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# Effect of rice husk ash addition on the consolidation characteristics of cohesive soils

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**Abstract**

One of the consequences of heavy urbanization in the cities is a widespread increase in high-rise buildings. A direct result of high-rise building construction is the increase in pressures applied to the foundation soils beneath the structures. This will cause high amount of settlements in most of the cohesive soils. Time dependent compaction of soils under constant stresses due to escape of water from voids is inevitable for most normally consolidated clays. Over a period of time, the gradual increase in effective stress in the soil layer will cause settlement. This event is referred to as consolidation. At this point, soil improvement techniques can be a good alternative for increasing the engineering properties of the soils. Rice husk ash is an organic pozzolanic by-product obtained by burning rice husks. Within the scope of this study, the consolidation characteristics of soils improved with rice husk ash, an organic pozzolanic waste product, were investigated by laboratory studies.

## 1. Introduction

One of the consequences of increasing urbanization is the necessity of higher buildings. The stresses caused by the high structural loads on the soils cause deformations. As a result of the compression and displacement of soil particles under load, settlement occurs in the ground. Time dependent settlements due to decrease in volume of water in the voids is called consolidation settlement [1].

Depending on soil type, various amounts of deformations are likely to develop in building foundations. These deformations cause the stress conditions of the soil under the structure to change. Due to the increase in stress conditions, settlements occur in the ground under the structure. Contrarily, swelling can also be observed as a result of the decrease in the stresses in the soil mass for any reason or the changes that may occur in the water levels. Engineering structures built on soils with high potential for settlement and swelling are exposed to forces arising from the swelling properties of soils. This affects the load bearing elements of the buildings while causing further deformations in the structure. Changes in the volume of the soil mass due to settlement and swelling properties are one of the most influential factors in geotechnical design [2].

In this study, the use of rice husk ash obtained by burning rice hulls, which is an organic waste product, in soil improvement works will be studied. Rice husk is an organic waste product resulting from the removal of the grains of rice (Figure 1). About one hundred million tons of rice husk per year are produced worldwide. In order to reduce the volume of waste, rice husk is burned as a fuel in ovens for rice drying, the burning effect volatilizes the organic compounds and water of the rice husk, and about 20% of the mass remains as rice husk ash. Rice husk ash, one of the pozzolanic additives, is obtained by burning rice husks. It is well known that clayey soils have significant potential of consolidation settlements and swelling problems depending of the type of clay minerals dominant in the soil mass. It is well known that clayey soils do not respond the immediate compactive activities but exhibits time dependent settlement [2]. When the clayey soils with low water permeability are subjected to vertical loads, the porosity decreases due to water escaping out of the soil voids. The aim of this study is to investigate the consolidation characteristics of low plasticity clays after mixing with rice husk ash as an additive material.

**Figure 1.** Rice husk ash

## 2. Material and Method

The phenomenon of compaction of soils under constant stresses by removing the water in their bodies, depending on time, is called consolidation. Over a period of time, the gradual increase in effective stress in the soil layer will cause settlement. This event is referred to as consolidation. This process continues until the excess pore water pressure caused by an increase in total stress is completely dissipated. The simplest consolidation case is one-way consolidation under the condition of zero lateral deformation. The swelling process, which is the opposite of consolidation, is a slow increase in the volume of a soil under negative excess pore water pressure [3]. The consolidation coefficient ($C_c$) is determined by a test apparatus called as oedometer.

The consolidation test begins by placing the soil samples in the consolidation ring with sufficient compression (Figure 2a, 2b, 3a and 3b).

The surfaces of the samples placed in the consolidation rings are smoothed and weighed with the help of a balance (Figure 4a and 4b).

Then, the soil sample placed in the ring is placed in the consolidation cell, bounded by porous stones from the bottom and top, and the cell is filled with water. The cells filled with water are placed in the consolidation instrument and a reading clock is placed on it to read the vertical deformations. Then, the necessary loads are placed on the lever arm of the consolidation tool and the loading process is started and the deformations are read at regular intervals for 24 hours. At the end of 24 hours, the next load is placed on the lever arm of the consolidation tool and the loading is started again and the readings are taken again for 24 hours. In our experiment, appropriate weight loadings were made corresponding to 25, 100, 400 and 1600 KPa pressures and the necessary readings were taken.

