NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Strength Characteristics of Lateritic Soil Reinforced with Waste Rubber Tyre Strips

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Article Info

Received 30 July 2020
Revised 03 August 2020
Accepted 04 August 2020
Available online 31 August 2020

Keywords:
Rubber Tyre Strips, Reinforced, Compaction, California Bearing Ratio, Dry Density

doi Crossref NIPES JOURNALS

https://doi.org/10.37933/nipes/2.3.2020.6

https://nipesjournals.org.ng

Abstract

Safe and effective disposal of waste tyres have become a challenge today as the number of wastes tyres lying about increase daily and pose both environmental pollution and health problem to individuals. This study is aimed at evaluating the characteristics strength of soil reinforced with waste rubber tyre strips which will in turn cause a major reduction and subsequent elimination of the problem aforementioned. The soil samples used for this research were obtained from the University of Benin, from three different bore holes at depths of 1.0m and 1.5m each. Soil tests were carried out on the soil sample in its natural state which included natural moisture content specific gravity, sieve analysis, Atterberg limit, compaction and California Bearing Ratio (CBR) tests. The soil samples were thereafter reinforced with the waste tyre strips of sizes 0.5cm and 0.8 cm. Compaction test and CBR test were also carried out on the soil reinforced with waste rubber tyre strips. The results from the test showed that the soil did not increase in strength but rather reduced because the value of the Maximum Dry Density (MDD) decreased slightly with the reinforcing material from 1.67g/cm^3 to 1.82g/cm^3 for the unreinforced to 1.62g/cm^3 to 1.73g/cm^3 for the reinforced likewise the CBR results which reduced from (3.01% to 20.32%) to (1.73% to 7.68%) for the soaked and from (5.04% to 24.77%) to (6.77% to 21.55%).

1. Introduction

The alteration of soils to improve or enhance their physical properties is known as soil stabilization. Improvements include increasing the dry unit weight, bearing capacities and, volume changes. It also alters the soil parameter such as shear strength, compressibility, density, hydraulic conductivity etc. The technique of soil stabilization can be categorized into a number of ways such as consolidation, vertical drains, vibration, surcharge load, admixtures, grouting and reinforcement and other methods [1]. The different types of methods used for soil stabilization are: soil stabilization using cement, soil stabilization using lime, soil stabilization using bitumen, mechanical stabilization and a new emerging technology of stabilization that is stabilization of soil by using geo textiles and geo synthetic fibers.

Geo synthetics are synthetic products used to stabilize terrain. They are synthetic products made from various types of polymers which may be either woven or non-woven. These are used to enhance the characteristics of soil and have provided a practical way of constructing civil engineering structures economically [2]. Geo synthetics are considered as bona fide engineering

materials that not only are filling in for scarce raw materials like cement and steel, but also are turning out to be a really sound and good alternative to the conventional designs.
In this study waste rubber tyres were used as geosynthetic material to improve the strength characteristics of a given soil sample [2].
Nigeria had an explosion in the number of vehicles in this 21st century and as such the generation of scrap tyres has increased over the years in Nigeria. The vehicle population of the world is rapidly increasing and so is the generation of waste tyres. A lot of research work is going on worldwide to cope with the problem. If growing numbers of waste tyre stockpiles are to be avoided, additional recycling and re use of tyres are essential. Waste tyres have characteristics that makes them not so easy to dispose and potentially combustible. Huge stockpiles and uncontrolled dumping of tyres throughout the country is a threat to the public health and environment. One of the alternative ways of disposing of waste tyre is to use them for geotechnical applications. With the introduction of waste tyre rubber in soil, its capacity to absorb and dissipate energy will be enhanced [3].
Huge quantities of scrap tyres are generated every day in Nigeria and other countries and land filling or stockpiling of scrap tyres is prone to cause environmental problems such as, largely occupied spaces, health hazards because scrap tyres will provide a natural breeding space for diseases and rodents, it also pose as a fire risk which will in turn result in air pollution in the event of its occurrence. Solid waste management is one of the major environmental problem worldwide. This work will provide a useful and suitable way of meeting the challenges of reducing the quantity of waste material (which is waste rubber tyres in this case) and also provide useful advantages from non-useful waste rubber tyre materials which will greatly improve and enhance the soil structure.
Geotechnical engineers around the world are in search of new alternate materials which are required both for cost effective solutions for ground improvement and for conservation of scarce natural resources. The use of shredded or crumb tyres for soil reinforcement will help in proper use and recycle of waste tyres. Use of waste rubber tyres in geotechnical engineering for improving the behavior of soil has received great attention in recent times. If scrap tyres are used as construction materials instead of burning them or leaving them lying and scattered all round, it would be useful in good manner for both civil and environmental sectors. In recent years, civil engineering applications using scrap tyres are light weight fill, insulation beneath roads, light weight backfill for retaining walls and also to improve the drainage conditions. The potential of using rubber from worn tyres in many civil engineering works has been studied for more than 30years [3],[4],[5],[6],[7],[8],[9].The application of waste tyres in various forms has been recently developed in reinforcing soil for a variety of geotechnical applications ranging from retaining structures and earth embankments, asphalt pavement and paving system, foundation beds and other applications[6].

