



**SCHOOL OF ENVIRONMENTAL TECHNOLOGY,
FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA, NIGER STATE, NIGERIA**

EDITORS IN CHIEF

R. E. Olagunju

B. J. Olawuyi

E. B. Ogunbode

**SETIC
2020
INTERNATIONAL
CONFERENCE**

BOOK OF PROCEEDINGS

MAIN THEME:

Sustainable Housing And Land Management



3RD -5TH MAY, 2021



**SCHOOL OF ENVIRONMENTAL TECHNOLOGY COMPLEX,
FUT, MINNA, NIGER STATE, NIGERIA**

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*Dean, School of Environmental Technology
Federal University of Technology Minna, Nigeria*

**School of Environmental
Technology International
Conference
(SETIC 2020)**

3RD - 5TH MAY, 2021

**Federal University of Technology Minna, Niger
State, Nigeria**

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EDITORS IN CHIEF

R. E. Olagunju

B. J. Olawuyi

E. B. Ogunbode

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“Sustainable Housing and Land Management”

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PREFACE

The School of Environmental Technology International Conference (SETIC 2020) is organised by School of Environmental Technology, Federal University of Technology Minna, Nigeria. In collaboration with Massey University New Zealand, Department of Civil Engineering Faculty of Civil Engineering and Built Environment Universiti Tun Hussein Onn Malaysia, Malaysia Centre For Professional Development and Industrial Project Development School of Professional and Continuing Education (SPACE) UTM-KL Malaysia, Global Academia, Department of Architecture, Faculty of Engineering and Architecture, Istanbul Gelisim University Istanbul Turkey, Sustainable Environmental and Technology (SET) Research Group, Department of Architecture, Universiti Sains Islam.

The main theme for this year conference is “SUSTAINABLE HOUSING AND LAND MANAGEMENT”. This promotes and encourage innovative and novelty for policy issues for inclusive and sustainable housing; access to finance for housing and land development; sustainable building materials; building cost management; sustainable and resilient cities; geoinformatics for land management; rapid urbanization; sustainable land use and spatial planning and gender issues in access to land.

The responses from participants for this conference are overwhelming, well attended, and successful. The operation mode was virtual for all participants who choose the oral presentation mode and physical for all poster medium presenters. Our participants are from various Universities and other sector across the globe, from countries like United State of America (USA), Turkey, Malaysia, China, Saudi Arabia, Kenya, New Zealand and South Africa just to mention a few. Hence, this conference provides a good platform for professionals, academicians and researchers to widen their knowledge and approach on latest advances in research and innovation. Papers presented in this conference cover a wide spectrum of science, engineering and social sciences.

Finally, a note of thanks must go to SETIC 2020 Local Organizing Committee (LOC) for their remarkable dedication in making this conference a success. We hope the event will prove to be an inspiring experience to all committee members and participants.

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ACKNOWLEDGEMENTS

The effort put together in achieving the success of SETIC 2020 is predicated on the feat of the first and second edition of School of Environmental Technology International Conference held in 2016 and 2018, respectively. The support and goodwill from Vice-Chancellor of Federal University of Technology, Dean School of Environmental Technology, Dr Dodo Y. A., Dr Moveh S. and many other highly motivated people are highly appreciated.

It is also my privilege and honour to welcome you all, on behalf of the Local Organizing Committee (LOC) to the 3rd edition of the Biennial School of Environmental International Conference (SETIC 2020). This Conference which was earlier schedule for 7th to 11 April, 2020 is holding now (3rd to 5th May, 2021) due to the challenges of COVID-19 Pandemic and the ASUU-FGN crisis which made our public Universities in Nigeria to be closed for about one year. We thank God for keeping us alive to witness the great SETIC2020 event, in an improved form exploiting the new-normal situation posed by the Pandemic for a hybrid (i.e. both physical and virtual) form of Conference participation.

The conference provides an international forum for researchers and professionals in the built environment and allied professions to address fundamental problems, challenges and prospects Sustainable Housing and Land Management. The conference is a platform where recognized best practices, theories and concepts are shared and discussed amongst academics, practitioners and researchers. This 2020 edition of SETIC has listed in the program a Round Table Talk on Housing Affordability beyond COVID-19 with selected Speakers from across the globe available to do justice on the topic of discussion.