After the loading tests are completed, the soil samples removed from the consolidation tool are weighed with the help of scales and left to dry in the drying oven for 24 hours (Figure 5a, 5b, 6a, 6b, 7a and 7b). As a result of all these experiments, the desired value is obtained by drawing the vertical stress versus void ratio graphs.

**Figure 2a.** Soil samples

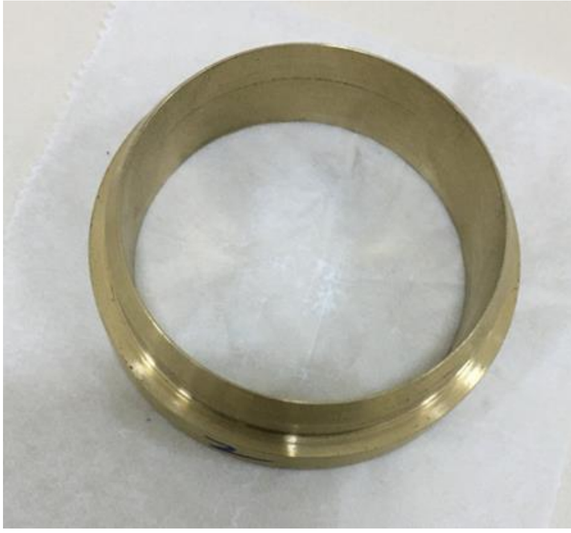

**Figure 2b.** Consolidation ring

**Figure 3a.** Placed soil sample

**Figure 3b.** Compressed soil sample

**Figure 4a.** Soil sample with smoothed surface

**Figure 4b.** Soil sample with smoothed surface

**Figure 5a.** After the loading tests

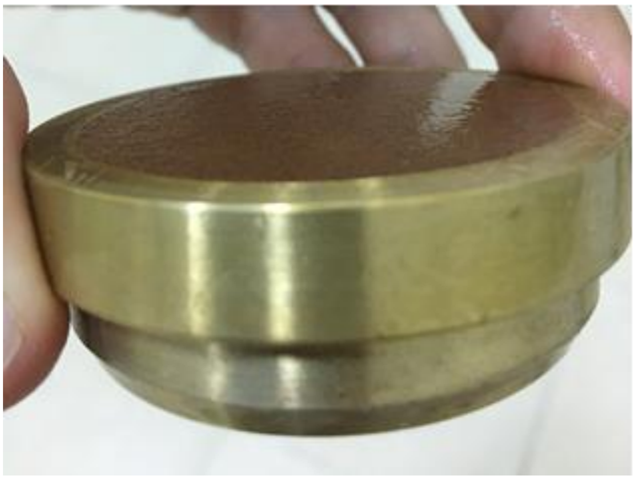

**Figure 5b.** After the loading tests

**Figure 6a.** Wet specimen


**Figure 6b.** Drying the specimen in the oven

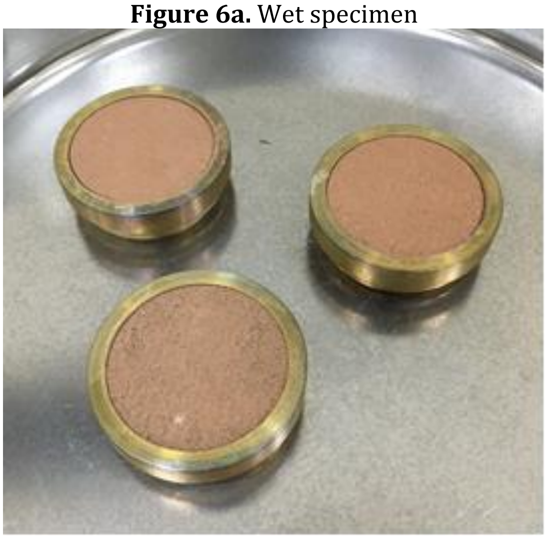

**Figure 7a.** Dried samples

**Figure 7b.** Removing the samples from the ring

In this study, the effect of rice husk ash on the consolidation settlement and swelling characteristics of low plasticity clayey soils was investigated by adding 5% and 10% by weight rice husk ash to the natural soil sample, respectively. The soil samples we used in the experiment were cured for 3 days by keeping the humidity constant in the desiccator. None of the samples were mixed with lime or cement within the scope of this study.

