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EVALUATION OF THE EFFECT OF PLASTIC BOTTLE (PET) WASTE ON STABLIZATION OF CLAY

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ABSTRACT

The volume of plastic wastes is increasing at a fast rate. Plastic waste is the third major constitute at municipal and industrial waste in cities. This study has been carried out to evaluate the effect the plastic waste on stabilization of clay soil to improve the compressive strength of soil. An experimental program was conducted to investigate the effect of Plastic bottle waste (PET) and evaluate the efficiency on clay soil as stabilizers. A series of laboratory compaction and triaxial tests were carried. Plastic bottles waste (PET) with length (5 – 10 mm) was used as reinforcement. Soil specimens were compacted at maximum dry density with different percentage of plastic bottle reinforcement 0.5, 1.5, 3, 6, 12 and 15 % of weight of clay soil). Results indicate that an increasing of plastic bottle content decrease the maximum dry density and increase the OMC. The highest increase in strength value was achieved when the soil reinforced with 1.5 % of plastic bottle

KEYWORDS: Clay soil, Plastic bottle (PET), stabilization, compaction

I. INTRODUCTION

In general, the quantity of plastics of all types consumed annually all over the world has been growing in a phenomenal way. The manufacturing processes, service industries and municipal solid wastes (MSW) generate numerous waste plastic materials. The increasing awareness about the environment has tremendously contributed to the concerns related with disposal of the generated wastes. It is believed that the management of solid waste is one of the major environmental concerns in the world. Due to limited space on landfills and increasing costs of plastics, utilization of waste plastics has become an attractive alternative for disposal. This paper provides a summary of experimental efforts on the utilization of poly(ethylene terephthalate) (PET) in civil engineering projects, mainly in road pavement, cements and concretes. Presented data indicate that use of waste PET for modification of asphalt, cement and concretes improved their selected properties, which makes economical this approach. Furthermore, using of waste PET in building materials reduce usage of new polymeric materials, which has significant effect on environment pollution (e.g. emission of carbon dioxide, waste disposal problems.)[1]

Plastics are commonly used substances which play an important role in almost every aspect of our lives. The widespread generation of plastics waste needs proper end-of-life management. The highest amount of plastics is found in containers and packaging‟s (i.g. bottles, packaging, cups), but they also are found in durables (e.g. tires, building materials, furniture.) and disposable goods (e.g medical devices) [2]. Diversity of plastics applications is related with their specific properties, low density, easy processing, good mechanical properties, good chemical resistance, excellent thermal and electrical insulating properties and low cost (in comparison to other materials).

Previous work:

Achmad Fauzi et al (2016) [3] investigated the Soil Engineering Properties Improvement by Utilization of Cut Waste Plastic and Crushed Waste Glass as Additive , the study concluded that the engineering properties of stabilized clayey samples were improved: The PI values were decreased when content of waste HDPE and Glass were increased, The CBR values were increased when content of waste HDPE and Glass increased and C, ϕ Values were decreased and increased respectively when content of waste HDPE and Glass were increased

Brajesh Mishra (2016) [4] investigated onuse of Polyethylene Terephathalate (PET) for Stabilization of Subgrade Soil of Road Pavement and concluded the following: 1.Liquid limit and plastic limit of reinforced soil with recycled PET fibers, increases with increase in content of PET fiber. With addition of PET fibers, the plasticity index was decreased by factors 0.77 for PET fiber content of 1.2%.

DUTTA and Sarde (2007) [5] investigated in their study the CBR behavior of stone dust/fly ash reinforced with 3 different sizes of waste plastic strips overlying saturated clay. The effect of waste plastic strips content on CBR and secant modulus of strip reinforced stone dust/fly ash overlying saturated clay was investigated. The study yielded the following conclusions: 1.Addition of waste plastic strip inclusions in stone dust/fly ash overlying saturated clay subgrade resulted in an appreciable increase in the CBR and the secant modulus. 2. The reinforcement benefits increased with an increase in waste plastic strip content and length. 3. The addition of waste plastic strips beyond 2% did not improve the CBR or secant modulus appreciably.

