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Utilization of Poly (ethylene terephthalate) Waste and Seashell (*Senilia senilis*) in the Production of Roof Tiles

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Abstract
Pollution has been a vital issue, especially in developing countries like Nigeria. Polyethylene terephthalate (pet) bottles from its introduction into the economy, has been a major pollutant of the environment, culminating a nuisance to the environment and unsafe habitat to human health. Water channels such as rivers and oceans are not exempted, as marine animals are also at risk of this due to the dumping of waste into our waterways. The utilization of waste pet bottles and seashell in the production of roof tiles will go a long way in the encouragement of proper disposal and management of waste. From this study, a mixture of pet bottles, river sand, and seashells in varying proportions were used to make roofing tiles. The composition with the highest strength is seen to be the P50b, which has 50% pet waste, 25% *Senilia senilis*, and 25% River sand. It has a smoother surface in comparison with the other compositions and more aesthetically appealing. The product showed more strength when compared with the commonly used asbestos sheets. The production of this roofing sheet will help provide affordable housing production of units, create job opportunities in both production & marketing, reduce importation of raw materials, and improve the economy of the nation.

Keywords: Compressive strength, fine aggregate, polyethylene terephthalate (PET), seashell (*Senilia senilis*), solid waste, sustainable materials

1. Introduction

The increase in the population growth of our world has kept the planet very busy and trying to keep up with the constant demands of humans [1]. The natural oil gotten from decayed organisms thousands of years ago comes in the form of a reserve that serves many human purposes. Natural oil, also called crude oil or petroleum, is used to make Polyethylene terephthalate (PET) widely used for various purposes such as bottles, containers, and especially packaging [2]. It can be seen all around us, in our homes, schools, offices, and many other places. Its most common application is in packaging because of its inert chemical property. It replaced other conventional packaging material methods because it is cheaper, lighter, and long-lasting [3]. The use of PET has expanded widely in its various applications [4]. Due to the PET's versatility against degradation, and its increase in production, the challenge of plastic pollution has advanced to become a risk to our natural habitat. It takes about 100-450 years for complete degradation of PET to happen on the earth's surface and far longer underwater, which is one of the leading causes of contamination of the earth [5]. Consistently, over 300 million tons of plastic are created yearly by different nations [6]. This rise in volume is a significant concern as debates have arisen on how the ecosystem would be able to keep up with the plastic invasion. This has led to studies on how to manage the volume of PET plastics present efficiently.

The four major disposal options for plastics include landfilling, incineration, recycling, and degradation. Numerous plastics can be recycled, and a portion of the materials used in the production of plastics can be retrieved [7]. Nonetheless, this strategy isn't completely used because of troubles with the gathering and sorting of plastic waste. Alternative ways of recycling have been brought up, leading to its incorporation into the engineering world. Only about 9% of produced PET plastic is recycled yearly, leaving 91% to litter and pollute both land and oceans [8].

Seashells are formed from secretions from mollusks, which provide a protection layer for these invertebrates and is mainly composed of the compound Calcium Carbonate [9]. The amount of calcium carbonate present in the seashell is almost as much as the amount present in the ordinary Portland cement [10]. The use of these seashells will help in providing cheaper alternative materials to be used in stabilizing materials. It can be said to have excellent binding properties, which are of the utmost importance during construction processes [11]. Seashells are lightweight in nature with a fine ceramic-like appearance [12]. Research work has shown that seashells have enormous potential in construction, particularly as fine aggregate in the concrete mix [13]. Wang et al. [14] investigated the use of seashells used as an alternative cementitious material. It was observed that using finely ground seashells in place of ordinary Portland cement showed that the water content in a mix could be better controlled to increased workability and contributed positively to the compressive strength. Soltanzadeh et al. [15] researched the probability of waste seashell as a chemical improver in the production of blended cement. It can be deduced that seashells helped reduce the dead load from structures when implemented with pozzolans in the production of cement. Also, the setting time of cement with seashells as a component was observed to be reduced. Senilia senilis has been identified as an advantageous object of study due to its chemical constituents. It is naturally very hard with a chalky feeling when crushed, which can be attributed to the presence of calcium oxide in it and the richest in micronutrients.

