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Comparison of the Effect of Geotextile and Palm Tree Pruning Waste on CBR Value of Sand Soil

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ABSTRACT

In recent years, geosynthetics have been widely used as soil improvement agent. Geotextiles, one of the types of geosynthetics, are mostly used for enhancing the bearing capacity of soils in addition to their functions such as separation, filtration, and drainage. In the current study, the usability of palm tree pruning waste (PTPW), which is inconvenient to store and dispose of as an alternative to geotextile, was investigated by conducting a series of CBR tests. Experiments were carried out on geotextile-reinforced and PTPW-reinforced sand in CBR mould at different burial depths. In addition, an unreinforced test was conducted for comparison purposes. In the light of the test results, an apparent improvement was observed in CBR values compared with unreinforced case. CBR values obtained from geotextile and PTPW-reinforced tests were found to be close to each other. Therefore, it is understood that PTPW is able to be used as an alternative to geotextile by getting rid of waste material. Additionally, its easy applicability makes it more attractive to use PTPW in soil improvement.

Geotekstil ve Palmiye Ağacı Budama Atıklarının Kum Zeminde CBR Değerine Olan Etkisinin Karşılaştırılması

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ÖZ

Son yıllarda, geosentetikler zemin iyileştirme elamanı olarak yaygın bir şekilde kullanılmaktadır. Geosentetik türlerinden biri olan geotekstiller, ayırma, filtreleme ve drenaj gibi fonksiyonlarının yanı sıra daha çok zeminlerin taşıma kapasitesini artırmak amacıyla kullanılmaktadır. Bu çalışmada, depolanması ve bertarafı zor olan palmiye ağacı budama atıklarının (PTPW) geotekstile alternatif olarak kullanılabilirliği bir dizi CBR testi yapılarak araştırılmıştır. Deneyler, farklı gömülme derinliklerinde CBR kalıbında geotekstil donatılı ve PTPW donatılı kum üzerinde gerçekleştirilmiştir. Ayrıca karşılaştırma amacıyla donatısız bir deney yapılmıştır. Deney sonuçlarına göre, CBR değerlerinde donatısız duruma göre belirgin bir iyileşme gözlemlenmiştir. Geotekstil ve PTPW ile donatılandırılarak yapılan bu deneylerden elde edilen CBR değerleri birbirine yakın bulunmuştur. Bu nedenle atık malzemeden kurtularak PTPW'nin geotekstile alternatif olarak kullanılabileceği anlaşılmaktadır. Ayrıca kolay uygulanabilirliği, zemin iyileştirmesinde PTPW'nin kullanımını daha cazip kılmaktadır.

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1. Introduction

Considering the highway subgrade, it should bear stresses due to the repeated traffic loads. Otherwise, it is unavoidable that road pavements can encounter distresses like rutting. To avoid this distress, base and/or subbase layer thickness of the pavement system should be increased because stresses induced by dynamic traffic loads are distributed over a larger area. Another way of avoiding this phenomenon is that weak subgrade can be replaced with high-quality soil, which is an expensive and impractical solution for this problem. Therefore, stabilization of the weak subgrade can be thought to be the more convenient way. There are several methods in the literature for enhancing the bearing capacity of subgrade. Geosynthetics, additives (i.e., fly ash, cement, lime, and bitumen), and fibers can be given as examples for these methods.

Geotextiles are one of the commonly used geosynthetics for improving the bearing capacity of the subgrade by redistributing the dynamic traffic loads over a larger area. There are many studies about the geotextile as a stabilization agent in the literature (Giroud et al., 1981; Haeri et al., 2000; Noorzad and Mirmoradi, 2010; Kazi et al., 2015; Ouri and Mahmoudi, 2018). However, apart from the commercially manufactured soil improvement materials, waste materials have been becoming more popular in recent years because of the fact that waste materials contaminate the world and harm living beings and nature. With the use of waste materials, it is ensured that both waste materials are disposed of, and the bearing capacity of weak soil is improved.

