STABILIZATION AND EXPERIMENTAL STUDY OF CLAY SOILS WITH NUTSHELL ASH

KİLLİ ZEMİNLERİN FINDIK KABUĞU KÜLÜ İLE STABİLİZASYONU ve DENEYSEL ÇALIŞMASI

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Geliş Tarihi / Received: 01.12.2020 | *Araştırma Makalesi/Research Article*

Kabul Tarihi / Accepted: 22.12.2020 | *DOI: 10.38065/euroasiaorg.385*

ABSTRACT

This study seeks to investigate the behaviour of the material composed with addition of waste nutshell ash into the predetermined fine-grained soil in various amounts. For this purpose, a sample was prepared from 10 nutshell ash and soil mixtures at the rates of 3%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%and 20%ash plus coal by weight. The impact of Nutshell Ash clay sample on the cohesion and internal frictional angle (indirect bearing power) was experimentally examined. As a result of the experiments, it was found that c=94.13 kPa and ϕ′ =10.97°was for clay additive of 3%, c=57.05 kPa and Φ=18.09 ° was for clay additive of 15%, c=76.37 kPa and ϕ′ 12.99 ° was for clay additive of 20%. The results were in line with the results of studies conducted with lime and fly ashes. As the amount of additive of the nutshell ash increases, c (cohesion) decreases and ϕ′ (internal friction angle) increases. In other words, the bearing power increases. In general the most appropriate results were found in use of 15% waste nutshell ash. In conclusion, it was found that in addition to cement, lime and fly ashes, waste ash of nut shell can also be used in soil stabilization of road and airport runway.

Keywords: Clay, ash, waste, fly ash, soil, stabilization, nutshell, road

ÖZET

Bu çalışma kapsamında, zemin özellikleri yol alt yapısı dolgusu için yetersiz olan yüksek plastisiteli bir kil zemine farklı oranlarda fındıkkabuğu külü atığı ilave edilerek kompakte edilen numunelerin mühendislik özellikleri incelenmiştir. Bu amaç doğrultusunda ağırlıkça %3, %5, %10 %15, %20, %25, %30, %35 ve %40 fındık kabuğu külü içeren zemin karışımları optimum su muhtevalarında hazırlanmış ve bu numunelerle mukavemet, kıvam limitleri ve permeabilite deneyleri yapılmıştır. Yapılan deney sonuçlarında fındık kabuğu külü katkılı kil numunelerin, %3 fındık kabuğu külü katkısı için mukavemet deneylerinden kohezyon değeri c=94.13 kPa ve içsel sürtünme açısı ϕ′ =10.97°, %15 kül katkısı için kohezyon değeri c=57.05 kPa ve içsel sürtünme açısı Φ=18.09° , %20 kül katkısı için kohezyon değeri c=76.37 kPa ve içsel sürtünme açısı ϕ′=12.99° düşen seviyeli permeabilite deneylerinden permeabilite katsayısı aynı oranlarda 10-10 cm/sn den 10-8 cm/sn yükseldiği; likit limit değerinin ise artan fındık kabuğu külüne göre azaldığı tespit edilmiştir. Genel olarak ağırlıkça %15 fındıkkabuğu külü atığı kullanımında en uygun sonuçlar elde edilmiştir. Yapılan deneysel çalışmalar sonucu, zeminlerin iyileştirilmesi ve amaca uygun hale getirilmesinde fındıkkabuğu külünün kullanılabilirliği gösterilmiştir. Zemin iyileştirilmesinde fındık kabuğu külü atığının kullanımı hem çevresel atığın değerlendirilmesini hem de zemin iyileştirilmesinin maliyetinin azaltılmasını sağlayacaktır.

Anahtar Kelimeler: Kil, kül, atık, uçucukül, zemin, fındıkkabuğu, yol

1. INTRODUCTION

Annual production of nut in Turkey is considered to be approximately 600,000-650,000 tonnes of shelled nuts. The rate of nut in the shell of the nut is half and half. According to the reports of TUIK 2016 (Turkish Statistical Institute), 65% of the nut production of the world is made in Turkey. Half of this rate is grown in Eastern Black Sea. and grow in Mediterranean Sea region; mainly in Turkey, Spain and Italy (Demirkaya et al., 2019). Nutshell is a crucial solid fuel with its calorific value of 4,200 kcal/kg. It is mainly used for heating purposes in heating systems at houses and as an auto-feed solid fuel in bakery ovens (Guney, 2013).

By means of a device called Kabukmatik (Shellmatic) which was developed for the nutshell that is widely used in Black Sea region for heating purposes at central heating stations, the nutshell generates an efficient burning-out, leading to a 1.5% of ash residual (Demirbaş, 1997; Demirkaya et al., 2019). Due to shell of the hazelnut is more than 50% by weight of total nut, hazelnut processing industry presents important amount of shell by-product (Pérez-Armada et al., 2019). Considering that according to the date taken from TUIK, annual average production of nut in Turkey is 650,000 tons, it is observed that an important amount of waste ash occurs. It is essential for Turkey and Black Sea due to being a capital for both.

Novel waste materials causing locational environmental contaminants have been utilized in the studies to contribute sustainability goals of World(Wang et al. 2019).

Bambara groundnut shell (Alabadan et al., 2005), Nigeria groundnut shell (Nwofor and Sule, 2012) and coconut shell (Utsev and Taku, 2012).

It has been thought that considering the utilization of wastes, waste nutshell ash could be used in clay soils suitable for stabilization in road-beds and could provide benefit. Thus, nutshell ash obtained from heating boilers were added into standard clays soil samples at certain rates and subjected to various standard soil tests (triaxial compression test, standard proctor test, free endurance test, etc.) to investigate the impacts of waste nutshell ash on the clay soil to be used for stabilization. Stabilization*, is defined as “stability degree” or correction by adding materials” by ARBA Stabilization Committee (1971).

Mixing lime and cement with the soil is known to improve the soil properties. Thus, lime and cement have been used in the stabilization of the soil for a long time. Lime and cement stabilization is applied successfully especially at highways and airports.(Nnabuıhe, Kıngsley Ikechukwu, 2018). Besides, geosynthetics have been increasingly used in the stabilization of soils recently.The literature is full of studies related to this issue (Yavuz, 2017).

The stabilization of the roadbeds with lime for paving purposes has been accepted as a more cost-effective alternative to traditional construction methods. Typical projects to draw upon lime stabilization are as follows: highways, main and side roads, passes and service roads, runways and aprons at the airports, car parking places, factory sites and ramp stabilization, farms and forest entrances, railroad rails, reclamation of contaminated areas , structural fill.

To investigate the usability of fly ashes in geotechnical applications, geotechnical properties of fly ashes (index, compaction, sliding strength and compressibility) obtained from Soma and Çatalağzı Thermic Plants were analysed. It was concluded that fly ashes could be used instead of earth fill materials and to improve high plasticity ashes (Wasti, 1990).

It was determined during consolidation experiments made over 12 different mixtures with the supplement of fly ash and cinders that as fly ash and cinders supplement increased, the compressibility decreased (Chu, Kao, 1993).

It was determined that where fly ash and lime was added into the clay with high swelling potential to improve the clay, CBR value increased, compression properties improved and swelling potential decreased (Nicholson, Kashyap, 1993).

Many crucial properties of engineering were developed through lime processes.In general, lime processing is supposed to enhance the resistance and endurance capacity of the soil, to reduce soil compressibility, to reduce the ground water flow or migration, to decrease the erosion caused by ground waters, to provide a solid ground for other structures and compressions, to decrease expensive/waste properties of the soil and to determine any types of heavy metals (Nahar, Kamrun, et al.,2018).

