Development Of Composite Floor Tiles Through the Blending of Waste Sachets, PET Bottles and Sand Aggregates

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Abstract- Non-biodegradable plastics are currently in mass production every day with a handful of them having very little or no recycling value, A need then arises to give plastic materials a 'second life' so they can be relived as other long term products while also improving their compositions, altering their structures and enhancing their properties. The research elucidates the production of interlock tiles from Low-Density Polyethylene (LDPE) and Polyethylene Terephthalate (PET) because they constitute the majority of plastic waste among others. The application of this recycling method solves the global plastics waste crisis because it can transform waste LDPE and PET into a valuable local resource. In this research, waste sachets (LDPE) and PET bottles were melted and mixed with sand to form samples of interlock tiles. Plastic materials were collected from drainages, streets, dumpsites, hostels, hotels and bars, in Anambra State, which were sorted before the Melting process began, during which sand was added as aggregate and after the incorporation of the sand the melt was poured into a dimensioned metal mould. The most appropriate mix ratios of plastic to sand, load-bearing capacity, and water adsorption tests are reported. The result shows that PET has higher mechanical properties than LDPE and LDPE has some elastic properties, It can also be noted that the blend ratio of LDPE: PET is (25%:75%) and can withstand maximum load, as compared to samples of other ratios. Generally, the composite tiles recorded test values comparable to that of the conventional tiles, resulting to durable, stronger, and corrosion resistant tiles. Hence, this study has shown that composite floor tiles are a better alternative to conventional cement tiles.

Indexed Terms- polymer recycling, plastic pollution, low-density polyethylene, polyethylene terephthalate, mix ratios, compression test.

I. INTRODUCTION

Plastic waste are not easily degradable and can remain for years in the environment. This research identified the proportions of different grades of plastic dumped in Anambra State. The reason for using this area as the case study is due to the large volume of plastic wastes generated by students and residents of this selected area. For an effective collection of plastic waste, the industries within this area were identified, as well as markets, hospitals, hostels, hotels, landfill pits, and the areas of informal waste management system, where there is no actual data (i.e. areas where wastes are burnt).

The plastic waste was sorted to determine the quantity and composition of each type of waste generated. Due to the high demands from students in this area, it was discovered that sachet water, take away packs and PET bottles i.e. Low-density polyethylene (LDPE) and Polyethylene Terephthalate among others constituted the majority of the type of plastic pollutants found in this area, which of course are notable for blocking the local drainage systems and also pose health risks to both humans and animals, most especially when burnt. According to Ecobarter (Kuje Abuja), Nigeria alone generates over 32 million tons of plastic wastes annually, out of which only 20-30% are collected by existing waste management systems. Worst still is people's lackadaisical attitude towards recycling, as plastics are constantly blocking our drainage systems leading to flooding and endangering the lives of the marine population. We live in an environment that is overly populated by non-biodegradable plastic wastes and if not recycled will, in the long run pose a threat to human health and existence. Statistically speaking, every single plastic ever created still exists today. There is no such thing as being disposed of plastics, when we throw them away, they must go somewhere else. This research work seeks to obtain the mix ratios of Polyethylene Terephthalate (PET) and Low-Density Polyethylene (LDPE) in other to determine the most effective blend that would provide the highest compressive strength and to access the performance of the composite tiles made with plastic wastes which will contribute in reducing the harmful effects on the environment. And also to develop different grades of tiles for different constructional applications at a suitable cost.

II. MATERIALS AND METHODS

2.1 Materials and equipment

The materials needed for this work were sourced locally and melted in three different barrels. The melted plastic (PET and LDPE) was each mixed with river bed sand ('sharp sand') particle size of the sand used was in the range of 0.15-4.75 mm, then the mixture was transferred to an oiled mould. The mould was left to set and allowed to cool.

