International Journal of Science and Advanced Innovative Research
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 6, Number 1, March 2021
http://www.casirmediapublishing.com

EVALUATION OF STRENGTH PROPERTIES OF SHREDDED PLASTIC FIBRE REINFORCED CONCRETE

[1]Zakka, P.W., [1]Anowai, S.I., [1]Ishaya, A. A., [2]Bang, D.P., [3]Yohanna, H.S., [1]Williams, F. W., [1]Agboju, S.E and [1]Obi, V. T
[1]Department of Building, University of Jos, Nigeria.
[2]Nigerian Film Corporation (NFC), Jos, Nigeria.
[3]Department of Building technology, Bells University of technology, Ota, Ogun State

ABSTRACT

Numerous waste materials are generated from manufacturing processes, service industries and municipal solid wastes. The increasing awareness about the environment has tremendously contributed to the concerns related with disposal of the generated wastes. Solid waste management is one of the major environmental concerns in the world. With the scarcity of space for land filling and due to its ever-increasing cost, waste utilization has become an attractive alternative to disposal. Today there are still many issues about landfill capacity problem. Plastics are one of the most widely used materials that change the human life for more than six decades ago. Plastic waste has a slow degradation rate. In this study Polyethylene Terephthalete (PET) is used as fibre to investigate the compressive and flexural behavior of concrete. To address this issue the fibers from used plastics were added in various percentages in the concrete. The aim of this research is to determine the strength of concrete produced using shredded plastic bottle fibre as reinforcement. The compressive and tensile strengths of various concrete specimens were tested to determine how the incorporation of recycled plastic as a replacement of coarse aggregate would affect the development of strength in the mixes. A series of five concrete mixes were compared at replacement increments of 0%, 5%, 10%, 15%, and 20%. All stages of plastic replacement showed a noticeable decrease in compressive strength. The test results were compared and the relationships between the observed and predicted strengths were given. It was observed that both the compressive and flexural strengths decreased with each increase in percentage addition of plastic. At 5% addition of PET there was a 20% decrease in compressive strength and a 40% decrease in flexural strength of concrete respectively. Thus, it was recommended that shredded polyethylene terephthalate can be used for non-structural elements.

Keywords: Evaluation, Strength, Properties, Shredded, Plastic, Reinforced, Concrete

INTRODUCTION

With global solid waste generation growing faster than ever, urban planning experts warn that growth will peak this century and won't begin to decline without transformative improvements in how we use and reuse content. Daniel Hoornweg and Perinaz Bhada-Tata, urban development specialists at the World Bank, put global Municipal Solid Waste (MSW) generation rates by 2025 at approximately 1.3 billion tons per annum. The study also projects that the global per capita rate of solid waste generation will grow from over 3.5 million tons per day in 2010 to over 6 million tons per day in 2025. The specialists cautioned that with the 'business as normal' scenario, levels of solid waste production would reach 11 million tons per day by 2100 and population growth and urbanization would outpace waste reduction unless drastic steps are taken (Hoornweg, 2013).

In today's world, the utility of plastic-based goods is rising day by day resulting in more plastic waste production leading to a crisis in waste disposal (Batayneh, Marie and Asi, 2007). Today, in almost every region, plastics are used, from small bottle caps to large containers such as laundry baskets and garbage pails. We are generating and using twenty times as much plastic as we did five decades ago. Plastic is a hydrocarbon monomer polymer and is widely used in everyday life in the form of polythene bags, food packaging products, water bottles, containers, cutting boards, electrical appliances, chairs, cars, plastic beverages, margarine, shampoo and detergent bottles, etc. In the modern world, plastic has become an essential part of everybody's life (Suganthy, Chandrasekar and Kumar 2013). Plastic related goods are used in every part of the world and hence the volume of waste generation is rising (Foti, 2013).