In particular the addition of quicklime has following impacts on geotechnical properties of coarse-grained soils: (Lucian, 2010). It absorbs moisture, thus reducing the moisture content within the soil, it increases optimum moisture content, it leads to decrease in Proctor Optimum density, it leads to increase in plastic limit, it decreases the plasticity, it leads to an outward flatting in Proctorcompaction curve, it leads to increase in California Bearing Ratio (CBR), it makes it possible to see all these impacts.

Within a longer period, pozzolanic reaction (Cement) occurs and thus results in a development in soil properties. (Kooleshwarsingh, Bin Mohmad Shariff, 2018).

- more increase in CBR
- unconfined compressive strength
- increase in scissoring strength
- increase in tensile strength
- developed stability against swelling and tensile
- developed resistance against freezing (Anon, 1990).

1.1 General Structure and Properties of Clay

Clay is a soil type that covers the earth in vast amounts, yet it is an important soil type that should be known considering its behaviour properties in relation to both soil and engineering. That the general structure of the clay is incalculable plays a key role in designing a structure. Clay grains differ from other soil grains in terms of their physical and chemical properties. Clay is a soil type that contains microscopic or much smaller grains. They chemically stem from hydrated aluminosilicates during the segregation of coarse grains of the bedrock following washing. Among the clay minerals are kaolinite montmorillonite and illite.

Clay grains physically differ from more coarse-grained soils as they are flat and long or bedded. Due to their shapes and small grain sizes, they have bigger specific surfaces with spherical or cubical grains.

When the clay is dry, it is hard; however, as the minerals in its content go through a change, they are plastic in water contents which frequently range from the normal to the excessive amount. The main reason of clay grains having plastic properties when mixed with water-=er each other. It is thought

that the difference in behaviours of rumpled and plasticized clay samples arises f/rom emplacement and changes of the grains (Hamzah, Yusof, Rahimi, 2019).

Water films surrounding clay grains are crucial as their specific surfaces are huge. Therefore, the water retained is much. Considering that the impact of adsorption powers goes down as it moves away from the surface of the grain, the surface tension of the water contacting with the grain and the retention impact on the grain go up as it moves away from the surface.

That the space between clay grains is very small causes permeability to be low in clay soils. Therefore, the drainage of clay soils is hard. The resistance put up against the water movement allows a long consolidation for clay soils. (Kumar, Gautam, Chaturvedı, 2018).

The consistency of clay soils varies in a wide range from a very viscous consistency to a viscous liquid consistency. Accordingly, huge differences occur in engineering properties such as the strength, transformation on load and compression .(Al-Soudany, Al-Gharbawı, Al-Noorı,2018).

Plasticity is characteristics of all cohesive soils. The connection between plasticity properties of a soil and soil components and their mechanic behaviour is essential in classification of soils. A soil that has a high percentage of clay generally has a liquid limit, plastic limit and a high plasticity index (Kalava, 1992; Şimşek, 2000).

1.2 Nutshell Ash and Stabilization

Soil Improvement Method through the Nutshell Ash can be used effectively to improve physical and chemical properties of swollen clays. To obtain a soil improved by means of this method, Nutshell Ash and the soil are mixed or colons made up of nutshell ash such as lime columns are formed in the soil.

1.2.1 Impact of the nutshell on Strength Properties

During the process of improving soils with ash, there are two main events, one of which is chemical and the other of which is physical. Chemical events occur within three different stages as ion Exchange, cementing and carbonation. Among physical events, on the other hand, are flocculation, change in plasticity index and volume, decrease in dry unit weight, increase in optimum water content, vacuum pressure, frost and moisture and properties related to the strength (Mahedi and Cetin, 2018).

The strength of the soil increases due to the cementing arising from pozzolanic reactions stemmed from addition of the nutshell ash. As chemical reactions occur depending on time when using admixture materials, the strength of the soil will increase over time.

1.2.2 Implementation of the Nutshell Ash Stabilization

The lime stabilization implementation applied generally on highways can be applied in two forms as soil mixture and construction of lime columns (Çıragöz, 1962).

- **Soil Mixture:** Stabilization with lime can be in form of onsite on-site mixture, mixture at permanent facility and mobile facility depending on soil and implementation. Upon on-site mixture, the soil to be improved is piled aside. The ash calculated is spread out over this soil. Mixtures on the road are implemented through grader or other mixture devices by watering slowly. Following an optimum water content and homogenous mixture, it is piled on the roadside. After checking the water content on the next day, it is spread over the desired road and subjected to compression and grading processes.

- **Lime Columns:** In this method the drilling is conducted until the required depth is reached. The ash is added into the soil from the drill sump as it is with lime. As the mixture valve available within the soil whirls around and rises, it mixes the clay and soil homogenously. Thus, an improved soil column is constructed. These constructed columns gain strength for 7 to 10 days. Thus bearing capacity of the soil is enhanced. Excavations and chamfers are fortified.

1.2.3 Advantages of the Method

Using waste nutshell ash, the soil stabilization will transform unfavourable soils into practical building materials which can be easily placed and compressed.

Stabilization with the nutshell ash has huge contributions to the environment. Therefore, a waste material is turned into good account. Being used as an admixture material, the waste nutshell ash stabilizes the soil on site without any need for the import of huge amounts of fillings by means of utilizing useless and unfavourable materials. It does not need piles to construct flooring layers and can reduce traffic burden on roads. Based on abovementioned reasons, following advantages will be shown:It will benefit the environment, ıt will reduce the cost,there will be fewer splits and fillings.

2. MATERIAL AND METHOD

Nut crushing process is carried out in industrial scaled crushing mills, nutmeat and shells are separated through forced wind systems and shells are stored after being sacked.

Figure 1.b shows sacksful of waste nutshell while Figure 1.b pictures the burning-out process by kabukmatik (300 C^0-350 C^0) and figure 1.d portrays the process of creating ash.

Figure 1. Generation of ash nutshell ash

First of all, properties of soil samples obtained from the land were determined. And it was determined that the soil was a clay soil (CH-OH)and in limits to be improved by stabilization.

XRF analysis, sieve analysis ASTM D422-63 and TS 1900-1, hydrometerand specific gravity tests were applied to the waste nutshell ash.

Samples obtained by adding nutshell ash into the plain soil and the soil by Sade 3%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%were subjected to TS 1900-1 to determine Atterberg consistency limits, TS 1900-1, to find out the diameter range of the grain, TS 1900-1 T1 to determine the relative density of soil grains, TS 1900-2 &ASTM 2166 to determine the cohesive unconfined compressive strength of soils, Proctor test, (CBR) TS EN 13286-47, falling-head permeability test, triaxial compression test and unconsolidated and undrained test (UU)TS 1900-2/T1 along with an evaluation.The utility of the nutshell ash with its improvement on the characteristics of the clay soil to be used for stabilization was assessed.

2.1 Materials to be stabilized-improved

According to AASHTO or Unified Soil Classification System, stabilization-improvement is considered for soils that go into A5, A6, A7, A-2-6, A-2-7 or CH, CL, MH, ML, GC, SC classes, have a plasticity index bigger than 10 (PI > 10) or whose California Bearing Ratio (Age CBR %) is< 10 or whose CBR percentage swelling percentage is > 3 (Weak Ground Stabilizers Technical Specification, 2005).

2.2 Water

For the soil-water mixture, the mixture process should be made under ideal moisture conditions, and for the continuation of the soil-water-lime reaction during and after the compression the water to be used should be fresh, clear and free of polluting matters (oil, acid, alkali matter, chloride, sulphate and organic matter). Sulphate should be mi S03 < 200 ppm.

2.3 Chemical Analysis of the Nutshell Ash

Properties of the nutshell ash used in the process of stabilization-improvement were analysed through XRF test and XRF test results have been given in Table 1 along with its comparison with results of other materials used in the stabilization process.

Table 1. XRF test result of nutshell, lime and fly ash.