Distinguished Conference participants, permit me to warmly welcome our Keynote and Guest Speakers:

- Prof. Ts. Dr. Mohd Hamdan Bin Ahmad, *Deputy Vice Chancellor (Development) Universiti Technology Malaysia (UTM)*;
- Assoc. Prof. Dr. James O.B. Rotimi, *Academic Dean Construction, School of Built Environment, College of Sciences, Massey University of New Zealand*;
- Assoc. Prof. Sr. Dr. Sarajul Fikri Mohammed, *General Manager, Centre for Professional Development and Industrial Project Development School of Professional and Continuing Education (SPACE), UTM-KL*.
- Prof. Ts. Dr. Zanail Abidin Akasah, *Visiting Professor on Sustainable Solar Integrated Design Building Design, International Micro Emission University (IMEU)/HIMIN Ltd. China & Senior Research Fellow, The Architects Resourcery, Jos, Nigeria*;
- Ar. Dr. Elina Mohd Husini, *Department of Architecture, Faculty of Engineering & Built Environment, Universiti Sains Islam*;
- Asst. Prof. Dr. Yakubu Aminu Dodo, *Department of Architecture, Faculty of Engineering and Architecture Istanbul Gelisim University, Istanbul Turkey*

and the five Speakers for our Round Table Talk on “Housing Affordability beyond COVID-19”

- Dr. Muhammad Mustapha Gambo, *Manager, Policy, Research and Partnerships, Shelter Afrique, Nairobi, Kenya*;

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- Prof. Dr. Soumia Mounir, *Department of Architecture Ecole Nationale d'Architecture d'Agadir [The National School of Architecture of Agadir], Morocco*
- Dr. Said Alkali Kori, *General Manager, Projects and Portfolio management, Family Homes Fund, Federal Ministry of Finance, Abuja;*
- Ts. Dr. Sasitharan Nagapan, *Department of Civil Engineering, Faculty of Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Malaysia;*
- Dr. Mercy Nguavese Shenge, *AIA Assoc. Historic District Commissioner, City of Rockville, MD, USA.*

for accepting to share from their knowledge, wealth of experience and be available to interact with participants on varied issues on “**Sustaining Housing and Land Management**”.

As reflected on the Conference program, the Conference activities will be Virtual for power point presenters to run in four parallel sessions on the Zoon platform while the participants for Poster presentations (mostly Postgraduate students) are expected to have their Posters displayed in the Environmental Complex Building of the Federal University of Technology, Minna. With a total of One Hundred and One (101) articles captured in the Conference Proceedings covering the seven subthemes of the Conference, I have no doubt that we are all in for an impactful experience at SETIC2020 as we brainstorm, exchange ideas, share knowledge and participate in evolving more approach to sustainable housing and land management drives.

I implore us all to enjoy every moment of the deliberations and ensure we maximize the great opportunity offered by the Conference to network for better research and career development as we also make new friends.

I also on behalf of myself and the LOC express our appreciation to the Dean, School of Environmental Technology and the entire Staff of the School for giving us the opportunity to steer the ship for SETIC2020. To the Reviewers and various Committees that served with us, I say thank you for helping us through despite the pressure of work.

Thanks, and God bless you all.

Olawuyi, B.J. (PhD)
Chairman, LOC
SETIC2020

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Assessment of Shredded Waste Poly-Ethylene Terephthalate (PET) Bottles Usage as Coarse Aggregate in Lightweight SHA Based Concrete Composite

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Abstract:

In this research report, the use of shredded waste Poly-ethylene Terephthalate (PET) bottle flakes as a lightweight aggregate in concrete was examined. Investigation was carried out on two groups of concrete samples, one made with only granite as coarse aggregate (control) and second made with PET and granite aggregate together as replacement for coarse aggregate. The PET replaced the granite coarse aggregate a varying percentage of 0%, 5%, 10% and 15%. Additionally, Sorghum Husk Ash (SHA) was also used as the replacement of cement on mass basis at the replacement ratio of 10% to reduce the amount of cement used and provide savings. The water–binder (w/b) ratio used in the mixtures were 0.55. The size of shredded PET flakes used in the preparation of concrete mixtures were between 1 and 4 mm. The results of the laboratory study and testing carried out showed that concrete comprising only granite aggregate, concrete containing PET and granite aggregate, and concrete modified with SHA as cement replacement can be drop into structural lightweight concrete category in terms of unit weight and strength properties. Therefore, it was concluded that there is a potential for the use of shredded waste PET as aggregate in the production of structural lightweight concrete. The use of shredded waste PET due to its low unit weight reduces the unit weight of concrete which results in a reduction in the self-weight of a structural concrete member of a building. Reduction in the dead weight of a building will help to reduce the seismic risk of the building since the earthquake forces linearly dependent on the dead-weight. Furthermore, it was also concluded that the use of industrial and agricultural wastes such as PET flakes and SHA in concrete provides some advantages, i.e., reduction in the use of natural resources, disposal of wastes, prevention of environmental pollution, and energy saving.