The world's annual plastic material consumption in the 1950's was about 5 million tons, now rising to 100 million tons in recent times, resulting in more plastic waste generation. Because of this plastic waste can be seen in every part of society everywhere (Sadiq and Khattak, 2015). Due to their poor biodegradability and existence in large amounts, the disposal of plastic waste in open environment contributes to numerous environmental problems, which disrupt the ecological balance of nature and are a major cause of health hazards to living beings (Merbouh et.al., 2014; Malak, 2015). Some of the rational forms for mitigating the effects of plastic wastes on the environment involves their use in other industries (Sadiq and Khattak, 2015).

Concrete industry tends to be the most viable sector that can absorb large amounts of plastic waste (Kosmatka and Panarese 2002). Concrete requires three basic ingredients in its simplest form-cement (the binder), aggregates (ranging from fine to coarse) and water (Gambhir, 2013). The constituent materials of concrete are naturally available in all parts of the world, but with the growing demand for concrete in different construction industries, such materials are becoming deficient every day (Kumar, 2014). Thus, both the problem of plastic waste disposal and the unavailability of the constituent materials of concrete can be managed effectively by using plastic waste in concrete.

The efficient use of plastic waste in concrete can improve various properties of concrete such as ductility and tensile strength. Moreover, using plastic waste in concrete also decreases its weight and thus buildings can be made more resistant to earthquake by using concrete plastic waste (Akcazogolu and Atis, 2010). Municipal waste management in Nigeria is still weak due to lack of equipment for the treatment and recycling of the waste. Third-world cities are rising at a very fast pace compared with developed nations. A UN-Habitat survey, for example, noted that Africa is the fastest urbanizing continent with cities such as Cairo, Lagos and Nairobi, Kinshasa among others growing at fast rates that would make them triple their current sizes by the year 2050 (UN-Habitat, 2010).

One critical concern is that while there is an excess of debris data in the aquatic world, there is a comparable lack of land-based plastic waste data. This is given the claim that 80% of plastic waste at sea is ground-based (Sheavly, 2005). The major terrestrial sources of aquatic plastic waste include stormwater runoff, combined sewage overflows, litter related to tourism, illegal dumping, manufacturing activities such as plastic resin pellets, accident and transport accidents, and landfill blowing (Allsopp, 2006). The ocean-based sources tend to be commercial fishing, recreational boaters, merchant/military/ research vessels, losses from transport, offshore oil and gas platforms (Sheavly, 2005).

Plastic is a large amount of waste in the aquatic world. Plastics account for an estimated 10% of household waste, the bulk of which is disposed of in landfill (Barnes, 2009; Hopewell, 2009). Nevertheless, plastic accounts for 60-80% of the waste found on shore, floating on the ocean or seabed (Barnes, 2005).
Landfills impact the soil and underlying landfill water surface (Salem, 2008) these water sources are heavily contaminated by waste. The chemical exude into the nearby water sources can cause damage to the resident 's atmosphere and health. These include ammonia (NH_3), Dissolved Organic Carbon (DOC), nutrients and heavy metals (Melynk, 2014). All the chemical substances cause harm to the eco system surrounding, environment and health

of the resident. Since, most developing nations in the wake of urbanization and industrialization are still grappling with the problem of adequate management of solid waste being generated. The aspect of the economy re-cycling PET will consume more energy and money compared to reuse PET in construction. Thus, re-use PET in construction would be an alternative way to prevent littering of PET and also save the budget of recycle PET in industry.

MATERIALS AND METHODS

This study assessed the viability, workability, Density, compressive strength, flexural strength, and water absorption of concrete made with plastic fibre.

Materials

Ordinary Portland Cement (binder), fine aggregates (river sand), coarse aggregates (crushed stones), shredded PET bottles and portable water for mixing were used in the course of the study. Series of tests were carried out on the materials to determine to identify their categories and suitability.

