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The Experimental Analysis of The Effect of Geotextile Reinforcement of Cohesive Soil on The Settlement and Bearing Capacity

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Abstract: The engineering properties of soils must be identified to design buildings and foundations in areas where soft clay or loose sand ground conditions predominate. These properties vary widely depending on the type of soil and terrain conditions, such as compaction, water content, consolidation pressure, loading, and drainage conditions. Soils may not always retain the desired properties. Structures built on soils with inadequate bearing capacity can experience excessive settlement or collapse. To reinforce weak soils, either deep foundations or ground improvement methods can be used. This study examined the effect of geotextile reinforcement on clay ground. Experiments were conducted at the Süleyman Demirel University Soil Mechanics Laboratory on clay samples from the provinces of İzmir and İstanbul to determine the index properties, settlement, and sliding resistance parameters of soils. After identifying the settlement and sliding values, geotextile was added, and its effect on settlement and bearing strength values was analyzed. Experiments were conducted by placing single-layered and double-layered geotextile in samples with optimum water content, water content 10% higher than optimum, and water content 10% lower than optimum. The effects on the settlement and bearing capacity of geotextiles mentioned in the article were examined. The results achieved after laboratory experiments are displayed with graphics and compared with each other. As a result of this study, it was observed that geotextile reinforcement increased the bearing capacity of the soil and controlled the settlement behavior.

Keywords: Clay, Geotextile, Bearing Capacity, Settlement, Unconfined compressive strength

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1. INTRODUCTION

In geotechnical engineering, soft clay grounds are regarded as problematic grounds in terms of both high compressibility and low load-bearing capacity. Various methods are employed to develop the bearing capacity and settlement behavior of such grounds. There are various ground improvement methods such as mini piles, ground anchoring, stone column, deep mixing, groundwater disposal, ground changing, additive material, filling. One of the methods of soil amendment, which has grown increasingly significant in current years, is the geosynthetic-reinforced grounds. Geotextiles can be applied in various ways to develop the engineering parameters of inconvenient and problematic soils. They, which are classified as woven or non-woven, are often applied in bevels, retaining constructions, highways, railways, fillings that settle on soft floors, and sub-base foundations for improvement (Koerner,1989). Quick and durable solutions can be created with geosynthetics. Experimental and theoretical researches connecting geosynthetics with clay grounds have been carried out.

Mandal and Sah (1992); examined the geogrid reinforcements placed horizontally on the clay ground layers, and the bearing strength of square foundations through model experiments. Improvement was observed at all settlement rates, and notable improvements were observed in the improvement factor in the range of u / B (reinforcement depth/foundation width) =0-0.25.

Ramaswamy and Purushothaman 1992); studied the bearing capacity of model foundations lying on clay ground reinforced with geogrid reinforcement by experimental studies. In clay ground and clay ground with geotextile, the bearing capacity reduced as the water content increased. While the bearing capacity ratio (BCR) of the clay reinforced with double-layered geogrid reinforcement in the optimum water content was 1.47 compared to the clay ground, this ratio was 1.11 in the wetter condition than the optimum, and it was 1.26 in the drier condition than optimum.

Shin et al. (1993) analyzed the bearing capacities of the strip foundation on a water-saturated clay ground reinforced with geogrid reinforcements by laboratory experiments. Model experiments were conducted on one type of clay, and the alteration of the average water content created changes in the undrained sliding strength. The undrained sliding strength *cu* was identified through the vane test. In laboratory experiments, the critical geogrid layer depth, layer width, primary reinforcement layer depth, and the highest Bearing Capacitiy Ratio BCR value and u/B (reinforce depth/foundation width) was assessed as 0.4.

Das et al. (1994) examined the bearing capacity of strip foundation on the sand and water-saturated clay ground reinforced by geogrid. Grounded on model experiments, optimum primary reinforcement depth, optimum total reinforcement depth, and width were determined for both types of soils. Das et al. reached a ratio between the reinforcement depth and the width of the foundation, B. The total reinforcement depth operating efficiently in the sand was determined to be 2B and 1.75B in clays. The primary reinforcement depth that provided the maximum bearing capacity was 0.30 B in the sands and 0.40B in the clays.

