENTONITE MIXTURES UNDER HIGH TEMPERATURES

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled "**AN INVESTIGATION OF EFFECTS OF BORON ADDITIVES ON THE PERMEABILITY AND SHEAR STRENGTH BEHAVIOR OF SAND-BENTONITE MIXTURES UNDER HIGH TEMPERATURES**" completed by **ŞÜKRAN GİZEM ALPAYDIN** under supervision of **PROF. DR. YELİZ YÜKSELEN AKSOY** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ABSTRACT

The importance of thermal behavior of soils has increased considerably in last decades. High thermal resistance and durable soils are needed for structures such as; nuclear waste disposal facilities, buried high voltage cables, energy piles etc. These structures cause thermal variations in the surrounding soils. The soil engineering properties are temperature dependent. For that reason, the change in engineering properties of soils should be investigated under high temperatures and thermal cycles. Sand-bentonite mixtures are usually used for impervious barriers at nuclear waste repositories, municipal solid waste landfill liners, etc. These mixtures must keep their strength and hydraulic conductivity properties without any changes for a very long time. The literature studies have shown that high temperature and thermal cycles have negative effects on the hydraulic conductivity and shear strength of soils. For that reason, the resistivity of sand-bentonite mixtures should be increased against high temperatures when they are used in liners.

Boron reduces heat expansion of the glasses, protects the glass against acid and scratches. Boron minerals are used in order to increase the thermal resistivity of materials in industry. Hence the boron minerals can be added to the sand-bentonite mixtures in order to improve strength and hydraulic conductivity properties of these mixtures against high temperature or thermal cycles.

In this study, compaction, shear strength and hydraulic conductivity properties of sand-bentonite mixtures were determined in the presence of boron mineral; namely colemanite, tincal and ulexite. The sand-bentonite mixtures were prepared with 10 and 20 percentage bentonite and boron minerals were added to these mixtures. The direct shear and the hydraulic conductivity tests were conducted under 80 Celsius degrees and room temperature.

Keywords: Boron, compaction, shear strength, hydraulic conductivity, high temperature, thermal behavior

BOR KATKILARININ KUM-BENTONİT KARIŞIMLARININ YÜKSEK ISILAR VARLIĞINDA PERMEABİLİTE VE KAYMA DAYANIMI DAVRANIŞI ÜZERİNDEKİ ETKİLERİNİN ARAŞTIRILMASI

ÖZ

Zeminlerin termal davranışının önemi son yıllarda önemli ölçüde artmıştır. Nükleer atık depolama sahaları, gömülü yüksek gerilim güç kabloları, enerji kazıkları vb. gibi ısıya maruz kalan mühendislik uygulamalarında yüksek termal dayanım ve dayanıklı zeminlere ihtiyaç vardır. Bu yapılar çevredeki zeminler üzerinde termal değişimlere neden olurlar. Zeminlerin mühendislik özellikleri sıcaklığa bağlı olarak değişmektedir. Bu nedenle zeminlerin mühendislik özelliklerindeki değişimler yüksek sıcaklık ve termal döngüler varlığında incelenmelidir. Kum-bentonit karışımları nükleer atık depo sahaları ve katı atık depolama alanlarında geçirimsiz bariyerler olarak kullanılmaktadır. Bu karışımlar hidrolik iletkenlik ve kayma dayanımı gibi özelliklerini uzun zaman boyunca değiştirmeden korumalıdırlar. Literatür çalışmaları, yüksek sıcaklık ve termal döngülerin zeminlerin hidrolik iletkenlik ve dayanımı üzerinde olumsuz etkileri olduğunu göstermiştir. Bu nedenle kum-bentonit karışımlarının dayanımı atık depolama sahalarındaki kil örtülerde kullanıldığında yüksek sıcaklıklara karşı arttırılmalıdır.

Bor, camların ısıl genleşmesini azaltır, camı asit ve çiziklere karşı korur. Endüstride malzemelerin termal dayanımlarını artırmak için bor mineralleri kullanılır. Bu nedenle, kum-bentonit karışımlarının yüksek sıcaklık veya termal döngülere karşı dayanım ve hidrolik iletkenlik özelliklerini arttırmak için bu karışımlara bor mineralleri ilave edilebilir.

Bu çalışmada, kum-bentonit karışımlarının kompaksiyon, kesme dayanımı ve hidrolik iletkenlik özellikleri, bor mineralleri olan kolemanit, tinkal ve üleksit varlığında incelenmiştir. Kum-bentonit karışımları yüzde 10 ve 20 oranında bentonit ile hazırlanmış ve bu karışımlara bor mineralleri eklenmiştir. Kesme kutusu ve hidrolik iletkenlik deneyleri 80 santigrat derece ve oda sıcaklığında gerçekleştirilmiştir.

Anahtar kelimeler: Bor, kompaksiyon, kesme dayanımı, hidrolik iletkenlik, yüksek sıcaklık, termal davranış

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INTRODUCTION

The fossil fuels are expensive and contaminant for environment. For that reason, the type and number of the thermo-active geo-structures increase in recent years. The thermo-active structures and projects are heat storage systems, buried high voltage cables, oil and gas pipelines, energy piles, CO_2 sequestration plants, geothermal energy, nuclear waste disposal facilities, ground improvement techniques using heating and freezing, sealed underground buildings such as subway and tunnel fire prevention design. These engineering projects are related with heat transfer through soil mass. Hence, there is a need to understand soil behavior with new phenomena in terms of mechanical and environmental variables. For that reason, the number of studies has been increased on thermo-mechanical behavior of soils during the past two decades. Thermal effects on the geo-structures and surrounding soil might have an effect on the soil/structure interface in thermo-active geo-structures. It is reported that the interaction between geo-structure and soil has a complex nature under the coupled thermo-mechanical loadings (Yavari, Tang, Pereira, & Hassen, 2016).

Even all Turkey's local energy sources will be used fully before 2020, it is not be possible to meet energy demands of Turkey. The nuclear power plants (NPP) are the most important alternative to the fossil fuels. For that reason, the nuclear power plant has been raised to be constructed in Turkey (Türkiye’nin Elektrik Üretimi ve Dağıtımı Şti. [TEÜD], 1999). In developed countries, most of the energy needs are met by NPP. In these countries, nuclear wastes generated by NPP are disposed in underground geological deposits. Nuclear waste should be properly isolated to prevent environmental pollution (International Atomic Energy Agency [IAEA], 1990, 2003).

The conceptual design of nuclear waste repositories is composed of multi-barrier systems. The multi-barrier system should provide enough conditions for isolation and controlled release of radionuclides. In these systems the natural geological barriers provided by the repository host rock and an engineered barrier system (EBS). The components of engineered barrier system are nuclear waste, waste canister, buffer materials, and backfill (Wang, 2010). Figure 1.1 is represented conceptual model of deep geological disposal of nuclear waste.

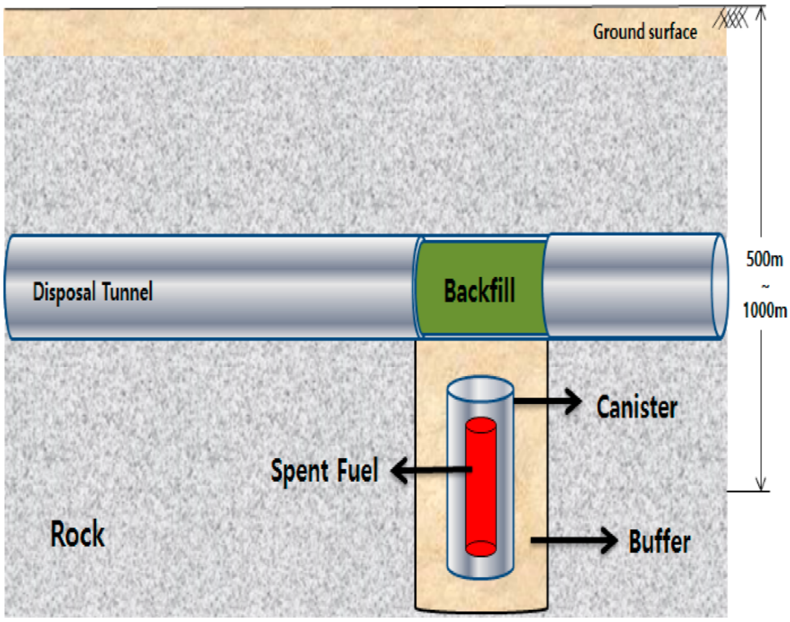


Figure 1.1 Conceptual nuclear waste repository model

It is vital that materials are mechanically stable, chemically resistant and have very low permeability for the success of nuclear waste storage isolation (IAEA, 2001). Because of their engineering properties, bentonite and sand-bentonite mixtures are preferred as buffer and filling material in the isolation of underground nuclear waste reservoirs in Sweden, Switzerland, Canada, Germany and France (Pusch, 1994). The purpose of using sand-bentonite barriers as impermeable barriers is to obtain a two-component insulating material. The sand forms a load-bearing frame and bentonite forms the impermeable barrier material filling the gaps in the sand component. Bentonite provides low hydraulic conductivity and high swelling pressure. The low hydraulic conductivity prevents water penetration and solute transport, it also provides a favorable chemical environment. Furthermore, the swelling pressure of bentonite should prevent the canister from sinking through the supporting bentonite layers and contact of the host rock with canister surface. Also, high swelling pressure provides self-sealing ability and fills voids between sand grains. The high self-healing capacity of bentonite prevents cracking and fissuring in the structure of buffer (Gens, 2003).

The buffer materials must sustainable and durable up to 10^6 years (Sellin & Leupin, 2013).

Energy structures directly connect to the soil and cause thermal variations on the underlying soils. In nuclear waste disposal facilities, the temperature increase due to decay heat has important effects on the host rock and buffer materials. Temperature increase (up to 90°C) decreased the long-term strength of the granite by about 10% (Liu, Cai, & Wang, 2007). When the temperature approximates to 100°C the buffer engineering properties may change by cementation and illitisation. In order to protect buffer materials and host rock the thermal conductivity of the canister is also controlled to avoid excessive temperature increases. For that reason, in many countries (Sweden, Finland, etc.) a temperature limit of 100°C is taken as a design limit. However, other conceptual designs limit temperature can be as high as 200°C (Gens & Olivella, 2014). Previous studies have investigated the behavior of soils up to 50°C. But in recent years, increasing interest in radioactive waste storage within clay barriers has led to the need to determine the thermomechanical behavior of soils up to 100°C (Abuel-Naga, Bergado, & Ramana et al., 2006).

The temperature increase also is reported in landfills. The temperature increase occurs due to biochemical processes and decomposition of organic components in wastes (Sinha & Kusakabe, 2008). The increase in temperature can adversely affect impermeable barriers in terms of mechanical and hydraulic behavior for the long term. Sand-bentonite mixtures are commonly used in landfill liners. Because bentonite is a material with low permeability and high-water retention capacity. Bentonite is a highly swelling clay and shrinks when becomes dry. For that reason, engineering properties of soil needs to be improved when bentonites are present. The properties of sand-bentonite mixtures should not change by time. For that reason, it is necessary to improve the properties of bentonites and sand-bentonite mixtures.

Hydraulic permeability of compacted clay barriers should be in the order of 1×10^{-7} cm/sec (Benson & Daniel, 1990). Radhakrishna, Chan, Crawhord, & Lau (1989); Westsik, Bray, Hodges, & Wheelwright (1981) stated that when the compacted bentonite-sand mixtures are used to isolate nuclear wastes, the hydraulic conductivity value should be 1×10^{-9} cm/sec and below.

1.1 Background

1.1.1 Thermal Effects on Soil Behavior

Heating soils to higher temperatures can lead to a significant effect on some engineering properties. Previous studies have shown that thermal cycles and high temperatures affect the hydraulic conductivity, volume change (compressibility-swelling) and shear strength properties of soils (Abuel-Naga, Bergado, & Ramana et al., 2006; Pusch, Karlnland, & Hokmark, 1990). The increment of temperature in the soil is a major problem in some cases. An increase in the hydraulic conductivity value due to heat increment will lead to irreversible environmental pollution in the impermeable sand-bentonite barriers used in nuclear waste isolation. Volumetric deformation or strength loss of soils around other energy structures will cause damage these structures. The long-term engineering properties of soils at impermeable clay barriers in such as nuclear power plants, energy piles, heat storage facilities should not change especially in the hydraulic conductivity properties as well as compressibility and strength properties against high temperatures and thermal cycles.

1.1.1.1 Thermal Effects on Shear Strength Behavior of Soils

The temperature increase has effects on the shear strength of soils. The magnitude of this effect depends on density, water content, soil type, mineralogical and chemical composition (Mitchell, 1969).

The thermo-mechanical behavior of reconstituted and natural clayey soils was investigated using triaxial cells with controlled temperature (20 to 60°C) in Burghignoli, Desideri, & Miliziano (2000) study. In this study, it was observed that increase of temperature cause change of volume of grains and rearrangement of particles. This volume change of grains is generally positive, however; volumetric deformation may be positive or negative. It was investigated that, change in void ratio by rearrangement of particles depends on stress history, thermal history, recent stress history, the time between and of primary consolidation and start of the mechanical load, start of thermal load change, duration of heating. It was related thermal and time dependent behavior of soil skeleton. Hence, the occurred deformations after heating due to rearrangement of particles are a kind of amplification of those responsible for creep deformations of the soil body at a constant temperature. In other words, temperature variations activate and amplify the creep deformations in soil.

The change in residual deviatoric stress depending on high temperature and temperature cycle was observed by Abuel-Naga, Bergado, & Ramana et al., (2006). In their test set-up the electric heater is located in the triaxial test cell. The temperature of the water in the cell was increased to 90°C and experiments were performed under this temperature. In this study, in terms of shear strength, higher peak shear strength values were obtained under high temperatures. Figure 1.2a shows normalized deviatoric stress (q/p_{cons}) versus axial deformation (ε_a) under undrained condition where q is the deviatoric stress and p_{cons} is effective consolidation stress. As seen from Figure 1.2a as temperature was increased, the peak deviatoric stress increased. When soft Bangkok clay samples subjected to temperature history (25-70-25°C and 25-90-25°C), before shearing the samples showed a similar increase in peak deviatoric stress. In addition, the axial strain values at peak deviatoric stress was lower for the samples subjected to temperature history than the samples at only elevated temperature.

Figure 1.2b shows deviatoric stress (q) versus axial deformation (ε_a) behavior of soft Bangkok clay under drained compression triaxial shear test on normally consolidated (NC) samples at 300 kPa. The results of this study have shown that higher peak deviatoric stresses were observed at higher temperatures. The residual deviatoric stress values of samples at different temperatures had similar values at large strains. In addition to this, soil samples sheared under high temperature have lower volumetric strains (Abuel-Naga, Bergado, & Ramana et al., 2006).

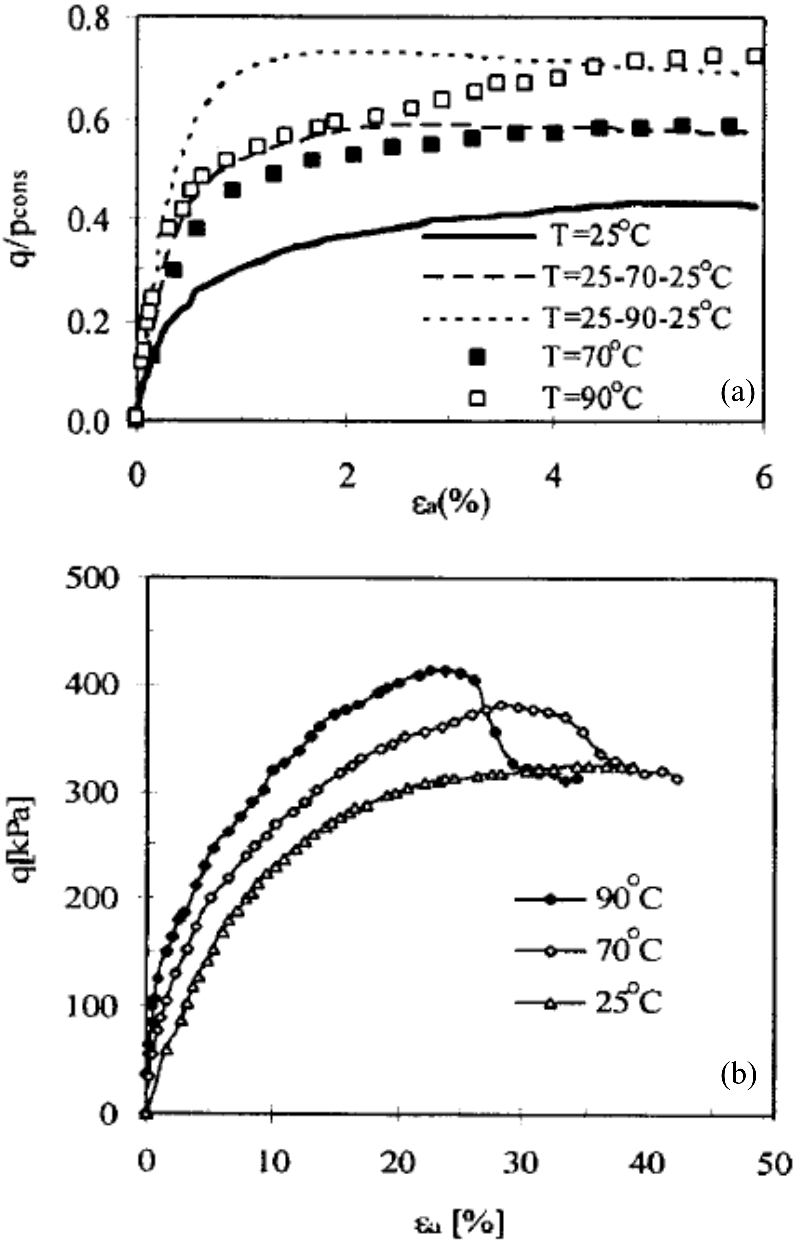


Figure 1.2 Triaxial compression tests on normally consolidated soft Bangkok clay a) Effect of temperature and temperature history on undrained test b) Drained test at different temperatures levels (Abuel-Naga, Bergado, & Ramana et al., 2006)

The shear strength parameters change on the previously heated samples were studied by Wang, Benway, & Arayssi (1990). The bentonite and kaolin were heated to 100°C in an electric oven for 24 hours. According to the test results, the internal friction angle of the kaolin was significantly increased due to the increasing temperature. However; it should be noted that the samples were heated before the experiments and then cooled in desiccator, then the experiments were performed at room temperature. By heating the bentonite to 100°C there is a sharp increase in the internal friction angle and a decrease in cohesion values. Thus, the high cohesive bentonite becomes a soil with low cohesion with increasing temperature and has a high internal friction angle specific to granular soils (Wang et al., 1990).

The shear strength of clay soils under high temperature was also investigated by Hong, Bian, Cui, Gao, & Zeng (2013). They reported that the effects of temperature on the shear strength of the clay are highly dependent on the volume change due to heating. They noted that thermal expansion causes a decrease in soil strength, however; at the same time thermal contraction increase the shear strength.

The soil and concrete interface interaction under thermo-mechanical loadings were investigated in Yavari et al., (2016) study. The temperature control system adapted direct shear tests performed on the sand, clay and clay/concrete interface at 5°C, 20°C and 40°C. According to results of this study the effect of temperature until 40°C is negligible on the shear strength of sand, clay and clay/concrete interface.

1.1.1.2 Thermal Effects on Compressibility Behavior of Soils

The previous studies have shown that temperature increase has detrimental effects on volume deformation of clay soils. The resistance of fabric changes against to temperature is explained with clay interparticle forces and viscous shear resistance of adsorbed water (Abuel-Naga, Bergado, & Lim, 2007).

In the study of Abuel-Naga, Bergado, & Ramana et al., (2006), soft Bangkok clay was heated up to 90°C by heating the water in the consolidation cell. It was observed that the change in the void ratio depends on the stress history, however; it is independent from the magnitude of the stress applied under high temperatures. The compressibility behavior of Bangkok clay was also influenced by the heating-cooling cycles. The normally consolidated Bangkok clay began to exhibit an over-consolidated clay behavior due to increased heat.

There are limited number of studies on the thermal behavior of sand. Recordon (1993), performed thermal consolidation test on fine sand samples temperatures between 2°C and 40°C. They observed that compression index and over consolidation ratio of sand samples were independent of temperature.

Volumetric changes of muddy clay were investigated under heat up to 100°C by Chen et al., (2016). In this study, it was determined that soils tend to decrease their volume under high temperature. The reasons for this phenomenon are the steam outflow of water, the steam outlet causing the displacement of the grains, the fracture of the grains and the degradation of organic matter. In another study volumetric deformation behavior of cohesive sediments under high temperature is observed by Dalla Santa, Galgaro, Tateo, & Cola, (2016). In this study, cohesive sediment samples were tested by heating up to 50°C with water in the oedometer cell. According to the results, sediments showed a permanent deformation of 9.3% with rising temperature.

One of the rare studies on soil mixture instead of one type of soil is the study of Sinha & Kusakabe (2008), on the volumetric change of sand-bentonite mixtures against high temperature. In this study, 10% bentonite-90% sand mixture was heated up to 75°C and volumetric strain behavior was observed. In NC conditions, the pore water pressure changes depending on temperature, and therefore the void ratio changes. It was determined that the increase in heat caused an increase in the amount of volumetric strain. Higher temperatures are more effective in volume changes. In the experimental results, when the temperature rises from 20°C to 45°C, the strain increased 0.37% and when the temperature increased from 20°C to 75°C the strain increased to 0.51%. In addition, the normally consolidated clays compressed as irreversibly and nonlinearly in terms of volumetric strain with rising temperature.

According to the previous studies, the volumetric variation of soils with increasing temperature is related to the value of plasticity index. Figure 1.3 shows the changes in the volume variation depending on the plasticity index in the tests performed at high temperature. Soils with high plasticity index were exposed to more volumetric changes due to temperature increase.

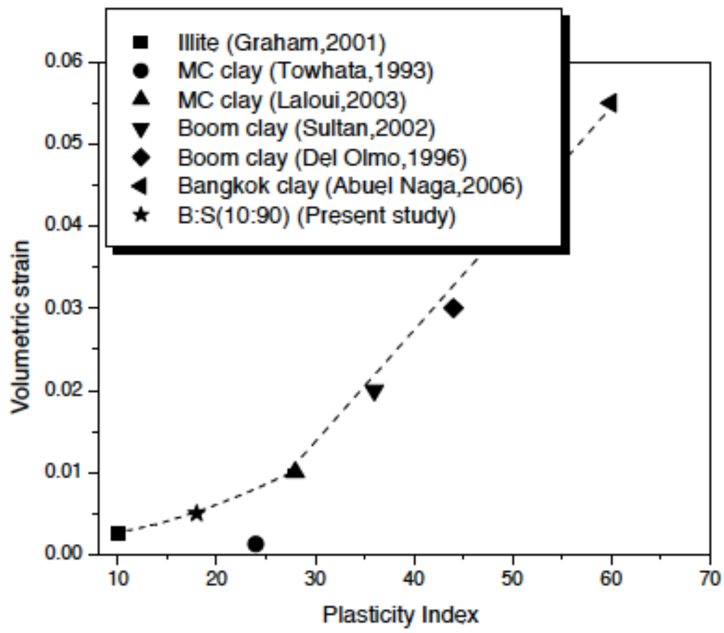


Figure 1.3 Volumetric strain with plasticity index of soil due to temperature change (Sinha & Kusakabe, 2008)

There are limited number of studies about the thermal effects on the swelling behavior of clay soils. The swelling behavior of the compacted bentonite was studied with increasing temperature by Pusch, Karlnland, & Hokmark (1990); Villar & Lloret (2004). According to the results obtained from these studies, the swelling pressure of Ca-bentonite and Ca-Mg bentonite decreases when heat was increased up to 80°C.

1.1.1.3 Thermal Effects on Hydraulic Conductivity Behavior of Soils

Increase in hydraulic conductivity due to rising temperature will be a problem in impermeable clay barrier applications and engineered barrier systems in nuclear waste repositories. Because of low hydraulic conductivity of bentonite, radionuclides transport by diffusion in bentonite. Bentonite very effective sorbent which delays the transport. For that reason, the hydraulic conductivity of bentonite has a vital importance in nuclear waste isolation systems. The effects of temperature on the hydraulic conductivity behavior of soils were investigated with limited number of studies. The general results have shown that the hydraulic conductivity of soils increases with increase in temperature. According to Cho, Lee, & Kang (1999); Pusch (2001), due to heating the viscosity of pore water decreases and this effect increases the hydraulic conductivity. For example, the hydraulic conductivity of compacted bentonite at 80°C was investigated to be 3-4 times higher than that measured at 20°C (Cho, Lee, & Kang, 1999). Romero, Gens, & Lloret (2001), reported that change in hydraulic conductivity values is smaller than it could be expected due to thermal change in water viscosity. Hence, clay fabric changes and porosity redistribution may alter the hydraulic conductivity with temperature. Figure 1.4 shows that the difference between experimentally measured and predicted from water kinematic viscosity hydraulic conductivity values.

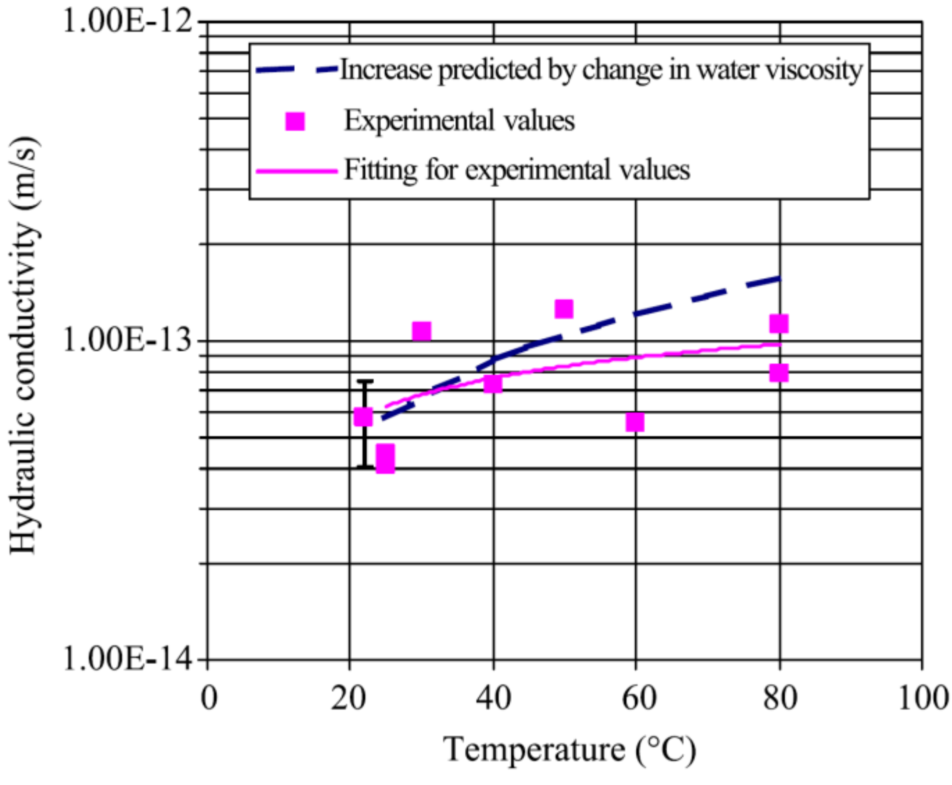


Figure 1.4 Comparison of hydraulic conductivity values determined experimentally and those predicted from the change in water kinematic viscosity at different temperatures (Villar & Lloret, 2004)

In order to test soft Bangkok clay, an electric heating device was placed in the flexible wall permeameter cell. The temperature of the water in the cell was increased to 90°C and tests were performed under this temperature by Abuel-Naga et al. (2006).

According to the results obtained in this study, it was shown that the hydraulic conductivity value of soft Bangkok clay increased under high temperature.

Aldaeef and Rayhani (2015) conducted a research to determine the effect of thermal cycles on hydraulic conductivity of compacted clay liners (CCLs) in simulated landfill conditions. The Halton clay, Leda clay and their mixtures with bentonite samples were subjected to thermal cycles and then hydraulic conductivity tests were performed. In this study, the sample was heated to 55°C for 8 hours by means of heating blanket and then cooled by closing the heat blanket. In this way, it was determined that hydraulic conductivity increased against rising temperature in the experiments carried out on three different clays after 15 and 30 cycles.

The hydraulic conductivity values of the expansive clay were determined from one dimensional consolidation test at elevated temperatures of 40°C and 60°C (Shirazi, 2014). It was reported that the temperature is the most effective parameter on the hydraulic conductivity. As temperature was increased, hydraulic conductivity values increased significantly.

The hydraulic conductivities Kyungju Ca-bentonite (dry densities of 1.4 Mg/m^3 to 1.8 Mg/m^3) were determined up to 150°C (Cho, Lee, & Kwon, 2011). The hydraulic conductivity values at a temperature 80°C were up to about three times those at 20°C. At higher temperatures (150°C), the hydraulic conductivities were up to about one order of magnitude higher than the hydraulic conductivities at 20°C (Figure 1.5). The change of hydraulic conductivities depending on temperature increase related with change in the viscosity and the density of the fluid and permeability of bentonite. Cho, Lee, & Kwon, (2011), also noted that if the temperature in the buffer is controlled below 100°C, the hydraulic conductivity of buffer may be low enough to inhibit radionuclide transport.

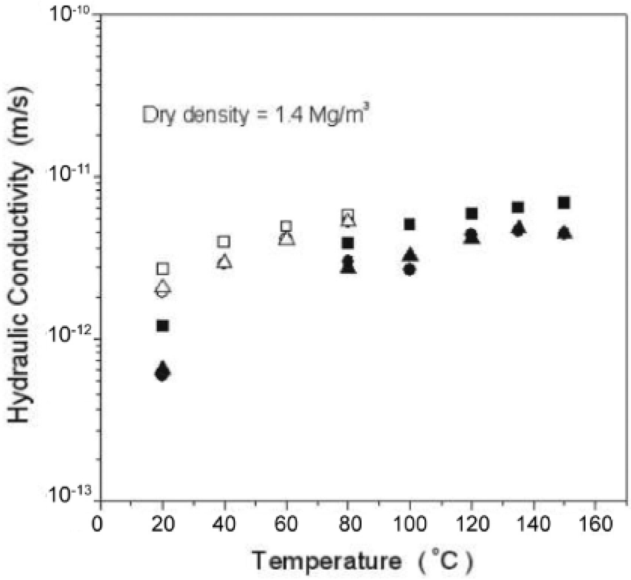


Figure 1.5 Hydraulic conductivity of compacted bentonite at different temperatures (Cho, Lee, & Kwon, 2011)

1.1.2 Boron Minerals

Boron is a natural compound which contains different proportions of boron oxides. Boron, which is present in the structure of the earth's crust at a rate of 0.001%, however; is not free in nature. It is prone to bond with oxygen and therefore has many boron-oxygen compounds. These boron-oxide compounds are called borates. The 51st common element in the earth's crust is boron, which is present as borates and borosilicates (Özkan, Çebi, & Delice, 1997). It is found in soil, rock and water on earth and is usually in the form of compounds. There are about 230 types of boron minerals known in nature. Boron is one of the most widely used raw materials in the industry as it can make many compounds and absorb neutrons. Therefore, it is quite common in the world. Boron oxide (B_2O_3) and boric acid (H_2BO_3) are the simplest form of boron compounds. When it is bonded with calcium, it is called as colemanite, with calcium-sodium it is called as ulexite and with sodium it is called as tincal (Sallı Bideci, 2016). Table 1.1 presents the major boron minerals and chemical formulas. The atomic number and atomic weight of boron, the first and lightest element of group 3A, indicated by the symbol "B" in the periodic table are 5 and 10.81, respectively (Güyagüler, 2001) (Figure 1.6).

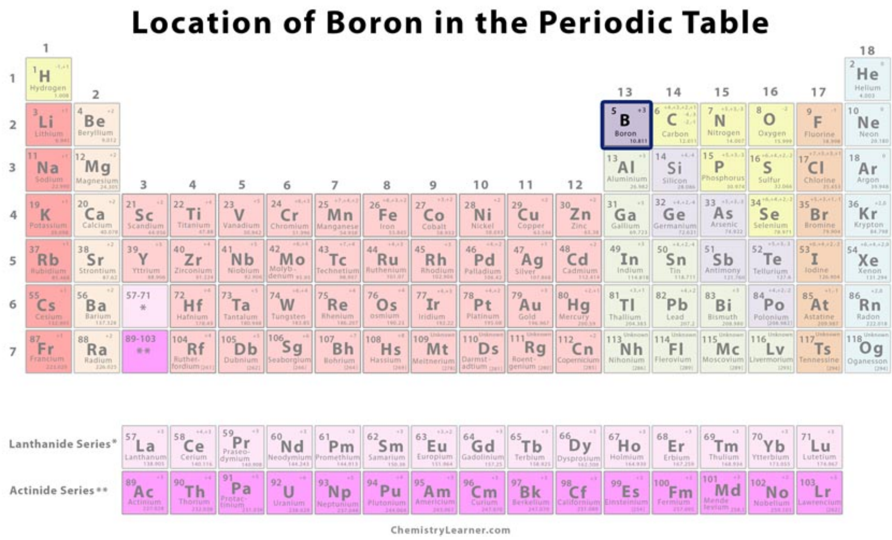


Figure 1.6 Location of boron in the periodic table (Chemistrylearner, 2019)

The melting point of the boron is 2190 ± 20 °C and the boiling point is 2250°C (Pehlivan, & Çetinkaya, 2004). Boron minerals are classified as Evaporites since they are formed by chemical precipitation from waters where evaporation is high (Yigitbasoglu, 2004). As an element, boron is a dark brown powder in amorphous form and a hard and brittle structure in crystallized form. Boron has properties between metal and nonmetal and is semi-conductive. Although the electrical conductivity of the boron is very low at room temperature, the conductivity increases sharply with increasing heat (İpekoğlu, & Polat, 1987).

There are two balanced isotopes in nature, 10B and 11B, which are 19.10-20.31% and 79.69-80.90% respectively (Özkan et al., 1997). The isotope 10B is used in nuclear materials and nuclear power plants due to its high thermal neutron retention (Boren, 2019).

The value of boron mines is generally measured by the B_2O_3 (boroxide) contained therein. The higher the amount of boron minerals B_2O_3 compound is considered to be valuable. Nowadays, the energy provided by fossil fuels is very harmful for the environment and does not have much life. Sodium borohydride ($NaBH_4$) is a good intermediate carrier for less harmful energy sources (Pehlivan, & Çetinkaya, 2004).

Table 1.1 Major boron minerals with commercial importance (Etimaden, 2019)

Minerals	**Formula**
Kernite	$Na_2B_40_7.4H_2O$
Tincalconite	$Na_2B_40_7.5H_2O$
Tincal	$Na_2B_40_7.10H_2O$
Probertite	$NaCaB_50_9.5H_2O$
Ulexite	$NaCaB_50_9.8H_2O$
Colemanite	$Ca_2B_6O_{11}.5H_2O$
Meyerhofferite	$Ca_2B_6O_{11}.7H_2O$
Inyoite	$Ca_2B_6O_{11}.\ 13H_2O$
Pandermite	$Ca_4B_{10}O_{19}.7H_2O$
Inderite	$Mg_2B_6O_{11}.15H_2O$
Hydroboracite	$CaMgB_6O_{11}.6H_2O$
Boracite	$Mg_3B_7O_{13}Cl$
Ascharite	$Mg_2B_2O_5.H_2O$
Datolite	$Ca_2B_2Si_2O_9.H_2O$
Sassolite (natural boric acid)	H_3BO_3

The most common uses of boron are fiberglass, insulation, textile or continuous-filament glass fibers, glass, enamels and frits, and fertilizers (Helvaci, 2005). As boron demand increased in nuclear technology, glass and ceramic industry, as abrasives and refractors, in agriculture, production of heat resistant polymers as catalysts, etc., the production of boron compounds increased considerably (Schmidt-München, 2007). Moreover, the importance of the chemistry and the thermal behavior of the boron has increased as the applications increase under high temperature (Rusen, 2018). Almost half of the use of boron in the world is in the glass industry. Boron oxide is added to the glass in the form of boron compounds such as anhydrous borax, boric acid, or minerals such as borax or colemanite. Boron minerals are used in borosilicate glasses. In borosilicate glass production, boron additive increases mechanical strength and resistance against thermal shocks (Sugozu, Mutlu, & Sugozu, 2016). Boron significantly reduces the expansion of glass by temperature and protects the glass from acid and scratching. In addition, boron provides high temperature resistance in glass. Temperature resistant glassware is used in electronics and space research (Yigitbasoglu, 2004).

Boron compounds and boron fibers are used for high strength and flexibility in plastics or metals. For example, the addition of boron increases the hardness and strength of the steel (Boren, 2019). Textile type fiberglass obtained from boron products does not conduct heat and electricity and is highly resistant to physical impacts (Etimaden, 2019).

Boron compounds are particularly effective in increasing thermal stability as well as preventing radiation transmission due to their light weight and cost advantages (Guzel, Sivrikaya, & Deveci, 2016). Boron is also used in nuclear power plants as a neutron absorbing material. Each boron atom absorbs about one neutron. Boron is unique in its ability to absorb thermal neutrons. Boron is used in cooling pools and control systems of reactors. It is also used for emergency shutdown of the reactor. Colemanite is used to reduce the environmental impact of nuclear waste (Yigitbasoglu, 2004).

Previous studies on the reaction of boron with clay structure have shown that the boron is held strongly by the aluminum or silicon tetrahedron portion in the clay structure. Adsorption of boron by clay reaches a maximum amount at pH 9-9.97 (Privett, 1987). When illite, montmorillonite and kaolin minerals are compared, the highest boron adsorption is done by illite and the least adsorption is done by kaolinite. But since the surface area of montmorillonite is higher than illite, it is accepted that montmorillonite can adsorb as much boron as illite (Keren, & Mezuman, 1981).

Boron minerals are produced in a limited number of countries. Leading countries in the boron production are Turkey and United States. These two countries provide 90% of the world's boron production (Helvaci, 2005). Of the world's total reserves, 63% were located in Turkey (Güyagüler, 2001). Boron deposits known in Turkey; Eskişehir-Kırka, Kütahya-Emet, Balıkesir-Bigadiç, Bursa-Kestelek (Boren, 2019).

1.1.2.1 Colemanite

Colemanite is a monoclinal mineral and is generally present in form of bright crystals. Typically, its color is white-gray and greenish gray. Mohs hardness of this mineral is about 4-4.5 and its specific gravity is 2.52. Colemanite is soluble in acid easily while it is insoluble in water. For example, the solubility of colemanite is 0.81 g/l in water at 25°C, which is a very small value. In addition, when the colemanite is heated above 400°C, it is scorched as powder by cracking (Özkan et al., 1997). The dissolution rate of colemanite increases as the temperature increases and the particle size decreases (Alkan, & Doğan, 2004). Colemanite, which is a very rich mineral in terms of boron, has the chemical formula $2CaO.3B_2O_3.5H_2O$ and B_2O_3 content is between 27 - 32% (Etimaden, 2019).

Although colemanite is generally used in boric acid production, it is also used in the production of borax, borax hydrates and sodium perborates (Frost, Scholz, Ruan, & Lima, 2016). It is used in many sectors such as; glass and ceramics sector. It increases durability of materials to the maximum level. It is also preferred frequently in metallurgy, fiberglass, fertilizer, detergent and cosmetics sectors (Etimaden, 2019).

When 8% colemanite is used in cement production, it reduces the clinker firing temperature and improves the properties of cement. The properties of boron additive cement such as; strength, water and gas permeability, hydration temperature is better than portland cement. The addition of colemanite in cement production reduces carbon dioxide emissions by 25-30%. In addition, colemanite is used to reduce environmental impact in the storage of nuclear waste (Yigitbasoglu, 2004). It can be found in Turkey, especially; Emet, Bigadic, Kestelek bed, and in the U.S.A. Photograph of colemanite mineral can be seen in Figure 1.7.

Colemanite has recently become important in high temperature applications, especially for the metallurgy, glass and ceramic industries. Therefore, it is very important to determine the changes in the structure of colemanite with increasing temperature. Rusen (2018), conducted thermal and mineralogical analysis of colemanite every 50°C from room temperature to melting temperature. According to this structural analysis, colemanite had the same chemical composition up to 300°C. Due to the removal of water at temperatures from 350°C to 650°C, the colemanite decomposed to amorphous B_2O_3 and CaO. At higher temperatures it recrystallized and began to melt just above 1080°C (Rusen, 2018).

Figure 1.7 Photograph of colemanite mineral (Webmineral, 2019)

Binici, Aksogan, & Durgun (2012), aimed to protect the rebars against corrosion by using materials obtained with basaltic pumice, ground granulated blast furnace slag, barite and colemanite mixtures as coating materials. After applying various corrosion tests, they obtained colemanite as the most effective coating material for corrosion protection.

Çimen & Dereli (2014), conducted unconfined compressive strength and swelling tests by adding colemanite mineral to 2%, 4%, 6%, 8% and 10% by weight to Na-bentonite clay. According to the test results, maximum unconfined compressive strength and maximum unit weight and minimum optimum water content were obtained in the samples with 2% colemanite additive. Reductions in swelling pressure were observed with increasing colemanite amount. In addition, colemanite decreased the liquid limit and plasticity index values. Since colemanite is a boron that contains calcium, it reduced the swelling potential of the bentonite and caused an increase in unconfined compressive strength (Çimen & Dereli 2014).

Durgun & Sevinç (2019), examined residual strengths of the concretes produced with ground granulated blast furnace slag (10, 20, 30%), waste glass powder (10, 20, 30%) and colemanite ore wastes (1,3,5%). These concretes were subjected to 200, 400, 600, 800, and 1000°C for 1 hour and then cooling process were applied these concretes. According to the results, concretes with colemanite ore waste showed better performances than other (Durgun, & Sevinç, 2019).

1.1.2.2 Tincal

Tincal or borax, which is a natural sodium borate decahydrate, is one of the most important commercially used boron mineral. Although tincal is generally colorless and transparent in nature, it can be found in pink or yellowish gray colors due to the various chemical components in it. Specific gravity of the tincal mineral is 1.72. In addition, the Mohs hardness is around 2-2.5. Crystal system of tincal is monocline and its crystal structure are short prism shape (Özkan et al., 1997). Figure 1.8 shows a photographic view of tincal mineral.

Figure 1.8 Photograph of tincal mineral (Webmineral, 2019)

Tincal having the chemical formula $Na_2B_4O_7.10H_2O$, contains 36.6% B_2O_3. Usually occurs in salty lakes in areas where evaporation is high. When tincal loses its water, it easily transforms into tincalconite. It is found together with ulexite and tincolconite intercalated with clays (Yigitbasoglu, 2004). In addition, the tincal mineral is freely crushed. Moreover, it easily dissolves in water. The solubility and rate of solution increases with rising water temperature. Tincal in large quantities is present in Turkey, USA and Argentina (Helvaci, 2005). In Turkey, tincal is produced especially in Kırka, Emet and Bigadiç (Buluttekin, 2008).

1.1.2.3 Ulexite

The main commercial mixed sodium-calcium borate, ulexite, can be found in nature in the form of edging strip, cauli, fibrous, cone, rosette, flock and stick (Etimaden, 2019). While the pure form of ulexite is white, there are also those whose appearance is as bright like silk (Yigitbasoglu, 2004). It is also called cotton rose because it is a slightly transparent mineral that is close to white (Özkan et al., 1997). The photographic view of the ulexite mineral is shown in Figure 1.9.

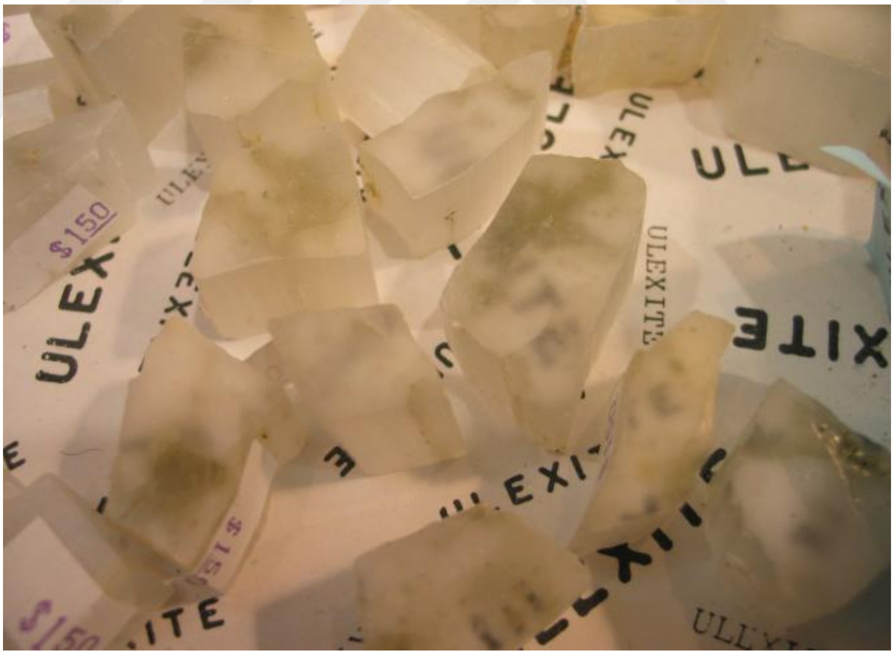


Figure 1.9 Photograph of ulexite mineral (Webmineral, 2019)

Specific gravity of ulexite is 1.96. In addition, while the solubility of ulexite is low in cold water, it is quite fast in hot water and acid. For example, the solubility value is 7.6 g/l in water at 25°C (Özkan et al., 1997). According to the Mohs scale, the hardness is 2.5 but it can reduce to 1.0 when it is in aggregate form. The crystal system of ulexite is triclin. The chemical formula of ulexite is $NaCaB_5O_9.8H_2O$ and the B_2O_3 content is 43.0% (Yigitbasoglu, 2004).

Ulexite is located on or near the surface. It is well qualified and therefore hard, dense and generally well-bedded (Helvaci, 2005). It usually occurs together with Colemanite, Hydroboraxite and Probertite. It is present in Turkey and Argentina. In our country, it is found especially in Kırka, Bigadiç and Emet regions (Yigitbasoglu, 2004).

Ulexite is a boron mineral commonly used in industry. It is used in the production of boron glass and in the ceramic industry thanks to its properties such as increasing heat resistance and being resistant to abrasion. Ulexite also has the property of increasing the hardness. For these reasons, ulexite is inclusive in the formulation of the brake lining (Sugozu et al., 2018).

1.2 Scope of This Study

The increase in the number and diversity of energy structures in recent decades has led to an increase in the number of studies on the thermal behavior of soils. However, when these studies are examined in the literature, it can be seen that the studies have been conducted on a single type (clay, silt) soil. However, sand-bentonite mixtures are used especially in the impermeable barrier applications used in nuclear waste disposal. It is very important to determine the soil properties which is used in impermeable barrier applications against high temperature. In addition, admixtures that will provide thermal resistance in sand-bentonite mixtures should be investigated.

The main purpose of this study is to develop boron added sand-bentonite mixtures used in energy structures especially in impermeable barriers at nuclear waste disposal areas which are durable in terms of engineering properties such as; hydraulic conductivity and shear strength against high temperature. The most important features that plays a role in the selection of boron minerals are heat resistance and low thermal expansion of boron minerals under high temperature. Our country is also the richest in terms of boron reserves in the world. If it is determined that boron can be used in heat resistant soil material, it is expected to make a major contribution to the national economy.

In this study, 10% and 20% sand-bentonite mixtures and the mixtures which were formed by adding 10%, 15% and 20% of boron minerals (colemanite, tincal and ulexite) to sand-bentonite mixtures, were used. Initially, the compaction tests were performed for each mixture, since the samples for were prepared according to compaction parameters for the direct shear and hydraulic conductivity tests. Direct shear tests were performed for all mixtures. Hydraulic conductivity tests were performed only in the presence of tincal mineral due to its high sodium content. After addition of boron to sand-bentonite mixtures for the improvement of soil against high temperature, the hydraulic conductivity and shear strength properties at room temperature were determined and the experiments were performed under 80°C to examine the thermal behavior of sand-bentonite mixtures. In this context, hydraulic conductivity and shear strength behavior of sand-bentonite mixtures with boron additives was determined under high temperature and their properties and stability were investigated against high temperature (80°C).

1.3 Outline of Thesis

This thesis consists of four chapters.

Material characterization and experimental methods in this study are explained in exhaustive in Chapter Two. This chapter presents grain size distribution, specific gravity, index properties, pH of materials used in this study. This chapter also contains sample preparation and test set-up for direct shear and hydraulic conductivity tests at room temperature and 80°C.

The compaction, shear strength and hydraulic conductivity behaviors of mixtures at room temperature are reported in Chapter Three. Chapter three also reports the direct shear and hydraulic conductivity test results at 80°C. The changes observed on the behavior of samples, which depends on boron percentage, boron mineral type and high temperature, also discusses in this chapter.

Finally, in Chapter Four, all test results presented in the previous chapter summarizes in the line of conclusions. The recommendations for future studies are also given in this chapter.

CHAPTER TWO
MATERIAL CHARACTERIZATION AND METHODS

2.1 Material Characterization

In this study, sand, Na-bentonite and boron minerals which are used in industry widely, namely; colemanite, tincal and ulexite were used. The Na-bentonite was supplied from Eczacıbaşı Esan Mining Company. Colemanite, tincal and ulexite were gathered from Eti Mining Operations General Directorate of Turkey. The materials which were used throughout this study are indicated in Figure 2.1.

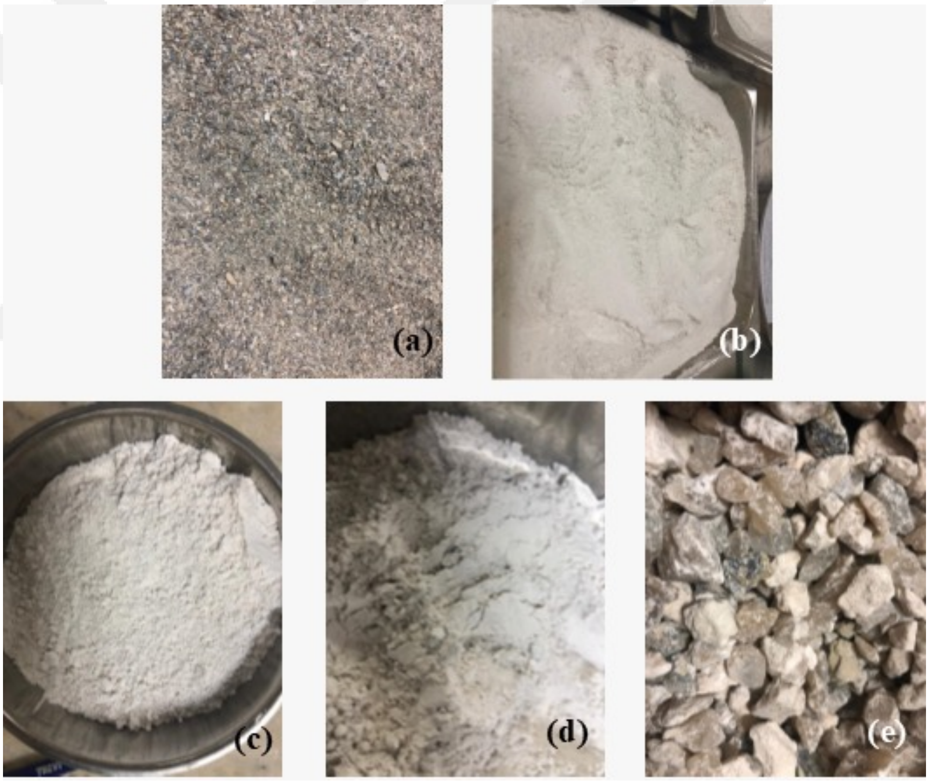


Figure 2.1 Materials used in this study a) sand b) bentonite c) colemanite d) tincal e) ulexite (Personal archive, 2018)

The grain size distribution curves of sand and bentonite which was used in the tests are given in Figure 2.2. According to this distribution the sand has 1.64% fine content. The sand is classified as sand (SW) according to the United Soil Classification System (USCS) (ASTM: D2487-17).

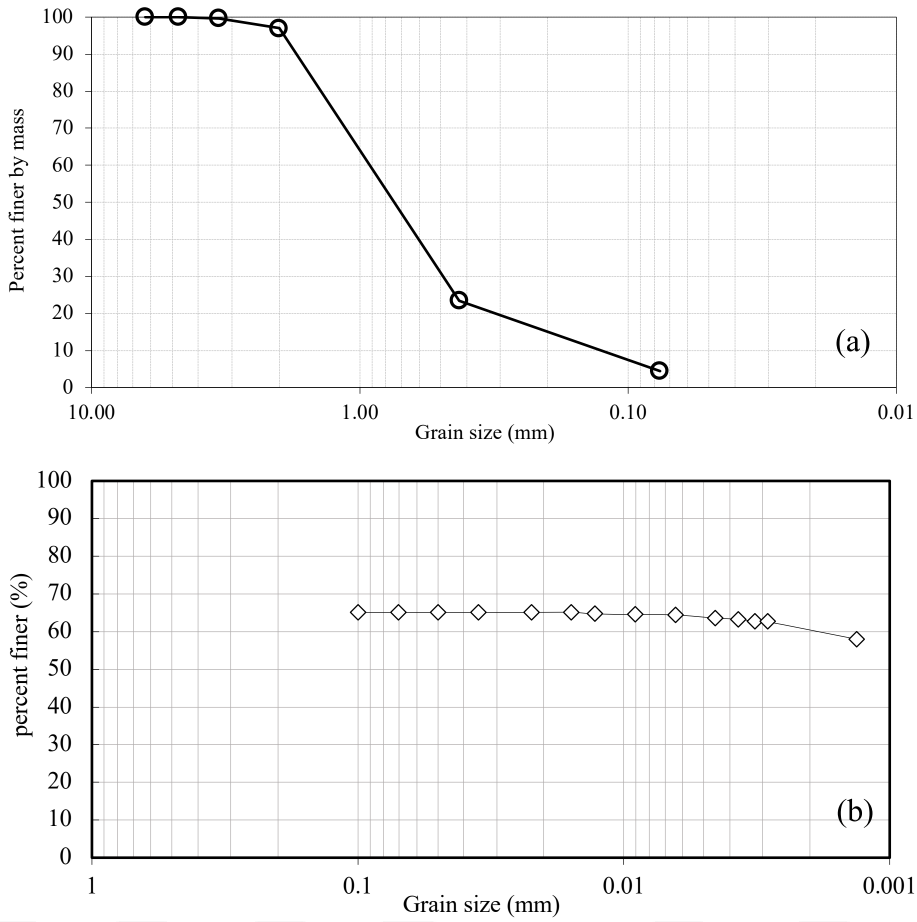


Figure 2. 2 Grain size distribution of a) sand, b) bentonite

Figure 2.3 also shows the grain size distribution curves of colemanite, tincal and ulexite.

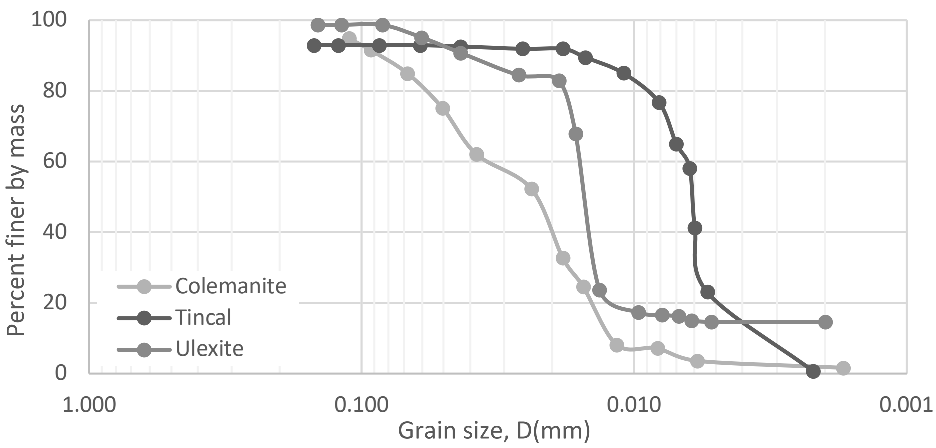


Figure 2.3 Grain size distribution of colemanite, tincal and ulexite

The liquid and plastic limit values of the bentonite are 476% and 70%, respectively. In addition to this, according to the results the specific gravity of bentonite is 2.70 and the clay fraction of bentonite is 60%.

The specific gravities of boron minerals are 2.44, 1.67 and 1.98 for colemanite, tincal and ulexite, respectively. The specific garavity values of tincal and ulexite comperatively lower than the colemanite, sand and bentonite.

The physico-chemical properties of these materials are summarized in Table 2.1.

Table 2.1 The physico-chemical properties of bentonite, sand and boron minerals samples

	Bentonite	Sand	Colemanite	Tincal	Ulexite
Specific Gravity	2.70	2.63	2.44	1.67	1.98
Liquid Limit (%)	476	-	37	61	33
Plastic Limit (%)	70	-	26	43	25
Plasticity Index (%)	406	-	11	18	8
pH	9.50	-	9.26	9.12	9.13

For all experiments, Na-bentonite and sand were used after drying for 24 hours in the oven (105°C). The sand was used by sieving through No.6 (3.35mm) after drying. Bentonite was used by sieving through No.200 (0.075mm) sieve. Tincal was used in its natural water content as its structure changes with heat (Figure 2.4). Similarly, ulexite and colemanite were used without drying. Furthermore, the tincal was crushed with jaw crusher and sieved through No.40 (0.425mm) for the experiments (Figure 2.5). Since ulexite and colemanite were supplied in ground form, they were used without any crushing and sieving process. The natural water contents of the boron minerals were determined at the beginning of each test and these values were considered at the sample preparation.

