Use of Polyethylene Terephthalate (PET) Flakes as Coarse Aggregates Replacement in Concrete Paving Blocks

Mwalimu K. Musau, Douglas Shitanda, Michael Githinji, Caroline Mwende

Abstract: ***Concrete paving blocks were first introduced in Holland to replace paver bricks which had become scarce due to the post-war building construction boom. In Kenya, paving blocks are used in construction of pavements in both residential and commercial areas. They can be used in areas with light or heavy traffic. Solid waste management has been a big challenge in Kenya for years. With growing population and demand for housing, it is of paramount importance to develop alternative uses of plastic waste. Concrete paving blocks containing PET flakes at 5%, 10%, 15%,25%,50%, 75% and 100% replacement ratios for coarse aggregates were prepared against a 30MPa control sample. Compressive strength, tensile strength and water absorption tests were carried out. at 5% replacement ratio, the paving blocks had compressive strength of 44.18MPa which is suitable for medium traffic areas.***

Keywords: Polyethylene Terephthalate (PET) Flakes, Coarse Aggregates, Compressive Strength, Tensile Split Strength.

I.INTRODUCTION

Paving blocks are concrete products that are easy to manufacture and at any location as long as there is adequate space and water. This has made the use of paving blocks widespread. They are versatile, aesthetically attractive, functional and cost effective and require little or no maintenance if correctly manufactured and laid (1).

Concrete paver blocks were first introduced in Holland in the fifties as replacement of paver bricks which had become scarce due to the post-war building construction boom. These blocks were rectangular in shape and had more or less the same size as the bricks. During the past five decades, the block shape has steadily evolved from non-interlocking to partially interlocking to fully interlocking to multiply interlocking shapes (5)The blocks are made of cement, sand, and ballast with water. To ensure the blocks are strong enough to carry vehicular loading, the mixing must be done in the right ratio and adequate curing for at least seven days.

Polyethylene Terephthalate (PET) is a plastic resin and the most common type of polyester. It is one of the common consumer plastic used and is widely employed as raw material products such as mineral water bottles, soft drink bottles, containers for packaging of food and other consumer goods(6)A study by (4) showed that, for a mix design of 1:4:6 (cement, fine aggregate, coarse aggregate), replacing coarse aggregates with PET at 25% produced concrete paving blocks with 15MPa compressive strength which was suitable for use in pedestrian areas.

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At 5% replacement ratio of fine aggregates with PET, (6) obtained paving blocks with 20.9MPa at 28 days. This shows that, PET is a potential replacement of aggregates in production of paving blocks.

Currently, the focal challenges facing the building and housing sector are highlighted and emphasized on the reduction of environmental impact. In this context, an environmentally and friendly sustainable materials are in full development (7).

Natural resources are depleting worldwide at the same time the generated wastes from industry and residential area are increasing substantially. The sustainable development for construction involves the use of non-conventional and innovative materials and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment (1)

The patient solid waste management crisis in Kenya calls for holistic approach and this includes alternative use of plastic. With the growing population so is the demand for housing and depletion of natural resources. This involved this research study.

II. EXPERIMENTAL PROGRAM

A. Materials

Fine aggregates

River sand was purchased from local suppliers in Machakos town. It conforms with standards in BS 882 including, being clean, free of salts and other inorganic substances.

Coarse aggregates

Well graded coarse aggregates of sizes 5-12mm were purchased from local suppliers in Machakos town.

Cement

Portland cement N-32 was purchased locally in from suppliers in Machakos town. This is the most popular type of cement in Kenya's construction industry.

Water

Portable water from the University was used.

PET flakes

Polyethylene terephthalate (PET) flakes from water bottles of maximum size 12mm were purchased from Mr. Green Africa- a plastic waste recycling company based in Nairobi county which has production capacity of 30-40tonns/month. Figure 1 shows unprocessed plastic waste.