Several studies have been conducted to reinforce pavement systems with geotextile, geocell, and geogrid. Most of these studies include laboratory tests (Aiban et al., 2006; Nair and Latha, 2016; Lal et al., 2016; Önal, 2021), and field tests (Hufenus et al., 2006; Chen et al., 2017; Imjai et al., 2019). Nevertheless, the current study has concentrated on the usability of palm tree pruning waste (PTPW) as a natural geotextile in the subgrade. With this regard, a series of CBR tests were conducted to understand the improvement in the load-deformation behavior of sand subgrade because CBR is both a relatively simple laboratory test to practice and a directly effective parameter in pavement design. Accordingly, there are several studies related to improving the load-deformation behavior of soil in the literature by conducting CBR test (Choudhary et al., 2010; Singh and Bagra, 2013; Sarbaz et al., 2014). Singh and Bagra (2013) carried out a series of CBR tests to understand the effect of usage of jute fiber on the bearing capacity of the subgrade. They used the jute fiber at four different contents (0.25 %, 0.50 %, 0.75 %, and 1.00 %), two different diameters (1 mm and 2 mm), and three different lengths (30 mm, 60 mm, and 90 mm). As a result of CBR tests, they found that as the content, diameter, and length of the jute fiber increase, the CBR value of the soil increases considerably as compared to the unreinforced case. They also concluded that the maximum increase in the CBR value corresponding to 200.49% achieved by 1.00% content of jute fiber having a diameter of 2 mm and length of 90 mm. Negi and Singh (2019) conducted CBR tests to determine the effect of reinforcement of woven and non-woven geotextiles on the bearing capacity of two different subgrades (clay and sand). They emphasized that woven geotextile performed better than non-woven geotextile in the

experiments. They stated that maximum CBR value (27 %) attained for sandy soil when woven geotextile located at half of the height of CBR mould. Also, the maximum CBR value was obtained when woven geotextile was placed at H/6 and H/2 from the surface as two-layer for clayey subgrade.
In the current study, five CBR tests were carried out to compare the performance of the PTPW as geotextile with commercially manufactured geotextile. In order to investigate the effect of the burial depth of reinforcement on the bearing capacity, experiments were performed at two different burial depths. The results of the CBR tests have also been compared with the unreinforced case.

2. Materials and Method

2.1. Sand Subgrade

The soil used in the tests as subgrade was sand. The properties and particle distribution curve of sand were given in Table 1 and Figure 1, respectively. The sand used in the CBR tests was poorly graded sand according to Unified Soil Classification System (USCS).

Table 1. Properties of sand soil

Properties	Value
D_{10} (mm)	0.36
D_{30} (mm)	0.55
D_{60} (mm)	0.76
Coefficient of uniformity, C_u	2.11
Coefficient of curvature, C_c	1.11
Specific gravity	2.74
Maximum dry density (kN/m^3)	16.57
Minimum dry density (kN/m^3)	14.12
Minimum void ratio, e_{min}	0.62
Maximum void ratio, e_{max}	0.94