### 2.1. Literature review

Aysu [1] investigated the effect of glass fiber additive on the strength, permeability and consolidation properties of the soil in high plasticity clay soils. Within the scope of the study, firstly, the geotechnical properties of the clay soil were determined and the physical properties of the glass fiber were defined. Glass fiber with a length of 12 mm was used in the study. The glass fiber ratio in the samples was added as a certain percentage by weight of the clay soil, randomly mixed with the clay soil and the mixture samples were prepared using the optimum water content. Bearing capacity, consolidation and permeability tests were carried out on the clay samples with and without additives saturated with water, and the effect of a certain amount of glass fiber additive on the bearing capacity, settlement and permeability of the clay soil was investigated. In addition, in high plasticity clay soils, the additive ratio of glass fiber additive that provides the strength, permeability and consolidation properties of the soil in the optimum way has been determined.

Yılmaz and Çelik [2] tried to improve the consolidation and swelling behavior of a clay from Erzurum Oltu region by using ground quartz sand. Within the scope of the study, ground sand was added to the clay soil in various proportions, compacted at optimum water content and consolidation tests were carried out. As a result of the consolidation and swelling experiments, it was determined that the swelling pressure and the volumetric compression coefficient decreased, while the consolidation coefficient increased as the ground sand ratio increased.

Behak [4] examined the effects of lime and rice husk ash on soil improvement studies. In this context, stabilization studies were carried out by applying combinations of rice husk ash and lime on sandy soils. In the experiments, it was observed that cementitious compounds were formed in soil mixtures containing rice husk ash and lime in different proportions. Unconfined compressive strength tests were carried out on soils treated with rice husk ash and lime. The results showed improvement in strength properties for all studied rice husk ash and lime contents and time periods. All soil samples produced as a result of the experiments were defined as modified rather than stabilized.

Çelik [5], investigated the fluidity, rheological, mechanical and stability properties of cement-based grout mixtures with rice husk ash added in his study. The experiments were carried out on 135 cylindrical samples and fifteen different mixtures prepared in three different water/binder ratios and various ratios of rice husk ash. The fluidity, plastic viscosity, apparent viscosity and cohesion properties of the prepared samples were investigated in the first part of the study. Subsequently, uniaxial unconfined compressive strength, amount of segregation and fracture criterion during axial loading were evaluated in the second part of the study. In the second section, it was observed that the mixing ratios were kept constant as in the first section and 20% by weight was mixed with a clay soil. The mixtures were cured at room conditions for 3, 7 and 28 days. With these tests, the unconfined compressive strength, elastic modulus values and settlement rates as a result of segregation were observed. Experiment results showed that rice husk ash and cement additive had a significant effect on the rheological, fluidity, unconfined compressive strength and stability properties of soils. The unconfined compressive strengths for all mixtures were found to be in acceptable ranges, remaining above 1 MPa and below 5% precipitation.

Aygün [6], carried out a soil improvement study by adding lime and rice husk ash to a silty soil. Within the scope of this study, firstly, the geotechnical properties of the soil sample were determined. Then, the soil sample, whose geotechnical properties were determined, was improved by using lime, rice husk ash and lime + rice husk ash. For soil improvement, 5% lime, 5%, 10%, 15%, 20% rice husk ash and their mixture combinations were added to the ground. Within the scope of this study, compaction, CBR and unconfined pressure tests were applied on the test samples. As a result of the compaction tests, it was observed that while the instantaneous undrained shear strength value was 30 kPa with the addition of 5% lime to the natural soil sample, it reached 86 kPa at the end of the 28-day curing period. If 20% rice husk ash was added to the natural soil sample, the instantaneous undrained shear strength value increased from 30 kPa to 48 kPa after 28 days of curing. Although there was some increase with the addition of rice husk ash alone to the ground, it was not significant. In the case of adding 5% lime + 20% rice husk ash to the natural soil sample, the instantaneous undrained shear strength value increased from 30 kPa to 186 kPa after 28 days of curing. As a result of the experimental studies, it was observed that the undrained shear strength values of the soil increased with the curing time. As a result of CBR experiments, free swelling and CBR values were examined. While the swelling value of the natural soil sample was 1.45 cm, the swelling value decreased to 0.03 cm after adding 5% lime to the ground and curing for 28 days. Likewise, the swelling values decreased with the addition of rice husk ash to the soil. While the CBR value of the natural soil sample was 6% at the end of the 28-day curing period, this value increased to 33% after the addition of 5% lime and the 28-day curing period. As a result of the CBR experiments, the CBR value for the natural sample was 6%, while this value was 20% as a result of the addition of rice husk. The greatest increase in CBR value was realized with the addition of lime and rice husk ash to the soil. As a result of permeability tests, it was observed that a slight decrease in permeability occurred with the addition of lime to the soil. If rice husk ash was added, the permeability of the soil increased. The permeability decreased when the two additives were added together. As a result of the experiments carried out within the scope of the study, it was observed that the physical properties of the soil improved with the addition of lime and rice husk ash together or separately.

