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Strength of Sand concrete Blocks Production Using Waste Plastic (Pet)

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ABSTRACT: *Sandcrete block is the most popular building material in construction industry. With the high cost of building it is becoming difficult for an average man to achieve an affordable housing. Again the dredging of sand for block production, the incessant dumping of plastics wastes in the environment is of great concern. This study aims to replace sand in sandcrete blocks production and investigate the suitability of using such blocks for building designs. This research discussed the material used, the methodology of production. The plastic was washed, dried, melted and shredded. Sieve analysis was performed on the sand and plastic samples, water absorption and compressive strength tests were conducted on the blocks at 28 days of curing. The tests revealed that the 5%replacement gave a good result of 3.27 N/mm² which is suitable for block making. The other compressive strength results were below the standard recommended by Nigerian Industrial Standard. For the production of cost effective and performing sandcrete blocks, plastic wastes will serve since they are cheaply available, sustainable and recyclable. This will also help to reduce environmental pollution level. To improve the quality of sandcrete blocks, suitable selection of constituent materials.*
Keywords: *Melted, Platics, Production, Sandcrete, Shredded*

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I. INTRODUCTION

Waste generation is one of the major problems around the world. The rapid increase as population and socio-economic growth affect the production of waste [9, 35] Plastic has become an integral part of our daily lives [19, 47 and 70]; and among all types of wastes, plastic is one of the most generated worldwide [122, 136]. About 12% of MSW generated are plastics, which is approximately 22.14 million tons [3, 55, 95, 106 and 119]. Every year, approximately 6.5 billion tons of plastic wastes are generated globally; the disposal of these plastics poses a considerable threat to the environment [15]. According to [14] plastic products contribute substantially to an ever-increasing volume of municipal solid waste (MSW) worldwide with PET topping the list, In 2017, a total of 41.5 million metric tons of PET waste was generated globally [72, 94]

In recent years substantial growth in the consumption of plastic is observed all over the world and this has led to huge quantities of plastic-related wastes [134] and it continues to pose a serious environmental concern globally because of its almost total non-biodegradable nature [19,15, 52, 115]. The increasing consumption of various types of plastic products is one of the most important challenges in environmental protection [32, 36 and 131]. In Nigeria, as in many countries of the world, the amount of plastic waste is increasing and occupies a large part of solid waste. The large growth in the use of plastic materials has generated a growing interest worldwide in reusing recycled polymers [2 and 5].This emphasizes that it is high time to rethink the necessity of plastic recycling and reusing [20]. Recycling of plastic waste to produce new materials has economic and ecological advantages and is considered one of the best solutions for disposing of plastic waste [63, 85 and 90]. As such, there is a need to find other means to dispose of plastic wastes. One possible avenue is in the construction industry, particularly infusing plastic wastes of different forms into concrete and product of Sand-concrete block in masonry construction. Doing such could yield positive impacts in the environment.

So the importance shelter plays can never be overemphasized because apart from food it is the second of the necessity of human needs [6]. Affordable housing that has aesthetic value and durability has been one of the basic needs of humans. Various materials are used in the building of house. Research reports have shown that in Nigeria, over 90% of walling units in houses and even physical infrastructure are constructed using sandcrete blocks [88]. The Building Code of Federal Republic of Nigeria [42], stipulates that aesthetics, durability, functionality, character and affordability of housing must be achieved through the application of all materials and components used in construction of buildings [12].