The equipment used in the research are listed below;

i. Metal Mold
ii. Melting barrel
iii. Weighing scale
iv. Hand Trowel
v. Metal Stirrer
vi. Nose Mask
vii. Firewood
viii. Personal protective equipment (PPE)

2.2 Methods

Samples of LDPE and PET plastic wastes mostly plastic bags, water sachets, PET bottles and containers were collected from different dumpsites, the plastic materials were sorted, washed with water and detergent and dried to ensure that the debris and other forms of impurities that could alter bonding of sand are eliminated and also to get rid of contaminants.

Figure 2.1: collection and sorting of plastic waste

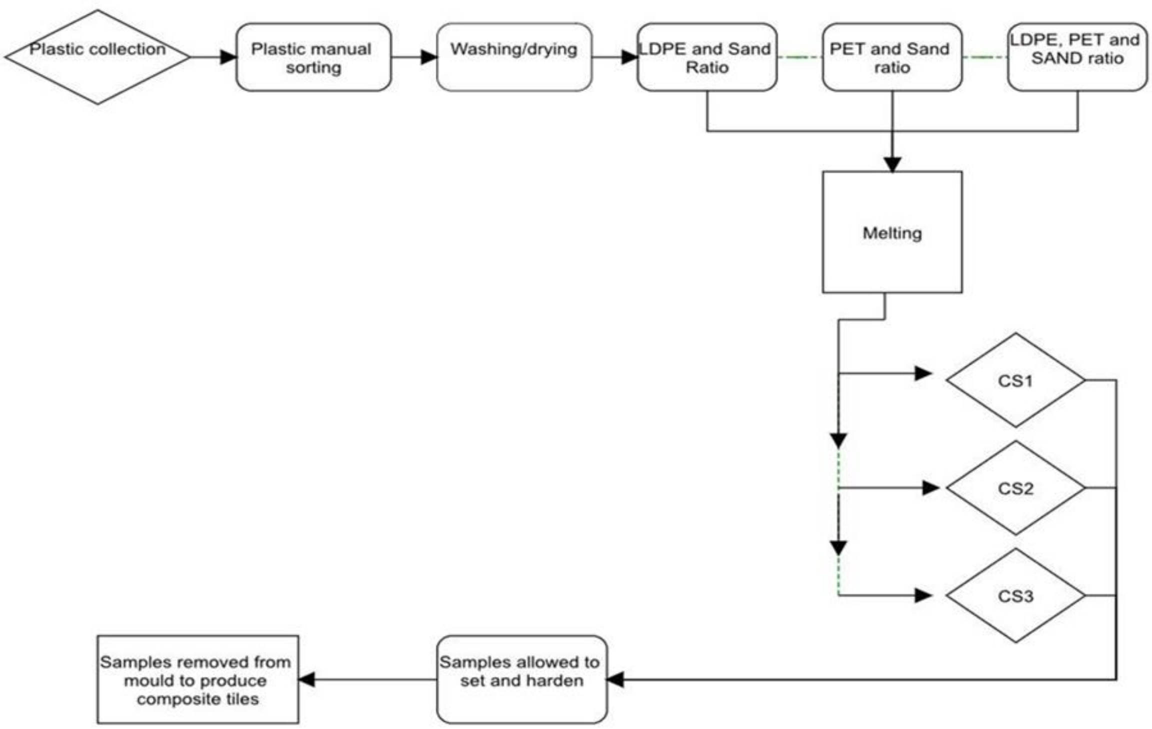


Figure 2: the methodology Process diagram

2.3 Melting Process

2.3.1 LDPE: Sand Blend

Different mixing ratios (part plastic {LDPE} to part sand) were used i.e., 1:1, 1:4 and 1:3 (See Table 2.1). Based on the blending ratios the samples were identified as Sp1, Sp2, and Sp3 respectively. Sample one (Sp1) possessed the optimum quality after casting and will be considered the control sample for the LDPE and Sand interlock tile, which is denoted as CS1 (control sample 1).

