Integrating Environmental Science and Engineering Management: Harnessing Polyethylene Waste for Sustainable Soil Stabilization

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Abstract— Soil plays a significant role within the survival of living beings on earth. In line with engineering, soil is one of the most relevant material resources used in different fields of work. In constructing roadway or highway structures, soil is the first thing you need to consider because it serves as the foundation where loads rest. Soil Stabilization is one of the methods used in improving the engineering property of soil to make it suitable and strong enough to bear forces. The conventional materials being used to stabilize the soil are cement, lime and chemicals. In this study, the researchers examined another material which could be an agent also for soil stabilization. With rapid increase of population globally, the demand in plastic materials especially polyethylene bags is also growing exponentially. Thus, the disposals of these have been a serious challenge to mankind. This research offers a study on the behavior of plastic waste strips as a soil stabilizing material. The materials used are polyethylene bags and polypropylene straws that have been cut into strips and locally available soil which is found to be clayey type of soil by conducting Sieve Analysis and Atterberg Limits Test. Series of Compaction Test and California Bearing Ratio Test with varying percentage of plastic strips are done to obtain data and information about the relevance of using the said material as a soil stabilizer. It is concluded that to achieve the maximum increase in CBR value of the clayey soil, the optimum plastic strips content is 1% of the weight of dry soil and further increase will only lower the CBR strength of the soil.

***Index Terms*— Soil, Waste, Soil Stabilization, Polyethylene, Sustainable.**

1. Introduction

Soil plays a big role for a foundation and embankments to be secure. Foundation is accountable for holding structures to the ground and for transferring all the loads of a building to the soil. To avoid failures and accidents, using the optimum type of soil is necessary and thus soil stabilization is needed for poor quality expansive soil to improve its properties.[1].

Soil stabilization refers to improving of engineering properties of soils used for sub-grade, sub-base and base course by means of additives which are mixed into the soil such as lime, bitumen, cement and chemical. After soil stabilization, compaction will take place to attain the desired improvement. It increases shear strength, enhances bearing capacity and lowers compressibility and the ability of the soil to allow liquids or gaseous material to pass through it. [2].

Plastic products have become an important part in our daily life. With the increasing number of population and rapid advancement of technology, the use of plastics such as polyethylene bags and bottles also increase. Consequently, the disposal of these wastes poses a serious challenge since most of these plastic materials are non-biodegradable and are unfit for burning as they emit harmful gases that can damage our atmosphere causing global warming.[4]

Thus, this study implies the examination of the effect of plastic waste strips as a stabilizer on poor soil such as clayey soil for which a sequence of test has been carried out with varying or changing percentages of polyethylene strips. The researchers also examine the significance of the study towards the reduction of the overwhelming number of plastic wastes in the country.[4].

2. Methodology

The study conducted various experiments in testing the

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properties of treated soil with plastic waste strips and evaluated the effects of it as a stabilizer and to land at the ideal level of it to be presented in soil. Then, they assessed the quantitative data from the experiment to know its significance to the reduction of polyethylene waste in the country.[1].

The study gathered different kinds of plastic waste and locally available natural soil. They collected plastic waste at home, school, stores and other possible sources then acquired a sample of available soil around. After, they shredded various sizes and types of plastic waste to put in experiment.

The analysis on the effect of low-density polyethylene and polypropylene plastic waste strips on soil as a stabilizer was carried out by a series of geotechnical and materials test.

Two sets of tests are done in the examination

(1) Soil Classification Test

(2) Geotechnical Tests for the Untreated and Treated soil.

To determine the optimum plastic strip content for the soil, a series of California Bearing Ratio test were done for each sample percentage of plastic strips; 0.5%, 1.0%, and 2.0%.[4].

A. *Analysis and Computation of Data*

Gathered information were examined through investigation of related literatures and studied similar experimentation related to the researcher's topic. Calculating the ideal level of plastic strips content that will be used and size of the plastic strips was performed as well as determining the number of plastic wastes that will reduce in the environment. Researchers also analyzed data gathered from different tests to support the objectives of the study.

B. *Experimental Procedure*

A progression of research facility test is directed on both untreated and also on plastic reinforced soil. The researchers examined the acquired soil that undergoes classification procedures. The following tests were performed: Sieve Analysis, Atterberg Limits, Standard Proctor Test and CBR Test.

C. *Wet Sieve Analysis*

A sieve analysis is a procedure or system utilized (ordinarily utilized in structural designing or sedimentology) to assess the molecule size appropriation (additionally called degree) of a granular material.

To determine the particle sizes of the soil, the researchers conducted manual wet sieve analysis by moving or shaking horizontally the sieve mesh with oven dried soil and sorting them with sizes of grains.