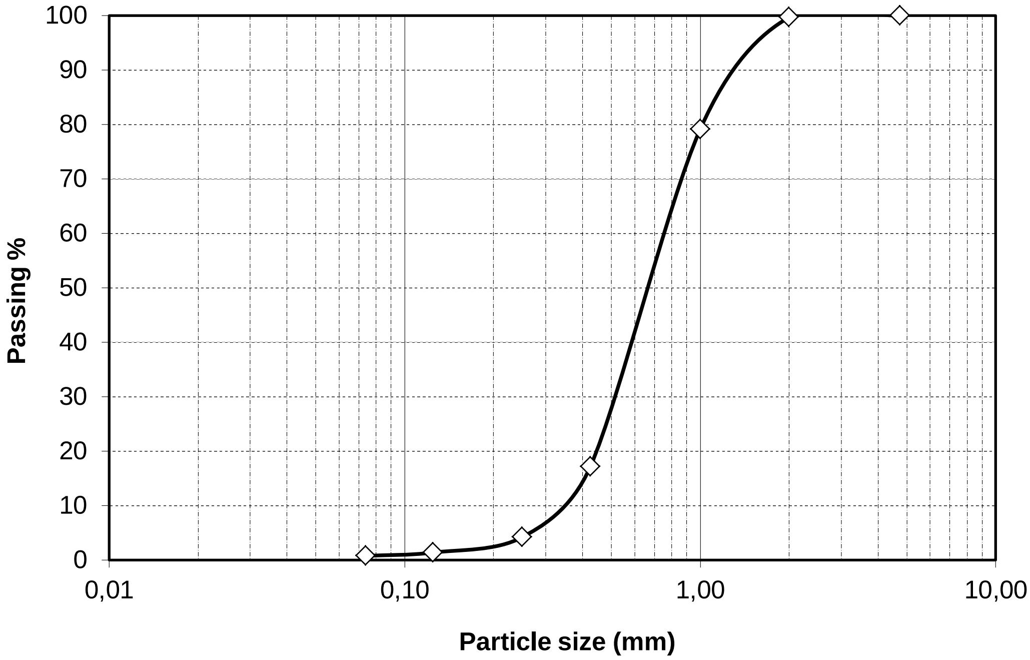

Figure 1. Particle size distribution curve of subgrade

2.2. Palm Tree Pruning Waste (PTPW)

Mexican fan palm (Washingtonia robusta), one of the palm tree species, is widely used as the ornamental tree at the central refuge and roadsides or woodland in Osmaniye Province of Turkey. Because of being a fast-growing palm species, approximately 35.70 kg/tree waste is generated through pruning activity every year (Garcia-Ortuno et al., 2011). In this study, PTPW was obtained from the pruning activity in the Osmaniye Korkut Ata University and photograph of the intact version is shown in Figure 2.

Figure 2. Palm Tree Pruning Waste (PTPW)

2.3. Geotextile

Geotextile used in the experimental study is made of polypropylene. The tensile strength of the geotextile 13 kN/m and 15 kN/m in the direction of machine and cross-machine, respectively. Furthermore, more detailed engineering properties obtained from the manufacturer are presented in Table 2.

Table 2. Properties of geotextile

Properties	Units	Value
Material Composition	-	Polypropylene (PP), white
Material Density	g/cm^2	250
Tensile Strength, md/cmd*	kN/m	13 / 15
Elongation at Break	%	50
Static Puncture Strength	N	2500
Dynamic Puncture Strength	mm	20
Liquid Permeability	m/s	0.06
Apparent Opening	mm	0.12
UV Resistance	%	70

*md = machine direction, cmd = cross-machine direction

2.4. Experimental Program

The geotextile and PTPW were prepared in a circular form whose dimensions are equal to the inner diameter of the CBR mould. The prepared samples used in the CBR tests are shown in Figure 3. CBR tests were conducted according to ASTM D4429-09a.