Sand-concrete block is one of the most common masonry units in construction in Nigeria. It consists of hardened cement and may be completely solid or contain single or multiple hollows. It is made from conventional cement mixes and various types of aggregates. Various types of blocks are manufactured to be used for wall construction especially in residential, commercial and industrial buildings. It accounts for about 90% of houses built in Nigeria [79]. Sandcrete block is a composite material containing a mixture of fine aggregate, cement and potable water moulded into different sizes [83, 12 and 100]. Sandcrete blocks is used for non-load bearing and partition walls. It does not only help to provides buildings with aesthetic value but also controls moisture infiltration and wind action; does not rust nor decay [124[. They are either manufactured as solid, hollow, or cellular [1]. It is called a hollow sandcrete block when holes which appear from the top of the block run through to the bottom of the block while solid blocks refer to those blocks without holes [102 and 79]. Sandcrete blocks are also used for fencing, barriers, cladding etc .Factors that determine the choice of walling units include compressive strength, durability, water absorption, density, cost, availability of materials, etc [83 and 133]; the quality and compressive strength of sandcrete blocks are determined by factors such as characteristics of constituent materials, time of mixing, production method adopted, methods of compacting, curing durations, and size and form of sandcrete blocks [110 and 100]. In research carried out by [14], 0, 5, 10, 15, 20 and 100% of shredded waste plastic was used as a partial substitute for fine aggregate. It was discovered that sandcrete blocks containing 5% shredded waste plastic have the highest compressive strength while the control samples have the best outcome as regards density and water absorption properties. In another research by [54], sandcrete blocks were produced using 10 – 40% of plastic powder as a partial replacement for fine aggregate. The outcome of this research shows that as the percent of plastic powder increases the bulk density and air content decrease. The main objectives of this research are to evaluate the compressive strength and water absorption properties of solid sandcrete block produced from the partial replacement of sharp sand with locally sourced PET and its compliance to [83]. Bearing in mind of the environmental mess caused by plastic wastes and the need to find a substitute for the sustainability of concrete researchers have dealt into the usage of plastic.

II. MATERIALS AND METHODS

2.1: Materials and Equipment

Materials used for this research are Portland cement, sharp sand, low density polyethylene (LDPE) pallets and potable water. Moreover, the study utilized the following equipment: universal testing machine, concrete block molder, and mechanical sieving machine. All the machines used were located at the Department of Civil Engineering Laboratory.

Ordinary Portland cement: Ordinary Portland cement was used for this research. It was purchased from a retail shop in Nnewi, Anambra state of Nigeria.

Fine Aggregates: The river sand was acquired from local dealers.

The (PET) wastes were gotten from Zee Industries in Nkpor, Anambra State where they were pulverized into granules. The PET wastes were sieved with 2 mm test sieve to obtain fine aggregate FA.

Water: Portable clean tap water used was obtained from the Department of Civil Engineering Laboratory UNIZIK Awka. Nigeria. . It conformed to stipulated standard (BS 3148: 1980)

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2.2 Methods

2.2.1 Tests

The following procedures were conducted. Preliminary tests were conducted to determine the specific gravity, fineness modulus, water absorption, moisture content as well as the bulk density of sand. Major tests of compressive strength and water absorption suggested by NIS 978:2017 were carried out.

2.2.1 Sieve analysis of river sand

Sieve analysis to determine the grain size distribution of the river sand and the plastic were carried out with respect to BS 812. Coefficient of curvature (Cc) and uniformity (Cu) were determined..

2.2.2 Bulk density of river sand.

The bulk density of the dried river sand was obtained according to ASTM C29 /C29M

2.2.3 Block moulding

The respective batch design of the sand was measured out, the respective percentage of the PET was added to it and mixed together. Cement was then added in the ratio of 1:8 (cement to sand) and the whole process of mixing continued until a uniform colour was achieved. Water was finally added and the mixing continued until thecolour of the paste was uniform. Five partial replacements mix of 5%, 10%, 15%, 20% and 25% were made. Each mix had 3 specimens. The sandcrete blocks of dimensions 450mm x 225mm x 150mm were moulded and manually vibrated and demoulded immediately. Each Percentage mix was respectively inscribed CB, B5, B10, B15, B20 and B25 for identification. The demoulded sandcrete blocks were kept in an open space for 24 hours to gain shape before curing. Curing was done by regularly sprinkling water on them in the morning and evening for 28 days. Major tests of compressive strength and water absorption suggested by []83 were carried out. The blocks were crushed after twenty-eight days of curing using a Universal Testing Machine (UTM).