D. *Atterberg Limits*

Liquid Limit Test – 100g of oven-dried soil that passed No. 40 (0.425 mm) sieve is obtained then 3 milliliter of water is added for the initial addition of water content and is mixed properly to equally distribute the water. The wet soil was placed to the Casagrande Apparatus that is calibrated and has a height of blow of 1.25cm. The soil was then separated in the center by a grooving tool. The number of rotations for second is 2 or 2 blows per second, the first attempt should have blown between 25-35 to close the gap of the soil then the number of rotations required to close the grove is recorded and a portion of soil is obtained to be oven dried. Repeated procedure is made but in different number of blows and the soil is getting more wet.

Plastic Limit Test - a portion left to the liquid limit is used and is air-dried because the moisture content is higher. Then, 8g of soil is rolled to a glass plate using fingers and palm of hand until it turns to a thread 1/8 inch (3mm). The procedure is repeated until the thread has visible breakage. The thread is then weighed and oven dried for 2 hours.

E. *Standard Proctor Test*

The researchers used the following materials and equipment, Cylindrical Metal Mold, Rammer, Weighing Balance, Thermostatically Controlled Oven, Steel Straight Edge, Pan, Sieve # 4, Sand Scoop, Mixing Tools (trowel) and sand. The degree of compaction of a given soil is measured in terms of its dry density. The dry density is maximum at the optimum water content, the soil is first oven dried and pulverized. The oven dried soil must undergo sieve through using #4 sieve, reject the coarser material. The soil sample was separated into 5 samples. The water substance of each example is balanced by including water. The first compaction has no water, the second compaction was added 150cc of water as well as 3rd, 4th and 5th compaction. For each set of compactions, the soil is placed in the Proctor compaction mold in three unique layers where each layer gets 25 blows of the standard mallet. Before putting each new layer, the outside of the past layers is scratched so as to guarantee a uniform appropriation of the compaction impacts. At the finish of the test, in the wake of expelling and drying of the example, the dry thickness and the water substance of the example is resolved for each Proctor compaction test. In light of the entire arrangement of results, a bend is plotted for the dry unit weight (or thickness) as a component of the water content. From this bend, the ideal water substance to arrive at the most extreme dry thickness can be acquired.

o determines the MDD and OMC, the following formulas were used.

$$\text{Wet Density} = \frac{Weight\ of\ Compacted\ Soil}{Volume\ of\ Mold}$$

$$\text{Volume of Mold} = \pi r^2 h$$

$$\text{Water Content} = \frac{Weight\ of\ water}{Weight\ of\ Dry\ Soil}$$

$$\text{Dry Density} = \frac{Wet\ Density}{1+w}$$

F. *California Bearing Ratio Test*

The CBR test is conducted by measuring the actual water content of the sample, this is necessary to find the needed water to achieve its optimum moisture content. Using denatured gas, it is added to a portion of the soil sample that is weighed and then burned until fully dried. The weight of the burned soil sample is subtracted to the weight of the soil portion that is acquired, and by this the actual water content of the soil is solved and the required water is added to the sample soil to achieve its OMC. Then, it is compacted by 25 blows per 3 layers as of subgrade soil. The compacted soil is weighed and is soaked to water for 24 hours. After, exactly one day the compacted soil sample is tested to the digital CBR machine.

G. Usage of Denatured Gas as a moisture remover

Denatured gas is known as a cleaning solvent that can remove vapor on solutions thus it is used to remove moisture content on soil samples because conducting various test such as CBR test needs faster ways than oven drying a soil, to avoid moisture going to the oven-dried sample. It is studied that no chemical reactions while burning the soil with this alcohol is occurring, that can affect the physical property of the soil.

3. Result And Discussion

Plastic waste can be served as soil stabilizer for sub-grade of foundations.

The researchers had the option to contemplate the impact of plastic strips over compaction and CBR parameters of soil using California Bearing Ratio test.

The researchers knew how many plastic strips are needed for every cubic meter of embankment by computing the exact ratio of plastic strips to a volume of soil.

The researchers analyzed how many tons of plastic waste will be lessen to the increasing number of it by using the quantitative data of waste gathered in the country.

A. Sieve Analysis

Wet sieve analysis is conducted because the sample soil is visibly had more fine-grained particles, and to determine its percentage of silt and clay.

Mass of oven dried sample 815.6 g
Mass of washed oven dried sample 209.4 g
Mass of material passing 0.075mm 606.2 g

Table 1.1.
Data Gathered from Sieve Analysis

Sieve Size (mm)	Mass Retained (g)	Mass Passing (g)	Percent Passing (%)	Percent Retained(%)
25.0		814.9	100	0
19.0	20.1	794.8	98	2
12.5	21.9	772.9	95	5
9.5	10.6	762.3	94	6
4.75	10.1	752.2	92	8
2.00	8.9	743.3	91	9
0.425	24.6	718.7	88	12
0.075	109.1	609.6	75	25
Pan	3.4			
Total	208.7			

From this table, it is observed that the percentage of soil passing through 0.075 mm (No.200 sieve) is 75%, so soil is classified as fine-grained soil.

