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Yüksek ve Düşük Plastisiteli Killerde Polipropilen Elyafın Etkisi

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Anahtar kelimeler:
Kil zemin,
Kür,
Polipropilen elyaf,
Tek eksenli basınç mukavemeti,
Zemin iyileştirilmesi.

ÖZET

Farklı katkılarla zemin stabilizasyonu uzun yıllardan beri geoteknik mühendislerinin ilgisini çekmektedir. Zemin stabilizasyonu ile zayıf zeminin taşıma kapasitesi arttırılmakta, toplam oturmalar azaltılmakta, dolgu ve şevlerin stabilitesi sağlanmakta, istinat duvarları desteklenmekte ve potansiyel sıvılaşma riskleri azaltılmaktadır. Bu metotlardan biri de zeminlerin katkı maddesi ile iyileştirilmesidir. Deney programında atık malzemenin değerlendirilmesi kapsamında stabilizasyon amacı ile polipropilen elyaf kullanılmıştır. Düşük ve yüksek plastisiteli killi zemine %0, %0.1, %0.5, %1.0, %1.5 polipropilen elyaf eklenmiştir. Çalışmada, hidrometre deneyi, özgül ağırlık deneyi, Atterberg limitleri, Standart proktor deneyi ve tek eksenli basınç dayanım deneyi yapılmıştır. Birleştirilmiş zemin sınıflandırma sistemine göre CL ve CH olarak belirlenen kil zemine elyaf ilave edilmesi, farklı kür süreleri sonunda mukavemet değerlerinde artışa neden olmuştur.

The Influence of Polypropylene Fiber on High and Low Plasticity Clay

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ABSTRACT

Soil stabilization with different additives has attracted the attention of geotechnical engineers for many years. With soil stabilization, the bearing capacity of weak soil is increased, total settlements are reduced, the stability of fills and slopes is ensured, retaining walls are supported and potential liquefaction risks are reduced. One of these methods is the improvement of soils with additives. Polypropylene fiber was used for stabilization purposes within the scope of evaluation of waste material in the experimental program. 0%, 0.1%, 0.5%, 1.0%, 1.5% polypropylene fiber was added to low and high plasticity clay soil. In the study, hydrometer test, specific gravity test, Atterberg limits, Standard proctor test and uniaxial compressive strength test were performed. Adding fiber to the clay soil, designated as CL and CH according to the unified soil classification system, caused an increase in the strength values at the end of different curing periods.

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INTRODUCTION

Today, due to the rapidly increasing construction and decreasing suitable soils for construction, it becomes necessary to build structures on almost all kinds of soils. Especially in transportation and road structures, many weak and problematic soils are sometimes encountered. Changing the construction site or using resistant soils are not a suitable solution due to the technological and economic reasons. On the other hand, increasing industrial wastes cause environmental pollution and the problem of eliminating these wastes is a common problem for all countries. These materials can be building materials such as lime [1], cement [2] and artificial polymers, or fly ash [3], marble dust [4] metal slag, used car tires, which are formed as industrial waste [5-6]. In recent years, the wastes have been used as an alternative additive material in the improvement of soils and it is a more economical solution to improve the properties of problematic soils. One of these soil improvements is the use of polypropylene [7-15]. Sengul et al., had studied the effect of polypropylene fiber on the properties of high clay soils [16]. They added 0.5% fiber to the soil and fiber additives were determined to increase the shear strength at ratios ranging from 3.0% to 21.0%. Komal et al., had investigated the polypropylene and nylon fiber in the soil mixture having silt [17]. Laboratory results have shown that polypropylene and nylon fiber changed the strength positively. Suriya et al., had conducted a study about the performance of the red soil before and after adding polypropylene [18]. They used different percentages of polypropylene (1%, 2%, 3%). The results showed that reinforcing of polypropylene fiber increased the properties of red soil. Çetin and Çetinkaya had studied about the stabilization of clay soils with fiber. In their studies, they reached the highest strength in clay soil with 1% fiber [19, 20].

In the present study, geotechnical properties of clayey soils amended with polypropylene fiber were determined. The novel approach of study is specifying the stabilization effect of fiber considering the clay consistency.