Fig 1: Plastic waste

Fig2: Blue PET flakes

III. MIX PROPORTIONS

The batching of materials was done using percentage by volume. The mix ratio was 1:0.5:1 (cement, sand and coarse aggregates). A control sample of M30 was prepared. Seven different samples were prepared at 5%, 10%, 15%, 25%, 50%, 75% and 100% coarse aggregate replacement ratios. A constant water-cement ratio of 0.4 was used. The mix proportions are shown in the table 1.

Table 1: Mix Proportion and Replacement Ratio

S. No.	Description	Cem	PET flakes	F.A	C.A
1	C35	1	0	0.5	1
2	5% Replacement	1	0.05	0.5	0.95
3	10% Replacement	1	0.10	0.5	0.90
4	15% Replacement	1	0.15	0.5	0.85
5	25% Replacement	1	0.25	0.5	0.75
6	50% Replacement	1	0.50	0.5	0.50
7	75% Replacement	1	0.75	0.5	0.25
8	100% Replacement	1	1.00	0.5	0.00

Legend

CA-Coarse Aggregates

F.A-Fine aggregates

Cem-Cement

All dry ingredients (cement, PET, fine aggregates and coarse aggregates) were carefully measured and poured in a concrete mixer where they were mixed for 3 minutes. Water was then added and mixing continued for five minutes. Due to the small volume of the concrete, it was further hand mixed in a mixing tray for two minutes. Total mixing time was ten minutes.

Fig 3: Hand mixing of concrete.

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IV. PRODUCTION OF PAVING BLOCKS

Concrete mixture was poured in a semi-automated moulding machine and well distributed. It was then vibrated for three minutes to ensure that no void spaces within the mould and to remove air bubbles present within the mix. The loaded timber mould was then transferred to a flat surface and allowed to dry for 24hrs. The demolded pavers were put in curing containers for stipulated time of 7,14,21 ad 28 days. The produced concrete blocks were rectangular in shape and measured 60mm*100mm*200mm

V. TESTS

A. Compressive strength test

In order to study the strength development in concrete, compressive strength tests were conducted as the ages of 7, 14, 21 and 28 days.

Compressive strength (N/mm^2)= Load at failure/area of the sample

Figure 4: Compressive strength test.

B. Split tensile test

After 28 days of curing, the samples were tested for split tensile strength.

Fig 5: Split sample

$T=2P/\pi Ld$.