Keywords: lightweight aggregate, Poly-ethylene Terephthalate (PET), Sorghum Husk Ash (SHA), Strength properties, Unit weight.

INTRODUCTION

Lightweight aggregate is an imperative material in plummeting the density or unit weight of concrete to produce earthquake resilient constructions since the earth tremor forces are linearly reliant on the mass of the structure (Jafari & Mahini 2017, Semiha et al., 2010). The use of Lightweight aggregates is largely meant for the reduction of the unit weight of concrete through substituting the conservative aggregates. Currently, there are numerous lightweight concrete submissions made with natural or artificial lightweight aggregates in the literature (Saikia et al. 2014, Islam et al. 2016, Madandoust et al. 2019, Ashrafian et al. 2020, Záleská et al. 2018). Though, the cost of non-natural lightweight aggregate production is high owed to necessity of high burning temperature or thermal treatment (Semiha et al. (2010). Consequently, unlike other common materials, using waste plastic pellets as lightweight aggregate in the manufacture of lightweight concrete has engrossed considerable interest and keen devotion from the researchers. This method offers both recycling of the plastic waste and manufacture of a lightweight concrete in an cost-effective manner (Hilal et al., 2021, Koide et al., 2002).

Poly-ethylene Terephthalate (PET), Polypropylene (PP), and Polystyrene (PS). Poly-ethylene (PE) are some of the plastic wastes used in lightweight concrete. The PET bottles are ahead of the wastes with its high growing speed of consumption. PET excels by its inherent values like strength, safety, cost-effectiveness and being lightweight, unbreakable and recyclable. Today, the food and beverages industry is increasingly using PET (polyethylene terephthalate) to replace glass and other materials. In Nigeria, the usage of PET started in a noticeable way only

very recently. It is projected that the demand will grow appreciably, especially for packaging soft drinks and water. Research indicates that the main driver of growth for PET (polyethylene terephthalate) bottles in Nigeria has been the food and beverage sector with water industry accounting for about sixty-five percent (65%) of PET (polyethylene terephthalate) usage in Nigeria (Foraminifera Market Research, n.d, Tuleun & Jimoh, 2018).

As a result of wild increase in the usage of PET bottles in our environment, solid waste problem is upstretched and over a hundred of years is required to degrade the waste PET bottles naturally (Ioakeimidis et al., 2016, Pol 2010). Hence, one of the realistic approaches for disposal of PET wastes, which causes environmental pollution, is using these wastes in the other manufacturing expanses, thus recycling the PET for beneficial, ecological and economic purpose. Several experimental studies have been carried out on using waste PET bottles as resin in polymer concrete and as fibre in fibrous concrete in recent years (Asdollah-Tabar et al., 2021; Patil et al., 2020; Batista et al., 2021; de Luna et al., 2020; Alani et al., 2020). Nevertheless, the utmost cost-effective use of waste PET bottles in concrete as being described by researcher to be shredded waste PET bottles used directly as aggregate in concrete fabrication. Thus, the use of PET wastes as aggregate in concrete will afford benefit in the disposal of wastes and reduce the environmental damages owed to the use of natural mineral aggregates resources (Semiha et al., 2010). Limited study on concrete fabricated with waste PET flakes as coarse aggregate are reported in literature (Islam et al. 2016; Saikia and de Brito, 2014; Silva et al., 2013; Ghaly and Gill, 2004). Though, besides waste PET, other plastic wastes such as HDPE, PE and PS have been used as aggregates in preparing various concrete composites (Naik et al., 1996). Plastic bottles shredded into PET flakes and pellets may be used successfully as substitution for coarse aggregates in cementitious concrete composites and be used for structural concrete member.