II. EXPERIMENTAL STUDY:

In order to achieve the stated objectives , this study was carried out in few stage .on the initial stage ,all the material and equipment's needed must be gathered or check for availability

Materials Used:

a. Soil:

The soil that has been used in this research was collected from Alneil Street (National Club Project) (see appendix A), located Khartoum, a state of Khartoum in fig (1). The soil passed through sieve No 4 and then air-dried, quartering method was used to prepare the soil (see fig1 and fig 2). The properties of soil were determined by standard test procedures and tabulated. The routine tests were done for characterization of soil.

Properties of Soil:

Fig 1: clay soil (National Club Project)

Fig 2: Qutering method

The properties of soil were determined by standard test procedures as per relevant IS codes and are furnished in table 1.

Table 1 Properties of Clay Soil

Properties	Standards	Value	Unit
Clay	-	58	%
Silt	-	22	%
Sand	-	20	%
Liquid Limit	ASTM: D4318-00	36.9	%
Plastic Limit	ASTM: D4318-00	27.85	%
Plasticity Index	ASTM: D4318-00	9.41	%
Shrinkage Limit -	ASTM: D4318-00	10	%
Specific gravity, Gs	ASTM: D854-02	2.43	
Max. Dry Density	ASTM: D698	1.68	*g/cm^3*
Optimum Moisture Content	ASTM: D698	18	%
Compressive Strength , qu	ASTM: D7181	219.8	*mPa*
Cohesion, C	ASTM: D7181	165.4	*kg/cm^2*
Angle Of Internal Friction (Φ)	ASTM: D7181	18	*Degree*
Soil Classification (USCS)	ASTM: D2487-00	CL-ML	-

b. Plastic bottle (PET) waste:

As outlined by Nabeel (2010) [8] in Khartoum state there are (7) soft drinks factories and more than fifty water bottling factories. All of these factories are using PET plastic bottles for their packaging. Four of the seven drinks factories in Khartoum North industrial area, two in Omdurman and one in Khartoum new North industrial area. Most of these factories distributing their products to all state of Sudan. There are also (4) four formal small- scale grinding plastic recycling units and many informal recycling units in Khartoum state. Only one of the formal units is grinding collected PET bottles for export.

For the present study, plastic waste (PET) was obtained from PET water and bottles in fig (2). The strips were cut into pieces and crushed of different lengths (5mm - 15mm) having average width of 5mm. and are randomly mixed with soil in varying percentages (0.5, 1.5, 3%, 6%, 9%, 12% and 15%) by dry weight of soil.

In general the steps required for recycling PET is not quite different from the other plastic types especially in the preparation steps. For purpose of this current work the preparation steps are:

Collection of PET: The PET bottle used in current study collected from plastic recycle industry in Khartoum state, the PET plastic bottle were collected from house holds domestic and from Canteens disposables fig 4

Sorting the plastic: Once the recyclable plastic materials were collected, the first stage of recycling began by sorting out the plastic material of different types. Plastic recycling is a complex process compared to other recycling process because of the different types of plastic that exists. Mixed plastic cannot be used as it is poor in quality. Therefore it's essential to sort out plastic materials. HDPE is thus sorted out. (Fig 5)

Shredding the plastic: The plastic materials were prepared for melting by cutting them into small pieces. The plastic items are fed into a machine which has set of blades that slice through the material and break the plastic into ***tiny bits (Fig 5).***

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Washing shredded plastic: All residues of products contained in the plastic items and various other contaminants are removed. A particular wash solution consisting of an alkaline, cationic detergent and water are used to effectively get rid of all the contaminants on the plastic (5).