2.2.4 Water absorption test

Water absorption tests were conducted to determine durability property of Sandcrete block. The initial weight of dried sandcrete blocks was determined on the 1st-day. With the aid of a Digital weighing scale which was carefully checked to ensure that its previous validation was still valid, the dry weight W_1 of each of the blocks was determined and recorded. After which they were all completely immersed in water for a duration of twenty-four (24) hours. After immersion, the weight of submerged sandcrete blocks was measured. Also, the wet weight (W_2) of each of the test-samples (blocks) was determined by weighing the water-immersed blocks with the same Digital weighing scale. The water absorption of the various blocks was estimated after immersing specimens in water for 24 hours.

Thus, Water Absorption Coefficient, % by mass, after 24 hours immersion in cold water in given by the formula

$$\frac{(W_2-W_1)}{W_1}\ x\ 100$$

Where: 1 'W_1 ' is Dry weight of test-sample (block) in Newton 'N'

2 'W_2 ' is Wet weight of test-sample (block) after being immersed in water for 24 hours in Newton 'N'

The average of result is reported.

2.2.5 Compressive Strength test

A manual compression testing machine available at the concrete laboratory of the department of civil engineering, UNIZIK was used for this purpose. In order to ensure that the crushing load was uniformly distributed around the block's surface during the crushing process; smooth wooden planks were placed at the top and bottom of the block sample. It was then positioned at the Centre between the crushing plates of the compression testing machine. The maximum crushing force (load) at which failure occurred was indicated and noted. After which, it was divided by the net Cross-sectional area of the test-sample (block), to obtain the Compressive-strength expressed in N/mm^2. The compressive strength of the sandcrete blocks was determined on the 28th -day

III. RESULTS AND DISCUSSION

3.1 Cement Characterization

Table 3.1 Chemical composition of OPC

Calcium oxide	62.68%
Silica	20.36%
Alumina	6.87%
Iron oxide	3.67%
Magnesia	1.77%
Sulphuric anhydride	2.24%
Tricalcium silicate	42.57%
Dicalcium silicate	26.33%
Tricalcium aluminate	2%
Tetra calcium alumino-ferrite	2.24%

Table 3.2 Properties of cement

Properties	Values obtained	Standard Values	Codes
Consistency	6.0mm		BS EN196-3: 1995
Fineness	2.5%	Should be less than 10	BS EN196- (2016)
Initial setting time	40 minutes	Not less than 30 minutes	BS EN196- 3(2005)
Final setting time	280 minutes	Not more than 600 minutes	BS EN196- 3(2005)
Specific gravity	3.15 g/cc.	3.1-3.16	BS 812: part 2: 1995

The brand of Cement that was used passed because the fineness was 2.5%, which is less than 10%. The specific gravity is within the range of (3.1-3.16). The result shows that the cement is of good quality, having good initial setting time of (40mins) and final setting time (280mins). It can be used for the purpose

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3.2. Aggregates Characterization

Table 3.3 Properties of fine aggregates

Properties	Sand	PET
Fineness modulus	3.98	3.60
Specific gravity	2.6	0.928
Water absorption	1.9% <3%	0.12% < 0.2%
Moisture Content	3%	1.67

Bulking of sand	1.6%	

Sieve size (mm)	**Mass Retained(g)**	**%Mass Retained**	**Cum. % Retained**	**Cumulative% Finer**
2.00	36	3.6	3.6	96.4
1.18	58	5.8	9.4	90.6
0.85	84	8.4	17.8	82.2
0.6	186	18.6	36.4	63.6
0.425	228	22.8	59.2	40.8
0.3	184	18.4	77.6	22.4
0.15	180	18	95.6	4.4
0.075	28	2.8	98.4	1.6
Tray	16	1.6	100	0
Total	1000		ΣF= 398	