Where: T= splitting tensile strength

P=maximum applied load indicated by testing machine

L=length

D=diameter

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C. Water Absorption

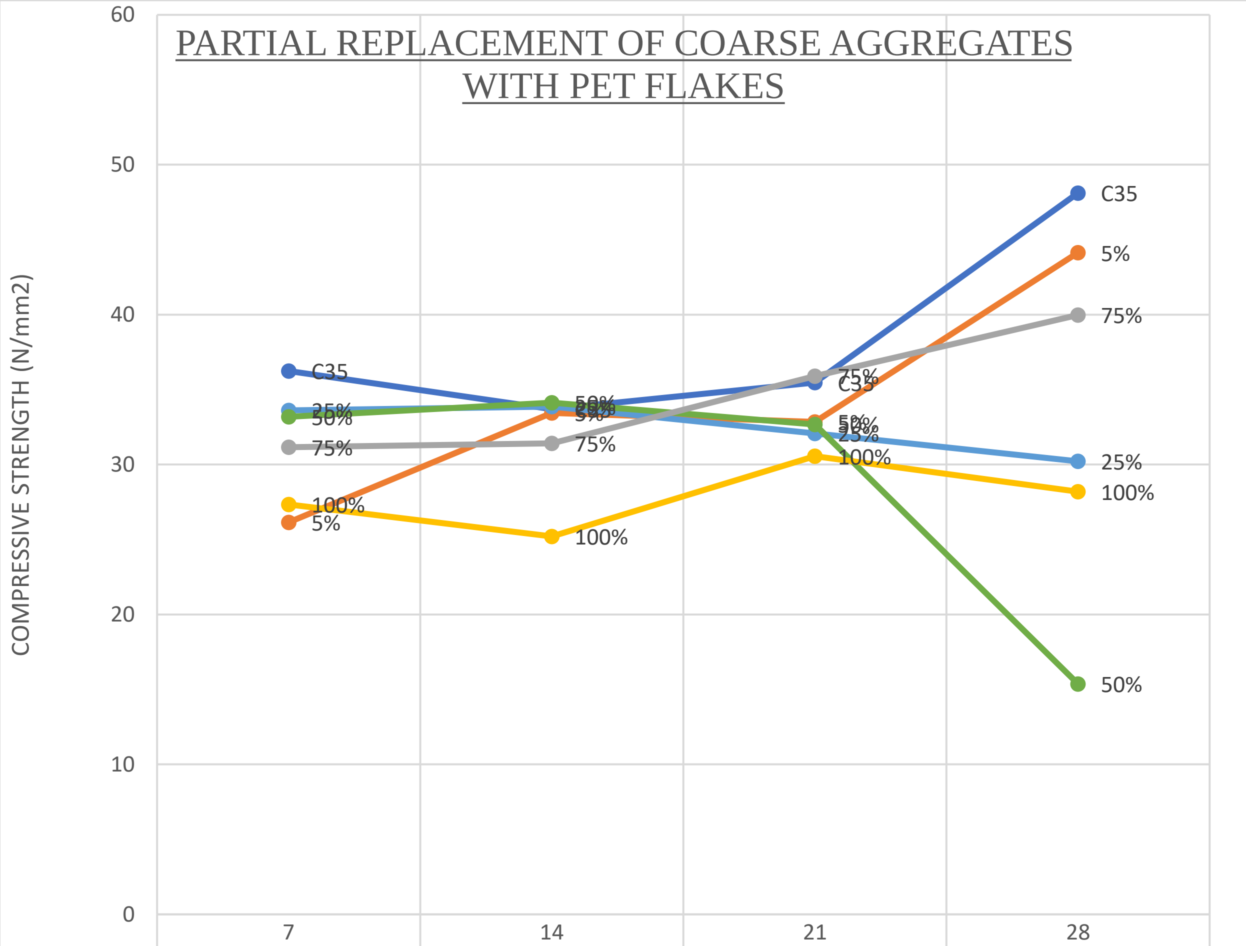
After 28 days of curing, samples were tested for water absorption. They were first weighed to get the wet weight, then placed in oven for 24 hrs. at 105ºC after which they were weighed to get oven dry weight.

Water absorption= ((WW-DW)/DW) *100
Where WW-wet weight
DW-dry weight after oven drying

VI. RESULTS AND DISCUSSION

A. Compressive strength

Compressive strength development over time is shown in figure 6.



	7	14	21	28
C35	36.25	33.7	35.47	48.12
5%	26.15	33.45	32.85	44.14
25%	33.62	33.87	32.09	30.22
50%	33.19	34.13	32.68	15.37
75%	31.16	31.41	35.91	39.98
100%	27.34	25.21	30.56	28.19

Fig6: Compressive strength

As the rate of replacement of coarse aggregates with PET flakes increased, the compressive strength was decreasing. At 28 days, compressive strength for concrete containing 5%, 10%, 15%, 25%, 50%, 75% and 100% was 44.14MPa, 30.22MPa, 15.37MPa, 39.98MPa and 28.19MPa respectively. A similar trend was observed by (4). However, at 5% replacement ratio, the paving blocks can be used in medium traffic areas since the compressive strength is above 40MsPa. At 25% replacement, the paving blocks are suitable for use in light traffic areas. The low adhesive strength between plastic surface and the cement paste was the reason attributed to the decreasing compressive strength (Farah et al., 2018)

B. Tensile splitting strength.

The reduction in compressive strength was similar to that of splitting strength. Figure 7 shows a comparative graph for both strengths.