In addition, SHA was used as a replacement of cement in concrete in previous studies. It is reported in many investigations that, the use of SHA in concrete as a cement replacement has positive influence on the properties of the fresh and hardened concrete (Ndububa & Nurudeen, 2015; Tuleun & Jimoh, 2018). In addition, it also provides economic benefits (Tuleun & Jimoh, 2018). It improves strength, reduces permeability and porosity, reduces alkali-silica expansion of hardened concretes (Ogork and Danja, 2018; Tijani, et al., 2019a; Tijani et al., 2019b). 10% SHA replacement level was reported as the optimum quantity for achieving a competitive value for compressive strength of resulting concrete (Ndububa & Nurudeen, 2015). Thus, in this research, SHA was also employed as a partial cement replacement to attain savings from the amount of cement used in the manufacture of lightweight concrete made with lightweight PET aggregates. The usage of SHA in concrete affords ecological advantages apart from the energy savings and contribution to the properties of strength and durability of concrete (Tuleun & Jimoh, 2018).

This study, hence, investigated the performance of lightweight concrete produced using SHA as the supplementary cementitious material and waste PET bottle, which partially replaced the mineral aggregates as coarse aggregate in varying percentage to optimize the most suitable quantity of PET for a structural light weight concrete. This is achieved by examining the physical and mechanical properties of concrete containing PET aggregates.

MATERIALS AND METHODS

In this study Portland cement (CEM 1 42.5N - Dangote 3X) produced by Dangote Cement Company was used as the binder for the control reference concrete mix. The Portland cement used as binder for both control reference concrete mix and blended mix in this research was

1 cement (90%) and SHA (10%) binder were 115 mins and 230 mins respectively. The specific gravity of the cement used was 3.15 g/cm³ and Blaine specific surface area was 3220 cm²/g.

Sorghum Husk used was gotten from a farm waste dump in wukara village of kyami district, FCT-Abuja, Nigeria. At first, the collected Sorghum Husk was treated by drying and screening to eliminate unwanted leaves and straw constituents. The treated Sorghum Husk were afterward burned in open air using a locally fabricated incinerator described in the literature (Abalaka and Okoli, 2013). The resulting Sorghum Husk Ash (SHA) was sieved to remove extraneous and unburned carbon materials. Ensuing, the resultant SHA particles were ground to sizes below 150 µm using a local milling device. Finally, the pulverized ash was sieved to 75 µm particles to obtain the SHA used for the subsequent experiments.

The specific gravity of SHA was 2.30 g/cm³ and Blaine specific surface area was 4210 cm²/g. The BET value for SHA was determined as 3.420 m³/g. If the particles are porous, or have a rough surface structure, the BET surface area will be greater than the Blaine surface area. For this SHA particle, the particle was determined not to be porous. Blaine fineness along with chemical reactivity of cementitious or fine particles materials composition and fineness controls early strength development. Actually, most Type III cements today are simply higher fineness types of the regular Type I, II or V cement formed at the same plant. The chemical composition of cement and SHA are given in Table 1.

Table 1: Chemical composition of Portland Cement (CEM 1) and Sorghum Husk Ash (SHA).

Oxides (%)	NaO	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₃	K ₂ O	CaO	TiO ₂	MnO	Fe ₂ O ₃	SO ₃	LOI
CEM 1	0.10	1.24	6.12	21.3	0.05	0.23	65.0	0.25	0.01	3.47	1.02	0.80
SHA	0.45	2.05	20.10	60.25	0.15	2.45	0.76	1.16	0.30	10.89	2.38	5.76

The shredded waste PET bottle flakes used as aggregate were supplied from Sarz Gen enterprise, a waste plastic recycled plant, in free trade zone, Sharada, Kano state, Nigeria. It was got by picking-up waste PET bottles and washing, then crushing into flakes by machines. The average maximum size of PET aggregate was 4 mm, and its specific gravity was 1.35 g/cm³. River sand with maximum size of 4.75 mm was used in this study. The absorption value of the sand was 1.33% and, the relative density at saturated surface dry (SSD) condition was 2.62 g/cm³. The grading of sand measured according to ASTM C33 (2019) showed that the present sand can be used in concrete production.

Mix proportions, sample preparation and testing methods

The water–binder (w/b) ratio used in this work was 0.55. CEM 1 Cement and SHA were used as the binder. SHA was used as a partial replacement of cement on weight base at the replacement ratio of 10%. Waste shredded PET flakes were used as substitution to coarse aggregate (crushes granite) in varying percentage of 0%, 5%, 10%, 15% and 20% in the M (1-5) and S (1-5) mixtures. M (1-5) signifies mixture without SHA content, while S (1-5) mixture is the concrete produces with 10% blended cement mix. The proportions of concrete mixtures are given in Table 2.