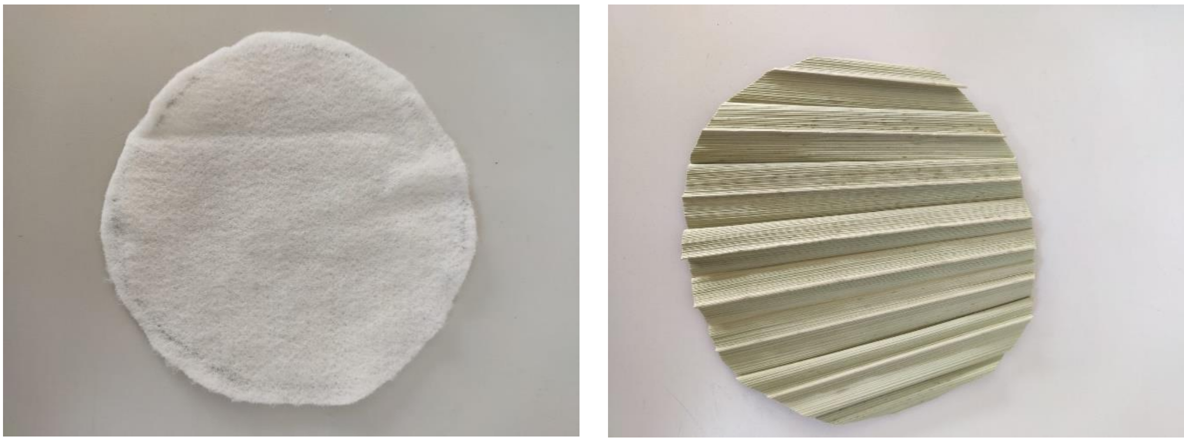

Figure 3. Geotextile and PTPW samples

In all the tests, the relative density of the sand subgrade was ensured to be constant (i.e., 80%). Firstly, after the unreinforced subgrade was prepared at 80% relative density by using a vibratory circular plate compactor with a diameter of 150 mm, CBR test was carried out. Then, two CBR tests were conducted as PTPW and geotextile-reinforced. PTPW and geotextile were located at a burial depth of one-eighth of the height of CBR mould in these tests. To investigate the effect of burial depth on the bearing capacity, two tests in which PTPW and geotextile were located at a burial depth of one-quarter of the height of the CBR mould were carried out as PTPW and geotextile-reinforced.

3. Results and Discussions

Figure 4 presents the experimental results obtained from geotextile and PTPW-reinforced subgrade at a burial depth of one-quarter of the height of CBR mould.

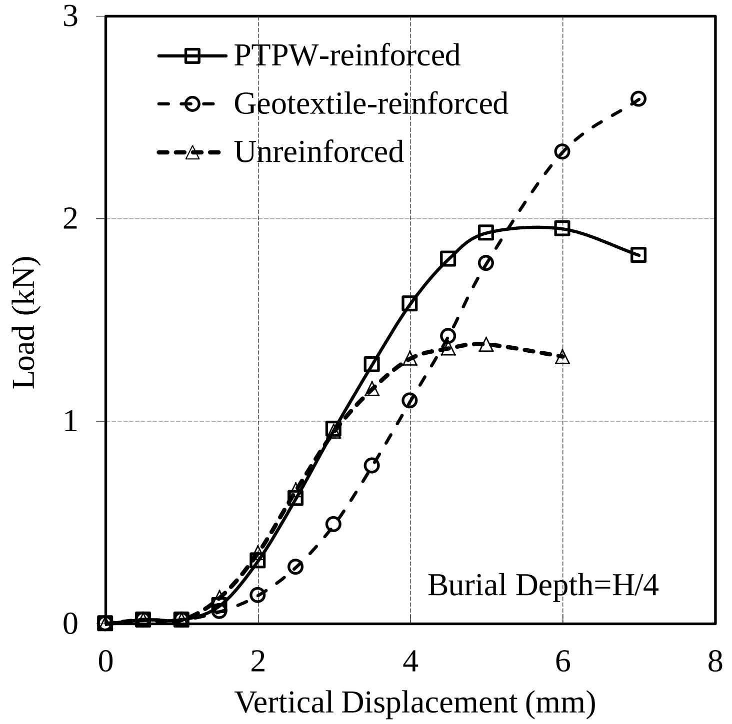

Figure 4. CBR test conducted at H/4 burial depth

As shown in Figure 4, both PTPW and geotextile-reinforced subgrade showed higher strength than unreinforced case at 5 mm deformation. Besides, PTPW reinforcement exhibited better performance than geotextile reinforcement. At 2.5 mm deformation, PTPW-reinforced subgrade carried 121% more load than geotextile-reinforced case while it carried 6% less load than unreinforced case. Interestingly, geotextile-reinforced subgrade carried 58% less load compared to unreinforced case. However, as the deformations increase, improvement in the bearing capacity due to reinforcement became more pronounced. Therefore, PTPW and geotextile-reinforced subgrade carried 40% and 29% more load than unreinforced subgrade at 5 mm deformation, respectively. Furthermore, PTPW-reinforced subgrade reached 8% higher load than geotextile-reinforced case at 5 mm deformation.