COMPOUNDS	NUTSHELL ASH	LIME (Ghabaee, 2015)	FLY ASH (Karasin, 2014)
	Weight (%)		
Na_2O	-	-	0.16
MgO	3.729	0.51	1.88
AI_2O_3	0.428	0.14	23.31
SiO_2	7.385	0.36	58.02
P_2O_5	4.813	0.03	-
SO_3	4.085	-	0.05
Cl	0.619	-	-
K_2O	28.391	0.02	1.76
CaO	46.696	65.45	3.78
TiO_2	0.178	-	1.76
Cr_2O_3	42 mg/kg		-
Mn_2O_3	1.102		-
Fe_2O_3	2.122		2.63
ZnO	231 mg/kg		-
SrO	0.422		-
Diğer		33.35	

Considering the ash analysis shown in Table 1, it is seen that Cao amount is more than 10%, which is 46%. These types of limes are in high-lime class (ASTM C618).

In general, ASTM classification is applied in fly ash classifications. Ashes that have more than 10% of CaO go into the high lime fly ash group within ASTM C618. Considering the nutshell ash analyses, it is observed that it contains CaO by 46% and goes into the high lime fly ash group. This is important as it also shows that it is a suitable material for road side soil stabilization.

3.EXPERIMENTAL STUDY

Following experiments were applied to the soil sample obtained from Ardahan Posof.:Sieve Analysis ,Atterberg Consistency Limits, Specific Weight ,California Bearing Ratio, Standard Proctor, Triaxial Compressive Strength, Unconfined Compressive Strength ,Falling-headPermeability.

3.1 Experiments Results of the Soil Sample

Test results given in this section belong to the additive-free soil sample used in studies. They show the grain-size curve belonging to the Soil-Fines in Figure 2a, the liquid limit value determined from Casagrande test in Figure 2b, the position of the sample in the plasticity chart and its soil class in Figure 2c, CBR test results in Figure 2d, the dry-wopt relation obtained from the standard proctor test in Figure 2e, the results of triaxial test results in Figure 2f and the load-displacement relation for the unconfined compression test in Figure 2g.

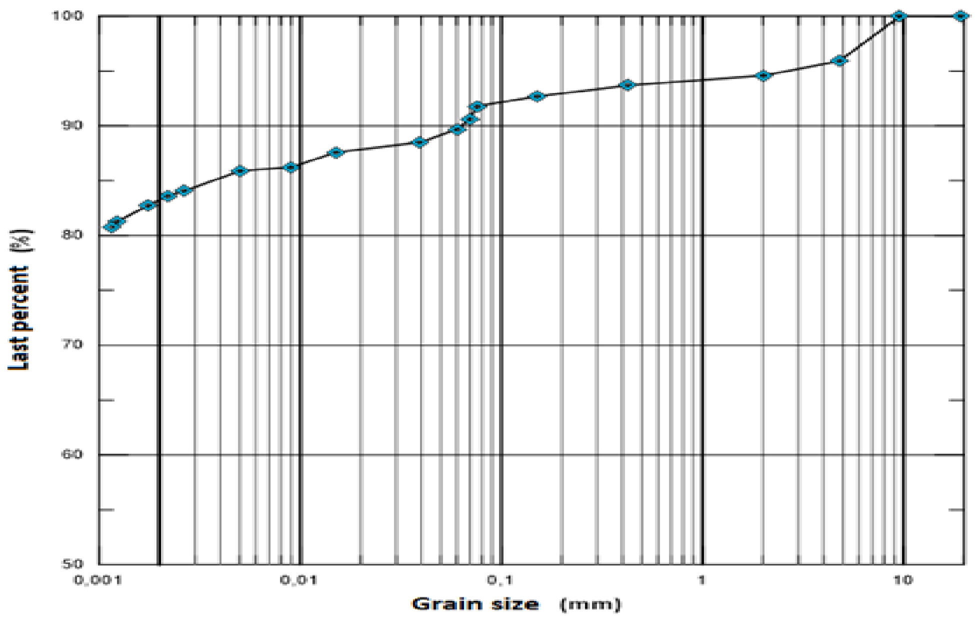

Figure 2a. Results of sieve analysis.

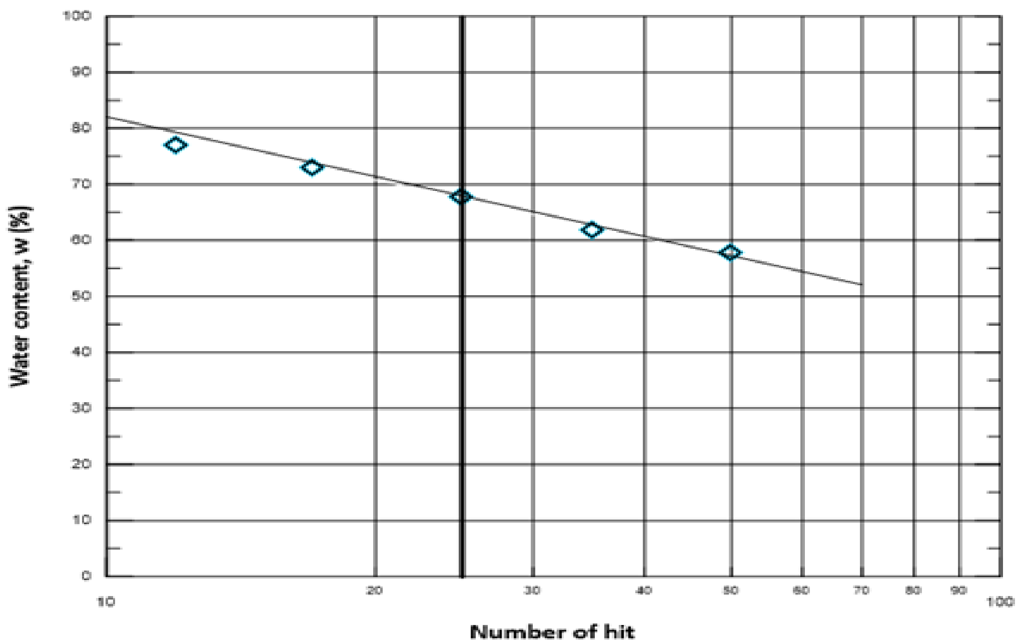

Figure 2b. The result of Casagrande test.