Aggregate

Fine and coarse aggregate were sourced locally. The fine aggregate used for this experiment was river sand sourced from Jengre in Bassa Local Government Area of Plateau State of Nigeria. Sieve analysis, specific gravity as well as bulk density tests were carried out on the sand used for the research in order to classify and obtain other parameters. The coarse aggregates gravel used was machine crushed 18mm average size and was obtained from PW Nig Ltd crushing plant, which is located in Vom, Jos South Government Area of Plateau State, Nigeria. The grading of the aggregate size distribution affects the compaction and workability, thus the strength of concrete. Sieve analysis is carried out to determine the proportion of the various sizes of the particles in the aggregate so as to ascertain compliance with recognized standards.

Cement

The cement is needed to provide the required matrix between the materials with the addition of mixing water. Dangote Ordinary Portland cement produced from Obajana plant in Kogi state was used for this research work. The tests carried out on the cement specimen include the initial and final setting times.

Shredded Polyethylene Terephthalate

International Journal of Science and Advanced Innovative Research
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 6, Number 1, March 2021
http://www.casirmediapublishing.com

Waste PET bottles were collected from refuse dumps and taken to Grand cereals at Rayfield, Jos where they were shredded mechanically in a shredding machine to an average of 7mm width and 10mm length. The shredded pieces were then weighed and added to the concrete at varying percentages by weight of the gravel.

Physical Properties of Polyethylene Terephthalete

A number of tests were carried out to determine the physical properties of shredded polythene. The result of the test is presented in Table 1.

Water

Water suitable for drinking was used for the production of samples. Table 2 presents the material constituents used in the study.

Table 1: Physical Properties of shredded Polyethylene Terephthalete

Un-compacted Bulk Density	931kg/m³
Compacted Bulk Density	986kg/m
Apparent Specific gravity	1.16
Colour	Transparent
Texture	Smooth

Table 2: Materials Per m³

Material	Specific Gravity	Bulk Density (kg/m³)	Mix 1:4:6 @ 0.65 Water/Cement Ratio (litres)	Quantity Per m³ of Concrete (kg)
Cement	*2.86*	1266	$\frac{1266}{2.86} x 1 = 443$	$\frac{1266}{7.260} x 1 = 174$
Fine aggregates	*2.6*	1630	$\frac{1630}{2.6} x 4 = 2508$	$\frac{1630}{7.260} x 4 = 449$
Coarse aggregates	*2.60*	1506	$\frac{1506}{2.6} x 6 = 3475$	$\frac{1506}{7.260} x 6 = 1244$
Water			$1266 x 0.65 = 833$	$\frac{1266}{7.260} x 0.65 = 113$
Total absolute volume			**7259 = 7.260m³ litres**	**1980 = 1.980**

Methods

Sieve analysis was performed on the aggregates (fine and coarse) used, to test for their properties and classifications. Similarly, the physical properties of the polyethylene terephthalete were also determined. A mix ratio of 1:4:6 was used based on the mix design. A constant water/cement ratio of 0.65 was used to achieve good workability of the matrix as a result of addition of PET fibres. Before mixing the required quantities of sand, stones, polythene shreds and water for the batch were weighed, cement and sand were thoroughly mixed before the coarse aggregates were added and finally the shredded PET bottles. The mixing of materials was done using a hand shovel after which the required quantity of water was added. The combined constituents were then mixed thoroughly on a platform continuously until a workable, smooth and consistent mixture was obtained.

Steel moulds were oiled in order to facilitate the easy demoulding of hardened concrete. The moulds were then filled with the mixed concrete, compacted and vibrated on a vibrating table for 1 minute. The samples were marked for easy identification and left for 24 hours to harden. After demoulding, the samples were cured in water for 7, 14, 21 and 28 days respectively. Water absorption and compressive strength tests were carried out on the concrete cubes moulded using (100 x 100 x 100)mm wooden moulds with varying percentages of polyethylene teraphthalete (5,10,15 and 20) respectively by weight of coarse aggregate (gravel). Similarly, tensile strength tests were carried out on the 100 x 100 x 500mm concrete beams concrete beams. Some of the samples were casted using 0% by weight of shredded PET bottles to serve as the control specimen. A total of 45 cubes and 45 beams were casted with each percentage increment having 9 cubes and 9 beams respectively.