Basha et al. [7], investigated the improvement potential of residual soil soils by adding rice husk ash and cement at different rates in their studies. In this context, the compaction, strength and X-ray diffraction properties of the soil were evaluated. As a result of the tests, they observed that both cement and rice husk ash reduced the plasticity of the soil. In addition, it is understood from the test results that the addition of rice husk ash and cement mixtures to the soil in optimum proportions provides a noticeable increase in mechanical properties.

Liu et al. [8], investigated the cementous material lime and rice husk ash and its use on expansive soil. In the study, lime and rice husk ash mixtures were used in different ratios and combinations. The swelling test, consolidation test, unconfined compression test, direct shear test, and so on were applied to the soil samples obtained. In addition, the samples obtained were kept in curing for 7, 14, 28 and 56 days. With the increase in rice husk ash-lime content and curing time, the deformation properties such as swelling potential, swelling pressure, compaction index, crack amount and the thinness of the expanding soil significantly decrease; meanwhile, strength properties including unlimited compressive strength, cohesion and internal friction angle were observed to be significantly improved. Considering the engineering performance and cost, a 15% mixing ratio and an initial water content of 1.2 times the optimum moisture content were recommended by the researcher to stabilize the expanded soil.

Muntohar et al. [9] made soil improvement studies by adding rice husk ash, lime and waste plastic fiber in different proportions to silty soils. In the studies carried out in this context, some experiments were carried out by adding waste plastic fiber in different proportions to a mixture of 12% lime first, then 12% lime + 12% rice husk ash and 12% lime + 12% rice husk ash. As a result of these experiments, it was observed that lime and rice husk ash mixtures increased the compressive and tensile strength of the soil by 4 or 5 times, respectively, the inclusion of plastic waste fibers played an important role in increasing the tensile strength and strength ratio of the stabilized soil, and the pressure increased as the curing age increased. It was concluded that the resistance increased even more.

Brooks [10], observed the effect of rice husk ash in his laboratory experiments on mixtures of high plasticity clay and rice husk ash in different proportions. His C.B.R. and as a result of unconfined compressive stress experiments, the optimum rice husk ash ratio was calculated as 12% by weight. The clay-rice husk ash mixture, in which 12% by weight rice husk ash is used, provides a 97% increase in the unconfined compressive stress, while this ratio is C.B.R. was 47% in the test.

Kar et al. [11] focused on the effect of short random fiber inclusion on consolidation settlement in compacted clays. To examine possible improvements in consolidation properties, local clay soil was reinforced with 10 percent of the dry weight of the soil by randomly distributing 15 and 20 mm lengths of polypropylene and coir fiber. The results showed that with the addition of polypropylene/coconut fibers to the soil, the compaction index and the volume variation coefficient decreased up to a certain fiber content and then increased.