Adams and Collin (1997) performed 34 loading experiments utilizing two different geosynthetics (geogrid and geocell) in order to determine the bearing strength and settlement properties of the surface foundations on geosynthetic reinforced grounds. The number of reinforcement layers, the distance between layers, first reinforcement depth, reinforcement type, and ground density are regarded as variable parameters. From the results achieved from the experiments, the addition of geosynthetic reinforcement has been given to improve the bearing capacity of the sand grounds by about 2.5 times. In the situation where the first reinforcement depth is 0.25B, the highest bearing capacity value is achieved.

Alawaji (2001) examined the strengthening of collapsible sand grounds with geogrid reinforcements, which are exposed to the collapse settlement because of water content. Consequently, Alawaji discovered that the most effective reinforcement design on the collapsible ground is for the situation where the geogrid width is higher four times than the diameter of the loaded area, and the depth of the foundation diameter is 10 %.

Bergado et al. (2001) compared the rise in bearing capacity of soft clay grounds reinforced with geotextile with both experimental and numerical analysis. In the experimental study, they applied the modified California Bearing Ratio (CBR) experimental setup. In their reinforcement studies, they used three different reinforcements of different rigidness. In the modeling, it was estimated that the elasticity modules of clay grounds were higher 315 times than that of the undrained sliding strength. With the parameters applied in these models, values very close to experimental results were achieved.

Dash et al.(2003) studied the effects of geocell on the soft clay ground on the granular filling layer on the small-scale model experiments. Subsequently, it has been discovered that with the convenient settlement of the geocell, the bearing capacity of the circular foundation can be increased seven times.

Noorzad and Mirmoradi (2010) carried out extensive research on clays, including geotextile reinforcement. They examined the effect of geotextiles with various permeability properties, water content, number of geotextile reinforcement, and plasticity on strength parameters of reinforced clay with the triaxial and unconfined compression test. Noorzad and Mirmoradi observed that geotextile reinforcement developed the strength parameters of the clay.

Karakan et al. (2015) studied the behavior of clay grounds reinforced with geotextile reinforcement. With the aim of defining the stress-strain behavior of clay ground samples, unconfined compression experiments have been carried out with and without reinforcement. In the study, in order to show the optimum water content and the change of water content that may happen in the field using clay with low plasticity, it was examined on the dry and wet sides of the compaction curve (± 2, +3, and ± 4). With these parameters, a series of experiment set, including at least three samples were developed. It has been observed that the use of reinforcement develops the mechanical properties of the ground, and the use of geotextiles improves the peak strength.

Çakar (2016) directed a series of unconfined compression tests to define the effects and potential advantages of the use of geotextiles on the mechanical behavior of clay grounds. The effect of the parameters influencing the mechanical properties of the geotextile reinforced material such as geotextile type (woven and non-woven), loading speed, the number of geotextile layers (non-layered, single-layered, two-layered, three-layered and four-layered) was examined.

Aslan (2021) in a study conducted on reinforced earthen walls; hard to get instead of granular filler, marginal filler, which is easier to obtain, was used by changing the filler type. By changing the reinforcement type of this filler (using more resistant reinforcement) and using geosynthetic with higher bending rigidity, an advantage was achieved in terms of construction time and cost of the structure, and it performed as well as granular fillers.

Noori ve Dehganyan (2021) in their study, geogrid and geotextile were placed in clay and sand soils in different numbers, at different depths and in different layers. When the situations of placing one row, two rows and three rows were compared, one row placement had no effect on reducing seating, but they saw a positive contribution in the others.

Demir et al. (2022) in their study, as a result of improving the soil with geotextile produced from hemp, free pressure and triaxial pressure test data showed that the use of

reinforcement had a significant positive effect on soil strength.
In this study, the effect of geotextile reinforcement, which is one of the improvement methods for clay soils, was investigated experimentally. To determine the soil parameters, classification experiments, uniaxial compression tests and consolidation tests were carried out on two different clay soils. Afterwards, clay soils were prepared at three water contents, one of which was optimum water content, and the changes in settlement and shear parameters were examined in case of single and double row geotextile placement.

2. MATERIAL AND METHOD

In the design of the foundations, it is essential to comprehend the engineering and index properties of the ground along with the structure load, load distribution, and structure features. To determine the engineering parameters of soils Sieve analysis, consistency limits and pycnometer tests were carried out. In this context, the index and compaction properties of clays obtained from Istanbul and Izmir were initially defined. At the end of the experiments, the sample from Istanbul province presented Low Plasticity Clay ground (CL) value and the sample from Izmir province High Plasticity Clay ground gave (CH) value. The test results are displayed collectively in Table 1.