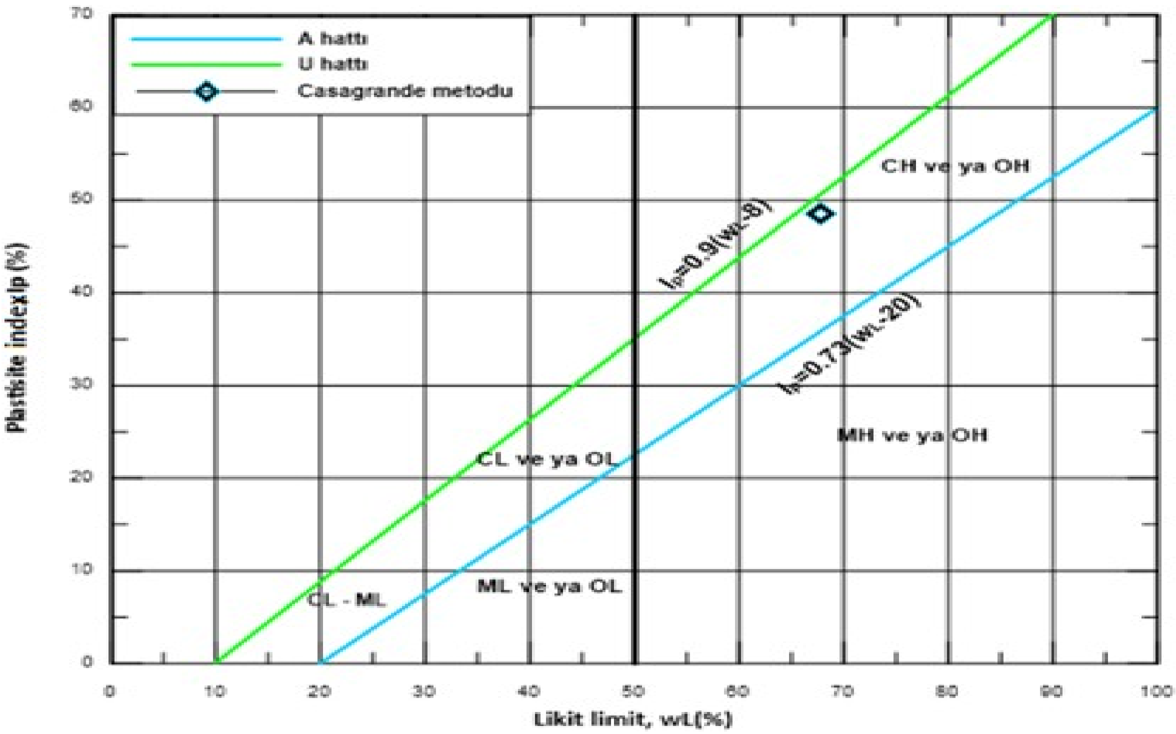

Figure 2c. The graph of liquid limit versus plastic index.

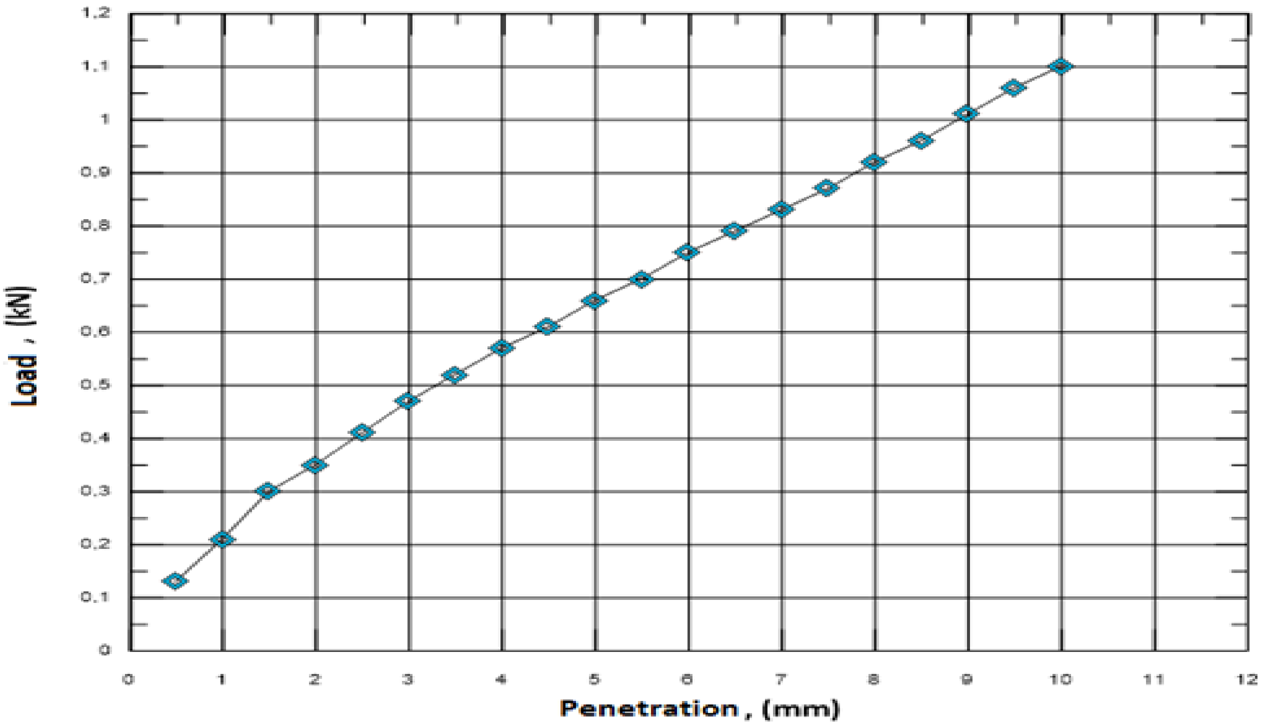

Figure 2d. The graph of penetration versus load.

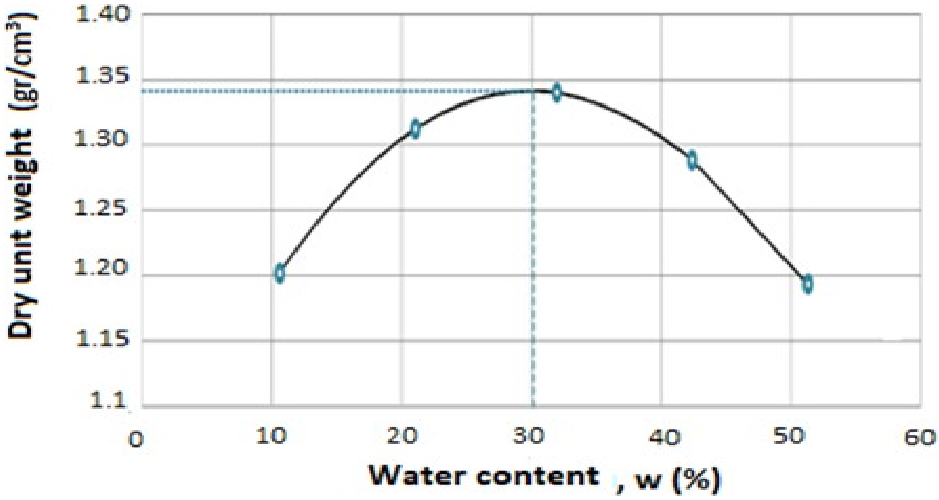

Figure 2e. The graph of water content versus dry unit weight.

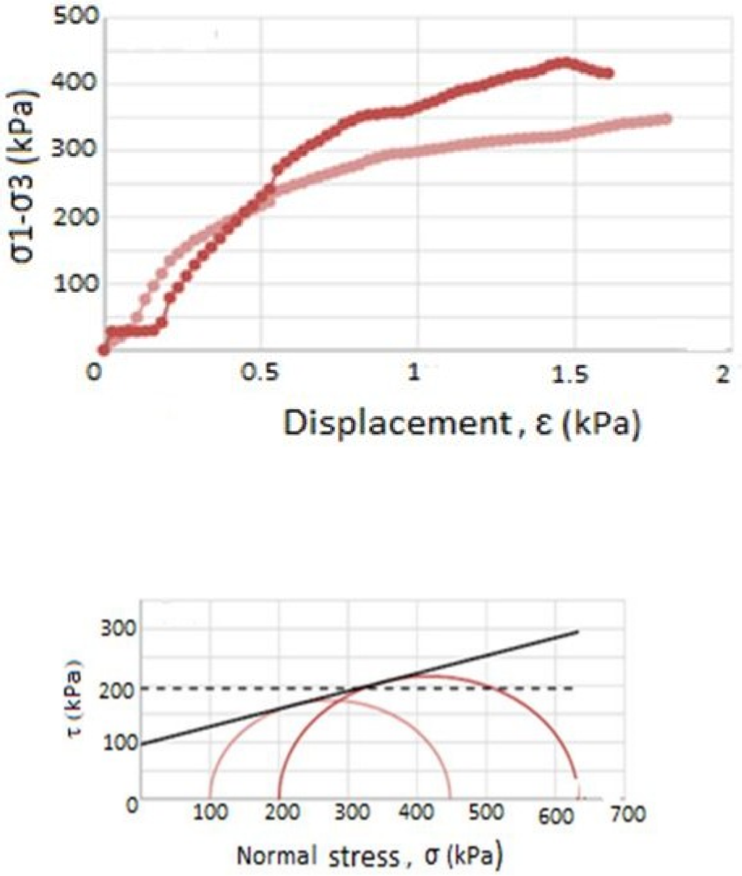

Figure 2f. The result of triaxial compressive strength.

