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POTENTIAL APPLICATION OF WASTE WATER SATCHET AND PLASTIC BOTTLES IN THE PRODUCTION OF CONCRETE TILES

[1]Aisien E. T. and [2]Okpewho M. F.

[1]Department of Environmental Management and Toxicology, University of Benin, Benin City.
[2]Department of Chemical Engineering, University of Benin, Benin City

Abstract

Plastic waste management is a major environmental problem in Nigeria and other countries in the world. As a management process we recycled waste water sachets and bottles into slabs for interlocking tiles. The wastes were collected from eateries and dumpsites within the University of Benin. They were washed, dried, weighed, melted and poured into aluminum molds and allowed to cure for 24hours. The composite tiles sand to plastic ratio of 50/50, 60/40, 70/30 and 80/20 were made. Using ASTM (C158 and D638) methods the water absorption test and compressive strength test were carried out. When immersed in either hot or cold water the tiles has a zero water absorption capacity. The result shows that as the percentage of sand increased from 50 to 60 percent with a maximum failure load of 60KN, the Compressive Strength, the Tensile Strength and the Modulus of Elasticity increased from 0.819 to 2.488 N/mm^2, 0.633 to 1.104 N/mm^2 and 4523.533 to 7885.287 N/mm^2. Further increase from 60 to 80 percent resulted in a decrease in compressive strength, tensile strength and Modulus of Elasticity from 2.488 to 0.611 N/mm^2, 1.104 to 0.547 N/mm^2 and 7882.675 to 3906.3 N/mm^2. The composite has low flammability. The results suggest that concrete containing plastic can be reasonably used in structural elements as for a normal concrete with cement as binder.

***Keywords*: Waste plastics, sand and interlocking tiles,**

INTRODUCTION

Plastic is any synthetic or semisynthetic organic polymer made from petrochemicals [1]. The role of plastics in human lives cannot be overemphasized ranging from use as household appliances, packaging materials, portable water and beverage containers, kitchen utensils, furniture, toys, automobile parts, polythene bags etc. [2]. Pure water sachets and bottles are disposed indiscriminately where they liter the floor, thereby increasing the volume of solid waste generated in the country. Economic growth, changing consumption and production pattern are resulting into rapid increase in generation of waste plastics globally [3]. Plastic waste management is a major environmental problem in Nigeria and other countries in the world. About 2.5 million tons of plastic wastes are generated per year in Nigeria [4]. An estimated 8 million tonnes of plastic is yearly released into the ocean, leading to degradation of marine habitat which eventually affects aquatic organisms [5]. Indiscriminate disposal on land and open air burning can lead to the release of toxic chemicals into the air, causing public health hazards [6&7]. Ingestion of plastic wastes is capable of causing obstruction and physical damage to bird's digestive system, reduce the digestive ability of the system leading to starvation, malnutrition and eventually, death [8]. Plastics are made of petrochemical with additive such as flame — retardants, stabilizers and oxidants. Hence, plastics are non — biodegradable and will remain in the environment for several thousands of years [9]. Since plastics are non — biodegradable, recycling is a means to reduce plastics in the waste stream, especially the million tonnes of waste plastics that enter the Earth's ocean every year [10]. Recycling has been used to convert waste plastics into useful plastic -based products such as plastic chair, infant bench, flower vase, buttons, slabs and kitchen utensils etc.

A slab is a paving stone, tile, brick, or brick-like piece of concrete, made in any desired shape commonly used as exterior flooring, building bricks or other purposes. A previous researcher [11) made paving blocks using polythene bags, sachet water bags, wrappers etc. collected from the surrounding waste collecting points in the municipality through recycling, thus, this research aimed to produce concrete tiles from wastewater sachets and bottles to reduce or eliminate the environmental problems associated with wastewater sachets and bottle disposals.

Correspondence Author: Aisien E.T., Email: eki.aisien@uniben.edu, Tel: +2348027364660

MATERIALS AND METHODS

COLLECTION OF MATERIALS

Plastic water bottles and wastewater sachets were picked from drainages, dumpsites and eateries, within the University of Benin, Benin City. Sharp sand or construction sand was collected from the Chemical Engineering Department Uniben. Aluminum molds were fabricated at agbado market, Benin City.

PREPARATION OF RAW MATERIALS

Sharp sand/construction sand was collected with clean polythene bags and sent to the laboratory where they were dried and sieved to remove large particles that can lead to pockets of air or pores in the finished cubes. The sharp sand used had a particle density of 2.65g/cm^3. The aluminum molds were predesigned by a fabricator, having the same dimension as a conventional cube. The molds were lubricated with waste engine oil before use. The waste plastics were rinsed with clean water to remove adhesive impurities and dirt, the covers and bottlenecks of the plastic bottles were removed as they cannot be melted and remolded.