Table 1. Index and Compaction Properties of Samples(Dikmen, 2013)

Sample	**PL(%)** Plastic limit	**LL(%)** Liquid limit	**IP(%)** Plasticity Index	**γ_s (gr/cm^3)** Natural unit volume weight	**γ_k (gr/cm^3)** Dry unit volume weight	**w_{opt}** opt. Water content
İstanbul (CL)	66.5	45	21.5	2.80	1.4	0.295
İzmir (CH)	19	78	59	2.75	1.4	0.3

An odometer test is carried out to measure the amount and speed of consolidation under vertical and axial pressure by providing drainage from the upper and lower surfaces of a water-saturated, disc-shaped and undisturbed soil sample, whose lateral deformation is prevented.In order to define the consolidation parameters of the samples provided by compressing at the maximum dry unit weight, and optimum water content collected from compaction tests, consolidation experiments (oedometer) were carried out. Gradual loading and unloading stages up to 16 kg / cm^2 have been performed on low plasticity and high plasticity clay grounds.

Technical specifications of the woven geotextile used in the experiments are presented in Table 2.

Table 2. Technical properties of geotextiles

Parameters	Value
Thickness	0,7 mm
Wweight	192 g/m^2
Tensile Strength	40 kN/m
Elongation	20 %
Static Puncture Resistance	4,8 kN
Dynamic Performance Resistance	11 mm
Water Permeability	16*10^{-3} m/sn

Later, after settling geotextile at h / 2 height in both ground samples, odometer experiments were repeated.Experimental images are presented in Figure 1.

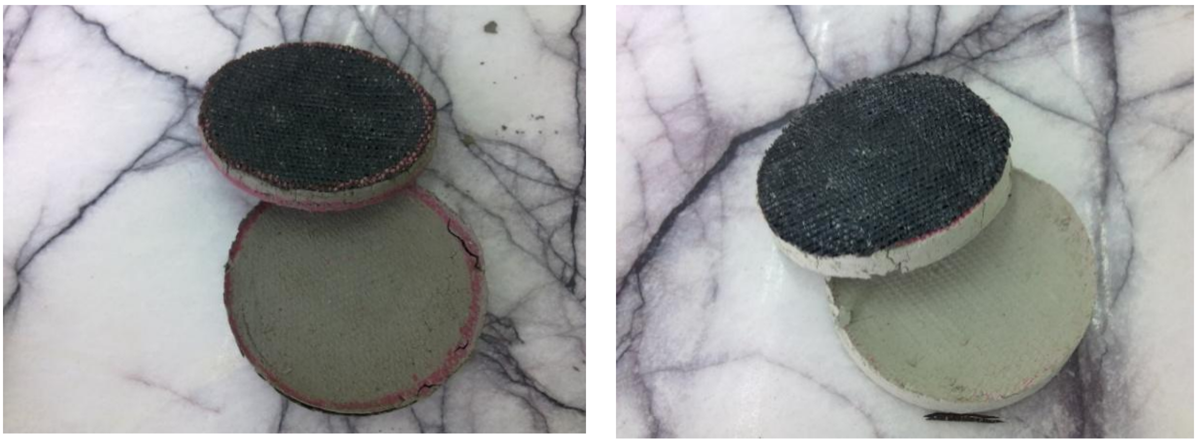
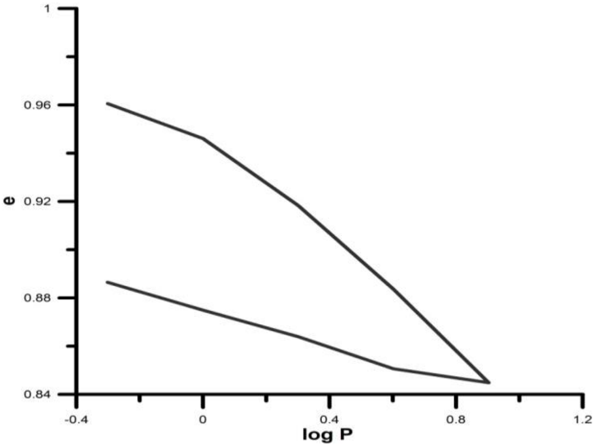
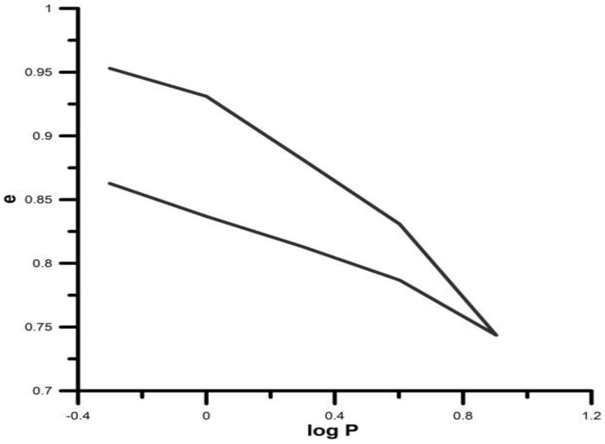