Figure 2.4 Tincal a) at the natural state b) after dry in the oven (Personal archive, 2018)

Figure 2.5 Preparation of tincal for tests a) jaw crusher to crush the tincal, b) crushed tincal, c) sieved tincal through No.40 (Personal archive, 2018)

2.2 Methods

2.2.1 Physical and Chemical Characteristics and Index Properties

Dry and wet sieving methods and hydrometer analysis were performed to obtain the particle size distributions of boron minerals (i.e. tincal, ulexite and colemanite) and sand (ASTM: D422-63, 2007). The sand was sieved by washing through No.200. The material remaining on the sieve was dried in the oven and the amount of material passing through No.200 was determined. Then, the sand remaining on No.200 was dried and sieved from the sieve set. The grain size distribution graphs were plotted after the hydrometer test was completed. As for boron minerals, each mineral was sieved by washing through No.200 under the protection of the No.40 sieve. After completion of hydrometer experiments, grain size distribution curves were drawn (Figure 2.3).

Specific gravities of materials were determined according to ASTM: D854-14(2014). The consistency limits of materials were determined based on ASTM: D4318-17e1. While Casagrande method was used to determine the liquid limit of ulexite, colemanite and bentonite, fall cone method was used for tincal.

The pH values of bentonite and boron minerals were measured based on ASTM: D4972-18 (2018). For boron minerals 1:1 ratio (20 g mineral - 20 ml de-ionized water) boron mineral and water were put in a plastic container and mixed for 1 hour with end -over- end shaker (Figure 2.6). Bentonite was shaked in the same way as 1:5 ratio (10 g of bentonite - 50 g de-ionized water). Then pH values were measured with pH meter as seen in Figure 2.7. When the constant value was attained, this value was recorded as the pH value of the mixture.

Figure 2.6 Shaking the plastic container on the shaker (Personal archive, 2019)

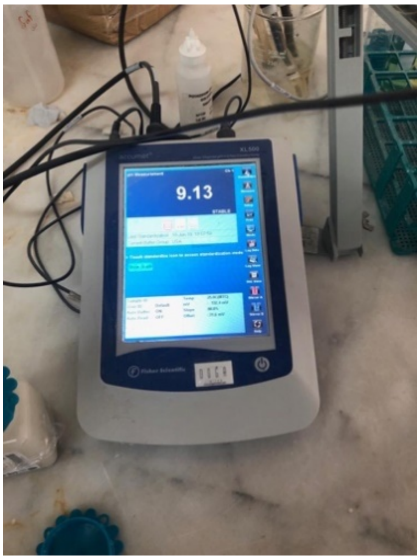


Figure 2.7 Photograph of pH meter (Personal archive, 2019)

2.2.2 Sample Preparation

The test mixtures were prepared in the following order: Firstly 10% or 15% or 20% of the total dry weight was weighed as boron mineral. Then the bentonite was added with 10% or 20% of remaining dry weight and the rest of the mixture was sand. Table 2 shows the percentages of the mixtures that were prepared for use in tests. The samples were named as abbreviation of bentonite as "B", sand as "S", Colemanite as "C", Tincal as "T" and Ulexite as "U". For example, 9B-81S-10T sample contains 9% bentonite, 81% sand and 10% tincal.

Table 2.2 Percentages of the mixtures

	Test sample		
	Colemanite	Tincal	Ulexite
		10B-90S	
10% Bentonite	9B-81S-10C	9B-81S-10T	9B-81S-10U
	8.5B-76.5S-15C	8.5B-76.5S-15T	8.5B-76.5S-15U
	8B-72S-20C	8B-72S-20T	8B-72S-20U
		20B-80S	
20% Bentonite	18B-72S-10C	18B-72S-10T	18B-72S-10U
	17B-68S-15C	17B-68S-15T	17B-68S-15U
	16B-64S-20C	16B-64S-20T	16B-64S-20U

2.2.3 Test Set-up

The compaction, direct shear and hydraulic conductivity tests were performed with the mixtures formed by adding boron minerals to sand-bentonite mixtures. In addition to room temperature the direct shear and hydraulic conductivity tests were carried out at 80°C. The test set-up for this study is given in Table 2.3.

Table 2.3 Test set-up

Test Sample	Compaction tests	Direct shear tests		Hydraulic conductivity tests	
		Room temperature	80°C	Room temperature	80°C
Colemanite	✓	✓	✓	-	-
Tincal	✓	✓	✓	✓	-
Ulexite	✓	✓	✓	-	-
10B-90S	✓	✓	✓	✓	✓
9B-81S-10C	✓	✓	✓	-	-
8.5B-76.5S-15C	✓	-	-	-	-
8B-72S-20C	✓	✓	✓	-	-
9B-81S-10T	✓	✓	✓	✓	✓
8.5B-76.5S-15T	✓	-	-	✓	-
8B-72S-20T	✓	✓	✓	✓	✓
9B-81S-10U	✓	✓	✓	✓	-
8.5B-76.5S-15U	✓	-	-	-	-
8B-72S-20U	✓	✓	✓	✓	-
20B-80S	✓	✓	✓	✓	-
18B-72S-10C	✓	✓	✓	-	-
17B-68S-15C	✓	-	-	-	-
16B-64S-20C	✓	✓	✓	-	-
18B-72S-10T	✓	✓	✓	✓	-
17B-68S-15T	✓	-	-	✓	-
16B-64S-20T	✓	✓	✓	✓	-
18B-72S-10U	✓	✓	✓	-	-
17B-68S-15U	✓	-	-	-	-
16B-64S-20U	✓	✓	✓	-	-

2.2.4 Compaction Tests

The compaction tests were carried out in accordance with ASTM: D698-(2012e2). Compaction parameters were determined for all mixtures. Firstly, dry materials were prepared at the specified percentages and mixed in a plastic bag as seen in Figure 2.8a. Then the water was added by spraying and the mixture was blended until getting homogeneous (Figure 2.8b). The sample was prepared in four different water contents for each experiment. Subsequently, the samples were placed in garbage bag and closed for 24 hours. At the end of this period, the experiments were performed.

Figure 2.8 Preparation of mixtures a) Dry materials b) wet mixture (Personal archive, 2017)

The height and inside diameter of the short mold, which were used for the compaction tests, are 5.86 cm and 15.28 cm, respectively. The short mold is showed in Figure 2.9.

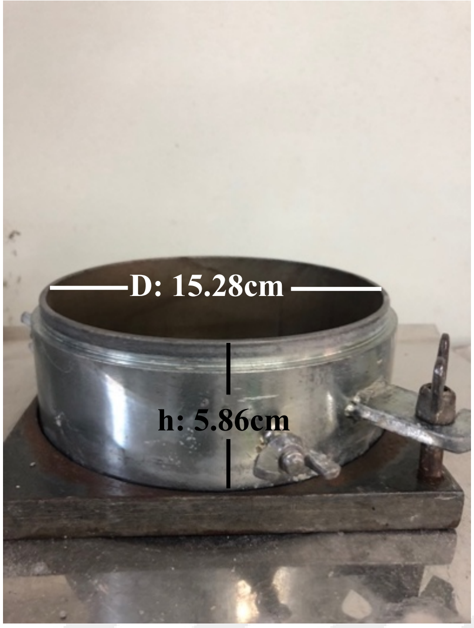


Figure 2.9 Short mold used for compaction tests (Personal archive, 2017)

The experiments were carried out by applying Standard Proctor energy in the automatic compactor (Figure 2.10). In this test, the mixtures were compacted into 2 layers by falling the 2.5 kg hammer from 305 mm. In addition, 43 drops were applied to each layer to obtain the Standard Proctor energy.

Figure 2.10 The automatic compactor, used for compaction tests (Personal archive, 2017)

After completion of the experiment, the soil was removed from the mold by a hydraulic jack. In order to determine the water content of the mixture, the sample that was taken from the compacted soil, was dried in the oven (105°C). Then, the necessary calculations were made and the 3rd order polynomial curve was drawn. The compaction characteristics (i.e. maximum dry density ($\gamma_{d,max}$) and optimum water content (w_{opt})) of each mixture were determined from this curve.

2.2.5 Direct Shear Tests

The direct tests were performed in accordance with ASTM: D3080 (2018). In the direct shear tests, the dry materials were mixed in a tray for homogeneity (Figure 2.11a-b). Then water was added to mixture (2% wet side of their optimum water content) and mixed with a spatula homogeneously (Figure 2.11c).

The soil sample was placed into the square mold (6cm) in 3 layers by compacting each layer at the dry unit weight value which was obtained from Standard Proctor test (Figure 2.12a). The mold was waited for 24 hours in the submerged condition to get full saturation. During saturation stage, the required weight was placed on the mold to prevent swelling (Figure 2.12b).

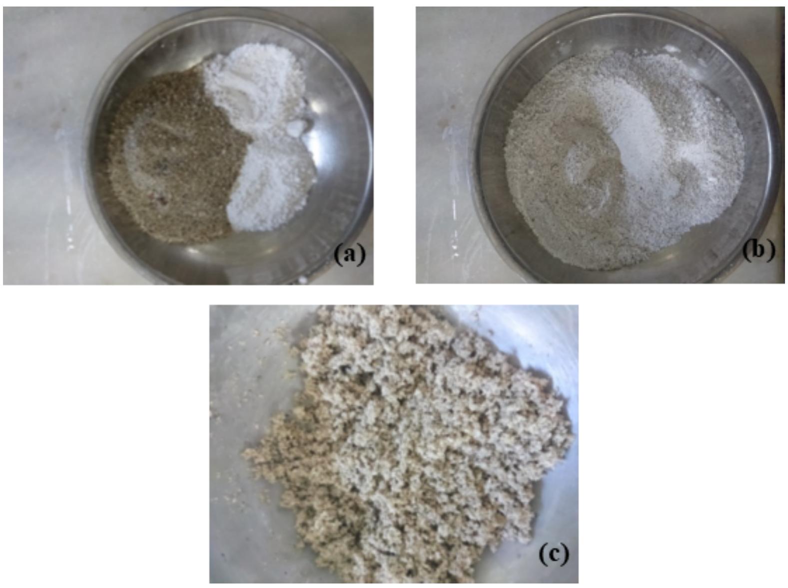


Figure 2.11 Preparation of the mixture for the shear test a) dry materials b) homogeneously mixed dry materials c) final mixture after water addition (Personal archive, 2019)

Figure 2.12 Sample preparation for shear test a) compacted sample in the mold b) submerged compacted sample (Personal archive, 2019)

Then the soil sample in the mold was carefully placed into the box and the cell was filled with water. Three different normal stresses (49, 98, 196 kPa) were applied in the direct shear tests, the samples were consolidated under these stress levels. Then, the samples were sheared with shear rate of 0.5 mm/min.

The direct shear tests were performed at room temperature and at 80°C. In the tests, heating was provided by heat rod which was specially produced according to the direct shear test box (Figure 2.13a). The temperature of the water in the cell was continuously kept at 80°C by means of the thermostat (Figure 2.13b-c). When the temperature of the water fell, the thermostat activated the resistance, and when the temperature was 80°C, it disabled the resistance. Thus, the temperature remained constant throughout the test.

The temperature of the water and the soil was measured by two separate K-type thermocouples (Figure 2.14a) and a digital thermometer (Figure 2.14b).

Figure 2.13 Heating tools for direct shear tests a) specially produced heat rod for the shear box b-c) thermostat for controlling water temperature (Personal archive, 2019)

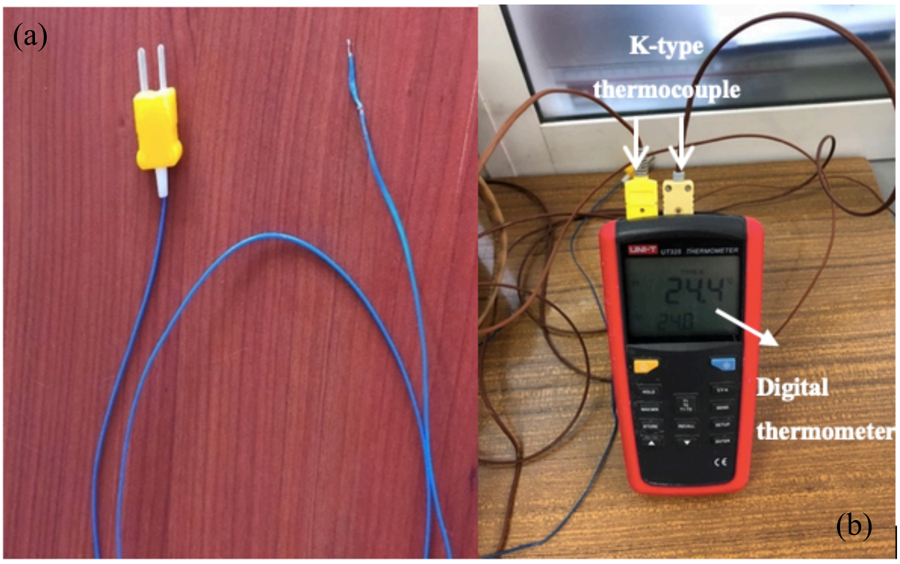


Figure 2.14 Tools for measuring and recording temperature during the tests under high temperature a) k-type thermocouple used in experiments b) digital thermometer (Personal archive, 2019)

The schematic presentation of the test set-up is given in Figure 2.15.

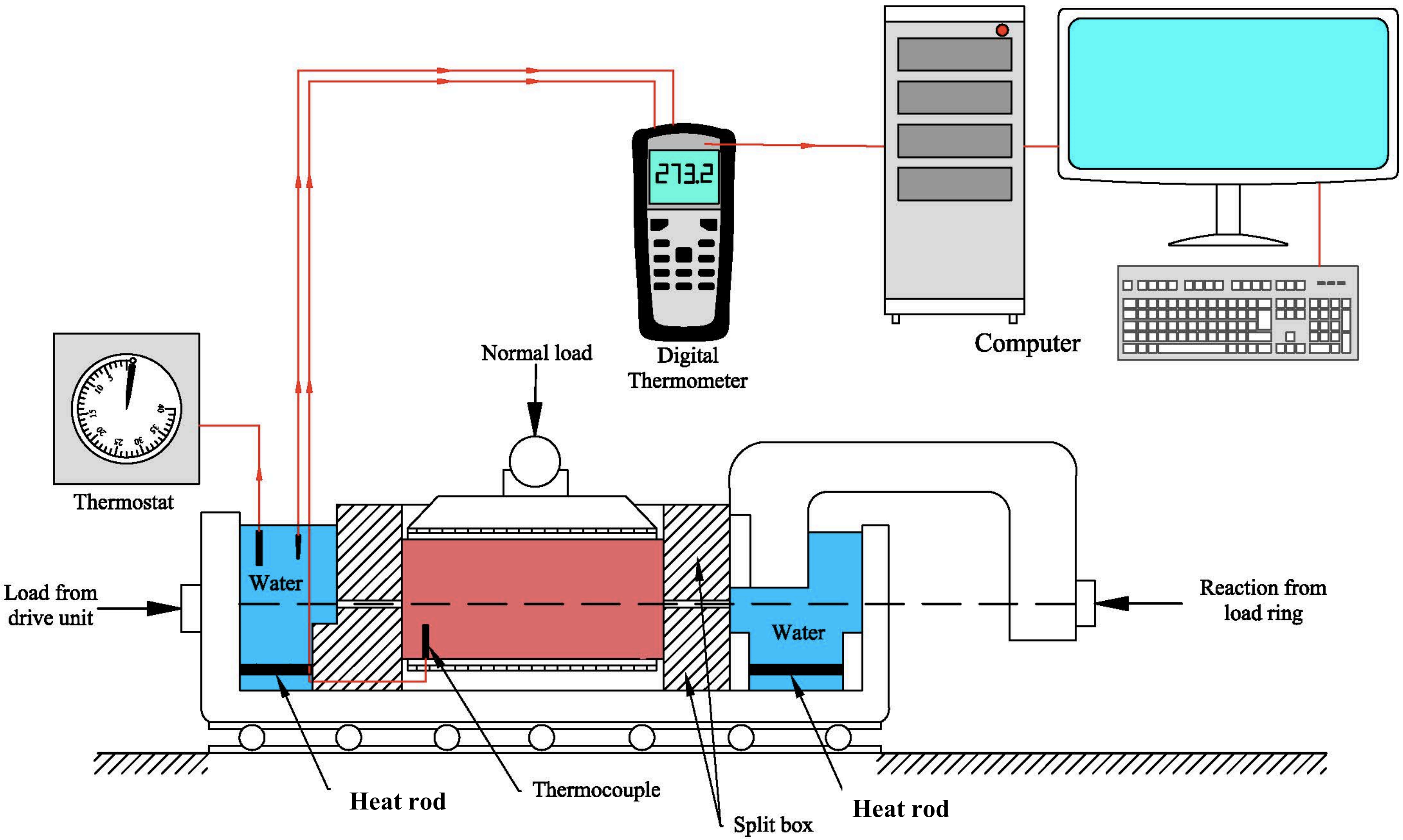


Figure 2.15 The schematic presentation of the test set-up

At the end of the tests, the soil samples were dried in an oven (105°C) to determine the final water content.

2.2.6 Hydraulic Conductivity Tests

Hydraulic conductivity tests were carried out according to ASTM: D5084-16a (2016). In these experiments, flexible wall permeameters were used. The falling head water and constant tail water method was applied. The hydraulic conductivity tests were studied with only tincal because of the high sodium content. In the hydraulic conductivity tests, the mixtures were prepared in a similar way as in the direct shear tests at the w_{opt}+2% water content. The prepared samples were placed in the plastic bag so that they could not take air, and they were waited for 24 hours to be ready for the experiment. The soil which was compacted with standard Proctor energy, was carefully removed from the mold by using a hydraulic jack (Figure 2.16).

Figure 2.16 Sample preparation for hydraulic conductivity test a) compacted soil b-c-d) removed of compacted sample with hydraulic jack e) the sample removed from mold (Personal archive, 2018)

While the specimen was mounted in the permeameter, 15 cm diameter geotextiles were placed at the bottom and over the compacted sample as shown in Figure 2.17a-

b. Then, the latex membrane and o rings were used to prevent the side-wall leakage. The latex membrane was placed so as to confine the sample and o-rings were fitted on the top and bottom caps (Figure 2.17 c-d). After that, the permeameter was filled with water (Figure 2.17e).

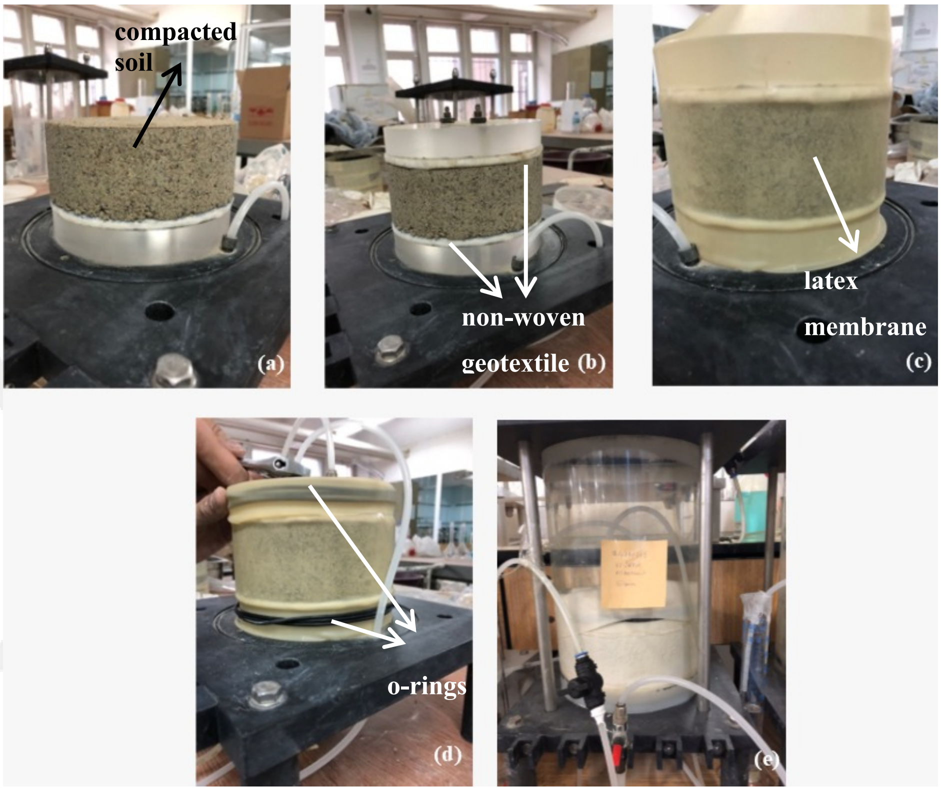


Figure 2.17 Preparation for hydraulic conductivity test a) Placement of the soil to the permeameter b) geotextiles placed on the top and bottom of the soil c) fitting latex membrane d) fitting of o-rings e) the permeameter after filling with water (Personal archive, 2018)

Figure 2.18 shows some hydraulic conductivity tests performed at room temperature. Back pressure was not applied for these tests. The flow occurred from top of the sample to the bottom. The de-ionize water was supplied from 50 ml glass burette and the effluent was collected in a 100 ml glass cylinder. Hydraulic conductivity tests were expressed as a function of pore volumes of flow. The hydraulic conductivity tests were carried out at room temperature and under high temperatures (80°C). For the experiments performed at room temperature, 50 kPa cell pressure and about 37 kPa effective stress were applied. Also, the hydraulic gradient was about 22.

Figure 2.18 Hydraulic conductivity tests at room temperature (Personal archive, 2018)

The tests carried out at 80°C could not be performed for all tincal mixtures due to lack of time and equipment. Only 10% sand-bentonite mixtures for 10% and 20% tincal additives were examined.

Specially designed permeameters have been used for tests at high temperature, considering that the Plexiglas cells may be damaged under high temperature in long term experiments. In order to withstand the high temperature in these permeameters, instead of Plexiglas cells, cells with aluminum material were manufactured that can be seen in Figure 2.19.

Figure 2.19 Specially designed for tests at high temperature (Personal archive, 2019)

Moreover, the top and bottom caps were made of aluminum. To the top of the cell, suitable holes for the heat rod, thermocouple and thermostat inlet were opened (Figure 2.20). In addition, a heat-resistant liquid seal was applied to the open areas to overcome the leakage problem.

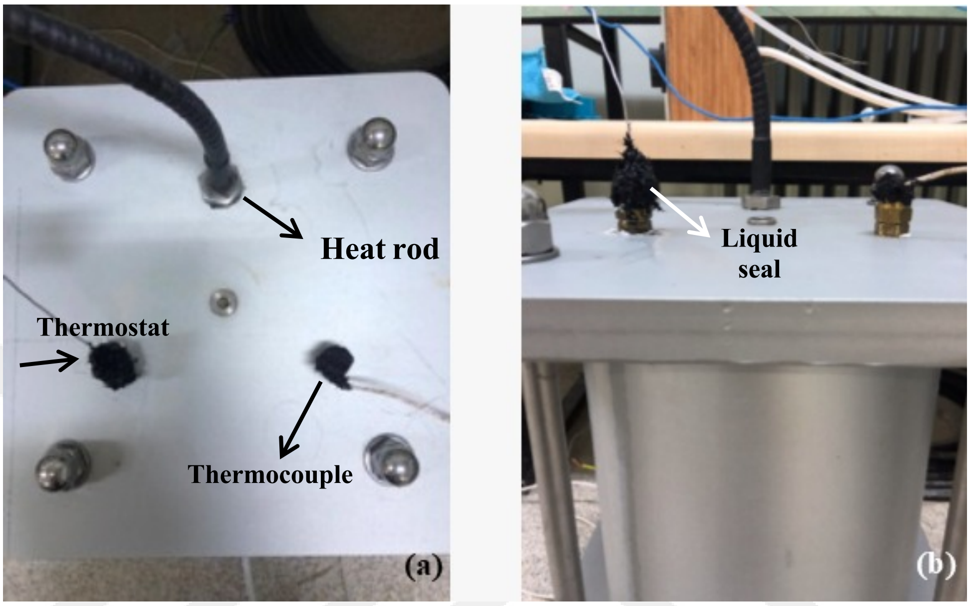


Figure 2.20 Preparation of the modified permeameter a) Insertion of resistance, thermostat and thermocouple in the cell b) application of liquid seal to prevent leakage (Personal archive, 2019)

Throughout the experiments, the thermocouple immersed in the hole above the cell measured the temperature of the water. To measure the temperature of the soil, a small hole was opened on the geotextile in the diameter of the thermocouple. The thermocouple was passed through a valve of the permeameter and the tip of the thermocouple was removed from the hole on the geotextile. In order to enter the thermocouple on the soil, a 2.5 cm deep hole was formed in line with the hole on the geotextile with the same diameter. This procedure is shown in Figure 2.21. Thus, the temperature of the soil could be measured throughout the experiment.

Temperatures were measured with K-type thermocouples immersed in water and placed in the soil. Thermocouples were connected to digital thermometers and temperature values were recorded depending on time. In order to keep the temperature of water in the cell continuously at 80°C, the thermostat system was connected to the permeameter cell as shown in Figure 2.22.

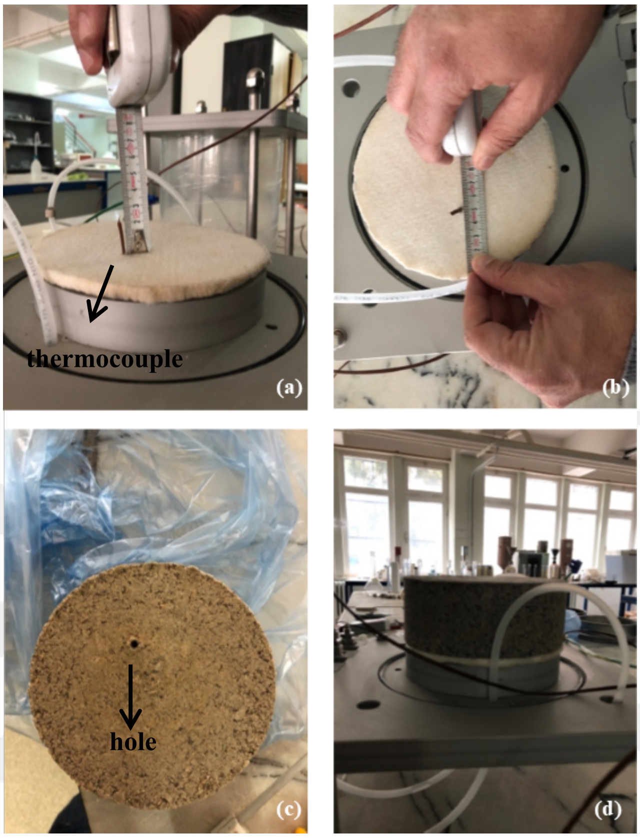


Figure 2.21 Placement of the sample into the permeameters for tests under high temperature a) forming the hole on the geotextile and passing the thermocouple through the hole b) measuring the location of the thermocouple c) forming the hole in line with the thermocouple on the soil d) placing the soil on the thermocouple (Personal archive, 2019)

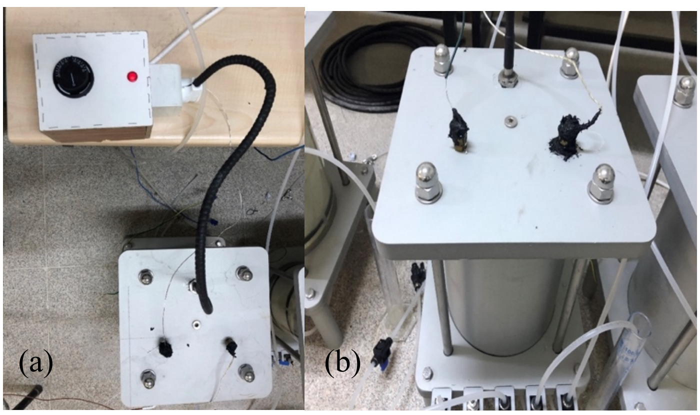


Figure 2.22 Flexible wall permeameter test cells a) thermostat connection b) top view of the cell (Personal archive, 2019)

The hydraulic conductivity test system at 80°C is indicated in Figure 2.23.

Figure 2.23 The hydraulic conductivity test system at 80°C a) passing the thermocouple through the valve b) thermostat system adjustment c) prevention with fuse box of electrical leakage (Personal archive, 2019)

In these tests performed at high temperature, the cell pressure was about 50 kPa. After the cell pressure was applied, air bubbles in the tube were removed and then, flow was started.

CHAPTER THREE
RESULTS AND DISCUSSIONS

The tests results performed throughout the thesis are presented in this chapter. In the first part, Standard Proctor test results of 10% and 20% sand-bentonite mixtures with boron additives are given. In the second part, the direct shear tests results of sand-bentonite mixtures with boron additives are presented at room temperature and 80°C. Finally, this chapter is completed by presenting the results of the hydraulic conductivity tests of the sand-bentonite mixtures with boron additives at room temperature and 80°C.

3.1 Compaction Tests Results

The compaction characteristics were examined by adding 10%, 15% and 20% colemanite, tincal and ulexite by weight to 10% and 20% sand-bentonite mixtures. The compaction tests were performed by applying Standard Proctor energy according to ASTM: D698-(2012e2). The compaction parameters were expressed as maximum dry unit weight ($\gamma_{d,max}$) and optimum water content (w_{opt}). Firstly, the compaction curves of the 10% and 20 % sand-bentonite mixtures (i.e. 10B-90S and 20B-80S) are shown in Figure 3.1.

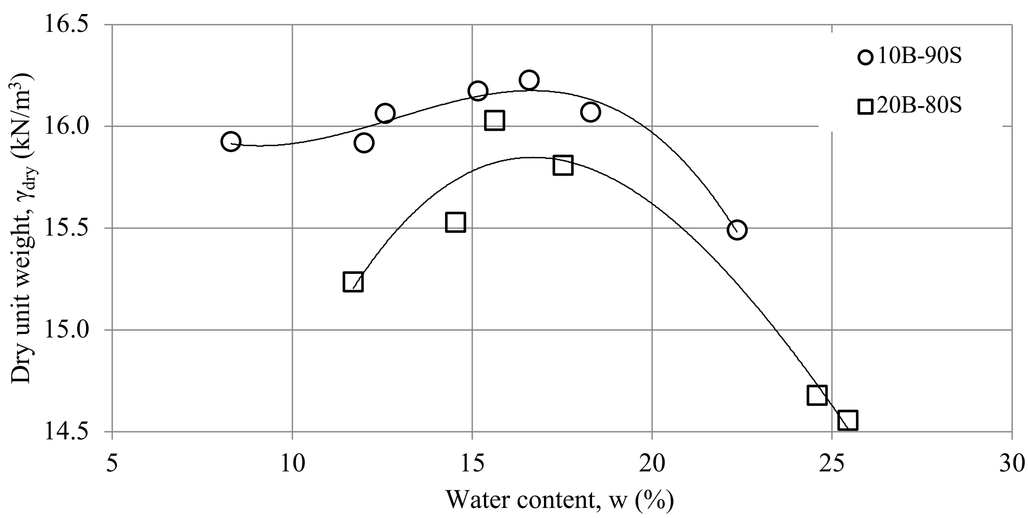


Figure 3.1 Compaction curves of sand-bentonite mixtures

As seen in Figure 3.1, the water content of 20B-80S increased slightly compared to 10B-90S, while the maximum dry unit weight is reduced slightly. The maximum dry unit weight decreased when bentonite content increased in the mixture. Because of high water adsorption capacity of bentonite, the optimum water content increased as bentonite content of the mixture was increased.

The compaction curves of boron minerals which were used in this thesis (i.e. colemanite, tincal, ulexite) are shown in Figure 3.2. For the boron minerals (i.e. colemanite, tincal, ulexite), tincal had the lowest maximum dry unit weight value, while colemanite had the highest value. On the contrary, in terms of optimum water content, tincal had the highest water content value, whereas colemanite had the lowest value. Ulexite was located between tincal and colemanite in terms of both compaction parameters ($\gamma_{d,max}$ = 15.99 kN/m^3 and w_{opt} = 15.7%).

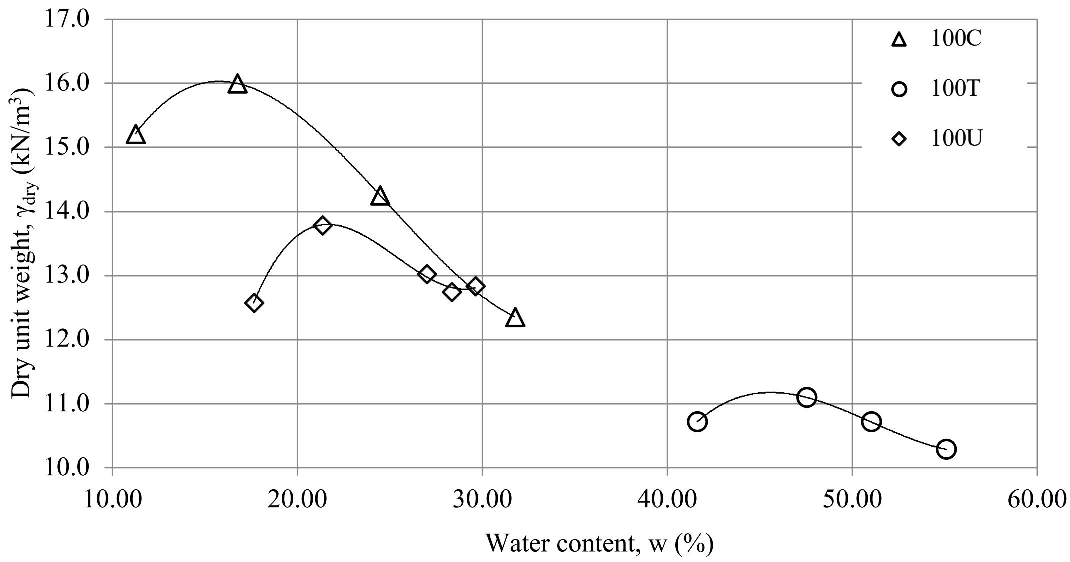


Figure 3.2 Compaction curves of boron minerals

The compaction curves of 10% sand-bentonite mixture and 10% sand-bentonite mixtures with boron additives are presented in Figure 3.3.

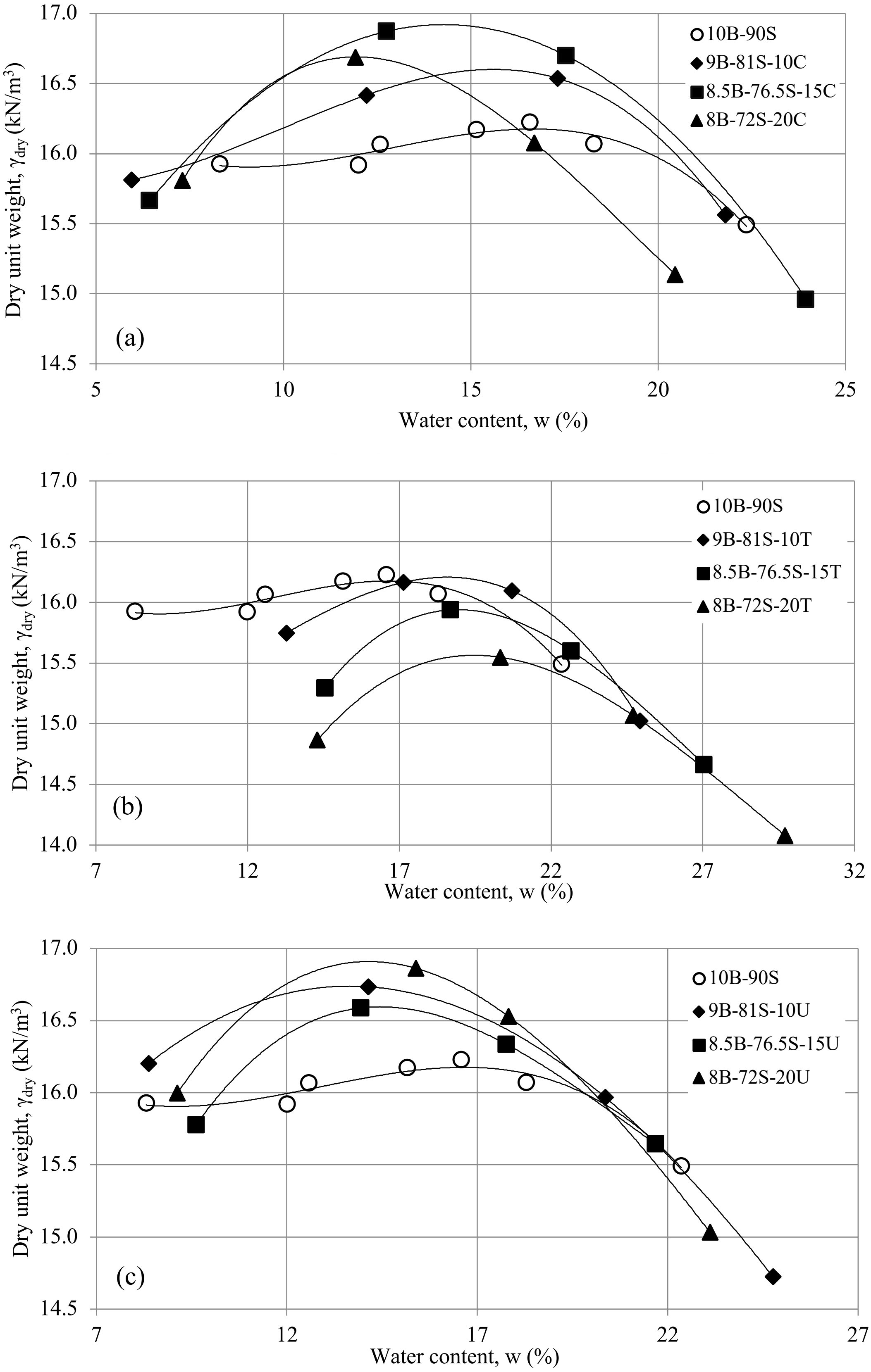


Figure 3.3 Compaction curves of 10% sand-bentonite mixtures in the presence of a) colemanite b) tincal c) ulexite

Figure 3.3a shows the compaction characteristics of the 10% bentonite in the presence of colemanite. The colemanite addition increased the maximum dry unit weight ($\gamma_{d,max}$) and decreased the optimum water content (w_{opt}) of the 10% sand-bentonite mixture. The maximum dry unit weight value of 10B-90S was 16.19 kN/m^3, while it was between 16.58 kN/m^3 and 16.97 kN/m^3 in the presence of colemanite. In addition, the optimum water content of additive-free sample was 16.5%, by colemanite addition it changed between 12.0% -15.5%.

As can be seen in Figure 3.3b, as tincal content increased the optimum water content and the maximum dry unit weight values generally decreased. As concentration of tincal increased from 10% to 20% the $\gamma_{d,max}$ value decreased from 16.19 to 15.20 kN/m^3.

Figure 3.3c shows that the effect of ulexite was likely colemanite for 10% sand-bentonite mixtures. Ulexite addition to 10B-90S mixtures reduced the optimum water content while increased the maximum dry unit weight.

The compaction curves of 20% sand-bentonite mixtures and 20% sand-bentonite mixtures with boron additives are shown in Figure 3.4. According to the results, $\gamma_{d,max}$ value of 20% sand-bentonite mixtures in the presence of colemanite, varied between 15.89 kN/m^3 and 16.29 kN/m^3, while the w_{opt} value changed between 14.5% and 19.0% (Figure 3.4a).

As shown in Figure 3.4b, 20% sand-bentonite mixtures in the presence of tincal showed a similar tendency to 10% sand-bentonite mixtures. That is, the tincal addition decreased $\gamma_{d,max}$ value and significantly increased w_{opt} value.

On the other hand, according to Figure 3.4c, the ulexite addition for 20% sand-bentonite mixtures did not increase the $\gamma_{d,max}$ value by showing a trend contrary to 10% sand-bentonite mixtures. Similarly, in the presence of ulexite, the w_{opt} value of 20% sand-bentonite mixtures was approximately similar to the non-additive 20B-80S.

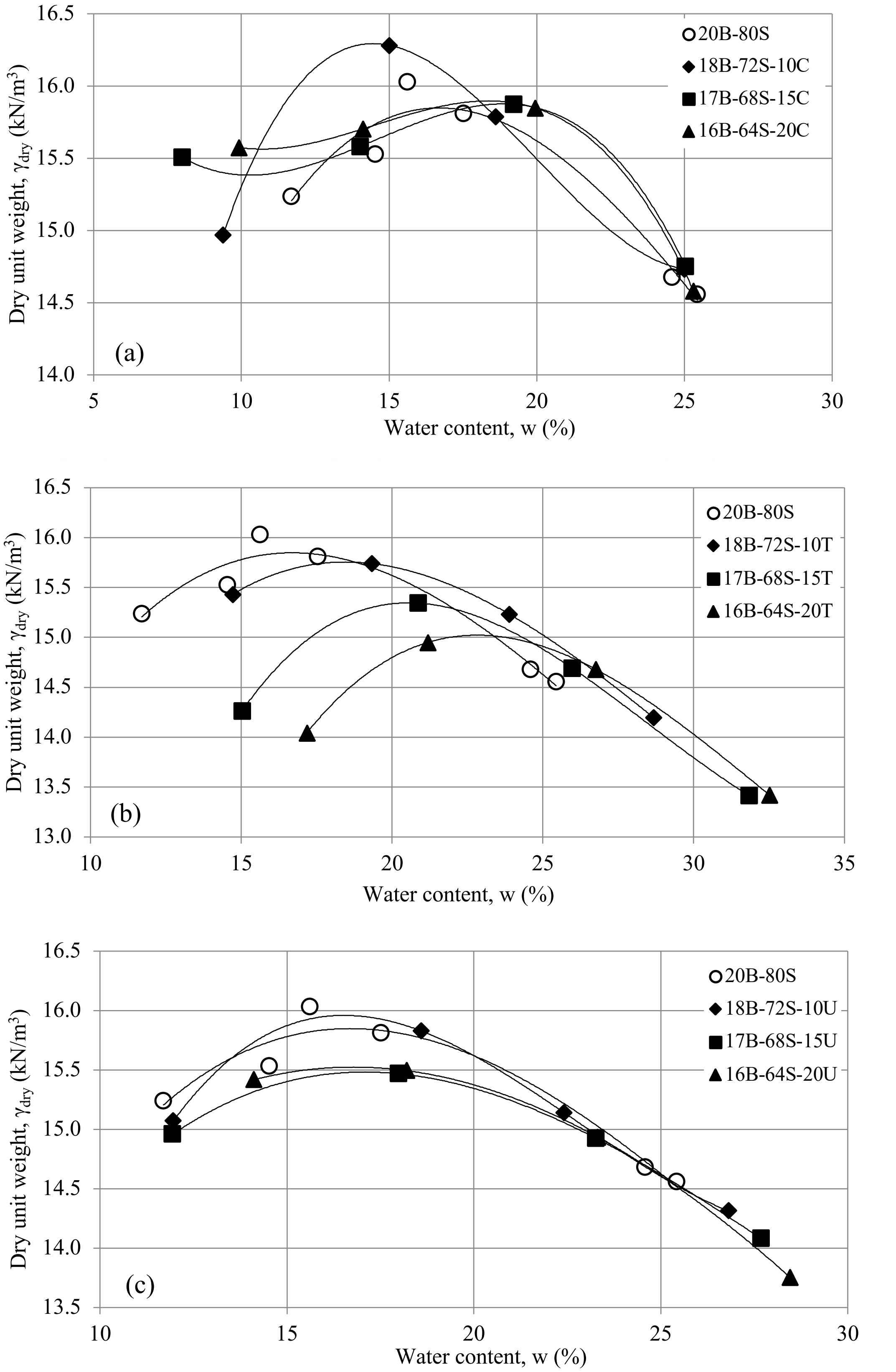


Figure 3.4 Compaction curves of 20% sand-bentonite mixtures in the presence of a) colemanite b) tincal c) ulexite

The compaction parameters obtained from compaction tests are given in Table 3.1.

Table 3.1 Compaction parameters of all mixtures and boron minerals

Group	Sample	$\gamma_{d,max}$ (kN/m^3)	w_{opt} (%)
	Colemanite	15.99	15.7
	Tincal	11.18	45.5
	Ulexite	13.83	21.5
10% Bentonite	10B-90S	16.19	16.5
	9B-81S-10C	16.58	15.5
	8.5B-76.5S-15C	16.97	14.2
	8B-72S-20C	16.68	12.0
	9B-81S-10T	16.19	18.5
	8.5B-76.5S-15T	15.99	19.0
	8B-72S-20T	15.60	19.5
	9B-81S-10U	16.78	13.5
	8.5B-76.5S-15U	16.58	14.5
	8B-72S-20U	16.87	14.2
20% Bentonite	20B-80S	15.89	16.8
	18B-72S-10C	16.28	14.5
	17B-68S-15C	15.89	19
	16B-64S-20C	15.89	18.5
	18B-72S-10T	15.79	18.5
	17B-68S-15T	15.30	20.5
	16B-64S-20T	15.01	23
	18B-72S-10U	15.99	16.5
	17B-68S-15U	15.50	17.1
	16B-64S-20U	15.50	16

3.1.1 Influence of Boron Percentage on the Compaction Characteristics

In this section, compaction parameters (i.e. $\gamma_{d,max}$ and w_{opt}) are investigated according to boron percentage. The compaction parameters of 10% and 20% sand-bentonite mixtures in the presence of boron minerals are illustrated in Figure 3.5 and 3.6, respectively.

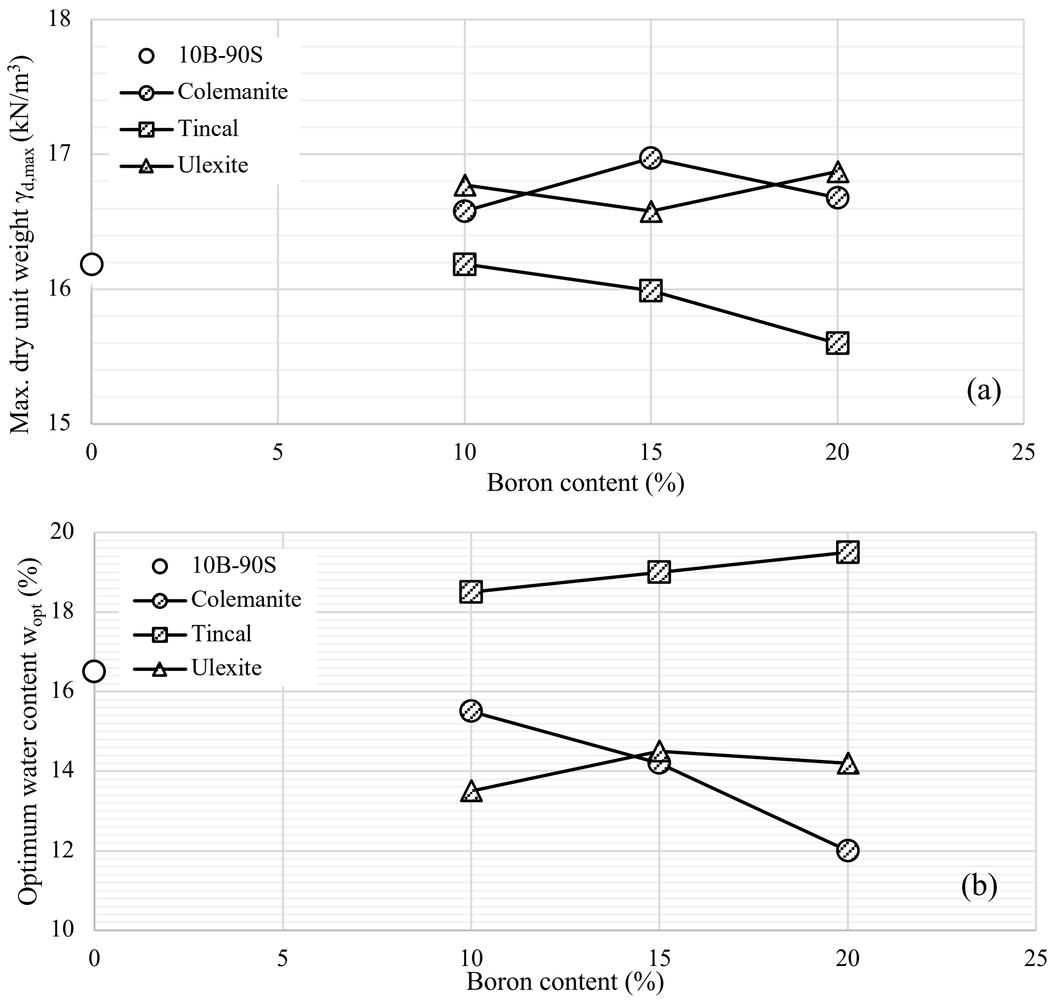


Figure 3.5 Compaction parameters a) max. dry unit weight b) optimum water content of 10% sand-bentonite mixtures in the presence of boron minerals

For the 10% sand-bentonite mixtures, $\gamma_{d,max}$ values are presented in Figure 3.5a in the presence of boron minerals. The $\gamma_{d,max}$ value of 10B-90S was taken as a reference value (16.19 kN/m^3). The 20% colemanite effect was not as high as 15% colemanite. The effect of 10% and 20% colemanite on $\gamma_{d,max}$ was almost the same. The $\gamma_{d,max}$ value rose to 16.58 kN/m^3 in the presence of 10% colemanite, 16.97 kN/m^3 in 15% colemanite and 16.68 kN/m^3 in 20% colemanite. The 10%, 15% and 20% tincal addition gradually decreased $\gamma_{d,max}$ value of sand-bentonite mixture. For example, $\gamma_{d,max}$ decreased to 16.19 kN/m^3 with 10% tincal, gradually fell to 15.60 kN/m^3 with 20% tincal. For ulexite, all the additive percentages increased the $\gamma_{d,max}$ value, but 15% ulexite increased $\gamma_{d,max}$ value less than 10% when compared with additive-free sample. The highest increase in $\gamma_{d,max}$ was obtained with 20% ulexite.

In Figure 3.5b, the optimum water content values for 10% sand-bentonite mixtures are presented depending on percentage of boron minerals. The reference value was the optimum water content of 10B-90S was 16.5%. Generally, all colemanite percentages reduced the w_{opt} value. However, the maximum amount of reduction investigated with 20% colemanite. In contrast to colemanite, tincal additive increased the w_{opt} value. There was a linear increase in the w_{opt} value with the addition of 10%, 15% and 20% tincal. It is seen that all percentages of the ulexite decreased the w_{opt} value when compared with additive-free sample. In addition, the highest decrease in w_{opt} value was seen in the presence of 10% ulexite. When the ulexite additive was 15% and 20%, the w_{opt} value decreased to approximately the same value.

Figure 3.6 shows the change of $\gamma_{d,max}$ and w_{opt} values for 20% sand-bentonite mixtures according to percentage of boron additives. As can be seen in Figure 3.6a, the 15.89 kN/m^3 $\gamma_{d,max}$ value of 20B-80S increased to 16.29 kN/m^3 with 10% colemanite. However, it should be noted that when the colemanite content increased from 10% to 15% colemanite, the $\gamma_{d,max}$ value did not change. Tincal content had the decreasing effect on $\gamma_{d,max}$ for 20% sand-bentonite mixture, like for 10% sand-bentonite mixture. The $\gamma_{d,max}$ decreased to 15.79 kN/m^3 with 10% tincal and to 15.01 kN/m^3 with 20% tincal. As for ulexite, 10% ulexite reduced $\gamma_{d,max}$ insignificantly, while 15% and 20% ulexite reduced $\gamma_{d,max}$ to 15.50 kN/m^3. While ulexite was increased from 15% to 20%, $\gamma_{d,max}$ did not change.

According to Figure 3.6b, the 10% colemanite additive reduced w_{opt} value of the 20B-80S from 16.8% to 14.5%. When the colemanite additive was 15% and 20%, w_{opt} value increased by approximately 2%. Similar to 10B-90S mixture tincal addition increased the w_{opt} value of 20B-80S mixtures. There was a linear increase trend in water content depending on tincal percentages, and water content reached up to 23% in the presence of 20% tincal. Ulexite addition had no effect on the water content of 20% sand-bentonite mixtures.

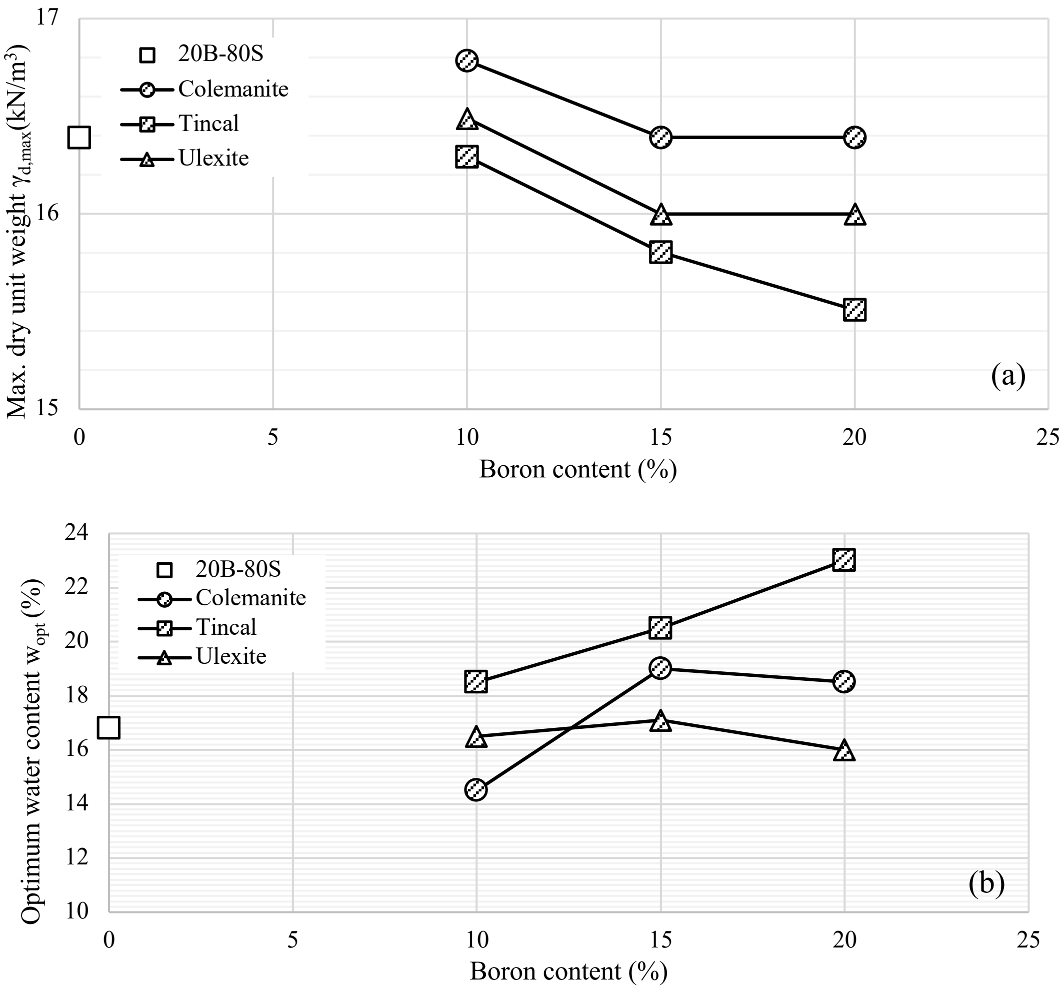


Figure 3.6 Compaction parameters a) max. dry unit weight b) optimum water content of 20% sand-bentonite mixtures in the presence of boron minerals

3.1.2 Influence of Boron Mineral Type on the Compaction Characteristics

In this section, compaction parameters were investigated according to boron mineral type. Figure 3.7 shows the effect of boron mineral type on $\gamma_{d,max}$ value for 10% and 20% sand-bentonite mixtures. The effect of boron mineral type on w_{opt} value for 10% and 20% sand-bentonite mixtures is shown in Figure 3.7.

