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UTILIZATION OF RECYCLED PLASTICS (HIGH DENSITY POLYETHYLENE) AS FINE AGGREGATES IN CONSTRUCTION

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Abstract

The quest for valorization of wastes in civil engineering has become prevalent in recent times. This study is an investigation into the potential use of recycled plastics (high density polyethylene) in the production of interlocking paving stones. After batching, 1:3:6 mix of concrete interlocking paving stones was produced in varying recycled plastics proportions of 5%, 10% and 20% as partial replacement for fine aggregates. The stones were moulded in plastic molds of size 220mm X 140mm X 60mm. It was seen that the compressive strength of the RHDPE-concrete interlocking stones at 28days of curing decreases linearly from 20.31MPa (for conventional concrete interlocking stones) to 11.37MPa (for 20% recycled plastics content) and statistically there are significant differences between the compressive strength values obtained for the interlocking stones. Concrete of 5% RHDPE content can be used in lightweight concrete and as interlocking paving stones in walkways only as it is not advisably recommended for car parks and other structural purposes as it tends to fail under heavy load.

KEYWORDS: Partial Replacement, Paving Stones, Recycled Plastics, Statistically Significant

INTRODUCTION

The quest for valorization of wastes in civil engineering has become prevalent in recent times. Moreover, it has also been observed by United Nations Environment Program (2009) that the rapid urbanization and industrialization all over the world has resulted in large deposition of waste polymer materials. The world's annual consumption of plastic materials has increased from around 5 million tons in the 1950s to nearly 100 million tons in 2001. Hence the need to valorize these plastic wastes. Tapkire et al. (2014) describes plastic as a material which contains one or more number of polymers having large molecular weight." Solid in its finished state or same state will manufacturing or processing into finished articles is known as Plastic. Looking to the global issue of environmental pollution by post-consumer plastic waste, research efforts have been focused on consuming this waste on massive scale in efficient and environmental friendly manner. Polymers have a number of vital properties, which when exploited alone or together, make a significant and expanding contribution to constructional needs. Bamborough (2001) gave the properties to include: being durable and corrosion resistant, having good insulation for cold, heat and sound saving energy, being economical and having a longer life, having free maintenance (such as painting is minimized), being hygienic and clean, having ease of processing/installation and having light weight. Ahmed and Raju (2015) observed that plastics can be used to replace the aggregate in the concrete mixture up to 80% and the use of plastics in concrete mix for a given water-cement ratio, reducing the tensile and Compressive strength and also lowering the density. Ghernouti et al. (2016) further affirms that Plastic Bag Waste aggregates can be used successfully to replace conventional aggregates in concrete without any long term detrimental effects and with acceptable strength development properties. Rahman et al. (2012) posited that the incorporation of Polyurethane Formaldehyde (PUF) into the masonry poly blocks makes the material very light compared to High Density Polyethylene (HDPE) modified concrete. PUF-based poly blocks can respond to the many needs of current and future construction works where lightweight materials are recommended while Wong et al. (2012) submitted that the use of recycled plastics in the permeable interlocking pavement system, as well as pavement reinstatement by reusable modular paving blocks, will reduce waste materials. Some other researches conducted on plastic wastes were highlighted as follows: **Tapkire et al. (2014) in their study concluded that** it is possible to use the plastic in concrete mix up to 20 % weight of coarse aggregate and that the use of recycled plastic aggregate in concrete is the best option for the disposal of plastic & ultimately reduces the plastic pollution in the environment. Patil et al. (2014) concluded that the modified concrete mix, with addition of plastic aggregate replacing conventional aggregate up to certain 20% gives strength within permissible limit. Density of concrete reduced after 20% replacement of coarse aggregates in a concrete; while Chowdhury et al. (2013) concluded from their study that Polyethene terephthalate (PET) aggregates concrete have less compression strength, flexural rigidity and tensile strength which can be attributed to the decreased bonding tendency of PET with cement matrix. But as the density of PET fiber is lower than the conventional aggregate, it is very useful in producing light weight construction entities. The thrust of this study is to investigate the use of recycled plastics (high density polyethylene) in the production of concrete interlocking paving stones.

MATERIALS AND METHODS

Materials used for the Study

These include Recycled Plastics (High Density Polyethylene), Ordinary Portland Cement, Fine and Coarse aggregates.