Fig 3: PET water and bottles

Fig 4: Collection of PET water and bottles Wastes

Fig 5: Sorting, Washing and crushing of PET water and bottles Wastes

Table 2 Properties of Plastic Waste (PET Bottle) Strips:

Test	Test method	value	Unit
Plastic type	PET Bottle	-	-
Average Width	Measurement	5	*mm*
Average thickness	Measurement	0.5	*mm*
Average Tensile Strength	ASTM D638	55	*mPa*
Specific gravity	ASTM D792	1.38	

Test Program:

The project has conducted various experiments to find the stabilization of clay soil using the wastes materials, the various test conducted to find the stabilization of clay soil based on the ASTM procedure are listed below:

3.1 Liquid Limit (ASTM D 4318 – 05)
3.2 Plastic Limit (ASTM D 4318 – 10)
3.3 Sieve Analysis (ASTM D 6913)
3.4 Specific Gravity (ASTM D 6473)
.5 Standard Proctor Compaction Test (ASTM D 1557)
3.6 Compressive Strength (ASTM D 2166)

Preparation of Soil Mixes:

Plastic PET bottle wastes and soils were prepared manually by hand mixing. Oven dried soil after passing through 4.75 mm sieve was taken and water added for clayey soil and mixed uniformly. For a particular percentage of fiber content, the 1/3 rd of total amount of plastic strips were distributed evenly and mixed thoroughly with wet soil. After mixing the 1/3rd amount , another 1/3rd amount were mixed in the same way. Lastly the rest 1/3rd amount was mixed with the wet soil. The wet plastic-mixed soils were then used for proctor tests and Triaxial tests.

Fig 6 PET Bottle use in the study

Fig 7 Plain Soil Mixed With PET bottle

III. RESULTS OF EXPERIMENTAL TESTS:

Soil samples, with and without plastic bottle chips, were tested to study the strength behavior of pure and reinforced silty soil. Now, the results of these laboratory tests will be interpreted.

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Results of compaction test:

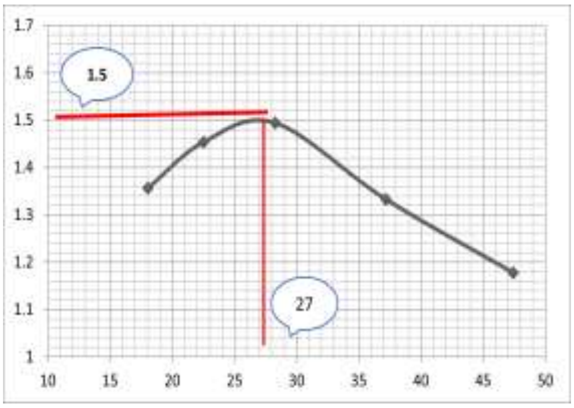


Fig 8 Relation between DD and MC (Soil+3%PET)

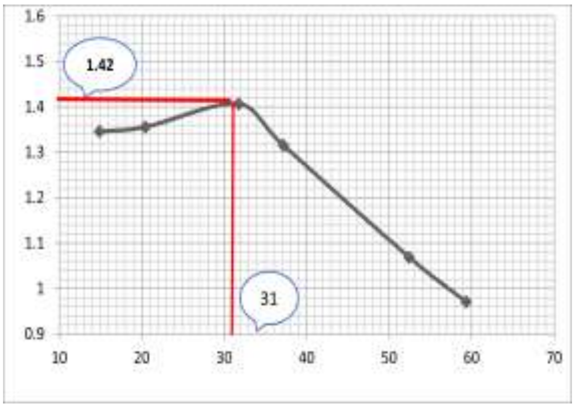


Fig 9 Relation between DD and MC (Soil+6%PET)

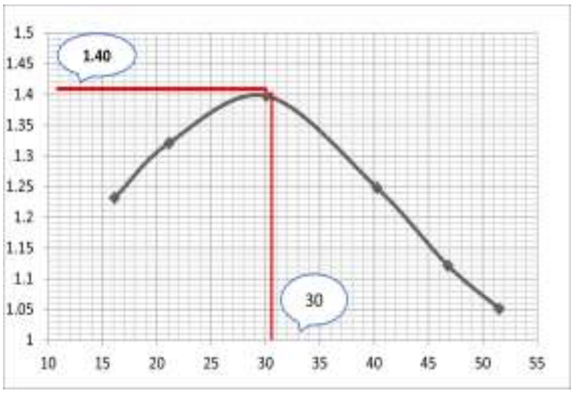


Fig 10Relation between DD and MC (Soil+9%PET)