Table 2.1 LDPE: Sand Mix Ratios

s/n	Samples	Mixing Ratio	Temp (°C)	Weight of Material (KG)		Percentage of Composition (%)	
				Plastic	Sand	Plastic	Sand
1	SP1	1:1	120	6.70	6.70	50	50
2	SP2	1:4	130	6.70	6.70	20	80
3	SP3	1:3	110	6.70	6.70	25	75

Control sample Cs1 is SP1

The collected LDPE samples were poured into the melting barrel and set ablaze. As it melts, the size reduced and more plastic were added gently into the melting barrel at the sides of the plastic that were already melting and thorough mixing was done until all the plastic melted and there was a consistent black liquid. Stirring and heating continued until all the lumps melted and a homogenous paste was obtained.

Fig2.2: Melting LDPE

Homogeneity was obtained at about 27 minutes into the melting process and during this time the oiled mould was preheated by placing them on the body of the hot barrel while getting ready for casting, 6.70kg of sand was then added into the barrel, this quenched the fire inside the barrel. Again, mixing was done thoroughly for another 12 minutes, then the melt was transferred into the mould and allowed to set.

Fig2.3: Transfer of LDPE: Sand Blend into the mould

The control sample for LDPE and SAND was 50:50 (plastic to sand). 6.70kg of LDPE and 6.70kg of SAND was able to make 7 interlocks tiles, hence, 0.957kg makes up one tile and thus one interlock tile is approximately 1kg by weight.

2.3.2 PET: Sand Blend

Again, different proportions of plastic (PET) to sand were melted however it was found that in Sample one, 50% of both PET and sand gave the best results after casting, which made sample one Sp1 the control sample (Cs2) for PET and Sand interlock tile

Table 2.2 PET: Sand Mix Ratios

s/n	Samples	Mixing Ratio	Temp (°C)	Weight of Material (KG)		Percentage of Composition (%)	
				Plastic	Sand	Plastic	Sand
1	SP1	1:1	280	6.70	6.70	50	50
2	SP2	1:4	190	6.70	6.70	20	80
3	SP3	1:3	260	6.70	6.70	25	75

Control Sample (Cs2) is SP1

The melting process for PET and SAND is the same as the previous method. The only difference was the use of combustibles (firewood) to speed up the progress as PET was more difficult to melt.

Figure 2.4: Melting PET Bottles

It took 33 minutes to obtain homogeneity during the melting process, after which sand was added into the mix and it was ready to be cast into the pre-heated mould after 40 minutes.

The control sample for PET and SAND was 50:50 (plastic to sand). 6.70kg of PET and 6.70kg of SAND was able to make 4 interlocks tiles, thus one interlock tile contains approximately 1.67kg of both plastic and sand by weight.

Figure 2.5: Transfer of PET: Sand Blend into the mould

2.3.3 LDPE: PET: Sand blend

2.3.3.1 LDPE: PET Mix Ratios

In other to obtain accurate proportions of all three materials, the different mix ratios of only plastic (LDPE and PET) were determined first and the most appropriate ratio was mixed with different proportions of sand.

Table 2.3 LDPE: PET Mix Ratios

s/n	Samples	Mixing Ratio	Temp (℃)	Weight of Material (KG)		Percentage of Composition (%)	
				Plastic	Sand	Plastic	Sand
1	SP1	1:4	280	6.70	6.70	20	80
2	SP2	1:1	260	6.70	6.70	50	50
3	SP3	2:3	285	6.70	6.70	40	60

From table 2.3 above, SP1 (one-part LDPE to four-part Sand) was the appropriate mix ratio.