Four samples of oven dried soil are used in determining the liquid limit with an increasing amount of water starting from 15-20ml and an increment of 1-3ml. The first sample should obtain 25-35 number of blows, the second sample should get 20-30 number of blows, the third sample should acquire 15-25 number of blows and lastly, the fourth sample should have 0-10 number of blows. The obtained water content of the 4 samples is then averaged to get the Liquid Limit of the soil. In terms of plasticity, the average between the water content of the two samples will be the plastic limit of the soil

Table 1.2.
Data Gathered for Atterberg Limits Test

	LIQUID LIMIT				PLASTIC LIMIT	
Determination Number	1	2	3	4	1	2
Container Number	1	2	3	4	11	12
Container + wet soil (g)	32.008	24.407	28.528	30.804	10.278	9.998
Container + dry soil (g)	27.905	21.843	25.048	27.402	10.041	9.831
Weight of water (g)	4.103	2.594	3.480	3.402	0.237	0.167
Container (g)	13.963	13.067	13.325	17.118	8.708	8.996
Dry soil (g)	13.942	8.776	11.723	10.284	1.333	0.835
Moisture Content (%)	29.43	29.56	29.69	33.08	17.78	20.00
Number of Blows	27	22	21	10		

Table 1.3. & 1.4.
Summary of Result for Seive Analysis and Atterberg Limits

SIEVE SIZE	%PASSING
4.75	92%
2.00	91%
0.425	88%
0.075	75%

LIQUID LIMIT	30%
PLASTIC LIMIT	19%
PLASTICITY INDEX	11%
GROUP INDEX	7%

B. Moisture-Density relations of soil

Table 1.5
Data Gathered for Compaction Test

TRIAL NUMBER	1	2	3	4	5
Water added, ml	150	150	150	150	150
Mold + wet soil, kg	4.8888	5.0198	5.0777	5.1657	5.1225
Mold, kg	3.2404	3.2404	3.2404	3.2404	3.2404
Wet soil, kg	1.6484	1.7794	1.8373	1.9253	1.8821
Wet density (kg/cu.m.)	1746.19	1884.96	1946.29	2039.51	1993.75

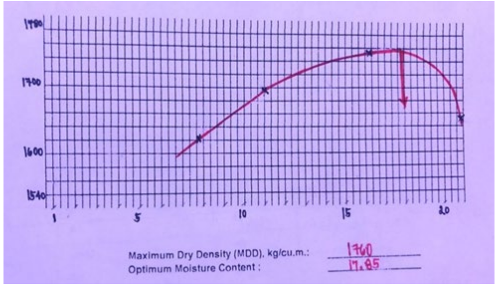

Fig.1. Graph for Maximum Dry Density and Optimum Moisture Content

VIRGIN/UNTREATED SOIL

MAXIMUM DRY DENSITY=1760 kg/cu.m

OPTIMUM MOISTURE CONTENT=17.85 ± 5% (17.35% - 18.35%)

TOTAL MASS OF SOIL SAMPLE=10700 g

MASS OF CONTAINER=101.6g

Actual Moisture

Content= (portion of soil sample– portion of soil sample burnt)/(portion of soil sample burnt-mass of container) x 100

Actual Moisture Content= (196.8g-194.1g)/(194.1g-101.6g) × 100

Actual Moisture Content= 2.92 %

Water needed= (Optimum Moisture Content-Actual Moisture Content) (Total mass of soil sample)

Water needed= (17.85% - 2.92%) (10700g)

Water needed= 1597.51ml

Note: The initial water that will be added to the total soil sample must be lesser than the obtained value of needed water to avoid excess water content due to soil permeability. Therefore, use 1500ml as initial water to be added to the soil sample.

Trial 1: Actual Water Content

Mass of Can used= 101g

Moisture Content= (portion of soil sample– portion of soil sample burnt)/(portion of soil sample burnt-mass of container) x 100

Moisture Content= (214.5g-198.1g)/(198.1g-101g) x 100

Moisture Content= 16. 89%

Note: The obtained moisture content did not reach the optimum moisture content 17.85% with a tolerance of ± .5% (17.35% - 18.35%). Therefore, add an approximate of 200ml water and then mix again.