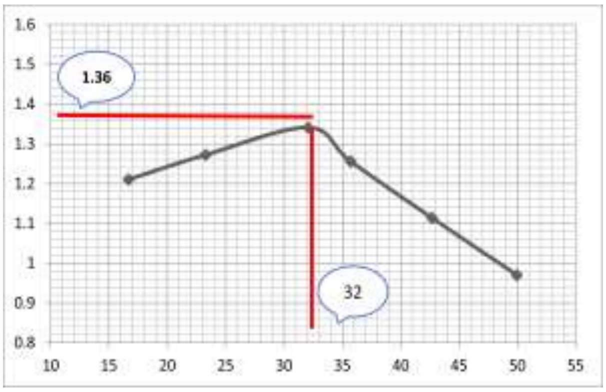


Fig 11 Relation between DD and MC (Soil+12%PET)

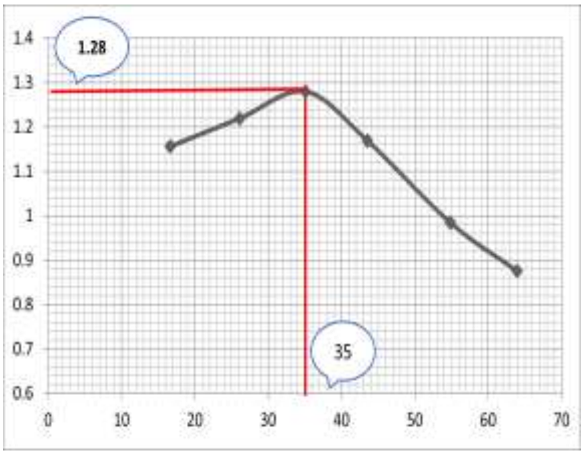


Fig 11 Relation between DD and MC (Soil+15%PET)

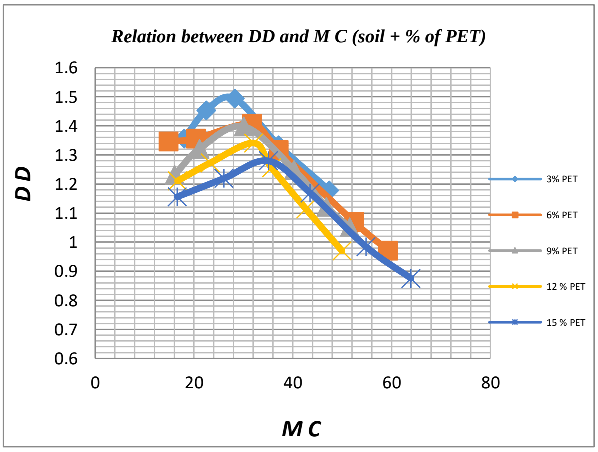


Fig 12 moisture content vs % cement waste

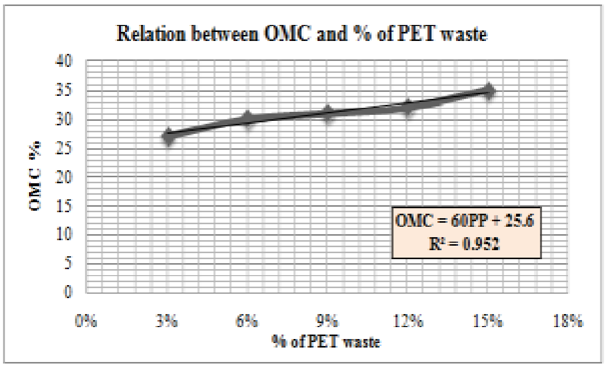
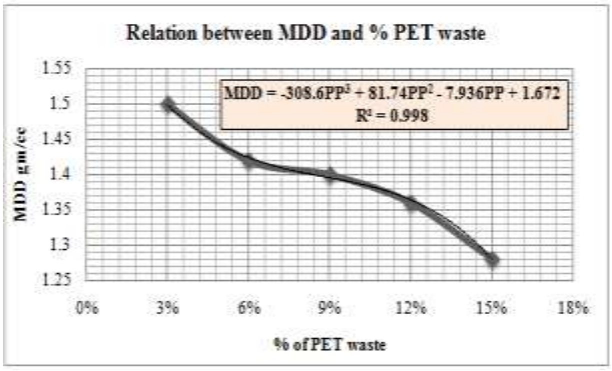