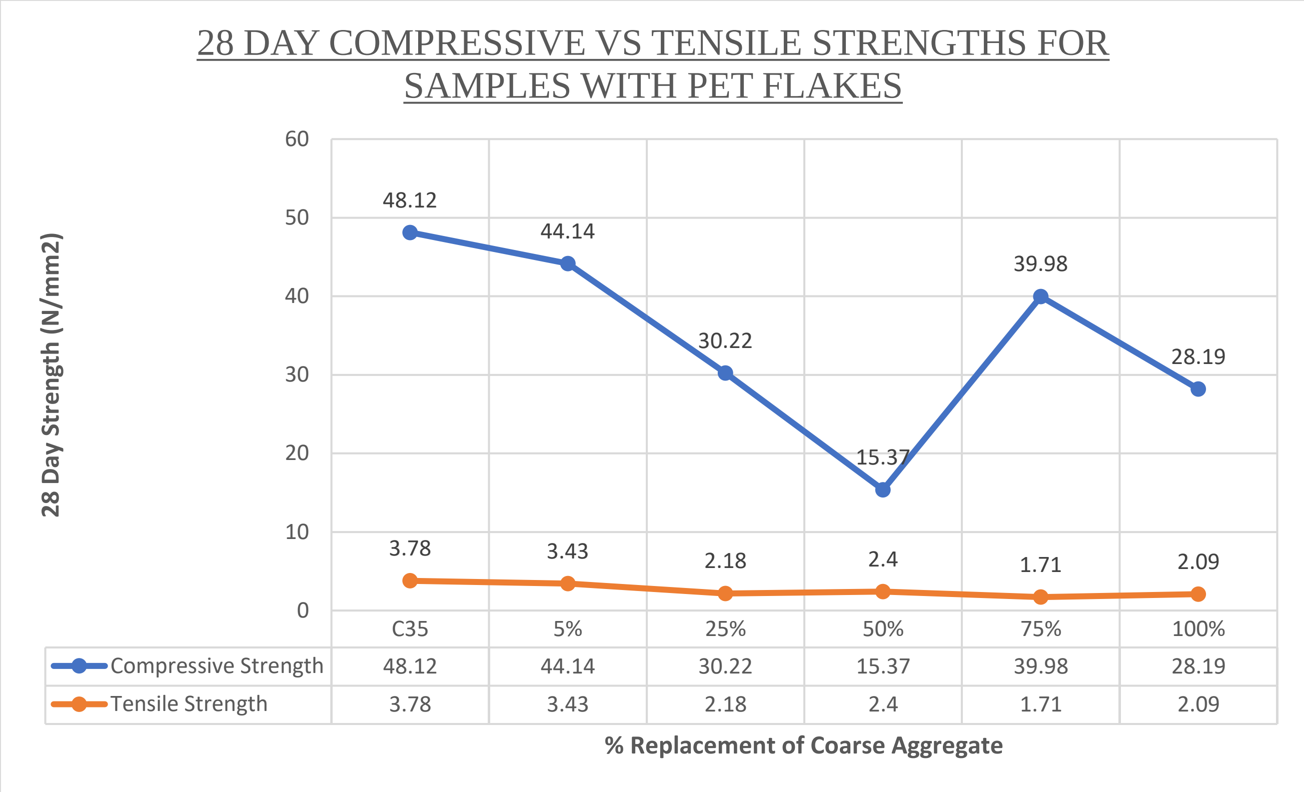


Fig 7: Compressive strength vs. Tensile strength.

As the compressive strength reduces, so does the tensile strength. The causes of reduced tensile strength are similar to those of compressive strength (3). The splitting tensile strength of concrete is mainly affected by the paste quality. The properties of aggregates affect the quality of paste and interfacial transition zone.