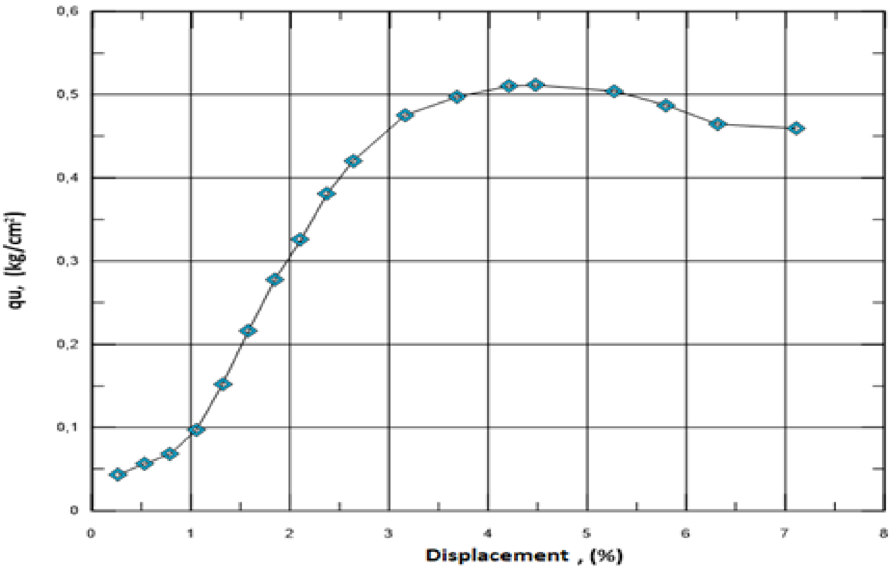

Figure 2g. The result of unconfined compressive strength.

According to the results of sieve analysis and hydrometer (Figure 2a), it was found that it contained 4.1% of gravel, 4.1% of sand, 8.8% of silt and 83% of clay. LL value (Figure 2b) was found as 67,9% from the Casagrande test. According to Atterberg consistency limits (Figure 2c), it was seen that the clay soil sample obtained as LL:67.9%, PL: 19.4% and PI: 48.5% was a high-plasticity (CH) class in the plastisitychart. According to California Bearing Ratio (Figure 2d), it was seen that

CBR value was low, and the swelling rate was slightly high (CBR: 3,3 Swelling Rate: %2,8). According to the Standard Proctor Test (Figure 2e), optimum water content is high and maximum density is low (Max. Density: 13,155 kN/m^3, Opt. Wn: %30,1). According to the Triaxial Compressive Strength (Figure 2f), results are (ϕ: 17,37 C: 96,40). According to the Unconfined Compressive Strength (Figure 2g), the result is (q_u: 50,26 kPa). The results of falling head permeability are given in Table 2.

Table 2. Test Results of Falling Head Permeability

Sample No:	TEST 1	TEST 2	TEST 3
Device No	1	1	1
Water level height at test start (Ho) cm	100	100	100
Pipe Area (a) cm²	0.2826	0.2826	0.2826
Sample Lenght (L) cm	9.9	9.9	8.9
Sample area (A) cm²	80.08	80.08	80.08
Elapsed time at test (t) sec	86400	86400	86400
Water level height at first test (h2) cm	88	91	89
Ambient Temperature C°	23	23	23
Permeability coefficient for test K cm/sn	5.16*10^{-8}	3.81*10^{-8}	4,23*10^{-8}
Average Permeability cofficient (K) cm/sec	4.40*10^{-8}		
Average Permeability cofficient (K) m/sec	4.40*10^{-10}		

3.2 Results Related To The Soil Sample Into Which The Waste Nutshell Ash Was Mixed

The admixture used during experiments at low rates showed different behaviours. As the rate of ash increased, prevenient behaviours started to be more consistent (at 10% and afterwards).

3.2.1 Consistency Limits

The experiment was launched after the nutshell ash sample sieved as 0,425mm was prepared at a 3% of ash at the beginning. Consistency limits obtained for various ash rates are given in Table 3.

Table 3: Consistency features of various ash rates

Mixture Pertence	LL (Liqued Limit) Value (%)	PL (Plastic Limit) Value (%)	PI (plasticity index Value	Gs (Security Number)
Soil Sample	67.9	19.4	48.5	2.46
Soil Sample (% 3 ash)	76.1	19.7	56.4	2.83
Soil Sample (% 5 ash)	69.8	17.9	51.9	2.76
Soil Sample (% 10 ash)	77.1	25.0	52.0	2.80
Soil Sample (% 15 ash)	72.3	26,3	46.0	2.81

Soil Sample (% 20 ash)	67.9	23.7	44.2	2.82
Soil Sample (% 20 ash + coal)	67.7	34.2	33.5	2.81
Soil Sample (% 25 ash)	66.6	24.2	42.4	2.81
Soil Sample (% 30 ash)	61.1	22.8	38.3	2.86
Soil Sample (% 35 ash)	59,7	23.5	36.2	2.87
Soil Sample (% 40 ash)	54.0	22.3	31.7	2.89

According to the soil sample without an admixture of ash, the liquid limit increased. There were fluctuations at the liquid limit values up to 15% of ash. It was determined that as the rate of ash rose to 40%, the liquid limit decreased, the plastic limit value increased in the least and the plasticity index dropped. Besides, it was determined that as the ash rate increased from 3% to 25%, grains in the sample adhered to each other and were forced during mixture and that at the rates of 25% and 40% there was a slow decrease in adhesion of the sample.

3.2.2 Specific Weight Experiment

The experiment was launched after the nutshell ash sample sieved as 4,75mm was prepared at a 3% of ash at the beginning. Fluctuations were observed at the specific weight value between 3% and 25%. The specific weight value increased between 30% and 40%.

3.2.3 Standard Proctor Test

The experiment was launched after the nutshell ash sample sieved as 4,75mm was prepared at a 3% of ash at the beginning. The obtained results are showed in Figure 3 and Figure 4. It rose to the highest density and lowest optimum water level at 20% of ash.

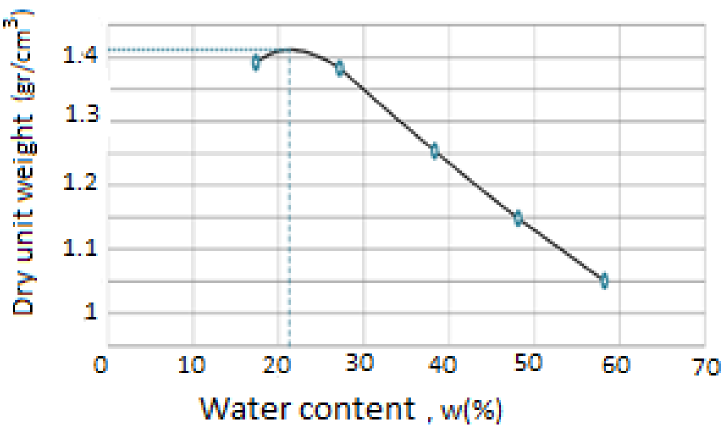

Figure 3. Proctor Test Soil Sample (20% of Waste Nutshell Ash).