Experimental Procedure

Waste plastic bottles collected were shredded and palletized into sand-like particles. The batching of the materials for the production of concrete interlocking paving stones was done in varying proportion of 0%, 5%, 10% and 20%. After batching, 1:3:6 mix of concrete interlocking paving stones was produced in varying recycled plastics proportions of 5%, 10% and 20% by weight of total aggregate content with 0.60 water-cement ratio. Slump and Compacting factor tests were conducted on fresh concrete mix to determine their workability. The stones were moulded in plastic moulds of size 220mm X 140mm X 60mm. Cube specimens of size 150mm X 150mm X 150mm were produced to determine the compressive strength of the concrete at 7^{th}, 14^{th}, 21^{st} and 28^{th} days of curing. The paving stones were first dried in an oven at a temperature of about 110^{0}C for a period of 24 hours, and later were allowed to cool to room temperature and weighed; this weight was recorded as dry weight. Afterward, the stones were immersed in a tank of water at approximately room temperature and also left to soak for a period of 24 hours, and were removed, cleaned and weighed; this weight was recorded as saturated weight. Likewise, flexural strength of beams cast with the recycled plastics-concrete mix was also determined.

RESULTS AND DISCUSSION

The recycled high density polyethylene (RHDPE) was found to have the following engineering/physical properties as shown in Table 1. Howbeit, reduction in slump was recorded as the recycled plastics content increases, that is, recycled plastic-concrete was not as workable as conventional concrete.

Table I: Age and sex distribution of the subjects and controls.

	Subjects		Controls	
Age (years)	Male (%)	Female (%)	Male (%)	Female (%)
5 – 8	45 (55.6)	24 (61.5)	45 (55.6)	24 (61.5)
9 – 11	36 (44.4)	15 (38.5)	36 (44.4)	15 (38.5)
Total	81 (100.0)	39 (100.0)	81 (100.0)	39 (100.0)

$\chi^2 = 0.39$, d.f = 1, $p < 0.535$

Table 2: Sieve Analysis of the Recycled Plastics

Sieve Diameter (mm)	% Retained	% Passing
9.5	-	100.0
4.75	12.5	87.5
2.36	1.5	86.0

The recycled plastics were found to have some features related to silty-sandy material, the particle size was well graded, a relatively large fraction of the particles (up to 86 percent) were found to be less than 2.36mm in size (as shown in Table 2). The compressive strength and the crack width of the recycled plastic-concrete interlocking stones were as represented in Figures 1 and 2 below. The use of recycled high density polyethylene as partial replacement for fine aggregates in concrete production reduces the bond strength and thus increasing the deflection considerably as shown in Table 3.

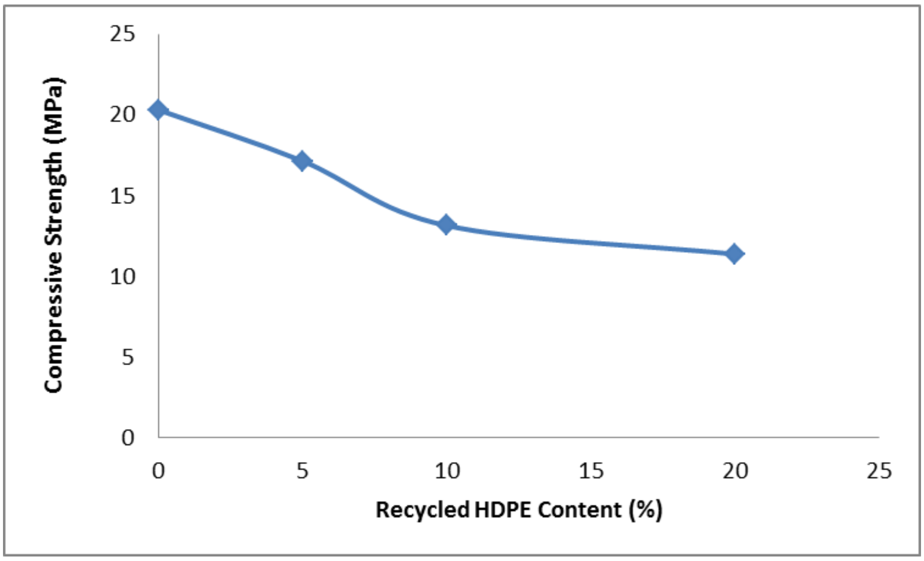

Figure 1: Compressive Strength – Recycled Plastics Content Characteristics of the Interlocking Stones at 28 days of Curing