Altundağ [12] investigated the consolidation characteristics of silty soils with the help of oedometer tests. In this study, the compression parameters of silty soils with different clay ratios and the pre-consolidation pressure values obtained by different methods were also investigated. For this purpose, after removing the clay and sand-sized particles from the silty soil sample taken from Adapazarı, the mixtures prepared by adding clay samples at certain rates were turned into a slurry by adding distilled water, and consolidation tests were carried out on the samples prepared by consolidating these slurries. 8 mixtures with different silt and clay ratios were prepared in the laboratory. The physical properties of these samples were measured. The 8 samples prepared were consolidated from the slurry in the laboratory under 100 kPa vertical stress and reconstituted. The samples were subjected to the consolidation test in a conventional oedometer instrument. By using the obtained consolidation curves, the pre-consolidation pressure values of the samples were determined according to 6 different methods found in the literature. In addition, using the data obtained from the experiments, the compression coefficient, consolidation coefficient, compression index, reloading index of each sample were calculated and the results were compared. As the clay content in the samples prepared as a result of the consolidation experiments and calculations increased, the consolidation coefficient values obtained decreased; compression coefficient, volumetric compression coefficient, compression index and recompression index values increased.

Erşan and Yıldırım [13], experimentally investigated the pore water pressure, shear deformation, consolidation settlements, shear strengths of normal consolidated clays under undrained cyclic loads and the factors affecting these behaviors using a dynamic simple shear test system. The samples were prepared in a sludge consolidation device. The experiments were performed by applying five times constant amplitude sinusoidal undrained cyclic loading and drainage after each repetitive load to the samples at different stress ratios and cycle numbers. After the fifth stage of drainage, the samples were statically cut. At the end of the study, it was observed that the resistance of the clays that were subjected to cyclic loading and drainage against subsequent cyclic loading increased, settlement, pore water pressure and shear deformation decreased after each cyclic loading. However, the shear strength of clays exposed to cyclic loading and drainage increased.

## 3. Results

Based on the data obtained from the tests performed, the vertical stress versus void ratio graphs of the natural sample and the samples with 5% rice husk ash and 10% rice husk ash added, respectively, are depicted in Figures 8, 9 and 10. The compression ($C_c$) and swell ($C_s$) indices calculated from the graphs are shown in Table 1.

**Table 1.** Test results to compare the compression and swell indices for the tested samples

| Test Name | Compression coefficient ($C_c$) | Swelling coefficient ($C_s$) | Water Contents (%) |
|---|---|---|---|
| Natural soil sample | 7.152E-05 | 1.542E-05 | 13.15 |
| %5 rice husk ash added sample | 8.553E-05 | 1.497E-05 | 15.94 |
| %10 rice husk ash added sample | 9.637E-05 | 1.507E-05 | 18.55 |