Trial 2: 200ml of water added

Mass of Can used= 101g

Moisture Content= (portion of soil sample– portion of soil sample burnt)/(portion of soil sample burnt-mass of container) x 100

Moisture Content= (192.5g-178.8g)/(178.8g-101g) x 100

Moisture Content= 17.61%

Table 1.6
Molding oisture Content for Virgin/ Untreated Soil

	MOLDING MOISTURE CONTENT		
	TEST NO.	1	2
	CAN NO.	A-3	A-6
A	Mass of Wet Soil + Can, g	181.7	188
B	Mass of Dry Soil + Can, g	159.9	165.2
C	Mass of Moisture, g (A-B)	21.8	22.8
D	Mass of can, g	36.1	36.7
E	Mass of Dry Soil, g (B-D)	123.8	128.5
F	Percent Moisture (C/E) × 100	17.61	17.74
	Average		17.68

Table 1.7.
Density Determination for Virgin/Untreated Soil

DENSITY DETERMINATION	
Volume of Mold., cu.m.	0.003224
Mass of sample + mold, kg	11.2080
Mass of mold, kg	6.7674
Mass of sample, kg	4.4406
Unit weight mass, kg/ cu.m.	1377
Percent moisture, %	17.68
Unit dry mass, kg/cu.m.	1170

Table 1.8.
% CBR for Virgin/ Untreated soil

Penetration Mm	Molded Total Load (kN)	Unit Load (kg/sq.cm.)	Corresponding Load (kg/sq.cm.)	Tested % CBR
0	0	0		
0.64	0.307	1.587		
1.27	0.535	2.765		
1.91	0.708	3.659		
2.54	0.811	4.191	70	6.10
5.08	1.110	5.736	106	5.52
7.62	1.304	6.739		

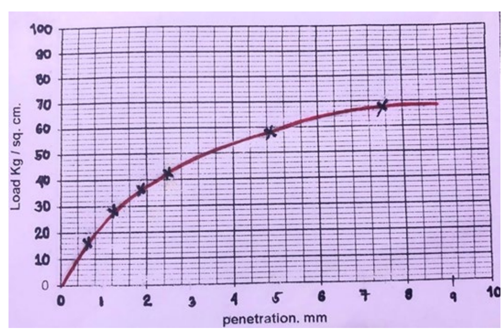

Fig.2. Graph for Load and Penetration of Virgin/ Untreated Soil

% Increase in CBR Value=(Highest CBR Value-CBR Value of Virgin Soil)/(CBR Value of Virgin Soil) x 100

% Increase in CBR Value=(7.15-6.10)/6.10 x 100

% Increase in CBR Value=17.21%

C. Ratio of Plastic Strips per Cubic Meter of Subgrade

After getting the optimum plastic content needed to the specific weight of soil subgrade (clayey soil) the ratio of plastic strips to cubic meter of subgrade is determined by:

Computing the volume of the subgrade of a 1km long and 6.1-meter-wide road (with a 300 mm thickness of soil subgrade)

Converting it to mass (density of sample soil is 1760 kg per cubic meter)

Multiplying it to the plastic strips content percentage (1%)

Solutions:

1Km of road of typical 6.1m width with 300 mm thickness of subgrade

Volume = 1000m x 6.1m x .3m

Volume = 1830 m^3

Dry density of clay soil = 176o kg/m^3

Mass = 1830 m3 (1760 kg/m^3)

Mass = 3,220,800 kg

Plastic Content = Mass (Optimum Plastic Percentage)

Plastic Content = 3,220,800 kg (1%)

Plastic Content = 32,208.8 Kg

4. Conclusion

The effect of plastic strips as soil stabilizer to clayey soil in subgrades is increased 17 % CBR strength than that of the untreated soil sample, it is achieved by adding optimum plastic content of 1% in the soil and further increase will only get lower CBR value.

It can be concluded that using waste plastic strips as a soil stabilizer can be a way to reduce the overwhelming increase to the waste pollution in the country by using it as an agent to soil stabilization.

Based on the comparative analysis of plastic waste strips among other usual admixtures, it is more economical and environmentally friendly to use.

It is computed that for every 1 km of road of typical 6.1 m width with 300 mm thickness of soil subgrade, roughly 33 metric tons of plastic strips waste will be needed or 3 garbage truck with full of waste will be lessen to the plastic waste in the area.

A. Future Directives

The test is done with only clayey soil and further tests are needed to evaluate the effectiveness of plastic waste strips as soil stabilizer to other types of soil.

The type of plastic used is only LDPE (Low Density Polyethylene), if other types of plastic such as HDPE, PET bottles or combinations of them are used the parameters of the soil will have different results. So, further tests are needed to determine the impacts of other types of plastic to soil improvement.

Large scale tests are needed to assess fully the behavior of plastic strips as a soil stabilizer on subgrades of soils.

Various other tests are need to be done such as permeability test, consolidation, direct shear and triaxial test to have more data to the impact of plastic waste strips on soil stabilization.

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