MATERIALS AND METHODS

Two types of clay soils were used in the studies (Fig. 1 and 2). The green clay soil was taken from the land surface in Sarıhıdır Village of Ürgüp District of Nevşehir Province. Ürgüp clay is classified as high plasticity clay according to USCS (ASTM D2487-17e1, 2020) and clay consistency since liquid limit is 97.60% and plastic limit is 31.20% [21]. The second type of clay soil in red color was taken from Avanos District of Nevşehir Province. Avanos clay is classified as low plasticity clay since liquid limit is 46.80% and plastic limit is 23.80%. The samples were brought to Konya Necmettin Erbakan University Engineering Faculty Civil Engineering Department Soil Mechanics Laboratory. The sieve analysis was performed according to (ASTM D6913/D6913M-17 2021), and hydrometer analysis was performed according to (ASTM D7928-21e1, 2021) [22, 23]. The results are shown in Figure 3. Atterberg limits of soils were determined according to ASTM D4318 (2018) [24]. The specific gravity of clays was determined following the ASTM D854-14 (2016) standard [25]. The soil specific gravity of CL soil was determined as 2.61, However the specific gravity of CH soil was determined as 2.65.

The polypropylene fiber used in the experimental studies was obtained from a company in Turkey (Figure 4). The polypropylene fiber is a waste material of factories. The technical properties of the polypropylene fiber used in the experiments are given in Table 1. In order to prepare the mixtures with optimum water content, polypropylene amounts were mixed on the clay soil and compressed in a standard proctor mold. Cylindrical samples were taken from the compressed soil for the unconfined pressure test. For sampling, cylindrical metal tubes with a diameter of 38 mm and a height of 76 mm were driven into the compacted soil (Figure 5). The inside of the cylinder tubes is lubricated with grease. The soil samples taken into the tubes were carefully removed with the help of a hydraulic jack. The extracted samples were bagged without waiting and placed in plastic containers with 1 - 2 cm high water at the bottom, and the plastic containers were covered. The compaction tests were performed according to (ASTM D698-12, 2021) [26]. In this test, the soil is compressed in a standard molt in 3 layers with 25 hits with a 2.5 kg hammer falling from 30.5 mm. In the unconfined pressure test, the cylindrical soil sample was subjected to only vertical pressure stress without being subjected to any lateral pressure. Loading was done by placing the soil sample between the plates. The samples were cured for 7 and 28 days. The unconfined compression tests were carried out on the samples removed from the cure according to ASTM D2166 [27] (Figure 6).

Figure 1. *CL soil*

Figure 2. *CH soil*

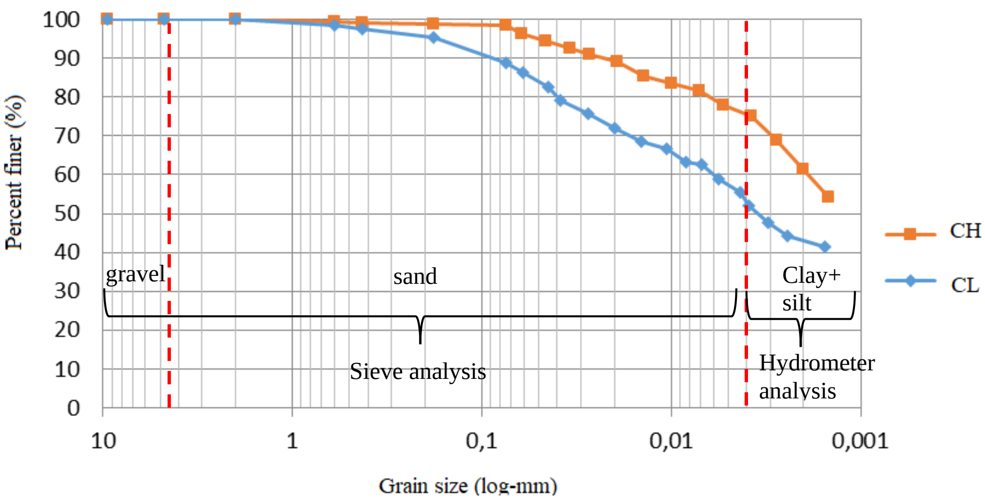

Figure 3. *The grain size distribution of the soils*

Figure 4. *The polypropylene fiber*

Table 1. *Technical characteristics of polypropylene fiber*

Chemical structure	100% polypropylene
Packaging	In 0.6 kg paper bags
Appearance-Color	White and embossed plain fiber
Shelf life	24 months from date of manufacture (Unopened package)
Storage conditions	It should be stored at a temperature range of 5 to 30 °C.
Intensity	0.91 g/cm^3
Length	12 mm
Diameter	32 µm
Melting point	170 °C
Tensile strength	430 MPa
Modulus of Elasticity in Tension	6 GPa
Thermal Conductivity	Low
Electrical Conductivity	Low
Acid Resistance	High