Fig 13OMCand % of PET waste



Fia 14 MMD and % PET waste

Results of triaxial test:

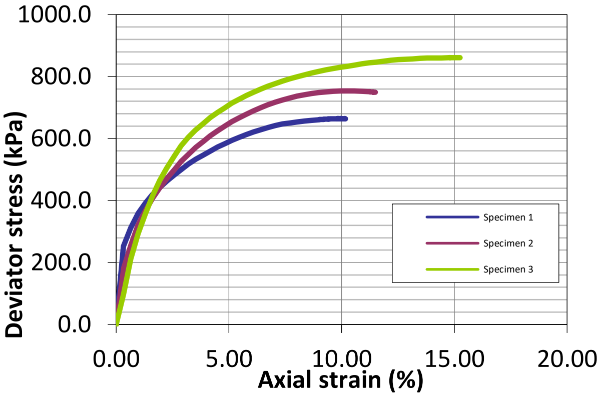


Fig 15 Relation between stress and strain (Soil+0.5%PET)

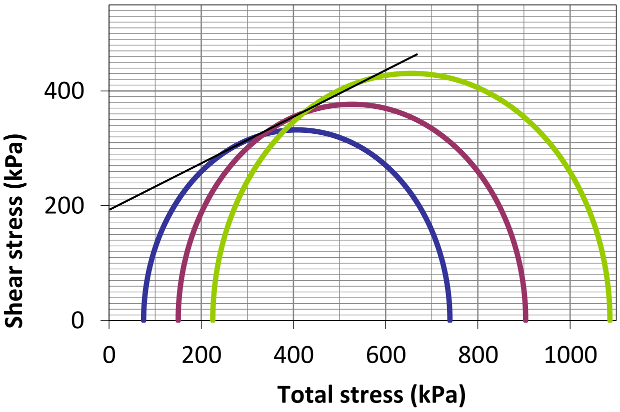


Fig 16 Relation between shear and total stress (Soil+0.5%PET)

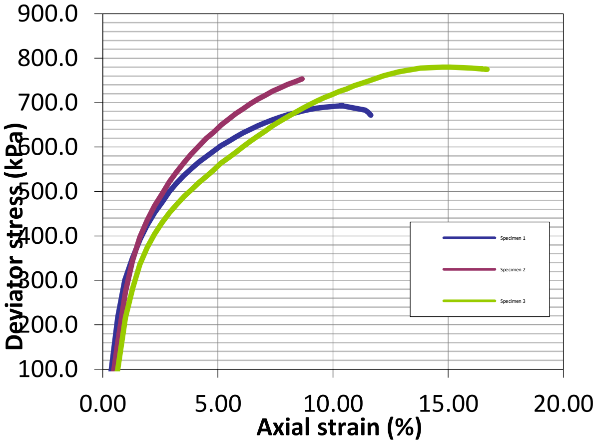


Fig 17 Relation between stress and strain (Soil+1.5%PET)

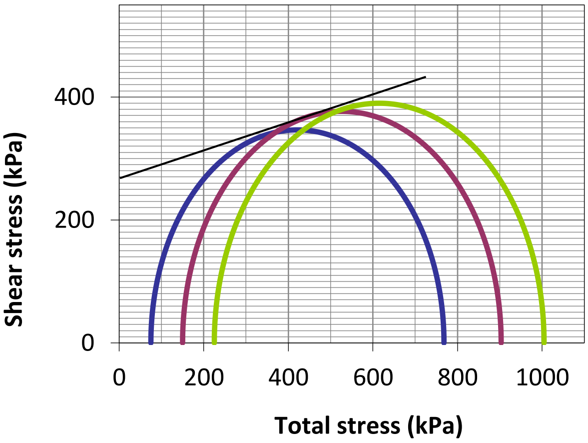


Fig 18 Relation between shear and total stress (Soil+1.5%PET)