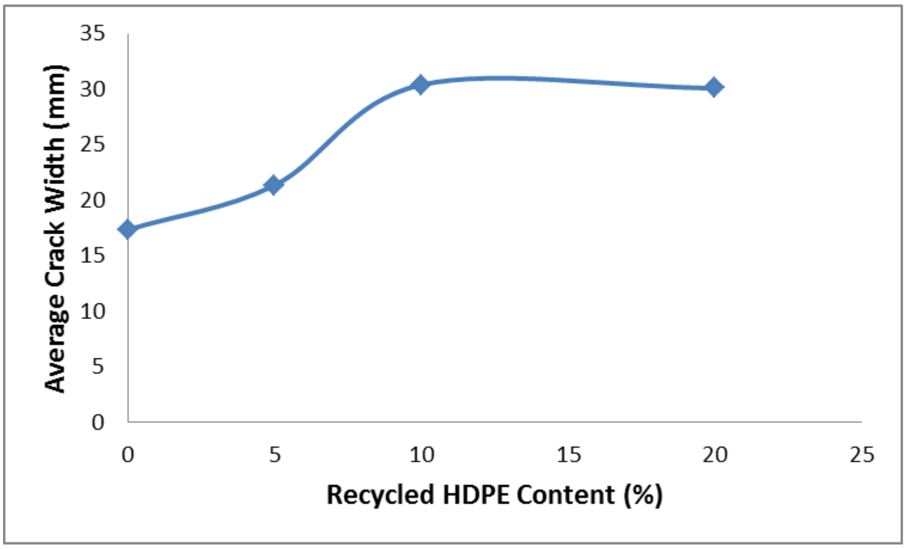

Figure 2: Crack Width – Recycled Plastics Content Characteristics of the Interlocking Stones

Table 3: Deflection of Reinforced Concrete Beam Constructed with Recycled HDPE - Concrete

Deflection (mm)	0.00	0.50	1.00	1.50	2.00	3.00	4.00	5.00	6.00	8.00
0%	0.00	76.00	89.33	104.00	113.00					
5%	0.00	52.66	58.22	64.00	73.33	85.33	89.53			
10%	0.00	24.67	34.67	40.53	48.00	60.67	64.59	71.40	75.00	
20%	0.00	20.67	24.53	29.33	42.30	47.33	50.50	56.78	64.36	70.67

The recycled plastics were found to have some features related to silty-sandy material, the particle size was well graded, a relatively large fraction of the particles (up to 86 percent) were found to be less than 2.36mm in size (as shown in Table 2). The compressive strength and the crack width of the recycled plastic-concrete interlocking stones were as represented in Figures 1 and 2 below. The use of recycled high density polyethylene as partial replacement for fine aggregates in concrete production reduces the bond strength and thus increasing the deflection considerably as shown in Table 3.

Table 4: Analysis of Variance in Compressive Strength

					T_j	T_j^2
0% RHDPE	0.88	3.14	3.85	6.31	14.18	201.07
5% RHDPE	-1.52	-0.89	2.33	3.14	3.06	9.36
10% RHDPE	-2.11	-1.4	-0.69	-0.60	-4.80	23.04
20% RHDPE	-3.96	-3.59	-3.16	-2.63	-13.34	177.96
	$\sum X_{jk}^2 = 136.39$				-0.90	411.43

$$\Sigma X_{jk}^2 = 0.88^2 + 3.14^2 + \ldots + (-2.63)^2 = 136.39$$

$$V = \Sigma X_{jk}^2 - \frac{T^{\wedge}2}{ab} = 136.34 \quad (a=4, b=4)$$

$$V_B = \frac{1}{b} \Sigma T_j^2 - \frac{T^{\wedge}2}{ab} = 102.81$$

$$V_W = V - V_B = 33.53$$

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Table 5: Analysis of Variance in Compressive Strength (F Computation)

Variation	Degrees of Freedom	Mean Square	F
Between Treatments			
$V_B = 102.81$	a-1=3	$S_B^2 = \frac{102.81}{3}=34.27$	$F=\frac{34.27}{2.79}=12.28$
Within Treatments			
$V_W = 33.53$	a(b-1)=12	$S_W^2 = \frac{33.53}{12}=2.79$	
Total V = 136.34	ab-1=15		

$F_{0.95}=3.49$ and $F_{0.99}=5.95$

Since the values of F at 5% and 1% confidence levels are less than the computed value, the null hypothesis is hereby rejected that is, there are significant differences between the compressive strength values.

CONCLUSION AND RECOMMENDATIONS

The compressive strength of the RHDPE-concrete interlocking stones at 28days of curing decreases linearly from 20.31MPa (for conventional concrete interlocking stones) to 11.37MPa (for 20% recycled plastics content) and statistically there are significant differences between the compressive strength values obtained for the interlocking stones. The modified concrete mix, with addition of plastic aggregate replacing conventional aggregate up to certain 20% gives strength with in permissible limit. Concrete of 5% RHDPE content can be used in lightweight concrete and as interlocking paving stones in walkways only as it is not advisably recommended for car parks and other structural purposes as it tends to fail under heavy load. The RHDPE-concrete tends to fail the more at higher values of 10% and 20% RHDPE content. Likewise, the RHDPE-concrete is not as workable as the conventional concrete and the crack width of the RHDPE-concrete tends to increase as the RHDPE content increases.

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