Figure 5. *Preparation and curing of samples*

Figure 6. *UCS machine and failed samples*

RESULTS AND DISCUSSION

Compaction Test Results

A series of compaction tests were performed to investigate the max dry density and optimum water content of soil samples with different percentage of polypropylene fiber for two types of clay. The polypropylene fiber addition caused some increases in dry unit volume weights for both soils. The dry unit volume weight reached the highest value by taking the value of 1.675 g/cm3 in the mixture of CL soil and 1.5% polypropylene fiber (Figure 7). In the mixture of CH soil and polypropylene fiber, the highest dry unit volume weight value was 1.380 g/cm3 with 1.0% contribution (Figure 8).

Increment of fiber amount in the stabilized soil leads to an increment in maximum dry density. The fiber material between the soil grains acts as reinforcement, causing the soil structure to be compressed more tightly. The best compaction was obtained when 1.5% fiber was added to the CL soil, while it was obtained when 1% fiber was added to the CH soil. The greatest compression is achieved in CH soil with a lower fiber ratio than in CL soil is due to the fact that the increased fiber ratio reduces the cohesion forces between high plasticity clay minerals.

As the fiber ratio in CL soil increases, the optimum water content increases. The capillary irregularity of the fiber material within the CL soil structure creates an environment suitable for water drainage and requires more water for maximum compaction. However, there is no significant correlation between fiber ratio and variation in optimum water content in CH soil. Due to clay mineralogy and cohesion forces between CH minerals, the fiber material may not be distributed homogeneously within the ground structure.