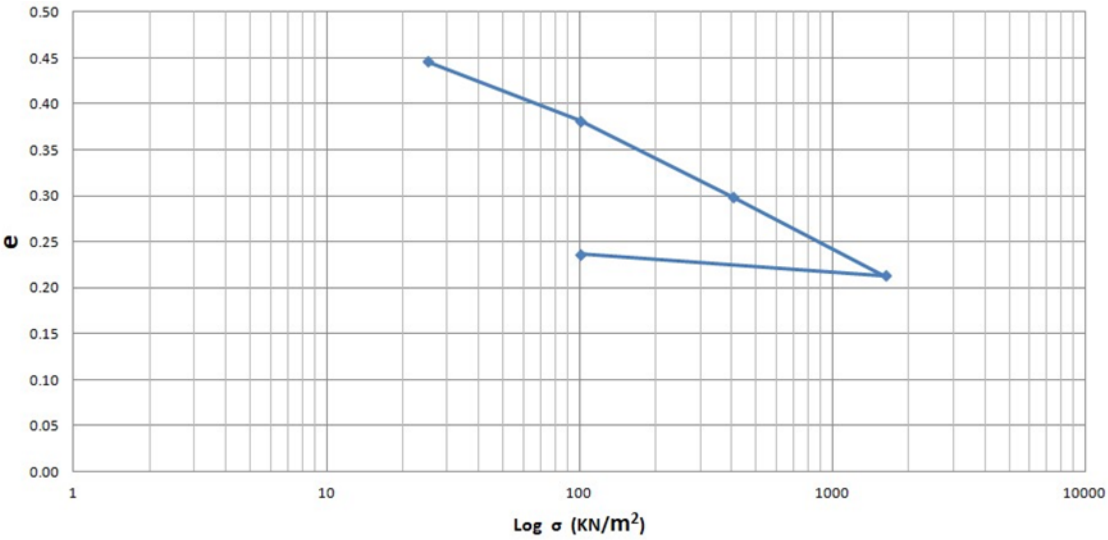


**Figure 8.** The vertical stress versus void ratio graph for the natural soil sample

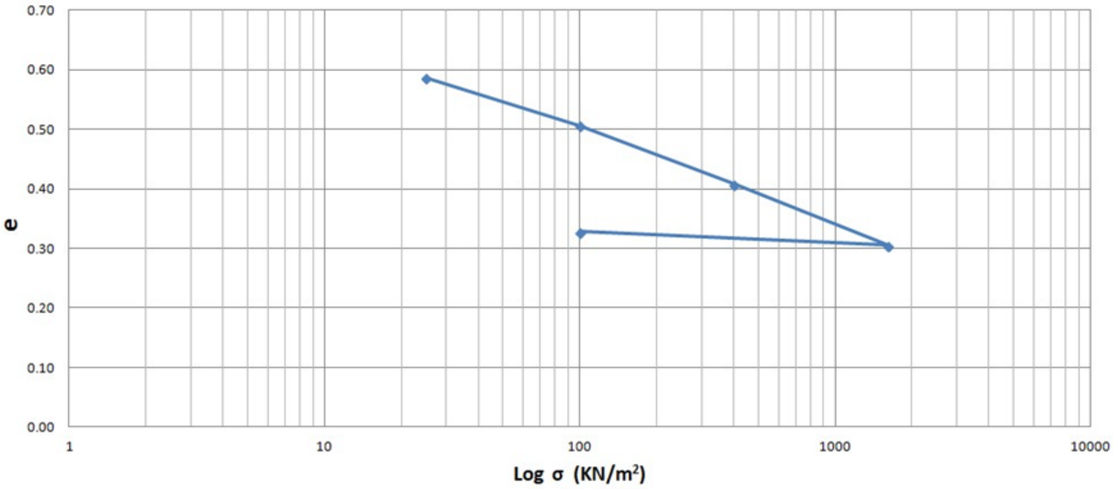


**Figure 9.** The vertical stress versus void ratio graph for the %5 rice husk ash added clayey soil

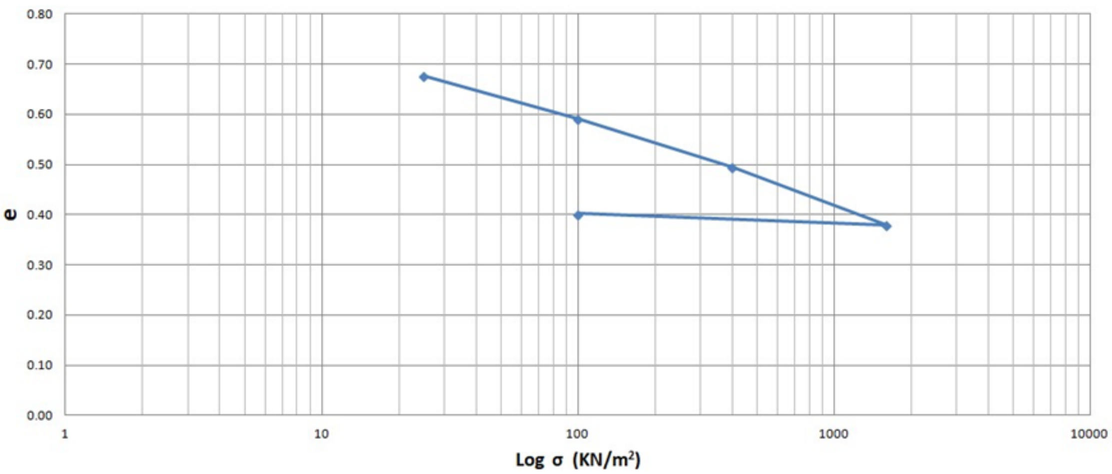


**Figure 10.** The vertical stress versus void ratio graph for the %10 rice husk ash added clayey soil

When the results of the consolidation test were investigated, it was observed that the smallest compression coefficient ($C_c$) was obtained in the natural sample and the highest compression coefficient was obtained in the 10% rice husk added sample. This can be explained with the high-water content of the %5 and %10 rice hush ash added soils. As the water content of the samples increases, the amount of dry mass decreases and the void ratio increases. Increasing void ratios cause an increase in the settlement coefficients in the experiments. In the consolidation test we have performed; it is observed that the settlement coefficients tend to increase because the water contents of the samples are different and higher than each other. In order to reduce this increase, it is necessary to keep the water contents constant or close to constant.