The waste plastics and sand were weighed with a mechanical weighing balance. The plastic to sand ratio was varied and defined before use, just as it is done with concrete. The plastics were weighed in categories of 1 kg and 0.5 kg, the sand 2 kg and 0.5 kg.

PRODUCTION PROCESS

Melting of the plastics (mixture): The plastics were gradually heated in an aluminum pot under intense heat until it melted at the temperature between 1100 and 1500^{o}C. The energy used came from organic waste (wood, paper, plant, debris).

Mixing of sand and melted plastics: Sand was added to the melted plastics when it was discovered that it had an appropriate consistency and mixed vigorously with mixing poles, until the mixture became homogenous, and a smooth consistency was formed. The mixing continued to avoid burning.

Molding and drying: The aluminum molds were lubricated with waste engine oil prior to use, and the mixture was poured into them on a metal table greased with engine oil to prevent sticking. The mixture was compacted and smoothened using hand trowel and left to cool. The products were placed in the sun for twenty-hours to dry up after which they are removed from the mold and were ready for use.

LABORATORY TEST ON THE CUBE PRODUCED

The following were carried out on the composite cubes to ascertain their suitability for floor tiling. Water absorption test, compressive test, frictional coefficient test, flammability test. Tensile strength test and modulus of elasticity test.

Water absorption (cold and hot testing)

In cold absorption testing, the weight of the composite and conventional cubes before immersion into the cold water was determined using a scale. After twenty-four hours (24 hours) of immersion, the weights of the cube samples were taken again. The mass difference was used in calculating the water absorption rate (%)

However, the hot absorption test involves weighing the composite and conventional samples using the weighing scale and thereafter dipping into boiling water for thirty minutes, after thirty minutes which the cubes were reweighed and the quantities of water absorbed determined.

Compressive Strength test:

The universal Testing Machine was used to carry out this test in compliance with [12]. The dimension of the cubes were taken and area calculated. The samples were placed on machine and loading was applied until there is a noticeable fracture in the composite and conventional material to obtain the failure load.

Frictional coefficient test:

The frictional coefficient test is used to obtain the slip properties of the cubes produced, this is done by placing the samples on a level platform, and a known mass of match box, calculator, and book was placed on the cube. With one end of the material in position, the opposite end of the cube was continuously raised such that the material inclines at an angle. The angle of inclination was increased until the mass placed on top of the cube rolled off. At this point the value of the angle of inclination was taken; this is called the angle of repose.

Flammability test:

The composite sample was placed in the direction of heat for about one second. The process was repeated but the duration of the release of heat on the cube was increased to five seconds.

Tensile strength test:

The tensile strength of the cubes was determined from the values obtained from the compressive test.

Modulus of Elasticity test:

The modulus of elasticity of the cube produced was determined using the values obtained from the compressive test.

Standard error of mean (SEM):

Standard Error of Mean was computed for each parameter measured for the triplicate cubes. Standard Error of Mean is a statistical term that measures the accuracy with which a sample represents a population.

RESULTS AND DISCUSSION

WATER ABSORPTION TEST

Table 1: ***Cold water absorption testing***

Sand/plastic	Ratio	Weight A after emersion. (Kg)	Weight B after emersion. (Kg)	Weight C after emersion. (Kg)	Amount of water absorbed (Kg)
50/50	1:1	3.425	3.305	3.510	0.00
60/40	3:2	3.750	3.450	3.550	0.00
70/30	7:3	3.810	3.875	3.851	0.00
80/20	4:1	4.400	4.115	4.235	0.00

Table 1 shows the result for cold water absorption of rubberized concrete tiles. The composite cubes produced from waste plastics had a zero absorption capacity when immersed in cold water. The result is comparable to previous research carried out by [13] and conventional cubes made with sand and cement which were also water resistant. Hence the composite cubes produced from the waste water sachets and plastic bottles can act as an alternative in place of the conventional ones.

Table 2: ***Hot water absorption testing***

Sand/plastic	Ratio	Weight A after emersion. (Kg)	Weight B after emersion. (Kg)	Weight C after emersion. (Kg)	Amount of water absorbed (Kg)
50/50	1:1	3.425	3.305	3.510	0.00
60/40	3:2	3.750	3.450	3.550	0.00
70/30	7:3	3.810	3.875	3.851	0.00
80/20	4:1	4.400	4.115	4.235	0.00

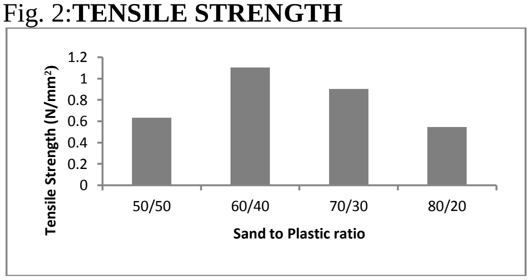
Table 2 shows the results of the hot water absorption of rubberized concrete tiles. It was observed that composite concrete tiles did not absorb water after thirty minutes of immersion in boiling water. Also, there was no crack on the composite sample tested, this showed the ability of the cube to resist heat from the boiling water.