Figure 5 presents the experimental results obtained from geotextile and PTPW-reinforced subgrade at a burial depth of one-eighth of the height of CBR mould.

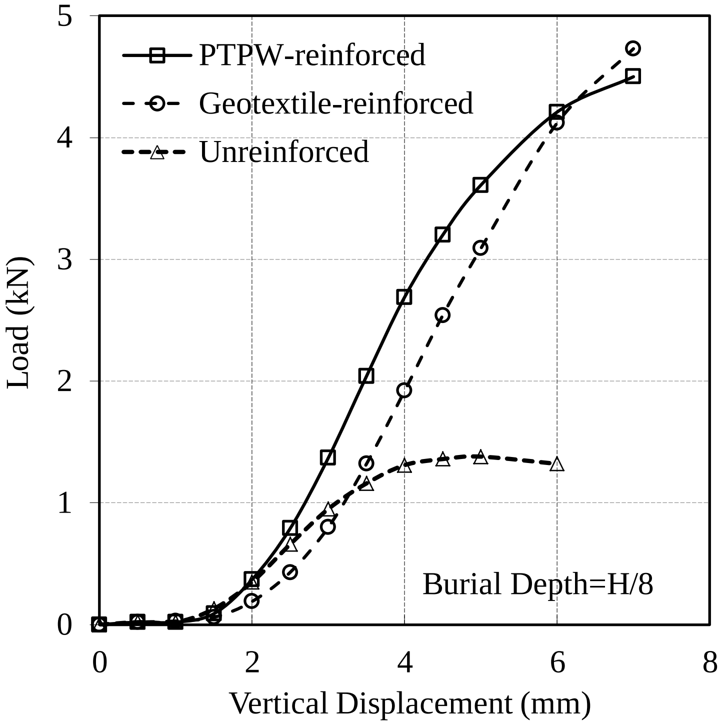

Figure 5. CBR test conducted at H/8 burial depth

As shown in Figure 5, both PTPW-reinforced and geotextile-reinforced subgrade showed higher strength than unreinforced case at 5 mm deformation. Besides, PTPW reinforcement exhibited better performance than geotextile reinforcement. At 2.5 mm deformation, PTPW-reinforced subgrade carried 84% more load than geotextile-reinforced, and it carried 20% more load than unreinforced case. Surprisingly, geotextile-reinforced subgrade carried 35% less load compared to unreinforced case. However, as the deformations increase, improvement in the bearing capacity due to reinforcement became more pronounced. Therefore, PTPW and geotextile-reinforced subgrade carried 162% and 124% more load than unreinforced subgrade at 5 mm deformation, respectively. Also, PTPW-reinforced subgrade reached 17% higher load than geotextile-reinforced case at 5 mm deformation.

Furthermore, performance improvement due to reinforcement in the bearing capacity can also be expressed via the bearing capacity improvement factor (I_f) suggested by Dash et. al., 2001. Bearing capacity improvement factor is defined as the ratio of the load carried with reinforcement at a specific deformation value to load carried by the unreinforced case at the same deformation; thus, the higher value of I_f means better improvement in the bearing capacity. Bearing capacity improvement factor of the all the reinforced cases presented in Table 3.