Figure 1. Consolidation test samples placed with geotextile (Dikmen, 2013)

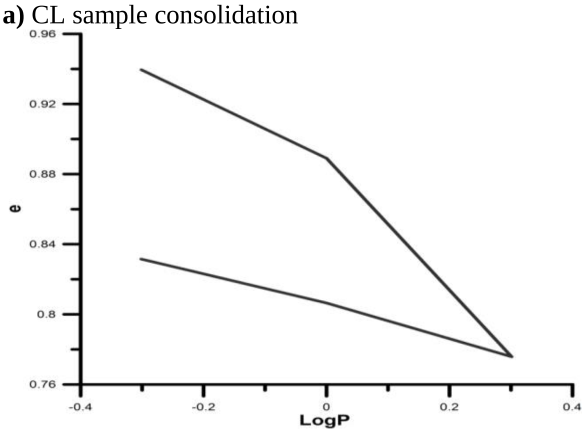
The test results completed on low-plasticity and high-plasticity clay samples and on the series placed with getorextile are presented graphically. The results achieved are displayed in the graphics in Figure 2.



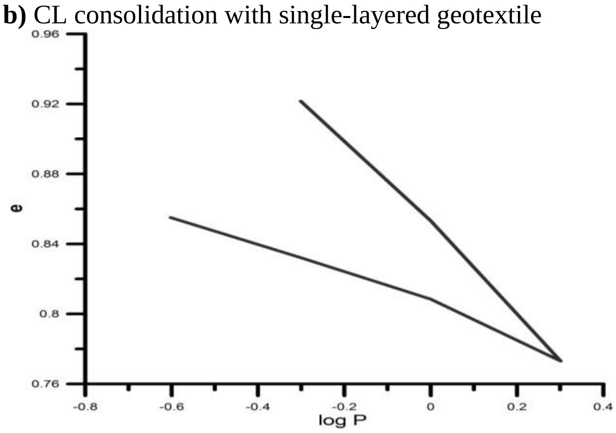
a) CL sample consolidation



b) CL consolidation with single-layered geotextile



c) CH sample consolidation



d) CH consolidation with single-layered geotextile

Figure 2. Odometer test result (Dikmen, 2013)

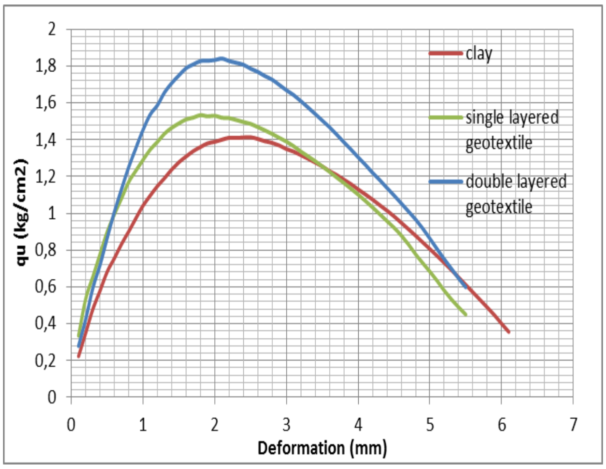
Unconfined compression tests have been conducted to define the undrained sliding strength of grounds. In both samples, experiments were conducted by putting clay on only single-layered geotextile at h / 2 height in clay sample and by placing double-layered geotextiles at h / 3-2h / 3 heights in clay sample. Free pressure test sample images are shown in figure 3.