Therefore, the utilization of Polyethylene Terephthalate, *Senilia senilis* seashell, and river sand for the production of the roof is believed to be a valuable addition to the Construction industry and Engineering knowledge. The exploitation of our waste will serve as a form of revenue generation for developing countries, thereby improving our economic value and promoting sustainable development.

2. Experimental work

2.1 Preparation of Roof tiles

The composition of the roof tiles includes washed PET flakes, washed *Senilia senilis* and River sand in varying proportions, as shown in Table 1. Once the quantity of the PET bottle flakes, river sand and ground *Senilia senilis* had been measured in the laboratory, it was then taken to the outdoor shed with the apparatus to be used. The PET flakes were subjected to heating up to 260-degree Celsius. The choice of percentage compositional variations is to produce a functional, durable, and affordable roof.

Table 1: Composition of the roof tiles studied

Compositions	**P40a**	**P40b**	**P50a**	**P50b**	**P60**	**P70**
PET Flakes (g)	2000	2000	2500	2500	3000	3500
PET Flakes (%)	40	40	50	50	60	70
Senilia senilis (g)	2000	1750	2000	1250	1000	1000
River sand (g)	1000	1250	500	1250	1000	500

*Where: **P40a**-40% Plastic, 40% Senilia senilis, 20% River sand; **P40b** – 40% Plastic, 35% Senilia senilis, 15% River sand; **P50a** – 50% Plastic, 40% Senilia senilis, 10% River sand; **P50b** – 50% Plastic, 25% Senilia senilis, 25% River sand; **P60** – 60% Plastic, 20% Senilia senilis, 20% River sand; P**70** – 70% Plastic, 20% Senilia senilis, 10% River sand.*

2.2 Melting of PET flakes, Addition of Fine Aggregates and *Senillia senilis* and control of Plasticity

The materials (PET flakes, seashell, and river sand) are weighed. The PET flakes were subjected to the heating of up to 260°C. If higher temperatures are met, the liquid PET will reach its elastic limit, making it susceptible to cracks. Locally made melting barrel with a revolution of 50rpm was used. The river sand and seashell were added to the heating PET flakes and stirred until homogeneity has been achieved to prevent air voids. The PET flakes should then be stirred consistently for uniformity in the melting process and ensure its plasticity is not lost. The liquid mix is transferred into the mold carefully and covered within ±5s. The formed roof tile is then removed from the mold. The grounded seashell, PET flakes, and roof tiles produced are shown in Figures 1a and b.

Figure 1 (a): Grounded seashell and PET flakes (b): Roof tile produced

2.3 Tests

Various tests carried out on the roof tile formed helps to determine if it is suitable enough and is up to the standard allowable for its utilization [16]. The materials used and roof tiles produced will also have some tests done on them. The following physical and mechanical tests were determined on materials and roof tiles produced: sieve analysis in line with ASTM C136 [17], specific gravity in accordance with ASTM C128 [18], density in line with ASTM 128 [18], water absorption in line with BS EN ISO 62 [19], compressive strength in accordance with BS EN ISO 604 [20], and flammability tests in line with UL 94 [21] standards.

3.0 Results and discussion

This includes the results and data gotten after the tests were carried out on the seashells, sand, recycled tiles, and conventional tiles.

3.1 Sieve Analysis

From Figure 2, it can be seen that the aggregate falls majorly in the 0.1 and 1 range on the log axis. The values from the Coefficient of uniformity and Coefficient of curvature, 3, and 1.02 respectively show that the sample is uniformly and well-graded with the majority of the sample falling within the 0.850mm and 0.600mm particle size.