Table 3.4 Sieve analysis of sand

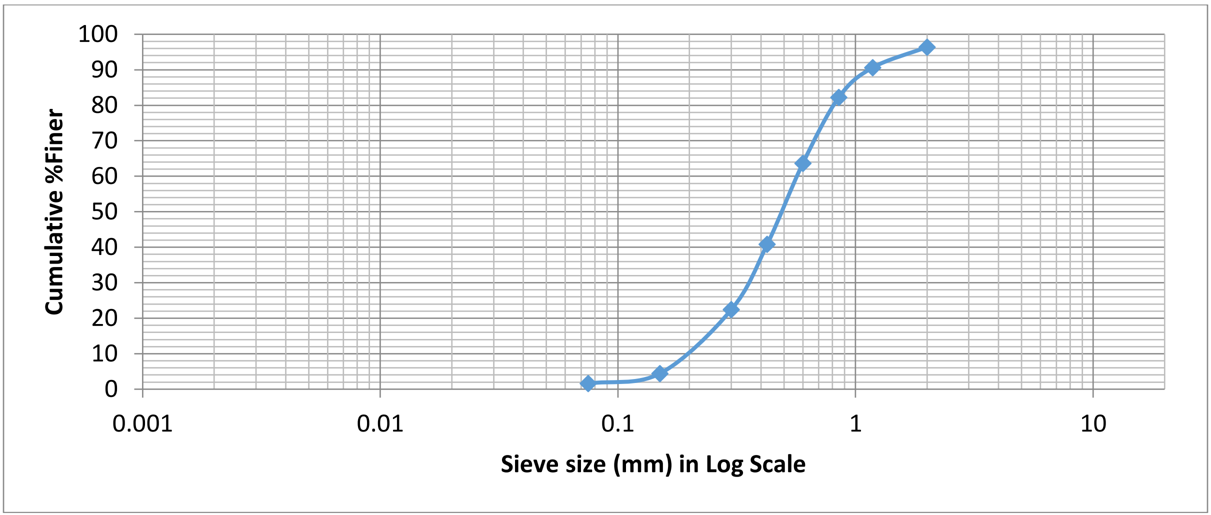

Fig.3.1: Sieve Analysis graph of Sand

The results are in accordance to the BS Standard. This has good properties and can be used in the concrete mix. The fine aggregate has less silt content so it is very helpful to be used in sandcrete block. The fine aggregate has less water absorption and this shows that aggregate will not absorb much water and hence less quantity of water is utilized.

$$\text{Fineness Modulus} = \frac{\Sigma F\ 398}{100} = 3.98$$

a). Calculation of the Coefficients of the Sand

Coefficient of Uniformity (Cu) $= \frac{D_{60}}{D_{10}}$

From the Sieve Analysis graph of Fine Aggregate D_{60}= 0.6; while D_{10} = 0.2

$\frac{D_{60}}{D_{10}} = \frac{0.6}{0.2} = 3$

Coefficient of Curvature (Cc) = $(D_{30})^2 / D_{60}$ x D_{10}

D_{30} = 0.35

$(D_{30})^2 = 0.35^2 = 0.1225$

D_{60} x D_{10} $= 0.6 \times 0.1225 = 0.12$

Coefficient of Curvature $= \frac{0.1225.}{0.12} = 1.02$

Table 3.5 Sieve analysis of fine aggregate (PET)

Sieve size (mm)	Mass Retained(g)	%Mass Retained	Cum % Retained	Cum% Finer
3.35	372	37.2	37.2	62.8
2	270	27	64.2	35.8
1.18	200	20	84.2	15.8

0.85	26	2.6	86.8	13.2
0.6	12	1.2	88	12
Tray	120	12	100	0
Total	1000	100	ΣF = 360.4	