2.3.3.2 Plastic (LDPE: PET) and Sand

Table 2.4 Plastic (LDPE: PET) and Sand Mix Ratio

s/n	Samples	Mixing Ratio	Temp (℃)	Weight of Material (KG)		Percentage of Composition (%)	
				Plastic	Sand	Plastic	Sand
1	SP1	1:1	280	6.70	6.70	50	50
2	SP2	1:3	260	6.70	6.70	25	75
3	SP3	1:9	280	6.70	6.70	10	90

The ratio 1:3 (one-part plastic which represents {one-part LDPE and four-part PET} to three-part sand) was determined to be the control sample Cs3. However, for quality check different mix samples were carried out, starting with 50:50 sand: plastic and then increasing the proportion of sand to 75% and 90% and sample two emerged with the highest quality.

Table 2.5 Control sample of LDPE: PET: SAND

s/n	Samples	Mixing	Weight of Material (KG)	Percentage of Composition (%)

		Ratio	LDPE	PET	Sand	LDPE	PET	Sand
1	CS3	1:4:3	6.70	6.70	6.70	13.3	53.4	33.3

The melting process was the same for melting all three samples together in the barrel, combustibles were used in this method and it took about 1 hour for the flame to go off, the other half of the barrel was used to cover the melt in other to quench the fire, this was done to regulate the temperature because it kept burning too hot. The sand was added into the mix, after an additional 10 minutes of mixing, homogeneity was obtained and the melt was transferred into the preheated mould.

Fig 2.6: Transfer of LDPE, PET and Sand Blend into the mould

6.70kg of LDPE, 6.70kg of PET and 6.70kg of SAND was able to make 5 interlock tiles, thus one interlock tile contains approximately 1.34kg of both plastic and sand by weight.

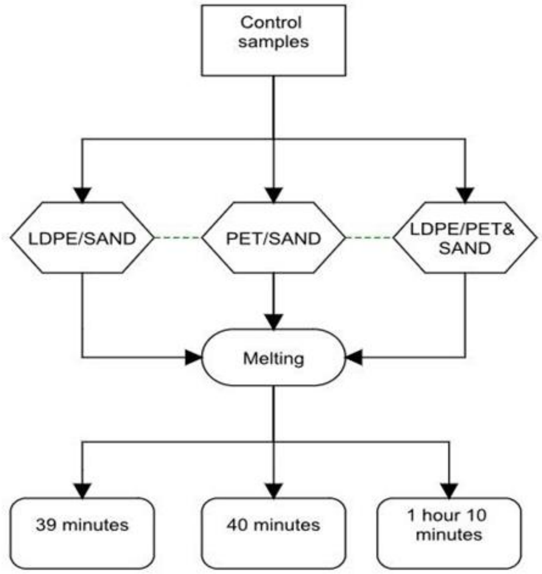
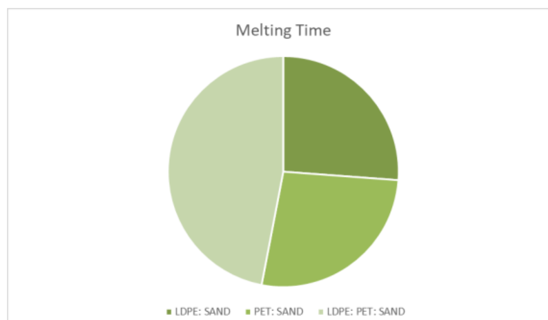


Fig 2.8 Process diagram showing the time range for the melting process



2.4 Casting Technique

The mould was washed and dried, and condemned engine oil was used as a lubricant so the tiles can easily come out when dried. The melt was then transferred into the preheated mould with the use of a trowel. The mixture was very hot so gloves were important. The mixture was pressed and worked into the mould.

2.4.1 Setting Process

The hot mixture was allowed to set, and the mould was repeatedly shaken to loosen the edges (a rocking motion works well). When the mixtures were completely dried, the mould was removed and the melt was allowed to cool properly.