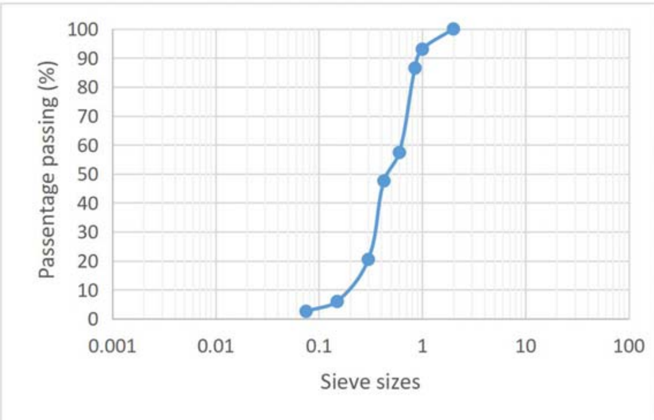

Figure 2: Grain size distribution for *Senilia senilis*

3.2 Specific Gravity

The specific gravity (SG) of the seashell was obtained to be 2.89 in line with ASTM C128 [18]. With this value, the sample is suitable for most construction processes, including road construction. If this sample density is to be determined with respect to the density of water, the same value of a density of 2.89. The SG of fine seashell produced in this current study is higher when compared with fine aggregates [7].

3.3 Water Absorption

The rate of water absorption was seen to decrease as the percentage of fine aggregate increased. Therefore, fine aggregate helped reduce the absorption rate, which shows great promise for use, especially in areas of intense rainfall and humidity, as shown in Figure 3. In comparison with a trial mix of concrete tile, the absorption rate was way higher than that of the plastic tiles and is line BS EN ISO62 [19].

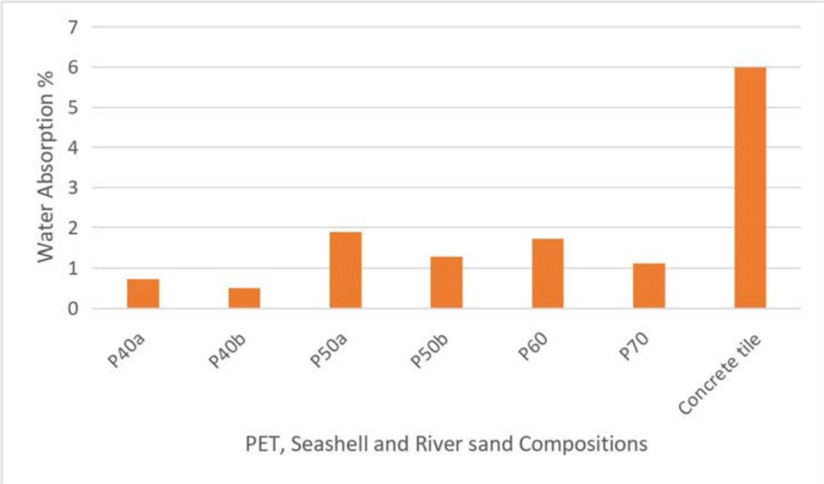

Figure 3: Water absorption in different Roof tile compositions

3.4 Compressive strength

The roof sample with 50% PET, 25% Seashells, and 25% Sand had the highest compressive strength with 1.86 N/mm^2, as shown in Figure 4. The current study produced higher strength compared results obtained in [1, 22]. Although lower than some other roof tile strengths, the values from this current study can be said to be higher than the roof strength produced when PET and fine aggregate only were combined.

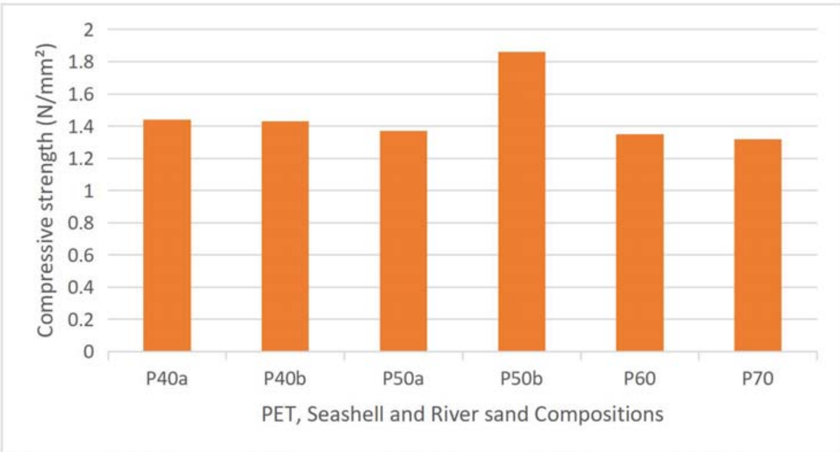

Figure 4. Compressive strength of varying proportion of PET, Seashell and River sand

3.5 Flammability

The vertical method of flammability test was used, and the following observations were recorded, as shown in Figure 5.