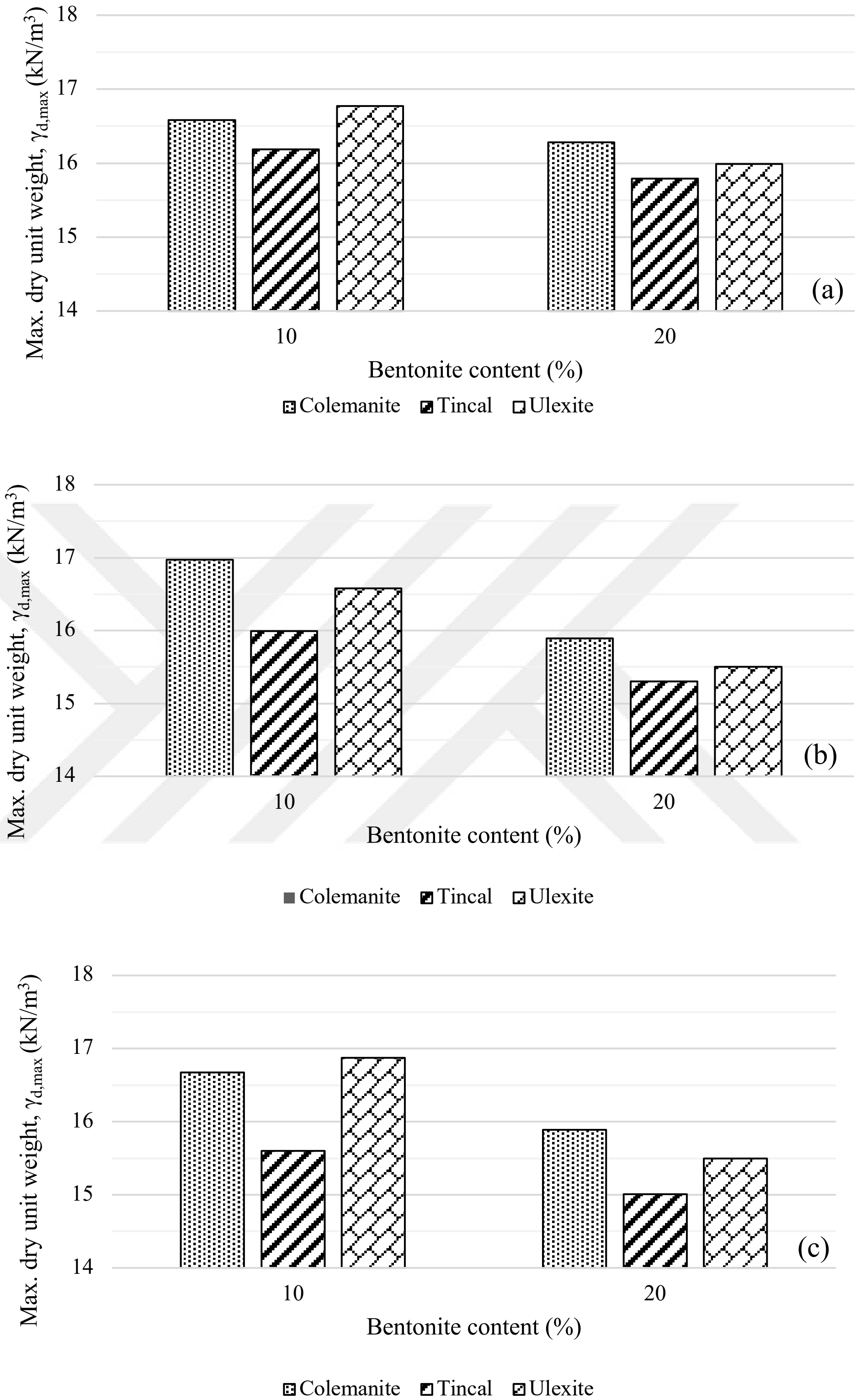


Figure 3.7 Max. dry unit weight value according to boron mineral type a) 10% boron minerals b) 15% boron minerals c) 20% boron minerals

In Figure 3.7a, the effect of %10 addition of boron mineral to sand-bentonite mixtures on the compaction parameters is shown. According to the Figure 3.7a, $\gamma_{d,max}$ values of 10% sand-bentonite mixtures were greater than that of 20% sand-bentonite mixtures. The boron mineral type which increased $\gamma_{d,max}$ value at most was ulexite for 10% sand-bentonite mixtures whereas colemanite for 20% sand-bentonite mixtures. Tincal provided the lowest $\gamma_{d,max}$ value for both mixtures. The $\gamma_{d,max}$ values of sand-bentonite mixtures containing 15% boron mineral are presented in Figure 3.7b. Colemanite addition caused, the highest $\gamma_{d,max}$ value for both 10% and 20% sand-bentonite mixtures. When 20% boron mineral addition was analyzed, colemanite which most increased the $\gamma_{d,max}$ value for the 20% sand-bentonite mixtures and it was ulexite for 10% sand-bentonite mixtures. It can be said that the increasing effect of colemanite on $\gamma_{d,max}$ value is more than ulexite and tincal.

As shown in Figure 3.8a, tincal was the boron mineral which increased the w_{opt} value in both mixtures most. Boron mineral which provided the highest w_{opt} value after tincal was colemanite for 10% sand-bentonite mixture and ulexite for 20% sand-bentonite mixture. When other boron minerals contents (15% and 20%) were compared, the type of boron mineral which increased the w_{opt} value the most, was clearly tincal. The effects of ulexite and colemanite were very close for 10% sand-bentonite mixtures containing 15% boron mineral (Figure 3.8b).

For 20% sand-bentonite mixture, w_{opt} value in the presence of colemanite was higher than w_{opt} value in the presence of ulexite (Figure 3.8b). Finally, in the presence of ulexite for 10% sand-bentonite mixtures containing 20% boron mineral, the w_{opt} value was higher than the w_{opt} value in the presence of colemanite. This was exactly opposite for 20% sand-bentonite mixtures.

For 20% sand-bentonite mixture, w_{opt} value in the presence of colemanite was higher than w_{opt} value in the presence of ulexite (Figure 3.8b). Finally, in the presence of ulexite for 10% sand-bentonite mixtures containing 20% boron mineral, the w_{opt} value was higher than the w_{opt} value in the presence of colemanite. This was exactly opposite for 20% sand-bentonite mixtures.

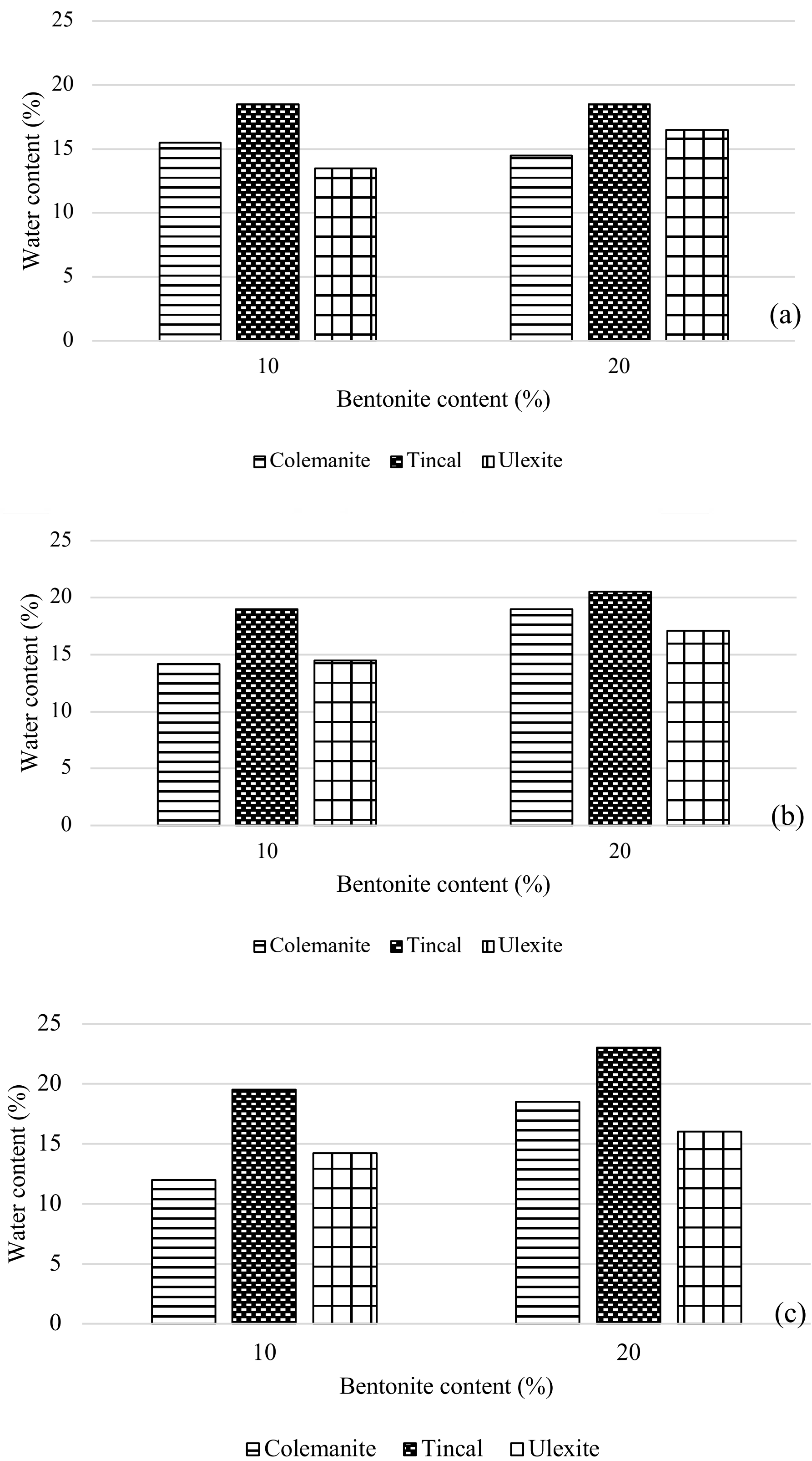


Figure 3.8 Optimum water content value according to boron mineral type a) 10% boron minerals b) 15% boron minerals c) 20% boron minerals

3.2 Shear Strength Behavior of Boron Added Sand-Bentonite Mixtures

The direct shear tests were conducted with 10% and 20% sand bentonite mixtures, boron minerals (i.e. colemanite, tincal, ulexite) and sand-bentonite mixtures in the presence of 10% and 20% boron minerals. The direct shear tests were performed both at room temperature (RT) and under high temperature at 80°C. The effects of boron minerals on shear strength behavior of sand-bentonite mixtures under high temperature were investigated.

In this section, shear stress-strain graphs are given under 196.1 kPa normal stress value. For each of the normal stress values (49, 98.1, 196.1 kPa), the maximum shear stress value was taken as the shear strength of the soil. In order to find the drained internal friction angle (Ø′) and cohesion value (c′), which are shear strength parameters, the shear stress versus normal stress at failure was drawn.

3.2.1 Shear Strength Behavior of Sand-Bentonite Mixtures

The shear stress-strain graphs of 10% and 20% sand-bentonite mixtures at room temperature and 80°C are given in Figure 3.9.

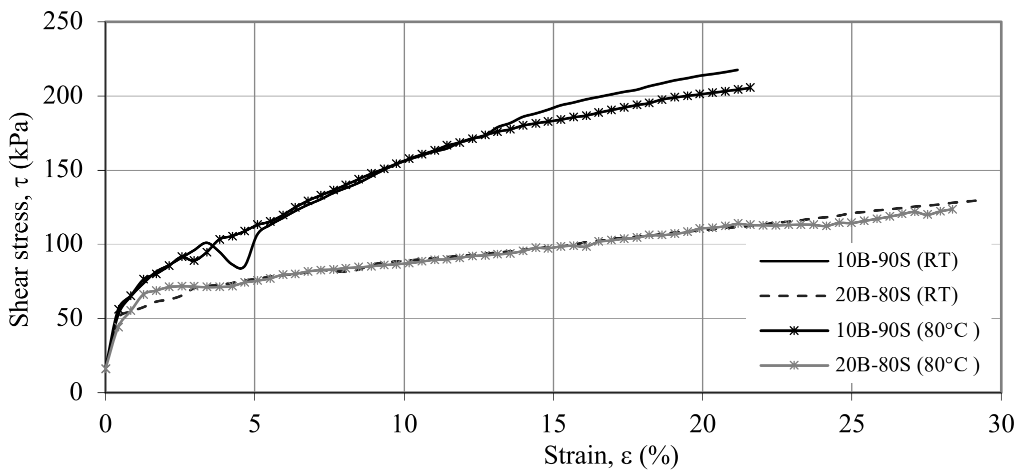


Figure 3.9 The shear stress-strain of 10B-90S and 20B-80S mixtures at room temperature and at 80°C

When the bentonite content increased from 10% to 20%, the maximum shear stress value decreased while the strain corresponding to the same shear stress value increased at room temperature. For the tests which were performed under 80°C temperature, the shear stress-strain behavior was almost the same as with room temperature. The temperature increase did not change the maximum shear strength values.

The shear failure envelopes at room temperature and 80°C are given in Figure 3.10 for both mixtures.

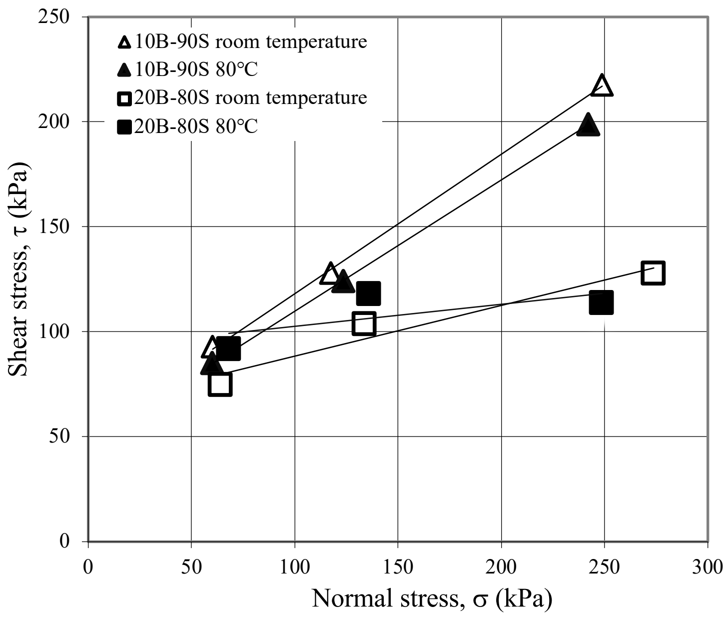


Figure 3.10 The shear failure envelopes of 10B-90S and 20B-80S at room temperature and at 80°C

When the bentonite content was increased from 10% to 20%, the maximum shear stress value under 196.1 kPa normal stress decreased from 217.6 to 128.0 kPa at room temperature and from 198.9 to 113.8 at 80°C. 10B-90S mixture had the highest internal friction angle value (Ø′) with 33.6°, while this value decrease to 6.0° for 20B-80S mixture at high temperature. In addition, the cohesion value (c′) of 20B-80S mixture under 80°C was 92.1 kPa which is the highest value.

3.2.2 Shear Strength Behavior of Boron Minerals

In addition to the soil mixtures, direct shear tests of boron minerals were performed at room temperature and 80°C. The shear stress-strain graphs of boron minerals are given in Figure 3.11. However, the direct shear test of tincal could not be performed at 80°C due to the collapse of the sample during the experiment.

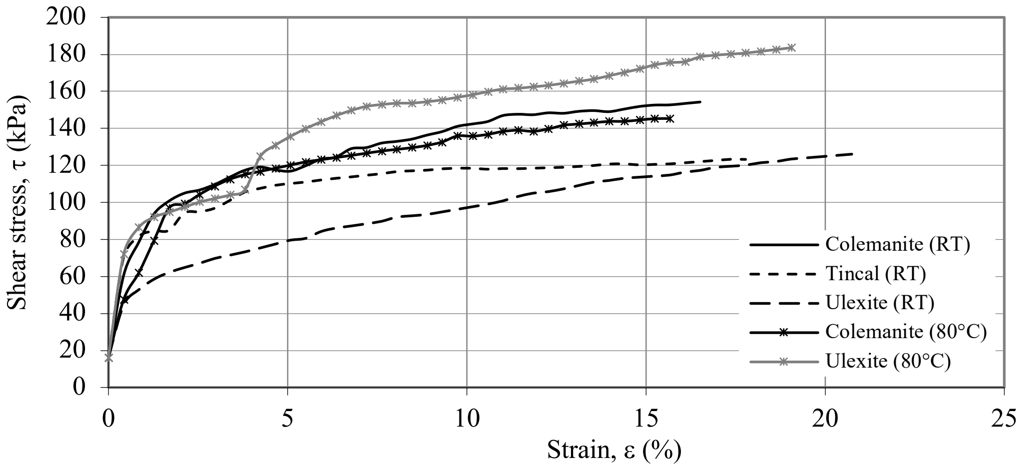


Figure 3.11 The shear stress-strain of boron minerals at room temperature and at 80°C

Colemanite achieved the highest maximum shear stress value at room temperature, while ulexite has the lowest value. Reversely ulexite had the highest shear stress value under 80°C. It should be noted that there is no significant difference at the maximum shear stress value of colemanite when temperature is increased from room temperature to 80°C.

According to the shear stress-normal stress graph of boron minerals given in Figure 3.12, the maximum shear stress values at room temperature are 141.7, 123.4, 116.7 kPa for colemanite, ulexite and tincal, respectively. The maximum shear stress value of ulexite at 80°C was 178.7 kPa which was the highest maximum shear stress value among boron minerals.

The shear strength parameters were obtained from Figure 3.12. The internal friction angle value of ulexite, which was 21.2° at room temperature, increased to 35.4° under 80°C, indicating a marked increase in the internal friction angle value with increasing heat. There was a noticeable increase in the internal friction angle value and a decrease in cohesion value of ulexite under high temperature. For colemanite, there was no change in shear strength parameters under high temperature. The internal friction angle was increased by only two degrees to 25.4° and the cohesion value increased by only 3 kPa to 34.7 kPa.

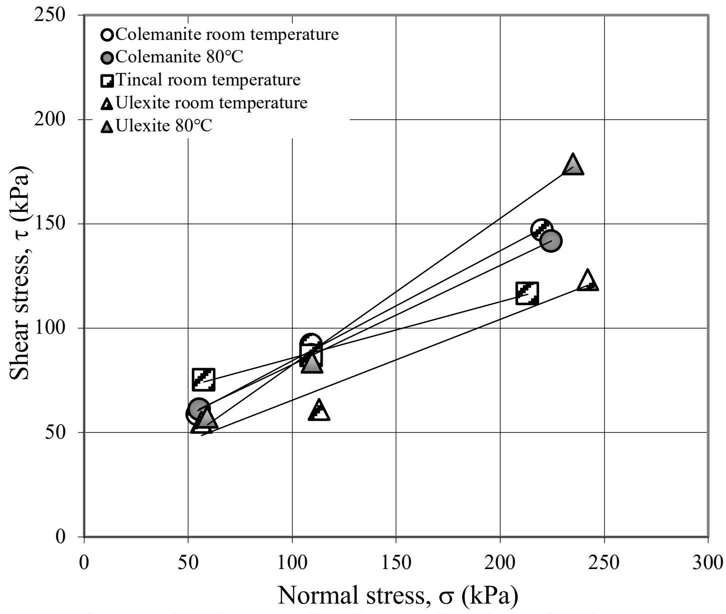


Figure 3.12 The shear failure envelopes of boron minerals at room temperature and at 80°C

3.2.3 The Effect of Boron Minerals on the Shear Strength Behavior of Sand-Bentonite Mixtures under High Temperatures

The direct shear tests of sand-bentonite mixtures in the presence of boron minerals were performed at room temperature and 80°C. Figure 3.13 shows the shear stress-strain graph of 10% sand-bentonite mixtures in the presence of colemanite.

It can be seen that the colemanite additive for 10% sand-bentonite mixtures reduced the maximum shear stress and increased strain at room temperature. However, in the presence of colemanite, maximum shear stress increased under high temperature when compared with those of room temperature values.

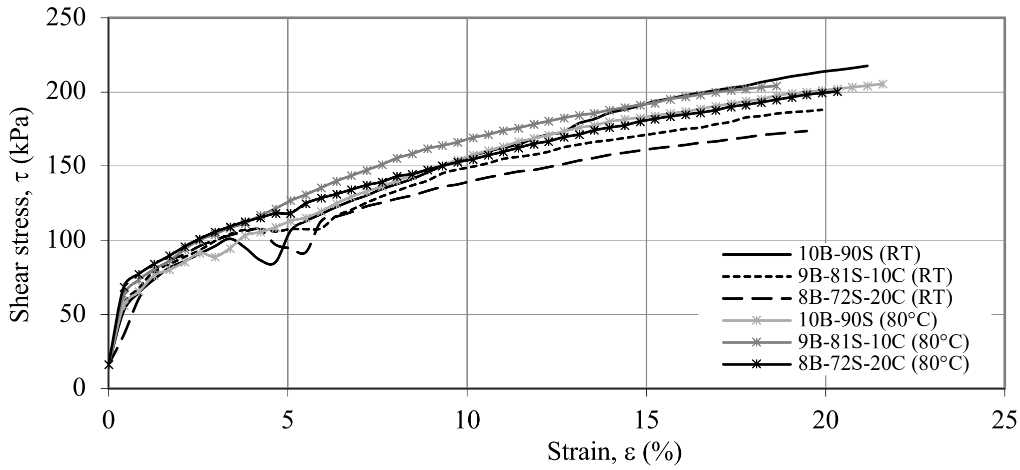


Figure 3.13 The shear stress-strain of 10% sand-bentonite mixtures in the presence of colemanite at room temperature and at 80°C

According to the shear stress-normal stress graph shown in Figure 3.14, the internal friction angle value of 9B-81S-10C mixture at 80°C (34.9°) was higher than the internal friction angle value of the 10B-90S mixture at both temperatures. The cohesion values of 10% sand-bentonite mixtures in the presence of colemanite varied between 34.9-50.4 kPa.

Figure 3.15 shows the shear stress-strain graph of 20% sand-bentonite mixtures in the presence of colemanite. The maximum shear stress of 20B-80S mixture decreased with 20% colemanite addition, whereas increased with 10% colemanite addition at room temperature. Moreover, 10% colemanite additive for 20% sand-bentonite mixtures led to a significant increase in the maximum shear stress at 80°C.

Figure 3.16 shows the shear stress-normal strain graph of 20% sand-bentonite mixtures in the presence of colemanite for room temperature and 80°C. According to the obtained shear strength parameters, the internal friction angle values increased in the presence of colemanite when temperature was increased to 80°C. The cohesion values also increased in the presence of 10% colemanite under high temperature.

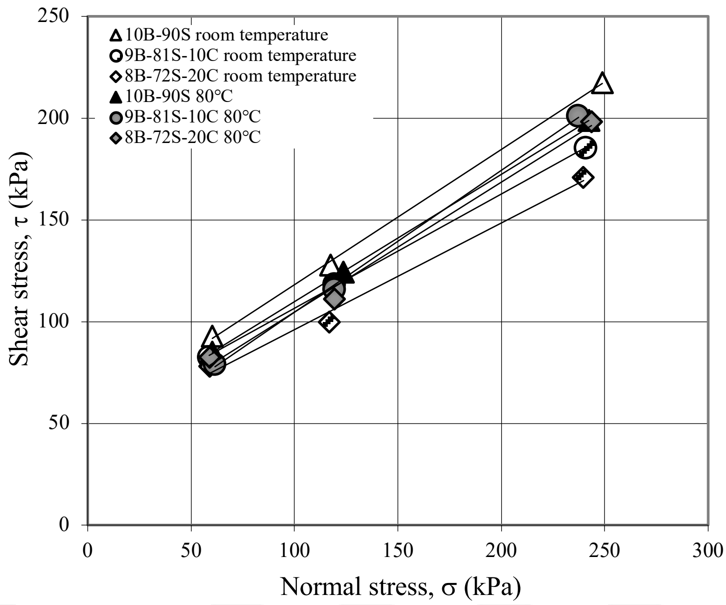


Figure 3.14 The shear failure envelopes of 10% sand-bentonite mixtures in the presence of colemanite at room temperature and at 80°C

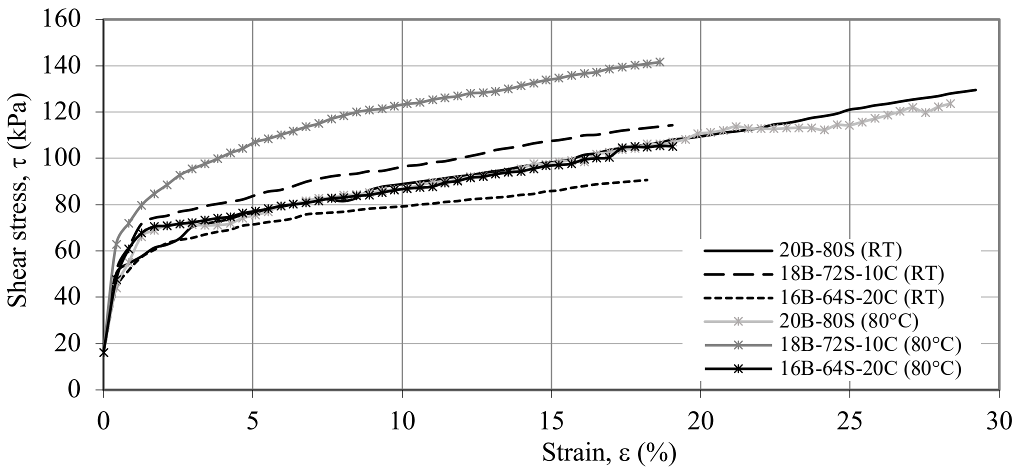


Figure 3.15 The shear stress-strain of 20% sand-bentonite mixtures in the presence of colemanite at room temperature and at 80°C

Figure 3.17 shows the shear stress-strain graph of 10% sand-bentonite mixtures in the presence of tincal. The maximum shear stress of 10B-80S mixture slightly decreased with increasing temperature. However, tincal additive caused an increment in the maximum shear stress of 8B-72S-20T mixture at high temperature.

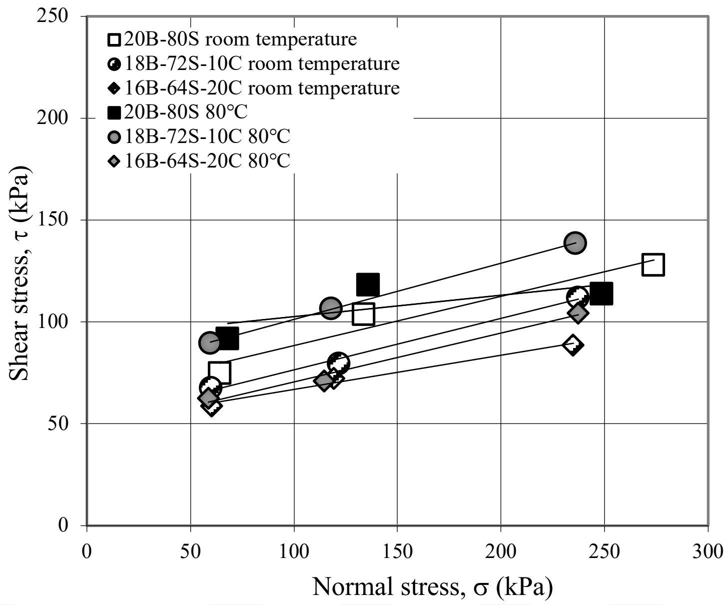


Figure 3.16 The shear failure envelopes of 20% sand-bentonite mixtures in the presence of colemanite at room temperature and at 80°C

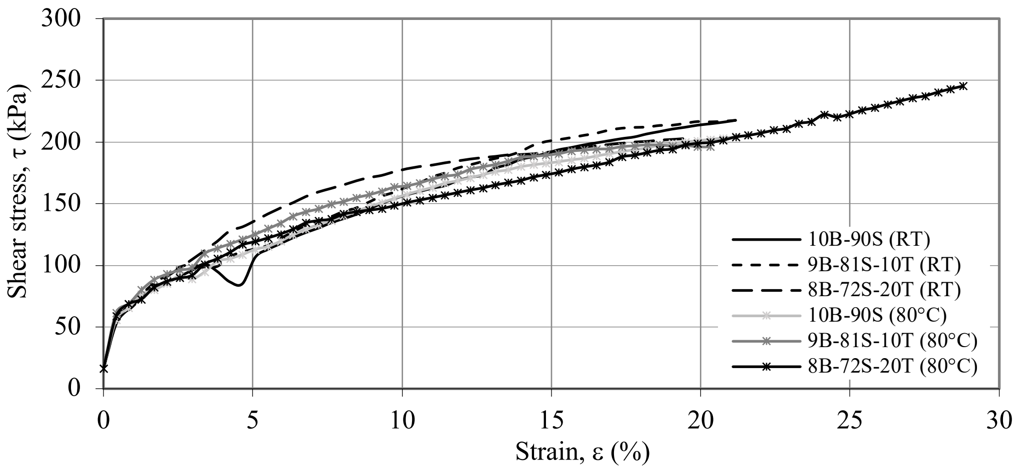


Figure 3.17 The shear stress-strain of 10% sand-bentonite mixtures in the presence of tincal at room temperature and at 80°C

Figure 3.18 indicates the shear stress-normal stress graph of 10% sand-bentonite mixtures in the presence of tincal for both room temperature and 80°C. The 10% tincal addition has no significant effect on the angle of internal friction values; however, when the tincal content increased to 20% the Ø′ values increased from 32.9° to 37.4° under high temperature.

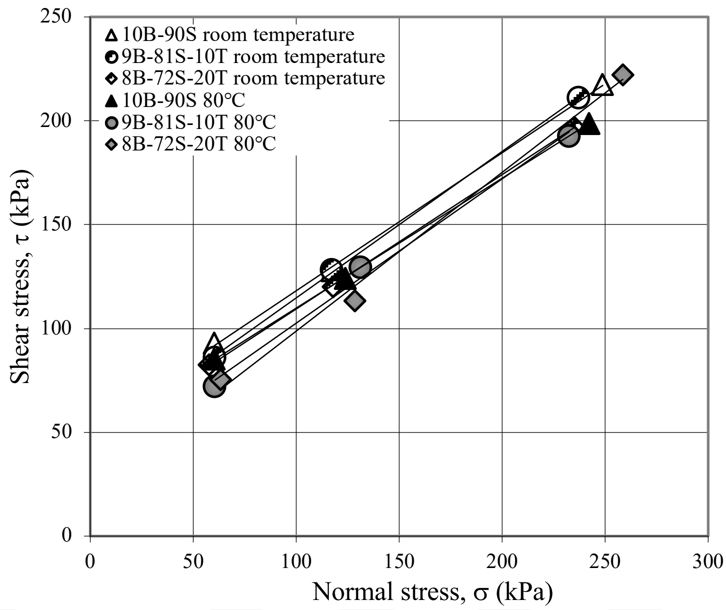


Figure 3.18 The shear failure envelopes of 10% sand-bentonite mixtures in the presence of tincal at room temperature and at 80°C

Figure 3.19 shows the shear stress-strain graph of 20% sand-bentonite mixtures in the presence of tincal both at room temperature and 80°C. The maximum shear stress of 20B-80S mixture increased with tincal additive under both room and high temperatures when compared with 20B-80S mixture. However, the increase in temperature caused a reduction in the maximum shear stress of 18B-72S-10T and 16B-64S-20T mixtures.

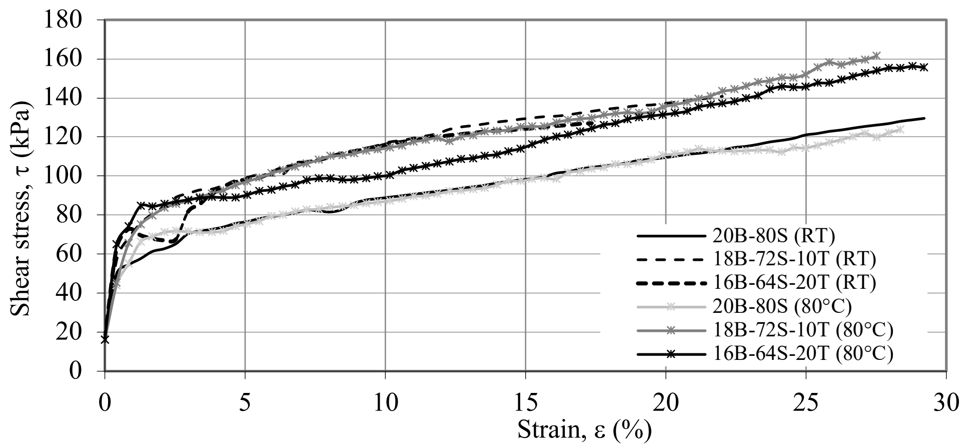


Figure 3.19 The shear stress-strain of 20% sand-bentonite mixtures in the presence of tincal at room temperature and at 80°C

Figure 3.20 shows the shear stress-normal stress graph of 20% sand-bentonite mixtures in the presence of tincal for both room temperature and 80°C. When 10% and 20% tincal were added to 20B-80S mixture, the angle of internal friction values increased; however, the cohesion values decreased to half of the room temperature values.

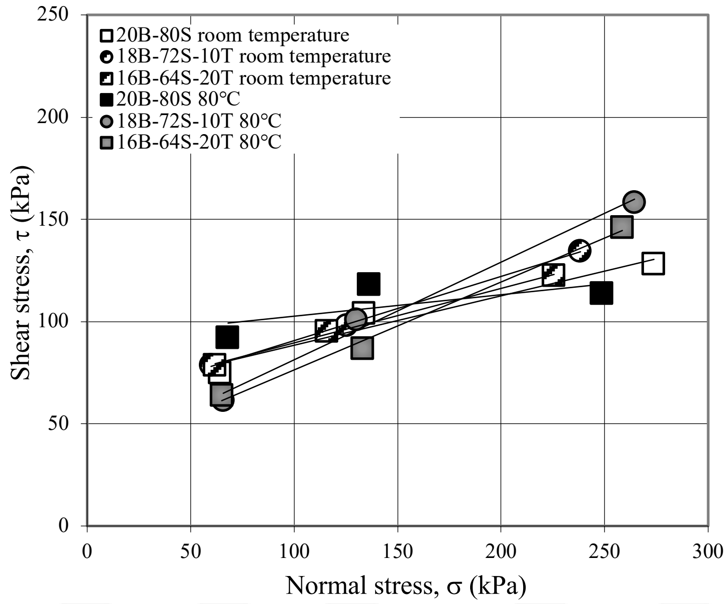


Figure 3.20 The shear failure envelopes of 20% sand-bentonite mixtures in the presence of tincal at room temperature and at 80°C

Figure 3.21 shows the shear stress-strain graph of 10% sand-bentonite mixtures in the presence of ulexite at room temperature and 80°C. The maximum shear stress of 10B-90S mixture increased with ulexite additive at 80°C.

The shear stress-normal stress graph of 10% sand-bentonite mixtures in the presence of ulexite for both room temperature and 80°C is given in Figure 3.22. The ulexite addition like other boron minerals increased the angle of internal friction and decreased the cohesion values. It should be noted that this effect is more significant with 20% ulexite.

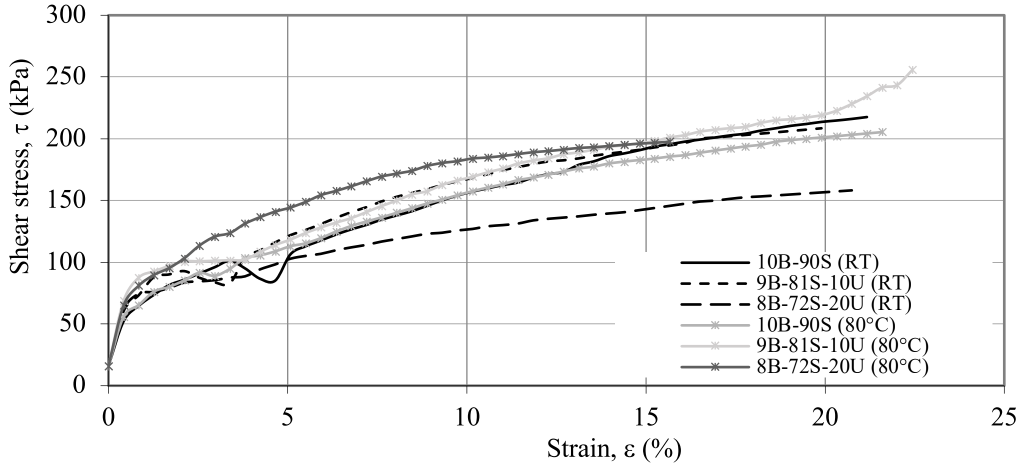


Figure 3.21 The shear stress-strain of 10% sand-bentonite mixtures in the presence of ulexite at room temperature and at 80°C

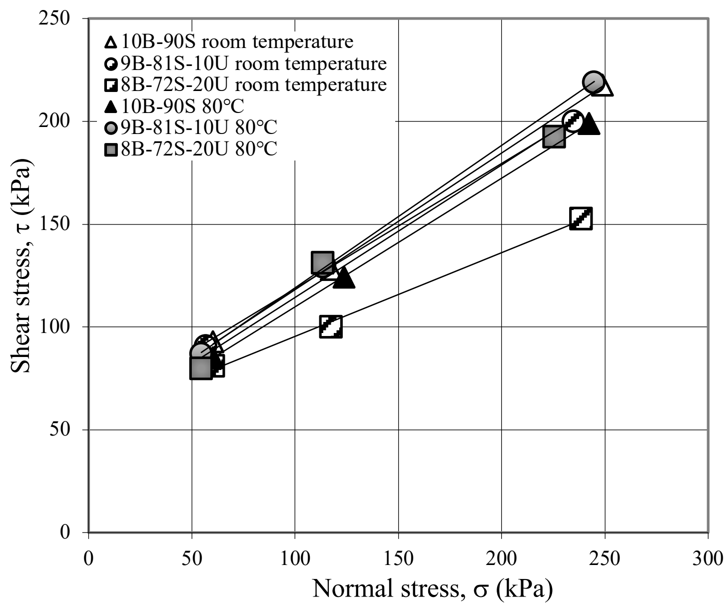


Figure 3.22 The shear failure envelopes of 10% sand-bentonite mixtures in the presence of ulexite at room temperature and at 80°C

Figure 3.23 shows the shear stress-strain graph of 20% sand-bentonite mixtures in the presence of ulexite at room temperature and 80°C. According to Figure 3.23, the maximum shear stress values of 18B-72S-10U and 16B-64S-20U mixtures increased with ulexite additive at 80°C, whereas decreased at room temperature.

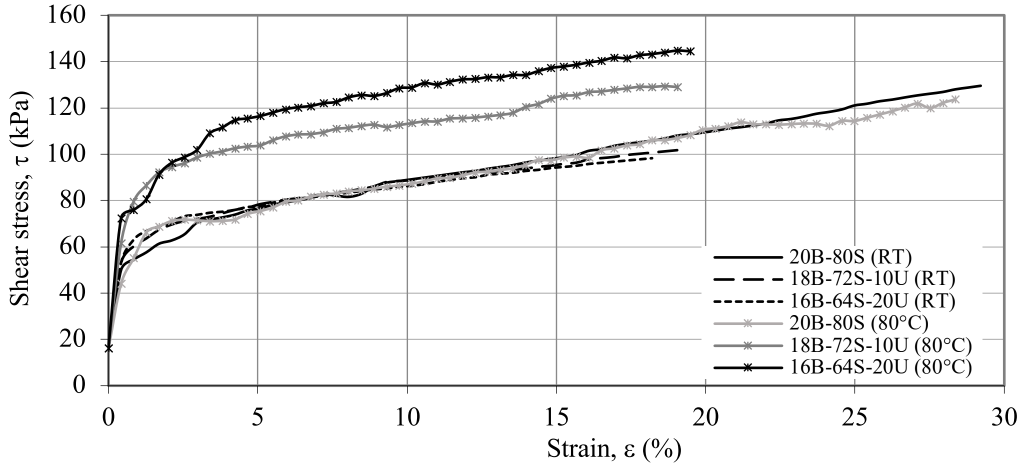


Figure 3.23 The shear stress-strain of 20% sand-bentonite mixtures in the presence of ulexite at room temperature and at 80°C

The shear stress-normal stress graph of 20% sand-bentonite mixtures in the presence of ulexite for both room temperature and 80°C is given in Figure 3.24. The ulexite increased the angle of internal friction almost double and also there was no significant decrease in the cohesion values.

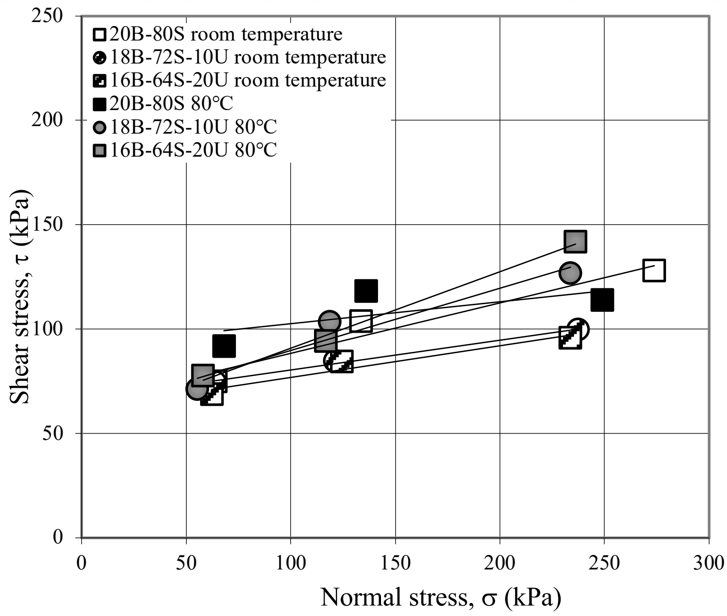


Figure 3.24 The shear failure envelopes of 20% sand-bentonite mixtures in the presence of ulexite at room temperature and at 80°C

Table 3.2 presents the shear strength parameters obtained from the direct shear tests at room temperature and 80°C for all samples.

Table 3.2 The shear strength parameters for all samples

Group	**Sample**	**Room Temperature**		**80°C**	
		Ø′(°)	**c′(kPa)**	**Ø′(°)**	**c′(kPa)**
	Colemanite	27.8	31.7	25.4	34.7
	Tincal	15.1	58.7	*	*
	Ulexite	21.2	26.8	35.1	12.1
10% Bentonite	10B-90S	33.6	51.7	32.0	47.3
	9B-81S-10C	29.3	50.4	34.9	34.9
	8B-72S-20C	27.7	43.7	32.6	40.9
	9B-81S-10T	35.2	44.2	34.8	33.1
	8B-72S-20T	32.9	44.7	37.4	22.3
	9B-81S-10U	31.3	57.8	34.7	49.8
	8B-72S-20U	22.1	54.8	32.8	50.0
20% Bentonite	20B-80S	13.6	64.3	6.0	92.1
	18B-72S-10C	14.2	51.2	15.4	70.7
	16B-64S-20C	9.5	50.1	13.5	46.6
	18B-72S-10T	17.2	59.9	25.5	33.5
	16B-64S-20T	14.8	63.0	23.3	33.3
	18B-72S-10U	8.1	66.2	16.6	60.0
	16B-64S-20U	8.6	61.7	20.1	54.2

*: Tincal collapsed when it was heated to 80℃

3.2.4 Influence of Temperature on the Shear Strength Behavior

Under this heading, the effect of temperature on the maximum shear stress (τ) and the shear strength parameters (Ø′, c′) was investigated for the mixtures. In this section, τ values were evaluated under 196.1 kPa normal stress. First, the effect of temperature on the shear strength behavior of sand-bentonite mixtures in the presence of colemanite was analyzed. Figure 3.25 shows the variation of the internal friction angle of 10B-90S and 20B-80S mixtures in the presence of colemanite with increasing temperature.

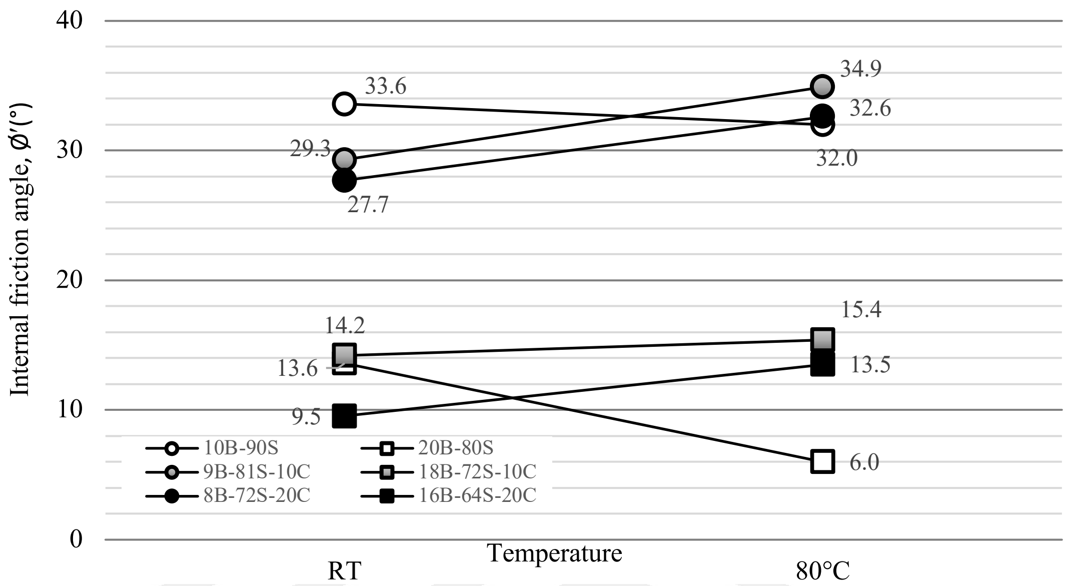


Figure 3.25 Internal friction angle values of 10% and 20% sand-bentonite mixtures in the presence of colemanite at room temperature and at 80°C

When the colemanite was added to sand-bentonite mixtures the internal friction angle value of 10B-90S mixture decreased slightly, while those of 9B-81S-10C and 8B-72S-20C mixtures increased with increasing temperature. For example, the Ø′ value of 9B-81S-10C at 29.3° at room temperature increased to 34.9° at 80°C and reached the highest Ø′ value for colemanite mixtures. It should be noted that this value was greater than the Ø′ value of 10B-90S both temperatures.

The shear strength behavior of 20B-80S mixtures is similar to 10B-90S mixtures. The Ø′ value of additive-free 20B-80S decreased with increasing temperature from 13.6° to 6.0°. However, the angle of internal friction values of 18B-72S-10C and 16B-64S-20C mixtures increased when temperature was increased to 80°C. Generally, the results have shown that the colemanite addition to sand-bentonite mixtures significantly increased the Ø′ values, when compared with 10B-90S and 20B-80S mixtures under high temperature.

Figure 3.26 presents the change of cohesion values of 10% and 20% sand-bentonite mixtures in the presence of colemanite with increasing temperature. The cohesion value of 10B-90S and 8B-72S-20C mixtures decreased slightly with increasing temperature. The c′ value of 9B-81S-10C decreased from 50.5 to 34.9 kPa with increasing temperature. This value was the lowest c′ value for colemanite added mixtures. The highest c′ value of 92.1 kPa was obtained with a sharp increase in the c′ value of 20B-80S mixture. The c′ value of the 18B-72S-10C mixture increased from 51.2 to 70.7 kPa with rising temperature.

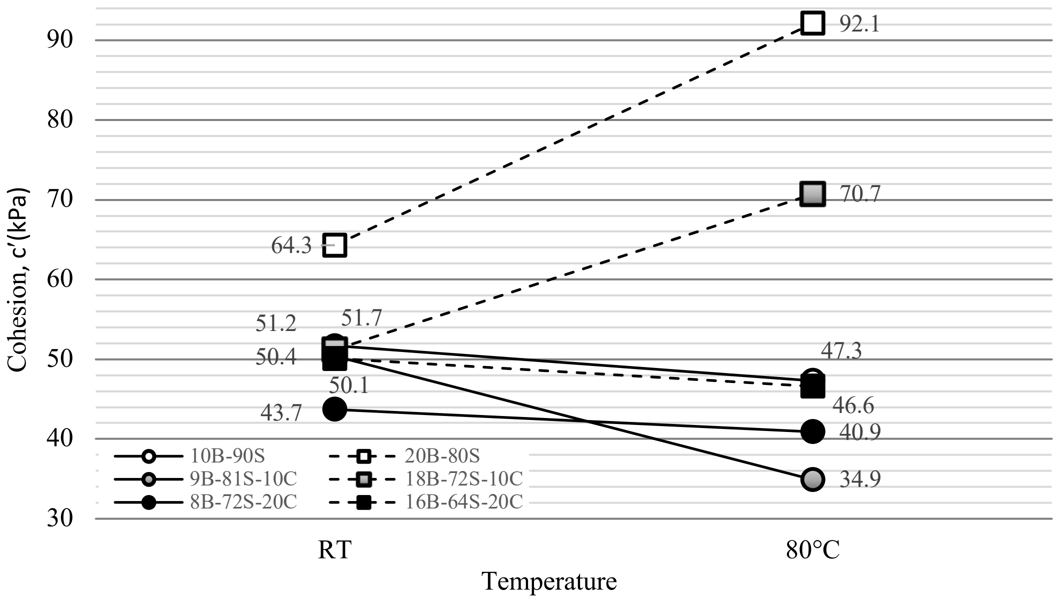


Figure 3.26 Cohesion values of 10% and 20% sand-bentonite mixtures in the presence of colemanite at room temperature and at 80°C

The change of maximum shear stress values of 10% and 20% sand-bentonite mixtures in the presence of colemanite with increasing temperature is shown in Figure 3.27. While the τ_{max} of 10B-90S mixture decreased with the temperature increment, it increased for 9B-81S-10C and 8B-72S-20C mixtures. The τ_{max} increased from 185.4 to 201.0 kPa for 9B-81S-10C and from 170.9 to 198.2 kPa for 8B-72S-20C with the rising temperature.

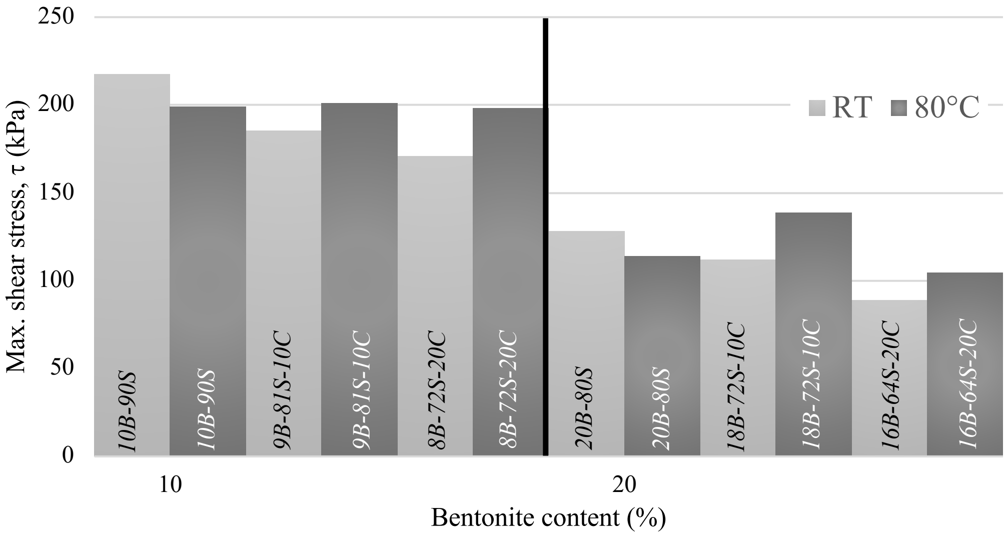


Figure 3.27 Maximum shear stress values of 10% and 20% sand-bentonite mixtures in the presence of colemanite at room temperature and at 80°C

When the additive free samples are considered, similar to 10B-90S mixture the τ_{max} decreased with increasing temperature for the 20B-80S mixture. However, the τ_{max} of mixtures in the presence of colemanite increased under high temperature. The τ_{max} of 18B-72S-10C and 16B-64S-20C mixtures were 112.0 and 88.8 kPa at room temperature increased to 138.7 and 104.5 kPa at 80°C, respectively.

Figure 3.28 indicates the change in the internal friction angle values of 10% and 20% sand-bentonite mixtures in the presence of tincal with increasing temperature. For the 10% sand-bentonite mixtures, the Ø′ value of the 9B-81S-10T mixture did not change with increasing temperature, while the Ø′ value of 8B-72S-20T increased. The Ø′ value of 8B-72S-20T was 32.9° at room temperature and 37.4° at 80°C, which was the highest Ø′ value for the all mixtures. The Ø′ values of 10% sand-bentonite mixtures in the presence of tincal at 80°C were higher than the additive-free 10B-90S samples under both temperatures.

The Ø′ value of 20B-80S mixture was 13.6° at room temperature and fell to 6.0° at 80°C. For mixtures with 20% bentonite in the presence of tincal, the Ø′ values increased significantly with increasing temperature. Specifically, the Ø′ value of the 18B-72S-10T increased from 17.2° to 25.5° with rising temperature. It can be said that the Ø′ values of mixtures in the presence of tincal generally increase with increasing temperature.

The alteration of cohesion values of 10% and 20% sand-bentonite mixtures in the presence of tincal with increasing temperature is given in Figure 3.29. The c′ value decreased with increasing temperature for 10% sand-bentonite mixtures in the presence of tincal. The highest decrease was observed for 8B-72S-10T mixture. The c′ value of 8B-72-10T mixture was half of those at high temperature. Similar to 10B-90S mixture, the c′ value was decreased for 20B-80S mixture in the presence of tincal. The c′ values were closed to each other of 18B-72S-10T and 16B-64S-20T mixtures, then they decreased to almost the same values under high temperature.

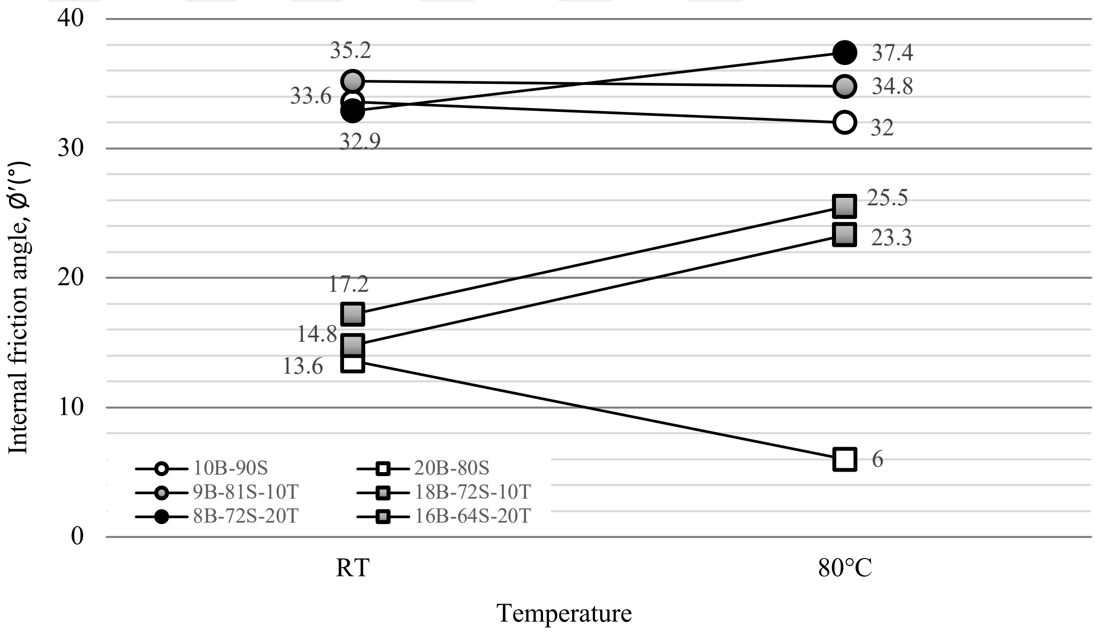


Figure 3.28 Internal friction angle values of 10% and 20% sand-bentonite mixtures in the presence of tincal at room temperature and at 80°C

The change of τ_{max} of 10% and 20% sand-bentonite mixtures in the presence of tincal with increasing temperature is given in Figure 3.30. The τ_{max} for 9B-81S-10T decreased from 211.2 kPa to 192.6 kPa with increasing temperature, whereas increased from 197.0 to 222.3 kPa for 8B-72S-20T. This value was higher than the τ_{max} of 10B-90S under both temperatures. It can be said that 20% tincal is more effective than 10%.

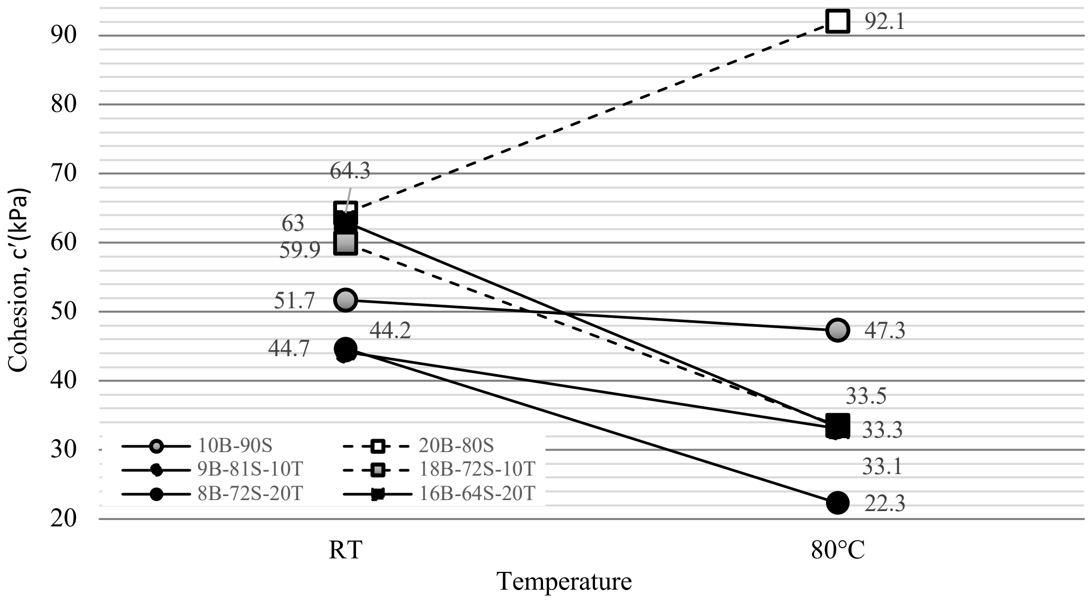


Figure 3.29 Cohesion values of 10% and 20% sand-bentonite mixtures in the presence of tincal at room temperature and at 80°C

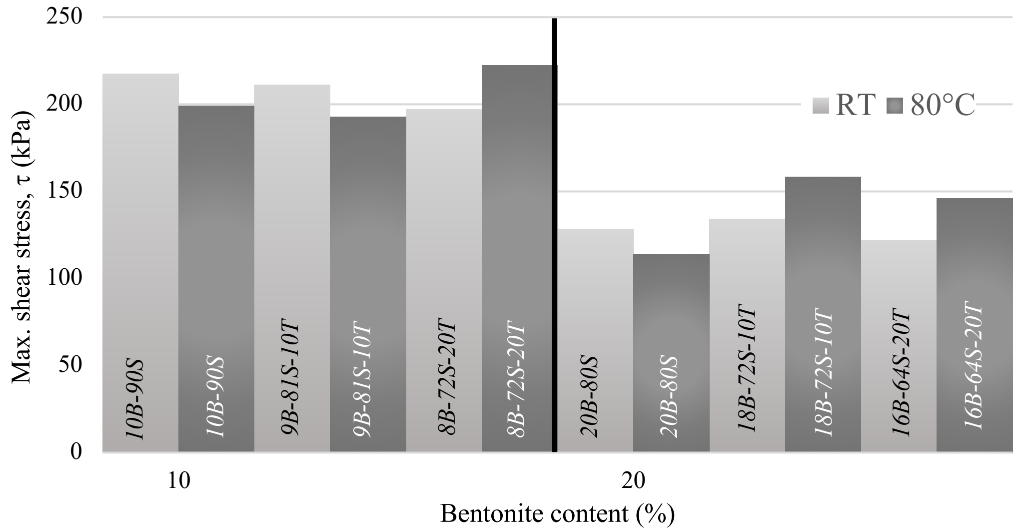


Figure 3.30 Maximum shear stress values of 10% and 20% sand-bentonite mixtures in the presence of tincal at room temperature and at 80°C

The τ_{max} of 20% sand-bentonite mixtures in the presence of tincal increased with rising temperature. The τ_{max} of 18B-72S-10T and 16B-64S-20T were increased from 134.0 to 158.2 kPa and from 122.1 to 145.9 kPa, respectively.