Cubical and cylindrical specimens with 100 x 100 x 100 mm and 100 x 200 mm dimensions respectively were prepared from fresh concrete mixtures. They were afterwards demoulded after 24 hours and immediately cured in water at 22 ± 2°C for 7, 28 and 56 days (ASTM C192/C192M (2007)). The samples were tested for compressive strength and tensile strength. In addition, slump test and the fresh unit weights test was conducted on the fresh concrete mix in accordance with the British Standards (BS EN 12350-2 (2009)). While the dry unit weights

test, was conducted on the hardened specimen. The compressive and tensile strength values of concrete specimens were measured by using the test methods according to (BS EN 12390-3, 2009 and ASTM C496/C496M, 2011). All testing measurements were obtained from three samples, and the average of three samples was presented and discussed in the study.

Table 2: The proportions of concrete mixtures by weight (%).

Mix ID	SHA (%)	PET (%)	SHA (kg/m ³)	CEM 1 (kg/m ³)	PET (kg/m ³)	Coarse Aggregate (kg/m ³)	Fine Aggregate (kg/m ³)	Water (kg/m ³)	SP (1%)
M1	0	0	0	404.26	0.00	1189.54	578.01	215.72	4.04
M2		5	0	404.26	59.48	1130.06	578.01	215.72	4.04
M3		10	0	404.26	118.95	1070.60	578.01	215.72	4.04
M4		15	0	404.26	178.43	1011.11	578.01	215.72	4.04
M5		20	0	404.26	237.91	951.63	578.01	215.72	4.04
S1	10	0	40.43	363.83	0.00	1189.54	578.01	215.72	4.04
S2		5	40.43	363.83	59.48	1130.06	578.01	215.72	4.04
S3		10	40.43	363.83	118.95	1070.60	578.01	215.72	4.04
S4		15	40.43	363.83	178.43	1011.11	578.01	215.72	4.04
S5		20	40.43	363.83	237.91	951.63	578.01	215.72	4.04

RESULTS AND DISCUSSION

Unit weight

Measured fresh unit weights and dry unit weights of concrete specimens at 7, 28 and 56 days are presented in Table 3. The fresh unit weights of M1-M5 and S1-S5 where M1 is mix without SHA and PET and S1 is mix containing 10% SHA and 0% PET which are the control samples. The mix proportions were presented in Table 2. The dry unit weights of all specimens decreased in course of time due to the evaporation of free water and as the due to the increase in percentage of the Pet in concrete due to the increase of the pore structure. The dry unit weight at 28 days hydration period values of concrete without SHA (M1-M5) and (S1-S2) were between 1138 m³ and 2243 kg/m³. The unit weight of M1-M5 is lower than the unit weight of S1-S2. Since the specific gravity of SHA was lower than CEM 1 cement as the binder, the dry unit weights of the concrete made with PET were lower than the concrete without PET (M1 and S1) serving as the control sample.

The relationship between the workability (slump) and the percentage replacement of the PET aggregate is displayed in Table 3. The slump value of both PET concrete containing 10% SHA by weight of cement and without SHA declines as the percentage replacement of the PET aggregate rises, as revealed in Table 3. The declining ratios of workability indicate 89.5%, and 94.7% in comparison with that of normal concrete at the percentage cement replacement ratio of 0%, and 10%, respectively. This may be attributed to not only the smooth shape of the PET but also to the absorption and hydrophilic property of SHA. The workability reduction experienced by the light weight concrete is due to the large surface area of the ash and the smooth surface of the PET. PET and SHA is capable of reducing the unit water content and the water-reducing agent content. It is expected that the reduction of the unit water content could compensate for the strength reduction of the PET/SHA concrete in the case of manufacturing the concrete with the same slump.

Table 3: Fresh and dry unit weights (kg/m^3) of concrete produced.