Tests

Compressive Strength Test on Sample Cubes

The compressive strength test was carried out using the crushing machine which was electrically operated. It consists of a calibrated circular measurement gauge having two indicating pointers (red and black), these pointers were set at zero mark of the gauge before performing any test. The black pointer drops while the red pointer remains at the point of failure to take the reading during failure. The machine has a pressure pump which is manually operated to jack the load platform up or down, both for releasing the crushed cube sample from the load platform and for crushing the cube sample in between the platform. The compressive testing machine was used to test the entire cubes for 7, 14 and 28 days respectively. The cubes were weighed on a scale before crushing. The weighing scale consists of a platform where the various samples were mounted for weighing and attached to it is a calibrated scale for taking the readings. The various weights were taken to determine the various densities of the sample produced.

Flexural Strength Test on Sample Beams

The beam test in flexure used for rectangular beam specimens, is an indirect measure to predict the tensile strength of concrete. The exterior fibres stress calculated at failure of the beam specimen is called modulus of rapture (MOR). The test was carried out in accordance with BS 1881: Part 118 (1983).

Water Absorption Test on Sample Cubes

The water absorption is measured based on the difference in weight between the samples in a saturated dry condition and that in the oven dry condition expressed as a percentage of dry weight. Water absorption for the samples were obtained by drying the samples in an oven to a constant temperature of 250°C, after this the samples were immersed in water for a period of 24 hours. The difference in weight was obtained and the water absorption was calculated as follows:

$$\text{Water absorption} = \frac{M2 - M1}{M1} \times 100$$

Where M_1 = Dry weight of sample

M_2 = Saturated weight of sample

RESULTS AND DISCUSSION

Physical Properties of Shredded Polyethylene Teraphthalete

The polyethylene terephthalete shreds used for this work have a smooth surface and are translucent in nature. The shreds are cut to a nominal average size of 7mm x 80mm with a general thickness of about 0.25mm. Table 9 shows the physical properties of the shreds used in this work. The polythene shreds have an apparent specific gravity of 1.16, they have a loose bulk density of 931kg/m^3 and a compacted bulk density of 986kg/m^3.

Hardened Concrete

Results of the influence of shredded polyethylene terephthalete as additives on the hardened concrete are discussed in terms of density, compressive strength, flexural strength and water absorption.

Density of Specimen

It is seen that density decreases with increased shredded PET bottles content as seen in table 3 and 4. This may be due to the fact that shredded PET bottles are of light weight. However, the density of specimen was observed to increase with the days of curing, which suggest that there is no deterioration of the said concrete.

Table 3: Variation of Density of Cubes (kg/m³) with Hydration Periods (Days)

Hydration Period (Days)	7		14		28	
Addition of PET (%)	Average weight (kg)	Density (kg/m³)	Average Weight (kg/m³)	Density (kg/m³)	Average Weight (kg/m³)	Density (kg/m³)
0	2.47	2470	2.54	2540	2.64	2640
5	1.96	1960	2.21	2210	2.18	2180
10	1.70	1700	2.13	2130	2.14	2140
15	1.55	1550	1.77	1770	1.96	1960
20	1.45	1450	1.55	1550	1.60	1600

Table 4: Average Density of Beams after 28 Days of Curing

International Journal of Science and Advanced Innovative Research
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 6, Number 1, March 2021
http://www.casirmediapublishing.com

Addition of PET (%)	Average Weight (kg)	Density(kg/m³)
0	12.94	2588
5	12.64	2528
10	10.86	2172
15	9.90	1980
20	8.94	1788

Compressive Strength of Hardened Concrete

Results of the compressive strengths development with hydration periods of 7, 14 and 28 days, at various percentages addition of shredded PET bottles are presented in Table 5 and 6. The results show that the compressive strength generally increases independently of the percentage addition of PET shreds with the hydration periods, which informs non-detoriation of the concrete.