Fig 2.9: Drying Process

Time taken for the various control sample to dry;

i. Time taken for LDPE and SAND to dry-1hour 5 minutes
ii. Time taken for PET and SAND to dry- 24 minutes
iii. Time taken for LDPE, PET and SAND to dry- 55 minutes

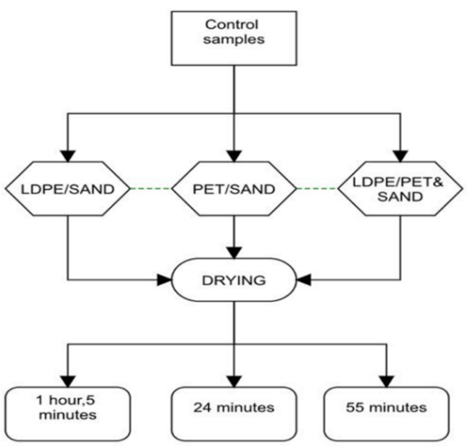


Fig 2.10: Process diagram showing the time taken for the melt to dry

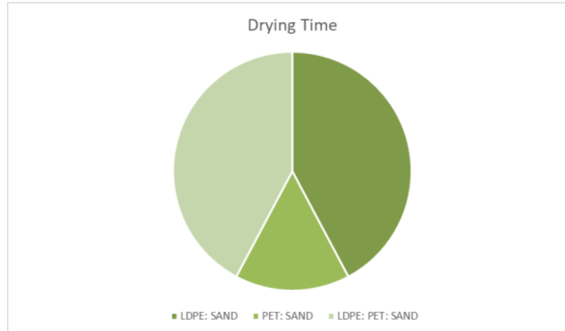


Table 2.6: control samples of LDPE, PET AND SAND

s/n	Samples	Mixing Ratio	Weight of Material (KG)			Percentage of Composition (%)		
			LDPE	PET	Sand	LDPE	PET	Sand
1	CS1	1:1	6.70	0	6.70	50	0	50
2	CS2	1:1	0	6.70	6.70	0	50	50
3	CS3	1:4:3	6.70	6.70	6.70	13.3	53.4	33.3

Fig: 2.11: the control samples of the interlock tiles after drying

III. RESULTS AND DISCUSSION

The results of the investigation are presented in Tables 3.1

Table 3.1

S/N	DIMENSION (mm)	LOAD (KN)	STRESS N/mm^2	DRY WEIGHT(g)	WATERABSORBTION (g)	WA (%)

Cs1	195x100x55	44.00	2.256	1959.8	1973.8	0.14
Cs2	195x100x55	162.89	8.353	1845.5	1846.2	0.007
Cs3	195x100x55	182.3	9.349	1846.6	1846.6	0.00

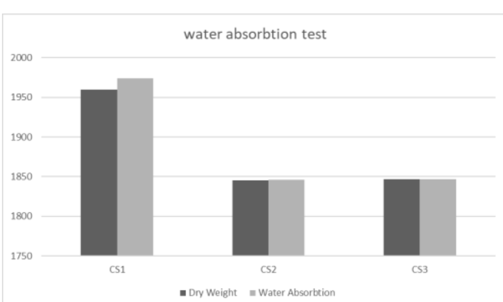
Results From Water Absorption Test.

Table 3.2: weight of the samples before and after immersion

Control samples	Weight before immersion(g) A	Weight after immersion(g) B
Cs1	1959.8	1973.8
Cs2	1845.5	1846.2
Cs3	1846.6	1846.6

Amount of water absorbed = Difference in weight before and after immersion B-A
Cs 1: 1973.8-1959.8= 14g
Cs 2: 1846.2-1845.5= 0.7g
Cs 3: 1846.6-1846.6= 0g

From the calculation above, LDPE and Sand blend (Cs1) registers water absorption of 14%, PET and Sand blend (Cs2) registers water absorption of 0.007%, and finally PET, LDPE and Sand blend (Cs3) registers of water absorption of about 0%. The above results are comparable to the conventional ceramic tiles sold in the market, however composite samples made of LDPE: PET and Sand blend registered 0% water absorption, and that of PET: Sand blend registered 0.007% compared to concrete ones that absorb a relatively high amount of water with an average absorption of 5% (Indian J. Biotechnol. 7, 2008). Hence, the composite tiles produced from these blends can act as an alternative in place of the ceramic tiles. The control sample one LDPE: Sand blend is however faced with a disadvantage since it registers more absorption of water.