The difference in the internal friction angle values of 10% and 20% sand-bentonite mixtures in the presence of ulexite with increasing temperature is given in Figure 3.31. The Ø′ values of both 10% and 20% sand bentonite mixtures in the presence of ulexite increased under elevated temperature (80°C). The Ø′ value of 8B-72S-20U increased from 22.1° (room temperature) to 32.8° (80°C). Although ulexite additive decreased the Ø′ values of additive-free 10B-90S and 20B-80S samples under room temperature, it increased the Ø′ values at 80°C.

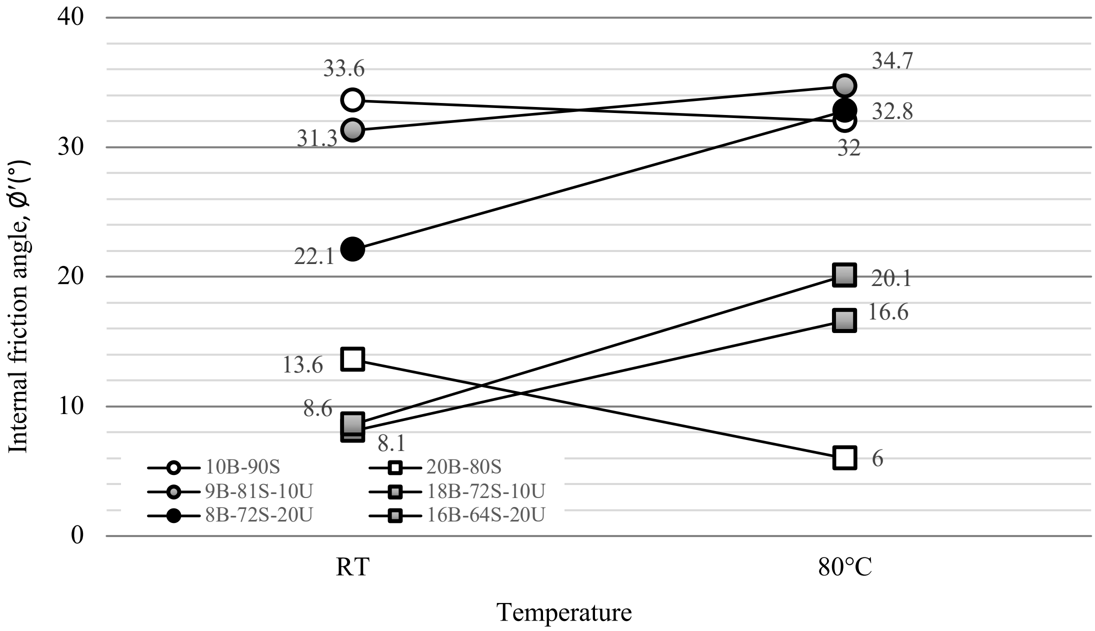


Figure 3.31 Internal friction angle values of 10% and 20% sand-bentonite mixtures in the presence of ulexite at room temperature and at 80°C

For the mixtures with 20% bentonite in the presence of 10% and 20% ulexite, the Ø′ values of 8.1° and 8.6° at room temperature increased to 16.6° and 20.1° at 80°C, respectively. These Ø′ values at high temperature were two times more than the Ø′ values at room temperature.

The change of cohesion values of 10% and 20% sand-bentonite mixtures in the presence of ulexite with increasing temperature is presented in Figure 3.32. The c′ value of 10% sand-bentonite mixtures in the presence of ulexite, decreased with increasing temperature. The c′ values of 9B-81S-10U and 8B-72S-20U mixtures, which were 57.8 and 54.8 kPa at room temperature, decreased to 49.8 kPa and 50 kPa, respectively, with an increase in the temperature.

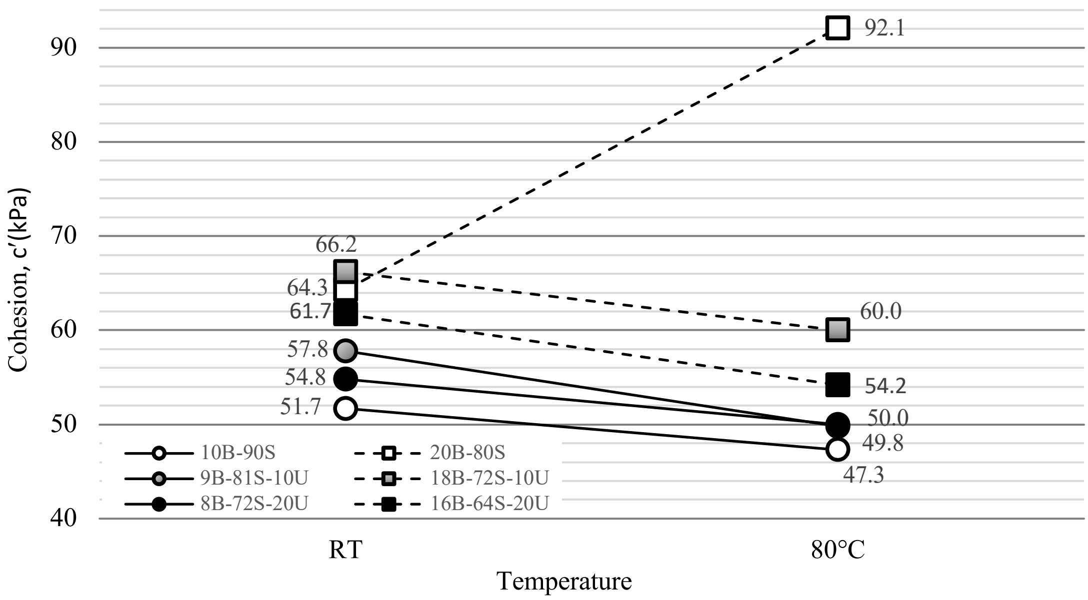


Figure 3.32 Cohesion values of 10% and 20% sand-bentonite mixtures in the presence of ulexite at room temperature and at 80°C

The c′ value was decreased for 20% sand-bentonite mixtures in the presence of ulexite. The c′ value of 18B-72S-10U decreased from 66.2 to 60.0 kPa with the temperature increment, and the c′ value of 16B-64S-20U decreased from 61.7 to 54.2 kPa.

Figure 3.33 shows the change of maximum shear stress values (τ_{max}) of 10% and 20% sand-bentonite mixtures in the presence of ulexite with increasing temperature. As shown in Figure 3.32, a significant increase in the maximum shear stress value was observed with increasing temperature for 9B-81S-10U mixture, however; τ_{max} of the 8B-72S-20U decreased at 80°C. The τ_{max} of the 9B-81S-10U increased from 200.0 to 219.1 kPa, which was higher than the τ_{max} of 10B-90S mixture at both temperatures.

The τ_{max} of 20% sand-bentonite mixture in the presence of ulexite increased significantly with increasing temperature. The τ_{max} of 18B-72S-10U and 16B-64S-20U mixtures increased from 99.7 and 95.8 kPa to 126.8 and 141.7 kPa, respectively. The ulexite addition to 20B-80S mixtures increased the τ_{max} at 80°C. Overall, the results have shown that the maximum shear stress values of sand-bentonite mixtures in the presence of ulexite at 80°C was generally higher than the values which were obtained under room temperature.

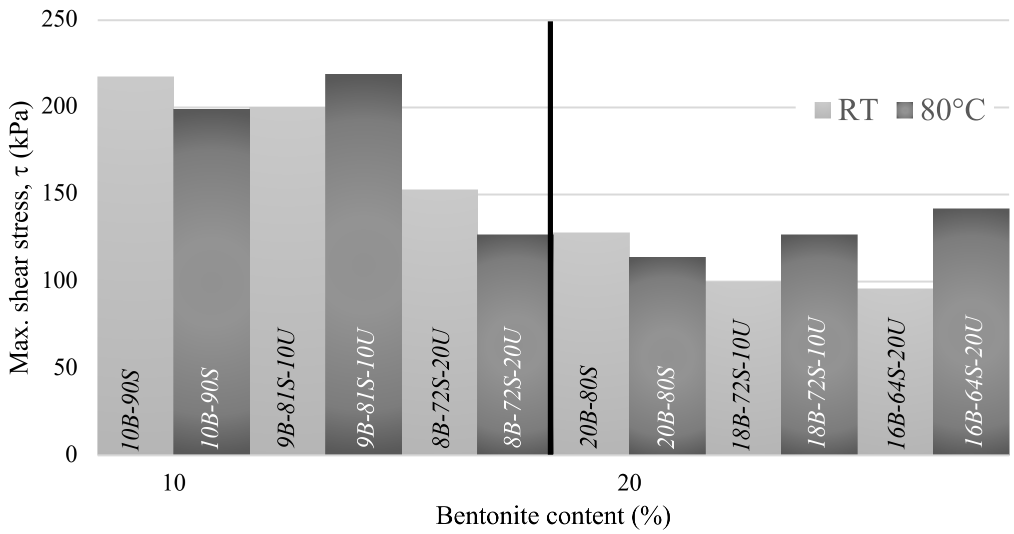


Figure 3.33 Maximum shear stress values of 10% and 20% sand-bentonite mixtures in the presence of ulexite at room temperature and at 80°C

3.2.5 Influence of Boron Percentage on the Shear Strength Behavior of Sand-Bentonite Mixtures

In this section, the effect of the percentage of boron additives for all mixtures on the shear strength (τ) and the shear strength parameters (Ø′, c′) was analyzed. First, the effect of boron percentage on the shear strength behavior of sand-bentonite mixtures in the presence of colemanite at room temperature was investigated. Figure 3.34 shows the change in internal friction angle and cohesion values depending on the colemanite percentage at room temperature.

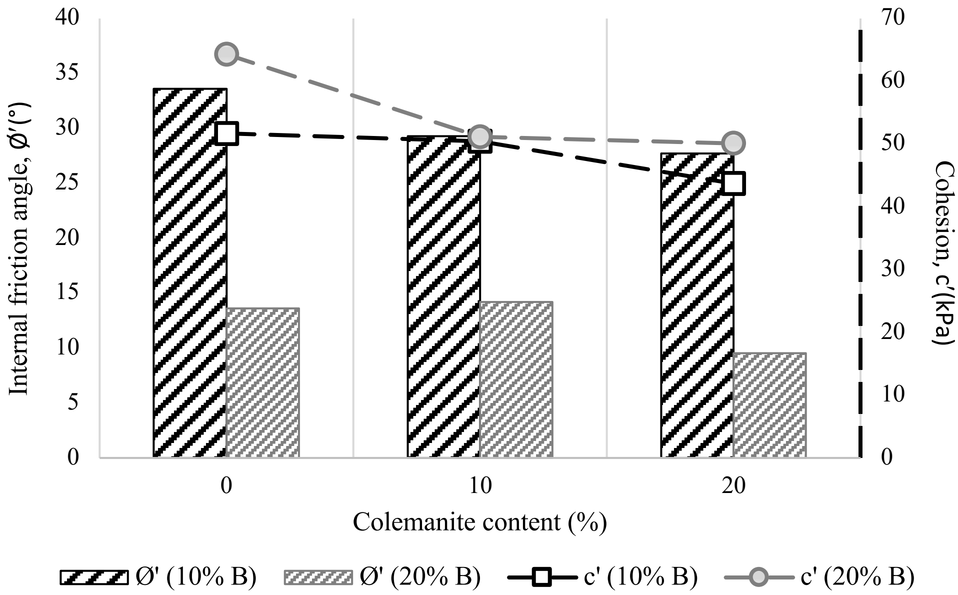


Figure 3.34 Internal friction angle and cohesion values depending on the colemanite percentage of sand-bentonite mixtures at room temperature

Increase in the colemanite percentage from 10% to 20% resulted in a decrease of Ø′ value from 29.3° to 27.7°. For 20% sand-bentonite mixtures, the Ø′ value of 20B-80S was increased from 13.6° to 14.2° with 10% colemanite and decreased to 9.5° with 20% colemanite.

The 10% colemanite did not affect c′ value of 10B-90S, which was 51.7 kPa, for 10% sand-bentonite mixtures at room temperature. When the percentage of colemanite was increased from 10% to 20%, the c′ value decreased from 50.4 to 43.7 kPa. The colemanite additives decreased c′ value at room temperature for 20% sand-bentonite mixtures, but increase in colemanite percentage from 10% to 20% did not change the c′ value significantly.

Figure 3.35 presents the internal friction angle and cohesion values depending on the colemanite percentage in sand-bentonite mixtures at 80°C. For 10% sand-bentonite mixtures, the Ø′ value of 10B-90S at 80°C was increased with both 10% and 20% colemanite. When the colemanite additive increased from 10% to 20%, the Ø′ value decreased from 34.9° to 32.6°. The Ø′ value of 20B-80S increased from 6.0° to 13.5°

and 15.4° with 20 and 10% colemanite, respectively. There was a slight decrease in Ø′ value, when increase in colemanite percentage from 10% to 20%.

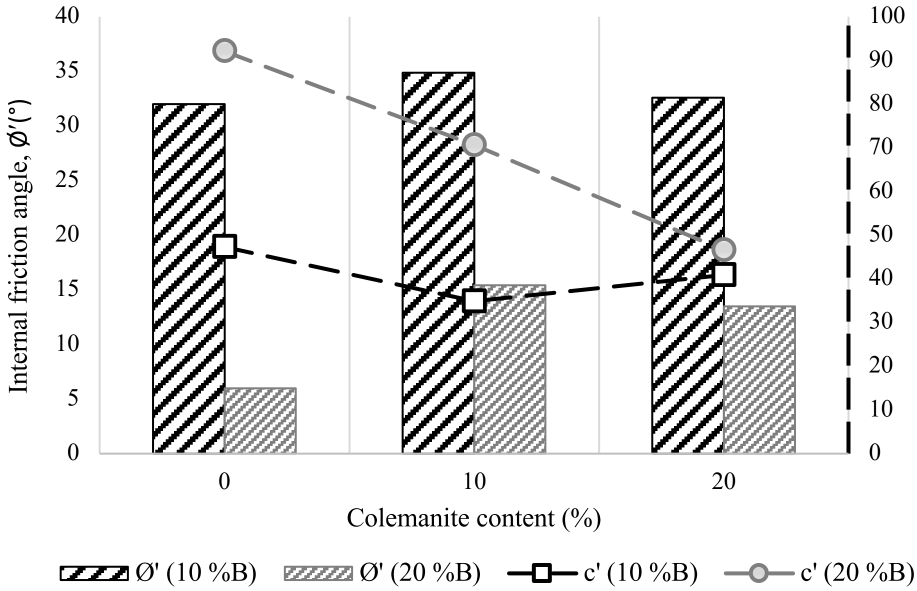


Figure 3.35 Internal friction angle and cohesion values depending on the colemanite percentage of sand-bentonite mixtures at 80°C

The colemanite addition decreased the c′ value of 10B-90S at 80°C. However, when the colemanite percentage was increased from 10% to 20%, c′ value increased from 34.9 to 40.9 kPa. For 20% sand-bentonite mixtures, colemanite additive decreased c′ values at 80°C. Increase in the colemanite percentage from 10% to 20% decreased the c′ values from 70.7 to 46.6 kPa. When the colemanite percentage increased, c′ values almost linearly and markedly decreased.

Figure 3.36 shows the maximum shear stress values (τ_{max}) considering the colemanite percentage in sand-bentonite mixtures at room temperature. The τ_{max} of 10% and 20% sand-bentonite mixtures in the presence of colemanite at room temperature were decreased. For example, the τ_{max} of additive-free 10% sand-bentonite mixtures were 217.6 kPa, while it decreased to 185.4 kPa and 170.9 kPa in the presence of 10% and 20% colemanite, respectively.

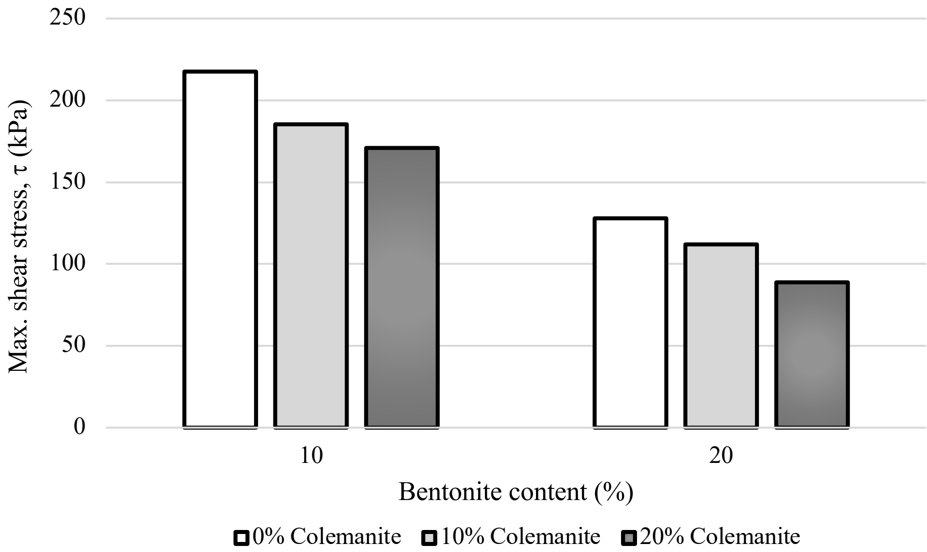


Figure 3.36 Maximum shear stress values depending on the colemanite percentage of sand-bentonite mixtures at room temperature

Change of the τ_{max} according to the colemanite percentage in sand-bentonite mixtures at 80°C are shown in Figure 3.37. The τ values of 10B-90S additive-free mixture with, 10% and 20% colemanite were very close to each other at 80°C. There was no significant effect on the τ_{max} when colemanite percentage was increased. For 20B-80S mixtures, 10% colemanite additive increased τ_{max} , whereas 20% colemanite decreased τ_{max}. However, increase in the colemanite from 10% to 20% decreased the τ_{max} from 138.7 to 104.5 kPa.

The internal friction angle and cohesion values depending on the tincal percentage of sand-bentonite mixtures at room temperature are given in Figure 3.38. The Ø′ value of 10B-90S under room temperature increased slightly with 10% tincal addition. However, there was no significant change with the 20% tincal addition. When the additive content increased from 10% to 20%, the Ø′ value decreased from 35.2° to 32.9°. Increase in tincal percentage from 10% to 20% caused a decrease in Ø′ value for 20B-80S mixtures.

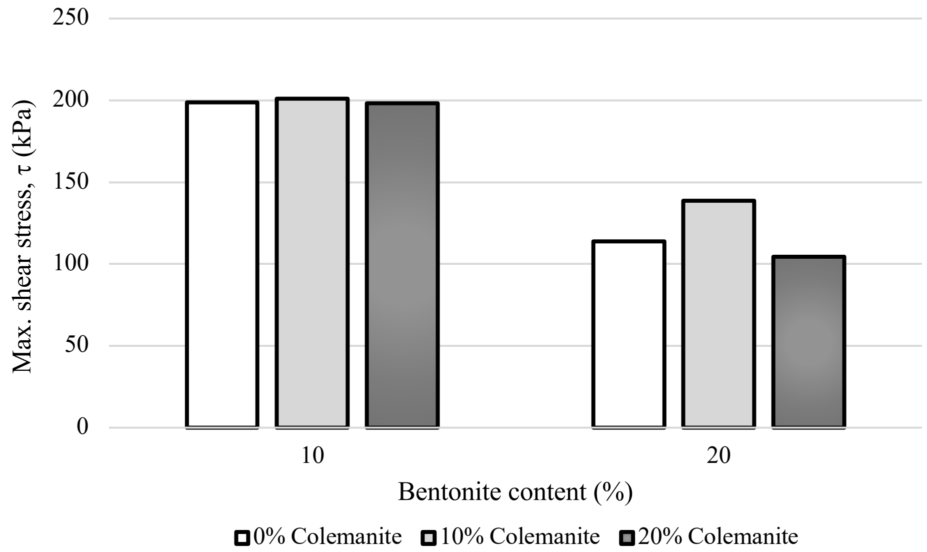


Figure 3.37 Maximum shear stress values depending on the colemanite percentage of sand-bentonite mixtures at 80°C

The tincal additive reduced the c′ value of 10B-90S mixtures at room temperature. However, when the tincal percentage was increased from 10% to 20%, the c′ value was almost unchanged. When tincal percentage increased from 10% to 20%, the c′ value increased insignificantly for 20% bentonite. Overall, it can be concluded that the tincal percentage for all sand-bentonite mixtures at room temperature had no significant effect on c′ values.

The internal friction angle and cohesion values according to the tincal percentage in sand-bentonite mixtures at 80°C are seen in Figure 3.39. When tincal percentage increased from 10% to 20%, the Ø′ value increased by almost 3.0° for 10B-90S mixtures, while it decreased by 2.0° for 20B-80S mixtures.

The tincal additive reduced the c′ value of 10B-90S mixtures at 80°C (Figure 3.39). When the tincal percentage was increased from 10% to 20%, the c′ value decreased from 33.1 to 22.3 kPa. The 10% tincal additive reduced the c′ value of additive-free 20B-80S mixture sharply to three times of the c′ value at 80°C. In addition to this, when tincal percentage increased from 10% to 20%, the c′ value did not change.

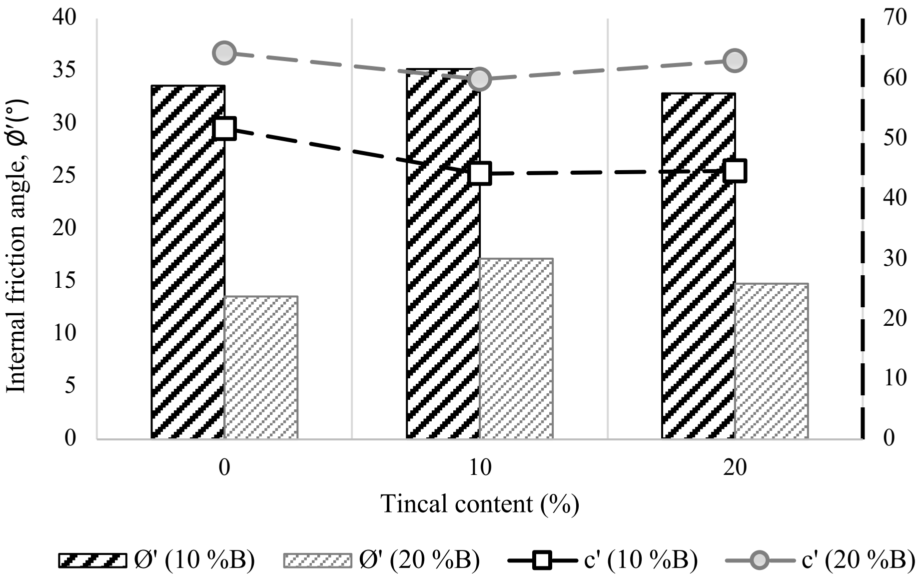


Figure 3.38 Internal friction angle and cohesion values depending on the tincal percentage of sand-bentonite mixtures at room temperature

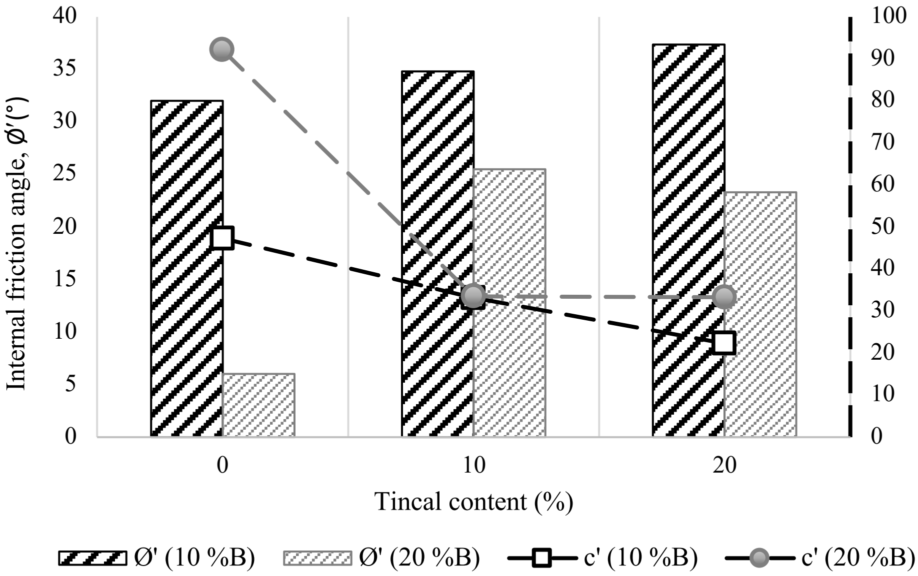


Figure 3.39 Internal friction angle and cohesion values depending on the tincal percentage of sand-bentonite mixtures at 80°C

Figure 3.40 presents the change of the τ_{max} depending on the tincal percentage in sand-bentonite mixtures at room temperature. The tincal additive increased the τ_{max} for 10% sand-bentonite mixtures at room temperature. However, 10% tincal increased the τ_{max} more than 20% tincal. In particular, the 10% and 20% tincal increased τ_{max} from

185.4 kPa to 211.2 and 200.0 kPa, respectively. The τ value decreased when the tincal content was increased to 20% for 20B-80S mixtures. Change of the τ_{max} according to the tincal percentage in sand-bentonite mixtures at 80°C are shown in Figure 3.41. When tincal percentage increased from 10% to 20%, the τ_{max} increased for 10B-90S mixtures while they decreased for 20B-80S mixtures.

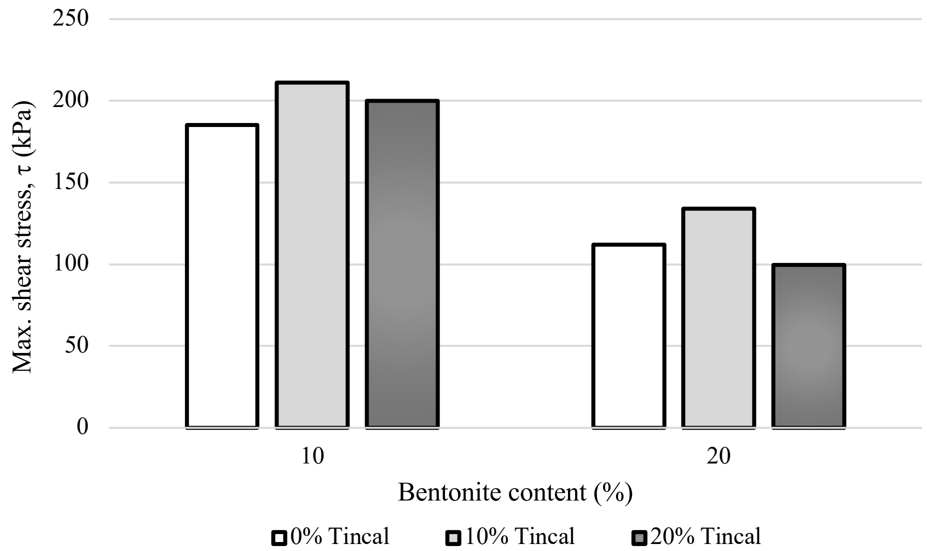


Figure 3.40 Maximum shear stress values depending on the tincal percentage of sand-bentonite mixtures at room temperature

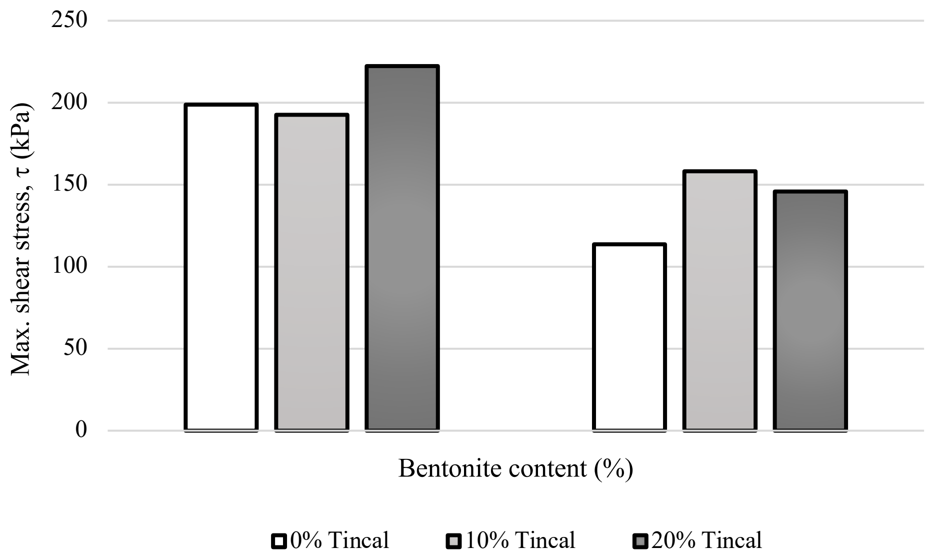


Figure 3.41 Maximum shear stress values depending on the tincal percentage of sand-bentonite mixtures at 80°C

The internal friction angle and cohesion values depending on the ulexite percentage in sand-bentonite mixtures at room temperature are given in Figure 3.42. When ulexite additive was added to the additive-free 10B-90S mixtures, the internal friction angle values decreased at room temperature. The internal friction angle of the 10B-90S mixture, decreased from 33.6° to 31.3° with 10% ulexite and to 22.1° with 20% ulexite. Similar to 10B-90S mixtures, the ulexite additive decreased Ø′ for 20B-80S mixtures. However, when the ulexite additive content was increased from 10 to 20% there was no significant change in the Ø′ values of 20B-80S mixtures.

The c′ value of 10B-90S increased with ulexite addition at room temperature. However, when the ulexite percentage was increased from 10% to 20%, the c′ value decreased from 57.8 to 54.8 kPa (Figure 3.42). For 20% sand-bentonite mixture, the ulexite additive at room temperature did not significantly affect the c′ value. When the ulexite percentage increased from 10% to 20%, the c′ value decreased slightly from 66.2 to 61.7 kPa.

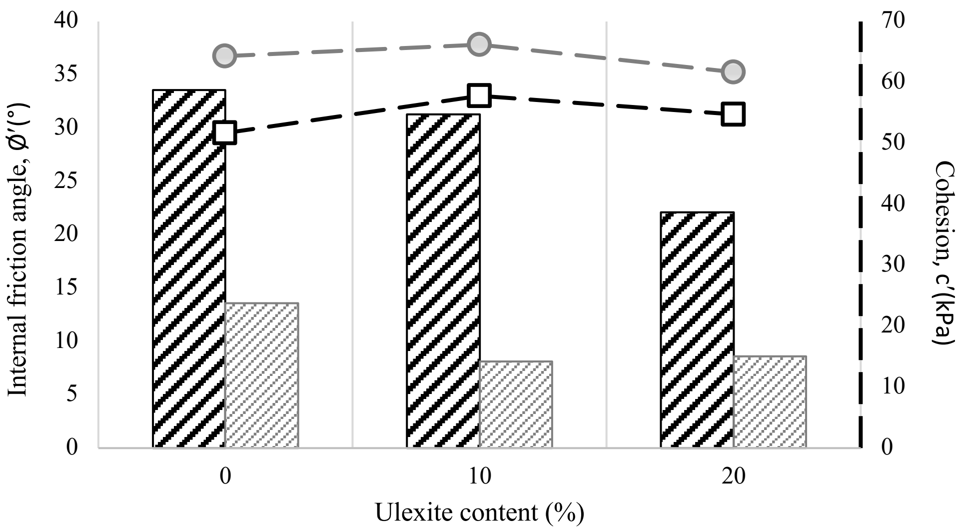


Figure 3.42 Internal friction angle and cohesion values depending on the ulexite percentage of sand-bentonite mixtures at room temperature

Figure 3.43 presents the internal friction angle and cohesion values according to the ulexite percentage of sand-bentonite mixtures at 80°C. The ulexite addition to 10%

additive-free sand-bentonite mixtures, the Ø′ values increased at 80°C. However, when the ulexite percentage increased from 10% to 20%, the Ø′ value decreased from 34.7° to 32.8°. Similar to 10% sand-bentonite mixtures, ulexite additive had increasing effect on the Ø′ values for 20% sand-bentonite mixtures. However, the rate of increase was greater than that of the 10% sand-bentonite mixtures. As ulexite content was increased from 10 to 20%, the Ø′ value increased from 16.6° to 20.1°.

The cohesion (c′) value of 10B-90S increased insignificantly with ulexite for 10% sand-bentonite mixtures at 80°C. When the ulexite percentage was increased from 10% to 20%, the c′ value did not change significantly (Figure 3.43). When ulexite percentage increased from 10% to 20%, c′ value decreased from 60.0 to 54.2 kPa for 20B-80S mixtures.

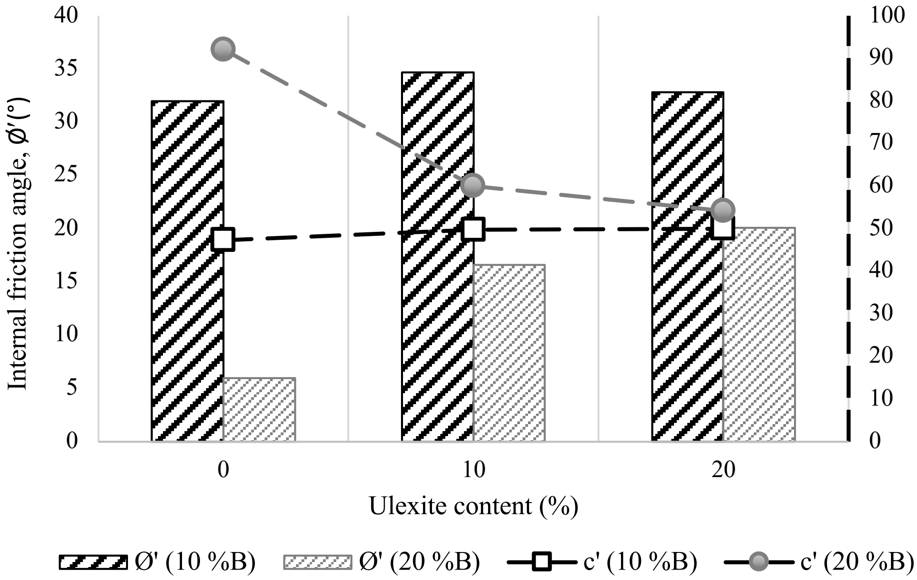


Figure 3.43 Internal friction angle and cohesion values depending on the ulexite percentage of sand-bentonite mixtures at 80°C

The τ_{max} of the sand-bentonite mixture according to the ulexite percentage change at room temperature are given in Figure 3.44. The ulexite additive decreased the τ_{max} for 10% sand-bentonite mixtures at room temperature. The maximum shear stress values of the 10B-90S mixtures decreased as the ulexite additive ratio increased at room temperature. The greater the ulexite percentage, the lower the τ_{max}. When expressed as more specifically, the τ_{max} of sand-bentonite mixture decreased from 217.6 kPa to 200.0 and 152.6 kPa when 10% and 20% ulexite was added to the mixture, respectively. The τ_{max} behavior of the 20B-80S mixtures at room temperature was similar to that of the 10B-90S mixtures. The ulexite addition decreased the τ_{max}. However, the increase in the ulexite percentage from 10% to 20% could not change the τ_{max} significantly.

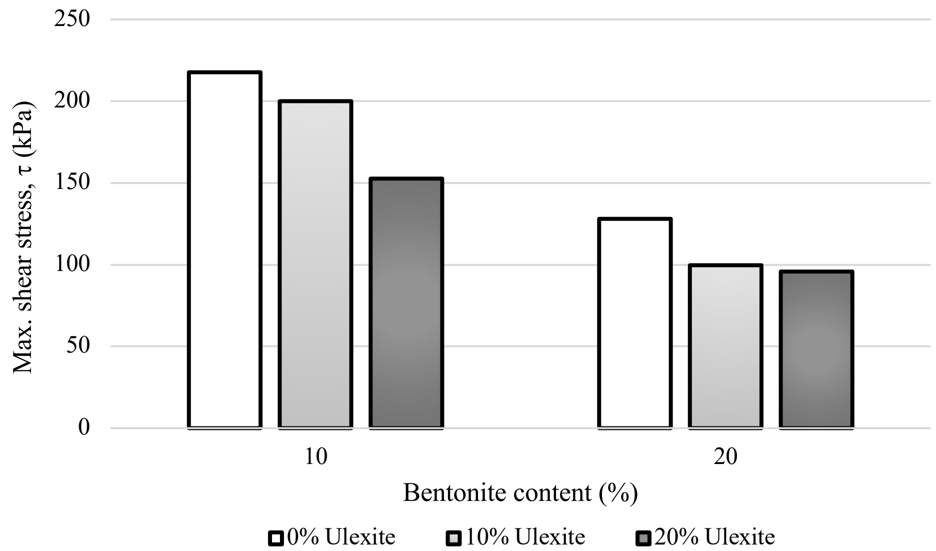


Figure 3.44 Maximum shear stress values depending on the ulexite percentage of sand-bentonite mixtures at room temperature

Change of the τ_{max} according to the ulexite percentage in sand-bentonite mixtures at 80°C are presented in Figure 3.45. As can be seen, the 10% ulexite additive increased the τ_{max} of at 80°C, while the 20% ulexite additive decreased the τ_{max} to 126.8 kPa by causing a dramatic decrement for 10B-90S mixtures. The ulexite addition to 20% sand-bentonite mixture increased the τ_{max}; additionally, as ulexite content increased τ_{max} increased, too.

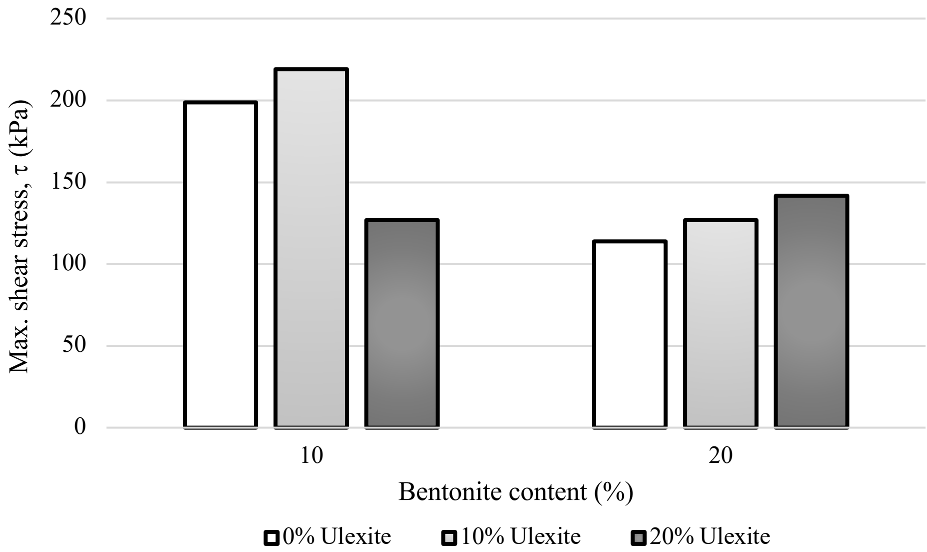


Figure 3.45 Maximum shear stress values depending on the ulexite percentage of sand-bentonite mixtures at 80°C

3.2.6 Influence of Boron Mineral Type on the Shear Strength Behavior

In this part, the maximum shear stress (τ_{max}) and shear strength parameters (Ø′, c′) of the mixtures according to the boron mineral type (i.e. colemanite, tincal, ulexite) in sand-bentonite mixtures were investigated. Figure 3.46 shows the internal friction angle and cohesion values according to boron mineral type for sand-bentonite mixtures in the presence of 10% boron at room temperature.

For the 10% sand-bentonite mixtures in the presence of 10% boron mineral, the highest Ø′ value at room temperature was provided by tincal addition. The lowest Ø′ value was obtained with colemanite. For the 20% sand-bentonite mixtures, the highest Ø′ value similar to 10% sand-bentonite mixtures, was observed in the presence of tincal. The lowest Ø′ value was obtained in the presence of ulexite.

In the presence of 10% ulexite at room temperature, c′ value was the highest value (57.8 kPa) for the 10% sand-bentonite mixtures, the lowest c′ value was obtained in the presence of tincal (44.2 kPa). When ulexite was added to 20% sand-bentonite mixtures, the c′ value reached its highest value, followed by tincal and colemanite, respectively.

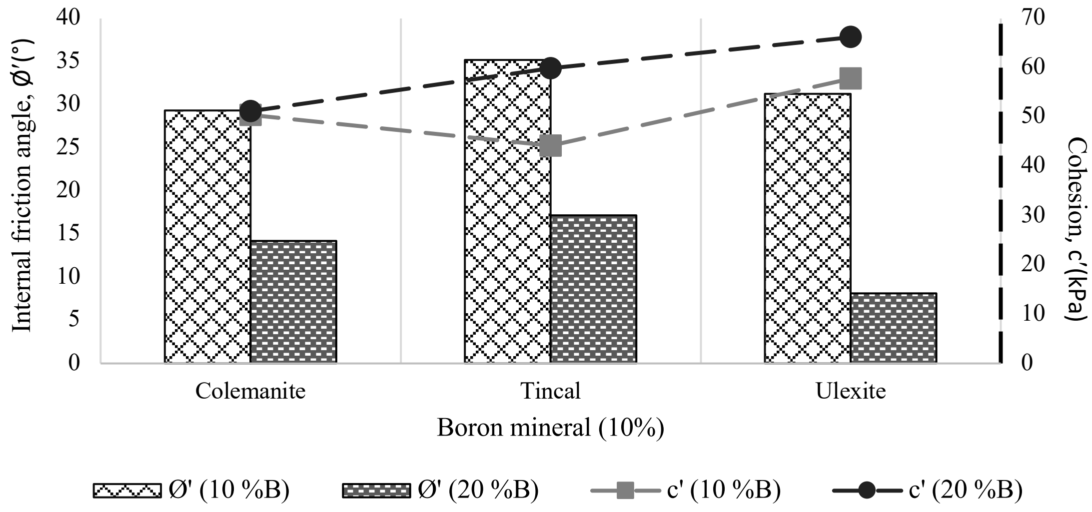


Figure 3.46 Internal friction angle and cohesion values according to boron mineral type for sand-bentonite mixtures in the presence of 10% boron at room temperature

The internal friction angle and cohesion values depending on boron mineral type in sand-bentonite mixtures in the presence of 20% boron at room temperature are presented in Figure 3.47. In the presence of 20% boron mineral, the highest Ø′ value at room temperature was obtained with tincal like 10% boron mineral addition as well.

For the 10% sand-bentonite mixtures in the presence of 20% boron mineral, c′ value was the highest value in the presence of ulexite at room temperature, while the lowest value was obtained with colemanite (Figure 3.47). In the presence of colemanite and tincal, the c′ value had very close values to each other. When tincal additive was used for 20% sand-bentonite mixtures, c′ value reached its highest value as 63.0 kPa.

The internal friction angle and cohesion values according to boron mineral type in sand-bentonite mixtures in the presence of 10% boron at 80℃ are given in Figure 3.48. In the presence of 10% boron minerals for 10B-90S mixtures in the presence of colemanite, tincal and ulexite, the Ø′ values were almost same and around 35.0° at 80℃. The highest Ø′ value was reached in the presence of tincal for 20B-80S mixtures, while the lowest Ø′ value was achieved in the presence of colemanite. The Ø′ was 25.4° with tincal, whereas it is 15.4° with colemanite.

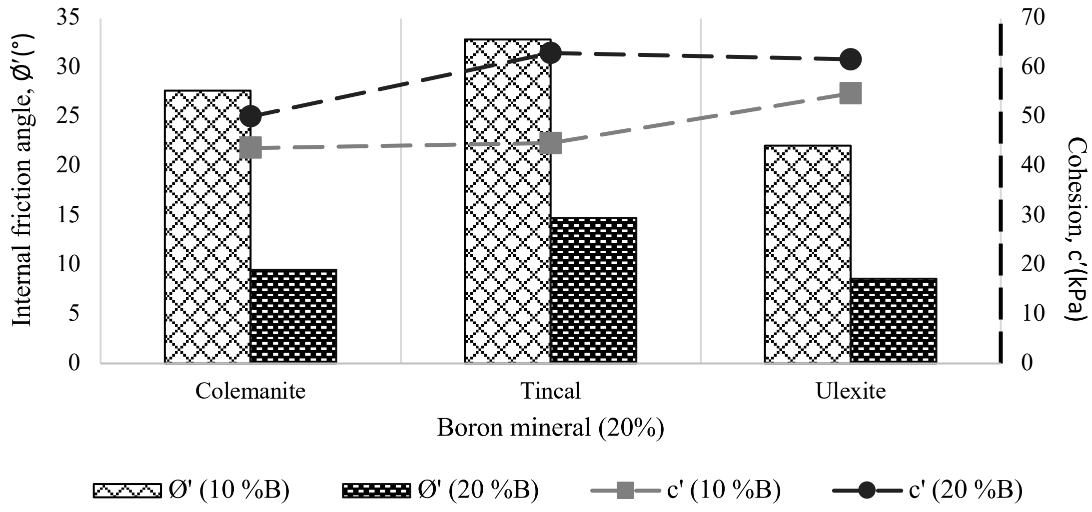


Figure 3.47 Internal friction angle and cohesion values according to boron mineral type for sand-bentonite mixtures in the presence of 20% boron at room temperature

When ulexite was used as boron mineral at 80℃ for 10B-90S mixtures in the presence of 10% boron mineral, c′ value reached its highest value and was 49.8 kPa (Figure 3.48). In the presence of colemanite and tincal, c′ values were closed to each other. For 20% sand-bentonite mixtures, c′ value was obtained as 70.7 kPa in the presence of colemanite and this value was higher than those obtained in the presence of other boron minerals.

Figure 3.49 shows the internal friction angle and cohesion values according to boron mineral type in sand-bentonite mixtures in the presence of 20% boron minerals at 80℃. In the presence of 20% boron mineral, the highest Ø′ value was obtained in the presence of tincal at 80℃ for 10% sand-bentonite mixtures and this value was 37.4°. This value was also the highest Ø′ value for all mixtures. In the presence of colemanite and ulexite, the Ø′ values were the same. The highest Ø′ value was obtained with tincal for the 20% sand-bentonite mixtures, followed by ulexite and colemanite, respectively.

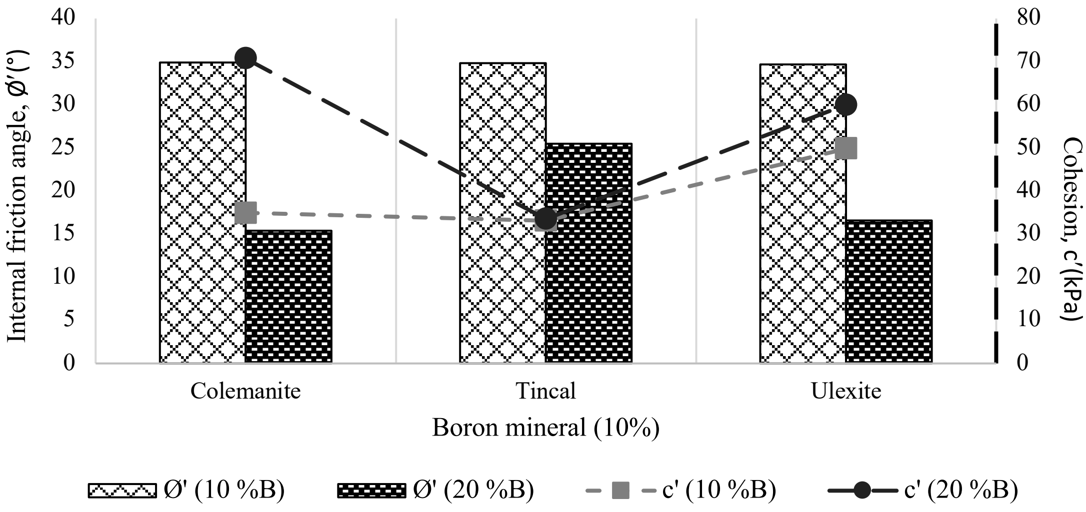


Figure 3.48 Internal friction angle and cohesion values according to boron mineral type for sand-bentonite mixtures in the presence of 10% boron at 80°C

In the presence of 20% all boron minerals, the c′ values were same for 10B-90S and 20B-80S mixtures at 80℃ (Figure 3.49). Specifically, the lowest c′ value was obtained in the presence of tincal, while the highest c′ value was obtained in the presence of ulexite. In details, the c′ value of 10% sand-bentonite mixtures in the presence of ulexite was 50.0 kPa, while in the presence of tincal was 22.3 kPa.

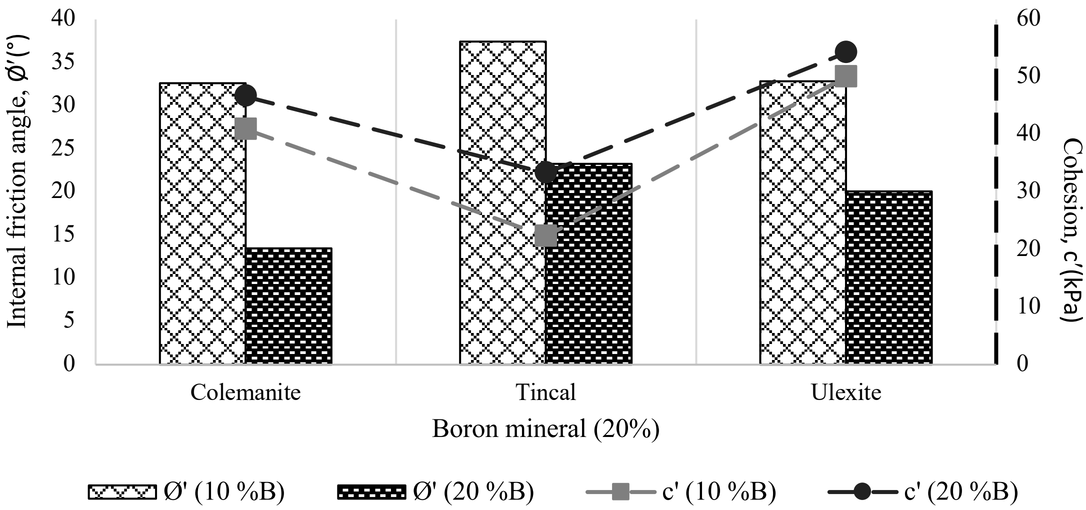


Figure 3.49 Internal friction angle and cohesion values according to boron mineral type for sand-bentonite mixtures in the presence of 20% boron at 80°C

Figure 3.50 shows the τ_{max} according to boron mineral type in sand-bentonite mixtures in the presence of 10% boron mineral at room temperature. In the presence of 10% boron mineral, the τ_{max} of 10B-90S mixtures were obtained as 211.2 kPa with tincal additive. When colemanite was added, the τ_{max} was the lowest. For 20B-80S mixtures, the highest τ_{max} was attained with tincal. The boron mineral that provided the lowest τ_{max} was ulexite and this value was 99.7 kPa.

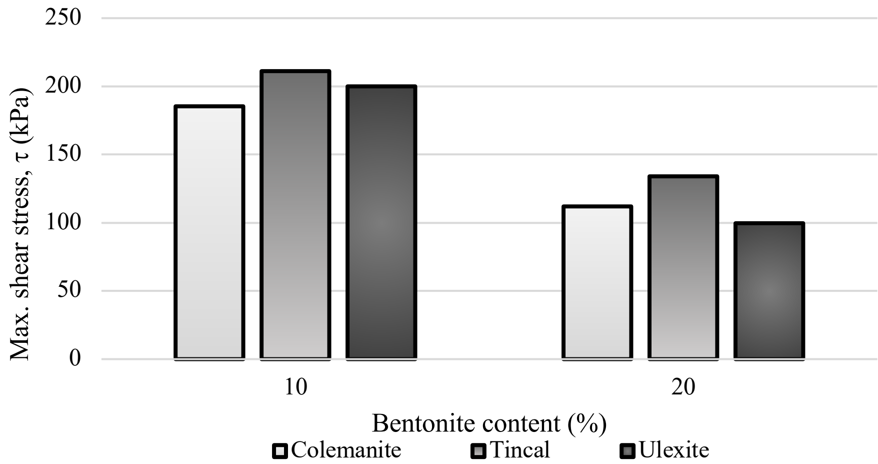


Figure 3.50 Maximum shear stress values according to boron mineral type for sand-bentonite mixtures in the presence of 10% boron at room temperature

The τ_{max} corresponding to boron mineral type in sand-bentonite mixtures in the presence of 20% boron mineral at room temperature are presented in Figure 3.51. The highest τ_{max} of 10B-90S and 20B-80S mixtures were obtained as 197.0 kPa and 122.1 kPa using tincal, respectively. The lowest τ_{max} was obtained in the presence of ulexite for 10B-90S mixtures and in the presence of colemanite for 20B-80S mixtures. The tincal addition was more effective than other boron minerals to increase the τ_{max} at room temperature.

The τ_{max} depending on boron mineral type in sand-bentonite mixtures in the presence of 10% boron mineral at 80℃ are shown in Figure 3.52. For 10B-90S mixtures in the presence of 10% ulexite was 219.1 kPa at 80℃. This value was the highest value among the boron minerals. The lowest τ_{max} was 192.6 kPa and obtained in the presence of tincal. Boron mineral, which increased the τ_{max} at most for 20B-80S mixtures, was tincal. By adding ulexite, the lowest τ_{max} of 20B-80S mixture was obtained.

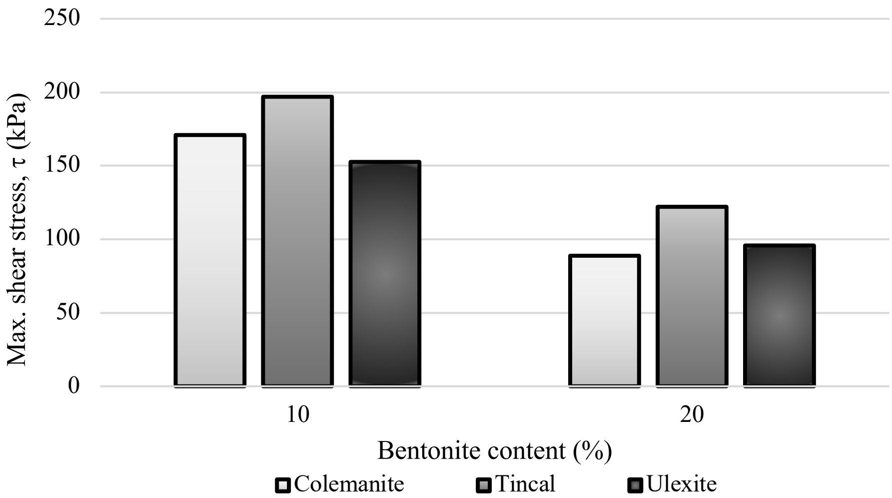


Figure 3.51 Maximum shear stress values according to boron mineral type for sand-bentonite mixtures in the presence of 20% boron at room temperature

The τ_{max} depending on boron mineral type in sand-bentonite mixtures in the presence of 20% boron at 80℃ are given in Figure 3.53. In the presence of 20% boron mineral, the τ_{max} of 10B-90S and 20B-80S mixtures reached the highest values in the presence of tincal. For 10B-90S mixtures, the lowest τ_{max} was obtained with ulexite, whereas it was obtained with colemanite for 20B-80S.

Previous studies have shown that increase in the temperature transforms the smectite mineral into more constant silicate phases. As a result of this, the water retaining ability of the clay reduces. Smectite transforms to illite depending on temperature, time and K^+ pore-water doping (Wersin, Johnson, & Snellman, 2006). If the ability of water adsorption of clay decreases, the strength of the clay should increase. However, according to results of this study the shear strength of both sand-bentonite mixtures decreased when temperature was increased from room temperature (~25 °C) to 80 °C. This result can be explained by viscous shear resistance of adsorbed water and fabric changes due to increase in temperature. As temperature increases, the viscosity of water which adsorbed by bentonite particles decreases. As a result of this, the shear strength of soils decreases. In the literature, it is reported that when temperature approximates to 100°C, the buffer properties may change by cementation and illitisation (Liu, Cai, & Wang, 2007). However, the cementation effect did not occur during the direct shear tests. Because the shear strength of the mixtures decreased. It should be noted that the existence of cementation effect should be investigated by further Scanning Electron Microscope (SEM) analyses. Another reason of decrease in shear strength can be the fabric change due to increase in temperature.

The results of this study have shown that, strength resistivity of both sand-bentonite mixtures increased with boron minerals. The boron is held strongly by the aluminum or silicon tetrahedron portion in the clay structure. Depending on the high surface area of montmorillonite can adsorb as much boron as illite (Keren, & Mezuman, 1981). For that reason, the boron was held by bentonite particles. Eventually, the shear strength of sand-bentonite increased as a result of both boron adsorption and material replacement. Because when the boron added to the sample both bentonite and sand content was decreased. The bentonite material was replaced with boron mineral which has a very high thermal resistivity. For that reason, the material replacement may be another reason of the increase in shear strength of sand-bentonite mixtures under high temperature.