Fig. 1:**COMPRESSIVE TEST**

Variation of Compressive Strength with sand to plastic ratio

The variation of the compressive strength with the sand to the plastic ratio of concrete is represented in Fig. 1. As the percentage of sand increases from 50 to 60 with a maximum failure load of 60KN, the compressive strength increased from 0.819 to 2.488 N/mm^2. Because plastic is a binder, increasing the percentage of sand from 50 to 60 did not affect the binding capacity as the plastic was just enough to hold the sand aggregate together. This result is similar to that of [13] on composite floor tiles with failure load 35KN. That is one of the reasons why this rubberized concrete can be used as an alternative for composite floor tiles where the loading will be less or will not be excessive or above its strength. Such as residential places where it will not be subjected to heavy-duty. It was also observed that the composite did not shatter under sudden loading hence, it has high ductility.

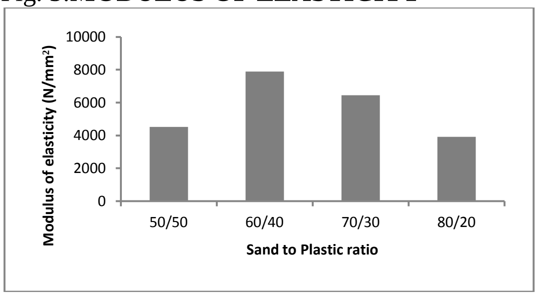
Fig. 2:**TENSILE STRENGTH**



Variation of Tensile Strength with sand to plastic ratio

Figure 2 shows the variation of tensile strength with sand to the plastic ratio of the concrete. There was an increase in tensile strength from 0.633 to 1.104 N/mm^2 as the percentage of sand increases from 50 to 60 and later decreased from 1.104 to 0.547 N/mm^2 as the sand ratio increased from 60 to 80%. It is seen here that the binding capacity of the plastic is a function of the amount of sand in the concrete. That is increasing the sand to 60% load to an increase in tensile strength but further increase to 80% resulted in a decrease in tensile strength. This result can be compared with that of [15].

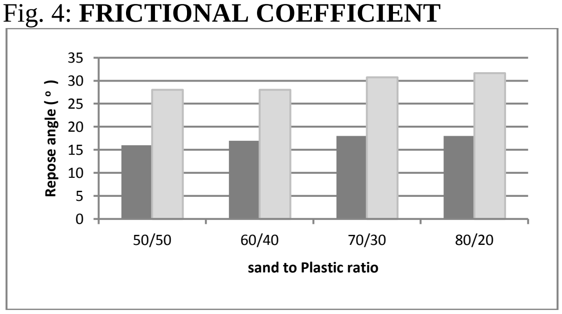
Fig. 3:**MODULUS OF ELASTICITY**



Variation of Modulus of elasticity with sand to plastic ratio

Figure 3 shows the Modulus of elasticity of sand to the plastic ratio in the rubberized concrete. As the percentage of sand increased from 50 to 60, the modulus of elasticity increased from 4523.533 to 7886.267 N/mm^2, and a further increase in the sand ratio from 60 to 80 resulted in a decrease in tensile strength from 7886.267 to 3906.3 N/mm^2. The modulus of elasticity decreases as the bond becomes weaker when there is increase in percentage of sand.

Fig. 4: **FRICTIONAL COEFFICIENT**



Variation of repose angle with sand to plastic ratio

The variation of repose angle with sand to the plastic ratio in the rubberized concrete is shown in Figure 4. As the percentage of sand increased from 50 to 60. Its response angle indicates the friction characteristics of the concrete increased from 10 to 31^o. Comparing this result with the one obtained from previous research by [13] on floor tiles having frictional coefficient ranging from 17.5 to 26^o. It can be deduced that the composite cube has a frictional coefficient close to the conventional cube with a repose angle of 35^o. For this reason, the composite cube produced from waste plastics can be used as paving stones at home to reduce the risk of slipping which can cause injury.

FLAMMABILITY TEST

It was observed that after the heat was applied to the surface of the composite for one second and five seconds separately there was a little noticeable change on the surface of the composite. This means that the composite did not burn after the heat was taken away. This, therefore, means that the composite has less flammability. This is an advantage as it makes it a good substitute for paving. This also means that on exposure of the composite to fire hazards, it will take considerable time before it burns off. Hence,it can be an alternative to conventional concrete tiles which do not burn and is resistant to the effect of fire.