## 4. Conclusion

In the consolidation tests performed; it is seen that rice husk ash has some effect on the consolidation characteristics of low plasticity clayey soils. However, it is not realistic to come to solid conclusions regarding the effect of rice hush ask additive on the consolidation characteristics of the soils since there is a discrepancy in the water content of the samples in this study. However, it is clear that rice hush ash is modifying the consolidation indices of clayey soils due to its pozzolanic effect which can provide some amount of improvement in the soils. The number of tests should be increased to get more realistic conclusion for this. As an anticipated future study, it is planned to carry out further consolidation tests on the samples with identical water content.

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**Author contributions**

**Abuzer Buluş Karakurt:** Conceptualization, Methodology, Software **Özgür Lütfi Ertuğrul:** Data curation, Writing-Original draft preparation, Validation.

**Conflicts of interest**

The authors declare no conflicts of interest.

**References**

1. Aysu, Ş. (2020). *Yüksek plastisiteli kil zeminlerde cam lifi katkısının zeminin mukavemet, permeabilite ve konsolidasyon özelliklerine etkisi* (Master's thesis, Konya Teknik Üniversitesi).
2. Yilmaz, M., & Çelik, S. (2013). Kil zeminin şişme basıncı ve konsolidasyon özelliklerine öğütülmüş kumun etkisinin araştırılması. *Kahramanmaraş Sütçü İmam Üniversitesi Mühendislik Bilimleri Dergisi*, *15*(2), 32-36.
3. Yılmaz, I., Keskin, İ., & Yıldırım, M. (2014). Zemin mekaniği: laboratuvar deneyleri ve problemler. Seçkin Yayıncılık.
4. Behak, L. (2017). Soil stabilization with rice husk ash. Rice: Technology and Production, 29.
5. Çelik, F. (2016). An İnvestigation Of Rheological and Mechanical Properties of Cement Base Grout Mixed with Rice Husk Ash. Doktora Tezi, Gaziantep Üniversitesi Fen Bilimleri Enstitüsü, Gaziantep.
6. Aygün, T. (2019). Siltli bir zeminin kireç ve pirinç kabuğu külü ile iyileştirilmesi. Kırklareli Üniversitesi Fen bilimleri Enstitüsü.
7. Basha, E., A., Hashim, R., Mahmud, H., B., Muntohar, A., S., (2004). Stabilization Of Residual Soil with Rice Husk Ash and Cement. Construction Of Building Materials, 19.6, 448-453.
8. Liu, Y., Su, Y., Namdar, A., Zhou, G., She, Y., & Yang, Q. (2019). Utilization of cementitious material from residual rice husk ash and lime in stabilization of expansive soil. Advances in Civil Engineering, 2019.
9. Muntohar, A. S., Widianti, A., Hartono, E., & Diana, W. (2013). Engineering properties of silty soil stabilized with lime and rice husk ash and reinforced with waste plastic fiber. Journal of materials in civil engineering, 25(9), 1260-1270.

10. Brooks, R. M. (2009). Soil stabilization with fly ash and rice husk ash. International Journal of Research and Reviews in Applied Sciences, 1(3), 209-217.
11. Kar, R. K., Pradhan, P. K., & Naik, A. (2012). Consolidation characteristics of fiber reinforced cohesive soil. Electronic Journal of Geotechnical Engineering, 17, 3861-3874.
12. Altundağ, Y. (2016). Siltli zeminlerin konsolidasyon karakteristikleri. Sakarya Üniversitesi Fen Bilimleri Enstitüsü.
13. Erşan, H., & Yıldırım, H. (2011). Tekrarlı yüklemeler etkisi altında zeminlerin konsolidasyonu. İTÜDERGİSİ/d, 5(3).
14. Karakurt, A. B., & Ertuğrul, Ö. L. (2022). Consolidation characteristics of clayey soils improved with rice husk ash. *Advanced Engineering Days (AED)*, *4*, 119-122.