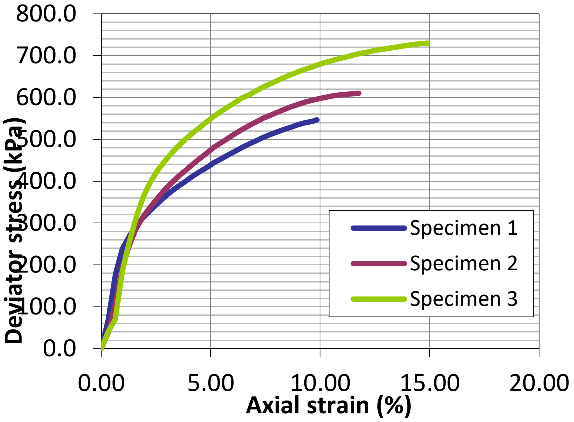


Fig 19 Relation between stress and strain (Soil+3%PET)

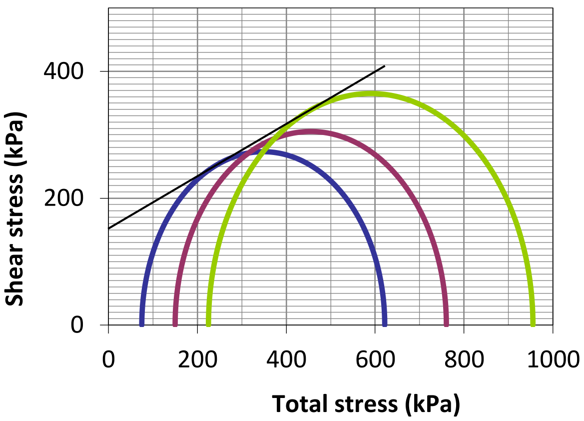


Fig 20 Relation between shear and total stress (Soil+3%PET)

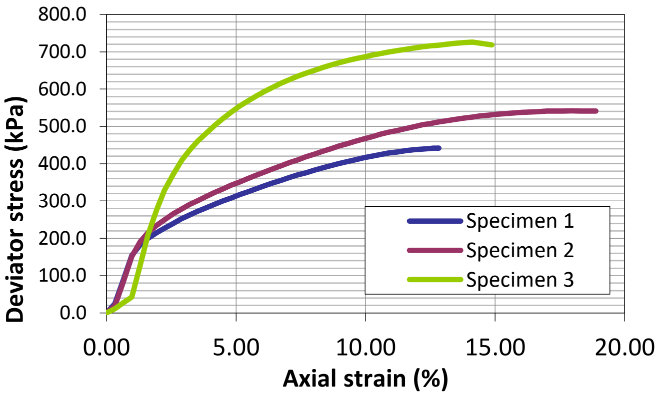


Fig 21Relation between stress and strain (Soil+6%PET)

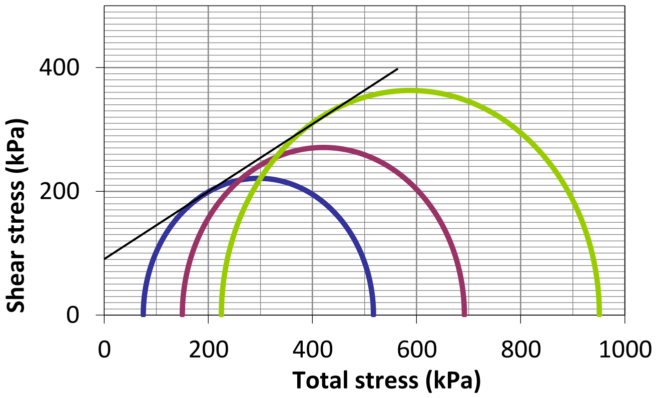


Fig 22Relation between shear and total stress (Soil+6%PET)