Mix ID	SHA (%)	PET (%)	Fresh Unit weight (kg/m^3)	Dry Unit weight (kg/m^3)			Slump (mm)
				7	28	56	
M1	0	0	2383.98	2254	2243	2201	95
M2		5	1915.72	2085	1831	1839	60
M3		10	1884.19	1965	1810	1847	50
M4		15	1855.44	1792	1744	1656	35
M5		20	1821.28	1557	1503	1453	10
S1	10	0	2316.23	2174	2115	2046	80
S2		5	1896.84	1847	1808	1745	55
S3		10	1853.39	1802	1766	1662	45
S4		15	1818.22	1744	1482	1384	25
S5		20	1781.74	1254	1138	1058	5

Compressive strength

Structural lightweight concrete is defined by ACI Committee, as the compressive strength of 28 days, which is higher than $15\text{--}17 \text{ N/mm}^2$. ACI Committee also opined that the air-dry unit weight of a structural lightweight concrete should be lower than 1850 kg/m^3 (ACI Committee 213R, 1987). The air-dry unit weights of the ten mixtures presented in Table 3 were lower than 1850 kg/m^3 ; in other words, they complied with the above definition in terms of unit weight. The compressive strength values of concrete measured in the laboratory are presented in Table 4. Table 4 shows that the compressive strength values at 28 days of the concrete specimens were quite higher than 17 N/mm^2 . When the unit weight and compressive strength values are considered together, M1-M5 and S1-S5 mixtures can be classified as a structural lightweight concrete

The 28 days compressive strength values of the mixtures containing only PET aggregates (M2-M5) were 33.28, 29.55, 26.27 and 23.40 N/mm^2 . These values reached 36.76, 32.22, 30.48, 25.91 N/mm^2 at 56 days, respectively (Table 4). The compressive strengths of S2-S5 mixtures (including PET and SHA together) were 32.90, 26.50, 25.98 and 21.33 N/mm^2 at 28 days. At 56 days, their levels raised to 37.93, 34.11, 31.87 and 27.11 N/mm^2 , respectively (Table 4). It was seen from these results that, the compressive strengths of the mixtures containing 10% SHA and varying percentage replacement of PET together were higher than the mixtures containing varying percentage replacement of PET without SHA at 56-day hydration period. This was an expected result. Nonetheless, the compressive strength values of PET aggregates with SHA blends (S2-S5) were found to be suitable. The compressive strength values of typical control normal weight concrete mixture (M1) which is set for evaluation purposes were 18.43, 32.54 and 34.35 N/mm^2 at 7, 28 and 56 days, respectively (Table 4).

It can be seen from Table 4 that the compressive strengths of concrete produced in this investigation developed rapidly at an early age up to 28 days, however, after 28 days the speed of compressive strength developments slowed down in long term (56 days). This result was found to be similar to the strength development of normal weight mortar.

It can be observed from Table 4 that, in general, the compressive strength of the concrete modified with SHA as cement replacement corresponding in pattern with the compressive strength of the cement concrete at 7 and 28 days. After that, they passed the compressive strength of concrete made with only cement as the binder. Replacement of cement with SHA increased the compressive strength of concrete when compared to strength of concrete made with cement only especially at 56 days.

Table 4: Compressive strength (N/mm²) of concrete produced.

Mix ID	SHA (%)	PET (%)	Compressive Strength (N/mm ²)			Tensile Strength (N/mm ²)		
			7	28	56	7	28	56
M1	0	0	18.43	32.54	34.35	2.05	3.85	3.98
M2		5	16.84	33.28	36.76	1.46	3.73	3.88
M3		10	14.65	29.55	32.22	1.36	3.34	3.57
M4		15	12.91	26.27	30.48	1.12	2.91	3.37
M5		20	10.44	23.40	25.91	0.73	2.39	3.13
S1	10	0	14.44	31.20	34.96	1.69	3.70	4.18
S2		5	13.22	32.90	37.93	1.25	3.56	3.94
S3		10	11.39	26.50	34.11	1.12	3.38	3.74
S4		15	10.16	25.98	31.87	0.71	3.22	3.62
S5		20	8.49	21.33	27.11	0.34	3.04	3.44

This could be seen from Table 4 that strengths development of S2 to S5 were better than the strength developments of M2 to M5 for concrete with age 56 days. It was explained in the literature that, the strength of concrete modified with Supplementary Cementitious Materials (SCMs) as cement replacement was lower than the strength of NPC concrete at early ages (Semiha *et al.*, 2010). However, when it was cured adequately, its strength could be equivalent or higher than the control concrete in long term (Fernandez and Malhotra, 1990; Yeau and Kim, 2005; Bilim, 2006; Yazici, 2006; Oner and Akyuz, 2007). The result observed in this study for SHA concrete was found to be in-agreement with the literature.