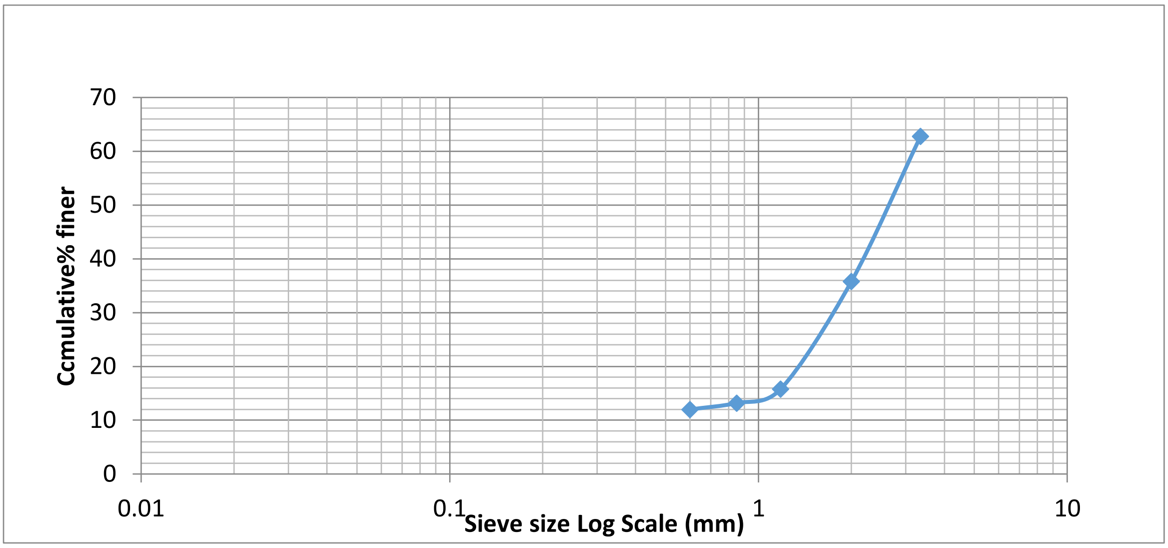

Fig.3.2 Sieve Analysis graph of PET

Fig.3.2 showed that the PET was not also well distributed rather is was uniformly distributed. The PET had a Coefficient of Uniformity (Cu) of 5.2 and a Coefficient of Curvature (Cc) of 1.74. The Cc value is within the recommended range of $1 \leq Cc < 3$ and below the Cu value of ≥ 6 recommended for sand (fine aggregate). Hence, the PET waste can be classified as poorly-graded fine aggregate. In terms of FM, the PET had FM of 3.6 which is slightly above the FM range of 2.3-3.1 recommended by [31] for FA. However, (ACI, E-701, 2007) stated that some natural sands may have FM that is outside the given range. So on this ground PET can be used as a fine aggregate replacement.

3.3 Water Absorption of the block

Table 3.6 Water Absorption

SAMPLE	$\frac{(W_2-W_1)}{W_1} x\ 100$
CB	3.8
B5	3.0
B10	2.7
B15	2.5
B20	1.7
B25	1.2

As can be seen, water absorption of control block (CB) was 3.8%. The percentage of water absorption of block decreased as the percentage of PET increased. Samples with PET had lower percentage of water absorption comparing to control block (CB). For instance, B5 has water absorption of 3.0% which is less than CB. Percentage of water absorption continuous to decrease with increase in PET percentage. The water absorption of brick samples B10, B15, B20 and B25 were 2.7%, 2.5% 1.7% and 1.2% respectively. This can be concluded that, the reduction of percentage of water absorption with the increment of PET was due to non-absorbent characteristic of PET.