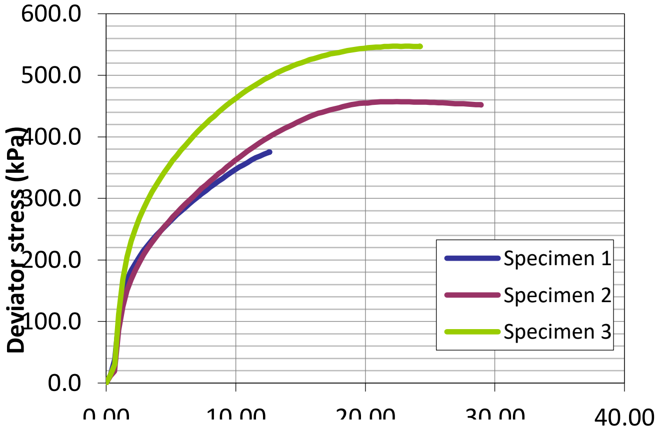


Fig 23 Relation between stress and strain (Soil+9%PET)

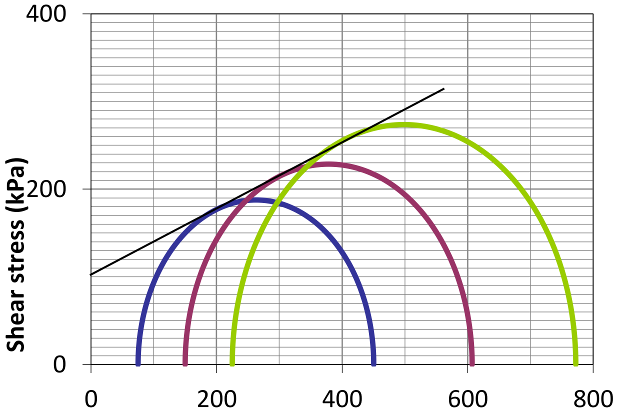


Fig 24Relation between shear and total stress (Soil+9%PET)