C. Water absorption

The rate of water absorption is shown in figure 8

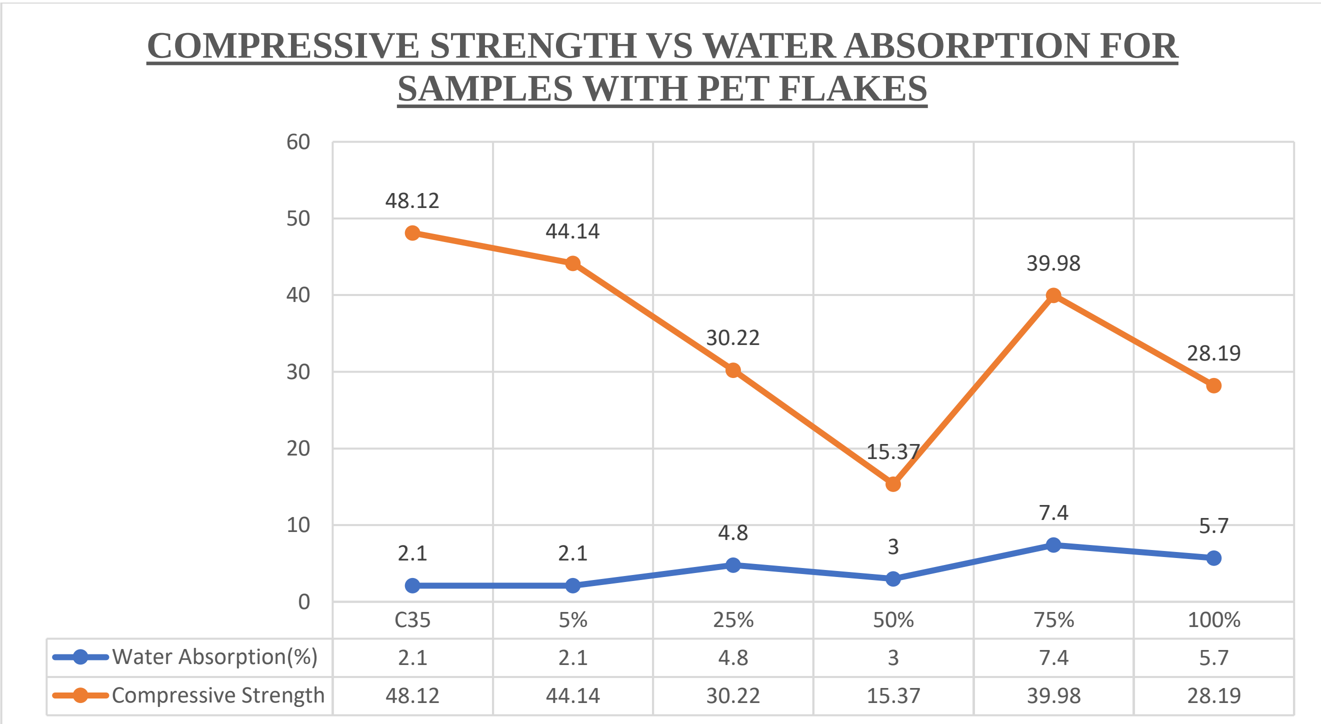


Fig8: Water absorption vs. compressive strength

Water absorption rate was varying for each replacement ratio. The highest water absorption rate was at 75% replacement rate at 7.4 % .ASTM states that the average absorption of test samples shall not be greater than 5% with no individual unit greater than 7% (2). At 5% replacement rate, water absorption rate was 2.1% which was similar to that of the control. It was also the same rate where highest compressive strength was obtained.

VII. CONCLUSION

The main focus of this study was to develop paving blocks with eco-friendly materials with emphasis on PET which is readily available. At 5% replacement rate of coarse aggregates with PET flakes, a compressive strength of 44.14MPa was obtained which is suitable for use in medium traffic areas. In addition, for light traffic areas, coarse aggregates can be replaced with PET at 25% whose compressive strength was 30.22 MPa.

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