Table 5: Variation of Compressive Strength of Cubes (N/mm²) with Hydration Periods (Days)

Hydration Period (Days)	7		14		28	
Addition of PET (%)	Average Load (N)	Compressive Strength (N/mm²)	Average Load (N)	Compressive Compressive Strength (N/mm³)	Load (N)	Average Strength (N/mm²)
0	133	13.3	142	14.2	206	20.6
5	96	9.6	114	11.4	164	16.4
10	77	7.7	77	7.7	126	12.6
15	23	2.3	30	3.0	52	5.2
20	15	1.5	20	2.0	40	4.0

Table 6: Percentage Decrease in Compressive Strength

Addition of PET (%)	Compressive strength at 28 Days	% Decrease in Compressive Strength
0	20.6	-
5	16.4	-20
10	12.6	-39
15	5.2	-74
20	4.0	-80

Flexural Strength of the Hardened Concrete

Table 7 and 8 shows the results of the flexural strength test at 14 days of curing. From the results obtained, it can be deduced that the behavior pattern of flexural strength follows that of compressive strength.

Failure pattern of Hardened Concrete

The failure pattern of PET concrete under both axial and tensile loading was observed to be improved as the concrete tends to be more ductile than brittle. At failure, the cracks and in most cases the crushing was observed to be much minimal compared to conventional sample (control). This could be as a result of the PET shreds acting as fibre which tends to hold the concrete constituents together and hence behaving as ductile material.

Table 7: Flexural strength of Beams at 28 Days of Curing

Addition of PET (%)	Average Weight (kg)	Flexural Strength (N/mm^2)
0	12.94	5
5	12.64	3
10	10.86	2
15	9.90	1.5
20	8.94	1

Table 8: Percentage Decrease in flexural Strength

Addition of PET (%)	Flexural strength at 28 Days	% Decrease in Flexural Strength
0	5	-
5	3	-40
10	2	-60
15	1.5	-70
20	1	-80

Water Absorption of the Hardened Concrete

Table 9 shows the relationship between average water absorption of the cubes and the various percentage of addition of polyethylene terephthalate shreds. The results show values between 6.8% and 9.6%. It can be observed that the water absorption increases with increase in polyethylene terephthalete content. This could be due to open spaces created by the presence of polyethylene terephthalate.

Table 9: Variation of Water Absorption (%) with Polyethylene terephthalete at 28 Days of Curing

Addition of PET (%)	Water/Cement Ratio	Water Absorption at 28 Days (%)
0	0.65	6.8
5	0.65	7.5
10	0.65	8.1
15	0.65	8.9
20	0.65	9.6

SUMMARY OF FINDINGS

The following summaries were made based on the analysis of the experimental result on materials performed and presented in chapter three and four viz.

(i) The specific gravity of the shredded polyethylene terephthalate was obtained to be 1.16

(ii) The bulk densities of the uncompacted and compacted polyethylene terephthalete shreds were obtained to be 931kg/m^3 and 986kg/m^3 respectively.

(iii) The values of density recorded ranged between 1,450kg/m3 and 2,540kg/m^3 which decreased with increase in polyethylene terephthalete content.

(iv) The values of compressive strength ranged between 1.00N/m^2 to 14.16 N/mm^2 up to 14 days of curing, the strength was also observed to increase with hydration period which inform non- deterioration of concrete.

(v) The results for the values of flexural strength range between 1 to 5 at 14 days of curing

(vi) The addition of polyethylene terephthalete fibres to concrete is observed to improve the brittlesness as failure of the specimens does not result in excessive cracking of the specimen

(vii) The results of water absorption give a range between 6.8% and 9.6% at 28 days of curing, with the minimum value of 5% addition of polyethylene terephthalate which increases with the addition of polyethylene terephthalate shreds.