This result is in line with the results of many researchers as enumerated. [10] produced blocks by incorporating melted PET bottles with sand. The results showed that the water absorption rate decreased as the PET content increases. Similar findings were also recorded when increasing the amount of PET [58] and PW [75, 123]. Besides PET, bricks made of a compact disc (CD) and sand recorded lower water absorption as compared to the conventional bricks [19, 111 and 121]. also proved that the water absorption rate of plastic sandcrete blocks is lower as compared with ordinary one. [21] suggested that the low water absorption rate of plastic sandcrete blocks was due to the low porosity of PET. The water absorption rate is also influenced by the size of aggregate. [132observed that the water absorption rate decreased as the amount of PET increased.[45] examined PET bead as a raw material in bricks manufacturing using an extruder. The findings evidenced that the water absorption decreasd along with amount of PET despite higher in strength and lower weight as compared with the conventional bricks. [78] demonstrated that the water absorption of bricks with 4.75 mm sand has higher water absorption rate of 5.7% at 1:5 plastic-to-sand ratio as compared with 1.8% when bricks produced with 600 mm sand size. Other studies also demonstrated that bricks made up of PW showed no change in terms of water absorption rate (Singhal and Netula, 2018; Mohan et al., 2016).

In contrast, [56] and [98] showed the water absorption rate increases along with the amount of PW. The highest water absorption rate of 12.28% [98] and 19.2% [56] were recorded when highest percentage of PW was used. A study conducted by [58] showed that the highest water absorption rate (2.2%) was recorded as the amount of PW increased. These findings suggested that probably the hydrophobicity and smooth surface of PW have decrease the adhesion force. In another study by [23] the water absorption rate for the soil bricks with PET aggregate is higher (21.66%) than in the control soil bricks. The rate increased with the amount of waste added due to the voids formed during the firing process which can be filled with water during the curing process. Again [78] demonstrated that the water absorption of block with 4.75 mm sand had higher water absorption rate of 5.7% at 1:5 plastic-to-sand ratio as compared with 1.8% when block is produced with 600 mm sand size.

3.4 Compressive Strength Test

Table 3.2: Compressive Strength of the block

Block No.	Compresive Strength (N/mm^2)	Av .C.S (N/mm^2)
CB_1	3.69	**3.63**
CB_2	3.57	
CB_3	3.64	
$B5_1$	3.26	3.27
$B5_2$	3.29	
$B5_3$	3.26	
$B10_1$	1.99	2.03 <2.5
$B10_2$	2.09	
$B10_3$	2.01	
$B15_1$	1,92	1.98
$B15_2$	1.20	
$B15_3$	2.02	
$B20_1$	1.88	1.89
$B20_2$	1.92	
$B20_3$	1.87	
$B25_1$	1.69	1.78
$B25_2$	1.89	
$B25_3$	1.76	

The CB, B5, B10, B15, B20 and B25 are sandcrete blocks made with 0, 5, 10, 15, 20 and 25% of PET. From the results, the CB has the highest compressive strength compared to others and the compressive strength reduces from CB down to B25. Sandcrete blocks made with PET as partial replacement gave a max compressive strength of 3.27 at 5%. The outcome of this research agrees with other works carried out by Akinyele and Toriola (2018); Anuradha, Panimayam, Chinnadurai, Pradeesh and Jaffer, (2017); Guendouz *et al.* (2016) and Alejo (2020). In the research carried out by Akinyele and Toriola (2018), 0, 5, 10, 15, 20 and 100% of shredded waste plastic was used as a partial substitute for fine aggregate. It was discovered that sandcrete blocks containing 5% had the highest compressive strength while the control samples had the best outcome as regards density. In another research by Guendouz *et al.* (2016), sandcrete blocks were produced using 10 – 40% of plastic powder as a partial replacement for fine aggregate. The result showed that as the percentage of plastic increased the compressive strength decreased. In another experiment, Ahmad *et al.* (2018) showed that increasing PW as raw material in paving block production decreased the compressive strength. Ahmad, Razali, Sahat and Kaamin (2018) showed control paver block with 0% replacement of PET recorded the highest compressive strength of 21.4 N/mm^2, followed by 20.9 N/mm^2, 12.2 N/mm^2 and 10.9 N/mm^2 for 5%, 10% and 15% of PET respectively. These findings suggested that lack of adhesion between PET wastes and cement paste could decrease the compressive strength.