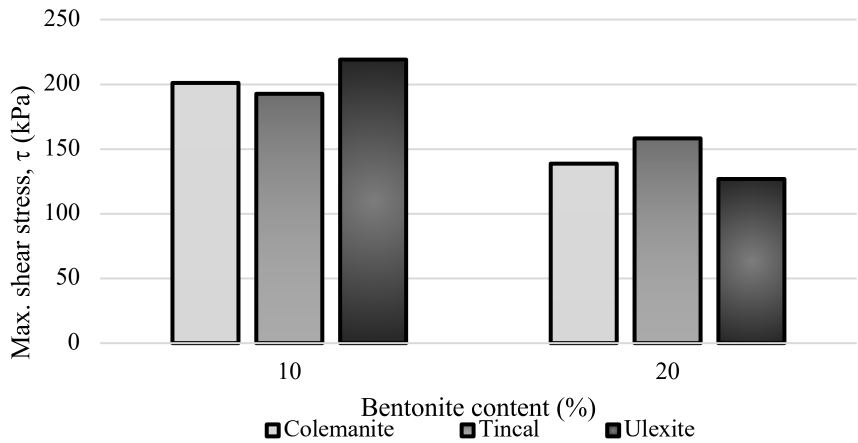


Figure 3.52 Maximum shear stress values according to boron mineral type for sand-bentonite mixtures in the presence of 10% boron at 80°C

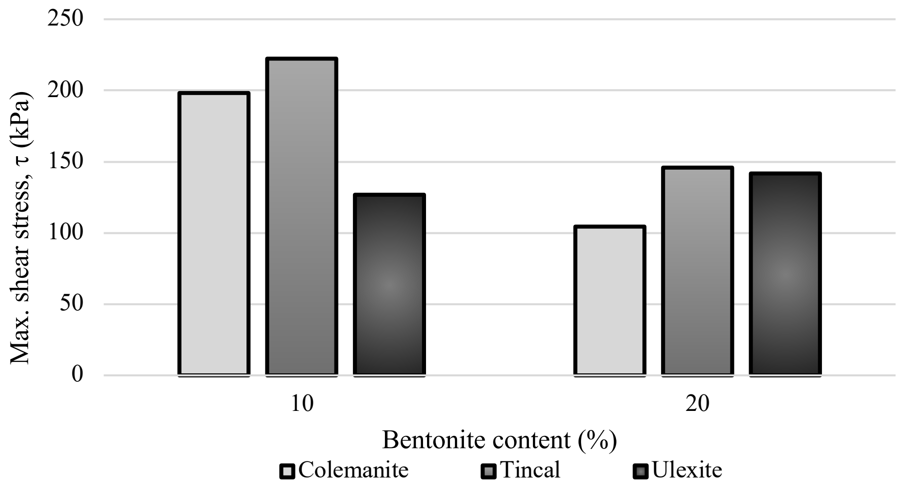


Figure 3.52 continues

3.3 Hydraulic Conductivity Tests Results

In this section, hydraulic conductivity test results of sand-bentonite mixtures, boron mineral namely; tincal and sand-bentonite mixtures in presence of tincal were presented. Because of low permeability of the samples, it takes quite long time for these tests to terminate the tests. The experiments have been still continuing and, in this thesis, the results were presented according to the most recently recorded values. Hydraulic conductivity (k) was calculated by averaging the last four readings. Hydraulic conductivity tests were carried out on 10B-90S, 9B-81S-10T and 8B-72S-20T mixtures under high temperature.

3.3.1 Hydraulic Conductivity Tests Results of Sand-Bentonite Mixtures at Room Temperature

The hydraulic conductivity of compacted 10% and 20% sand-bentonite mixtures were expressed as a function of pore volume of flow (PVF). The hydraulic conductivity test results of 10B-90S and 20B-80S mixtures are shown in Figure 3.54a and Figure 3.54b, respectively. In addition, outflow to inflow (Q_{out}/Q_{in}) ratios are presented in Figures 3.54a and b.

According to Figure 3.54a and b, the current hydraulic conductivity values of both 10B-90S and 20B-80S mixtures were obtained $1.7x10^{-11}$ m/s. The hydraulic conductivity value was the same for both mixtures. However, the experiments have been continuing and there is no outflow at the 20B-80S mixture test yet. In addition, the Q_{out}/Q_{in} ratios of the 10B-90S have not yet been stabilized Approximately, 0.5 PVFs passed through both samples. While the PVFs increased in the 10B-90S mixture, the hydraulic conductivity decreased slightly, while the 20B-80S mixture did not show significant changes.

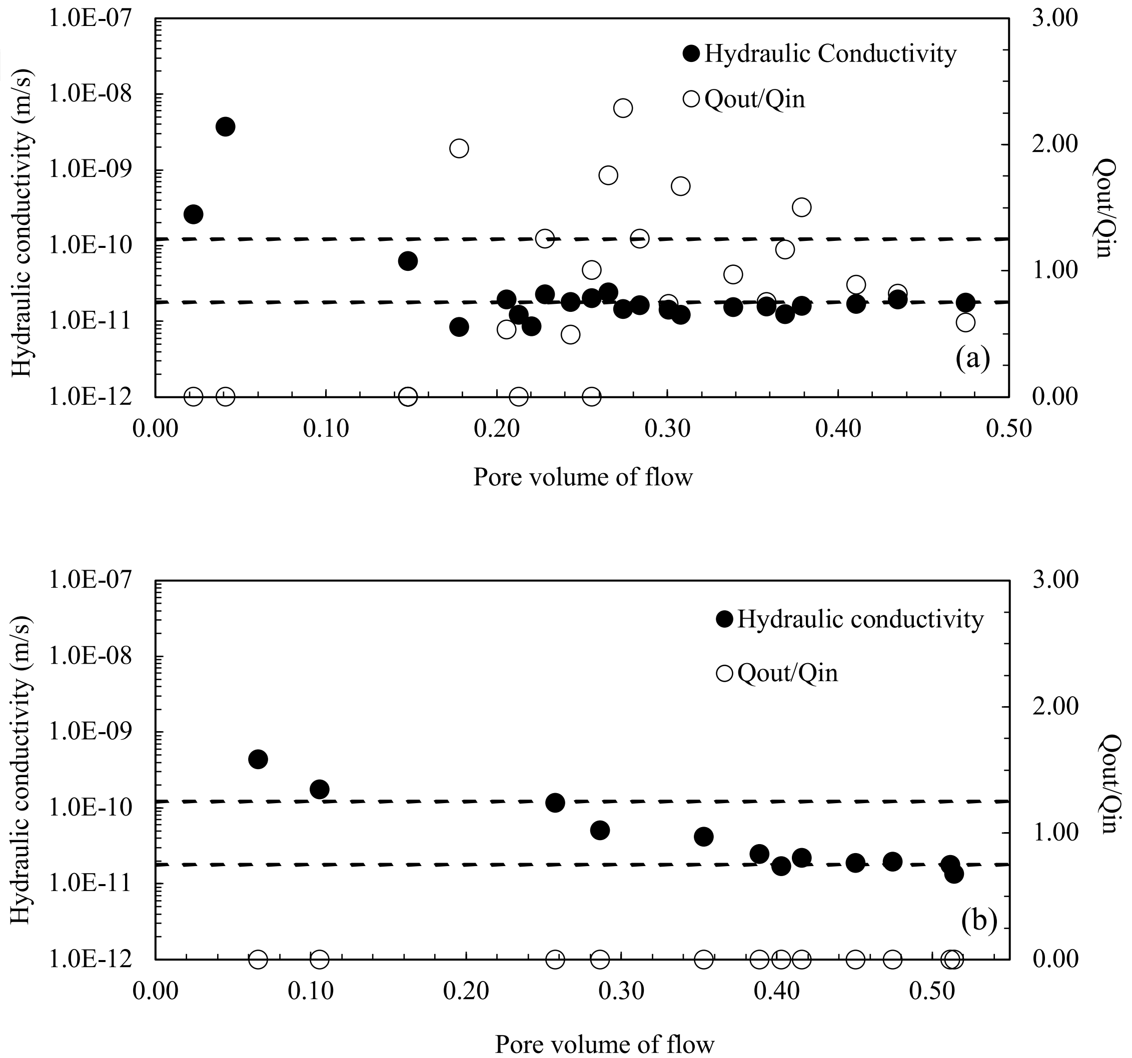


Figure 3.53 Hydraulic conductivity-PVF graphs of sand-bentonite mixtures at room temperature a)10B-90S b)20B-80S

3.3.2 Hydraulic Conductivity Test Result of Tincal at Room Temperature

Figure 3.55 shows the hydraulic conductivity test result of tincal. In addition, outflow to inflow (Q_{out}/Q_{in}) ratios are given in this figure.

As shown in Figure 3.55, the hydraulic conductivity value of tincal was determined as 7.1×10^{-12} m/s. This value is significantly lower than the additive-free sand-bentonite mixtures. The Q_{out}/Q_{in} ratios were not yet in the range of 0.75 and 1.25. Although this test started on 17.10.2018, 0.13 PVFs had passed through the sample.

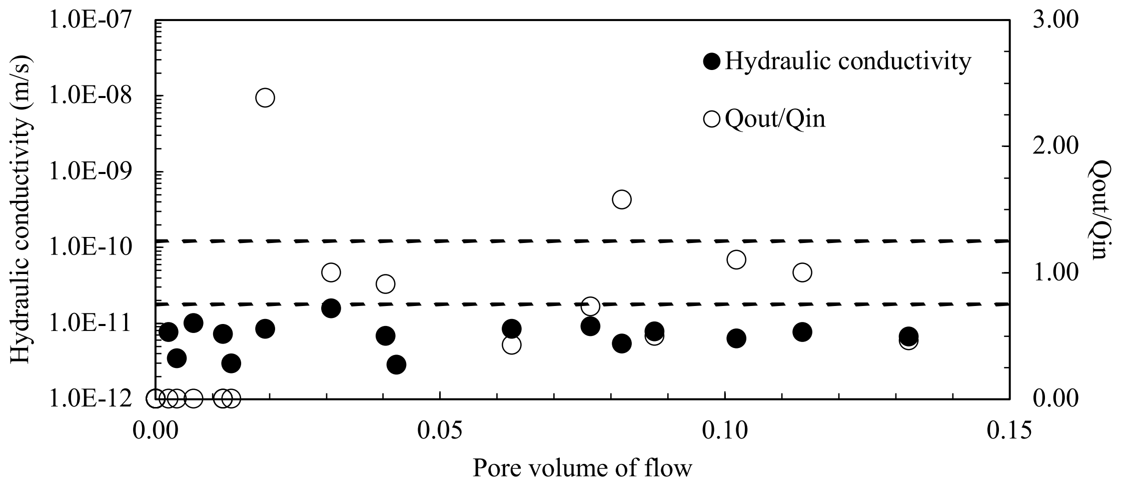
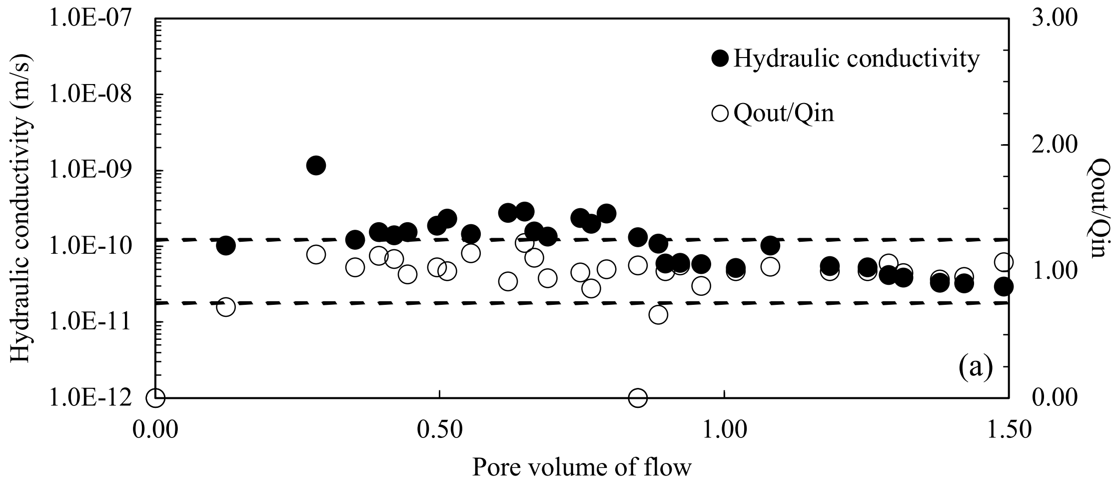
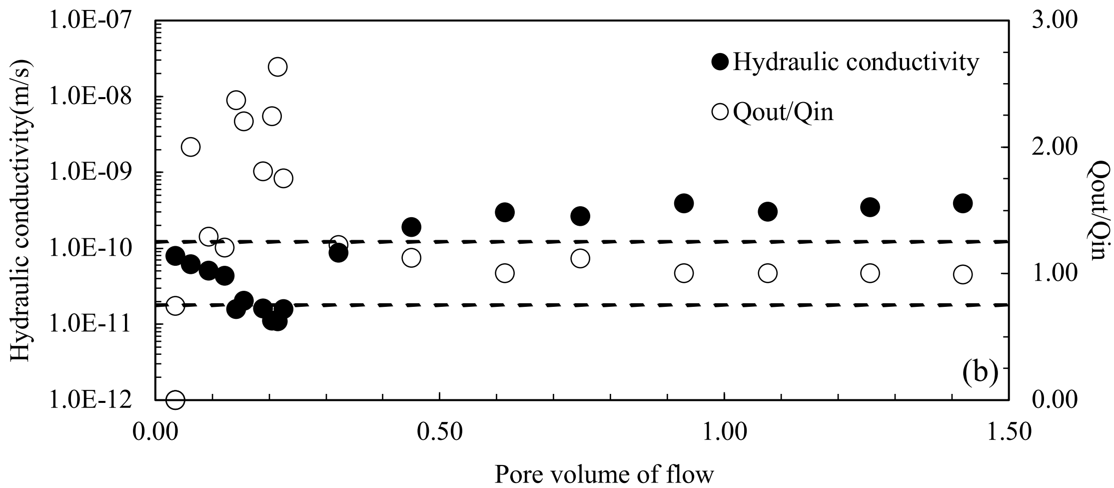


Figure 3.54 Hydraulic conductivity-PVF graphs of tincal at room temperature

3.3.3 The Effect of Boron Mineral (Tincal) on the Hydraulic Conductivity Behavior of Sand-Bentonite Mixtures at Room Temperature

The hydraulic conductivity of 9B-81S-10T, 8.5B-76.5S-15T, 8B-72S-20T and 18B-72S-10T, 17B-68S-15T, 16B-64S-20T mixtures at room temperature are shown in Figures 3.56(a, b, c) and Figures 3.57(a, b, c), respectively.





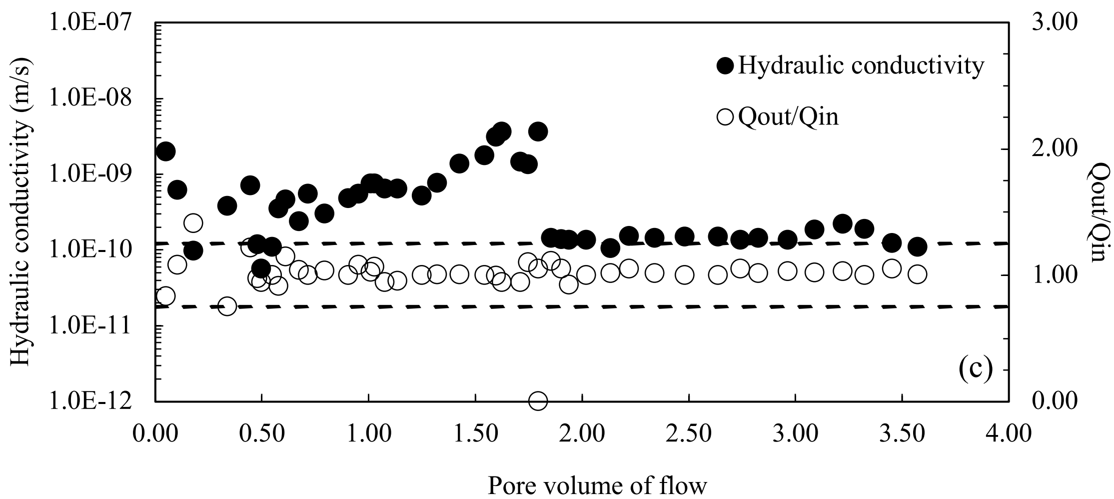


Figure 3.55 Hydraulic conductivity-PVF graphs of a) 9B-81S-10T, b)8.5B-76.5S-15T, c) 8B-72S-20T mixtures at room temperature

The hydraulic conductivity of the 9B-81S-10T mixture was $3.4x10^{-11}$ m/s, which was determined from Figure 3.56a. The Q_{out}/Q_{in} ratios were between 0.75 and 1.25. Approximately 1.50 PVFs passed through the sample. According to the Figure 3.56b, the hydraulic conductivity value of 8.5B-76.5S-15T mixture was $3.5x10^{-10}$ m/s. The Q_{out}/Q_{in} ratios were between 0.75 and 1.25. In addition, 1.50 PVF passed through this compacted sample. Figure 3.56c gives the hydraulic conductivity value of 8B-72S-20T mixture, which was the last 10% bentonite mixture in the presence of tincal, as $1.6x10^{-10}$ m/s. Although the Q_{out}/Q_{in} ratios were in the range of 0.75-1.25, after approximately 1.8 PVFs passed through the sample, the hydraulic conductivity (k) value began to decrease from $3.6x10^{-9}$ m/s. A total of 3.5 PVFs passed through the sample.

As can be seen in Figure 3.57 a hydraulic conductivity value of 18B-72S-10T mixture was obtained as $1.4x10^{-11}$ m/s. This value was about 2.5 times less than the hydraulic value of the 10% bentonite mixture in the presence of 10% tincal. The Q_{out}/Q_{in} ratios have not yet settled between 0.75 and 1.25. Approximately 0.40 PVFs passed through the sample. According to the data obtained from Figure 3.57b, the hydraulic conductivity value of 17B-68S-15T mixture was determined $2.2x10^{-11}$ m/s. This hydraulic conductivity value was approximately 16 times less than the hydraulic conductivity value of 10% sand-bentonite mixture in the presence of the same amount tincal. The Q_{out}/Q_{in} ratios have not entered a pattern. Approximately 0.60 PVFs passed through this compacted test sample. The hydraulic conductivity value of the 16B-64S-20T mixture, which was the third of the 20% bentonite mixtures in the presence of tincal, was obtained from Figure 3.57 c as $1.1x10^{-11}$ m/s. This value was approximately 15 times less than the k value of 10% sand-bentonite mixture containing 20% tincal. The Q_{out}/Q_{in} ratios did not continue regularly. About 0.4 PVFs passed through the sample. In general, permeability was lower in 20% sand-bentonite mixtures compared to 10% sand-bentonite mixtures. Therefore, the tests were progressing more slowly and have not terminated yet.

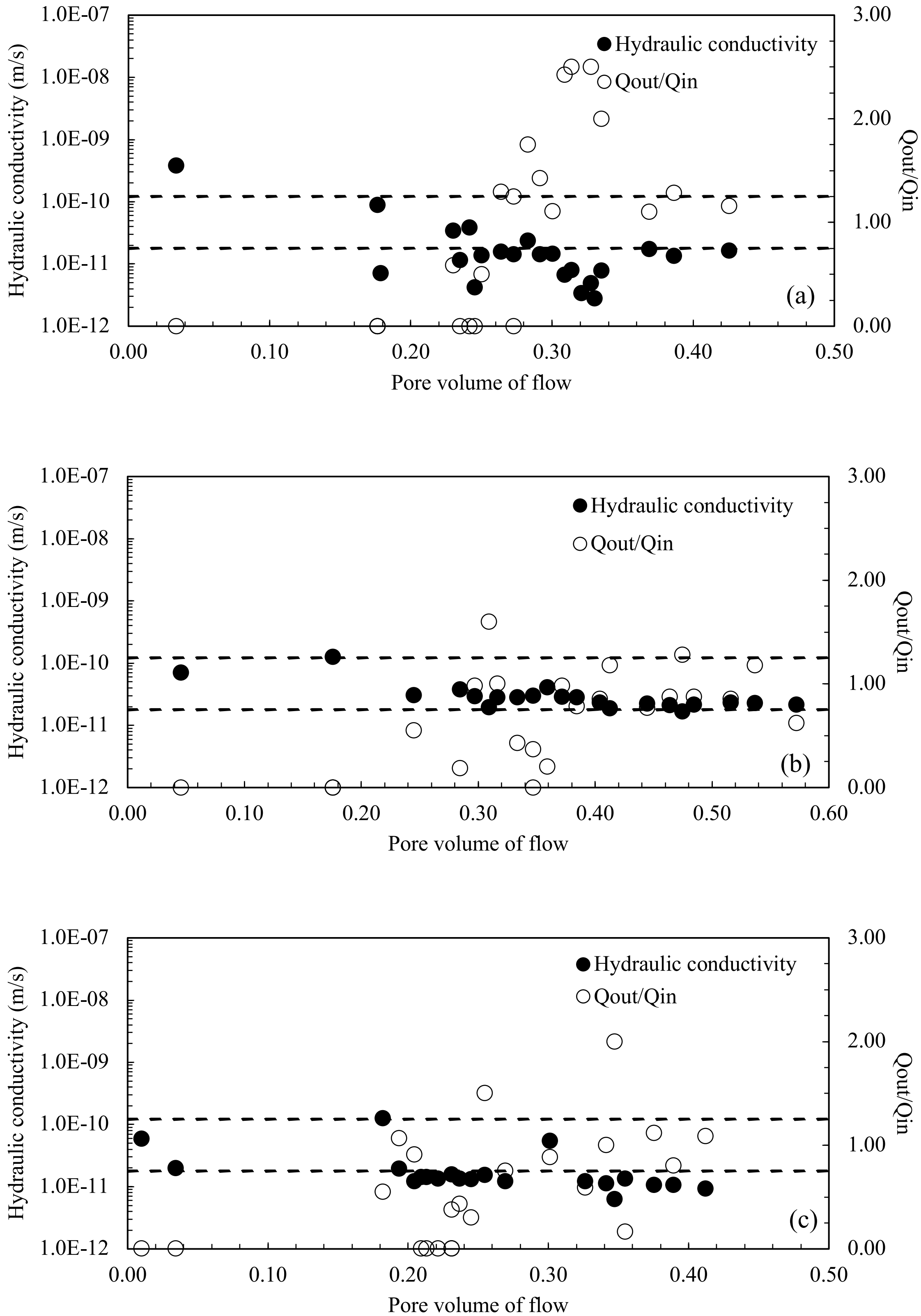


Figure 3.56 Hydraulic conductivity-PVF graphs of a)18B-72S-10T, b)17B-68S-15T, c)16B-64S-20T mixtures at room temperature

Table 3.3 presents the k values sand-bentonite mixtures in the presence of tincal at room temperature.

Table 3.3 Hydraulic conductivity values of sand-bentonite mixtures in the presence of tincal

Group	Sample	k (m/s)
	100T	$7.1x10^{-12}$
	10B-90S	$1.7x10^{-11}$
10 % Bentonite	9B-81S-10T	$3.4x10^{-11}$
	8.5B-76.5S-15T	$3.5x10^{-10}$
	8B-72S-20T	$1.6x10^{-10}$
	20B-80S	$1.7x10^{-11}$
20 % Bentonite	18B-72S-10T	$1.4x10^{-11}$
	17B-68S-15T	$2.2x10^{-11}$
	16B-64S-20T	$1.1x10^{-11}$

3.3.4 Influence of Boron (Tincal) Percentage on the Hydraulic Conductivity Behavior of Sand-Bentonite Mixtures

According to Figure 3.58a, 10% tincal was added to 10B-90S mixture and hydraulic conductivity increased two times and reached $3.4x10^{-11}$ m/s. By increasing the tincal content from 10 to 15%, the hydraulic conductivity value increased by ten times to $3.5x10^{-10}$ m/s. Increasing the tincal percentage from 15% to 20% had an inverse effect on the hydraulic conductivity and reduced it by more than half to $1.6x10^{-10}$ m/s. According to these results, hydraulic conductivity value of 10% sand-bentonite mixtures increased with tincal addition. It should be noted that 20% tincal additive increased the hydraulic conductivity value less than 15% tincal additive.

As shown in Figure 3.58b, the hydraulic conductivity value did not show a significant change with 10% tincal addition to 20% sand-bentonite mixtures. By increasing the tincal percentage from 10% to 15%, the hydraulic conductivity value increased by 1.5 times (from $1.4x10^{-11}$ to $2.2x10^{-11}$). When tincal percentage was increased from 15% to 20%, tincal showed the opposite effect on hydraulic conductivity just like 10% sand-bentonite mixtures and the hydraulic conductivity decreased to 1.1×10^{-11} m/s. There was no effect of the tincal additive on the hydraulic conductivity values of 20% sand-bentonite mixtures as much as 10% sand-bentonite mixtures. Even though the tincal additive generally increased the hydraulic conductivity value, 20% tincal additive reduced the hydraulic conductivity of 20% sand-bentonite mixtures.

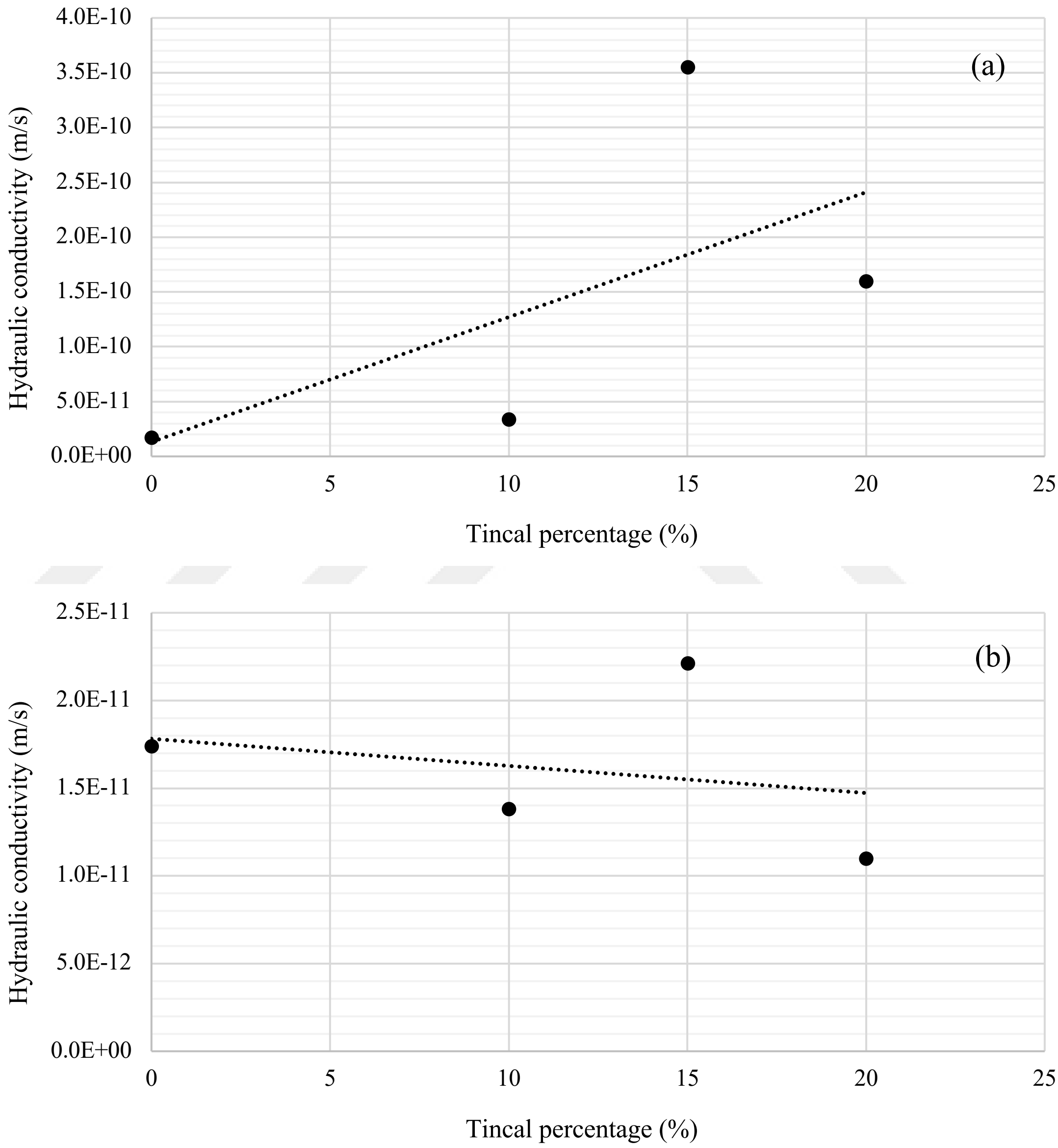


Figure 3.57 Hydraulic conductivity-tincal percentage graphs of mixtures a) 10% bentonite, b) 20% bentonite

Tincal contains Na (sodium) ions in its structure. It was expected that when sand-bentonite mixture was mixed with tincal mineral, Na^+ ions is expected to adsorb by bentonite. When the Na^+ ions are adsorbed by bentonite, the diffuse double layer thickness of bentonite particles increases, hence the hydraulic conductivity of bentonite decreases. The tests have not been terminated yet. However, the reason of such kind of behavior may be related with material replacement. The bentonite which has very high swelling potential replaces with tincal additive. For that reason, the hydraulic conductivity increases in the presence of tincal.

CHAPTER FOUR
CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Thermally resistant soils are needed around the energy structures. In order to increase thermal resistivity of soils, boron minerals may be used because of their widely usage in heat resistant materials production. In the content of this thesis, the compaction behavior of 10% and 20% sand-bentonite mixtures were investigated in the presence of boron minerals (i.e. colemanite, tincal, ulexite) at room temperature. The shear strength and hydraulic conductivity behaviors of these mixtures were examined in the presence of boron minerals at room temperature and high temperature (80°C). The summary of the compaction tests results is given below:

- For the boron minerals, tincal had the lowest maximum dry unit weight value, whereas colemanite had the highest value. On the contrary, in terms of optimum water content, tincal had the highest value, while colemanite had the lowest value. Ulexite was located between tincal and colemanite in terms of both compaction parameters.

- The colemanite addition increased $\gamma_{d,max}$ and decreased w_{opt} in 10% sand-bentonite mixtures. For the 20% sand-bentonite mixtures, though the 10% colemanite additive increased the $\gamma_{d,max}$ value and decreased the w_{opt} value, the $\gamma_{d,max}$ value did not change and the w_{opt} values increased in the other colemanite percentages.

- Tincal additive caused a decrease in $\gamma_{d,max}$ value and an increase in w_{opt} value in both 10% and 20% sand-bentonite mixtures. As the tincal percentage was increased, decrease amount in $\gamma_{d,max}$ value and increase amount in w_{opt} value also increased.

- The ulexite addition led to an increase in $\gamma_{d,max}$ value and a decrease in w_{opt} value in 10% sand-bentonite mixtures. For the 20% sand-bentonite mixtures, the ulexite additive generally decreased the $\gamma_{d,max}$ value. Ulexite additive had no significant effect on the w_{opt} value of 20% sand-bentonite mixtures.

- The boron additive, which increased the $\gamma_{d,max}$ value at most was 15% colemanite for 10% sand-bentonite mixtures. In the presence of 20% tincal, $\gamma_{d,max}$ value was obtained at the lowest value and w_{opt} was the highest value in both 10% and 20% sand-bentonite mixtures. In addition, in 20% sand-bentonite mixture in the presence of 10% colemanite, $\gamma_{d,max}$ was the highest value and w_{opt} was the lowest value.

The summary of the direct shear tests results is given below:

- Among the boron minerals, colemanite had the highest Ø′ value with 27.8° at room temperature. The highest Ø′ value was obtained with ulexite mineral at 80°C.

- Colemanite achieved the highest maximum shear stress value at room temperature, while ulexite has the lowest value. However, reversely ulexite had the highest shear stress value under 80°C. There was no significant difference in terms of maximum shear stress behavior of colemanite at 80°C when compared with room temperature.

- Although the Ø′ value of the 10B-90S mixture showed an insignificant change in increasing temperature, the Ø′ value of 20B-80S decreased by half. In addition, the τ values of both mixtures decreased when the temperature was increased.

- The decrease in shear strength parameters for additive-free mixtures was gained back much more in the presence of boron minerals under high temperature.

- By adding boron minerals to 10% bentonite mixtures at room temperature, Ø′ values generally decreased. In this group, the c′ values increased only in the presence of ulexite at room temperature. In the 20% sand-bentonite mixture with at room temperature, Ø′ value increased in the presence of colemanite and tincal. The c′ values in 20% sand-bentonite mixtures were generally decreased in the presence of boron minerals at room temperature.

- The only boron mineral that increased the c′ value of 10% sand-bentonite mixtures at 80°C was ulexite. For 20% sand-bentonite mixtures, decreased c′ value in the presence of all boron minerals at 80°C.

- The τ_{max} were generally reduced in the presence of boron minerals at room temperature. At 80°C, when boron mineral was added to additive-free mixtures, τ_{max} increased. In addition, in the presence of colemanite, tincal and ulexite, the τ_{max} of the mixtures generally increased as the temperature increased.

- The general results have shown that in the presence of boron minerals, the shear strength of the sand-bentonite mixtures increases with rising temperature. It can be concluded that the addition of boron minerals increases the thermal resistance of sand-bentonite mixtures.

- In the field applications both boron minerals can be used in order to increase shear strength of sand-bentonite mixtures; however, the effect of 10% tincal can be more pronounced.

The summary of the hydraulic conductivity tests results is given below:

- The hydraulic conductivity value of 10B-90S mixture was 1.7×10^{-11} m/s. The hydraulic conductivity of boron mineral (tincal) used in the experiments was 7.1×10^{-12} m/s.

- For 10% sand-bentonite mixtures, tincal additive increased the hydraulic conductivity values. The additive 15% tincal increased the hydraulic conductivity value approximately 20 times (3.5×10^{-10} m/s).

- There was no effect of the tincal additive on the hydraulic conductivity values of 20% sand-bentonite mixtures as much as 10% sand-bentonite mixtures. Even though the tincal additive generally increased the hydraulic conductivity value,10% and 20% tincal additive reduced the hydraulic conductivity of 20% sand-bentonite mixtures slightly.

4.2 Recommendations for Future Research

In this thesis, the shear strength and hydraulic conductivity behaviors of sand-bentonite mixtures in the presence of boron minerals were investigated. According to results of this study, it was seen that the boron minerals have very effective on the increase in thermal resistivity of soils in terms of engineering properties. Based on the thesis, the following recommendations for future research are suggested:

- The compressibility behavior of soils under high temperature is very important. Therefore, the compressibility behavior of boron added mixtures used in this study should be examined both under room and high temperatures and also in the presence of thermal cycles.

- Furthermore, in future studies, especially for mixtures in the presence of tincal, hydraulic conductivity tests should be completed under high temperature and thermal cycles.

- Direct shear tests should also be performed in the presence of thermal cycles. In addition, by reducing the shear rate, long-term (24-48 hours) tests should be performed under room temperature and high temperature and compared with the results obtained from the direct shear tests completed in this study.

- In this study, for all thermal experiments, the temperature of soil was raised abruptly. However, the gradual increase in temperature may vary in the soil behavior. The thermal tests should also be repeated by applying a gradual increase in temperature and compared with the results obtained from the experiments performed by instantaneous heating.

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APPENDICES

APPENDIX A- THE DIRECT SHEAR TEST RESULTS

Table A-1 The direct shear test result of 10B-90S mixture at room temperature

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m^3 :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	16	40	63.5	9.24	14.23	19.11	0.26	0.40	0.53	0.42
20	0.05	35.70	19	50	85	9.87	16.31	23.58	0.28	0.46	0.66	0.85
30	0.08	35.54	24	48	100	10.91	15.89	26.70	0.31	0.45	0.75	1.27
40	0.10	35.39	24	44	113	10.91	15.06	29.40	0.31	0.43	0.83	1.69
50	0.13	35.24	24	44	120	10.91	15.06	30.86	0.31	0.43	0.88	2.12
60	0.15	35.09	30	55	128	12.15	17.35	32.52	0.35	0.49	0.93	2.54
70	0.18	34.93	35	65	136	13.19	19.43	34.18	0.38	0.56	0.98	2.96
80	0.20	34.78	42	73.5	144	14.65	21.19	35.84	0.42	0.61	1.03	3.39
90	0.23	34.63	45.5	81.5	133	15.37	22.86	33.56	0.44	0.66	0.97	3.81
100	0.25	34.48	49.5	87	118	16.21	24.00	30.44	0.47	0.70	0.88	4.23
110	0.28	34.32	52.5	94	115	16.83	25.45	29.82	0.49	0.74	0.87	4.66
120	0.30	34.17	56	99	150	17.56	26.49	37.09	0.51	0.78	1.09	5.08
130	0.33	34.02	57.5	104	160	17.87	27.53	39.17	0.53	0.81	1.15	5.50
140	0.36	33.87	60.5	109.8	167	18.49	28.74	40.62	0.55	0.85	1.20	5.93
150	0.38	33.71	63	114	174	19.01	29.61	42.08	0.56	0.88	1.25	6.35
160	0.41	33.56	66	118	180	19.63	30.44	43.32	0.59	0.91	1.29	6.77
170	0.43	33.41	68.8	122.5	185	20.22	31.38	44.36	0.61	0.94	1.33	7.20
180	0.46	33.26	72	126	191	20.88	32.10	45.61	0.63	0.97	1.37	7.62
190	0.48	33.10	73.2	129	195.5	21.13	32.73	46.54	0.64	0.99	1.41	8.04
200	0.51	32.95	75	133	200	21.50	33.56	47.48	0.65	1.02	1.44	8.47
210	0.53	32.80	78	135	206	22.13	33.97	48.73	0.67	1.04	1.49	8.89
220	0.56	32.65	78.5	137	212	22.23	34.39	49.97	0.68	1.05	1.53	9.31
230	0.58	32.49	81	140	217	22.75	35.01	51.01	0.70	1.08	1.57	9.74
240	0.61	32.34	83.5	143	221	23.27	35.63	51.84	0.72	1.10	1.60	10.16
250	0.64	32.19	85.5	146	224	23.69	36.26	52.47	0.74	1.13	1.63	10.58
260	0.66	32.04	87.5	147	227	24.10	36.47	53.09	0.75	1.14	1.66	11.01
270	0.69	31.89	89	149.5	229	24.41	36.99	53.51	0.77	1.16	1.68	11.43
280	0.71	31.73	91.2	151	234	24.87	37.30	54.54	0.78	1.18	1.72	11.85
290	0.74	31.58	93	153.5	237	25.24	37.82	55.17	0.80	1.20	1.75	12.28
300	0.76	31.43	94	155.2	238.5	25.45	38.17	55.48	0.81	1.21	1.77	12.70
310	0.79	31.28	95	156.5	246	25.66	38.44	57.04	0.82	1.23	1.82	13.12
320	0.81	31.12	97	157.2	249	26.08	38.59	57.66	0.84	1.24	1.85	13.55
330	0.84	30.97	98.2	157.8	254	26.33	38.71	58.70	0.85	1.25	1.90	13.97
340	0.86	30.82	100	158	256	26.70	38.75	59.12	0.87	1.26	1.92	14.39
350	0.89	30.67	101.5	159	258.5	27.01	38.96	59.64	0.88	1.27	1.94	14.82
360	0.91	30.51	102.2	159.8	261.5	27.16	39.13	60.26	0.89	1.28	1.97	15.24
370	0.94	30.36	103	160	262.8	27.32	39.17	60.53	0.90	1.29	1.99	15.66
380	0.97	30.21	103.5	160	264.5	27.43	39.17	60.88	0.91	1.30	2.02	16.09
390	0.99	30.06	103.9	160.2	265.5	27.51	39.21	61.09	0.92	1.30	2.03	16.51
400	1.02	29.90	104	160.2	266.5	27.53	39.21	61.30	0.92	1.31	2.05	16.93
410	1.04	29.75	104.2	160.2	267.5	27.57	39.21	61.51	0.93	1.32	2.07	17.36
420	1.07	29.60	104.5	160.2	268	27.63	39.21	61.61	0.93	1.32	2.08	17.78
430	1.09	29.45	105	160.2	270.0	27.74	39.21	62.03	0.94	1.33	2.11	18.20
440	1.12	29.29	105.2	160.2	271.2	27.78	39.21	62.27	0.95	1.34	2.13	18.63
450	1.14	29.14	105		272.5	27.74		62.55	0.95		2.15	19.05
460	1.17	28.99	104		273.0	27.53		62.65	0.95		2.16	19.47
470	1.19	28.84	103		273.8	27.32		62.82	0.95		2.18	19.90
480	1.22	28.68	103		273.8	27.32		62.82	0.95		2.19	20.32
490	1.24	28.53	101.8		274.0	27.07		62.86	0.95		2.20	20.74
500	1.27	28.38	101.5		274.5	27.01		62.96	0.95		2.22	21.17
510	1.30	28.23	101			26.91			0.95			21.59
520	1.32	28.08	99			26.49			0.94			22.01

Table A-2 The direct shear test result of 10B-90S mixture at 80°C

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m³ :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm²	-	-	-	kg	kg	kg	kg/cm²	kg/cm²	kg/cm²	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	17	43.5	70	9.45	14.96	20.47	0.26	0.42	0.57	0.42
20	0.05	35.70	26	54	86	11.32	17.14	23.79	0.32	0.48	0.67	0.85
30	0.08	35.54	29.5	60	104.5	12.05	18.39	27.63	0.34	0.52	0.78	1.27
40	0.10	35.39	36	66.2	110.5	13.40	19.68	28.88	0.38	0.56	0.82	1.69
50	0.13	35.24	36	73.5	119	13.40	21.19	30.65	0.38	0.60	0.87	2.12
60	0.15	35.09	38	70	129	13.82	20.47	32.73	0.39	0.58	0.93	2.54
70	0.18	34.93	42	70	124	14.65	20.47	31.69	0.42	0.59	0.91	2.96
80	0.20	34.78	43.5	68	133	14.96	20.05	33.56	0.43	0.58	0.96	3.39
90	0.23	34.63	44	83.5	147	15.06	23.27	36.47	0.43	0.67	1.05	3.81
100	0.25	34.48	47.2	87	150	15.73	24.00	37.09	0.46	0.70	1.08	4.23
110	0.28	34.32	49	89.2	154.8	16.10	24.46	38.09	0.47	0.71	1.11	4.66
120	0.30	34.17	51.5	92	161	16.62	25.04	39.38	0.49	0.73	1.15	5.08
130	0.33	34.02	53.9	95	164	17.12	25.66	40.00	0.50	0.75	1.18	5.50
140	0.36	33.87	55.2	99	170.2	17.39	26.49	41.29	0.51	0.78	1.22	5.93
150	0.38	33.71	58	103	178	17.97	27.32	42.91	0.53	0.81	1.27	6.35
160	0.41	33.56	61	106	184.5	18.60	27.95	44.26	0.55	0.83	1.32	6.77
170	0.43	33.41	63.8	109.8	189.5	19.18	28.74	45.30	0.57	0.86	1.36	7.20
180	0.46	33.26	65	113	194	19.43	29.40	46.23	0.58	0.88	1.39	7.62
190	0.48	33.10	66	118	199	19.63	30.44	47.27	0.59	0.92	1.43	8.04
200	0.51	32.95	68.5	120	204	20.15	30.86	48.31	0.61	0.94	1.47	8.47
210	0.53	32.80	71	122	209	20.67	31.27	49.35	0.63	0.95	1.50	8.89
220	0.56	32.65	73.2	124	213	21.13	31.69	50.18	0.65	0.97	1.54	9.31
230	0.58	32.49	74	126	217.5	21.30	32.10	51.12	0.66	0.99	1.57	9.74
240	0.61	32.34	74.9	130	221.5	21.48	32.93	51.95	0.66	1.02	1.61	10.16
250	0.64	32.19	77.8	132	225	22.09	33.35	52.67	0.69	1.04	1.64	10.58
260	0.66	32.04	78	133	228	22.13	33.56	53.30	0.69	1.05	1.66	11.01
270	0.69	31.89	79.5	134.5	232	22.44	33.87	54.13	0.70	1.06	1.70	11.43
280	0.71	31.73	81.5	135.5	234	22.86	34.08	54.54	0.72	1.07	1.72	11.85
290	0.74	31.58	83.5	137	236.5	23.27	34.39	55.06	0.74	1.09	1.74	12.28
300	0.76	31.43	83.5	138	239	23.27	34.60	55.58	0.74	1.10	1.77	12.70
310	0.79	31.28	84.5	138.2	241.5	23.48	34.64	56.10	0.75	1.11	1.79	13.12
320	0.81	31.12	85.5	138.8	242.5	23.69	34.76	56.31	0.76	1.12	1.81	13.55
330	0.84	30.97	87	140	245	24.00	35.01	56.83	0.77	1.13	1.83	13.97
340	0.86	30.82	88	141	246	24.21	35.22	57.04	0.79	1.14	1.85	14.39
350	0.89	30.67	88.5	142	246.5	24.31	35.43	57.14	0.79	1.16	1.86	14.82
360	0.91	30.51	89.9	142.5	247	24.60	35.53	57.25	0.81	1.16	1.88	15.24
370	0.94	30.36	90	142.5	248	24.62	35.53	57.45	0.81	1.17	1.89	15.66
380	0.97	30.21	91	143.5	248.3	24.83	35.74	57.52	0.82	1.18	1.90	16.09
390	0.99	30.06	92.9	144	249.8	25.22	35.84	57.83	0.84	1.19	1.92	16.51
400	1.02	29.90	93	144	251	25.24	35.84	58.08	0.84	1.20	1.94	16.93
410	1.04	29.75	93	144.2	252	25.24	35.88	58.29	0.85	1.21	1.96	17.36
420	1.07	29.60	93.1	144.9	253	25.27	36.03	58.49	0.85	1.22	1.98	17.78
430	1.09	29.45	93.2	144.9	253.5	25.29	36.03	58.60	0.86	1.22	1.99	18.20
440	1.12	29.29	94	144.9	255.5	25.45	36.03	59.01	0.87	1.23	2.01	18.63
450	1.14	29.14	94	144.9	256.0	25.45	36.03	59.12	0.87	1.24	2.03	19.05
460	1.17	28.99	94	145	256.0	25.45	36.05	59.12	0.88	1.24	2.04	19.47
470	1.19	28.84	94	145.2	256.0	25.45	36.09	59.12	0.88	1.25	2.05	19.90
480	1.22	28.68	94	145.3	256.0	25.45	36.11	59.12	0.89	1.26	2.06	20.32
490	1.24	28.53	93.5	145.5	256.0	25.35	36.15	59.12	0.89	1.27	2.07	20.74
500	1.27	28.38	93.5	145.5	256.0	25.35	36.15	59.12	0.89	1.27	2.08	21.17
510	1.30	28.23	93.5	145.5	256.0	25.35	36.15	59.12	0.90	1.28	2.09	21.59
520	1.32	28.08	93.5	145.5		25.35	36.15		0.90	1.29		22.01
530	1.35	27.92	93.5	145.5		25.35	36.15		0.91	1.29		22.44
540	1.37	27.77	93.5	145.5		25.35	36.15		0.91	1.30		22.86
550	1.40	27.62	93.5	145.5		25.35	36.15		0.92	1.31		23.28
560	1.42	27.47	93.5			25.35			0.92			23.71

Table A-3 The direct shear test result of 20B-80S mixture at room temperature

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m³ :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm²	-	-	-	kg	kg	kg	kg/cm²	kg/cm²	kg/cm²	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	17	34.5	59.5	9.45	13.09	18.28	0.26	0.37	0.51	0.42
20	0.05	35.70	22	41	67	10.49	14.44	19.84	0.29	0.40	0.56	0.85
30	0.08	35.54	26.5	42	72	11.43	14.65	20.88	0.32	0.41	0.59	1.27
40	0.10	35.39	29	42	78	11.95	14.65	22.13	0.34	0.41	0.63	1.69
50	0.13	35.24	33	49.5	80	12.78	16.21	22.54	0.36	0.46	0.64	2.12
60	0.15	35.09	34	54	84	12.98	17.14	23.37	0.37	0.49	0.67	2.54
70	0.18	34.93	36.5	57	92.2	13.50	17.76	25.08	0.39	0.51	0.72	2.96
80	0.20	34.78	36.5	59	94	13.50	18.18	25.45	0.39	0.52	0.73	3.39
90	0.23	34.63	37.5	61.5	95	13.71	18.70	25.66	0.40	0.54	0.74	3.81
100	0.25	34.48	40.5	64	96.5	14.34	19.22	25.97	0.42	0.56	0.75	4.23
110	0.28	34.32	42.2	66	99	14.69	19.63	26.49	0.43	0.57	0.77	4.66
120	0.30	34.17	44.1	70	100	15.08	20.47	26.70	0.44	0.60	0.78	5.08
130	0.33	34.02	46.2	73	102	15.52	21.09	27.12	0.46	0.62	0.80	5.50
140	0.36	33.87	48	75	103	15.89	21.50	27.32	0.47	0.63	0.81	5.93
150	0.38	33.71	50	75.8	104	16.31	21.67	27.53	0.48	0.64	0.82	6.35
160	0.41	33.56	51.5	77.5	105	16.62	22.02	27.74	0.50	0.66	0.83	6.77
170	0.43	33.41	53	78.5	107	16.93	22.23	28.15	0.51	0.67	0.84	7.20
180	0.46	33.26	54.5	80	105.5	17.24	22.54	27.84	0.52	0.68	0.84	7.62
190	0.48	33.10	55	82	104	17.35	22.96	27.53	0.52	0.69	0.83	8.04
200	0.51	32.95	56.5	83	105.5	17.66	23.17	27.84	0.54	0.70	0.84	8.47
210	0.53	32.80	58	84	110	17.97	23.37	28.78	0.55	0.71	0.88	8.89
220	0.56	32.65	59	85	112	18.18	23.58	29.19	0.56	0.72	0.89	9.31
230	0.58	32.49	59	85.5	112.5	18.18	23.69	29.30	0.56	0.73	0.90	9.74
240	0.61	32.34	60	86.5	113	18.39	23.89	29.40	0.57	0.74	0.91	10.16
250	0.64	32.19	61	87.5	113.5	18.60	24.10	29.50	0.58	0.75	0.92	10.58
260	0.66	32.04	62	90	114	18.80	24.62	29.61	0.59	0.77	0.92	11.01
270	0.69	31.89	62.5	91.5	114.5	18.91	24.93	29.71	0.59	0.78	0.93	11.43
280	0.71	31.73	63	92.2	115	19.01	25.08	29.82	0.60	0.79	0.94	11.85
290	0.74	31.58	63.8	92.5	115.2	19.18	25.14	29.86	0.61	0.80	0.95	12.28
300	0.76	31.43	64.8	92.5	116	19.38	25.14	30.02	0.62	0.80	0.96	12.70
310	0.79	31.28	65.5	93.2	116.5	19.53	25.29	30.13	0.62	0.81	0.96	13.12
320	0.81	31.12	66	94	117	19.63	25.45	30.23	0.63	0.82	0.97	13.55
330	0.84	30.97	67	94.8	118	19.84	25.62	30.44	0.64	0.83	0.98	13.97
340	0.86	30.82	67	95	118.5	19.84	25.66	30.54	0.64	0.83	0.99	14.39
350	0.89	30.67	67	95.8	119	19.84	25.83	30.65	0.65	0.84	1.00	14.82
360	0.91	30.51	67.2	96	119.2	19.88	25.87	30.69	0.65	0.85	1.01	15.24
370	0.94	30.36	67.5	97	119.9	19.95	26.08	30.83	0.66	0.86	1.02	15.66
380	0.97	30.21	67.8	97.5	121.9	20.01	26.18	31.25	0.66	0.87	1.03	16.09
390	0.99	30.06	68.5	98.5	122.2	20.15	26.39	31.31	0.67	0.88	1.04	16.51
400	1.02	29.90	69	98.8	123.5	20.26	26.45	31.58	0.68	0.88	1.06	16.93
410	1.04	29.75	69.5	99.5	124	20.36	26.60	31.69	0.68	0.89	1.07	17.36
420	1.07	29.60	70	100	124.2	20.47	26.70	31.73	0.69	0.90	1.07	17.78
430	1.09	29.45	70.5	100.8	124.5	20.57	26.87	31.79	0.70	0.91	1.08	18.20
440	1.12	29.29	70.5	101	125.0	20.57	26.91	31.89	0.70	0.92	1.09	18.63
450	1.14	29.14	70.5	101.5	126.0	20.57	27.01	32.10	0.71	0.93	1.10	19.05
460	1.17	28.99	71	102	126.0	20.67	27.12	32.10	0.71	0.94	1.11	19.47
470	1.19	28.84	71	102	126.2	20.67	27.12	32.14	0.72	0.94	1.11	19.90
480	1.22	28.68	71	102.5	126.5	20.67	27.22	32.21	0.72	0.95	1.12	20.32
490	1.24	28.53	71	102.2	127.0	20.67	27.16	32.31	0.72	0.95	1.13	20.74
500	1.27	28.38	71.8	102.5	127.0	20.84	27.22	32.31	0.73	0.96	1.14	21.17
510	1.30	28.23	71.8	102.8	127.2	20.84	27.28	32.35	0.74	0.97	1.15	21.59
520	1.32	28.08	72	102.5	127.5	20.88	27.22	32.41	0.74	0.97	1.15	22.01
530	1.35	27.92	72	102.8	128.5	20.88	27.28	32.62	0.75	0.98	1.17	22.44
540	1.37	27.77	72	102.2	128.5	20.88	27.16	32.62	0.75	0.98	1.17	22.86
550	1.40	27.62	72.2	102.2	129.0	20.92	27.16	32.73	0.76	0.98	1.18	23.28
560	1.42	27.47	72.5	102.5	129.8	20.99	27.22	32.89	0.76	0.99	1.20	23.71
570	1.45	27.31	72.5	103	130.0	20.99	27.32	32.93	0.77	1.00	1.21	24.13
580	1.47	27.16	72.5	103	130.5	20.99	27.32	33.04	0.77	1.01	1.22	24.55
590	1.50	27.01	72.5	104	131.9	20.99	27.53	33.33	0.78	1.02	1.23	24.98
600	1.52	26.86	72.5	104	132.0	20.99	27.53	33.35	0.78	1.03	1.24	25.40
610	1.55	26.70	72.2	104.8	132.5	20.92	27.70	33.45	0.78	1.04	1.25	25.82
620	1.57	26.55	72.2	105.2	132.5	20.92	27.78	33.45	0.79	1.05	1.26	26.25
630	1.60	26.40	72.2	106	132.8	20.92	27.95	33.52	0.79	1.06	1.27	26.67
640	1.63	26.25	72.2	106	133.0	20.92	27.95	33.56	0.80	1.06	1.28	27.09
650	1.65	26.09	72.2	106	133.0	20.92	27.95	33.56	0.80	1.07	1.29	27.52
660	1.68	25.94	72.2	106	133.0	20.92	27.95	33.56	0.81	1.08	1.29	27.94
670	1.70	25.79	72.2	106	133.5	20.92	27.95	33.66	0.81	1.08	1.31	28.36
680	1.73	25.64			133.5			33.66			1.31	28.79
690	1.75	25.48			133.5			33.66			1.32	29.21