a) Low plasticity clay sample

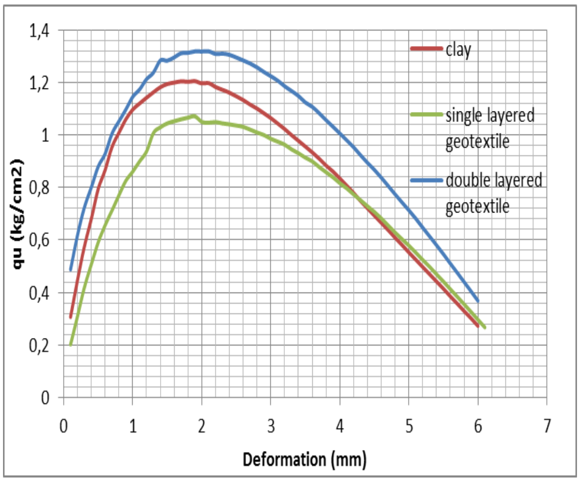
b) High plasticity clay sample

Figure 3. Free pressure test samples (Dikmen, 2013)

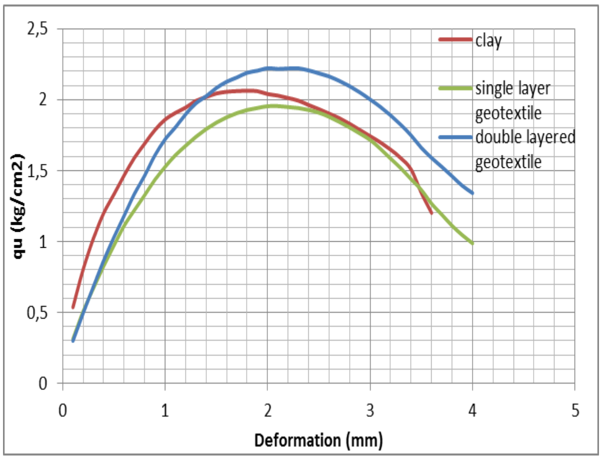
Samples were provided in 3 different water contents such as optimum water content, wopt + 10% more than water content, wopt-10% less than water content. Experiments were repeated for three separate water contents and single-layered and double-layered combinations. The results obtained are classified according to low and high plasticity and water content and are shown in the graphs in Figure 4.