Splitting tensile strength

The effect of substituting granite aggregate with waste bottle PET flakes at varying percentage with various w/c ratios is presented in Table 4. As illustrated in table 4, the general trend of tensile strength is decreasing when the amount of PET particles increases. For instance, for the both concrete mix without SHA (M2-M5) and concrete mix with 10% SHA, reduction occurred in tensile strength. This can be attributed to the negative effect of the smooth surface texture of the PET flakes on the bond strength between the PET, matrix and the aggregates. The increase surface area of PET particles compare to granite coarse aggregate is also a factor to consider. In addition, as the PET ratio increases, the reduction in splitting tensile strength is more significant.

Conclusions

The following conclusions were made from this experimental work:

- i. Concrete containing only PET aggregate and concrete modified with SHA as cement replacement produced in this study drop into structural lightweight concrete category.
- ii. The use of SHA reduced the slump and both wet and dry unit weight of the specimens. It also increased the compressive and tensile strength of the samples.
- iii. The compressive and tensile strength values of the concrete containing PET and SHA together were higher than the concrete containing only PET aggregates.
- iv. Based on the experimental study, the use of shredded waste PET flakes in concrete has a potential to reduce the dead weight of concrete, thus, can reduce the earthquake risk of a building, and it could be helpful in the design of an earthquake resistant building.
- v. The usage of industrial and agricultural wastes such as shredded waste PET flakes and SHA in concrete production would be helpful and resourceful in solving a part of the world present day environmental concern, in reduction and recycling plastic waste which has become a menace to the environment and also for achieving a cleaner environment and reduce the depletion of the ozone layer and energy saving.

REFERENCE

- Abalaka A, & Okoli O. (2013). Comparative effects of air and water curing on concrete containing optimum rice husk ash replacement. *Journal of Emerging Trends in Engineering and Applied Sciences* 4 (1):60-65.
- ACI Committee 213R (1987). Guide for structural lightweight aggregate concrete. *Manual of Concrete Practice*.
- Alani, A. H., Bunnori, N. M., Noaman, A. T., & Majid, T. A. (2020). Mechanical characteristics of PET fibre-reinforced green ultra-high performance composite concrete. *European Journal of Environmental and Civil Engineering*, 1-22.
- Asdollah-Tabar, M., Heidari-Rarani, M., & Aliha, M. R. M. (2021). The effect of recycled PET bottles on the fracture toughness of polymer concrete. *Composites Communications*, 25, 100684.
- Ashrafian, A., Shokri, F., Amiri, M. J. T., Yaseen, Z. M., & Rezaie-Balf, M. (2020). Compressive strength of Foamed Cellular Lightweight Concrete simulation: New development of hybrid artificial intelligence model. *Construction and Building Materials*, 230, 117-148.
- ASTM C192/C192M (2007) Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory. *Standard Practices*. ASTM International, West Conshohocken PA, United States of America (USA).
- ASTM C496/C496M-11 A (2004) Standard Test Method for Splitting Tensile Strength of Cylinder Concrete Specimens. *ASTM West Conshohocken*.
- BS EN 12350-2 (2009) Testing fresh concrete. Part 2: Slump-test. *British Standards Institution London, United Kingdom (UK)*.
- BS EN 12350-3 (2009) Testing of Hardened concrete: Compressive Strength Test Specimens (BS EN 12350. *British Standard Institute, London, United Kingdom (UK)*.
- BS EN 12390-3 (2009) Compressive strength, Test specimens, Concretes, Compression testing, Cement and concrete technology, Mechanical testing, Failure (mechanical). *British Standard Institute, London, United Kingdom (UK)*.
- Batista, W. G. S., Costa, B. L. S., Aum, P. T. P., Oliveira, Y. H., & Freitas, J. C. O. (2021). Evaluation of reused polyester resin from PET bottles for application as a potential barrier material. *Journal of Petroleum Science and Engineering*, 108776.
- de Luna, A. M., & Shaikh, F. U. A. (2020). Anisotropy and bond behaviour of recycled Polyethylene terephthalate (PET) fibre as concrete reinforcement. *Construction and Building Materials*, 265, 120-331.
- Foraminifera Market Research (n.d). PET Bottle Recycling in Nigeria; The Feasibility Report. Retrieved from <https://foramfera.com/marketresearchreports/manufacturing-market-research-reports/pet-bottle-recycling-in-nigeria-the-feasibility-report/>
- Ghaly, A. Gill, M. (2004). Compression and deformation performance of concrete containing postconsumer plastics, *Journal of Materials and Civil Engineering*, 16 (4) (2004) 289–296.
- Hilal, N., Al Saffar, D. M., & Ali, T. K. M. (2021). Effect of egg shell ash and strap plastic waste on properties of high strength sustainable self-compacting concrete. *Arabian Journal of Geosciences*, 14(4), 1-11.
- Islam Md. J., Meherier S. Md., Rakinul Islam A.K.M. (2016). Effects of waste PET as coarse aggregate on the fresh and harden properties of concrete. *Construction and Building Materials*, 125 (1) 946–950.
- Ioakeimidis, C., Fotopoulou, K. N., Karapanagioti, H. K., Geraga, M., Zeri, C., Papathanassiou, E., & Papatheodorou, G. (2016). The degradation potential of PET bottles in the marine environment: An ATR-FTIR based approach. *Scientific reports*, 6(1), 1-8.
- Jafari, S., & Mahini, S. S. (2017). Lightweight concrete design using gene expression programming. *Construction and Building Materials*, 139, 93-100.
- Madandoust, R., Kazemi, M., Talebi, P. K., & de Brito, J. (2019). Effect of the curing type on the mechanical properties of lightweight concrete with polypropylene and steel fibres. *Construction and Building Materials*, 223, 1038-1052.
- Naik T.R. Singh, S.S. Huber, C.O. Brodersen, B.S. (1996). Use of post-consumer waste plastics in cement-based composites, *Cement and Concrete Research*, 26 (10), 1489–1492.
- Ndububa, E. E., & Nurudeen, Y. (2015). Effect of guinea corn husk ash as partial replacement for cement in concrete. *OSR Journal of Mechanical and Civil Engineering*, 12(2), 40-45.
- Ogork, E. N., & Danja, Y. N. (2018). Evaluation of properties of cement and concrete containing sorghum chaff ash. *Bayero Journal of Engineering and Technology*, 13(1), 45-53.
- Patil, Y. D., Waysal, S. M., & Dholakiya, B. Z. (2020). Feasibility of PET Resin as a Cement Substitute for Sustainable Construction. In *IOP Conference Series: Materials Science and Engineering* (Vol. 829, No. 1, p. 012005). IOP Publishing.
- Pol, V. G. (2010). Upcycling: converting waste plastics into paramagnetic, conducting, solid, pure carbon microspheres. *Environmental science & technology*, 44(12), 4753-4759.