CONCLUSION

From the preliminary studies of the feasibility of using shredded polyethylene terephthelete as admixture in concrete production, the following conclusions were drawn;

(i) Compressive strength of concrete is affected by addition of plastic pieces and it goes on decreasing as the percentage of plastic increases. The addition of 5% by weight of polyethylene terephthalate decreases the compressive strength of concrete up to 20%

(ii) The use of the recycled plastic in the concrete reduced the overall concrete bulk density when compared to conventional concrete which lead to produce light-weight concrete.

(iii) Flexural strength decreases as the PET aggregate content increases. The addition of 5% of polyethylene terephthalate decreases the flexural strength of concrete up to 40%.

(iv) From the results of the water absorption test it is seen that water absorption increases with the addition of PET fibres with the optimum value being at 5% addition of polyethylene terephthalate fibres.

REFERENCES

Akcaozoglu, S., Atis, C. D. and Akcaozoglu, K. 2010. An investigation on the use of shredded waste PET bottles as aggregate in lightweight concrete. *Waste management 30(2):285-290*

Allsopp, M., Walters, A., Santillo, D. & Johnston, P. (2006) Plastic Debris in the World's Oceans. Greenpeace International. . *Arivalagan.S,* *International Journal Of Engineering Sciences & Research Technology 11, 443-449 (2016)*

Barnes, D.K.A & Milner, P. (2005) Drifting plastic and its consequences for sessile organism *dispersal in the Atlantic Ocean. Marine Biology 14(6), 815-825.*

Batayneh, M., Marie, I. and Asi, I. 2007. Use of selected waste materials in concrete mixes. *Waste management, **27(12)**,1870-1876*

Dora Foti, (2011) "Preliminary analysis of concrete reinforced with waste bottles PET fibers" Construction and Building Materials • January 2011.

Gambhir, M. L. (2013). *Concrete Technology: Theory and Practice. Tata McGraw-Hill Education*

Hoornweg D, Bhada-Tata P, Kennedy C (2013). Environment: Waste production must peak this century. Accessed from http://www.nature.com/news/ environment-waste- production-must-peak-this-century1.14032. www:inhabitat.com (http://inhabitat.com/ africas-first-plastic-bottle-house-rises-in-nigeria/ nigeria-bottle-house-1/). Accessedon March 23, 2016.

Kosmatka, S. H. & Panarese, W. C. (2002). *Design and control of concrete mixtures*. Skokie, IL: Portland Cement Association **5420**.

Kumar, A., Srivastava, V. And Kumar, R. (2014) . Effect of Waste Polythene on Compressive Strength of Concrete. Journal *of Academia and Industrial Research (JAIR), **3(3)**, 152-155.*

Malak, K. R. (2015). Use of waste plastic in concrete mixture as aggregate replacement. *International Journal Of Engineering, Education And Technology (ARDIJEET) **3(2)**.*

Melynk (2014) *Flexural behavior of polyethylene terephthalate (PET) Fibre in concrete pg. 3-4.*

Merbouh, M., Glaoui, B., Mazouz, A. and Belhachemi, M. 2014. *Use the Plastic Bag Waste in Cement Concrete. EurAsia Waste Management Symposium 1-6.*

Sadiq, M. M. and Khattak, M. R. 2015. Literature Review on Different Plastic Waste Materials Use in Concrete. *Journal of Emerging Technologies and Innovative Research (JETIR) 2(6), 1800-1803.*

Sheavly S.B. (2005). Sixth Meeting of the UN Open-ended Informal Consultative Processes on Oceans & the Law of the Sea. Marine debris – an overview of a critical issue for our oceans. June 6-10, 2005. From *http://www.un.org/Depts/los/consultative_process/consultative_process*.htm

United Nations Environmental Programme (UNEP), "Converting Waste Plastics into a *Resource", http://www.unep.or.jp/,2009.*