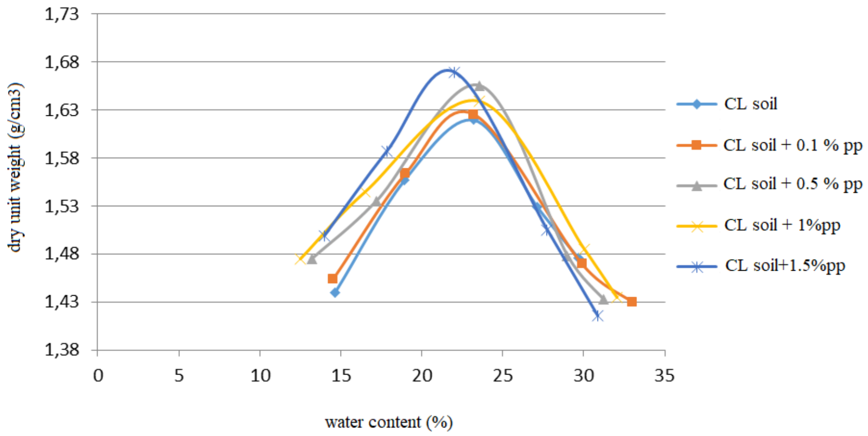

Figure 7. *Compaction curves of CL soil and polypropylene fiber mixtures*

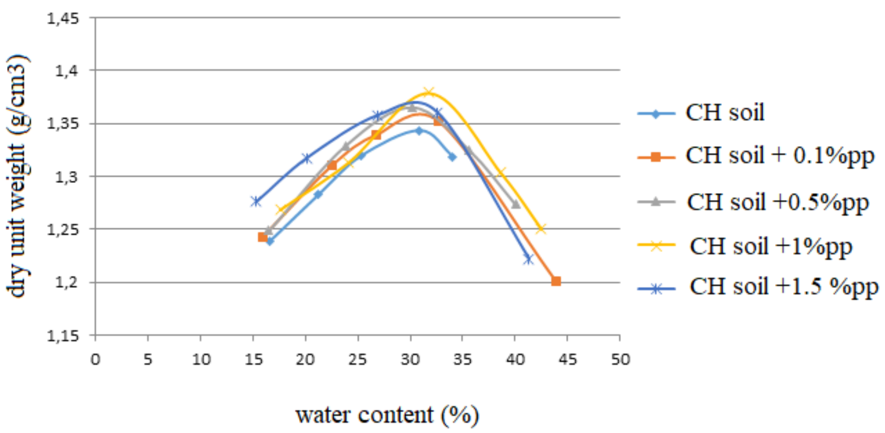

Figure 8. *Compaction curves of CH soil and polypropylene fiber mixtures*

Unconfined Compressive Strength Test Results

In this study, it was observed that the polypropylene fiber caused an increase in the strength of both CL soil and CH soil. According to the results of the unconfined pressure test performed on polypropylene fiber-added samples, the highest strength values were obtained with 1.0% polypropylene fiber additive by weight of the clay for both soil types (CL and CH soil). For CL soil, it was observed that 1.0% fiber additive increased the strength by 67% compared to natural clay at the end of 7 days of curing (Figure 9) and this value reached 81% at the end of 28 days of curing (Figure 10). Again, for CH soil, it was determined that with the addition of 1.0% polypropylene fiber, there was a 53% increase compared to natural clay at the end of 7 days of curing (Figure 11), and this rate reached 78% at the end of 28 days of curing (Figure 12).

The addition of polypropylene fiber increased the uniaxial strength in low plasticity clay more than high plasticity clay. According to the results of the unconfined compressive test, it was observed that the most effective ratio in soil - fiber mixed samples was 1.0%. If we compare the strength of polypropylene fibers on CL and CH soil, at the end of the 28-day curing period, the CL soil reached a strength of 463 kPa, while this value remained at 399 kPa on the CH soil. In their studies, Çetinkaya and Çetin added 1% fiber to the clay soil and achieved the highest strength. The polypropylene fiber could be used as a soil improvement material in future studies [19, 20].

As the amount of fiber increases, the ductility of the stabilized CL soil increases to 17% compared to natural clay (15%), while the ductility of the stabilized CH soil decreases from 8% to 3-4%.

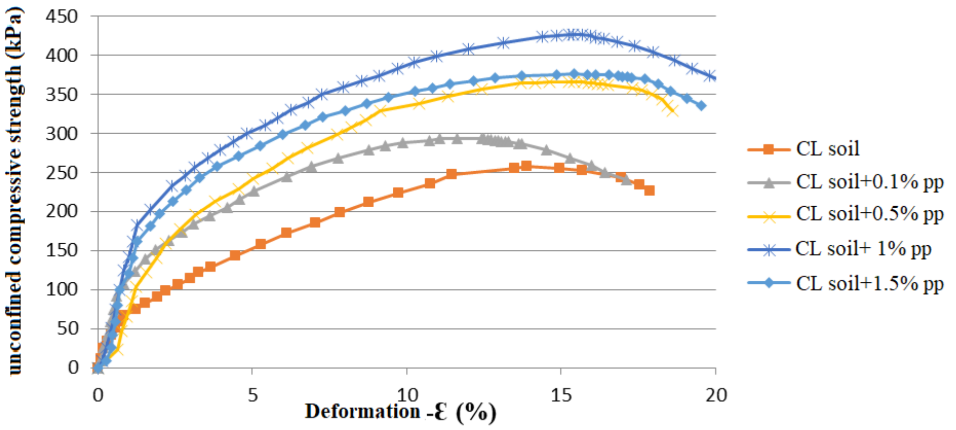

Figure 9. *Unconfined compressive test results of 7 days cured CL soil samples*

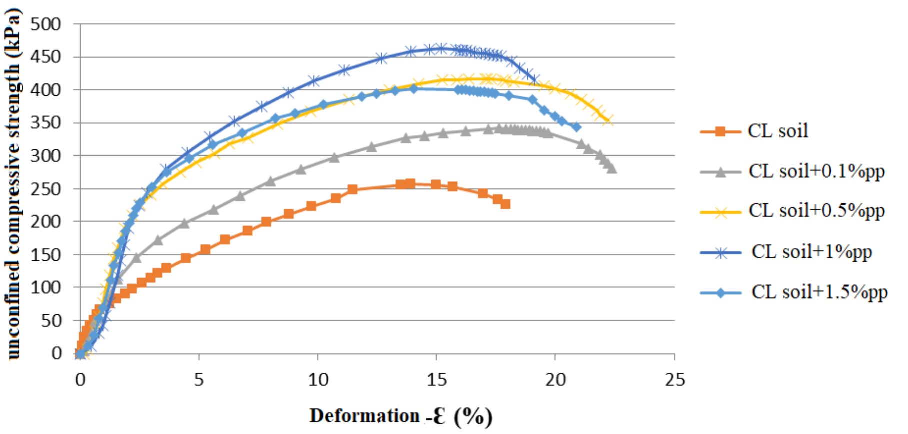

Figure 10. *Unconfined compressive test results of 28 days cured CL soil samples*