CALCULATIONS

Table 3: *Failure load of samples:*

Sand/Plastic	Ratio	Failure load A (kN)	Failure load B (kN)	Failure load C (kN)
50/50	1:1	18	20	21
60/40	3:2	59	59.10	61
70/30	7:3	39.5	40	40.5
80/20	4:1	14	14	16

Surface area of cube = 24000mm²

Compression = $\frac{Failure\ load}{Surface\ area}$

Standard Error of Mean = $\frac{Sandard\ deviation}{\sqrt{sample\ size}}$

Standard deviation = $\sqrt{\frac{\sum(x-\bar{x})^2}{N}}$

Where;

x = individual value

$\bar{x}$ = Mean value

N = number of samples

Sand/Plastic Ratio: 50/50

Compression strength: 0.833, 0.75, 0.875

$\bar{x} = \frac{0.833+0.75+0.875}{3} = 0.819$

Table 4: *Variation of Compressive Strength with sand to plastic ratio*

$(x-\bar{x})^2$
$(0.833-0.819)^2 = 0.0002$
$(0.75-0.819)^2 = 0.005$
$(0.875-0.819)^2 = 0.008$

$\Sigma(x-x)^2 = 0.008$

Standard deviation = $\sqrt{\frac{0.008}{3}} = 0.052$

Standard error of mean = $\frac{0.052}{\sqrt{3}} = 0.030$

Mean value ± SEM = 0.819 ± 0.030

Tensile Strength of Concrete = $0.7\sqrt{Fck}$

Where;

F_{ck} = characteristic compressive strength

Sand/Plastic Ratio: 50/50

Tensile strength: 0.639, 0.606, 0.655

$\bar{x} = \frac{0.639+0.606+0.655}{3} = 0.633$

Table 5: *Variation of Tensile Strength with sand to plastic ratio*

$(x-\bar{x})^2$
$(0.639-0.633)^2 = 0.00004$
$(0.606-0.633)^2 = 0.0007$
$(0.655-0.633)^2 = 0.0005$

$\Sigma(x-x)^2 = 0.001$

Standard deviation = $\sqrt{\frac{0.001}{3}} = 0.018$

Standard error of mean = $\frac{0.018}{\sqrt{3}} = 0.010$

Mean value ± SEM = 0.633 ± 0.010

Modulus of Elasticity of concrete = $5000\sqrt{F_{ck}}$

Where F_{ck} = characteristic compressive strength

Sand/Plastic Ratio: 50/50

Modulus of Elasticity: 4563.4, 4330.1, 4677.1

$\bar{x} = \frac{4563.4+4330.1+4677.1}{3} = 4523.533$

Table 6: Modulus of elasticity test:

$(x-\bar{x})^2$
$(4563.4-4523.533)^2 = 1589.377$
$(4330.1-4523.533)^2 = 37416.325$
$(4677.1-4523.533)^2 = 23582.823$

$\Sigma(x-x)^2 = 62588.525$

Standard deviation = $\sqrt{\frac{62588.525}{3}} = 144.440$

Standard error of mean = $\frac{144.440}{\sqrt{3}} = 83.392$

Mean value ± SEM = 4523.533 ± 83.392

Table 7: Frictional coefficient: Repose angles using match box

Sand/Plastic	Ratio	A	B	C
50/50	1:1	15	16	17
60/40	3:2	16	16	19
70/30	7:3	17	18.5	18.5
80/20	4:1	17	18	19

Sand/Plastic Ratio: 50/50

Angle of repose: 15, 16, 17

$\bar{x} = \frac{15+16+17}{3} = 16$

Table 8: Frictional coefficient: Repose angles using match box for Sand/Plastic Ratio: 50/50

$(x - \bar{x})^2$
$(15\text{-}16)^2 = 1$
$(16\text{-}16)^2 = 0$
$(17\text{-}16)^2 = 1$

$\Sigma(x - x)^2 = 2$

Standard deviation = $\sqrt{\frac{2}{3}} = 0.816$

Standard error of mean = $\frac{0.816}{\sqrt{3}} = 0.471$

Mean value ± SEM = 16 ± 0.471

CONCLUSION

The following conclusions can be drawn from these analyses:

1. The composite slabs produced from recycled plastic and sand had zero water absorption capacity.
2. The slab with sand to the plastic ratio of 60 to 40 gave the best concrete property (Compressive strength, Tensile strength, and Modulus of elasticity).
3. The friction characteristics of the composite had a repose angle of 31º.
4. The composite slab had low flammability.
5. The plastic wastes (pure water sachets and plastic bottles) which pose hazards to human beings and the environment can be converted into a useful plastic-based products such as slabs by adopting a simple recycling method.

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