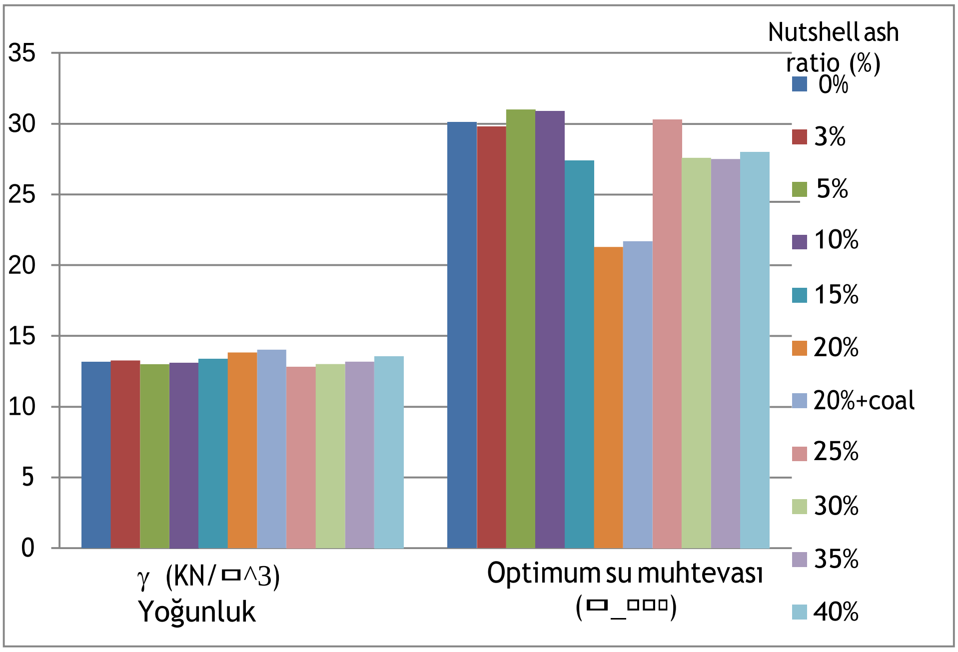

Figure 4. The density and optimum water content variance graph of the soil samples with additive nutshell ash

3.2.4 CBR Test

The experiment was launched after the nutshell ash sample sieved as 4,75mm was prepared at a 3% of ash at the beginning. While it rose to the highest CBR value at 25% of ash, the lowest swelling value was observed at 30% and 40% of ash (Figure5).

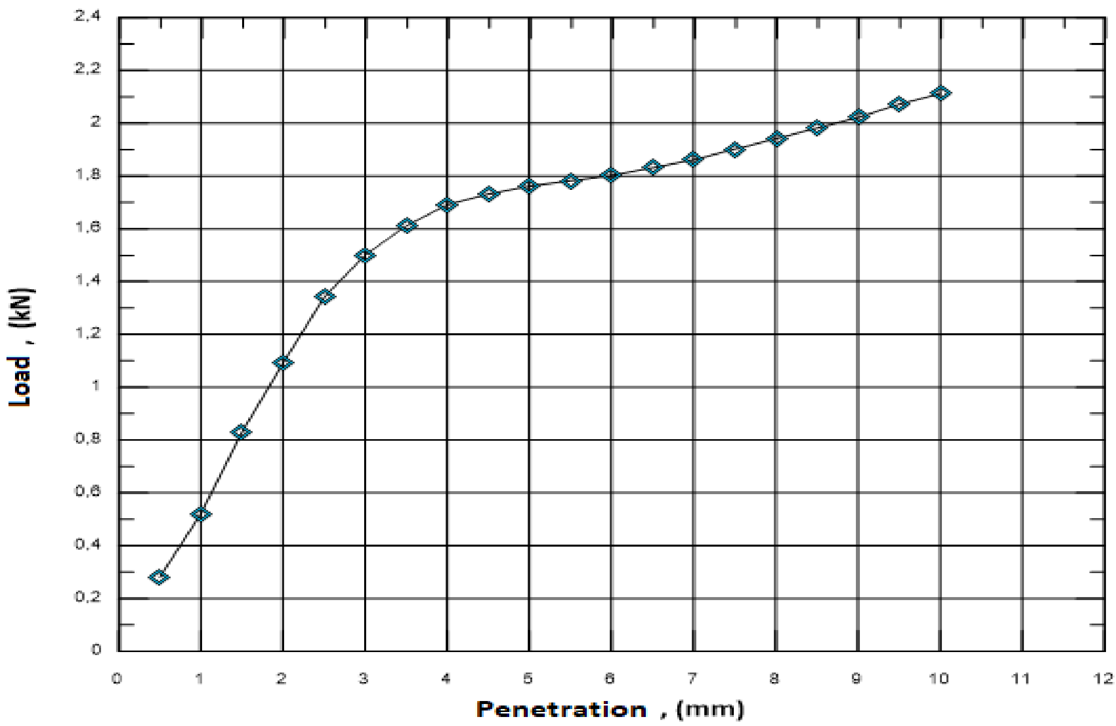

Figure 5: CBR Test Soil Sample (20% of Waste Nutshell Ash) All experimental data obtained for various mixture rates are given in Table 4.

Table 4. CBR test results obtained for various nutshell ash rates

Mixer Percent	CBR	Swelling
Soil Sample	3.3	2.8
Soil Sample (% 3 ash)	1.4	6.7
Soil Sample (% 5 ash)	1.1	7.2
Soil Sample (% 10 ash)	2.0	5.2
Soil Sample (% 15 ash)	8.1	3.1
Soil Sample (% 20 ash)	10.1	1.8
Soil Sample (% 20 ash + coal)	9.7	0.3
Soil Sample (% 25 ash)	19.1	0.4
Soil Sample (% 30 ash)	18.9	0.2
Soil Sample (% 35 ash)	17.6	0.3
Soil Sample (% 40 ash)	16.0	0.2

3.2.5 Triaxial Compressive Test

Test samples were mixed at ash rate values determined and prepared again at the proctor rate. Samples were observed to have fluctuations between 3% and 15%. It was also observed that angle of internal friction decreased while the cohesion value increased between 20% and 40%. It was determined that during the demolding process, as the rate of ash increased, there was difficulty.The relation between the angle of internal friction and cohesion value of the triaxial test data obtained is given in Figure 6 for all mixture rates.