2. Methodology

The materials used for this study include lateritic soil and discarded/waste rubber tyre. The lateritic soil samples were obtained using the hand auger from three boreholes on the site B section of Ugbowo campus of University of Benin, Benin City, Edo State in Nigeria. The rubber tyres were cut manually with a knife as mechanically shredding proved impossible in the environment. The width of the rubber tyre was 0.7cm and 0.5cm respectively with a length of 10cm (size of CBR mould) as shown in Figure 1.

2.1 Soil Sampling and Laboratory Testing

The soil samples were collected from three boreholes at depths of 1.0m, 1.5m, and 2.0m respectively. The samples were then taken for investigations at the University of Benin Geotechnical Engineering Laboratory, with the following investigations carried out in accordance with British Standard [10]:

i. Natural Moisture Content
ii. Specific Gravity
iii. Particle Size Analysis (sieve analysis)
iv. Consistency/Atterberg Limits (liquid limit and plastic limit)
v. Compaction Test
vi. CBR (California bearing ratio) Test

Figure 1: Rubber strips

3. Results and Discussion

3.1 Natural Moisture Content and Specific Gravity Test

The natural moisture content and specific gravity test carried out on the samples are presented in Table 1.

Table 1. Natural Moisture Content and Specific Gravity Test

S/N	LOCATION	NATURAL MOISTURE CONTENT	SPECIFIC GRAVITY
1	BH1, 1.0m	19.44	2.49
2	BH1, 1.5m	17.62	2.42
3	BH2, 1.0m	19.63	2.60
4	BH2, 1.5m	18.69	2.51
5	BH3, 1.0m	18.85	2.50
6	BH3, 1.5m	19.28	2.56

The result of the natural moisture content ranged from 17.62% to 19.63%. The specific gravity result ranged from 2.42 to 2.60.

3.2. Sieve Analysis Test

The result of the sieve analysis test carried out on the samples collected from the three boreholes is shown in Table 2.

Table 2. **Sieve Analysis**

S/N	LOCATION	PERCENTAGE (%) PASSING SIEVE NUMBERS			AASHTO CLASSIFICATION
		1.18mm	0.425mm	0.075mm	
1	BH1, 1.0m	98.00	70.90	36.70	A-7-5
2	BH1, 1.5m	97.00	74.50	37.20	A-7-5
3	BH2, 1.0m	97.80	72.30	43.30	A-7-5
4	BH2, 1.5m	97.90	71.50	44.90	A-2-5
5	BH3, 1.0m	97.80	67.20	50.10	A-7-5
6	BH3, 1.5m	98.80	76.00	38.50	A-7-5

It can be seen that the soil particles percentage passing through the 1.18mm sieve ranges from 97.00% - 98.80%, the percentage passing through the sieve 0.425mm sieve ranges from 67.20 % - 76.00% while the percentage passing through the 0.075mm sieve ranges from 36.70% – 50.10% On the average since the soil percentage passing the 0.075mm sieves is above 35% , this indicate that the soil is fine grained.

3.3. Atterberg Limit / Consistency Test

The result of the Atterberg limit test carried out on the samples collected from the three boreholes is presented in Table 3.

Table 3. **Atterberg Limit Test**

S/N	LOCATION	LL (%)	PL (%)	PI (%)	PLASTICITY
1	BH1, 1.5m	34.33	15.94	18.38	CL
2	BH1, 1.5m	35.07	15.80	19.28	CL
3	BH2, 1.0m	29.17	18.08	11.09	CL
4	BH2, 1.5m	33.68	18.21	15.48	CL
5	BH3, 1.0m	38.64	17.97	20.67	CL
6	BH3, 1.5m	35.57	11.67	23.90	CL

The Atterberg limit test result shows that the liquid limit of the soil ranges from 29.17% to 35.57%, the plastic limit ranging from 15.80% to 18.21% and the plasticity index ranges from 11.09% to 23.90%. A plasticity index between 0-15 indicates a low plasticity, 15 -30 is moderate plasticity while 30 and above indicates high plasticity [11]. This indicate that the samples are finely graded soils of medium plasticity.

3.4 Compaction Test Result

Table 4. **Compaction Test**

S/N	LOCATION	MAXIMUM DRY DENSITY (MDD) (g/cm^3)	OPTIMUM MOISTURE CONTENT (OMC) (%)
1	BH1, 1.m	1.74	14.4
2	BH1, 1.5m	1.67	15.4
3	BH2, 1.0m	1.73	14.4
4	BH2, 1.5m	1.82	14.5
5	BH3, 1.0m	1.73	14.1
6	BH3, 1.5m	1.70	15.0

The compaction test shows that the Maximum Dry Density (MDD) ranges from 1.67g/cm^3 to 1.82g/cm^3 while the Optimum Moisture Content (OMC) ranges from 14.1% to 15.4%. The fairly high water content of the soil indicates the presence of clay.