1. Test on P40a: Upon applying heat to the roof tile surface, there was no noticeable change for 1 minute 22 seconds. After 2 minutes, there was very minimal damage to the roof tile, although some signs of melting were beginning to occur.
2. Test on P40b: Upon applying heat to the roof tile surface, there was no noticeable change for 1 minute 28 seconds. After 2 minutes, there was very minimal damage to the roof tile, although some signs of melting were beginning to occur.
3. Test on P50a: Upon applying heat to the roof tile surface, there was no noticeable change for 1 minute 10 seconds. After 2 minutes, there was very minimal damage to the roof tile, although some signs of melting were beginning to occur.
4. Test on P50b: Upon applying heat to the roof tile surface, there was no noticeable change for 1 minute 15 seconds. After 2 minutes, there was very minimal damage to the roof tile, although some signs of melting were beginning to occur.
5. Test on P60: Upon the application of heat to the roof tile surface, there was no noticeable change for 46 seconds. After 2 minutes, some visible damage had been done due to melting.
6. Test on P70: Upon the application of heat to the roof tile surface, there was no noticeable change for 40 seconds. After 2 minutes, noticeable damage had been done due to melting.

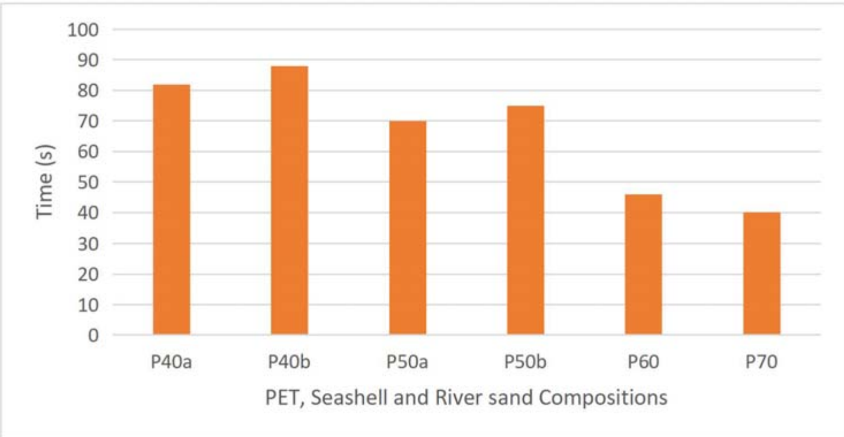

Figure 5: Bar chart showing flammability of compositions

Generally, the higher the percentage of fine aggregate, the lower the flammability. The flammability of the samples was relatively acceptable, considering its property and its reaction to heat action.

4. Conclusion

The utilization of Polyethylene terephthalate (PET) and seashells in the production of roof tiles showed adequate results. It can be concluded that PET wastes show a great promise in the production of sustainable roof tiles through recycling. Its presence is detrimental to animal and human health, and its recycling helps clean up our environment. The roof tiles produced showed relatively low water absorption in comparison to concrete roof tiles. This makes it very suitable in regions of high rainfall and humidity. The composition with the highest strength is seen to be the P50b, which has 50% PET waste, 25% *Senilia senilis,* and 25% River sand. It has a smoother surface in comparison with the other compositions and more aesthetically appealing. The flammability of the samples was relatively acceptable, considering its property and its reaction to heat action. The plastic roofing tiles have been observed to be more durable and resilient to leakages and resistant to external factors. Further studies on how to make the roof tiles more fire-resistant is recommended to be done on the roof tiles for a better and more lasting effect. Also, due to the application possibility and composition of the obtained composite, it is necessary to perform aging tests and economic analysis.

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