Open Peer Review on Qeios

The Effects of Polypropylene Wastes on the Compressive Strength of Grade 25 Concrete

Richie Umasabor[1], Oluwadamilola Ayomikun Longe[1]

1 University of Benin

Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.

Abstract

The effect of polypropylene waste on the compressive strength of grade 25 concrete was studied. This was due to the increased problem of environmental pollution which may lead to flooding these wastes are causing in our environment. The research used the experimental methods in carried out the study. The polypropylene were pulverized to sand particle sizes and dosed at 5 %, 10 %, 15 % and 20 % by weight as partial replacement of sand in grade 25 concrete, cured for 7 days, 14 days, 21 days and 28 days respectively.

The results reveal that polypropylene can be substituted with sand in concrete up to 15% by weight with a negligible decrease of 3.7 % of compressive strength when compared to the control concrete. This depicts that polypropylene can be used in producing sustainable concrete.

Umasabor, R.I., and **Longe, O.A**

Department of Civil Engineering, University of Benin, Nigeria

umasabor.richie@uniben.edu,

Keywords: Polypropylene, blended concrete, compressive strength, plastic wastes.

Introduction

Concrete is a very essential material used in construction industry. It comprises of cement, sand, granite and water in the right proportions depending on the concrete grade (Umasabor, 2019). The grade of concrete used determines its compressive strength and other mechanical properties. The increasing use of concrete globally has put serious pressure on our natural resources which has led to shortages in recent times.

The effects of plastic waste on ecosystems, wildlife, and human health have made it a significant environmental problem in recent years. Recycling plastic waste is a crucial step toward sustainable waste management, and the construction sector is showing increasing interest in using plastic waste as an additional ingredient in the creation of concrete. Recently, there has been interest in the impact of plastic waste recycling on concrete's mechanical qualities.

Polypropylene (PP) is the clear thermoplastics used in the various applications of packaging, wrapping and constitutes major aspects of food wastes in our households (Umasabor and Daniel, 2020). In recent years polyethylene (PE) and polypropylene terephthalate (PET) have been used as sustainable material for concrete research studies. The results of numerous studies reported in literature relating to recycling plastic waste on the mechanical properties of concrete have been encouraging (Alina, 2021).

In a study conducted by Harikrisna et al. (2021) on the mechanical properties of concrete using plastic wastes: a review, they found out that the compressive and flexural strengths of the blended concrete reduced by a slight amount when compared to the control concrete at 5% weighted replacement of plastic wastes with sand in concrete.

In a study by Siddique et al. (2008), it was found that the addition of plastic waste up to 10% by weight of cement in concrete mixtures increased the compressive strength and flexural strength of the concrete. The study also found that the durability of the concrete was improved by reducing the water-cement ratio. Another study conducted by Siddique et al. (2008) also investigated the effect of recirculation of plastic waste on the compressive strength of concrete. Recycled PET bottles and HDPE bottles, both made of plastic, were employed in the study as two different forms of plastic waste. The results demonstrated that the addition of plastic waste in concrete improved slightly its compressive strength. Another study by Khatib et al. (2019) looked into the impact of plastic waste recycling on concrete's flexural strength. The study's plastic waste was made up of recycled PET bottles. The outcomes demonstrated that adding plastic waste to concrete increased slightly its flexural strength.

A study by Madandoust et al. (2011) investigated the effect of using different types of plastic waste in concrete. The study found that the use of low and high density polyethylene improved the compressive strength of the concrete, while the use of polypropylene (PP) reduced the compressive strength of the concrete. The study also found that the use of LDPE and HDPE improved the flexural strength of the concrete, while the use of PP reduced the flexural strength of the concrete. The impact of recycling plastic trash on the tensile strength of concrete was examined in a recent study by Guan et al. (2020). Recycled PET bottles were employed in the study as plastic waste. According to the research, adding plastic waste to concrete increased its tensile strength.

Jaivignesh and Sofi (2017) performed a study on the properties of concrete with plastic waste as aggregate. They added steel fibre to the concrete and used the plastic plate to substitute fine aggregates as well as coarse aggregates in dosage of 10%, 15 % and 20% respectively. The authors reported the reduction in concrete compressive strength but suggested its usage because it will help in reduction of waste material and improvement of the environment.

Osei (2014) performed experiments on plastics aggregate in concrete. He replaced the coarse aggregates by 25%, 50%, 75% and 100% with plastic using 1:2:4 concrete. The author reported a reduction in compressive strength of concrete as well as density of concrete. He further opined that any substitution of aggregates more than 36% is not ideal for structural concrete but suitable for light weight concrete. Subramani and Pugal (2015) performed experiments on plastic waste as coarse aggregates in concrete. The optimum results was obtained at 10% replacement of aggregates with plastic when the concrete was dosed with 5%, 10% and 15% plastic replacement with aggregates.