3.5. California Bearing Ratio (CBR) Test Result

The result of the California Bearing Ratio test is presented in Table 5.

Table 5 California Bearing Ratio Results

S/N	BOREHOLE ID	SAMPLING DEPTH	PRESSURE LAYER	UNSOAKED		SOAKED	
				2.5mm	5.0mm	2.5mm	5.0mm
1	BH1	1.0m	BOTTOM	6.94	8.11	7.76	6.47
			TOP	11.73	13.26	13.62	9.43
2		1.5m	BOTTOM	24.77	22.19	7.43	6.80
			TOP	14.29	14.80	9.66	7.34
3	BH2	1.0m	BOTTOM	10.24	10.08	7.43	6.79
			TOP	16.52	17.92	9.66	7.34
4		1.5m	BOTTOM	19.82	19.18	17.75	16.00
			TOP	12.88	15.56	20.32	18.14
5	BH3	1.0m	BOTTOM	22.88	18.63	3.38	3.01
			TOP	5.04	7.12	6.69	4.44
6		1.5m	BOTTOM	16.27	17.92	5.12	4.66
			TOP	8.51	10.47	9.25	6.68

Table 6. **Specifications for Road Pavement Structural Materials [12]**

S/N	PAVEMENT STRUCTURAL COMPONENT	MINIMUM VALUE OF SOAKED CBR (%)
1	Base course (natural or unstabilized soil material)	80
2	Base course (cement stabilized soil)	180
3	Sub-base	30
4	Sub grade/foundation soil	5-11

The soaked CBR result which is the critical ranges from 3.01% to 20.32% while that for the unsoaked ranges from 5.04% to 24.77%.
From the minimum value of soaked CBR which is 3.01%, it can be concluded that the soil did not fall within the sub grade/foundation soil and therefore will need reinforcement. This is in accordance with Table 6 [12].

3.6 Reinforced Soil

After reinforcing the soil with the waste tyre strips the results of the compaction and California Bearing Ratio test carried out are presented in Tables 7 and 8.

Table 7. Compaction Test Result

S/N	LOCATION	MAXIMUM DRY DENSITY (MDD) (g/cm^3)	OPTIMUM MOISTURE CONTENT (OMC) (%)
1	BH1, 1.m	1.67	12.60
2	BH1, 1.5m	1.68	13.80

3	BH2, 1.0m	1.73	12.90
4	BH2, 1.5m	1.65	14.60
5	BH3, 1.0m	1.62	15.2
6	BH3, 1.5m	1.62	16.60

The compaction test results of the reinforced soils shows that the Maximum Dry Density (MDD) ranges from 1.62g/cm^3 to 1.73g/cm^3 while the Optimum Moisture Content (OMC) ranges from 12.6% to 16.60%.

Table 8. California Bearing Ratio Results

S/N	BOREHOLE ID	SAMPLING DEPTH	PRESSURE LAYER	UNSOAKED		SOAKED	
				2.5mm	5.0mm	2.5mm	5.0mm
1	BH1	1.0m	BOTTOM	13.76	14.69	7.35	5.64
			TOP	21.55	20.71	5.04	4.22
2		1.5m	BOTTOM	8.51	8.88	4.38	4.38
			TOP	11.06	9.97	1.90	2.03
3	BH2	1.0m	BOTTOM	12.14	12.33	6.94	5.04
			TOP	6.77	8.60	5.86	4.77
4		1.5m	BOTTOM	12.72	13.92	1.73	3.34
			TOP	12.55	11.51	2.89	2.36
5	BH3	1.0m	BOTTOM	11.64	11.45	7.68	6.68
			TOP	8.51	8.88	3.63	3.51
6		1.5m	BOTTOM	12.55	11.56	1.98	3.62
			TOP	7.51	8.38	6.77	5.92

The soaked CBR result of the reinforced soil ranges from 1.73% to 7.68% while that for the unsoaked ranges from 6.77% to 21.55%.
Comparing Tables 4 and 5 with that of Tables 7 and 8, it was observed that the soil did not increase in strength but rather reduced because the value of the MDD decreased slightly with the reinforcing material from 1.67g/cm^3 to 1.82g/cm^3 for the unreinforced to 1.62g/cm^3 to 1.73g/cm^3 for the reinforced likewise the CBR results which reduced from (3.01% to 20.32%) to (1.73% to 7.68%) for the soaked and from (5.04% to 24.77%) to (6.77% to 21.55%).
There could be an increase in the strength properties of the soil if the waste rubber tyres are shredded into smaller sizes than in strips and further used with a binder in accordance with the study carried out by Rajasekha et. al. [9].

4. Conclusion

From the summary of results obtained from all the tests conducted on the soil, the soil can be classified as A-7-5 which is a fine grained soil of medium plasticity with a general subgrade rating of fair to poor according to AASTHO classification which means that the soil has to be reinforced before it can be used as subgrade. The soil did not show any increase in strength after reinforcement with the waste tyre strips as the compaction test result shows reduction in the Maximum Dry Density and the Optimum Moisture Content. The soaked and unsoaked CBR test result obtained after reinforcement also did not show any improvement.

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