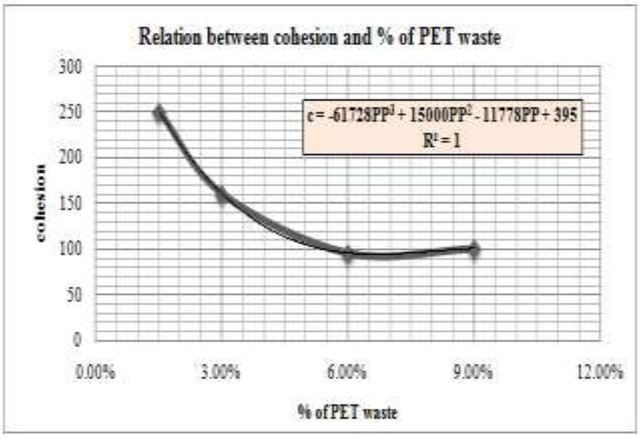


Fig 25 Relation between cohesion and % PET waste

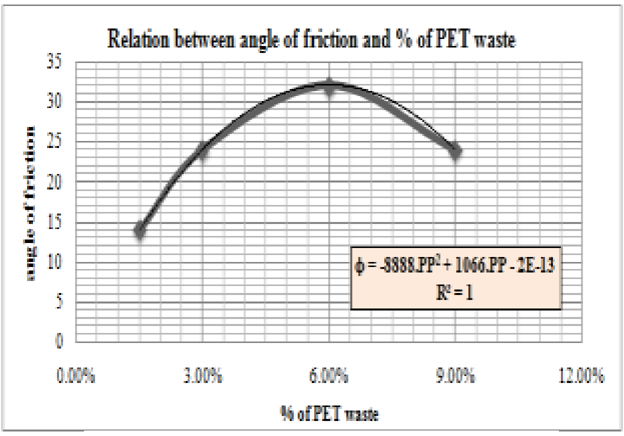


Fig 26 Relation between angle of friction and % PET waste

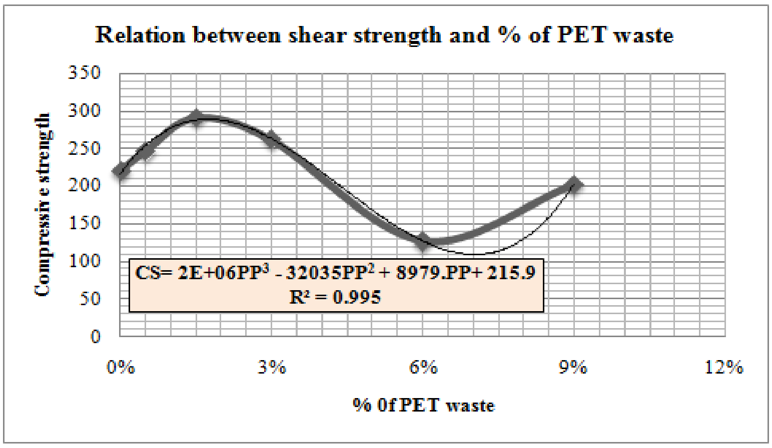


Fig 27 Relation between shear strength and % PET waste

IV. DISCUSSION OF RESULTS:

The results obtained from the different tests are summarized and discussed as following:

Standard Proctor Compaction Test Result

The OMC and MDD reported in Table (4.6) and the relation between the OMC and the MDD and the %s of PET waste presented in Fig (12), relation between the OMC and %s of PET waste in Fig (13) and relation between the MDD and %s of PET waste in Fig (14). The results indicated that the OMC increased from 27 to 35 % with the increasing of the plastic PET bottle content and MDD parameters decreased from 1.50 to 1.28 with the increasing of plastic PET bottle contents in mixed soil.

New formulae obtained by excel sheet to determine the OMC and MDD based on the percentages of PET waste as bellow:

$$\mathrm{OMC} = 60\mathrm{PP} + 5.26 \ldots\ldots (1)$$

$$\mathrm{MDD} = -308.6\mathrm{PP}^3 + 81.74\mathrm{PP}^2 - 7.936\mathrm{PP} + 1.672 \ldots\ldots (2)$$

Where PP: percentage of plastic PET bottle waste

Consolidated Triaxial Test Result

The shear parameters for the soil reinforced by 0.5, 1.5, 3, 6 and 9% of the PET bottles waste summarized in Table (4.9) and the relation between cohesion and %s of PET bottles waste plotted in Fig (4.81) and it indicated that an increasing of PET bottle waste increased the cohesion up to 1.5% and decreased when added greater than 1.5% of PET bottle waste, also the relation between the angle of friction and %s of PET bottle waste plotted in Fig (4.82) and it indicated that an increasing of PET bottle waste increased the angle of friction up to 6% of PET bottle waste.

New formulae obtained by excel sheet to determine the cohesion and angle of friction based on the percentages of cement waste as bellow:

$$C = -61728PP^3+15000PP^2-11778PP+395 \quad (R^2 = 1) \ldots\ldots (4)$$

$$\phi = -8888.PP^2 + 1066.PP - 2E\text{-}13 \quad (R^2 = 1) \ldots\ldots (5)$$

$$CS = 2E{+}06PP^3 - 32035PP^2 + 8979.PP + 215.9 \quad (R^2 = 0.995) \ldots\ldots (6)$$

V. CONCLUSION AND RECOMMENDATION:

According to the laboratory tests conducted to investigate the effect of using the various percentages of waste plastic bottles as reinforced material to improve the strength behavior of clay soil, the following conclusions are obtained:

a. For soil reinforced by plastic PET bottle waste the results indicate that the maximum dry density decreased with the increase in the PET content from 1.50 *g/cm³* to 1.08 *g/cm³*, which is due to lower density of PET compare to the soil particles. Also an increasing of PET bottle waste content decreased the optimum moisture content from 27% to 35%.

b. For soil reinforced by PET bottle waste an increases of PET waste reduced the cohesion(c) of soils significantly, this may be due to the separation of clay particles by plastic pieces and the angle of friction (ϕ) up to 6% of PET waste content, and the maximum shear strength (386 *mPa*) achieved at 1.5% of PET bottle waste content

c. Equations 1 to 6 was predicted by excel sheet to determine the relation between OMC, MDD, cohesion (c), angle of friction (ϕ) and shear strength and the % of PET waste respectively.

As a result of this study it is recommended to use not more than 1.5% of PET bottle waste

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