Table 3. Bearing capacity improvement factor

Reinforcement Type	Burial Depth (u)	Bearing capacity improvement factor (I_f)										
PTPW	H/4	1.00	1.00	0.69	0.89	0.94	1.01	1.10	1.21	1.32	1.40	1.48
Geotextile	H/4	1.00	1.00	0.46	0.40	0.42	0.52	0.67	0.84	1.04	1.29	1.77
PTPW	H/8	1.00	1.00	0.69	1.06	1.20	1.44	1.76	2.05	2.35	2.62	3.19
Geotextile	H/8	1.00	1.50	0.46	0.54	0.65	0.84	1.14	1.47	1.87	2.24	3.12
Deformation (mm)		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0

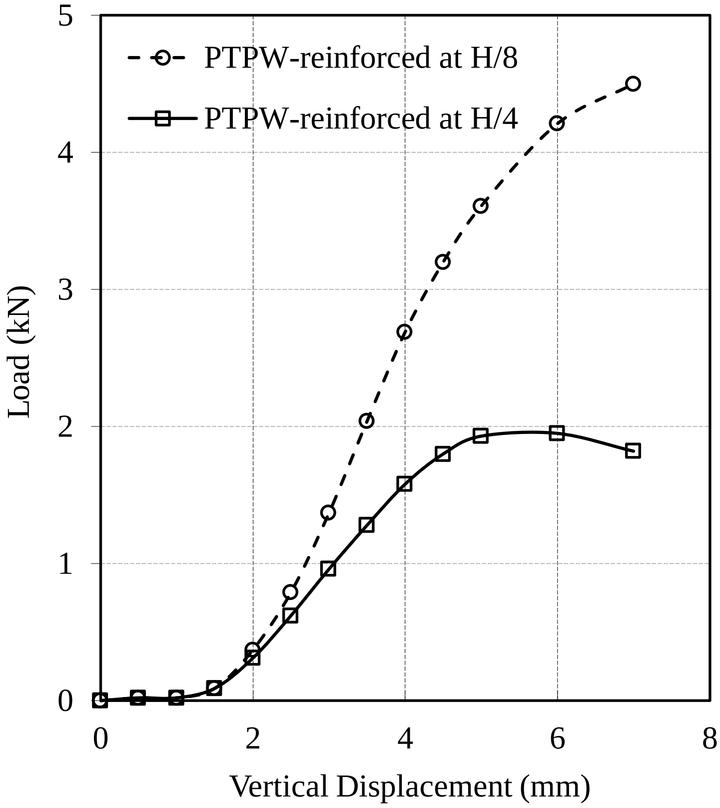

Figure 6. CBR test conducted at H/4 and H/8 burial depth for PTPW-reinforced subgrade

Figure 6 shows the effect of the burial depth on the bearing capacity of PTPW-reinforced subgrade. It is obvious from the Figure 6 that as the burial depth decreases, the bearing capacity of the subgrade increases considerably. It can be deduced from the Figure 6 that when burial depth decreased from H/4 to H/8, the load carried by PTPW-reinforced subgrade increased at the rate of 27% at 2.5 mm deformation and increased at the rate of 87% at 5 mm deformation.

4. Conclusions

In the current study, the effect of the palm tree pruning waste (PTPW) on the bearing capacity and the usability of it as a geotextile were investigated. With this purpose, a series of CBR tests were carried out by locating PTPW and geotextile at different burial depths in sand subgrade with a relative density of 80%. PTPW-reinforced test results at 2.5 mm and 5 mm deformation exhibited higher CBR values than geotextile-reinforced cases. Furthermore, the CBR value of the geotextile reinforced subgrade was less than unreinforced case at 2.5 mm deformation. It was understood from the CBR test results that PTPW was improved more the bearing capacity of the subgrade than geotextile reinforced case. As a result, it is considered to be that use of PTPW can be environment friendly alternative to commercially manufactured geotextile.

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Statement of Conflict of Interest

Authors have declared no conflict of interest.

Author's Contributions

The contribution of the authors is equal.

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