Most of the researches above have focused on polyethylene terephthalate (PET), polyethylene (PE), low density polyethylene (LDPE) and high density polyethylene (HDPE) as coarse replacement in concrete. Due to the depletion of our natural resources in form of fine and coarse aggregate, there is need to utilize some wastes materials like polypropylene as partial replacement of fine aggregate in concrete.

This study seeks to contribute to the development of more resilient and sustainable construction materials by elucidating the effects of polypropylene (PP) as a partial replacement of fine aggregate in concrete. By doing this, we may be capable of reducing the negative environmental effects, bridging the gap in shortages of natural materials and eventually promote circular economy.

Materials and methods

The materials used in this study include Portland cement, coarse and fine aggregate, polypropylene and water. The polypropylene was ground as shown in Figure 1, to the same fineness with the fine aggregate before added to the grade 25 concrete at 5%, 10%, 15% and 20% replacement by weight respectively. The total polypropylene concrete cast was sixty (60) with dimension 100mm x 100m x 100mm. The compressive strength test was carried out according to BS EN12390-3 (2019) methodology. Other tests which include sieve analysis, slump test and water absorption test were carried using various standards.

Figure 1. Processed polypropylene samples

Results and discussion

Sieve analysis test

The fine aggregate, coarse aggregate and polypropylene samples were subjected to sieve analysis according to ASTM C136 (2014). The results can be found in Figure 2.

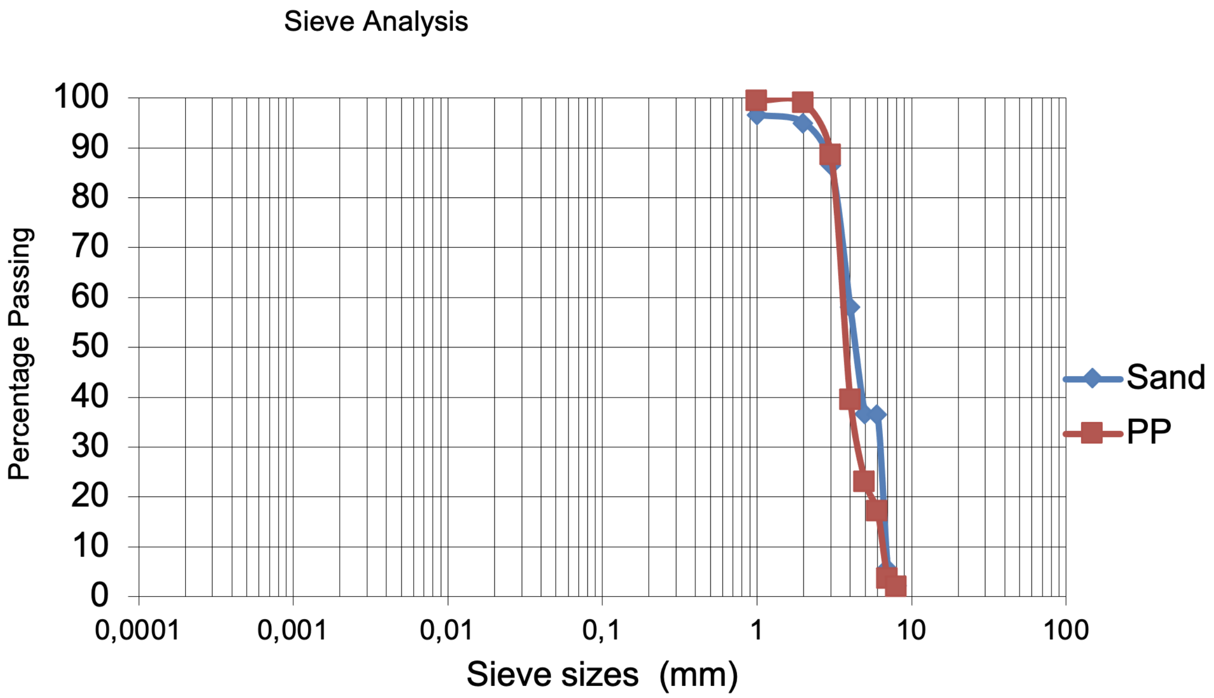

Figure 2. Sieve analysis of sand and polypropylene samples

Slump Test

The slump test was carried out according to ASTM C143 (2003) standards at 0%, 5%, 10%, 15% and 20% respectively. The results are shown in Table 1. The PP concrete was observed to be having a lower slump as the percentages of PP increases in the concrete. This may be due to the inability of the polypropylene sample present in the mix to absorb the water in the concrete. This behavior was observed by Umasabor and Daniel (2020).

Table 1. Slump test for PP and control concrete

% of ground PP	Slump (mm)
0	25
5	23
10	21
15	15
20	15

Specific gravity test

Specific gravity test were carried out on the fine aggregate and PP samples according to ASTM C127 (2015). The results revealed that the fine aggregate and PP samples had specific gravity of 2.65 and 0.92 respectively. This shows that the PP samples were lighter than the fine aggregate.