Table A-4 The direct shear test result of 20B-80S mixture at 80°C

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :* 6X6X2
Örnek Ağırlığı	*(sample weight) gr :*
Doğal b.h.a	*(natural unit weight) t/m^3 :*
Yükleme Hızı	*(loading rate) mm/dak :* 0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması Local Dial Reading			Yatay Kesme Kuvveti Horizantal Shear Force			Kayma Gerilmesi Shear Stress			Birim Def. Strain
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	23	46.5	49	10.70	15.58	16.10	0.30	0.43	0.45	0.42
20	0.05	35.70	27.5	56.5	68	11.63	17.66	20.05	0.33	0.49	0.56	0.85
30	0.08	35.54	32	60	87	12.57	18.39	24.00	0.35	0.52	0.68	1.27
40	0.10	35.39	36.5	64	91	13.50	19.22	24.83	0.38	0.54	0.70	1.69
50	0.13	35.24	35	66	94.5	13.19	19.63	25.56	0.37	0.56	0.73	2.12
60	0.15	35.09	38	68.8	95	13.82	20.22	25.66	0.39	0.58	0.73	2.54
70	0.18	34.93	43.5	69.5	94	14.96	20.36	25.45	0.43	0.58	0.73	2.96
80	0.20	34.78	47	70	92.8	15.69	20.47	25.20	0.45	0.59	0.72	3.39
90	0.23	34.63	49	71	92.5	16.10	20.67	25.14	0.46	0.60	0.73	3.81
100	0.25	34.48	50	73.2	93	16.31	21.13	25.24	0.47	0.61	0.73	4.23
110	0.28	34.32	53	69	96.5	16.93	20.26	25.97	0.49	0.59	0.76	4.66
120	0.30	34.17	50.5	72	98	16.41	20.88	26.28	0.48	0.61	0.77	5.08
130	0.33	34.02	51.5	76	100	16.62	21.71	26.70	0.49	0.64	0.78	5.50
140	0.36	33.87	52.8	78.5	103.5	16.89	22.23	27.43	0.50	0.66	0.81	5.93
150	0.38	33.71	54	79.5	104	17.14	22.44	27.53	0.51	0.67	0.82	6.35
160	0.41	33.56	55.5	80	106	17.45	22.54	27.95	0.52	0.67	0.83	6.77
170	0.43	33.41	56	81	107	17.56	22.75	28.15	0.53	0.68	0.84	7.20
180	0.46	33.26	57	82	107	17.76	22.96	28.15	0.53	0.69	0.85	7.62
190	0.48	33.10	58.5	83	107.9	18.08	23.17	28.34	0.55	0.70	0.86	8.04
200	0.51	32.95	59	84	108	18.18	23.37	28.36	0.55	0.71	0.86	8.47
210	0.53	32.80	60.2	85.5	108.5	18.43	23.69	28.47	0.56	0.72	0.87	8.89
220	0.56	32.65	61	86.5	109.2	18.60	23.89	28.61	0.57	0.73	0.88	9.31
230	0.58	32.49	62.2	87	109.5	18.84	24.00	28.67	0.58	0.74	0.88	9.74
240	0.61	32.34	62.3	88	110	18.87	24.21	28.78	0.58	0.75	0.89	10.16
250	0.64	32.19	62.5	89	111	18.91	24.41	28.99	0.59	0.76	0.90	10.58
260	0.66	32.04	62.8	89.5	112.3	18.97	24.52	29.26	0.59	0.77	0.91	11.01
270	0.69	31.89	64	90	112	19.22	24.62	29.19	0.60	0.77	0.92	11.43
280	0.71	31.73	65.2	91.5	113	19.47	24.93	29.40	0.61	0.79	0.93	11.85
290	0.74	31.58	66	92	114.2	19.63	25.04	29.65	0.62	0.79	0.94	12.28
300	0.76	31.43	66.5	92	114.2	19.74	25.04	29.65	0.63	0.80	0.94	12.70
310	0.79	31.28	66.8	92	114.5	19.80	25.04	29.71	0.63	0.80	0.95	13.12
320	0.81	31.12	67.8	92	114.9	20.01	25.04	29.80	0.64	0.80	0.96	13.55
330	0.84	30.97	68	91.5	116.5	20.05	24.93	30.13	0.65	0.81	0.97	13.97
340	0.86	30.82	69.2	91.9	119	20.30	25.02	30.65	0.66	0.81	0.99	14.39
350	0.89	30.67	69.8	91.9	118	20.42	25.02	30.44	0.67	0.82	0.99	14.82
360	0.91	30.51	71	94	119	20.67	25.45	30.65	0.68	0.83	1.00	15.24
370	0.94	30.36	72	96	119	20.88	25.87	30.65	0.69	0.85	1.01	15.66
380	0.97	30.21	72.9	98	117.5	21.07	26.28	30.34	0.70	0.87	1.00	16.09
390	0.99	30.06	74	98.5	121.5	21.30	26.39	31.17	0.71	0.88	1.04	16.51
400	1.02	29.90	75.1	100	122	21.53	26.70	31.27	0.72	0.89	1.05	16.93
410	1.04	29.75	75.3	101	123	21.57	26.91	31.48	0.72	0.90	1.06	17.36
420	1.07	29.60	75.3	102	123	21.57	27.12	31.48	0.73	0.92	1.06	17.78
430	1.09	29.45	75.3	103.5	124.8	21.57	27.43	31.85	0.73	0.93	1.08	18.20
440	1.12	29.29	75.5	104	124	21.61	27.53	31.69	0.74	0.94	1.08	18.63
450	1.14	29.14	75.9	105	124.5	21.69	27.74	31.79	0.74	0.95	1.09	19.05
460	1.17	28.99	76.5	106	125.5	21.82	27.95	32.00	0.75	0.96	1.10	19.47
470	1.19	28.84	77	107	128.0	21.92	28.15	32.52	0.76	0.98	1.13	19.90
480	1.22	28.68	77.5	108	128.0	22.02	28.36	32.52	0.77	0.99	1.13	20.32
490	1.24	28.53	78.5	108.8	128.5	22.23	28.53	32.62	0.78	1.00	1.14	20.74
500	1.27	28.38	79	109.8	130.0	22.34	28.74	32.93	0.79	1.01	1.16	21.17
510	1.30	28.23	79.3	111	128.0	22.40	28.99	32.52	0.79	1.03	1.15	21.59
520	1.32	28.08	80	111.5	127.0	22.54	29.09	32.31	0.80	1.04	1.15	22.01
530	1.35	27.92	81	112.5	126.0	22.75	29.30	32.10	0.81	1.05	1.15	22.44
540	1.37	27.77	82	113	125.5	22.96	29.40	32.00	0.83	1.06	1.15	22.86
550	1.40	27.62	82.9	114	125.0	23.15	29.61	31.89	0.84	1.07	1.15	23.28
560	1.42	27.47	83.2	114.5	124.0	23.21	29.71	31.69	0.85	1.08	1.15	23.71
570	1.45	27.31	83.5	115.2	122.0	23.27	29.86	31.27	0.85	1.09	1.14	24.13
580	1.47	27.16	84	116	124.0	23.37	30.02	31.69	0.86	1.11	1.17	24.55
590	1.50	27.01	85.3	116.5	123.0	23.64	30.13	31.48	0.88	1.12	1.17	24.98
600	1.52	26.86	85.5	117.5	124.0	23.69	30.34	31.69	0.88	1.13	1.18	25.40
610	1.55	26.70	85.8	119	125.0	23.75	30.65	31.89	0.89	1.15	1.19	25.82
620	1.57	26.55	86	119.5	126.0	23.79	30.75	32.10	0.90	1.16	1.21	26.25
630	1.60	26.40	86.5	121	127.3	23.89	31.06	32.37	0.91	1.18	1.23	26.67
640	1.63	26.25	87.5	121	128.5	24.10	31.06	32.62	0.92	1.18	1.24	27.09
650	1.65	26.09	87.5	121.8	125.0	24.10	31.23	31.89	0.92	1.20	1.22	27.52
660	1.68	25.94	88.5	122	127.0	24.31	31.27	32.31	0.94	1.21	1.25	27.94
670	1.70	25.79	88.5	122	128.0	24.31		32.52	0.94		1.26	28.36
680	1.73	25.64	88.5	122		24.31			0.95			28.79
690	1.75	25.48	89	122.3		24.41			0.96			29.21

Table A-5 The direct shear test result of 9B-81S-10C mixture at room temperature

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*	
Sondaj No	*(Boring No) :*	
Örnek No	*(Sample No) :*	
Derinlik	*(Depth) :*	

Yapan	*(Tested By) :*	
Tarih	*(Date) :*	

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m³ :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması			Yatay Kesme Kuvveti			Kayma Gerilmesi			Birim Def.
			Local Dial Reading			*Horizantal Shear Force*			*Shear Stress*			*Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm²	-	-	-	kg	kg	kg	kg/cm²	kg/cm²	kg/cm²	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	21	42	71	10.28	14.65	20.67	0.29	0.41	0.58	0.42
20	0.05	35.70	27	59	90	11.53	18.18	24.62	0.32	0.51	0.69	0.85
30	0.08	35.54	33	67.5	110	12.78	19.95	28.78	0.36	0.56	0.81	1.27
40	0.10	35.39	40.5	76	117	14.34	21.71	30.23	0.41	0.61	0.85	1.69
50	0.13	35.24	44	78	125	15.06	22.13	31.89	0.43	0.63	0.91	2.12
60	0.15	35.09	45.5	80	132	15.37	22.54	33.35	0.44	0.64	0.95	2.54
70	0.18	34.93	47	83	142	15.69	23.17	35.43	0.45	0.66	1.01	2.96
80	0.20	34.78	47.8	85.5	149.5	15.85	23.69	36.99	0.46	0.68	1.06	3.39
90	0.23	34.63	49	87	153.5	16.10	24.00	37.82	0.46	0.69	1.09	3.81
100	0.25	34.48	49.5	92.5	153.5	16.21	25.14	37.82	0.47	0.73	1.10	4.23
110	0.28	34.32	51	92.5	150	16.52	25.14	37.09	0.48	0.73	1.08	4.66
120	0.30	34.17	53	92.5	151.8	16.93	25.14	37.46	0.50	0.74	1.10	5.08
130	0.33	34.02	55.5	91	151	17.45	24.83	37.30	0.51	0.73	1.10	5.50
140	0.36	33.87	58.5	90	151	18.08	24.62	37.30	0.53	0.73	1.10	5.93
150	0.38	33.71	60.5	93	164	18.49	25.24	40.00	0.55	0.75	1.19	6.35
160	0.41	33.56	62.5	99	170	18.91	26.49	41.25	0.56	0.79	1.23	6.77
170	0.43	33.41	64.5	103.5	177	19.32	27.43	42.70	0.58	0.82	1.28	7.20
180	0.46	33.26	67.5	106.5	183	19.95	28.05	43.95	0.60	0.84	1.32	7.62
190	0.48	33.10	69.5	108.5	188	20.36	28.47	44.99	0.62	0.86	1.36	8.04
200	0.51	32.95	72	112.5	193	20.88	29.30	46.02	0.63	0.89	1.40	8.47
210	0.53	32.80	74.5	114.5	197	21.40	29.71	46.86	0.65	0.91	1.43	8.89
220	0.56	32.65	77	116	204	21.92	30.02	48.31	0.67	0.92	1.48	9.31
230	0.58	32.49	79.5	115.5	207	22.44	29.92	48.93	0.69	0.92	1.51	9.74
240	0.61	32.34	80.5	120	209	22.65	30.86	49.35	0.70	0.95	1.53	10.16
250	0.64	32.19	81	121.5	211.5	22.75	31.17	49.87	0.71	0.97	1.55	10.58
260	0.66	32.04	82.5	123	215	23.06	31.48	50.60	0.72	0.98	1.58	11.01
270	0.69	31.89	83	124.5	216	23.17	31.79	50.80	0.73	1.00	1.59	11.43
280	0.71	31.73	84.5	127	217	23.48	32.31	51.01	0.74	1.02	1.61	11.85
290	0.74	31.58	85	129	219	23.58	32.73	51.43	0.75	1.04	1.63	12.28
300	0.76	31.43	87	130.5	222.5	24.00	33.04	52.16	0.76	1.05	1.66	12.70
310	0.79	31.28	88.5	131	224	24.31	33.14	52.47	0.78	1.06	1.68	13.12
320	0.81	31.12	89.5	132.5	225.5	24.52	33.45	52.78	0.79	1.07	1.70	13.55
330	0.84	30.97	90	134	226	24.62	33.76	52.88	0.79	1.09	1.71	13.97
340	0.86	30.82	90.5	136	227	24.73	34.18	53.09	0.80	1.11	1.72	14.39
350	0.89	30.67	91	137	228	24.83	34.39	53.30	0.81	1.12	1.74	14.82
360	0.91	30.51	92	137	229	25.04	34.39	53.51	0.82	1.13	1.75	15.24
370	0.94	30.36	92.5	138.5	230	25.14	34.70	53.71	0.83	1.14	1.77	15.66
380	0.97	30.21	93	140	231	25.24	35.01	53.92	0.84	1.16	1.78	16.09
390	0.99	30.06	93.5	140.5	231	25.35	35.12	53.92	0.84	1.17	1.79	16.51
400	1.02	29.90	93.5	142	233	25.35	35.43	54.34	0.85	1.18	1.82	16.93
410	1.04	29.75	93.5	142.5	234	25.35	35.53	54.54	0.85	1.19	1.83	17.36
420	1.07	29.60	93.5	143.5	237	25.35	35.74	55.17	0.86	1.21	1.86	17.78
430	1.09	29.45		143.5	237		35.74	55.17		1.21	1.87	18.20
440	1.12	29.29		143.5	238		35.74	55.38		1.22	1.89	18.63
450	1.14	29.14		143.5	238		35.74	55.38		1.23	1.90	19.05
460	1.17	28.99			237.5			55.27			1.91	19.47
470	1.19	28.84			237.5			55.27			1.92	19.90

Table A-6 The direct shear test result of 9B-81S-10C mixture at 80°C

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m³ :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm²	-	-	-	kg	kg	kg	kg/cm²	kg/cm²	kg/cm²	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	25	30	82	11.11	12.15	22.96	0.31	0.34	0.64	0.42
20	0.05	35.70	33	58	100	12.78	17.97	26.70	0.36	0.50	0.75	0.85
30	0.08	35.54	36	65	112	13.40	19.43	29.19	0.38	0.55	0.82	1.27
40	0.10	35.39	40	70.5	121	14.23	20.57	31.06	0.40	0.58	0.88	1.69
50	0.13	35.24	42	76.5	134	14.65	21.82	33.76	0.42	0.62	0.96	2.12
60	0.15	35.09	41	78	144	14.44	22.13	35.84	0.41	0.63	1.02	2.54
70	0.18	34.93	41	77.5	150	14.44	22.02	37.09	0.41	0.63	1.06	2.96
80	0.20	34.78	40	78	156.5	14.23	22.13	38.44	0.41	0.64	1.11	3.39
90	0.23	34.63	46	79	161	15.48	22.34	39.38	0.45	0.65	1.14	3.81
100	0.25	34.48	49	85.5	169	16.10	23.69	41.04	0.47	0.69	1.19	4.23
110	0.28	34.32	51	89.5	176	16.52	24.52	42.49	0.48	0.71	1.24	4.66
120	0.30	34.17	53	92.5	184	16.93	25.14	44.15	0.50	0.74	1.29	5.08
130	0.33	34.02	54	94.5	190	17.14	25.56	45.40	0.50	0.75	1.33	5.50
140	0.36	33.87	55.5	98	196.5	17.45	26.28	46.75	0.52	0.78	1.38	5.93
150	0.38	33.71	57	100	203	17.76	26.70	48.10	0.53	0.79	1.43	6.35
160	0.41	33.56	58.5	102.5	208	18.08	27.22	49.14	0.54	0.81	1.46	6.77
170	0.43	33.41	61	106.5	213	18.60	28.05	50.18	0.56	0.84	1.50	7.20
180	0.46	33.26	62	108.5	218	18.80	28.47	51.22	0.57	0.86	1.54	7.62
190	0.48	33.10	63	112	224	19.01	29.19	52.47	0.57	0.88	1.58	8.04
200	0.51	32.95	65	114.5	227.5	19.43	29.71	53.19	0.59	0.90	1.61	8.47
210	0.53	32.80	65.5	115.5	232	19.53	29.92	54.13	0.60	0.91	1.65	8.89
220	0.56	32.65	68	119	234	20.05	30.65	54.54	0.61	0.94	1.67	9.31
230	0.58	32.49	68.5	121	236.5	20.15	31.06	55.06	0.62	0.96	1.69	9.74
240	0.61	32.34	68.5	124.5	240	20.15	31.79	55.79	0.62	0.98	1.73	10.16
250	0.64	32.19	70	125	242	20.47	31.89	56.21	0.64	0.99	1.75	10.58
260	0.66	32.04	71.5	126.5	245	20.78	32.21	56.83	0.65	1.01	1.77	11.01
270	0.69	31.89	72.5	128	246.5	20.99	32.52	57.14	0.66	1.02	1.79	11.43
280	0.71	31.73	73	130	249	21.09	32.93	57.66	0.66	1.04	1.82	11.85
290	0.74	31.58	74	132	251	21.30	33.35	58.08	0.67	1.06	1.84	12.28
300	0.76	31.43	75	133	253	21.50	33.56	58.49	0.68	1.07	1.86	12.70
310	0.79	31.28	75.5	135	254.5	21.61	33.97	58.80	0.69	1.09	1.88	13.12
320	0.81	31.12	76	135	255	21.71	33.97	58.91	0.70	1.09	1.89	13.55
330	0.84	30.97	76.5	136	257	21.82	34.18	59.32	0.70	1.10	1.92	13.97
340	0.86	30.82	76.5	137	258	21.82	34.39	59.53	0.71	1.12	1.93	14.39
350	0.89	30.67	77.5	137.5	259.5	22.02	34.49	59.84	0.72	1.12	1.95	14.82
360	0.91	30.51	77.5	138	260	22.02	34.60	59.95	0.72	1.13	1.96	15.24
370	0.94	30.36	78	139	262.5	22.13	34.80	60.47	0.73	1.15	1.99	15.66
380	0.97	30.21	78	139	263	22.13	34.80	60.57	0.73	1.15	2.01	16.09
390	0.99	30.06	79	139	264	22.34	34.80	60.78	0.74	1.16	2.02	16.51
400	1.02	29.90	79	139.5	264.5	22.34	34.91	60.88	0.75	1.17	2.04	16.93
410	1.04	29.75	79.5	139.5	265	22.44	34.91	60.99	0.75	1.17	2.05	17.36
420	1.07	29.60	80	140	265	22.54	35.01	60.99	0.76	1.18	2.06	17.78
430	1.09	29.45	80	140	265	22.54	35.01	60.99	0.77	1.19	2.07	18.20
440	1.12	29.29	80	140	265	22.54	35.01	60.99	0.77	1.20	2.08	18.63
450	1.14	29.14	81.5	140		22.86	35.01		0.78	1.20		19.05
460	1.17	28.99	82			22.96			0.79			19.47
470	1.19	28.84	82.5			23.06			0.80			19.90
480	1.22	28.68	83			23.17			0.81			20.32
490	1.24	28.53	82.5			23.06			0.81			20.74
500	1.27	28.38	82.5			23.06			0.81			21.17

Table A-7 The direct shear test result of 8B-72S-20C mixture at room temperature

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m^3 :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması			Yatay Kesme Kuvveti			Kayma Gerilmesi			Birim Def.
			Local Dial Reading			Horizantal Shear Force			Shear Stress			Strain
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	18	39	35	9.66	14.02	13.19	0.27	0.39	0.37	0.42
20	0.05	35.70	28	50	78	11.74	16.31	22.13	0.33	0.46	0.62	0.85
30	0.08	35.54	32	57	105	12.57	17.76	27.74	0.35	0.50	0.78	1.27
40	0.10	35.39	36	64.5	121	13.40	19.32	31.06	0.38	0.55	0.88	1.69
50	0.13	35.24	37.5	69.5	128	13.71	20.36	32.52	0.39	0.58	0.92	2.12
60	0.15	35.09	39	74	137	14.02	21.30	34.39	0.40	0.61	0.98	2.54
70	0.18	34.93	39	77	143	14.02	21.92	35.63	0.40	0.63	1.02	2.96
80	0.20	34.78	40	79.5	148	14.23	22.44	36.67	0.41	0.65	1.05	3.39
90	0.23	34.63	40	80	151.5	14.23	22.54	37.40	0.41	0.65	1.08	3.81
100	0.25	34.48	45	83.5	153	15.27	23.27	37.71	0.44	0.67	1.09	4.23
110	0.28	34.32	47.5	84.5	135	15.79	23.48	33.97	0.46	0.68	0.99	4.66
120	0.30	34.17	50	83.8	130	16.31	23.33	32.93	0.48	0.68	0.96	5.08
130	0.33	34.02	52	88.5	125	16.73	24.31	31.89	0.49	0.71	0.94	5.50
140	0.36	33.87	54	91	159	17.14	24.83	38.96	0.51	0.73	1.15	5.93
150	0.38	33.71	55	93.5	163.3	17.35	25.35	39.85	0.51	0.75	1.18	6.35
160	0.41	33.56	57.5	95	167.5	17.87	25.66	40.73	0.53	0.76	1.21	6.77
170	0.43	33.41	59	97	173	18.18	26.08	41.87	0.54	0.78	1.25	7.20
180	0.46	33.26	61.8	100	176	18.76	26.70	42.49	0.56	0.80	1.28	7.62
190	0.48	33.10	63	101	179.5	19.01	26.91	43.22	0.57	0.81	1.31	8.04
200	0.51	32.95	65	103.5	182	19.43	27.43	43.74	0.59	0.83	1.33	8.47
210	0.53	32.80	67.5	104.5	186	19.95	27.63	44.57	0.61	0.84	1.36	8.89
220	0.56	32.65	69	105	189.5	20.26	27.74	45.30	0.62	0.85	1.39	9.31
230	0.58	32.49	70.5	107	191	20.57	28.15	45.61	0.63	0.87	1.40	9.74
240	0.61	32.34	71.5	108	194	20.78	28.36	46.23	0.64	0.88	1.43	10.16
250	0.64	32.19	72.5	108.5	196.5	20.99	28.47	46.75	0.65	0.88	1.45	10.58
260	0.66	32.04	73.8	109	198.5	21.26	28.57	47.17	0.66	0.89	1.47	11.01
270	0.69	31.89	74.2	110	200.5	21.34	28.78	47.58	0.67	0.90	1.49	11.43
280	0.71	31.73	76.5	112	201	21.82	29.19	47.69	0.69	0.92	1.50	11.85
290	0.74	31.58	77	113	203	21.92	29.40	48.10	0.69	0.93	1.52	12.28
300	0.76	31.43	77.9	114	205	22.11	29.61	48.52	0.70	0.94	1.54	12.70
310	0.79	31.28	79	115	207.5	22.34	29.82	49.04	0.71	0.95	1.57	13.12
320	0.81	31.12	79.8	115.5	209	22.50	29.92	49.35	0.72	0.96	1.59	13.55
330	0.84	30.97	80.5	116	211	22.65	30.02	49.77	0.73	0.97	1.61	13.97
340	0.86	30.82	82	116.5	212	22.96	30.13	49.97	0.74	0.98	1.62	14.39
350	0.89	30.67	83	117	213	23.17	30.23	50.18	0.76	0.99	1.64	14.82
360	0.91	30.51	83.5	117.5	214	23.27	30.34	50.39	0.76	0.99	1.65	15.24
370	0.94	30.36	84.5	118.5	214.5	23.48	30.54	50.49	0.77	1.01	1.66	15.66
380	0.97	30.21	85	119.5	215	23.58	30.75	50.60	0.78	1.02	1.67	16.09
390	0.99	30.06	85.5	119.5	216	23.69	30.75	50.80	0.79	1.02	1.69	16.51
400	1.02	29.90	86	119.5	216	23.79	30.75	50.80	0.80	1.03	1.70	16.93
410	1.04	29.75	86	119.5	217	23.79	30.75	51.01	0.80	1.03	1.71	17.36
420	1.07	29.60	85.5	119.5	217.5	23.69	30.75	51.12	0.80	1.04	1.73	17.78
430	1.09	29.45	86	119.5	218.5	23.79	30.75	51.32	0.81	1.04	1.74	18.20
440	1.12	29.29	86		218.5	23.79		51.32	0.81		1.75	18.63
450	1.14	29.14	86		218.5	23.79		51.32	0.82		1.76	19.05
460	1.17	28.99			218.5			51.32			1.77	19.47

Table A-8 The direct shear test result of 8B-72S-20C mixture at 80°C

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m^3 :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması			Yatay Kesme Kuvveti			Kayma Gerilmesi			Birim Def.
			Local Dial Reading			*Horizantal Shear Force*			*Shear Stress*			*Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	23	53	92	10.70	16.93	25.04	0.30	0.47	0.70	0.42
20	0.05	35.70	31	65	107	12.36	19.43	28.15	0.35	0.54	0.79	0.85
30	0.08	35.54	34	76.5	118	12.98	21.82	30.44	0.37	0.61	0.86	1.27
40	0.10	35.39	36	80	127	13.40	22.54	32.31	0.38	0.64	0.91	1.69
50	0.13	35.24	37	83.5	137	13.61	23.27	34.39	0.39	0.66	0.98	2.12
60	0.15	35.09	37	84	145.5	13.61	23.37	36.15	0.39	0.67	1.03	2.54
70	0.18	34.93	41	83	152.5	14.44	23.17	37.61	0.41	0.66	1.08	2.96
80	0.20	34.78	48	86.5	158	15.89	23.89	38.75	0.46	0.69	1.11	3.39
90	0.23	34.63	53	82	163	16.93	22.96	39.79	0.49	0.66	1.15	3.81
100	0.25	34.48	57	89	166.5	17.76	24.41	40.52	0.52	0.71	1.18	4.23
110	0.28	34.32	58	92	170.5	17.97	25.04	41.35	0.52	0.73	1.20	4.66
120	0.30	34.17	60.5	96	170	18.49	25.87	41.25	0.54	0.76	1.21	5.08
130	0.33	34.02	62	100	180	18.80	26.70	43.32	0.55	0.78	1.27	5.50
140	0.36	33.87	65	103	185	19.43	27.32	44.36	0.57	0.81	1.31	5.93
150	0.38	33.71	67	105	188.5	19.84	27.74	45.09	0.59	0.82	1.34	6.35
160	0.41	33.56	68.5	107	192.5	20.15	28.15	45.92	0.60	0.84	1.37	6.77
170	0.43	33.41	71	109	196.5	20.67	28.57	46.75	0.62	0.86	1.40	7.20
180	0.46	33.26	73	111.5	199	21.09	29.09	47.27	0.63	0.87	1.42	7.62
190	0.48	33.10	75	112	204	21.50	29.19	48.31	0.65	0.88	1.46	8.04
200	0.51	32.95	76.5	113	205.5	21.82	29.40	48.62	0.66	0.89	1.48	8.47
210	0.53	32.80	78.5	112	209	22.23	29.19	49.35	0.68	0.89	1.50	8.89
220	0.56	32.65	79.5	112	212	22.44	29.19	49.97	0.69	0.89	1.53	9.31
230	0.58	32.49	81.5	112	215	22.86	29.19	50.60	0.70	0.90	1.56	9.74
240	0.61	32.34	83	112.5	217	23.17	29.30	51.01	0.72	0.91	1.58	10.16
250	0.64	32.19	83.5	114	220	23.27	29.61	51.64	0.72	0.92	1.60	10.58
260	0.66	32.04	85.5	115.5	222.5	23.69	29.92	52.16	0.74	0.93	1.63	11.01
270	0.69	31.89	86	117.5	225.5	23.79	30.34	52.78	0.75	0.95	1.66	11.43
280	0.71	31.73	86.5	118	228.5	23.89	30.44	53.40	0.75	0.96	1.68	11.85
290	0.74	31.58	88	119	230	24.21	30.65	53.71	0.77	0.97	1.70	12.28
300	0.76	31.43	89	121	233	24.41	31.06	54.34	0.78	0.99	1.73	12.70
310	0.79	31.28	89	123	234.5	24.41	31.48	54.65	0.78	1.01	1.75	13.12
320	0.81	31.12	89.5	123.5	237.5	24.52	31.58	55.27	0.79	1.01	1.78	13.55
330	0.84	30.97	89.5	125	239	24.52	31.89	55.58	0.79	1.03	1.79	13.97
340	0.86	30.82	90	125	240	24.62	31.89	55.79	0.80	1.03	1.81	14.39
350	0.89	30.67	90.5	126.5	242.5	24.73	32.21	56.31	0.81	1.05	1.84	14.82
360	0.91	30.51	91.5	128	243.8	24.93	32.52	56.58	0.82	1.07	1.85	15.24
370	0.94	30.36	91.5	128.5	245	24.93	32.62	56.83	0.82	1.07	1.87	15.66
380	0.97	30.21	92	129.8	245.5	25.04	32.89	56.93	0.83	1.09	1.88	16.09
390	0.99	30.06	92	130	246	25.04	32.93	57.04	0.83	1.10	1.90	16.51
400	1.02	29.90	92.5	131.5	247	25.14	33.25	57.25	0.84	1.11	1.91	16.93
410	1.04	29.75	92.5	132.5	249	25.14	33.45	57.66	0.85	1.12	1.94	17.36
420	1.07	29.60	92.5	133	249.5	25.14	33.56	57.77	0.85	1.13	1.95	17.78
430	1.09	29.45	92.5	133	250.5	25.14	33.56	57.97	0.85	1.14	1.97	18.20
440	1.12	29.29	92.5	133	251.5	25.14	33.56	58.18	0.86	1.15	1.99	18.63
450	1.14	29.14		133	252.5		33.56	58.39		1.15	2.00	19.05
460	1.17	28.99			253.5			58.60			2.02	19.47
470	1.19	28.84			253.5			58.60			2.03	19.90
480	1.22	28.68			253.5			58.60			2.04	20.32

Table A-9 The direct shear test result of 9B-81S-10T mixture at room temperature

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*
Sondaj No	*(Boring No) :*
Örnek No	*(Sample No) :*
Derinlik	*(Depth) :*

Yapan	*(Tested By) :*
Tarih	*(Date) :*

Örnek Boyutları	*(sample dimensions) cm :* 6X6X2
Örnek Ağırlığı	*(sample weight) gr :*
Doğal b.h.a	*(natural unit weight) t/m^3 :*
Yükleme Hızı	*(loading rate) mm/dak :* 0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	16	44	65	9.24	15.06	19.43	0.26	0.42	0.54	0.42
20	0.05	35.70	27	56.5	90	11.53	17.66	24.62	0.32	0.49	0.69	0.85
30	0.08	35.54	31.5	65	105	12.47	19.43	27.74	0.35	0.55	0.78	1.27
40	0.10	35.39	30	65	120	12.15	19.43	30.86	0.34	0.55	0.87	1.69
50	0.13	35.24	29	55	130.5	11.95	17.35	33.04	0.34	0.49	0.94	2.12
60	0.15	35.09	28	54	141	11.74	17.14	35.22	0.33	0.49	1.00	2.54
70	0.18	34.93	29	55.5	144	11.95	17.45	35.84	0.34	0.50	1.03	2.96
80	0.20	34.78	37.5	75	139	13.71	21.50	34.80	0.39	0.62	1.00	3.39
90	0.23	34.63	44	82	140	15.06	22.96	35.01	0.43	0.66	1.01	3.81
100	0.25	34.48	49	89	152.5	16.10	24.41	37.61	0.47	0.71	1.09	4.23
110	0.28	34.32	51	95	158.5	16.52	25.66	38.86	0.48	0.75	1.13	4.66
120	0.30	34.17	52	102	161.5	16.73	27.12	39.48	0.49	0.79	1.16	5.08
130	0.33	34.02	54	110	165.5	17.14	28.78	40.31	0.50	0.85	1.18	5.50
140	0.36	33.87	56.5	115	174	17.66	29.82	42.08	0.52	0.88	1.24	5.93
150	0.38	33.71	58.5	118.5	182	18.08	30.54	43.74	0.54	0.91	1.30	6.35
160	0.41	33.56	60.5	123	189.5	18.49	31.48	45.30	0.55	0.94	1.35	6.77
170	0.43	33.41	62	127	194.5	18.80	32.31	46.34	0.56	0.97	1.39	7.20
180	0.46	33.26	64	132.5	199	19.22	33.45	47.27	0.58	1.01	1.42	7.62
190	0.48	33.10	66	136	205	19.63	34.18	48.52	0.59	1.03	1.47	8.04
200	0.51	32.95	68	138	208.5	20.05	34.60	49.25	0.61	1.05	1.49	8.47
210	0.53	32.80	69.5	143	215	20.36	35.63	50.60	0.62	1.09	1.54	8.89
220	0.56	32.65	72	145	221.5	20.88	36.05	51.95	0.64	1.10	1.59	9.31
230	0.58	32.49	73.5	147.5	225.5	21.19	36.57	52.78	0.65	1.13	1.62	9.74
240	0.61	32.34	75.2	150.5	231	21.55	37.19	53.92	0.67	1.15	1.67	10.16
250	0.64	32.19	76.5	153.5	235	21.82	37.82	54.75	0.68	1.17	1.70	10.58
260	0.66	32.04	78	154.5	241.5	22.13	38.02	56.10	0.69	1.19	1.75	11.01
270	0.69	31.89	80	156	245	22.54	38.34	56.83	0.71	1.20	1.78	11.43
280	0.71	31.73	81.5	157.5	250	22.86	38.65	57.87	0.72	1.22	1.82	11.85
290	0.74	31.58	83.5	158	252.8	23.27	38.75	58.45	0.74	1.23	1.85	12.28
300	0.76	31.43	84.2	158.5	255.5	23.42	38.86	59.01	0.75	1.24	1.88	12.70
310	0.79	31.28	85.5	159	258	23.69	38.96	59.53	0.76	1.25	1.90	13.12
320	0.81	31.12	86	159.8	260	23.79	39.13	59.95	0.76	1.26	1.93	13.55
330	0.84	30.97	87.5	160	263.8	24.10	39.17	60.74	0.78	1.26	1.96	13.97
340	0.86	30.82	88	160	270	24.21	39.17	62.03	0.79	1.27	2.01	14.39
350	0.89	30.67	89.5	160	273	24.52	39.17	62.65	0.80	1.28	2.04	14.82
360	0.91	30.51	91	160	273.8	24.83	39.17	62.82	0.81	1.28	2.06	15.24
370	0.94	30.36	91.8	160.2	274.8	25.00	39.21	63.02	0.82	1.29	2.08	15.66
380	0.97	30.21	92	160.5	276	25.04	39.27	63.27	0.83	1.30	2.09	16.09
390	0.99	30.06	93	160.8	277	25.24	39.33	63.48	0.84	1.31	2.11	16.51
400	1.02	29.90	93.3	160.5	279.2	25.31	39.27	63.94	0.85	1.31	2.14	16.93
410	1.04	29.75	93.3	160.2	279.8	25.31	39.21	64.06	0.85	1.32	2.15	17.36
420	1.07	29.60	94	159.5	279.2	25.45	39.06	63.94	0.86	1.32	2.16	17.78
430	1.09	29.45	94.2	159	278.0	25.49	38.96	63.69	0.87	1.32	2.16	18.20
440	1.12	29.29	94.2	158.8	278.3	25.49	38.92	63.75	0.87	1.33	2.18	18.63
450	1.14	29.14	94.5	156.2	277.0	25.56	38.38	63.48	0.88	1.32	2.18	19.05
460	1.17	28.99	94.5	154.8	277.5	25.56	38.09	63.58	0.88	1.31	2.19	19.47
470	1.19	28.84	94.5		278.0	25.56		63.69	0.89		2.21	19.90
480	1.22	28.68	94.5		276.0	25.56		63.27	0.89		2.21	20.32
490	1.24	28.53	94.5		275.0	25.56		63.06	0.90		2.21	20.74
500	1.27	28.38	94.5		274.5	25.56		62.96	0.90		2.22	21.17

Table A-10 The direct shear test result of 9B-81S-10T mixture at 80°C

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	***(Job Name) :***	
Sondaj No	***(Boring No) :***	
Örnek No	***(Sample No) :***	
Derinlik	***(Depth) :***	

Yapan	***(Tested By) :***
Tarih	***(Date) :***

Örnek Boyutları	***(sample dimensions) cm :***	6X6X2
Örnek Ağırlığı	***(sample weight) gr :***	
Doğal b.h.a	***(natural unit weight) t/m³ :***	
Yükleme Hızı	***(loading rate) mm/dak :***	0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm²	-	-	-	kg	kg	kg	kg/cm²	kg/cm²	kg/cm²	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	29	36	80	11.95	13.40	22.54	0.33	0.37	0.63	0.42
20	0.05	35.70	31	45	92	12.36	15.27	25.04	0.35	0.43	0.70	0.85
30	0.08	35.54	32	51	111	12.57	16.52	28.99	0.35	0.46	0.82	1.27
40	0.10	35.39	33	57.8	125	12.78	17.93	31.89	0.36	0.51	0.90	1.69
50	0.13	35.24	35	63.5	132	13.19	19.11	33.35	0.37	0.54	0.95	2.12
60	0.15	35.09	39	64.5	137	14.02	19.32	34.39	0.40	0.55	0.98	2.54
70	0.18	34.93	44	65	140	15.06	19.43	35.01	0.43	0.56	1.00	2.96
80	0.20	34.78	46	67	158.5	15.48	19.84	38.86	0.45	0.57	1.12	3.39
90	0.23	34.63	48	74	165	15.89	21.30	40.21	0.46	0.62	1.16	3.81
100	0.25	34.48	50.5	79.5	170	16.41	22.44	41.25	0.48	0.65	1.20	4.23
110	0.28	34.32	53	84	175.5	16.93	23.37	42.39	0.49	0.68	1.23	4.66
120	0.30	34.17	54.5	88	181.5	17.24	24.21	43.64	0.50	0.71	1.28	5.08
130	0.33	34.02	55.5	92.5	188	17.45	25.14	44.99	0.51	0.74	1.32	5.50
140	0.36	33.87	57	96.2	194.5	17.76	25.91	46.34	0.52	0.77	1.37	5.93
150	0.38	33.71	57.5	98	203	17.87	26.28	48.10	0.53	0.78	1.43	6.35
160	0.41	33.56	58	99.5	207.5	17.97	26.60	49.04	0.54	0.79	1.46	6.77
170	0.43	33.41	59	103	210.5	18.18	27.32	49.66	0.54	0.82	1.49	7.20
180	0.46	33.26	60.5	104.5	215.5	18.49	27.63	50.70	0.56	0.83	1.52	7.62
190	0.48	33.10	61.8	107	218	18.76	28.15	51.22	0.57	0.85	1.55	8.04
200	0.51	32.95	62.5	109	222	18.91	28.57	52.05	0.57	0.87	1.58	8.47
210	0.53	32.80	62.9	112.5	224.5	18.99	29.30	52.57	0.58	0.89	1.60	8.89
220	0.56	32.65	64	115	228	19.22	29.82	53.30	0.59	0.91	1.63	9.31
230	0.58	32.49	65	117	232	19.43	30.23	54.13	0.60	0.93	1.67	9.74
240	0.61	32.34	65.5	119	232.5	19.53	30.65	54.23	0.60	0.95	1.68	10.16
250	0.64	32.19	66	121.5	235	19.63	31.17	54.75	0.61	0.97	1.70	10.58
260	0.66	32.04	67	123	238.5	19.84	31.48	55.48	0.62	0.98	1.73	11.01
270	0.69	31.89	68	125	241	20.05	31.89	56.00	0.63	1.00	1.76	11.43
280	0.71	31.73	68.5	126.5	242	20.15	32.21	56.21	0.64	1.01	1.77	11.85
290	0.74	31.58	70	127	247	20.47	32.31	57.25	0.65	1.02	1.81	12.28
300	0.76	31.43	70.5	127.5	249	20.57	32.41	57.66	0.65	1.03	1.83	12.70
310	0.79	31.28	70.5	128	250.5	20.57	32.52	57.97	0.66	1.04	1.85	13.12
320	0.81	31.12	71.5	129	253.2	20.78	32.73	58.53	0.67	1.05	1.88	13.55
330	0.84	30.97	72	129	256.2	20.88	32.73	59.16	0.67	1.06	1.91	13.97
340	0.86	30.82	72.5	129	256.3	20.99	32.73	59.18	0.68	1.06	1.92	14.39
350	0.89	30.67	73.5	128.5	256.4	21.19	32.62	59.20	0.69	1.06	1.93	14.82
360	0.91	30.51	73.5	129	256.7	21.19	32.73	59.26	0.69	1.07	1.94	15.24
370	0.94	30.36	73.5	129	258.5	21.19	32.73	59.64	0.70	1.08	1.96	15.66
380	0.97	30.21	74	129.5	258.3	21.30	32.83	59.59	0.70	1.09	1.97	16.09
390	0.99	30.06	74.2	129.8	258	21.34	32.89	59.53	0.71	1.09	1.98	16.51
400	1.02	29.90	74.2	131.5	257	21.34	33.25	59.32	0.71	1.11	1.98	16.93
410	1.04	29.75	74.2	132	258	21.34	33.35	59.53	0.72	1.12	2.00	17.36
420	1.07	29.60	74.2	132.5	257.5	21.34	33.45	59.43	0.72	1.13	2.01	17.78
430	1.09	29.45	74.2	133.3	257.2	21.34	33.62	59.37	0.72	1.14	2.02	18.20
440	1.12	29.29	74.2	133.8	255.5	21.34	33.72	59.01	0.73	1.15	2.01	18.63
450	1.14	29.14	74.8	135	252.8	21.46	33.97	58.45	0.74	1.17	2.01	19.05
460	1.17	28.99	74.8	135.2	252.2	21.46	34.01	58.33	0.74	1.17	2.01	19.47
470	1.19	28.84	74.5	136	249.0	21.40	34.18	57.66	0.74	1.19	2.00	19.90
480	1.22	28.68	74.5	137.5	247.5	21.40	34.49	57.35	0.75	1.20	2.00	20.32
490	1.24	28.53	74.5	138		21.40	34.60		0.75	1.21		20.74
500	1.27	28.38	74.5	138.5		21.40	34.70		0.75	1.22		21.17
510	1.30	28.23	74.5	138.5		21.40	34.70		0.76	1.23		21.59
520	1.32	28.08	74.5	139		21.40	34.80		0.76	1.24		22.01
530	1.35	27.92	74.8	139.2		21.46	34.85		0.77	1.25		22.44
540	1.37	27.77	74.8	139.2		21.46	34.85		0.77	1.25		22.86
550	1.40	27.62	74.8	139.8		21.46	34.97		0.78	1.27		23.28
560	1.42	27.47		140			35.01			1.27		23.71
570	1.45	27.31		140.5			35.12			1.29		24.13
580	1.47	27.16		141			35.22			1.30		24.55
590	1.50	27.01		141.5			35.32			1.31		24.98
600	1.52	26.86		142			35.43			1.32		25.40
610	1.55	26.70		142			35.43			1.33		25.82
620	1.57	26.55		142			35.43			1.33		26.25
630	1.60	26.40		143.5			35.74			1.35		26.67
640	1.63	26.25		143.5			35.74			1.36		27.09

Table A-11 The direct shear test result of 8B-72S-20T mixture at room temperature

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m³ :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması			Yatay Kesme Kuvveti			Kayma Gerilmesi			Birim Def.
			Local Dial Reading			*Horizantal Shear Force*			*Shear Stress*			*Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	19	36	75	9.87	13.40	21.50	0.28	0.37	0.60	0.42
20	0.05	35.70	22	44	83.5	10.49	15.06	23.27	0.29	0.42	0.65	0.85
30	0.08	35.54	26	44.5	100	11.32	15.17	26.70	0.32	0.43	0.75	1.27
40	0.10	35.39	29	43	115	11.95	14.85	29.82	0.34	0.42	0.84	1.69
50	0.13	35.24	32.5	43	128.5	12.67	14.85	32.62	0.36	0.42	0.93	2.12
60	0.15	35.09	32	44	139.5	12.57	15.06	34.91	0.36	0.43	0.99	2.54
70	0.18	34.93	31.5	59.5	151	12.47	18.28	37.30	0.36	0.52	1.07	2.96
80	0.20	34.78	31.5	69.5	162.5	12.47	20.36	39.69	0.36	0.59	1.14	3.39
90	0.23	34.63	40	75	174.5	14.23	21.50	42.18	0.41	0.62	1.22	3.81
100	0.25	34.48	44	82	188	15.06	22.96	44.99	0.44	0.67	1.30	4.23
110	0.28	34.32	46	85	192.5	15.48	23.58	45.92	0.45	0.69	1.34	4.66
120	0.30	34.17	49	88.5	200	16.10	24.31	47.48	0.47	0.71	1.39	5.08
130	0.33	34.02	51.8	93	208	16.68	25.24	49.14	0.49	0.74	1.44	5.50
140	0.36	33.87	54.9	97.2	215	17.33	26.12	50.60	0.51	0.77	1.49	5.93
150	0.38	33.71	56.5	99	221	17.66	26.49	51.84	0.52	0.79	1.54	6.35
160	0.41	33.56	58.5	101	228	18.08	26.91	53.30	0.54	0.80	1.59	6.77
170	0.43	33.41	60	104.5	233	18.39	27.63	54.34	0.55	0.83	1.63	7.20
180	0.46	33.26	63.9	109	236.5	19.20	28.57	55.06	0.58	0.86	1.66	7.62
190	0.48	33.10	65	111.5	240	19.43	29.09	55.79	0.59	0.88	1.69	8.04
200	0.51	32.95	67.9	115	244	20.03	29.82	56.62	0.61	0.90	1.72	8.47
210	0.53	32.80	70	117	247	20.47	30.23	57.25	0.62	0.92	1.75	8.89
220	0.56	32.65	73.5	119.5	248.5	21.19	30.75	57.56	0.65	0.94	1.76	9.31
230	0.58	32.49	76	122	252	21.71	31.27	58.29	0.67	0.96	1.79	9.74
240	0.61	32.34	78.5	125	254.5	22.23	31.89	58.80	0.69	0.99	1.82	10.16
250	0.64	32.19	81	127	256	22.75	32.31	59.12	0.71	1.00	1.84	10.58
260	0.66	32.04	83	130.5	256.5	23.17	33.04	59.22	0.72	1.03	1.85	11.01
270	0.69	31.89	86	132.2	258	23.79	33.39	59.53	0.75	1.05	1.87	11.43
280	0.71	31.73	88	134.8	259	24.21	33.93	59.74	0.76	1.07	1.88	11.85
290	0.74	31.58	89	136.5	260	24.41	34.28	59.95	0.77	1.09	1.90	12.28
300	0.76	31.43	90.5	138.5	260.5	24.73	34.70	60.05	0.79	1.10	1.91	12.70
310	0.79	31.28	92	139.5	260.5	25.04	34.91	60.05	0.80	1.12	1.92	13.12
320	0.81	31.12	93	141	261	25.24	35.22	60.16	0.81	1.13	1.93	13.55
330	0.84	30.97	94	142.5	260	25.45	35.53	59.95	0.82	1.15	1.94	13.97
340	0.86	30.82	95	144	259.5	25.66	35.84	59.84	0.83	1.16	1.94	14.39
350	0.89	30.67	95	144.8	259.7	25.66	36.01	59.89	0.84	1.17	1.95	14.82
360	0.91	30.51	95.2	145.5	260.2	25.70	36.15	59.99	0.84	1.18	1.97	15.24
370	0.94	30.36	95.2	146	260.8	25.70	36.26	60.11	0.85	1.19	1.98	15.66
380	0.97	30.21	94.5	147	261.9	25.56	36.47	60.34	0.85	1.21	2.00	16.09
390	0.99	30.06	94	147.8	262	25.45	36.63	60.36	0.85	1.22	2.01	16.51
400	1.02	29.90	93.5	148	262	25.35	36.67	60.36	0.85	1.23	2.02	16.93
410	1.04	29.75	93	148	262	25.24	36.67	60.36	0.85	1.23	2.03	17.36
420	1.07	29.60	90.2	148	262	24.66	36.67	60.36	0.83	1.24	2.04	17.78
430	1.09	29.45	88.5	147	261.2	24.31	36.47	60.20	0.83	1.24	2.04	18.20
440	1.12	29.29	87.9	146	261.2	24.19	36.26	60.20	0.83	1.24	2.05	18.63
450	1.14	29.14	86.2	146	260.5	23.83	36.26	60.05	0.82	1.24	2.06	19.05
460	1.17	28.99		145.2	260.0		36.09	59.95		1.25	2.07	19.47
470	1.19	28.84		144.5			35.95			1.25		19.90

Table A-12 The direct shear test result of 8B-72S-20T mixture at 80°C

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	Yapan	*(Tested By) :*
Sondaj No	*(Boring No) :*	Tarih	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m^3 :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	22	40	75	10.49	14.23	21.50	0.29	0.40	0.60	0.42
20	0.05	35.70	23.5	52.2	92	10.80	16.77	25.04	0.30	0.47	0.70	0.85
30	0.08	35.54	25	55	98	11.11	17.35	26.28	0.31	0.49	0.74	1.27
40	0.10	35.39	27	58.5	114	11.53	18.08	29.61	0.33	0.51	0.84	1.69
50	0.13	35.24	28	59	122	11.74	18.18	31.27	0.33	0.52	0.89	2.12
60	0.15	35.09	30	74	126	12.15	21.30	32.10	0.35	0.61	0.91	2.54
70	0.18	34.93	38	77.5	129	13.82	22.02	32.73	0.40	0.63	0.94	2.96
80	0.20	34.78	40.5	82	144	14.34	22.96	35.84	0.41	0.66	1.03	3.39
90	0.23	34.63	41	85.3	150.5	14.44	23.64	37.19	0.42	0.68	1.07	3.81
100	0.25	34.48	41	89.8	158.5	14.44	24.58	38.86	0.42	0.71	1.13	4.23
110	0.28	34.32	42.5	93	168	14.75	25.24	40.83	0.43	0.74	1.19	4.66
120	0.30	34.17	44	97.4	171.5	15.06	26.16	41.56	0.44	0.77	1.22	5.08
130	0.33	34.02	45.5	101.5	175.5	15.37	27.01	42.39	0.45	0.79	1.25	5.50
140	0.36	33.87	46.5	105	180	15.58	27.74	43.32	0.46	0.82	1.28	5.93
150	0.38	33.71	47.5	107	185.5	15.79	28.15	44.47	0.47	0.84	1.32	6.35
160	0.41	33.56	48.5	108.5	192.9	16.00	28.47	46.00	0.48	0.85	1.37	6.77
170	0.43	33.41	49.5	111	195	16.21	28.99	46.44	0.49	0.87	1.39	7.20
180	0.46	33.26	50	112.9	196	16.31	29.38	46.65	0.49	0.88	1.40	7.62
190	0.48	33.10	50.5	114	201.5	16.41	29.61	47.79	0.50	0.89	1.44	8.04
200	0.51	32.95	51	115	203.5	16.52	29.82	48.21	0.50	0.90	1.46	8.47
210	0.53	32.80	51.5	116	204.5	16.62	30.02	48.41	0.51	0.92	1.48	8.89
220	0.56	32.65	52	117	205.5	16.73	30.23	48.62	0.51	0.93	1.49	9.31
230	0.58	32.49	52.5	117.5	208	16.83	30.34	49.14	0.52	0.93	1.51	9.74
240	0.61	32.34	53	118	211	16.93	30.44	49.77	0.52	0.94	1.54	10.16
250	0.64	32.19	54	120.2	213	17.14	30.90	50.18	0.53	0.96	1.56	10.58
260	0.66	32.04	55.5	120.5	215	17.45	30.96	50.60	0.54	0.97	1.58	11.01
270	0.69	31.89	57	121	217	17.76	31.06	51.01	0.56	0.97	1.60	11.43
280	0.71	31.73	57.5	121	219	17.87	31.06	51.43	0.56	0.98	1.62	11.85
290	0.74	31.58	58	120.2	221	17.97	30.90	51.84	0.57	0.98	1.64	12.28
300	0.76	31.43	60	120	222.5	18.39	30.86	52.16	0.59	0.98	1.66	12.70
310	0.79	31.28	60	119	225	18.39	30.65	52.67	0.59	0.98	1.68	13.12
320	0.81	31.12	60.5	119	226.5	18.49	30.65	52.99	0.59	0.98	1.70	13.55
330	0.84	30.97	61	119	228	18.60	30.65	53.30	0.60	0.99	1.72	13.97
340	0.86	30.82	62	120.5	231	18.80	30.96	53.92	0.61	1.00	1.75	14.39
350	0.89	30.67	63	119.3	232.5	19.01	30.71	54.23	0.62	1.00	1.77	14.82
360	0.91	30.51	63.2	119	234	19.05	30.65	54.54	0.62	1.00	1.79	15.24
370	0.94	30.36	64.2	120.4	236.5	19.26	30.94	55.06	0.63	1.02	1.81	15.66
380	0.97	30.21	65.5	121.2	238	19.53	31.10	55.38	0.65	1.03	1.83	16.09
390	0.99	30.06	66	121	239	19.63	31.06	55.58	0.65	1.03	1.85	16.51
400	1.02	29.90	66	120.9	241	19.63	31.04	56.00	0.66	1.04	1.87	16.93
410	1.04	29.75	67	120.1	246	19.84	30.88	57.04	0.67	1.04	1.92	17.36
420	1.07	29.60	68.5	119.8	246.5	20.15	30.81	57.14	0.68	1.04	1.93	17.78
430	1.09	29.45	69.8	119	248.0	20.42	30.65	57.45	0.69	1.04	1.95	18.20
440	1.12	29.29	70	119.3	249.5	20.47	30.71	57.77	0.70	1.05	1.97	18.63
450	1.14	29.14	70.5	119.5	249.5	20.57	30.75	57.77	0.71	1.06	1.98	19.05
460	1.17	28.99	71.5	122	252.5	20.78	31.27	58.39	0.72	1.08	2.01	19.47
470	1.19	28.84	72.2	122	253.0	20.92	31.27	58.49	0.73	1.08	2.03	19.90
480	1.22	28.68	72.5	122	252.5	20.99	31.27	58.39	0.73	1.09	2.04	20.32
490	1.24	28.53	73	122.5	253.5	21.09	31.38	58.60	0.74	1.10	2.05	20.74
500	1.27	28.38	73.9	122.5	255.7	21.28	31.38	59.05	0.75	1.11	2.08	21.17
510	1.30	28.23	74.5	122.8	256.0	21.40	31.44	59.12	0.76	1.11	2.09	21.59
520	1.32	28.08	74.5	124	257.0	21.40	31.69	59.32	0.76	1.13	2.11	22.01
530	1.35	27.92	74.8	124.8	258.5	21.46	31.85	59.64	0.77	1.14	2.14	22.44
540	1.37	27.77	74.8	123.8	259.0	21.46	31.65	59.74	0.77	1.14	2.15	22.86
550	1.40	27.62	74.5	124	263.0	21.40	31.69	60.57	0.77	1.15	2.19	23.28
560	1.42	27.47	74.8	124.3	263.5	21.46	31.75	60.67	0.78	1.16	2.21	23.71
570	1.45	27.31	75.5	124	269.5	21.61	31.69	61.92	0.79	1.16	2.27	24.13
580	1.47	27.16	76	125.2	265.0	21.71	31.94	60.99	0.80	1.18	2.25	24.55
590	1.50	27.01	77	125	266.5	21.92	31.89	61.30	0.81	1.18	2.27	24.98
600	1.52	26.86	77.9	126	269.0	22.11	32.10	61.82	0.82	1.20	2.30	25.40
610	1.55	26.70	78.5	127.2	270.0	22.23	32.35	62.03	0.83	1.21	2.32	25.82
620	1.57	26.55	78.8	127.2	272.0	22.29	32.35	62.44	0.84	1.22	2.35	26.25
630	1.60	26.40	80	127.5	273.5	22.54	32.41	62.75	0.85	1.23	2.38	26.67
640	1.63	26.25	80.5	128.5	275.0	22.65	32.62	63.06	0.86	1.24	2.40	27.09
650	1.65	26.09	81.2	129	275.5	22.79	32.73	63.17	0.87	1.25	2.42	27.52
660	1.68	25.94	83	131	277.5	23.17	33.14	63.58	0.89	1.28	2.45	27.94
670	1.70	25.79	83.5	133.3	279.0	23.27	33.62	63.90	0.90	1.30	2.48	28.36
680	1.73	25.64	84	133	280.2	23.37	33.56	64.15	0.91	1.31	2.50	28.79
690	1.75	25.48	84.5			23.48			0.92			29.21
700	1.78	25.33	85			23.58			0.93			29.63

Table A-13 The direct shear test result of 9B-81S-10U mixture at room temperature

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m^3 :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması (Local Dial Reading)			Yatay Kesme Kuvveti (Horizantal Shear Force)			Kayma Gerilmesi (Shear Stress)			Birim Def. (Strain)
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	10	35.5	78	8.00	13.30	22.13	0.22	0.37	0.62	0.42
20	0.05	35.70	16	48	100	9.24	15.89	26.70	0.26	0.45	0.75	0.85
30	0.08	35.54	20	55	125	10.08	17.35	31.89	0.28	0.49	0.90	1.27
40	0.10	35.39	25	63	128	11.11	19.01	32.52	0.31	0.54	0.92	1.69
50	0.13	35.24	29	72	132	11.95	20.88	33.35	0.34	0.59	0.95	2.12
60	0.15	35.09	32	73	122	12.57	21.09	31.27	0.36	0.60	0.89	2.54
70	0.18	34.93	38.5	73	115	13.92	21.09	29.82	0.40	0.60	0.85	2.96
80	0.20	34.78	43.5	80	113	14.96	22.54	29.40	0.43	0.65	0.85	3.39
90	0.23	34.63	49.5	88	147.5	16.21	24.21	36.57	0.47	0.70	1.06	3.81
100	0.25	34.48	54	95	157	17.14	25.66	38.54	0.50	0.74	1.12	4.23
110	0.28	34.32	57	99	167	17.76	26.49	40.62	0.52	0.77	1.18	4.66
120	0.30	34.17	60.5	103	176	18.49	27.32	42.49	0.54	0.80	1.24	5.08
130	0.33	34.02	65	108	182	19.43	28.36	43.74	0.57	0.83	1.29	5.50
140	0.36	33.87	68	113	189	20.05	29.40	45.19	0.59	0.87	1.33	5.93
150	0.38	33.71	71	115	196.5	20.67	29.82	46.75	0.61	0.88	1.39	6.35
160	0.41	33.56	74.9	120	203	21.48	30.86	48.10	0.64	0.92	1.43	6.77
170	0.43	33.41	77	123	208.5	21.92	31.48	49.25	0.66	0.94	1.47	7.20
180	0.46	33.26	80	126	215	22.54	32.10	50.60	0.68	0.97	1.52	7.62
190	0.48	33.10	82	129	220	22.96	32.73	51.64	0.69	0.99	1.56	8.04
200	0.51	32.95	85	134	224	23.58	33.76	52.47	0.72	1.02	1.59	8.47
210	0.53	32.80	87.5	139.5	227.5	24.10	34.91	53.19	0.73	1.06	1.62	8.89
220	0.56	32.65	90	144.5	232	24.62	35.95	54.13	0.75	1.10	1.66	9.31
230	0.58	32.49	93	148	235.5	25.24	36.67	54.86	0.78	1.13	1.69	9.74
240	0.61	32.34	95	151.5	238.5	25.66	37.40	55.48	0.79	1.16	1.72	10.16
250	0.64	32.19	97.5	155.5	242	26.18	38.23	56.21	0.81	1.19	1.75	10.58
260	0.66	32.04	100	158	246	26.70	38.75	57.04	0.83	1.21	1.78	11.01
270	0.69	31.89	102	160	248.5	27.12	39.17	57.56	0.85	1.23	1.81	11.43
280	0.71	31.73	104	162	251	27.53	39.58	58.08	0.87	1.25	1.83	11.85
290	0.74	31.58	106	164	253	27.95	40.00	58.49	0.88	1.27	1.85	12.28
300	0.76	31.43	108	165	253	28.36	40.21	58.49	0.90	1.28	1.86	12.70
310	0.79	31.28	109	166.5	254	28.57	40.52	58.70	0.91	1.30	1.88	13.12
320	0.81	31.12	110	167.5	256	28.78	40.73	59.12	0.92	1.31	1.90	13.55
330	0.84	30.97	105	167.5	257.2	27.74	40.73	59.37	0.90	1.31	1.92	13.97
340	0.86	30.82	107	167.9	258	28.15	40.81	59.53	0.91	1.32	1.93	14.39
350	0.89	30.67	107	167.9	259	28.15	40.81	59.74	0.92	1.33	1.95	14.82
360	0.91	30.51	107	167.5	260.5	28.15	40.73	60.05	0.92	1.33	1.97	15.24
370	0.94	30.36	107	167	261.5	28.15	40.62	60.26	0.93	1.34	1.98	15.66
380	0.97	30.21	107	167	263	28.15	40.62	60.57	0.93	1.34	2.01	16.09
390	0.99	30.06	107	167	266.5	28.15	40.62	61.30	0.94	1.35	2.04	16.51
400	1.02	29.90	106.5	167	266.5	28.05	40.62	61.30	0.94	1.36	2.05	16.93
410	1.04	29.75	106.5	167	266.5	28.05	40.62	61.30	0.94	1.37	2.06	17.36
420	1.07	29.60	106.5	165	266.5	28.05	40.21	61.30	0.95	1.36	2.07	17.78
430	1.09	29.45	106	164	266.5	27.95	40.00	61.30	0.95	1.36	2.08	18.20
440	1.12	29.29			266.5			61.30			2.09	18.63
450	1.14	29.14			266.5			61.30			2.10	19.05
460	1.17	28.99			266.5			61.30			2.11	19.47
470	1.19	28.84			266.5			61.30			2.13	19.90