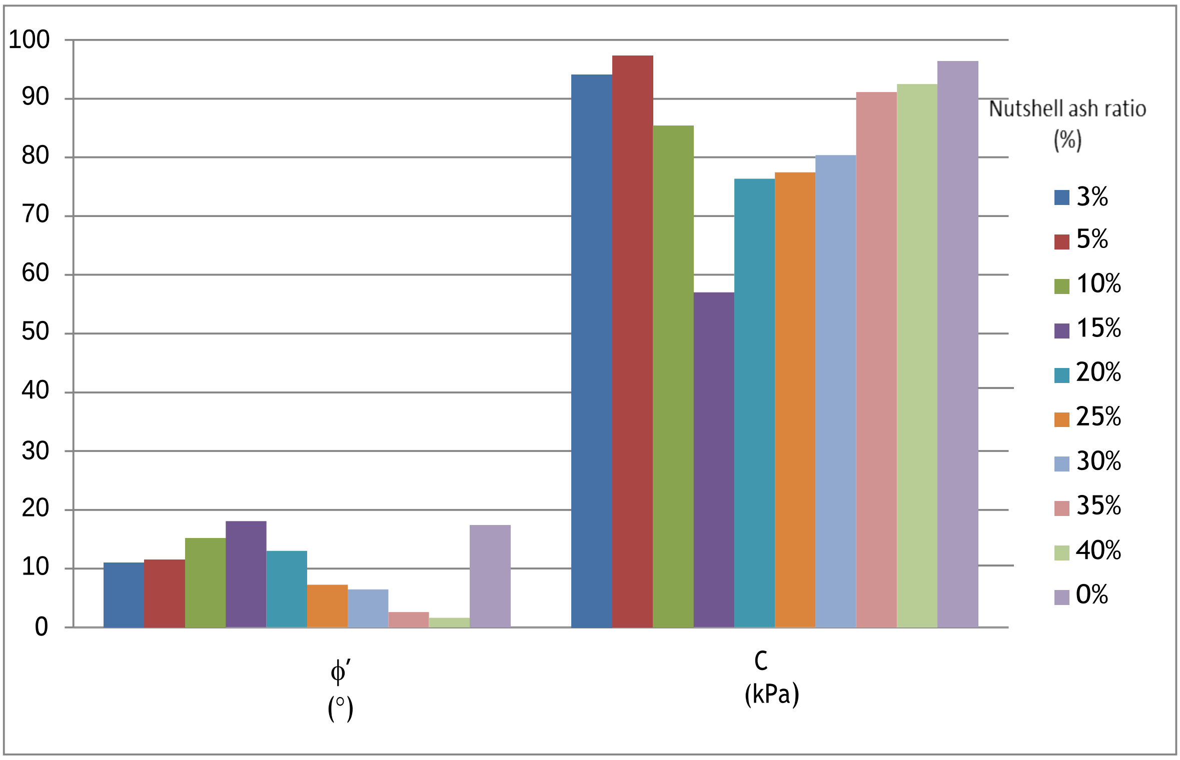

Figure 6. The angle of internal friction and cohesion variance graph of the soil samples with additive nutshell ash

3.2.6 Compressive Test

Test samples were mixed at ash rate values determined and prepared again at the proctor rate. The obtained results are indicated in Figure 7. Though samples were observed to have fluctuations between 3% and 15%, the highest value was obtained at 15% of ash. It was also determined that unconfined compressive value decreased between 30% and 40% and thatduring the demolding process, as the rate of ash increased, there was difficulty.

During the unconfined compressive test applied to the cohesive soils according to TS 1900-2 and ASTM 2165 on samples prepared through addition of various amounts of clay soil and nutshell ash;

The most outstanding values from the unconfined compressive test were obtained from the clay soil sample prepared through addition of 15% of nutshell ash. The test is shown in Figure 7.

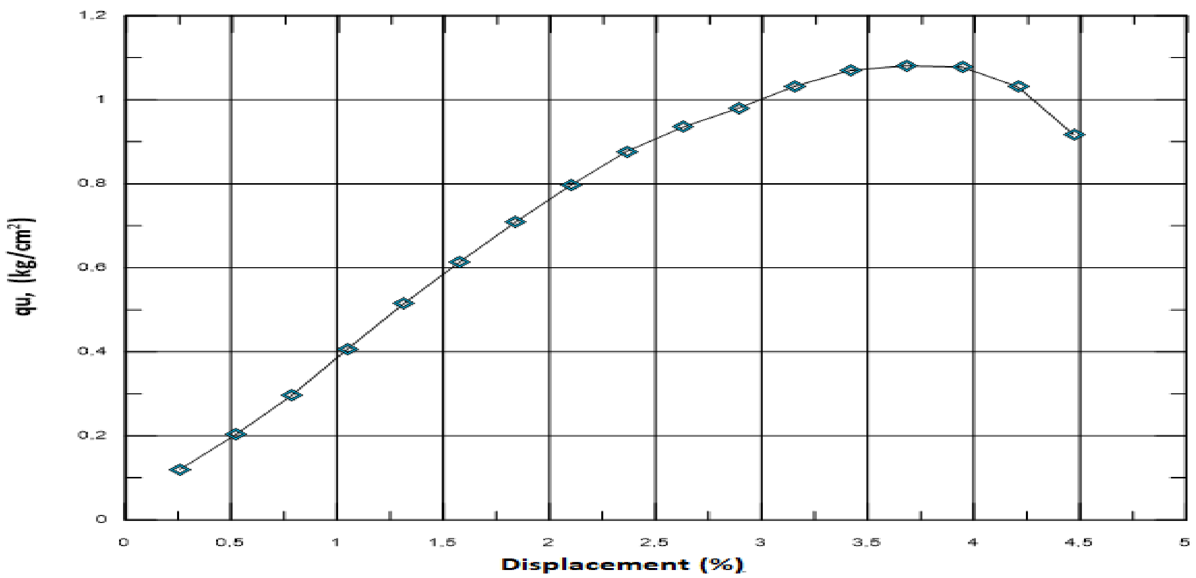

Figure 7. The unconfined compressive test carried out with the sample prepared with 15% of waste nutshell ash and clay soil.

3.2.7. The Falling-head PermeabilityTest

Test samples were mixed at ash rate values determined and prepared again at the proctor rate. The obtained results are indicated in Figure 8. Although there slight changes in test results, values were observed to be almost close.

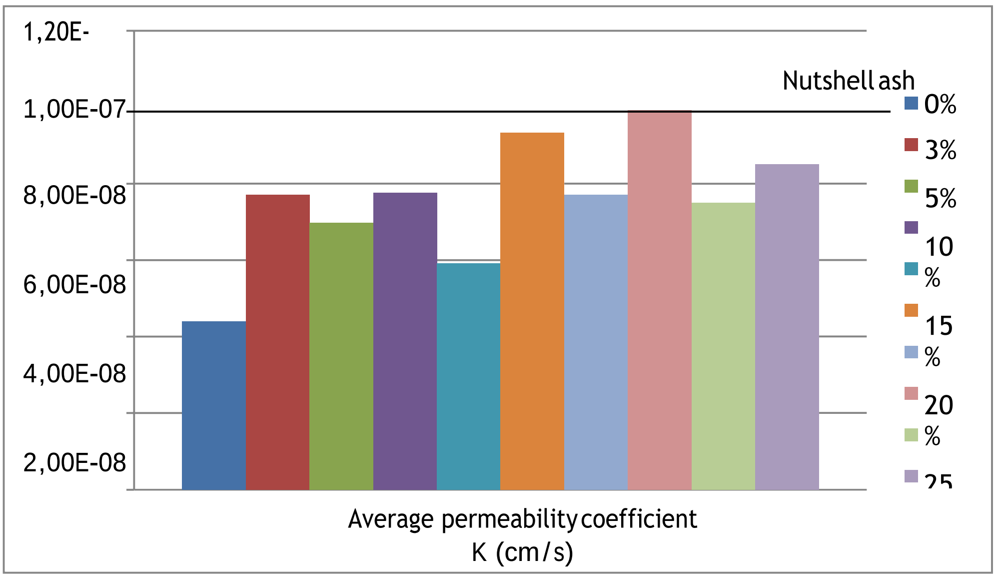

Figure 8. Average permeability coefficient values obtained from the falling-head permeability test.

3.2.8 Swelling

The results of swelling test are showed in Figure 9. It was determined that the swelling rate of the nutshell ash decreased as of 20%.