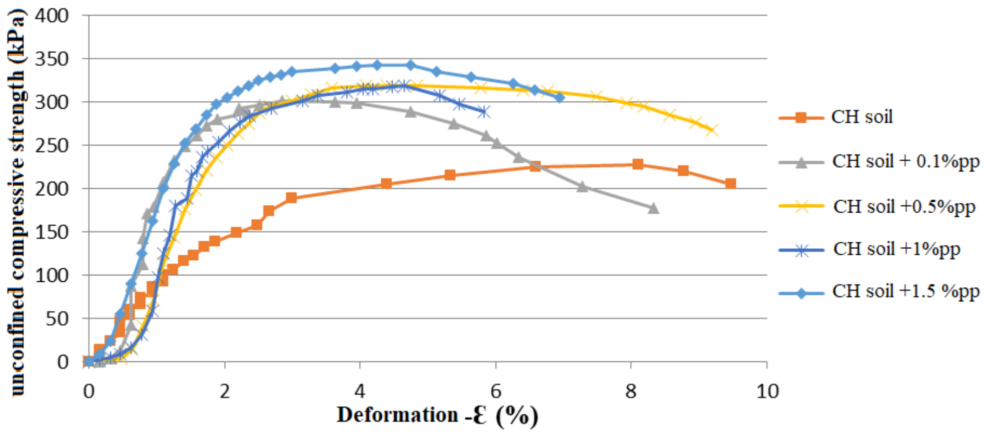

Figure 11. *Unconfined compressive test results of 7 days cured CH soil samples*

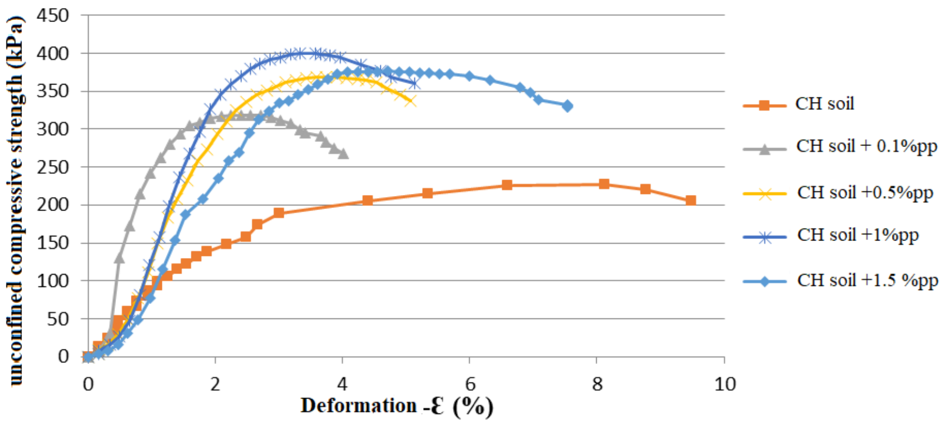

Figure 12. *Unconfined compressive test results of 28 days cured CH soil samples*

CONCLUSION

In the present study, compaction and strength characteristics of polypropylene fiber stabilized low and high plasticity clays were determined. The results are summarized below:

- The optimum fiber ratio to obtain maximum dry density is 1.5% for CL soil and 1.0% for CH soil. Increment of fiber amount in the stabilized soil leads to an increment in maximum dry density. The fiber material between the soil grains acts as reinforcement, causing the soil structure to be compressed more tightly.
- Increment of the fiber ratio in CL soil, the optimum water content increases since capillary irregularity of the fiber material in the soil structure creates an environment suitable for water drainage However, there is no significant correlation between fiber ratio and variation in optimum water content in CH soil due to complex clay mineralogy.
- The optimum fiber ratio to obtain maximum strength is 1.0% for CL and CH soil types.
- As the amount of fiber increases, the ductility of the stabilized CL soil increases to 17% compared to natural clay (15%), while the ductility of the stabilized CH soil decreases from 8% to 3-4%.

Test results show that polypropylene fiber can be used in clay stabilization. The optimum fiber ratio can be determined by deciding whether compaction or strength results are prioritized in soil improvement works.

Conflict of interest

The authors have no conflicts of interest to disclose for this study.

Authorship contribution statement

A.S.S.: Data Curation, Investigation, Writing-Original Draft, Writing - Review & Editing, **A.O.:** Data Curation, Investigation.

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