Other researchers like Wahid *et al*. (2015) examined the characteristic of bricks made up of crushed and uniform-sized PET as a replacement for conventional aggregate. The findings showed that the less binding property of plastics decreased the compressive strength as the PET amount increased. Besides PET, the compressive strength of bricks made up of HDPE and PE (Prem and Gomathi, 2017) and mixture of polycarbonate and polystyrene (Mondal *et al.,* 2019) aggregates also decreased as content of PW increased. Hiremath and Shetty (2014) also demonstrated producing brick using PET waste along with laterite quarry waste and bitumen. The study recorded that the compressive strength of brick depends on the percentage of plastic. The compressive strength increases along with plastics content up to a certain limit and subsequently, it decreased. Increasing the volume of PET weakened the interfacial zone between cement paste and sharp sand.

In contrast, Dinesh *et al.* (2018) demonstrated that plastic paving block recorded higher compressive strength of 5 N/mm2 as compared with the control paver block (1N/mm^2). Similarly, Velmurugan *et al.* (2019) reported that paving block produced using 30% PE waste and 70% fly ash recorded the highest compressive strength of 22.85 N/mm^2 as compared to the concrete paving block (17 N/mm^2). Similar thoughts were shared by Mahajan *et al.* (2018) and Alighiri et al. (2019) as the compressive strength of bricks increased as the amount of PW increased. Another study by Singhal and Netula (2018) indicted that bricks produced using melted PW recorded the highest compressive strength of 5.6 N/mm^2. This showed that higher PW content could elevate the compressive strength of the bricks. Mohan *et al.* (2016) showed that the highest compressive strength (11 N/mm^2) was recorded when 70% of PW was used. Compact disc (CD) was also utilised to manufacture bricks by Singh *et al.* (2017).

The study suggested that bricks made up of PW have higher compressive strength (10.6 MPa) as compared with the conventional bricks (1.77 MPa). This is further proved by Thirugnanasambantham *et al.* (2017) where plastic sand bricks made up of PE bags had the highest compressive strength of 5.56 N/mm^2 as compared to fly ash bricks (3.38 N/mm^2). Shah *et al.* (2017) revealed that bricks made up of 100% plastic dust have higher compressive strength as compared to burnt bricks and are lighter in weight. Besides the amount of PW, the types and sizes of PW also influences the compressive of the plastic bricks. Intan and Santosa (2019) proved that bricks with LDPE have less strength as compared with PET due to their molecular weight and intermolecular forces. Misal *et al*. (2019) showed that bricks made up of coarse sand grains of 4.75 mm have higher compressive strength (6.7 N/mm^2) as compared with 600 mm sand (6.5 N/mm^2). Due to the fact thast finer sand absorbed more water resulting in insufficient water for hydration that caused reduction in workability and strength (Ling *et al.,* 2020). Aiswaria *et al*. (2018) manufactured bricks by incorporating melted PET bottles with manufactured sand (M-sand). The compressive strength increased with more plastics content up to a certain limit and subsequently decreased.

IV. SUMMARY AND CONCLUSION

Waste PET threatens the environmental sustainability and public health in developing countries (DCs) because of limited recycling options. Constructing masonry walls with plastic-bonded sand interlocking blocks sustainably transforms problematic waste plastics into a valuable resource. The research data revealed that plastic-bonded sandcrete blocks are lightweight. Using plastic-bonded sandcrete blocks in wall panels significantly reduces consction costs. Inclusion of the PET reduces water absorption and porosity of the blocks. The compressive strength of the materiatruls also decreased with the poly bubble content in the composition. In this research, waste plastic in the form of plastic bottles (PET) were successfully used in making paving blocks. The sand-waste plastic blocks had better water absorption properties than sand-cement blocks. This quality makes the sand-plastic blocks suitable for use in damp areas.

4.1 For further research

There are many modifications to the production of this hollow block construction walling material product. 1) Future researchers are recommended to check other ratios next to 1:5. The ratio above this may have adequate strength versus more economical. 2) Other ingredients can be added to minimize plastics and sand since the plastics are higher shrinkage

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