Table A-14 The direct shear test result of 9B-81S-10U mixture at 80°C

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı *(Job Name) :*
Sondaj No *(Boring No) :*
Örnek No *(Sample No) :*
Derinlik *(Depth) :*

Yapan *(Tested By) :*
Tarih *(Date) :*

Örnek Boyutları *(sample dimensions) cm :* 6X6X2
Örnek Ağırlığı *(sample weight) gr :*
Doğal b.h.a *(natural unit weight) t/m³ :*
Yükleme Hızı *(loading rate) mm/dak :* 0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	20	39.5	92.5	10.08	14.13	25.14	0.28	0.39	0.70	0.42
20	0.05	35.70	27	54	125	11.53	17.14	31.89	0.32	0.48	0.89	0.85
30	0.08	35.54	33	63.5	133	12.78	19.11	33.56	0.36	0.54	0.94	1.27
40	0.10	35.39	43	70	140	14.85	20.47	35.01	0.42	0.58	0.99	1.69
50	0.13	35.24	48.5	70.5	145.5	16.00	20.57	36.15	0.45	0.58	1.03	2.12
60	0.15	35.09	57	75.5	145	17.76	21.61	36.05	0.51	0.62	1.03	2.54
70	0.18	34.93	61.5	87	145	18.70	24.00	36.05	0.54	0.69	1.03	2.96
80	0.20	34.78	68	95	145	20.05	25.66	36.05	0.58	0.74	1.04	3.39
90	0.23	34.63	73	103	145	21.09	27.32	36.05	0.61	0.79	1.04	3.81
100	0.25	34.48	77.5	109	155	22.02	28.57	38.13	0.64	0.83	1.11	4.23
110	0.28	34.32	82	115	163.5	22.96	29.82	39.89	0.67	0.87	1.16	4.66
120	0.30	34.17	86.5	118	170	23.89	30.44	41.25	0.70	0.89	1.21	5.08
130	0.33	34.02	90.5	121.5	178	24.73	31.17	42.91	0.73	0.92	1.26	5.50
140	0.36	33.87	94	126	184.5	25.45	32.10	44.26	0.75	0.95	1.31	5.93
150	0.38	33.71	98	131	190	26.28	33.14	45.40	0.78	0.98	1.35	6.35
160	0.41	33.56	101	136	195	26.91	34.18	46.44	0.80	1.02	1.38	6.77
170	0.43	33.41	103	139.5	202	27.32	34.91	47.90	0.82	1.04	1.43	7.20
180	0.46	33.26	106	142.5	209	27.95	35.53	49.35	0.84	1.07	1.48	7.62
190	0.48	33.10	108	146.5	215	28.36	36.36	50.60	0.86	1.10	1.53	8.04
200	0.51	32.95	109.5	150	222	28.67	37.09	52.05	0.87	1.13	1.58	8.47
210	0.53	32.80	109.5	153	225	28.67	37.71	52.67	0.87	1.15	1.61	8.89
220	0.56	32.65	110	156	232	28.78	38.34	54.13	0.88	1.17	1.66	9.31
230	0.58	32.49	110	158	236.5	28.78	38.75	55.06	0.89	1.19	1.69	9.74
240	0.61	32.34	109.5	160.5	240	28.67	39.27	55.79	0.89	1.21	1.73	10.16
250	0.64	32.19	109.5	163.5	244.5	28.67	39.89	56.73	0.89	1.24	1.76	10.58
260	0.66	32.04	106.5	165.5	248	28.05	40.31	57.45	0.88	1.26	1.79	11.01
270	0.69	31.89	105.5	167	253	27.84	40.62	58.49	0.87	1.27	1.83	11.43
280	0.71	31.73	103.5	167.9	255.5	27.43	40.81	59.01	0.86	1.29	1.86	11.85
290	0.74	31.58	102.5	168	257	27.22	40.83	59.32	0.86	1.29	1.88	12.28
300	0.76	31.43	102	168.5	260.5	27.12	40.93	60.05	0.86	1.30	1.91	12.70
310	0.79	31.28	100	168.8	261.5	26.70	41.00	60.26	0.85	1.31	1.93	13.12
320	0.81	31.12	99	169	263.5	26.49	41.04	60.67	0.85	1.32	1.95	13.55
330	0.84	30.97	98	169	265.5	26.28	41.04	61.09	0.85	1.33	1.97	13.97
340	0.86	30.82	96	169	266	25.87	41.04	61.19	0.84	1.33	1.99	14.39
350	0.89	30.67	95	169	267	25.66	41.04	61.40	0.84	1.34	2.00	14.82
360	0.91	30.51		169	268.2		41.04	61.65		1.34	2.02	15.24
370	0.94	30.36		169	271		41.04	62.23		1.35	2.05	15.66
380	0.97	30.21		169	272.3		41.04	62.50		1.36	2.07	16.09
390	0.99	30.06			275			63.06			2.10	16.51
400	1.02	29.90			275.8			63.23			2.11	16.93
410	1.04	29.75			276			63.27			2.13	17.36
420	1.07	29.60			276			63.27			2.14	17.78
430	1.09	29.45			279			63.90			2.17	18.20
440	1.12	29.29			280.5			64.21			2.19	18.63
450	1.14	29.14			280.2			64.15			2.20	19.05
460	1.17	28.99			280.5			64.21			2.21	19.47
470	1.19	28.84			281.5			64.42			2.23	19.90
480	1.22	28.68			285			65.14			2.27	20.32
490	1.24	28.53			291			66.39			2.33	20.74
500	1.27	28.38			298.0			67.84			2.39	21.17
510	1.30	28.23			306.0			69.51			2.46	21.59
520	1.32	28.08			307.0			69.71			2.48	22.01
530	1.35	27.92			322.0			72.83			2.61	22.44

Table A-15 The direct shear test result of 8B-72S-20U mixture at room temperature

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m^3 :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	14	36	80	8.83	13.40	22.54	0.25	0.37	0.63	0.42
20	0.05	35.70	24	49	102	10.91	16.10	27.12	0.31	0.45	0.76	0.85
30	0.08	35.54	28	57	104	11.74	17.76	27.53	0.33	0.50	0.77	1.27
40	0.10	35.39	30	62	109	12.15	18.80	28.57	0.34	0.53	0.81	1.69
50	0.13	35.24	33	65	116	12.78	19.43	30.02	0.36	0.55	0.85	2.12
60	0.15	35.09	35	67	117	13.19	19.84	30.23	0.38	0.57	0.86	2.54
70	0.18	34.93	36	67.5	118	13.40	19.95	30.44	0.38	0.57	0.87	2.96
80	0.20	34.78	37.5	69	121	13.71	20.26	31.06	0.39	0.58	0.89	3.39
90	0.23	34.63	35.5	64	122	13.30	19.22	31.27	0.38	0.55	0.90	3.81
100	0.25	34.48	36	58	131	13.40	17.97	33.14	0.39	0.52	0.96	4.23
110	0.28	34.32	40.5	63	137	14.34	19.01	34.39	0.42	0.55	1.00	4.66
120	0.30	34.17	43	77	144	14.85	21.92	35.84	0.43	0.64	1.05	5.08
130	0.33	34.02	44.5	80.5	147	15.17	22.65	36.47	0.45	0.67	1.07	5.50
140	0.36	33.87	47	84	149	15.69	23.37	36.88	0.46	0.69	1.09	5.93
150	0.38	33.71	49	87	153	16.10	24.00	37.71	0.48	0.71	1.12	6.35
160	0.41	33.56	52	90	156	16.73	24.62	38.34	0.50	0.73	1.14	6.77
170	0.43	33.41	53.9	94	158.5	17.12	25.45	38.86	0.51	0.76	1.16	7.20
180	0.46	33.26	57	96	162	17.76	25.87	39.58	0.53	0.78	1.19	7.62
190	0.48	33.10	59	98.5	164.5	18.18	26.39	40.10	0.55	0.80	1.21	8.04
200	0.51	32.95	60	100	167	18.39	26.70	40.62	0.56	0.81	1.23	8.47
210	0.53	32.80	62	103	169.5	18.80	27.32	41.14	0.57	0.83	1.25	8.89
220	0.56	32.65	64	105	170	19.22	27.74	41.25	0.59	0.85	1.26	9.31
230	0.58	32.49	67	107	172	19.84	28.15	41.66	0.61	0.87	1.28	9.74
240	0.61	32.34	68	108	173	20.05	28.36	41.87	0.62	0.88	1.29	10.16
250	0.64	32.19	70	109.5	175.5	20.47	28.67	42.39	0.64	0.89	1.32	10.58
260	0.66	32.04	71	111	176	20.67	28.99	42.49	0.65	0.90	1.33	11.01
270	0.69	31.89	72	112	177	20.88	29.19	42.70	0.65	0.92	1.34	11.43
280	0.71	31.73	74	114	180	21.30	29.61	43.32	0.67	0.93	1.37	11.85
290	0.74	31.58	75.5	115	181	21.61	29.82	43.53	0.68	0.94	1.38	12.28
300	0.76	31.43	76.9	115.5	181.5	21.90	29.92	43.64	0.70	0.95	1.39	12.70
310	0.79	31.28	78	115.5	182	22.13	29.92	43.74	0.71	0.96	1.40	13.12
320	0.81	31.12	79.5	116.5	183	22.44	30.13	43.95	0.72	0.97	1.41	13.55
330	0.84	30.97	80.5	116.9	183.5	22.65	30.21	44.05	0.73	0.98	1.42	13.97
340	0.86	30.82	82	117	184	22.96	30.23	44.15	0.74	0.98	1.43	14.39
350	0.89	30.67	83	117	185.5	23.17	30.23	44.47	0.76	0.99	1.45	14.82
360	0.91	30.51	84	117.5	187	23.37	30.34	44.78	0.77	0.99	1.47	15.24
370	0.94	30.36	85	118.5	188.5	23.58	30.54	45.09	0.78	1.01	1.49	15.66
380	0.97	30.21	85.5	118.5	190	23.69	30.54	45.40	0.78	1.01	1.50	16.09
390	0.99	30.06	86	119	191.5	23.79	30.65	45.71	0.79	1.02	1.52	16.51
400	1.02	29.90	86.2	119	191.5	23.83	30.65	45.71	0.80	1.02	1.53	16.93
410	1.04	29.75	86.8	119	192.5	23.96	30.65	45.92	0.81	1.03	1.54	17.36
420	1.07	29.60	87	119	193.2	24.00	30.65	46.07	0.81	1.04	1.56	17.78
430	1.09	29.45	87	119	193	24.00	30.65	46.02	0.81	1.04	1.56	18.20
440	1.12	29.29	87	119	193	24.00	30.65	46.02	0.82	1.05	1.57	18.63
450	1.14	29.14	87.5	119	193	24.10	30.65	46.02	0.83	1.05	1.58	19.05
460	1.17	28.99	87.5		193	24.10		46.02	0.83		1.59	19.47
470	1.19	28.84	87.5		193	24.10		46.02	0.84		1.60	19.90
480	1.22	28.68	87.5		193	24.10		46.02	0.84		1.60	20.32
490	1.24	28.53	87.5		193	24.10		46.02	0.84		1.61	20.74
500	1.27	28.38	87.5			24.10			0.85			21.17

Table A-16 The direct shear test result of 8B-72S-20U mixture at 80°C

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m³ :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	34.5	59	86	13.09	18.18	23.79	0.37	0.51	0.66	0.42
20	0.05	35.70	39	70.5	113.5	14.02	20.57	29.50	0.39	0.58	0.83	0.85
30	0.08	35.54	42	78	128	14.65	22.13	32.52	0.41	0.62	0.91	1.27
40	0.10	35.39	43	75	137	14.85	21.50	34.39	0.42	0.61	0.97	1.69
50	0.13	35.24	43	73	150	14.85	21.09	37.09	0.42	0.60	1.05	2.12
60	0.15	35.09	46	92	167	15.48	25.04	40.62	0.44	0.71	1.16	2.54
70	0.18	34.93	56.5	101	178.5	17.66	26.91	43.01	0.51	0.77	1.23	2.96
80	0.20	34.78	63	109	182.5	19.01	28.57	43.84	0.55	0.82	1.26	3.39
90	0.23	34.63	70	117	194.5	20.47	30.23	46.34	0.59	0.87	1.34	3.81
100	0.25	34.48	75.5	122.5	202.5	21.61	31.38	48.00	0.63	0.91	1.39	4.23
110	0.28	34.32	78.5	123	209	22.23	31.48	49.35	0.65	0.92	1.44	4.66
120	0.30	34.17	81.5	133.5	213.5	22.86	33.66	50.28	0.67	0.99	1.47	5.08
130	0.33	34.02	84	138	220	23.37	34.60	51.64	0.69	1.02	1.52	5.50
140	0.36	33.87	86.5	141	228	23.89	35.22	53.30	0.71	1.04	1.57	5.93
150	0.38	33.71	88	146	232.5	24.21	36.26	54.23	0.72	1.08	1.61	6.35
160	0.41	33.56	90	150	237.5	24.62	37.09	55.27	0.73	1.11	1.65	6.77
170	0.43	33.41	92.5	152.5	243	25.14	37.61	56.41	0.75	1.13	1.69	7.20
180	0.46	33.26	94.5	157	248	25.56	38.54	57.45	0.77	1.16	1.73	7.62
190	0.48	33.10	95.5	160	250.5	25.76	39.17	57.97	0.78	1.18	1.75	8.04
200	0.51	32.95	96	162	253	25.87	39.58	58.49	0.79	1.20	1.78	8.47
210	0.53	32.80	97	163	258	26.08	39.79	59.53	0.80	1.21	1.82	8.89
220	0.56	32.65	97.5	166.5	260.5	26.18	40.52	60.05	0.80	1.24	1.84	9.31
230	0.58	32.49	97.5	168	261.5	26.18	40.83	60.26	0.81	1.26	1.85	9.74
240	0.61	32.34	98	170	263.5	26.28	41.25	60.67	0.81	1.28	1.88	10.16
250	0.64	32.19	98	170	263.5	26.28	41.25	60.67	0.82	1.28	1.88	10.58
260	0.66	32.04	98	170	264	26.28	41.25	60.78	0.82	1.29	1.90	11.01
270	0.69	31.89	97	171	265	26.08	41.45	60.99	0.82	1.30	1.91	11.43
280	0.71	31.73	97.2	171	266	26.12	41.45	61.19	0.82	1.31	1.93	11.85
290	0.74	31.58	97	171	266	26.08	41.45	61.19	0.83	1.31	1.94	12.28
300	0.76	31.43	97	171.5	266.5	26.08	41.56	61.30	0.83	1.32	1.95	12.70
310	0.79	31.28	96.5	171.5	267	25.97	41.56	61.40	0.83	1.33	1.96	13.12
320	0.81	31.12	96.5	172	266.5	25.97	41.66	61.30	0.83	1.34	1.97	13.55
330	0.84	30.97	96.5	172	266.5	25.97	41.66	61.30	0.84	1.35	1.98	13.97
340	0.86	30.82	95.5	171.5	266.5	25.76	41.56	61.30	0.84	1.35	1.99	14.39
350	0.89	30.67	95.5	171.5	266.5	25.76	41.56	61.30	0.84	1.36	2.00	14.82
360	0.91	30.51	95.5	170.5	266	25.76	41.35	61.19	0.84	1.36	2.01	15.24
370	0.94	30.36	95.5	169.5	266	25.76	41.14	61.19	0.85	1.36	2.02	15.66
380	0.97	30.21	95.5	169.5		25.76	41.14		0.85	1.36		16.09
390	0.99	30.06	95.5	169		25.76	41.04		0.86	1.37		16.51
400	1.02	29.90		168			40.83			1.37		16.93

Table A-17 The direct shear test result of 18B-72S-10C mixture at room temperature

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m^3 :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması (Local Dial Reading)			Yatay Kesme Kuvveti (Horizantal Shear Force)			Kayma Gerilmesi (Shear Stress)			Birim Def. (Strain)
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	19	29.5	61.5	9.87	12.05	18.70	0.28	0.34	0.52	0.42
20	0.05	35.70	26	41	79.5	11.32	14.44	22.44	0.32	0.40	0.63	0.85
30	0.08	35.54	32	45	96.5	12.57	15.27	25.97	0.35	0.43	0.73	1.27
40	0.10	35.39	36	48	100.5	13.40	15.89	26.80	0.38	0.45	0.76	1.69
50	0.13	35.24	39	51.5	101.5	14.02	16.62	27.01	0.40	0.47	0.77	2.12
60	0.15	35.09	40.5	54	104	14.34	17.14	27.53	0.41	0.49	0.78	2.54
70	0.18	34.93	42.5	55.5	105	14.75	17.45	27.74	0.42	0.50	0.79	2.96
80	0.20	34.78	44	57	107	15.06	17.76	28.15	0.43	0.51	0.81	3.39
90	0.23	34.63	45	58.5	108	15.27	18.08	28.36	0.44	0.52	0.82	3.81
100	0.25	34.48	45	59.5	109	15.27	18.28	28.57	0.44	0.53	0.83	4.23
110	0.28	34.32	43.5	62	110	14.96	18.80	28.78	0.44	0.55	0.84	4.66
120	0.30	34.17	40	63	112.5	14.23	19.01	29.30	0.42	0.56	0.86	5.08
130	0.33	34.02	40	63.5	114.5	14.23	19.11	29.71	0.42	0.56	0.87	5.50
140	0.36	33.87	40	65	115	14.23	19.43	29.82	0.42	0.57	0.88	5.93
150	0.38	33.71	47	66.5	117	15.69	19.74	30.23	0.47	0.59	0.90	6.35
160	0.41	33.56	48.5	67	119.5	16.00	19.84	30.75	0.48	0.59	0.92	6.77
170	0.43	33.41	49.5	68.5	121	16.21	20.15	31.06	0.49	0.60	0.93	7.20
180	0.46	33.26	51.5	69	122	16.62	20.26	31.27	0.50	0.61	0.94	7.62
190	0.48	33.10	52	69	122.5	16.73	20.26	31.38	0.51	0.61	0.95	8.04
200	0.51	32.95	52.5	69	122.5	16.83	20.26	31.38	0.51	0.61	0.95	8.47
210	0.53	32.80	54	69.8	123.5	17.14	20.42	31.58	0.52	0.62	0.96	8.89
220	0.56	32.65	55.5	70.5	123	17.45	20.57	31.48	0.53	0.63	0.96	9.31
230	0.58	32.49	55.5	70.5	124	17.45	20.57	31.69	0.54	0.63	0.98	9.74
240	0.61	32.34	56	71	125	17.56	20.67	31.89	0.54	0.64	0.99	10.16
250	0.64	32.19	57.2	73	125	17.81	21.09	31.89	0.55	0.66	0.99	10.58
260	0.66	32.04	58	73.5	126	17.97	21.19	32.10	0.56	0.66	1.00	11.01
270	0.69	31.89	58.5	73.5	126	18.08	21.19	32.10	0.57	0.66	1.01	11.43
280	0.71	31.73	59.5	74	127	18.28	21.30	32.31	0.58	0.67	1.02	11.85
290	0.74	31.58	60.5	74.5	128	18.49	21.40	32.52	0.59	0.68	1.03	12.28
300	0.76	31.43	61	75	129	18.60	21.50	32.73	0.59	0.68	1.04	12.70
310	0.79	31.28	62.5	75	130.5	18.91	21.50	33.04	0.60	0.69	1.06	13.12
320	0.81	31.12	63	75	131	19.01	21.50	33.14	0.61	0.69	1.06	13.55
330	0.84	30.97	63.5	75	131.5	19.11	21.50	33.25	0.62	0.69	1.07	13.97
340	0.86	30.82	64	75.5	132.5	19.22	21.61	33.45	0.62	0.70	1.09	14.39
350	0.89	30.67	64.5	75.5	133	19.32	21.61	33.56	0.63	0.70	1.09	14.82
360	0.91	30.51	65	75.5	133	19.43	21.61	33.56	0.64	0.71	1.10	15.24
370	0.94	30.36	65.5	75.5	133.5	19.53	21.61	33.66	0.64	0.71	1.11	15.66
380	0.97	30.21	66.5	76	134.5	19.74	21.71	33.87	0.65	0.72	1.12	16.09
390	0.99	30.06	67	76	134	19.84	21.71	33.76	0.66	0.72	1.12	16.51
400	1.02	29.90	67.5	77.5	134.5	19.95	22.02	33.87	0.67	0.74	1.13	16.93
410	1.04	29.75	68	78	135	20.05	22.13	33.97	0.67	0.74	1.14	17.36
420	1.07	29.60	68.5	80.5	135	20.15	22.65	33.97	0.68	0.77	1.15	17.78
430	1.09	29.45	69.5	82.5	135	20.36	23.06	33.97	0.69	0.78	1.15	18.20
440	1.12	29.29	69.5	83	135	20.36	23.17	33.97	0.70	0.79	1.16	18.63
450	1.14	29.14	69.5	84	135	20.36	23.37	33.97	0.70	0.80	1.17	19.05
460	1.17	28.99		85			23.58			0.81		19.47
470	1.19	28.84		85			23.58			0.82		19.90
480	1.22	28.68		85			23.58			0.82		20.32
490	1.24	28.53		85			23.58			0.83		20.74

Table A-18 The direct shear test result of 18B-72S-10C mixture at 80°C

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	
Sondaj No	*(Boring No) :*	
Örnek No	*(Sample No) :*	
Derinlik	*(Depth) :*	

Yapan	*(Tested By) :*	
Tarih	*(Date) :*	

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m³ :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm²	-	-	-	kg	kg	kg	kg/cm²	kg/cm²	kg/cm²	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	35	52	82	13.19	16.73	22.96	0.37	0.47	0.64	0.42
20	0.05	35.70	45	62	97.5	15.27	18.80	26.18	0.43	0.53	0.73	0.85
30	0.08	35.54	49.5	64	110.5	16.21	19.22	28.88	0.46	0.54	0.81	1.27
40	0.10	35.39	56.5	66	118.5	17.66	19.63	30.54	0.50	0.55	0.86	1.69
50	0.13	35.24	58	67.5	124.5	17.97	19.95	31.79	0.51	0.57	0.90	2.12
60	0.15	35.09	60.5	73	131	18.49	21.09	33.14	0.53	0.60	0.94	2.54
70	0.18	34.93	63	75	135	19.01	21.50	33.97	0.54	0.62	0.97	2.96
80	0.20	34.78	64.5	76	138	19.32	21.71	34.60	0.56	0.62	0.99	3.39
90	0.23	34.63	67.5	77	141	19.95	21.92	35.22	0.58	0.63	1.02	3.81
100	0.25	34.48	69	78	144.5	20.26	22.13	35.95	0.59	0.64	1.04	4.23
110	0.28	34.32	70	78.5	147	20.47	22.23	36.47	0.60	0.65	1.06	4.66
120	0.30	34.17	74	83	151	21.30	23.17	37.30	0.62	0.68	1.09	5.08
130	0.33	34.02	75	89.5	152.5	21.50	24.52	37.61	0.63	0.72	1.11	5.50
140	0.36	33.87	77.5	94.5	154.5	22.02	25.56	38.02	0.65	0.75	1.12	5.93
150	0.38	33.71	79.5	96.5	156.5	22.44	25.97	38.44	0.67	0.77	1.14	6.35
160	0.41	33.56	80.5	97.5	158.5	22.65	26.18	38.86	0.67	0.78	1.16	6.77
170	0.43	33.41	82.5	101	160	23.06	26.91	39.17	0.69	0.81	1.17	7.20
180	0.46	33.26	84.5	104	162.5	23.48	27.53	39.69	0.71	0.83	1.19	7.62
190	0.48	33.10	85.5	107	164	23.69	28.15	40.00	0.72	0.85	1.21	8.04
200	0.51	32.95	85.5	108	165.5	23.69	28.36	40.31	0.72	0.86	1.22	8.47
210	0.53	32.80	87	108.5	166	24.00	28.47	40.41	0.73	0.87	1.23	8.89
220	0.56	32.65	88	109	166	24.21	28.57	40.41	0.74	0.88	1.24	9.31
230	0.58	32.49	88.5	109.5	167	24.31	28.67	40.62	0.75	0.88	1.25	9.74
240	0.61	32.34	89.5	110.5	167.5	24.52	28.88	40.73	0.76	0.89	1.26	10.16
250	0.64	32.19	90	111.5	167.5	24.62	29.09	40.73	0.76	0.90	1.27	10.58
260	0.66	32.04	90.5	113	168.5	24.73	29.40	40.93	0.77	0.92	1.28	11.01
270	0.69	31.89	92	114.5	169	25.04	29.71	41.04	0.79	0.93	1.29	11.43
280	0.71	31.73	93.5	117	169	25.35	30.23	41.04	0.80	0.95	1.29	11.85
290	0.74	31.58	93.5	117	170	25.35	30.23	41.25	0.80	0.96	1.31	12.28
300	0.76	31.43	94	118	169.5	25.45	30.44	41.14	0.81	0.97	1.31	12.70
310	0.79	31.28	95.5	118	169.5	25.76	30.44	41.14	0.82	0.97	1.32	13.12
320	0.81	31.12	96.5	120	170	25.97	30.86	41.25	0.83	0.99	1.33	13.55
330	0.84	30.97	97.5	120.5	171	26.18	30.96	41.45	0.85	1.00	1.34	13.97
340	0.86	30.82	97.5	122.5	172	26.18	31.38	41.66	0.85	1.02	1.35	14.39
350	0.89	30.67	98.5	123.5	172.8	26.39	31.58	41.83	0.86	1.03	1.36	14.82
360	0.91	30.51	98.5	124	173	26.39	31.69	41.87	0.86	1.04	1.37	15.24
370	0.94	30.36	99	125	173.8	26.49	31.89	42.04	0.87	1.05	1.38	15.66
380	0.97	30.21	99.5	125	174	26.60	31.89	42.08	0.88	1.06	1.39	16.09
390	0.99	30.06	99.8	126	174	26.66	32.10	42.08	0.89	1.07	1.40	16.51
400	1.02	29.90	101	128	175	26.91	32.52	42.28	0.90	1.09	1.41	16.93
410	1.04	29.75	101.5	128	175	27.01	32.52	42.28	0.91	1.09	1.42	17.36
420	1.07	29.60	102	128	175	27.12	32.52	42.28	0.92	1.10	1.43	17.78
430	1.09	29.45	102	128	175	27.12	32.52	42.28	0.92	1.10	1.44	18.20
440	1.12	29.29	102	128	175	27.12	32.52	42.28	0.93	1.11	1.44	18.63
450	1.14	29.14	102			27.12			0.93			19.05

Table A-19 The direct shear test result of 16B-64S-20C mixture at room temperature

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m^3 :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	19.5	32	48	9.97	12.57	15.89	0.28	0.35	0.44	0.42
20	0.05	35.70	26.5	42	62	11.43	14.65	18.80	0.32	0.41	0.53	0.85
30	0.08	35.54	27	52	71.5	11.53	16.73	20.78	0.32	0.47	0.58	1.27
40	0.10	35.39	25	55	76.5	11.11	17.35	21.82	0.31	0.49	0.62	1.69
50	0.13	35.24	25.5	56	81	11.22	17.56	22.75	0.32	0.50	0.65	2.12
60	0.15	35.09	25	56	83	11.11	17.56	23.17	0.32	0.50	0.66	2.54
70	0.18	34.93	25	58	84	11.11	17.97	23.37	0.32	0.51	0.67	2.96
80	0.20	34.78	35.5	58.5	86	13.30	18.08	23.79	0.38	0.52	0.68	3.39
90	0.23	34.63	38	60	87.5	13.82	18.39	24.10	0.40	0.53	0.70	3.81
100	0.25	34.48	39	62	88.5	14.02	18.80	24.31	0.41	0.55	0.71	4.23
110	0.28	34.32	39.5	63	91	14.13	19.01	24.83	0.41	0.55	0.72	4.66
120	0.30	34.17	40.5	64	91.5	14.34	19.22	24.93	0.42	0.56	0.73	5.08
130	0.33	34.02	41	65	92.5	14.44	19.43	25.14	0.42	0.57	0.74	5.50
140	0.36	33.87	42	65.5	93	14.65	19.53	25.24	0.43	0.58	0.75	5.93
150	0.38	33.71	43	67.5	94	14.85	19.95	25.45	0.44	0.59	0.75	6.35
160	0.41	33.56	43.5	68	96.3	14.96	20.05	25.93	0.45	0.60	0.77	6.77
170	0.43	33.41	44.5	68.5	96.5	15.17	20.15	25.97	0.45	0.60	0.78	7.20
180	0.46	33.26	45	69.5	96.5	15.27	20.36	25.97	0.46	0.61	0.78	7.62
190	0.48	33.10	45.5	69.5	96.5	15.37	20.36	25.97	0.46	0.62	0.78	8.04
200	0.51	32.95	46.5	69.5	97	15.58	20.36	26.08	0.47	0.62	0.79	8.47
210	0.53	32.80	47.5	70	97.5	15.79	20.47	26.18	0.48	0.62	0.80	8.89
220	0.56	32.65	47.5	70	97.5	15.79	20.47	26.18	0.48	0.63	0.80	9.31
230	0.58	32.49	48.5	71	97.5	16.00	20.67	26.18	0.49	0.64	0.81	9.74
240	0.61	32.34	48.5	71.5	97.5	16.00	20.78	26.18	0.49	0.64	0.81	10.16
250	0.64	32.19	49	72	98	16.10	20.88	26.28	0.50	0.65	0.82	10.58
260	0.66	32.04	49.5	72	98	16.21	20.88	26.28	0.51	0.65	0.82	11.01
270	0.69	31.89	49.5	72.5	98.5	16.21	20.99	26.39	0.51	0.66	0.83	11.43
280	0.71	31.73	50	72.5	98.5	16.31	20.99	26.39	0.51	0.66	0.83	11.85
290	0.74	31.58	50.5	73	99	16.41	21.09	26.49	0.52	0.67	0.84	12.28
300	0.76	31.43	51	73.5	99	16.52	21.19	26.49	0.53	0.67	0.84	12.70
310	0.79	31.28	51.5	74	99	16.62	21.30	26.49	0.53	0.68	0.85	13.12
320	0.81	31.12	52	74.5	99	16.73	21.40	26.49	0.54	0.69	0.85	13.55
330	0.84	30.97	52.5	74.5	99.5	16.83	21.40	26.60	0.54	0.69	0.86	13.97
340	0.86	30.82	53	74.5	99.5	16.93	21.40	26.60	0.55	0.69	0.86	14.39
350	0.89	30.67	53.2	75	100.5	16.97	21.50	26.80	0.55	0.70	0.87	14.82
360	0.91	30.51	53.5	75	100.5	17.04	21.50	26.80	0.56	0.70	0.88	15.24
370	0.94	30.36	54	75	101.5	17.14	21.50	27.01	0.56	0.71	0.89	15.66
380	0.97	30.21	54	75.5	102	17.14	21.61	27.12	0.57	0.72	0.90	16.09
390	0.99	30.06	54.5	75.5	102.5	17.24	21.61	27.22	0.57	0.72	0.91	16.51
400	1.02	29.90	54.8	76	102.5	17.31	21.71	27.22	0.58	0.73	0.91	16.93
410	1.04	29.75	55	76	102.5	17.35	21.71	27.22	0.58	0.73	0.91	17.36
420	1.07	29.60	55.5	76.5	102.5	17.45	21.82	27.22	0.59	0.74	0.92	17.78
430	1.09	29.45	55.5	76.5	102.5	17.45	21.82	27.22	0.59	0.74	0.92	18.20
440	1.12	29.29	56	76.5		17.56	21.82		0.60	0.74		18.63
450	1.14	29.14	56	76.5		17.56			0.60			19.05
460	1.17	28.99	56									19.47
470	1.19	28.84	56									19.90

Table A-20 The direct shear test result of 16B-64S-20C mixture at 80°C

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*	
Sondaj No	*(Boring No) :*	
Örnek No	*(Sample No) :*	
Derinlik	*(Depth) :*	

Yapan	*(Tested By) :*	
Tarih	*(Date) :*	

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m³ :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması			Yatay Kesme Kuvveti			Kayma Gerilmesi			Birim Def.
			Local Dial Reading			*Horizantal Shear Force*			*Shear Stress*			*Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	32	38.5	55	12.57	13.92	17.35	0.35	0.39	0.48	0.42
20	0.05	35.70	39.5	49	78	14.13	16.10	22.13	0.40	0.45	0.62	0.85
30	0.08	35.54	44	59	89.5	15.06	18.18	24.52	0.42	0.51	0.69	1.27
40	0.10	35.39	40	61	94	14.23	18.60	25.45	0.40	0.53	0.72	1.69
50	0.13	35.24	38	62.9	94	13.82	18.99	25.45	0.39	0.54	0.72	2.12
60	0.15	35.09	35	63.5	95	13.19	19.11	25.66	0.38	0.54	0.73	2.54
70	0.18	34.93	36	65	95.5	13.40	19.43	25.76	0.38	0.56	0.74	2.96
80	0.20	34.78	33	66	96.5	12.78	19.63	25.97	0.37	0.56	0.75	3.39
90	0.23	34.63	48	67	97.5	15.89	19.84	26.18	0.46	0.57	0.76	3.81
100	0.25	34.48	48.5	68	98	16.00	20.05	26.28	0.46	0.58	0.76	4.23
110	0.28	34.32	49	70	100	16.10	20.47	26.70	0.47	0.60	0.78	4.66
120	0.30	34.17	49	71.5	101	16.10	20.78	26.91	0.47	0.61	0.79	5.08
130	0.33	34.02	49.5	72.5	102	16.21	20.99	27.12	0.48	0.62	0.80	5.50
140	0.36	33.87	50	73	103.5	16.31	21.09	27.43	0.48	0.62	0.81	5.93
150	0.38	33.71	51	74	104	16.52	21.30	27.53	0.49	0.63	0.82	6.35
160	0.41	33.56	52.5	74	104.5	16.83	21.30	27.63	0.50	0.63	0.82	6.77
170	0.43	33.41	53.5	74	105.5	17.04	21.30	27.84	0.51	0.64	0.83	7.20
180	0.46	33.26	54	74.2	106.5	17.14	21.34	28.05	0.52	0.64	0.84	7.62
190	0.48	33.10	54.5	75	106.5	17.24	21.50	28.05	0.52	0.65	0.85	8.04
200	0.51	32.95	55	75	107	17.35	21.50	28.15	0.53	0.65	0.85	8.47
210	0.53	32.80	56	75	107	17.56	21.50	28.15	0.54	0.66	0.86	8.89
220	0.56	32.65	56.5	75	108	17.66	21.50	28.36	0.54	0.66	0.87	9.31
230	0.58	32.49	56.5	76	109	17.66	21.71	28.57	0.54	0.67	0.88	9.74
240	0.61	32.34	57	76.5	109.5	17.76	21.82	28.67	0.55	0.67	0.89	10.16
250	0.64	32.19	57.5	76.5	109.5	17.87	21.82	28.67	0.56	0.68	0.89	10.58
260	0.66	32.04	58.5	76.5	109.5	18.08	21.82	28.67	0.56	0.68	0.89	11.01
270	0.69	31.89	58.5	77	111.5	18.08	21.92	29.09	0.57	0.69	0.91	11.43
280	0.71	31.73	59.5	77	112	18.28	21.92	29.19	0.58	0.69	0.92	11.85
290	0.74	31.58	60	77	113.5	18.39	21.92	29.50	0.58	0.69	0.93	12.28
300	0.76	31.43	60.5	77.2	113.5	18.49	21.96	29.50	0.59	0.70	0.94	12.70
310	0.79	31.28	61	78	114.5	18.60	22.13	29.71	0.59	0.71	0.95	13.12
320	0.81	31.12	61	78.5	115	18.60	22.23	29.82	0.60	0.71	0.96	13.55
330	0.84	30.97	62	78.5	115	18.80	22.23	29.82	0.61	0.72	0.96	13.97
340	0.86	30.82	62.2	79	116	18.84	22.34	30.02	0.61	0.72	0.97	14.39
350	0.89	30.67	62.9	79	117	18.99	22.34	30.23	0.62	0.73	0.99	14.82
360	0.91	30.51	63.2	79	117	19.05	22.34	30.23	0.62	0.73	0.99	15.24
370	0.94	30.36	63.5	79	117	19.11	22.34	30.23	0.63	0.74	1.00	15.66
380	0.97	30.21	63.5	79	119	19.11	22.34	30.65	0.63	0.74	1.01	16.09
390	0.99	30.06	64	79	119	19.22	22.34	30.65	0.64	0.74	1.02	16.51
400	1.02	29.90	64	79	119	19.22	22.34	30.65	0.64	0.75	1.02	16.93
410	1.04	29.75	64		124	19.22		31.69	0.65		1.07	17.36
420	1.07	29.60	64		124	19.22		31.69	0.65		1.07	17.78
430	1.09	29.45	64		123	19.22		31.48	0.65		1.07	18.20
440	1.12	29.29			123			31.48			1.07	18.63
450	1.14	29.14			122			31.27			1.07	19.05

Table A-21 The direct shear test result of 18B-72S-10T mixture at room temperature

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m³ :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	16	24.5	72	9.24	11.01	20.88	0.26	0.31	0.58	0.42
20	0.05	35.70	22.5	27	91	10.60	11.53	24.83	0.30	0.32	0.70	0.85
30	0.08	35.54	25	38.5	103.5	11.11	13.92	27.43	0.31	0.39	0.77	1.27
40	0.10	35.39	26.5	45.5	111.5	11.43	15.37	29.09	0.32	0.43	0.82	1.69
50	0.13	35.24	25	50	117.5	11.11	16.31	30.34	0.32	0.46	0.86	2.12
60	0.15	35.09	26	48.5	125	11.32	16.00	31.89	0.32	0.46	0.91	2.54
70	0.18	34.93	26.5	47	127.5	11.43	15.69	32.41	0.33	0.45	0.93	2.96
80	0.20	34.78	31	52	130	12.36	16.73	32.93	0.36	0.48	0.95	3.39
90	0.23	34.63	43	60	130	14.85	18.39	32.93	0.43	0.53	0.95	3.81
100	0.25	34.48	46	63.5	132.5	15.48	19.11	33.45	0.45	0.55	0.97	4.23
110	0.28	34.32	48.8	67.5	135	16.06	19.95	33.97	0.47	0.58	0.99	4.66
120	0.30	34.17	51.5	70	138	16.62	20.47	34.60	0.49	0.60	1.01	5.08
130	0.33	34.02	55.2	73.2	139.5	17.39	21.13	34.91	0.51	0.62	1.03	5.50
140	0.36	33.87	58	74.5	138.5	17.97	21.40	34.70	0.53	0.63	1.02	5.93
150	0.38	33.71	60.5	77.5	138.5	18.49	22.02	34.70	0.55	0.65	1.03	6.35
160	0.41	33.56	63.5	79.8	147	19.11	22.50	36.47	0.57	0.67	1.09	6.77
170	0.43	33.41	65.5	81.5	147.2	19.53	22.86	36.51	0.58	0.68	1.09	7.20
180	0.46	33.26	67.2	83.5	148.5	19.88	23.27	36.78	0.60	0.70	1.11	7.62
190	0.48	33.10	69.2	86	151	20.30	23.79	37.30	0.61	0.72	1.13	8.04
200	0.51	32.95	71	86.5	151	20.67	23.89	37.30	0.63	0.73	1.13	8.47
210	0.53	32.80	72.5	88	153	20.99	24.21	37.71	0.64	0.74	1.15	8.89
220	0.56	32.65	73.5	89.5	154.5	21.19	24.52	38.02	0.65	0.75	1.16	9.31
230	0.58	32.49	75.2	91	156	21.55	24.83	38.34	0.66	0.76	1.18	9.74
240	0.61	32.34	76	93	157.9	21.71	25.24	38.73	0.67	0.78	1.20	10.16
250	0.64	32.19	77.2	94.5	158.2	21.96	25.56	38.79	0.68	0.79	1.21	10.58
260	0.66	32.04	78	95	159.2	22.13	25.66	39.00	0.69	0.80	1.22	11.01
270	0.69	31.89	79	96	160	22.34	25.87	39.17	0.70	0.81	1.23	11.43
280	0.71	31.73	79.5	97.5	161	22.44	26.18	39.38	0.71	0.83	1.24	11.85
290	0.74	31.58	80	98	163.5	22.54	26.28	39.89	0.71	0.83	1.26	12.28
300	0.76	31.43	81	98.5	164.5	22.75	26.39	40.10	0.72	0.84	1.28	12.70
310	0.79	31.28	82	99	164.6	22.96	26.49	40.12	0.73	0.85	1.28	13.12
320	0.81	31.12	83.2	99.5	165	23.21	26.60	40.21	0.75	0.85	1.29	13.55
330	0.84	30.97	83.5	99.6	165.5	23.27	26.62	40.31	0.75	0.86	1.30	13.97
340	0.86	30.82	84.5	100	165.5	23.48	26.70	40.31	0.76	0.87	1.31	14.39
350	0.89	30.67	85	100.5	165.8	23.58	26.80	40.37	0.77	0.87	1.32	14.82
360	0.91	30.51	85.5	101	165.8	23.69	26.91	40.37	0.78	0.88	1.32	15.24
370	0.94	30.36	85.5	102	165.8	23.69	27.12	40.37	0.78	0.89	1.33	15.66
380	0.97	30.21	85.8	102	165.2	23.75	27.12	40.25	0.79	0.90	1.33	16.09
390	0.99	30.06	86	102.5	165.2	23.79	27.22	40.25	0.79	0.91	1.34	16.51
400	1.02	29.90	86.2	103	165.6	23.83	27.32	40.33	0.80	0.91	1.35	16.93
410	1.04	29.75	86.5	103.5	165.9	23.89	27.43	40.39	0.80	0.92	1.36	17.36
420	1.07	29.60	86.5	103.9	166.2	23.89	27.51	40.46	0.81	0.93	1.37	17.78
430	1.09	29.45	86.5	104	166.2	23.89	27.53	40.46	0.81	0.93	1.37	18.20
440	1.12	29.29	86.5	104	166.2	23.89	27.53	40.46	0.82	0.94	1.38	18.63
450	1.14	29.14	86	104.5	166.2	23.79	27.63	40.46	0.82	0.95	1.39	19.05
460	1.17	28.99	86	105	165.5	23.79	27.74	40.31	0.82	0.96	1.39	19.47
470	1.19	28.84	86	105.3	165.5	23.79	27.80	40.31	0.82	0.96	1.40	19.90
480	1.22	28.68	86	106	165.5	23.79	27.95	40.31	0.83	0.97	1.41	20.32
490	1.24	28.53	86	106	165.5	23.79	27.95	40.31	0.83	0.98	1.41	20.74
500	1.27	28.38	86	106	165.5	23.79	27.95	40.31	0.84	0.98	1.42	21.17
510	1.30	28.23		106	165.5		27.95	40.31		0.99	1.43	21.59
520	1.32	28.08		106.5	165.5		28.05	40.31		1.00	1.44	22.01
530	1.35	27.92		106.5			28.05			1.00		22.44
540	1.37	27.77		106.2			27.99			1.01		22.86
550	1.40	27.62		106.5			28.05			1.02		23.28
560	1.42	27.47		106.5			28.05			1.02		23.71
570	1.45	27.31		106.5			28.05			1.03		24.13
580	1.47	27.16		106.5			28.05			1.03		24.55

Table A-22 The direct shear test result of 18B-72S-10T mixture at 80°C

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :* 6X6X2
Örnek Ağırlığı	*(sample weight) gr :*
Doğal b.h.a	*(natural unit weight) t/m^3 :*
Yükleme Hızı	*(loading rate) mm/dak :* 0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	19.5	47.5	51	9.97	15.79	16.52	0.28	0.44	0.46	0.42
20	0.05	35.70	28	53.5	86.3	11.74	17.04	23.85	0.33	0.48	0.67	0.85
30	0.08	35.54	34	47	102.5	12.98	15.69	27.22	0.37	0.44	0.77	1.27
40	0.10	35.39	34	50	110	12.98	16.31	28.78	0.37	0.46	0.81	1.69
50	0.13	35.24	34	62	116	12.98	18.80	30.02	0.37	0.53	0.85	2.12
60	0.15	35.09	34	60	119	12.98	18.39	30.65	0.37	0.52	0.87	2.54
70	0.18	34.93	35	65	121	13.19	19.43	31.06	0.38	0.56	0.89	2.96
80	0.20	34.78	35.3	66	124	13.25	19.63	31.69	0.38	0.56	0.91	3.39
90	0.23	34.63	36.3	68.8	126	13.46	20.22	32.10	0.39	0.58	0.93	3.81
100	0.25	34.48	37	70	128.3	13.61	20.47	32.58	0.39	0.59	0.95	4.23
110	0.28	34.32	37.5	74	132	13.71	21.30	33.35	0.40	0.62	0.97	4.66
120	0.30	34.17	37.8	74	134.5	13.77	21.30	33.87	0.40	0.62	0.99	5.08
130	0.33	34.02	38	75.5	137	13.82	21.61	34.39	0.41	0.64	1.01	5.50
140	0.36	33.87	40	77	140	14.23	21.92	35.01	0.42	0.65	1.03	5.93
150	0.38	33.71	40.3	78.5	142	14.29	22.23	35.43	0.42	0.66	1.05	6.35
160	0.41	33.56	40.9	80.2	144	14.42	22.59	35.84	0.43	0.67	1.07	6.77
170	0.43	33.41	43.2	81.9	146	14.90	22.94	36.26	0.45	0.69	1.09	7.20
180	0.46	33.26	43.5	82	148.1	14.96	22.96	36.69	0.45	0.69	1.10	7.62
190	0.48	33.10	43.8	83.2	150.5	15.02	23.21	37.19	0.45	0.70	1.12	8.04
200	0.51	32.95	43.5	83.2	150.2	14.96	23.21	37.13	0.45	0.70	1.13	8.47
210	0.53	32.80	43.5	84.2	151	14.96	23.42	37.30	0.46	0.71	1.14	8.89
220	0.56	32.65	43.5	85.8	152.5	14.96	23.75	37.61	0.46	0.73	1.15	9.31
230	0.58	32.49	43	86.2	152.5	14.85	23.83	37.61	0.46	0.73	1.16	9.74
240	0.61	32.34	43.2	86.2	153.5	14.90	23.83	37.82	0.46	0.74	1.17	10.16
250	0.64	32.19	43.8	87.5	154	15.02	24.10	37.92	0.47	0.75	1.18	10.58
260	0.66	32.04	43.8	87.5	156.2	15.02	24.10	38.38	0.47	0.75	1.20	11.01
270	0.69	31.89	45.2	88	156.8	15.31	24.21	38.50	0.48	0.76	1.21	11.43
280	0.71	31.73	45.2	88.8	157.5	15.31	24.37	38.65	0.48	0.77	1.22	11.85
290	0.74	31.58	45.5	88.5	154	15.37	24.31	37.92	0.49	0.77	1.20	12.28
300	0.76	31.43	45.5	89.5	156.9	15.37	24.52	38.52	0.49	0.78	1.23	12.70
310	0.79	31.28	45.6	89.5	157	15.40	24.52	38.54	0.49	0.78	1.23	13.12
320	0.81	31.12	45.5	90.5	159	15.37	24.73	38.96	0.49	0.79	1.25	13.55
330	0.84	30.97	45.5	91	158.5	15.37	24.83	38.86	0.50	0.80	1.25	13.97
340	0.86	30.82	45.6	92.5	158.5	15.40	25.14	38.86	0.50	0.82	1.26	14.39
350	0.89	30.67	45.8	92.8	159.8	15.44	25.20	39.13	0.50	0.82	1.28	14.82
360	0.91	30.51	45.3	94.5	159.2	15.33	25.56	39.00	0.50	0.84	1.28	15.24
370	0.94	30.36	42.5	94.8	158.5	14.75	25.62	38.86	0.49	0.84	1.28	15.66
380	0.97	30.21	43.9	94.9	160.5	15.04	25.64	39.27	0.50	0.85	1.30	16.09
390	0.99	30.06	44.8	95.2	161.2	15.23	25.70	39.42	0.51	0.86	1.31	16.51
400	1.02	29.90	44.9	95.1	161.2	15.25	25.68	39.42	0.51	0.86	1.32	16.93
410	1.04	29.75	44.5	95.3	161	15.17	25.72	39.38	0.51	0.86	1.32	17.36
420	1.07	29.60	45	96.5	162	15.27	25.97	39.58	0.52	0.88	1.34	17.78
430	1.09	29.45	45.2	96.8	162.2	15.31	26.03	39.62	0.52	0.88	1.35	18.20
440	1.12	29.29	46.7	97.5	162	15.62	26.18	39.58	0.53	0.89	1.35	18.63
450	1.14	29.14	46	97.9	160.5	15.48	26.26	39.27	0.53	0.90	1.35	19.05
460	1.17	28.99	46	97.9	160.5	15.48	26.26	39.27	0.53	0.91	1.35	19.47
470	1.19	28.84	46.2	98	163.0	15.52	26.28	39.79	0.54	0.91	1.38	19.90
480	1.22	28.68	46.8	98.3	163.8	15.64	26.35	39.96	0.55	0.92	1.39	20.32
490	1.24	28.53	46.8	99	164.5	15.64	26.49	40.10	0.55	0.93	1.41	20.74
500	1.27	28.38	47	99.3	166.0	15.69	26.55	40.41	0.55	0.94	1.42	21.17
510	1.30	28.23	48	100	166.8	15.89	26.70	40.58	0.56	0.95	1.44	21.59
520	1.32	28.08	49	100.9	169.0	16.10	26.89	41.04	0.57	0.96	1.46	22.01
530	1.35	27.92	50	102.2	169.2	16.31	27.16	41.08	0.58	0.97	1.47	22.44
540	1.37	27.77	52	103.2	170.5	16.73	27.36	41.35	0.60	0.99	1.49	22.86
550	1.40	27.62	51.5	103.9	172.1	16.62	27.51	41.68	0.60	1.00	1.51	23.28
560	1.42	27.47	51.3	105	172.1	16.58	27.74	41.68	0.60	1.01	1.52	23.71
570	1.45	27.31	51.2	105	173.0	16.56	27.74	41.87	0.61	1.02	1.53	24.13
580	1.47	27.16	51.2	105.8	171.9	16.56	27.90	41.64	0.61	1.03	1.53	24.55
590	1.50	27.01	51.5	105	173.0	16.62	27.74	41.87	0.62	1.03	1.55	24.98
600	1.52	26.86	52.5	105.2	176.5	16.83	27.78	42.60	0.63	1.03	1.59	25.40
610	1.55	26.70	52.5	105.2	178.8	16.83	27.78	43.07	0.63	1.04	1.61	25.82
620	1.57	26.55	52.7	105.2	176.0	16.87	27.78	42.49	0.64	1.05	1.60	26.25
630	1.60	26.40	53	105.2	176.9	16.93	27.78	42.68	0.64	1.05	1.62	26.67
640	1.63	26.25	52.7	105.2	176.9	16.87	27.78	42.68	0.64	1.06	1.63	27.09
650	1.65	26.09	52.9	105.2	178.3	16.91	27.78	42.97	0.65	1.06	1.65	27.52
660	1.68	25.94	54.2			17.18			0.66			27.94
670	1.70	25.79	55			17.35			0.67			28.36
680	1.73	25.64	55			17.35			0.68			28.79

Table A-23 The direct shear test result of 16B-64S-20T mixture at room temperature

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :* 6X6X2
Örnek Ağırlığı	*(sample weight) gr :*
Doğal b.h.a	*(natural unit weight) t/m³ :*
Yükleme Hızı	*(loading rate) mm/dak :* 0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm²	-	-	-	kg	kg	kg	kg/cm²	kg/cm²	kg/cm²	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	11	35	83	8.21	13.19	23.17	0.23	0.37	0.65	0.42
20	0.05	35.70	19	47	99	9.87	15.69	26.49	0.28	0.44	0.74	0.85
30	0.08	35.54	22	55	93	10.49	17.35	25.24	0.30	0.49	0.71	1.27
40	0.10	35.39	23	60	89.5	10.70	18.39	24.52	0.30	0.52	0.69	1.69
50	0.13	35.24	25	66.5	87.5	11.11	19.74	24.10	0.32	0.56	0.68	2.12
60	0.15	35.09	26	64.5	88	11.32	19.32	24.21	0.32	0.55	0.69	2.54
70	0.18	34.93	31.2	64	111.5	12.40	19.22	29.09	0.36	0.55	0.83	2.96
80	0.20	34.78	35	75.5	117.5	13.19	21.61	30.34	0.38	0.62	0.87	3.39
90	0.23	34.63	38.5	77	127	13.92	21.92	32.31	0.40	0.63	0.93	3.81
100	0.25	34.48	42	79.5	131.5	14.65	22.44	33.25	0.42	0.65	0.96	4.23
110	0.28	34.32	43	82	135.5	14.85	22.96	34.08	0.43	0.67	0.99	4.66
120	0.30	34.17	45.8	85	136	15.44	23.58	34.18	0.45	0.69	1.00	5.08
130	0.33	34.02	48	87.8	137	15.89	24.16	34.39	0.47	0.71	1.01	5.50
140	0.36	33.87	50	90	140.5	16.31	24.62	35.12	0.48	0.73	1.04	5.93
150	0.38	33.71	52.8	92.8	144	16.89	25.20	35.84	0.50	0.75	1.06	6.35
160	0.41	33.56	55.5	95	145	17.45	25.66	36.05	0.52	0.76	1.07	6.77
170	0.43	33.41	57	95.5	147	17.76	25.76	36.47	0.53	0.77	1.09	7.20
180	0.46	33.26	58.5	97.5	148	18.08	26.18	36.67	0.54	0.79	1.10	7.62
190	0.48	33.10	60	99.5	150	18.39	26.60	37.09	0.56	0.80	1.12	8.04
200	0.51	32.95	61	100.5	152	18.60	26.80	37.51	0.56	0.81	1.14	8.47
210	0.53	32.80	63.2	101.8	152.9	19.05	27.07	37.69	0.58	0.83	1.15	8.89
220	0.56	32.65	64.3	103	154.2	19.28	27.32	37.96	0.59	0.84	1.16	9.31
230	0.58	32.49	65.8	104	155	19.59	27.53	38.13	0.60	0.85	1.17	9.74
240	0.61	32.34	67	105	156.5	19.84	27.74	38.44	0.61	0.86	1.19	10.16
250	0.64	32.19	68.7	105.5	157	20.20	27.84	38.54	0.63	0.86	1.20	10.58
260	0.66	32.04	70	106.2	157.5	20.47	27.99	38.65	0.64	0.87	1.21	11.01
270	0.69	31.89	70.5	108	158.2	20.57	28.36	38.79	0.65	0.89	1.22	11.43
280	0.71	31.73	72.2	109	158.2	20.92	28.57	38.79	0.66	0.90	1.22	11.85
290	0.74	31.58	72.8	109.8	158.8	21.05	28.74	38.92	0.67	0.91	1.23	12.28
300	0.76	31.43	73.5	111	158.8	21.19	28.99	38.92	0.67	0.92	1.24	12.70
310	0.79	31.28	74	111.5	158.9	21.30	29.09	38.94	0.68	0.93	1.25	13.12
320	0.81	31.12	74.8	112	158.9	21.46	29.19	38.94	0.69	0.94	1.25	13.55
330	0.84	30.97	74.8	112.2	158.9	21.46	29.23	38.94	0.69	0.94	1.26	13.97
340	0.86	30.82	75.8	112.5	158.2	21.67	29.30	38.79	0.70	0.95	1.26	14.39
350	0.89	30.67	76.2	113	158.2	21.75	29.40	38.79	0.71	0.96	1.27	14.82
360	0.91	30.51	77	113.5	157.8	21.92	29.50	38.71	0.72	0.97	1.27	15.24
370	0.94	30.36	78	113.5	157.8	22.13	29.50	38.71	0.73	0.97	1.27	15.66
380	0.97	30.21	78.5	113.5	157.8	22.23	29.50	38.71	0.74	0.98	1.28	16.09
390	0.99	30.06	79	113.5	157.5	22.34	29.50	38.65	0.74	0.98	1.29	16.51
400	1.02	29.90	79.5	113.5	157.5	22.44	29.50	38.65	0.75	0.99	1.29	16.93
410	1.04	29.75	80	113.5	157.0	22.54	29.50	38.54	0.76	0.99	1.30	17.36
420	1.07	29.60	80.8	113.2		22.71	29.44		0.77	0.99		17.78
430	1.09	29.45	80.9	113		22.73	29.40		0.77	1.00		18.20
440	1.12	29.29	81	113		22.75	29.40		0.78	1.00		18.63
450	1.14	29.14	81.1	112.9		22.77	29.38		0.78	1.01		19.05
460	1.17	28.99	81.2	112.9		22.79	29.38		0.79	1.01		19.47
470	1.19	28.84	81.5	112.9		22.86	29.38		0.79	1.02		19.90
480	1.22	28.68	81.8	112.9		22.92	29.38		0.80	1.02		20.32
490	1.24	28.53	81.8	112.9		22.92	29.38		0.80	1.03		20.74
500	1.27	28.38	81.8	112.9		22.92	29.38		0.81	1.04		21.17
510	1.30	28.23	81.8			22.92			0.81			21.59
520	1.32	28.08	81.8			22.92			0.82			22.01
530	1.35	27.92	81.3			22.81			0.82			22.44
540	1.37	27.77	80.9			22.73			0.82			22.86
550	1.40	27.62	78.5			22.23			0.80			23.28