Results from Crushing Test

The values of the load bearing capacity of the composite was as follows

i. The control sample one (Cs1); LDPE and sand = 44KN
ii. The control sample two (Cs2); PET and sand = 162.89KN
iii. The control sample three (Cs3); PET, LDPE and sand= 182.3KN

For a material to be used as floor tile it must have high load bearing capacity because people and objects of different weight will be distributed on the tiles. The control sample one, Cs1. was compromised when impact force was applied to it, the tile registered lower ductility compared the rest of the sample rendering it brittle with a low resistance to impact strength.

LDPE: Sand blend (Cs1) produces very hard but brittle tiles, and as a result does not give room for dislocation motions which in turn can lead to service failure over time, this is however a similar property of the conventional concrete tiles which makes it a good alternative for interlocking tiles. It also registered a little amount of water absorption which beats that of concrete tiles which are considered to be a good absorber of water. However, the conventional tiles will withstand a higher temperature than the composite tiles. Thus, these composite tiles are as durable as the conventional tiles. They can be used as an alternative in applications such as children playgrounds, dog parks, and outdoor gaming centers, generally places where it would not be required to carry heavy loads.

PET: SAND blends (Cs2) have higher impact strength and fracture toughness values as compared with LDPE: SAND blends (Cs1). The control sample two however registered higher ductility than the LDPE: Sand bend, it also possesses visible pores on its surface, making it more porous than that of LDPE: PET: Sand blend (Cs3)

Fig 3.1 Porous Surface of the PET: Sand Blend

The PET: Sand blend (Cs2) offers ductile tiles, with a little amount of porosity that gives room for slight dislocation motion which enables them to withstand external forces for a very long period without any cracks hence having an advantage over the conventional concrete tiles however a setback to this is that it is accompanied with slight distortion in shape and size of the tile. In terms of water absorption the composite tiles absorbed very little water compared to the conventional tiles, they can be used as an alternative in applications such as sidewalks and private and commercial floorings.

Fig 3.2: plastic tiles used as sidewalks

The LDPE: PET: Sand blend produced the optimum tiles with the highest quality, the control sample 3 thus becomes the optimum control sample because it has the highest resistance to stress. The blend offers a less brittle and more ductile structure compared to the other blends and offers properties that are thus comparable with the conventional interlock tiles. It registered no absorption of water from the test carried out, it offered a less porous and stronger material compared to the other samples. These tiles are more durable, and offers more economic and environmental value, they can be used as an alternative for the conventional concrete interlock tiles in every application.

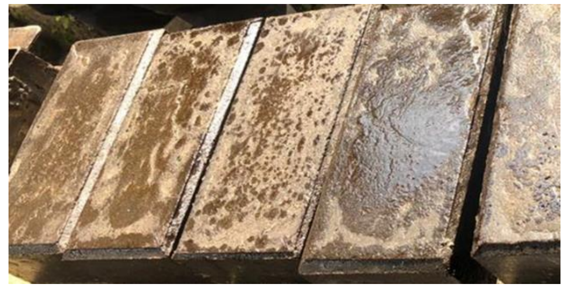


Fig 3.3: LDPE, PET and Sand Blend (the optimum control sample)

CONCLUSION

The production of plastics has increased significantly causing a big problem in the world, these plastics have very little to no recycling value chain and are causing serious environmental pollution problems most especially in developing countries. In conclusion interlock tiles made from PET wastes, LDPE wastes and sand aggregates register similar and higher performances relative to the conventional tiles, the strength of the composite interlock tile was found to be equally comparable to the strength of conventional ceramic tiles. It is recommended that recycling should be adopted as the main method of plastic waste management in other to reduce the hazards that improper waste management constitute.

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