- Saikia, N. de Brito J. (2014). Mechanical properties and abrasion behaviour of concrete containing shredded PET bottle waste as a partial substitution of natural aggregate, *Constr. Build. Mater.* 52 (2014) 236–244.
- Semiha A., Atis C. D., Akçaözoglu K. (2010). An investigation on the use of shredded waste PET bottles as aggregate in lightweight concrete. *Waste Management*, 30 (1), 285–290.
- Silva, R.V. de Brito, J. Saikia, N. (2013). Influence of curing conditions on the durability-related performance of concrete made with selected plastic waste aggregates, *Cem. Concr. Compos.* 35 (1) 23–31.
- Tijani, M. A., Ajagbe, W. O., Ganiyu, A. A., & Agbede, O. A. (2019b). Sustainable pervious concrete incorporating sorghum husk ash as cement replacement. In *IOP Conference Series: Materials Science and Engineering* (Vol. 640, No. 1, p. 012051). IOP Publishing.
- Tijani, M. A., Ajagbe, W. O., Olawale, S. O. A., Ganiyu, A. A., Agbede, O. A., & Muscat, O. (2019a). Experimental study on the properties of sorghum husk ash pervious concrete. In *1st International conference on engineering and environmental sciences*, 351-353.
- Tuleun, L. Z., & Jimoh, A. A. (2018). Effect of the Blend of Cement-Sorghum Waste Ash (*Sorghum Vulgare*) on the Flexural Strength Properties of Concrete.
- Záleská, M., Pavlikova, M., Pokorný, J., Jankovský, O., Pavlík, Z., & Černý, R. (2018). Structural, mechanical and hygrothermal properties of lightweight concrete based on the application of waste plastics. *Construction and Building Materials*, 180, 1-11.