Table A-24 The direct shear test result of 16B-64S-20T mixture at 80°C

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı *(Job Name) :*		**Yapan** *(Tested By) :*	
Sondaj No *(Boring No) :*		**Tarih** *(Date) :*	
Örnek No *(Sample No) :*			
Derinlik *(Depth) :*			

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m³ :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması / Horizontal Dial Reading	Yatay Deplasman / Horizontal Replacement	Düzeltilmiş Alan / Corrected Area A'	Yük Diali Okuması (Local Dial Reading) D_1	D_2	D_3	Yatay Kesme Kuvveti (Horizantal Shear Force) P_1	P_2	P_3	Kayma Gerilmesi (Shear Stress) τ_1	τ_2	τ_3	Birim Def. (Strain) ε
-	cm	cm²	-	-	-	kg	kg	kg	kg/cm²	kg/cm²	kg/cm²	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	17	30	86	9.45	12.15	23.79	0.26	0.34	0.66	0.42
20	0.05	35.70	19	43	101.5	9.87	14.85	27.01	0.28	0.42	0.76	0.85
30	0.08	35.54	20	49.5	119	10.08	16.21	30.65	0.28	0.46	0.86	1.27
40	0.10	35.39	25	53	118	11.11	16.93	30.44	0.31	0.48	0.86	1.69
50	0.13	35.24	28	56	119.5	11.74	17.56	30.75	0.33	0.50	0.87	2.12
60	0.15	35.09	31	58.5	121	12.36	18.08	31.06	0.35	0.52	0.89	2.54
70	0.18	34.93	35.5	59.5	122	13.30	18.28	31.27	0.38	0.52	0.90	2.96
80	0.20	34.78	39.5	59.5	123	14.13	18.28	31.48	0.41	0.53	0.91	3.39
90	0.23	34.63	41	63.5	123	14.44	19.11	31.48	0.42	0.55	0.91	3.81
100	0.25	34.48	43	64.5	122	14.85	19.32	31.27	0.43	0.56	0.91	4.23
110	0.28	34.32	43	65	121.5	14.85	19.43	31.17	0.43	0.57	0.91	4.66
120	0.30	34.17	42.5	66	123	14.75	19.63	31.48	0.43	0.57	0.92	5.08
130	0.33	34.02	42	67	125.5	14.65	19.84	32.00	0.43	0.58	0.94	5.50
140	0.36	33.87	42	67	126	14.65	19.84	32.10	0.43	0.59	0.95	5.93
150	0.38	33.71	42.5	67	128	14.75	19.84	32.52	0.44	0.59	0.96	6.35
160	0.41	33.56	43.2	67	129	14.90	19.84	32.73	0.44	0.59	0.98	6.77
170	0.43	33.41	44	66	132	15.06	19.63	33.35	0.45	0.59	1.00	7.20
180	0.46	33.26	44	67.5	132.5	15.06	19.95	33.45	0.45	0.60	1.01	7.62
190	0.48	33.10	44.8	67.8	132	15.23	20.01	33.35	0.46	0.60	1.01	8.04
200	0.51	32.95	45.2	68	130	15.31	20.05	32.93	0.46	0.61	1.00	8.47
210	0.53	32.80	46.5	68.2	129.5	15.58	20.09	32.83	0.48	0.61	1.00	8.89
220	0.56	32.65	46.5	69	130	15.58	20.26	32.93	0.48	0.62	1.01	9.31
230	0.58	32.49	46.5	70.3	130.5	15.58	20.53	33.04	0.48	0.63	1.02	9.74
240	0.61	32.34	47.5	70	131	15.79	20.47	33.14	0.49	0.63	1.02	10.16
250	0.64	32.19	47	69.5	134	15.69	20.36	33.76	0.49	0.63	1.05	10.58
260	0.66	32.04	46.5	70.1	135	15.58	20.49	33.97	0.49	0.64	1.06	11.01
270	0.69	31.89	46.5	70.9	136	15.58	20.65	34.18	0.49	0.65	1.07	11.43
280	0.71	31.73	46.5	71	137	15.58	20.67	34.39	0.49	0.65	1.08	11.85
290	0.74	31.58	46.5	71.3	138	15.58	20.74	34.60	0.49	0.66	1.10	12.28
300	0.76	31.43	47	71.9	139	15.69	20.86	34.80	0.50	0.66	1.11	12.70
310	0.79	31.28	47.2	72	139	15.73	20.88	34.80	0.50	0.67	1.11	13.12
320	0.81	31.12	47	72.5	140	15.69	20.99	35.01	0.50	0.67	1.12	13.55
330	0.84	30.97	47	73.2	140.2	15.69	21.13	35.05	0.51	0.68	1.13	13.97
340	0.86	30.82	47.5	74	142	15.79	21.30	35.43	0.51	0.69	1.15	14.39
350	0.89	30.67	47.6	75	143	15.81	21.50	35.63	0.52	0.70	1.16	14.82
360	0.91	30.51	47.9	75	145.5	15.87	21.50	36.15	0.52	0.70	1.18	15.24
370	0.94	30.36	48	75.5	148	15.89	21.61	36.67	0.52	0.71	1.21	15.66
380	0.97	30.21	48.5	76	149.8	16.00	21.71	37.05	0.53	0.72	1.23	16.09
390	0.99	30.06	48.8	76.1	150	16.06	21.73	37.09	0.53	0.72	1.23	16.51
400	1.02	29.90	49.2	76.2	151.8	16.14	21.75	37.46	0.54	0.73	1.25	16.93
410	1.04	29.75	50	77.5	153	16.31	22.02	37.71	0.55	0.74	1.27	17.36
420	1.07	29.60	50	77.5	154.8	16.31	22.02	38.09	0.55	0.74	1.29	17.78
430	1.09	29.45	50.2	77.9	155	16.35	22.11	38.13	0.56	0.75	1.29	18.20
440	1.12	29.29	50.5	78.5	157	16.41	22.23	38.54	0.56	0.76	1.32	18.63
450	1.14	29.14	51	78.7	157.5	16.52	22.27	38.65	0.57	0.76	1.33	19.05
460	1.17	28.99	51	78.5	157.5	16.52	22.23	38.65	0.57	0.77	1.33	19.47
470	1.19	28.84	51.5	79	157.5	16.62	22.34	38.65	0.58	0.77	1.34	19.90
480	1.22	28.68	51.5	79.5	157.5	16.62	22.44	38.65	0.58	0.78	1.35	20.32
490	1.24	28.53	52.2	79.8	157.9	16.77	22.50	38.73	0.59	0.79	1.36	20.74
500	1.27	28.38	52.5	80	160.0	16.83	22.54	39.17	0.59	0.79	1.38	21.17
510	1.30	28.23	52.9	80.2	160.5	16.91	22.59	39.27	0.60	0.80	1.39	21.59
520	1.32	28.08	53.2	80.5	160.5	16.97	22.65	39.27	0.60	0.81	1.40	22.01
530	1.35	27.92	53.5	81.1	160.8	17.04	22.77	39.33	0.61	0.82	1.41	22.44
540	1.37	27.77	54	82	162.0	17.14	22.96	39.58	0.62	0.83	1.43	22.86
550	1.40	27.62	54.5	82	163.0	17.24	22.96	39.79	0.62	0.83	1.44	23.28
560	1.42	27.47	55	82.2	166.0	17.35	23.00	40.41	0.63	0.84	1.47	23.71
570	1.45	27.31	55.5	82.5	167.0	17.45	23.06	40.62	0.64	0.84	1.49	24.13
580	1.47	27.16	56.5	83.5	165.5	17.66	23.27	40.31	0.65	0.86	1.48	24.55
590	1.50	27.01	56.5	83.8	164.5	17.66	23.33	40.10	0.65	0.86	1.48	24.98
600	1.52	26.86	56.5	84.2	166.0	17.66	23.42	40.41	0.66	0.87	1.50	25.40
610	1.55	26.70	56.5	84.3	165.0	17.66	23.44	40.21	0.66	0.88	1.51	25.82
620	1.57	26.55	56.8	84.5	166.0	17.72	23.48	40.41	0.67	0.88	1.52	26.25
630	1.60	26.40	57	84.5	167.2	17.76	23.48	40.66	0.67	0.89	1.54	26.67
640	1.63	26.25	58	85.2	168.0	17.97	23.62	40.83	0.68	0.90	1.56	27.09
650	1.65	26.09	58	85.3	168.5	17.97	23.64	40.93	0.69	0.91	1.57	27.52
660	1.68	25.94	58	85.5	169.2	17.97	23.69	41.08	0.69	0.91	1.58	27.94
670	1.70	25.79	58.5	85.5	168.0	18.08	23.69	40.83	0.70	0.92	1.58	28.36
680	1.73	25.64		86	168.0		23.79	40.83		0.93	1.59	28.79
690	1.75	25.48		86.5	166.0		23.89	40.41		0.94	1.59	29.21
700	1.78	25.33		86.5			23.89			0.94		29.63

Table A-25 The direct shear test result of 18B-72S-10U mixture at room temperature

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m^3 :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	19	33.5	65	9.87	12.88	19.43	0.28	0.36	0.54	0.42
20	0.05	35.70	21.5	37.5	77	10.39	13.71	21.92	0.29	0.38	0.61	0.85
30	0.08	35.54	26.5	41	82.5	11.43	14.44	23.06	0.32	0.41	0.65	1.27
40	0.10	35.39	30	52	88.5	12.15	16.73	24.31	0.34	0.47	0.69	1.69
50	0.13	35.24	32	58	91.9	12.57	17.97	25.02	0.36	0.51	0.71	2.12
60	0.15	35.09	33	63	94	12.78	19.01	25.45	0.36	0.54	0.73	2.54
70	0.18	34.93	35.5	65.5	95	13.30	19.53	25.66	0.38	0.56	0.73	2.96
80	0.20	34.78	32.5	67	96	12.67	19.84	25.87	0.36	0.57	0.74	3.39
90	0.23	34.63	32	70	98	12.57	20.47	26.28	0.36	0.59	0.76	3.81
100	0.25	34.48	40	70	100	14.23	20.47	26.70	0.41	0.59	0.77	4.23
110	0.28	34.32	42	70.5	101	14.65	20.57	26.91	0.43	0.60	0.78	4.66
120	0.30	34.17	45	70	103	15.27	20.47	27.32	0.45	0.60	0.80	5.08
130	0.33	34.02	45	70	104	15.27	20.47	27.53	0.45	0.60	0.81	5.50
140	0.36	33.87	44	72	105	15.06	20.88	27.74	0.44	0.62	0.82	5.93
150	0.38	33.71	45.2	74	105.5	15.31	21.30	27.84	0.45	0.63	0.83	6.35
160	0.41	33.56	47.5	75.5	106.5	15.79	21.61	28.05	0.47	0.64	0.84	6.77
170	0.43	33.41	48	76	107	15.89	21.71	28.15	0.48	0.65	0.84	7.20
180	0.46	33.26	49	76	107.5	16.10	21.71	28.26	0.48	0.65	0.85	7.62
190	0.48	33.10	50.5	77	108	16.41	21.92	28.36	0.50	0.66	0.86	8.04
200	0.51	32.95	51.5	78	109	16.62	22.13	28.57	0.50	0.67	0.87	8.47
210	0.53	32.80	53	79	110	16.93	22.34	28.78	0.52	0.68	0.88	8.89
220	0.56	32.65	54	80	112.5	17.14	22.54	29.30	0.53	0.69	0.90	9.31
230	0.58	32.49	55	81	112.5	17.35	22.75	29.30	0.53	0.70	0.90	9.74
240	0.61	32.34	56	81.5	112.5	17.56	22.86	29.30	0.54	0.71	0.91	10.16
250	0.64	32.19	56.5	83	113	17.66	23.17	29.40	0.55	0.72	0.91	10.58
260	0.66	32.04	57	83.5	113	17.76	23.27	29.40	0.55	0.73	0.92	11.01
270	0.69	31.89	57.5	84	114	17.87	23.37	29.61	0.56	0.73	0.93	11.43
280	0.71	31.73	58.5	84.5	114.5	18.08	23.48	29.71	0.57	0.74	0.94	11.85
290	0.74	31.58	59	85	114.5	18.18	23.58	29.71	0.58	0.75	0.94	12.28
300	0.76	31.43	59.5	85.5	114	18.28	23.69	29.61	0.58	0.75	0.94	12.70
310	0.79	31.28	60.5	86.5	114	18.49	23.89	29.61	0.59	0.76	0.95	13.12
320	0.81	31.12	61	86.5	114	18.60	23.89	29.61	0.60	0.77	0.95	13.55
330	0.84	30.97	61.5	87	114	18.70	24.00	29.61	0.60	0.77	0.96	13.97
340	0.86	30.82	62.5	87.5	114.5	18.91	24.10	29.71	0.61	0.78	0.96	14.39
350	0.89	30.67	63	88	114.5	19.01	24.21	29.71	0.62	0.79	0.97	14.82
360	0.91	30.51	64	89	115	19.22	24.41	29.82	0.63	0.80	0.98	15.24
370	0.94	30.36	64.8	89.5	115	19.38	24.52	29.82	0.64	0.81	0.98	15.66
380	0.97	30.21	65.2	90	116.5	19.47	24.62	30.13	0.64	0.82	1.00	16.09
390	0.99	30.06	65.8	90	116.5	19.59	24.62	30.13	0.65	0.82	1.00	16.51
400	1.02	29.90	66.5	90.5	116.5	19.74	24.73	30.13	0.66	0.83	1.01	16.93
410	1.04	29.75	67	91	117	19.84	24.83	30.23	0.67	0.83	1.02	17.36
420	1.07	29.60	67.2	91	117	19.88	24.83	30.23	0.67	0.84	1.02	17.78
430	1.09	29.45	68	91.5	117	20.05	24.93	30.23	0.68	0.85	1.03	18.20
440	1.12	29.29	68.5	92	117	20.15	25.04	30.23	0.69	0.85	1.03	18.63
450	1.14	29.14	69	92.5	117	20.26	25.14	30.23	0.70	0.86	1.04	19.05
460	1.17	28.99	69	92.5		20.26	25.14		0.70	0.87		19.47
470	1.19	28.84	69.5	92.5		20.36	25.14		0.71	0.87		19.90
480	1.22	28.68	70	92.5		20.47	25.14		0.71	0.88		20.32
490	1.24	28.53	70.5	92.5		20.57	25.14		0.72	0.88		20.74
500	1.27	28.38	71	92.5		20.67	25.14		0.73	0.89		21.17
510	1.30	28.23	71.2			20.71			0.73			21.59
520	1.32	28.08	71.8			20.84			0.74			22.01
530	1.35	27.92	72			20.88			0.75			22.44
540	1.37	27.77	72			20.88			0.75			22.86
550	1.40	27.62	72.5			20.99			0.76			23.28
560	1.42	27.47	72.5			20.99			0.76			23.71
570	1.45	27.31	72.5			20.99			0.77			24.13
580	1.47	27.16	72.5			20.99			0.77			24.55
590	1.50	27.01	72.5			20.99			0.78			24.98

Table A-26 The direct shear test result of 18B-72S-10U mixture at 80°C

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :* 6X6X2
Örnek Ağırlığı	*(sample weight) gr :*
Doğal b.h.a	*(natural unit weight) t/m^3 :*
Yükleme Hızı	*(loading rate) mm/dak :* 0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	25	46	80	11.11	15.48	22.54	0.31	0.43	0.63	0.42
20	0.05	35.70	31	60	111	12.36	18.39	28.99	0.35	0.52	0.81	0.85
30	0.08	35.54	34	68	122.5	12.98	20.05	31.38	0.37	0.56	0.88	1.27
40	0.10	35.39	35.5	74.5	131.5	13.30	21.40	33.25	0.38	0.60	0.94	1.69
50	0.13	35.24	35.5	79	135	13.30	22.34	33.97	0.38	0.63	0.96	2.12
60	0.15	35.09	35.5	83	137	13.30	23.17	34.39	0.38	0.66	0.98	2.54
70	0.18	34.93	52	84	140.5	16.73	23.37	35.12	0.48	0.67	1.01	2.96
80	0.20	34.78	60	86	142.5	18.39	23.79	35.53	0.53	0.68	1.02	3.39
90	0.23	34.63	68	88	143.5	20.05	24.21	35.74	0.58	0.70	1.03	3.81
100	0.25	34.48	70	93	145	20.47	25.24	36.05	0.59	0.73	1.05	4.23
110	0.28	34.32	73	97	145.5	21.09	26.08	36.15	0.61	0.76	1.05	4.66
120	0.30	34.17	73.5	98	145.5	21.19	26.28	36.15	0.62	0.77	1.06	5.08
130	0.33	34.02	75	99.5	148.5	21.50	26.60	36.78	0.63	0.78	1.08	5.50
140	0.36	33.87	76.2	101.5	150.5	21.75	27.01	37.19	0.64	0.80	1.10	5.93
150	0.38	33.71	77	102.5	151	21.92	27.22	37.30	0.65	0.81	1.11	6.35
160	0.41	33.56	78	103.5	150.5	22.13	27.43	37.19	0.66	0.82	1.11	6.77
170	0.43	33.41	79	105.5	151	22.34	27.84	37.30	0.67	0.83	1.12	7.20
180	0.46	33.26	80	107.5	152.5	22.54	28.26	37.61	0.68	0.85	1.13	7.62
190	0.48	33.10	81	110	152.5	22.75	28.78	37.61	0.69	0.87	1.14	8.04
200	0.51	32.95	81.2	110	153	22.79	28.78	37.71	0.69	0.87	1.14	8.47
210	0.53	32.80	81.5	111.5	153	22.86	29.09	37.71	0.70	0.89	1.15	8.89
220	0.56	32.65	81.8	114.5	150.5	22.92	29.71	37.19	0.70	0.91	1.14	9.31
230	0.58	32.49	82	114.5	151	22.96	29.71	37.30	0.71	0.91	1.15	9.74
240	0.61	32.34	82.5	115.5	151.5	23.06	29.92	37.40	0.71	0.93	1.16	10.16
250	0.64	32.19	82.5	116	151.8	23.06	30.02	37.46	0.72	0.93	1.16	10.58
260	0.66	32.04	82.8	116	151	23.13	30.02	37.30	0.72	0.94	1.16	11.01
270	0.69	31.89	83	116.5	152	23.17	30.13	37.51	0.73	0.94	1.18	11.43
280	0.71	31.73	83	118	151.5	23.17	30.44	37.40	0.73	0.96	1.18	11.85
290	0.74	31.58	83	118	151	23.17	30.44	37.30	0.73	0.96	1.18	12.28
300	0.76	31.43	83	118.5	151	23.17	30.54	37.30	0.74	0.97	1.19	12.70
310	0.79	31.28	82.8	119	151	23.13	30.65	37.30	0.74	0.98	1.19	13.12
320	0.81	31.12	82	119.5	151.5	22.96	30.75	37.40	0.74	0.99	1.20	13.55
330	0.84	30.97	81.5	119.5	154.5	22.86	30.75	38.02	0.74	0.99	1.23	13.97
340	0.86	30.82	81.5	119.8	155.5	22.86	30.81	38.23	0.74	1.00	1.24	14.39
350	0.89	30.67	81.5	120	158	22.86	30.86	38.75	0.75	1.01	1.26	14.82
360	0.91	30.51	81	120.3	159	22.75	30.92	38.96	0.75	1.01	1.28	15.24
370	0.94	30.36	81	120.5	158.5	22.75	30.96	38.86	0.75	1.02	1.28	15.66
380	0.97	30.21	81	121.5	159.5	22.75	31.17	39.06	0.75	1.03	1.29	16.09
390	0.99	30.06	81	122	159	22.75	31.27	38.96	0.76	1.04	1.30	16.51
400	1.02	29.90	81	122	159	22.75	31.27	38.96	0.76	1.05	1.30	16.93
410	1.04	29.75		122.5	159		31.38	38.96		1.05	1.31	17.36
420	1.07	29.60		122.5	159		31.38	38.96		1.06	1.32	17.78
430	1.09	29.45		122.5	158		31.38	38.75		1.07	1.32	18.20
440	1.12	29.29		122.5	157.5		31.38	38.65		1.07	1.32	18.63
450	1.14	29.14			156			38.34			1.32	19.05

Table A-27 The direct shear test result of 16B-64S-20U mixture at room temperature

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m^3 :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg)		
[Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	18.5	34	65	9.76	12.98	19.43	0.27	0.36	0.54	0.42
20	0.05	35.70	22	49.5	82	10.49	16.21	22.96	0.29	0.45	0.64	0.85
30	0.08	35.54	24	54	88	10.91	17.14	24.21	0.31	0.48	0.68	1.27
40	0.10	35.39	28.5	58.5	91	11.84	18.08	24.83	0.33	0.51	0.70	1.69
50	0.13	35.24	28.5	62	94	11.84	18.80	25.45	0.34	0.53	0.72	2.12
60	0.15	35.09	31	58	97.5	12.36	17.97	26.18	0.35	0.51	0.75	2.54
70	0.18	34.93	32	57	98	12.57	17.76	26.28	0.36	0.51	0.75	2.96
80	0.20	34.78	32.5	52	99	12.67	16.73	26.49	0.36	0.48	0.76	3.39
90	0.23	34.63	35.5	54.5	99.2	13.30	17.24	26.53	0.38	0.50	0.77	3.81
100	0.25	34.48	38.5	57.5	100	13.92	17.87	26.70	0.40	0.52	0.77	4.23
110	0.28	34.32	41	64.5	101.5	14.44	19.32	27.01	0.42	0.56	0.79	4.66
120	0.30	34.17	42.5	67	101.5	14.75	19.84	27.01	0.43	0.58	0.79	5.08
130	0.33	34.02	43.5	68	103.5	14.96	20.05	27.43	0.44	0.59	0.81	5.50
140	0.36	33.87	45	69	104.5	15.27	20.26	27.63	0.45	0.60	0.82	5.93
150	0.38	33.71	46.5	70.5	105.2	15.58	20.57	27.78	0.46	0.61	0.82	6.35
160	0.41	33.56	48	72	105.5	15.89	20.88	27.84	0.47	0.62	0.83	6.77
170	0.43	33.41	49.5	74	106	16.21	21.30	27.95	0.49	0.64	0.84	7.20
180	0.46	33.26	50.5	74.5	106.5	16.41	21.40	28.05	0.49	0.64	0.84	7.62
190	0.48	33.10	51.8	75	107	16.68	21.50	28.15	0.50	0.65	0.85	8.04
200	0.51	32.95	53.5	76	107.5	17.04	21.71	28.26	0.52	0.66	0.86	8.47
210	0.53	32.80	54	76.2	108	17.14	21.75	28.36	0.52	0.66	0.86	8.89
220	0.56	32.65	55	77	108	17.35	21.92	28.36	0.53	0.67	0.87	9.31
230	0.58	32.49	54.5	77.5	108.5	17.24	22.02	28.47	0.53	0.68	0.88	9.74
240	0.61	32.34	56	78.5	108.5	17.56	22.23	28.47	0.54	0.69	0.88	10.16
250	0.64	32.19	57	79	109	17.76	22.34	28.57	0.55	0.69	0.89	10.58
260	0.66	32.04	57.5	79.5	110	17.87	22.44	28.78	0.56	0.70	0.90	11.01
270	0.69	31.89	58	80.2	110.5	17.97	22.59	28.88	0.56	0.71	0.91	11.43
280	0.71	31.73	58.5	80.9	111	18.08	22.73	28.99	0.57	0.72	0.91	11.85
290	0.74	31.58	59	81.5	111	18.18	22.86	28.99	0.58	0.72	0.92	12.28
300	0.76	31.43	59.5	81.9	112	18.28	22.94	29.19	0.58	0.73	0.93	12.70
310	0.79	31.28	60	82	112	18.39	22.96	29.19	0.59	0.73	0.93	13.12
320	0.81	31.12	60.5	82.5	112	18.49	23.06	29.19	0.59	0.74	0.94	13.55
330	0.84	30.97	61	83	112.5	18.60	23.17	29.30	0.60	0.75	0.95	13.97
340	0.86	30.82	61.5	84	112.5	18.70	23.37	29.30	0.61	0.76	0.95	14.39
350	0.89	30.67	61.9	84.5	113	18.78	23.48	29.40	0.61	0.77	0.96	14.82
360	0.91	30.51	62	84.8	113	18.80	23.54	29.40	0.62	0.77	0.96	15.24
370	0.94	30.36	63	85.2	113	19.01	23.62	29.40	0.63	0.78	0.97	15.66
380	0.97	30.21	64	85.8	113.5	19.22	23.75	29.50	0.64	0.79	0.98	16.09
390	0.99	30.06	64.5	86.2	113.5	19.32	23.83	29.50	0.64	0.79	0.98	16.51
400	1.02	29.90	64.5	87	113.5	19.32	24.00	29.50	0.65	0.80	0.99	16.93
410	1.04	29.75	64.9	87.2	113.5	19.41	24.04	29.50	0.65	0.81	0.99	17.36
420	1.07	29.60	65.2	87.2	113.5	19.47	24.04	29.50	0.66	0.81	1.00	17.78
430	1.09	29.45	65.2	87.2	113.5	19.47	24.04	29.50	0.66	0.82	1.00	18.20
440	1.12	29.29	65.8	87.8		19.59	24.16		0.67	0.82		18.63
450	1.14	29.14	66.2	88		19.68	24.21		0.68	0.83		19.05
460	1.17	28.99	66.2	88		19.68	24.21		0.68	0.83		19.47
470	1.19	28.84	66.8	88		19.80	24.21		0.69	0.84		19.90
480	1.22	28.68	66.8	88.5		19.80	24.31		0.69	0.85		20.32
490	1.24	28.53	66.8	88.5		19.80	24.31		0.69	0.85		20.74
500	1.27	28.38	67.2	89		19.88	24.41		0.70	0.86		21.17
510	1.30	28.23	67.2	89		19.88			0.70			21.59
520	1.32	28.08	67.2	89		19.88			0.71			22.01
530	1.35	27.92	67.2	89		19.88			0.71			22.44
540	1.37	27.77	67.2			19.88			0.72			22.86

Table A-28 The direct shear test result of 16B-64S-20U mixture at 80°C

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m^3 :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	26	57	99	11.32	17.76	26.49	0.32	0.50	0.74	0.42
20	0.05	35.70	33.5	68	104.5	12.88	20.05	27.63	0.36	0.56	0.77	0.85
30	0.08	35.54	37	75	112	13.61	21.50	29.19	0.38	0.61	0.82	1.27
40	0.10	35.39	37	79	130	13.61	22.34	32.93	0.38	0.63	0.93	1.69
50	0.13	35.24	37	81	138	13.61	22.75	34.60	0.39	0.65	0.98	2.12
60	0.15	35.09	37	83	141.5	13.61	23.17	35.32	0.39	0.66	1.01	2.54
70	0.18	34.93	30	83	146	12.15	23.17	36.26	0.35	0.66	1.04	2.96
80	0.20	34.78	35	90.5	157.5	13.19	24.73	38.65	0.38	0.71	1.11	3.39
90	0.23	34.63	46	94.5	161	15.48	25.56	39.38	0.45	0.74	1.14	3.81
100	0.25	34.48	57.5	96	165.5	17.87	25.87	40.31	0.52	0.75	1.17	4.23
110	0.28	34.32	60	98	166	18.39	26.28	40.41	0.54	0.77	1.18	4.66
120	0.30	34.17	65	100	166.8	19.43	26.70	40.58	0.57	0.78	1.19	5.08
130	0.33	34.02	68.5	101	168.5	20.15	26.91	40.93	0.59	0.79	1.20	5.50
140	0.36	33.87	72	103	170	20.88	27.32	41.25	0.62	0.81	1.22	5.93
150	0.38	33.71	73	103.5	170.5	21.09	27.43	41.35	0.63	0.81	1.23	6.35
160	0.41	33.56	74.5	104	170.5	21.40	27.53	41.35	0.64	0.82	1.23	6.77
170	0.43	33.41	75.5	104.5	171.5	21.61	27.63	41.56	0.65	0.83	1.24	7.20
180	0.46	33.26	77	105	171.5	21.92	27.74	41.56	0.66	0.83	1.25	7.62
190	0.48	33.10	78.5	106	173.8	22.23	27.95	42.04	0.67	0.84	1.27	8.04
200	0.51	32.95	80	106	174.5	22.54	27.95	42.18	0.68	0.85	1.28	8.47
210	0.53	32.80	80.9	106.5	173	22.73	28.05	41.87	0.69	0.86	1.28	8.89
220	0.56	32.65	81	106.8	174	22.75	28.11	42.08	0.70	0.86	1.29	9.31
230	0.58	32.49	82	107	176.5	22.96	28.15	42.60	0.71	0.87	1.31	9.74
240	0.61	32.34	82.5	107	176	23.06	28.15	42.49	0.71	0.87	1.31	10.16
250	0.64	32.19	83	108	178	23.17	28.36	42.91	0.72	0.88	1.33	10.58
260	0.66	32.04	84	108	176	23.37	28.36	42.49	0.73	0.89	1.33	11.01
270	0.69	31.89	84	108.5	177	23.37	28.47	42.70	0.73	0.89	1.34	11.43
280	0.71	31.73	84.9	109	177.5	23.56	28.57	42.80	0.74	0.90	1.35	11.85
290	0.74	31.58	85	109	176.8	23.58	28.57	42.66	0.75	0.90	1.35	12.28
300	0.76	31.43	85.5	109	177	23.69	28.57	42.70	0.75	0.91	1.36	12.70
310	0.79	31.28	85.5	109.5	176	23.69	28.67	42.49	0.76	0.92	1.36	13.12
320	0.81	31.12	85.8	109.5	176.5	23.75	28.67	42.60	0.76	0.92	1.37	13.55
330	0.84	30.97	86.2	109.8	175.5	23.83	28.74	42.39	0.77	0.93	1.37	13.97
340	0.86	30.82	86.2	109.8	177	23.83	28.74	42.70	0.77	0.93	1.39	14.39
350	0.89	30.67	86.2	109.8	178	23.83	28.74	42.91	0.78	0.94	1.40	14.82
360	0.91	30.51	86.2	110	178	23.83	28.78	42.91	0.78	0.94	1.41	15.24
370	0.94	30.36	87	110.5	178	24.00	28.88	42.91	0.79	0.95	1.41	15.66
380	0.97	30.21	87	111	178.5	24.00	28.99	43.01	0.79	0.96	1.42	16.09
390	0.99	30.06	87	111	178.5	24.00	28.99	43.01	0.80	0.96	1.43	16.51
400	1.02	29.90	87	111	179.5	24.00	28.99	43.22	0.80	0.97	1.45	16.93
410	1.04	29.75	87	111	178	24.00	28.99	42.91	0.81	0.97	1.44	17.36
420	1.07	29.60	87	111	178.8	24.00	28.99	43.07	0.81	0.98	1.46	17.78
430	1.09	29.45	87	111	178.5	24.00	28.99	43.01	0.81	0.98	1.46	18.20
440	1.12	29.29			178.5			43.01			1.47	18.63
450	1.14	29.14			178.5			43.01			1.48	19.05
460	1.17	28.99			177			42.70			1.47	19.47

Table A-29 The direct shear test result of 100C at room temperature

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m^3 :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	22.5	39	78	10.60	14.02	22.13	0.30	0.39	0.62	0.42
20	0.05	35.70	28	53	109	11.74	16.93	28.57	0.33	0.47	0.80	0.85
30	0.08	35.54	30.5	65	135	12.26	19.43	33.97	0.34	0.55	0.96	1.27
40	0.10	35.39	34.5	72	146.5	13.09	20.88	36.36	0.37	0.59	1.03	1.69
50	0.13	35.24	38	78	153	13.82	22.13	37.71	0.39	0.63	1.07	2.12
60	0.15	35.09	40	81.5	155.2	14.23	22.86	38.17	0.41	0.65	1.09	2.54
70	0.18	34.93	41	83	159.5	14.44	23.17	39.06	0.41	0.66	1.12	2.96
80	0.20	34.78	45	85.5	165.5	15.27	23.69	40.31	0.44	0.68	1.16	3.39
90	0.23	34.63	48	86	171	15.89	23.79	41.45	0.46	0.69	1.20	3.81
100	0.25	34.48	49.5	87	173	16.21	24.00	41.87	0.47	0.70	1.21	4.23
110	0.28	34.32	50.5	88	169.5	16.41	24.21	41.14	0.48	0.71	1.20	4.66
120	0.30	34.17	53	90	167.5	16.93	24.62	40.73	0.50	0.72	1.19	5.08
130	0.33	34.02	54	95.5	171.5	17.14	25.76	41.56	0.50	0.76	1.22	5.50
140	0.36	33.87	57	99	176.5	17.76	26.49	42.60	0.52	0.78	1.26	5.93
150	0.38	33.71	59	102.5	177.5	18.18	27.22	42.80	0.54	0.81	1.27	6.35
160	0.41	33.56	59	105	184	18.18	27.74	44.15	0.54	0.83	1.32	6.77
170	0.43	33.41	60	106	184	18.39	27.95	44.15	0.55	0.84	1.32	7.20
180	0.46	33.26	60	109	187	18.39	28.57	44.78	0.55	0.86	1.35	7.62
190	0.48	33.10	60.5	111	187.5	18.49	28.99	44.88	0.56	0.88	1.36	8.04
200	0.51	32.95	61	112	188.5	18.60	29.19	45.09	0.56	0.89	1.37	8.47
210	0.53	32.80	62	114	191	18.80	29.61	45.61	0.57	0.90	1.39	8.89
220	0.56	32.65	62	117.5	193	18.80	30.34	46.02	0.58	0.93	1.41	9.31
230	0.58	32.49	63	117.5	196.5	19.01	30.34	46.75	0.59	0.93	1.44	9.74
240	0.61	32.34	64.5	117.5	197.5	19.32	30.34	46.96	0.60	0.94	1.45	10.16
250	0.64	32.19	64	117	198.5	19.22	30.23	47.17	0.60	0.94	1.47	10.58
260	0.66	32.04	64	117	202.5	19.22	30.23	48.00	0.60	0.94	1.50	11.01
270	0.69	31.89	63	117	202.5	19.01	30.23	48.00	0.60	0.95	1.51	11.43
280	0.71	31.73	62.5	117	201	18.91	30.23	47.69	0.60	0.95	1.50	11.85
290	0.74	31.58	62.5	117	201.5	18.91	30.23	47.79	0.60	0.96	1.51	12.28
300	0.76	31.43	61.5	116	200	18.70	30.02	47.48	0.59	0.96	1.51	12.70
310	0.79	31.28	60	116	200.5	18.39	30.02	47.58	0.59	0.96	1.52	13.12
320	0.81	31.12	60	116.5	200	18.39	30.13	47.48	0.59	0.97	1.53	13.55
330	0.84	30.97	60	115.5	198	18.39	29.92	47.06	0.59	0.97	1.52	13.97
340	0.86	30.82	60	116	199	18.39	30.02	47.27	0.60	0.97	1.53	14.39
350	0.89	30.67	59.5	116.5	200	18.28	30.13	47.48	0.60	0.98	1.55	14.82
360	0.91	30.51	59.5	116.5	200	18.28	30.13	47.48	0.60	0.99	1.56	15.24
370	0.94	30.36	59	116	199	18.18	30.02	47.27	0.60	0.99	1.56	15.66
380	0.97	30.21		116	199		30.02	47.27		0.99	1.56	16.09
390	0.99	30.06		116	199		30.02	47.27		1.00	1.57	16.51
400	1.02	29.90		116			30.02			1.00		16.93

Table A-30 The direct shear test result of 100C at 80°C

DİREKT KESME DENEYİ
(DIRECT SHEAR TEST)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :* 6X6X2
Örnek Ağırlığı	*(sample weight) gr :*
Doğal b.h.a	*(natural unit weight) t/m^3 :*
Yükleme Hızı	*(loading rate) mm/dak :* 0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	30	53.5	55	12.15	17.04	17.35	0.34	0.48	0.48	0.42
20	0.05	35.70	36.5	69	80	13.50	20.26	22.54	0.38	0.57	0.63	0.85
30	0.08	35.54	40	78	110	14.23	22.13	28.78	0.40	0.62	0.81	1.27
40	0.10	35.39	42.3	85	140	14.71	23.58	35.01	0.42	0.67	0.99	1.69
50	0.13	35.24	38	86	143	13.82	23.79	35.63	0.39	0.68	1.01	2.12
60	0.15	35.09	41	89.5	151	14.44	24.52	37.30	0.41	0.70	1.06	2.54
70	0.18	34.93	41.5	91	158	14.54	24.83	38.75	0.42	0.71	1.11	2.96
80	0.20	34.78	41.5	92.5	163.5	14.54	25.14	39.89	0.42	0.72	1.15	3.39
90	0.23	34.63	42.5	92.5	167	14.75	25.14	40.62	0.43	0.73	1.17	3.81
100	0.25	34.48	48.5	88	169	16.00	24.21	41.04	0.46	0.70	1.19	4.23
110	0.28	34.32	50	87.5	171	16.31	24.10	41.45	0.48	0.70	1.21	4.66
120	0.30	34.17	51.5	85	173	16.62	23.58	41.87	0.49	0.69	1.23	5.08
130	0.33	34.02	53.5	100	175	17.04	26.70	42.28	0.50	0.78	1.24	5.50
140	0.36	33.87	56.2	103.5	176	17.60	27.43	42.49	0.52	0.81	1.25	5.93
150	0.38	33.71	57	103.5	177	17.76	27.43	42.70	0.53	0.81	1.27	6.35
160	0.41	33.56	58	104.5	178	17.97	27.63	42.91	0.54	0.82	1.28	6.77
170	0.43	33.41	59	105.5	179	18.18	27.84	43.12	0.54	0.83	1.29	7.20
180	0.46	33.26	60.5	106	180	18.49	27.95	43.32	0.56	0.84	1.30	7.62
190	0.48	33.10	61.5	107	180.5	18.70	28.15	43.43	0.56	0.85	1.31	8.04
200	0.51	32.95	62.8	109	181	18.97	28.57	43.53	0.58	0.87	1.32	8.47
210	0.53	32.80	63	110	182	19.01	28.78	43.74	0.58	0.88	1.33	8.89
220	0.56	32.65	64.5	111	184	19.32	28.99	44.15	0.59	0.89	1.35	9.31
230	0.58	32.49	65.5	111	188.2	19.53	28.99	45.03	0.60	0.89	1.39	9.74
240	0.61	32.34	66	110	187	19.63	28.78	44.78	0.61	0.89	1.38	10.16
250	0.64	32.19	66	109	187.5	19.63	28.57	44.88	0.61	0.89	1.39	10.58
260	0.66	32.04	66.2	108	189	19.68	28.36	45.19	0.61	0.89	1.41	11.01
270	0.69	31.89	67	106.5	189	19.84	28.05	45.19	0.62	0.88	1.42	11.43
280	0.71	31.73	67	106	187	19.84	27.95	44.78	0.63	0.88	1.41	11.85
290	0.74	31.58	67	107	188	19.84	28.15	44.99	0.63	0.89	1.42	12.28
300	0.76	31.43	67	107	190	19.84	28.15	45.40	0.63	0.90	1.44	12.70
310	0.79	31.28	67	104	190	19.84	27.53	45.40	0.63	0.88	1.45	13.12
320	0.81	31.12	67	105	190	19.84	27.74	45.40	0.64	0.89	1.46	13.55
330	0.84	30.97	67	106	190	19.84	27.95	45.40	0.64	0.90	1.47	13.97
340	0.86	30.82	67	105	189	19.84	27.74	45.19	0.64	0.90	1.47	14.39
350	0.89	30.67		105	189		27.74	45.19		0.90	1.47	14.82
360	0.91	30.51		105	189		27.74	45.19		0.91	1.48	15.24
370	0.94	30.36		105	188		27.74	44.99		0.91	1.48	15.66
380	0.97	30.21		105			27.74			0.92		16.09

Table A-31 The direct shear test result of 100T at room temperature

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :* 6X6X2
Örnek Ağırlığı	*(sample weight) gr :*
Doğal b.h.a	*(natural unit weight) t/m^3 :*
Yükleme Hızı	*(loading rate) mm/dak :* 0.5

Normal Yükler P (kg) *[Normal Loads P (kg)]*		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	**Yük Diali Okuması** *Local Dial Reading*			**Yatay Kesme Kuvveti** *Horizantal Shear Force*			**Kayma Gerilmesi** *Shear Stress*			**Birim Def.** *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	19	43.5	95.5	9.87	14.96	25.76	0.28	0.42	0.72	0.42
20	0.05	35.70	27	57	114.5	11.53	17.76	29.71	0.32	0.50	0.83	0.85
30	0.08	35.54	27.5	58	119	11.63	17.97	30.65	0.33	0.51	0.86	1.27
40	0.10	35.39	31	63	119	12.36	19.01	30.65	0.35	0.54	0.87	1.69
50	0.13	35.24	30	66.5	134.5	12.15	19.74	33.87	0.34	0.56	0.96	2.12
60	0.15	35.09	32	66	135	12.57	19.63	33.97	0.36	0.56	0.97	2.54
70	0.18	34.93	32.8	77.5	137.5	12.74	22.02	34.49	0.36	0.63	0.99	2.96
80	0.20	34.78	35.2	85	144	13.23	23.58	35.84	0.38	0.68	1.03	3.39
90	0.23	34.63	35	88	151	13.19	24.21	37.30	0.38	0.70	1.08	3.81
100	0.25	34.48	38	90	153.5	13.82	24.62	37.82	0.40	0.71	1.10	4.23
110	0.28	34.32	42	92.9	155.5	14.65	25.22	38.23	0.43	0.73	1.11	4.66
120	0.30	34.17	43	94	156.3	14.85	25.45	38.40	0.43	0.74	1.12	5.08
130	0.33	34.02	44	96.5	156.8	15.06	25.97	38.50	0.44	0.76	1.13	5.50
140	0.36	33.87	47	99.5	157.8	15.69	26.60	38.71	0.46	0.79	1.14	5.93
150	0.38	33.71	49.8	102	158.5	16.27	27.12	38.86	0.48	0.80	1.15	6.35
160	0.41	33.56	51.2	103.2	158.9	16.56	27.36	38.94	0.49	0.82	1.16	6.77
170	0.43	33.41	56	104.9	159.5	17.56	27.72	39.06	0.53	0.83	1.17	7.20
180	0.46	33.26	58.5	106	160	18.08	27.95	39.17	0.54	0.84	1.18	7.62
190	0.48	33.10	61	106.9	161	18.60	28.13	39.38	0.56	0.85	1.19	8.04
200	0.51	32.95	63	107.9	160.8	19.01	28.34	39.33	0.58	0.86	1.19	8.47
210	0.53	32.80	65.5	108.3	160.5	19.53	28.42	39.27	0.60	0.87	1.20	8.89
220	0.56	32.65	68	108.9	160.8	20.05	28.55	39.33	0.61	0.87	1.20	9.31
230	0.58	32.49	70	109	160.5	20.47	28.57	39.27	0.63	0.88	1.21	9.74
240	0.61	32.34	72.2	109.5	159.5	20.92	28.67	39.06	0.65	0.89	1.21	10.16
250	0.64	32.19	74	109.5	157.8	21.30	28.67	38.71	0.66	0.89	1.20	10.58
260	0.66	32.04	76	109.5	157.5	21.71	28.67	38.65	0.68	0.89	1.21	11.01
270	0.69	31.89	77.5	109.5	156.5	22.02	28.67	38.44	0.69	0.90	1.21	11.43
280	0.71	31.73	78.5	109.5	156	22.23	28.67	38.34	0.70	0.90	1.21	11.85
290	0.74	31.58	79.5	109.5	155.5	22.44	28.67	38.23	0.71	0.91	1.21	12.28
300	0.76	31.43	80.9	109.5	155	22.73	28.67	38.13	0.72	0.91	1.21	12.70
310	0.79	31.28	81.9	109.5	154.8	22.94	28.67	38.09	0.73	0.92	1.22	13.12
320	0.81	31.12	83	109.5	154.7	23.17	28.67	38.07	0.74	0.92	1.22	13.55
330	0.84	30.97	83.5	109.5	155	23.27	28.67	38.13	0.75	0.93	1.23	13.97
340	0.86	30.82	83.8	109	154.2	23.33	28.57	37.96	0.76	0.93	1.23	14.39
350	0.89	30.67	84.5	109	152.5	23.48	28.57	37.61	0.77	0.93	1.23	14.82
360	0.91	30.51	84.5	108.5	152	23.48	28.47	37.51	0.77	0.93	1.23	15.24
370	0.94	30.36	84.5	108.3	151.5	23.48	28.42	37.40	0.77	0.94	1.23	15.66
380	0.97	30.21	83.9	108	151.5	23.35	28.36	37.40	0.77	0.94	1.24	16.09
390	0.99	30.06	83	107	151.5	23.17	28.15	37.40	0.77	0.94	1.24	16.51
400	1.02	29.90	82.2	106.9	151.5	23.00	28.13	37.40	0.77	0.94	1.25	16.93
410	1.04	29.75	81.5	106.5	151.5	22.86	28.05	37.40	0.77	0.94	1.26	17.36
420	1.07	29.60	80.9	106	150.5	22.73	27.95	37.19	0.77	0.94	1.26	17.78
430	1.09	29.45	80.5	105.3		22.65	27.80		0.77	0.94		18.20
440	1.12	29.29	80	105		22.54	27.74		0.77	0.95		18.63
450	1.14	29.14	79.5			22.44			0.77			19.05
460	1.17	28.99	79.5			22.44			0.77			19.47
470	1.19	28.84	79			22.34			0.77			19.90

Table A-32 The direct shear test result of 100U at room temperature

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :* 6X6X2
Örnek Ağırlığı	*(sample weight) gr :*
Doğal b.h.a	*(natural unit weight) t/m^3 :*
Yükleme Hızı	*(loading rate) mm/dak :* 0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	20	28.5	50	10.08	11.84	16.31	0.28	0.33	0.45	0.42
20	0.05	35.70	27	38	64	11.53	13.82	19.22	0.32	0.39	0.54	0.85
30	0.08	35.54	30	42	73.5	12.15	14.65	21.19	0.34	0.41	0.60	1.27
40	0.10	35.39	29	48	79.5	11.95	15.89	22.44	0.34	0.45	0.63	1.69
50	0.13	35.24	29	53	83.5	11.95	16.93	23.27	0.34	0.48	0.66	2.12
60	0.15	35.09	36.5	57	87	13.50	17.76	24.00	0.38	0.51	0.68	2.54
70	0.18	34.93	39	62	91	14.02	18.80	24.83	0.40	0.54	0.71	2.96
80	0.20	34.78	41	63.5	93.5	14.44	19.11	25.35	0.42	0.55	0.73	3.39
90	0.23	34.63	43.5	63.5	96	14.96	19.11	25.87	0.43	0.55	0.75	3.81
100	0.25	34.48	45.5	64	99	15.37	19.22	26.49	0.45	0.56	0.77	4.23
110	0.28	34.32	47	64	102	15.69	19.22	27.12	0.46	0.56	0.79	4.66
120	0.30	34.17	48	63	105	15.89	19.01	27.74	0.47	0.56	0.81	5.08
130	0.33	34.02	48.5	63.5	106	16.00	19.11	27.95	0.47	0.56	0.82	5.50
140	0.36	33.87	48.5	65	111.5	16.00	19.43	29.09	0.47	0.57	0.86	5.93
150	0.38	33.71	49.5	65.8	114	16.21	19.59	29.61	0.48	0.58	0.88	6.35
160	0.41	33.56	50	65.8	115.2	16.31	19.59	29.86	0.49	0.58	0.89	6.77
170	0.43	33.41	51.5	64.8	116.5	16.62	19.38	30.13	0.50	0.58	0.90	7.20
180	0.46	33.26	52	64.5	118	16.73	19.32	30.44	0.50	0.58	0.92	7.62
190	0.48	33.10	53	64.5	121	16.93	19.32	31.06	0.51	0.58	0.94	8.04
200	0.51	32.95	53.5	64.5	121.5	17.04	19.32	31.17	0.52	0.59	0.95	8.47
210	0.53	32.80	54	64	122	17.14	19.22	31.27	0.52	0.59	0.95	8.89
220	0.56	32.65	54.5	64.5	123.5	17.24	19.32	31.58	0.53	0.59	0.97	9.31
230	0.58	32.49	54.5	64.8	125	17.24	19.38	31.89	0.53	0.60	0.98	9.74
240	0.61	32.34	54.9	65	126.5	17.33	19.43	32.21	0.54	0.60	1.00	10.16
250	0.64	32.19	55	65	128	17.35	19.43	32.52	0.54	0.60	1.01	10.58
260	0.66	32.04	55	65	130	17.35	19.43	32.93	0.54	0.61	1.03	11.01
270	0.69	31.89	55.5	64.5	133	17.45	19.32	33.56	0.55	0.61	1.05	11.43
280	0.71	31.73	55.5	65	135	17.45	19.43	33.97	0.55	0.61	1.07	11.85
290	0.74	31.58	55.8	65	135.5	17.51	19.43	34.08	0.55	0.62	1.08	12.28
300	0.76	31.43	55.8	65	137	17.51	19.43	34.39	0.56	0.62	1.09	12.70
310	0.79	31.28	56	65.5	139	17.56	19.53	34.80	0.56	0.62	1.11	13.12
320	0.81	31.12	56	65.5	141	17.56	19.53	35.22	0.56	0.63	1.13	13.55
330	0.84	30.97	56	65.5	141.5	17.56	19.53	35.32	0.57	0.63	1.14	13.97
340	0.86	30.82	56	65.5	142.5	17.56	19.53	35.53	0.57	0.63	1.15	14.39
350	0.89	30.67	56		142.5	17.56		35.53	0.57		1.16	14.82
360	0.91	30.51	56		142.5	17.56		35.53	0.58		1.16	15.24
370	0.94	30.36	56		142.5	17.56		35.53	0.58		1.17	15.66
380	0.97	30.21	56		144	17.56		35.84	0.58		1.19	16.09
390	0.99	30.06			144.5			35.95			1.20	16.51
400	1.02	29.90			146			36.26			1.21	16.93
410	1.04	29.75			146			36.26			1.22	17.36
420	1.07	29.60			146			36.26			1.22	17.78
430	1.09	29.45			147			36.47			1.24	18.20
440	1.12	29.29			147			36.47			1.24	18.63
450	1.14	29.14			148			36.67			1.26	19.05
460	1.17	28.99			148			36.67			1.27	19.47
470	1.19	28.84			148			36.67			1.27	19.90
480	1.22	28.68			148			36.67			1.28	20.32
490	1.24	28.53			148			36.67			1.29	20.74

Table A-33 The direct shear test result of 100U at 80°C

DİREKT KESME DENEYİ
(*DIRECT SHEAR TEST*)

İşin Adı	*(Job Name) :*	**Yapan**	*(Tested By) :*
Sondaj No	*(Boring No) :*	**Tarih**	*(Date) :*
Örnek No	*(Sample No) :*		
Derinlik	*(Depth) :*		

Örnek Boyutları	*(sample dimensions) cm :*	6X6X2
Örnek Ağırlığı	*(sample weight) gr :*	
Doğal b.h.a	*(natural unit weight) t/m^3 :*	
Yükleme Hızı	*(loading rate) mm/dak :*	0.5

Normal Yükler P (kg) [Normal Loads P (kg)]		
P_1	P_2	P_3
18	36	72

Yatay Dial Okuması	Yatay Deplasman	Düzeltilmiş Alan	Yük Diali Okuması *Local Dial Reading*			Yatay Kesme Kuvveti *Horizantal Shear Force*			Kayma Gerilmesi *Shear Stress*			Birim Def. *Strain*
Horizantal Dial Reading	Horizantal Replacement	Corrected Area A'	D_1	D_2	D_3	P_1	P_2	P_3	τ_1	τ_2	τ_3	ε
-	cm	cm^2	-	-	-	kg	kg	kg	kg/cm^2	kg/cm^2	kg/cm^2	%
0	0.00	36.00	0	0	0	5.92	5.92	5.92	0.16	0.16	0.16	0.00
10	0.03	35.85	17	42	98	9.45	14.65	26.28	0.26	0.41	0.73	0.42
20	0.05	35.70	23	73	123	10.70	21.09	31.48	0.30	0.59	0.88	0.85
30	0.08	35.54	28.5	76	132	11.84	21.71	33.35	0.33	0.61	0.94	1.27
40	0.10	35.39	31	79.5	136	12.36	22.44	34.18	0.35	0.63	0.97	1.69
50	0.13	35.24	32	80	140	12.57	22.54	35.01	0.36	0.64	0.99	2.12
60	0.15	35.09	33.5	81	144	12.88	22.75	35.84	0.37	0.65	1.02	2.54
70	0.18	34.93	35	83	146.5	13.19	23.17	36.36	0.38	0.66	1.04	2.96
80	0.20	34.78	35.5	95	149	13.30	25.66	36.88	0.38	0.74	1.06	3.39
90	0.23	34.63	43.5	99.5	153	14.96	26.60	37.71	0.43	0.77	1.09	3.81
100	0.25	34.48	46	101	182.5	15.48	26.91	43.84	0.45	0.78	1.27	4.23
110	0.28	34.32	47	103	192	15.69	27.32	45.82	0.46	0.80	1.33	4.66
120	0.30	34.17	48	105.5	199	15.89	27.84	47.27	0.47	0.81	1.38	5.08
130	0.33	34.02	48.5	108.5	205	16.00	28.47	48.52	0.47	0.84	1.43	5.50
140	0.36	33.87	49.5	109	210	16.21	28.57	49.56	0.48	0.84	1.46	5.93
150	0.38	33.71	50	109.5	214.5	16.31	28.67	50.49	0.48	0.85	1.50	6.35
160	0.41	33.56	50.5	109	218	16.41	28.57	51.22	0.49	0.85	1.53	6.77
170	0.43	33.41	51.5	109	220.5	16.62	28.57	51.74	0.50	0.86	1.55	7.20
180	0.46	33.26	52.5	108.5	221	16.83	28.47	51.84	0.51	0.86	1.56	7.62
190	0.48	33.10	52.5	108	221	16.83	28.36	51.84	0.51	0.86	1.57	8.04
200	0.51	32.95	52.5	108.5	220	16.83	28.47	51.64	0.51	0.86	1.57	8.47
210	0.53	32.80	53.5	109	220	17.04	28.57	51.64	0.52	0.87	1.57	8.89
220	0.56	32.65	53.5	108	220.5	17.04	28.36	51.74	0.52	0.87	1.58	9.31
230	0.58	32.49	53.5	107	221.5	17.04	28.15	51.95	0.52	0.87	1.60	9.74
240	0.61	32.34	53.5	105	222.5	17.04	27.74	52.16	0.53	0.86	1.61	10.16
250	0.64	32.19	53.5	104	224	17.04	27.53	52.47	0.53	0.86	1.63	10.58
260	0.66	32.04	53.5	103	225	17.04	27.32	52.67	0.53	0.85	1.64	11.01
270	0.69	31.89	53.5	103	224.5	17.04	27.32	52.57	0.53	0.86	1.65	11.43
280	0.71	31.73	53.5	103.5	224.5	17.04	27.43	52.57	0.54	0.86	1.66	11.85
290	0.74	31.58	54	102.5	224.5	17.14	27.22	52.57	0.54	0.86	1.66	12.28
300	0.76	31.43	54	103	225	17.14	27.32	52.67	0.55	0.87	1.68	12.70
310	0.79	31.28	54	101	225.5	17.14	26.91	52.78	0.55	0.86	1.69	13.12
320	0.81	31.12	54	100	226	17.14	26.70	52.88	0.55	0.86	1.70	13.55
330	0.84	30.97	54.5	99	227.5	17.24	26.49	53.19	0.56	0.86	1.72	13.97
340	0.86	30.82	54.5		229	17.24		53.51	0.56		1.74	14.39
350	0.89	30.67	54.5		230.5	17.24		53.82	0.56		1.75	14.82
360	0.91	30.51	54.5		232.5	17.24		54.23	0.57		1.78	15.24
370	0.94	30.36	54.5		233	17.24		54.34	0.57		1.79	15.66
380	0.97	30.21	54.5		232.5	17.24		54.23	0.57		1.80	16.09
390	0.99	30.06	54.5		235	17.24		54.75	0.57		1.82	16.51
400	1.02	29.90	55		235	17.35		54.75	0.58		1.83	16.93
410	1.04	29.75	55.5		234.5	17.45		54.65	0.59		1.84	17.36
420	1.07	29.60	55.5		234	17.45		54.54	0.59		1.84	17.78
430	1.09	29.45	55.5		234	17.45		54.54	0.59		1.85	18.20
440	1.12	29.29	55.5		234	17.45		54.54	0.60		1.86	18.63
450	1.14	29.14	55.5		234	17.45		54.54	0.60		1.87	19.05
460	1.17	28.99	55.5			17.45		5.92	0.60			19.47
470	1.19	28.84	55.5			17.45			0.61			19.90