Water absorption test

This test was carried out according to ASTM D570-98 (2018) standards and the results as shown in Table 2 states that the water intake of the PP concrete reduced for 5% and 10% while there was an increase in water intake at 15 % and 20 % respectively. These may be due to the increased surface area of the blended concrete which was corroborated by Madandoust et al. (2011).

Table 2. Water absorption test for 7 days

% of ground PP	% of water absorbed
0	1.65
5	1.17
10	1.03
15	2.15
20	2.69

Compressive strength test

The compressive strength test were carried out according to BS EN 12390-3 (2019) methodology. The results as shown in Figure 3 indicates an initial decrease of compressive strength at 5% PP concrete but an increase was experience at 15% PP concrete for all curing durations of the PP concrete. This decrease may be due to the polypropylene concrete samples, reduced water absorption intake at 5% weighted replacement. The sudden increase might be due to the increased water absorption intake of the PP concrete at 15% weighted replacement which may lead to more hydration reactions. This finding was corroborated by Subramani and Pugal (2015).

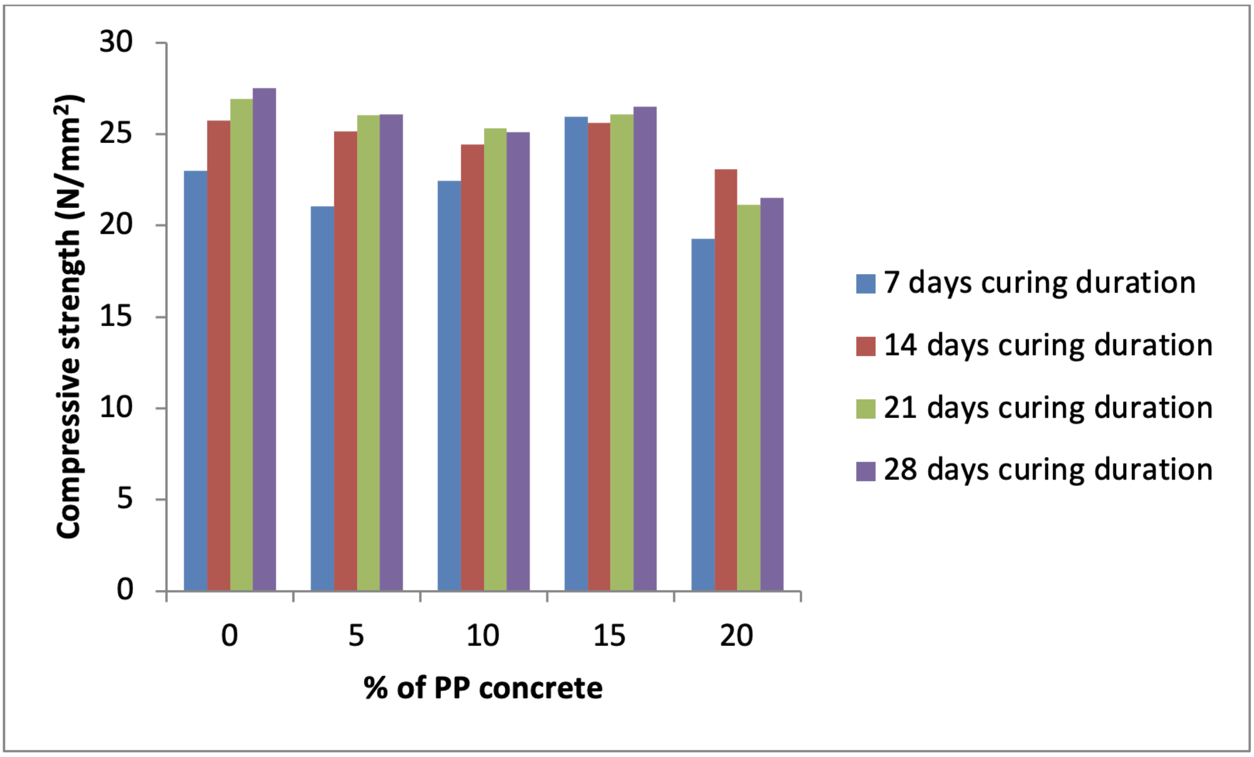

Figure 3. Compressive strengths of PP concrete at different curing durations

Conclusion

The study concludes as follows;

1. There was a gradual decrease in slump values up to 20 % PP replacement in concrete.
2. The specific gravity of the polypropylene was lower when compared to the fine aggregate value.
3. The water absorption values of the PP concrete decreased at 5 % and 10 % but increased at 15 % and 20 % respectively.
4. The optimum compressive strength for the PP concrete was obtained at 15 % with a value of 26.51 N/mm^2 for 28 days curing duration.
5. The use of polypropylene in concrete is possible according to this study, creating circular economy for the polypropylene waste materials and may help to reduce environmental pollution.

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