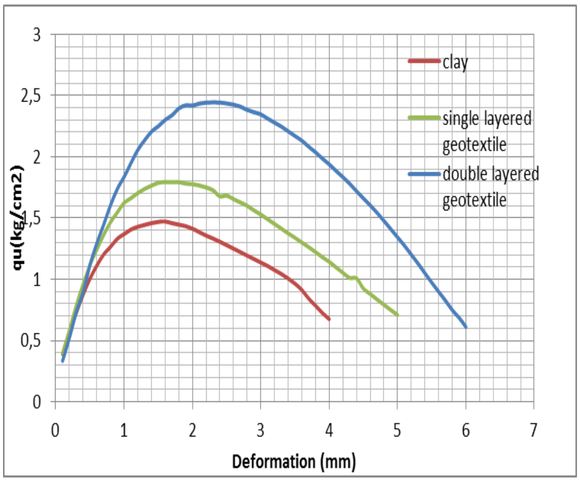
a) CL opt water content



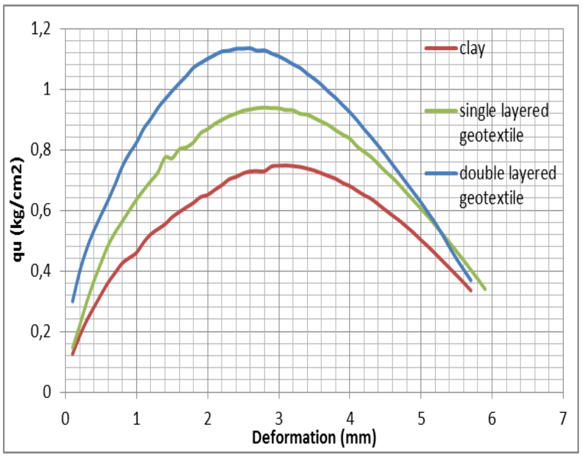
b) CH opt water content



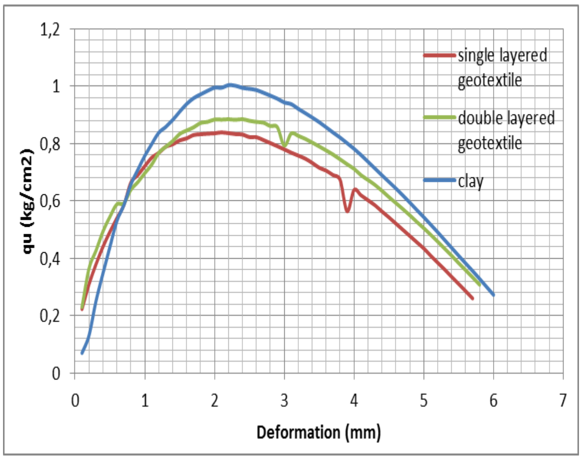
c) CL 10 % less than opt water content



d) CH 10 % less than opt water content



e) CL 10 % more than opt water content



f) CH 10 % more than opt water content

Figure 4. Free pressure test results (Dikmen, 2013)

In the low plasticity clay sample, the unconfined compressive strength obtained at optimum water content was 1.4 kg/cm^2 for clay alone, 1.5 kg/cm^2 for single-layer geotextile reinforcement and 1.8 kg/cm^2 for double-layer geotextile reinforcement. In the low plasticity clay sample, the unconfined compressive strength obtained at a water content of 10% less than the optimum water content was 1.8 kg/cm^2 for clay alone, 2 kg/cm^2 for single-layer geotextile reinforcement, and 2.2 kg/cm^2 for double-layer geotextile reinforcement. In a low plasticity clay sample, the unconfined compressive strength obtained at 10% more water content than the optimum water content is 0.76 kg/cm^2 for clay alone, 0.94 kg/cm^2 for single-layer geotextile reinforcement, 1.15 kg/cm^2 for double-layer geotextile reinforcement. was obtained.

In the high plasticity clay sample, the unconfined compressive strength obtained at optimum water content was 1.1 kg/cm^2 for clay alone, 1.2 kg/cm^2 for single layer geotextile reinforcement, and 1.32 kg/cm^2 for double layer geotextile reinforcement. In the high plasticity clay sample, the unconfined compressive strength obtained at a water content of 10% less than the optimum water content was 1.5 kg/cm^2 for clay alone, 1.8 kg/cm^2 for single-layer geotextile reinforcement, and 2.45 kg/cm^2 for double-layer geotextile reinforcement. In the low plasticity clay sample, the unconfined compressive strength obtained at 10% more water content than the optimum water content was 0.84 kg/cm^2 for clay alone, 0.88 kg/cm^2 for single-layer geotextile reinforcement, and 1.0 kg/cm^2 for double-layer geotextile reinforcement.

3. DISCUSSION AND CONCLUSIONS

In this study, first a literature review was conducted about clay soils and improvement methods. Then, index tests, uniaxial compression tests and consolidation tests were performed on two different clay soils in the laboratory to determine the parameters of the soil. Geotextile offered significant technical and financial advantages when applied correctly. The test results are shown below in detail and comparatively. In general evaluation, geotextile reinforcement reduced the settlement amount in clay soils.
Geotextile reinforcement increased the unconfined compressive strength values of the soil. As the number of geotextile layers increases, the strength of the soil also increases, and this increase clearly indicates the bearing capacity. Additionally, as the number of reinforcement increases, the soil becomes more ductile in tension.

The results achieved can be summed up as follows:

- The geotextile in the low plasticity clay ground placed at 0.5h height of the odometer ring decreased the settlement values of the ground by 50% at the same load level.
- The geotextile in the high plasticity clay ground placed at 0.5h height of the odometer ring decreased the settlement values of the ground by 15% at the same load level.
- The unconsolidated-undrained unconfined compressive strength performed in the optimum water content of the low plasticity clay ground rose by 1% in the case of placing a single-layered geotextile, while it rose by 20% in the case of placing a double-layered geotextile.
- In the optimum water content of clay ground with the low plasticity, the unconsolidated-undrained unconfined compressive strength in the water content 10 % less than optimum water content increased by 10% while the double-layered geotextile increased by 30%.
- The unconsolidated-undrained unconfined compressive strength in the optimum water content of the clay with high plasticity rose by 1% in the case of putting a single- layered geotextile, while it increased by 20% in the case of putting a double-layered geotextile.
- In the optimum water content of clay ground with the high plasticity, the unconsolidated-undrained unconfined compressive strength in the water content 10 % less than optimum water content increased by 30% while in the case of placing a single-layered geotextile, it rose by 70%.
- In the optimum water content of the high and low plasticity clay ground, the water content 10 % more than optimum water of unconsolidated-undrained unconfined compressive strength did not noticeably change if single and double-layered geotextile was placed on the ground. Since there was excess water than needed in the ground, the strength values of the clay ground were negatively influenced.

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Conflict of Interest
The authors have no conflicts of interest to declare.

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REFERENCES

Adams, M.T. ve Collin, J. G., (1997). Large Model Spread Footing Load Tests on Geosynthetic Reinforced Soil Foundation, ASCE Journal of Geotechnical and Geoenvironmental Engineering, 66-72.

Alawaji, H. A., (2001). Settlement and Bearing Capacity of Geogrid – water content 10% higher than optimum Reinforced Sand over Collapsible Soil. Geotextiles and Geomembranes, 19, 75-88.

Aslan E., (2021). Performance of Marginal Fillers Reinforced with Geosythetics Under Static Loads. Bursa Uludağ University Graduate School of Natural and Applied Sciences Department of Civil Engineering. Master's thesis, 123 p.

Bergado D. T., Youwai S., Haic C. N., Voottipruex P., (2001). Interaction of Nonwoven Needle-Punched Geotextiles Under Axisymmetric Loading

Conditions. Geotextiles and Geomembranes, 19, 299-328.

Çakar, G., (2016). Investigation of the behavior of geotextile reinforced clays in the laboratory, Master's Thesis, Balıkesir University Graduate School of Natural and Applied Sciences, Balıkesir.

Das, B.M., Shin, E.C., Omar, M.T., (1994). The Bearing Capacity Of Surface Strip Foundations On Geogrid-Reinforced Sand And Clay – A Comparative Study. Geotechnical And Geological Engineering, 12, 1-14.

Dash S. K., Sireesh S. and Sitharam T. G., (2003). Model Studies on Circular Footing Supported on Geocell Reinforced Sand Underlain by Soft Clay.

Demir, E., Kolay, E. & Karaduman, Y. (2022). Kenevirden İmal Edilen Geotekstilin Sıkıştırılmış Bazı Zeminlerin Dayanımı Üzerindeki Etkisi. Mühendislik Bilimleri ve Araştırmaları Dergisi, 4 (2) , 266-277 . DOI: 10.46387/bjesr.1167983

Dikmen M., (2013). Experimental investigation of the effect of geotextile reinforcement on the settlement and bearing capacity behavior of foundations resting on clay soil using the Plaxis 3D program, Süleyman Demirel University. Institute of Science and Technology. Department of Civil Engineering. Master's thesis, 106p.

Karakan E., Okucu A., Yağcı B., (2015) Stress-strain and strength parameters of geotextile reinforced clays. 6th Geotechnical Symposium, November 2015, Adana

Koerner, R.M., (1989). "Designing with Geosynthetics", Prentice Hall, Englewood Cliffs, New Jersey.

Mandal, J. N., Sah, H., (1992). Bearing Capacity Tests on Geogrid-Reinforced Clay, Geotextiles and Geomembranes. 327-333.

Noorı M.S. and K. Dehghanıan K., (2021). Settlement Analysis of Geosynthetics Reinforced Embankments, Dicle University Journal of Engineering) 12:4, Page 699-709, doi:10.24012/dumf.1002256

Noorzad, R., Mirmoradi S.H., (2010), Laboratory evaluation of the behavior of a geotextile reinforced clay, Geotextiles and Geomembranes, 28,386-392.

Ramaswamy S.D., and Purushothaman P., (1992). Model footings of geogrid reinforced clay. Proceedings of the Indian Geotechnical Conference on Geotechnique Today, 183-186.

Shin E., Das B., Puri S., Yen S., Cook E., (1993). Bearing Capacity of Strip Foundation on Geogrid-Reinforced Clay. Tech. Note, American Society for Testing and Materials, 534-541.