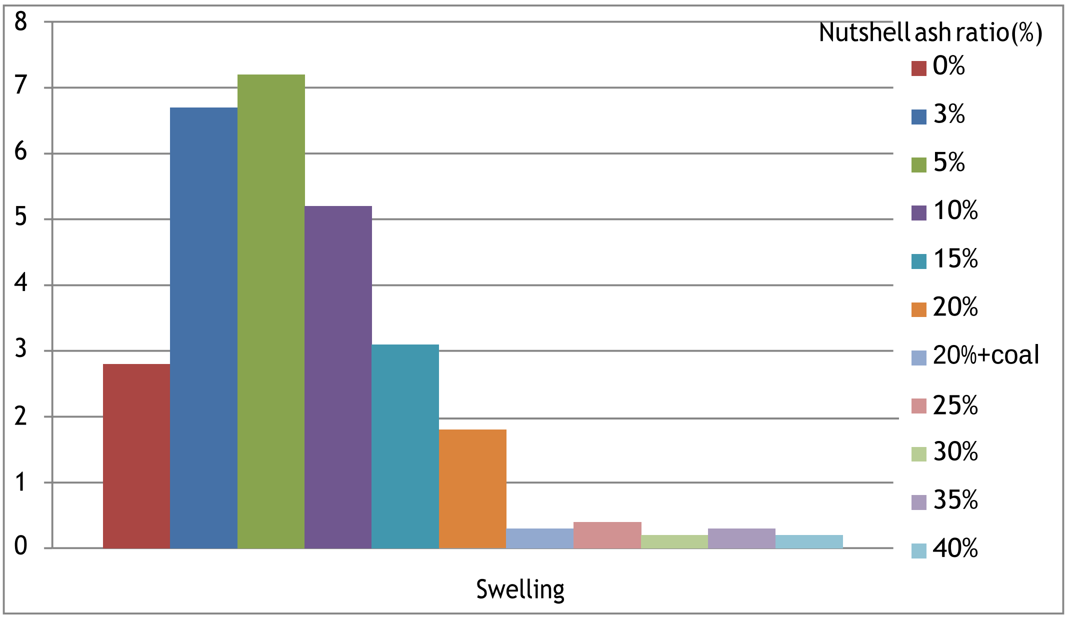

Figure 9: Swelling rates of the samples obtained from the waste nutshell ash and clay soil

It was concluded that the admixture of the fly ash to six different soils dropped the swelling potential of the soil. It was also shown that the admixture of 16% of fly ash to the clay soil which had around 14% of swelling potential dropped the swelling potential to 0.8% (Ferguson, 1993).

TABLE 5: SUMMARY OF TEST RESULTS NUTSHELL ASH

Project Name	Dr. Mahmut DURMAZ - STABILIZATION and EXPERIMENTAL STUDY of CLAY SOILS WITH NUTSHELL ASH	27.12.2017	

Sample Information			c 55b & 5g	*Sieve Analysis*		*Liquid Limit*	*Plastic Limit*	*Plasticity Index*	*Soil Classification*	*Unit Weight*	*Sprecific Gravity*	*Californiya Bearing Ratio*		*Standard Proctor Test*		*Triaxial Comp. Test* UU		*Unconfined Compressive Strength*	*Falling Head Permeability*
Lab. No	*Sample No*	*Depth (m)*	w (%)	+4mm *Gra*	-200 *Silt+*	LL (%)	PL (%)	PI (%)	-	P (g/cm^3)	Gs	CBR (%)	swelling (%)	Ykmax	w_{opt} (%)	ϕ (°)	c (kPa)	q_u (kPa)	K (cm/sn)
6335	Soil Sample			4,1	91,8	67,9	19,4	48,5		1,70	2,46	3,3	2,8	13,155	30,1	17,37	96,40	50,26	4,40E-08
6336	Soil Sample (% 3 Nutshell					67,5	19,7	47,8		1,60	2,83	3,9	6,7	13,258	29,8	10,97	94,13	79,45	7,71E-08
6337	Soil Sample (% 5 Nutshell					67,2	17,9	47,3		1,59	2,76	4,7	7,2	13,003	29,3	11,48	97,30	83,15	6,98E-08
6338	Soil Sample (% 10 Nutshell					66,7	25,0	41,7		1,60	2,80	6,3	5,2	13,103	28,9	15,21	85,41	94,69	7,76E-08
6339	Soil Sample (% 15 Nutshell					66,3	26,3	40		1,57	2,81	8,1	3,1	13,382	27,4	18,09	57,05	106,05	5,92E-08
6340	Soil Sample (% 20 Nutshell					66,7	23,7	43		1,61	2,82	10,1	1,8	13,841	21,3	12,99	76,37	77,86	9,34E-08
6340a	Soil Sample (% 20 Nutshell					67,7	34,2	33,5		1,74	2,81	9,7	0,3	14,037	21,7	-	-	97,57	-
6341	Soil Sample (% 25 Nutshell					65,2	24,2	41		1,64	2,81	19,1	0,4	12,833	30,3	7,24	77,46	59,29	7,71E-08
6342	Soil Sample (% 30 Nutshell					61,1	22,8	38,3		1,67	2,86	18,9	0,2	13,021	27,6	6,47	80,40	59,46	9,92E-08
6343	Soil Sample (% 35 Nutshell					59,7	23,5	36,2		1,67	2,87	17,6	0,3	13,186	27,5	2,61	91,14	58,23	7,50E-08
6344	Soil Sample (% 40 Nutshell					54,0	22,3	31,7		1,57	2,89	16,0	0,2	13,558	28,0	1,62	92,47	33,05	8,51E-08

It is seen in Table 5 that when adding 15% of nutshell ash to the soil sample suitable for road-bed stabilization, best results were obtained and the soil turned out to be stable. It can be concluded that the waste nutshell ash could be used during the stabilization process of soils as is. Moreover, parts remaining on the sieve that did not fully burn out were analysed and compared with the sample into which 20% of clay soil was added and with the ash sample which full burned out.It was also determined that results were generally close to each other, however, the unconfined compressive strength of the sample (20% ash+caol) increased.

3. RESULTS AND DISCUSSION

An unconfined compressive test was carried out with the pure soil sample, and samples prepared in optimum water content determined from standard proctor tests (compaction) done by fractionally adding waste nutshell ash. It was observed from the tests done that the unconfined compressive strength value of 50.26 kPa determined for the pure soil sample increased depending on the rate of added waste nutshell ash and that it reached to a maximum 106 kPa unconfined compressive strength with an additive rate of 15%. It was found that the nutshell ash increased the binding feature and cohesion value of the soil sample and that in the end there was an over 100% of improvement on the unconfined compressive strength depending on the nutshell ash.

The liquid limit value of the pure clay sample used in experimental studies was found as 67.9%. It was found that although there was not a change in the liquid limit value up to a mixture rate of 15% depending on the added nutshell ash, the liquid limit value decreased prominently following the 15% of mixture rate and the impact of the nutshell ash was observed in the clay behaviour. It was also determined that the nutshell ash considerably decreased the water need of the clay soil sample and that the clay tended towards the low plasticity clay class from the high plasticity clay class. Therefore, depending on the content, the water retention characteristic decreased in the clay, and it is foreseen that this behaviour will decrease swelling behaviours of the clay considerably.

At the beginning, depending on the nutshell ash with an additive of the pure clay soil sample falling into the very low-low class at a value of 3.3. CBR, CBR value increased and at a content of 25% it reached to a 19.1 CBR value and fell into medium-good soil class to make it usable particularly as a road infrastructure material.

4. CONCLUSIONS

The main emphasis of this study was on the importance of making stabilization works related to the waste nutshell ash and clay soil. There are studies related to fly ashes and similar results were obtained in this study.

As a result of the experiments, it was found that c= 94.13 kPa ϕ'=10.97°, was for clay additive of 3%, c=57.05 kPa and ϕ'=18.09°was for clay additive of 15%, c=76.37 kPa and ϕ'=12,99 ° was for clay additive of 20%.

As the admixture amount of the nutshell ash increased, the c(cohesion) decreased and Φ(angle of internal friction)increased. In other words, the bearing power increased.

The highest unconfined compressive strength was obtained after the waste nutshell ash was added to the clay soil sample by 15%.

Optimum results were obtained where the admixture was between 15% and 20% for the clay soil stabilization as a result of experimental studies related to the waste nutshell ash.

As a conclusion of this study, it was determined that the waste nutshell ash could be applied for soil stabilizations. There will be huge economic contributions to the country by means of use of this material, particularly during road works and soil stabilizations, though it is considered as waste and leads to pollution. Besides, it will contribute to the environment as damages to the environment will be minimized.

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