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Assessing the Performance of Polypropylene Waste-Modified Concrete in Structural Applications: A Case Study of FUNAAB Health Centre, Nigeria

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Abstract- ***Polypropylene plastic (PPP) products have added immensely to the world's increasing non-biodegradable Municipal Solid Waste (MSW). This paper focused on assessing the generation rate of PPP waste products from MSW collected within the Federal University of Agriculture (FUNAAB) health center, Alabata, state of Ogun, Nigeria in accordance with ASTM D5231-92 standard. The physico-mechanical properties of concrete produced by partially substituting fine aggregate with PPP were also assessed. Forty-five concrete cubes, cylinders and beams were cast replacing fine aggregate with PPP at 2.5%, 5%, 7.5%, and 10% using Grade 25 concrete having a mix of water: cement: sand : granite in ratio of 0.55:1:2:4. The workability and mechanical tests were tested. The municipal solid waste (MSW) characterization study showed that Polypropylene (PPP) waste constituted 21% of the general waste fraction (equivalent to about 16% of the total municipal solid waste (MSW) generated), with a daily generation rate of 0.9345 kg/day. As the ratio of polypropylene plastic (PPP) replacing fine aggregate in concrete rose, the slump and compaction factor values exhibited a downward trend. The mechanical strengths of the concrete after 28 curing days decreased progressively from 0% to 10% replacement, with the 2.5% replacement level giving the best mechanical performance among the PPP mixes. All replacement levels up to 10% nonetheless met the 17.24 MPa minimum compressive strength specified by ACI 213 (2014) for structural concrete use, indicating that up to 10% of polypropylene plastic (PPP) waste generated from municipal solid waste (MSW) streams can be effectively recycled and utilized as an alternative replacement for fine aggregate in structural-grade concrete, achieving a modest reduction in density without falling below this minimum strength requirement.***

Keywords: Municipal Solid Waste, Polypropylene Plastic, Aggregate Replacement, Building Sustainability.

I. INTRODUCTION

Mailing envelopes, food wastes, dried leaves, dusts, grass clippings, broken furniture, animal dung, sewage sludge, industrial rubbish, and general waste are examples of municipal solid waste (MSW) (Hosetti, 2006). The frequency of MSW generation varies from locality to locality and time to time (Gidarakos, et al., 2006). The global production of plastics rose from a mere 2 million metric tons in 1952 to a staggering 322 million metric tons by 2015, marking an exponential growth of over 16,000% (Yuetan et al., 2021). (Turkeswari, et al., 2021; Muller, et al., 2017; Riahi, et al., 2021; Requena, et al., 2018; Geyer, et al., 2017; El-Rahman, et al. 2018) estimated, a staggering 8.3 billion metric tonnes of plastic waste had accumulated by 2017, a sobering reflection of our unsustainable plastic consumption patterns. Due to its inability to transform its waste into wealth after being recycled or reused, plastic has steadily become a nuisance. High melting point-recycled plastics are often used to replace aggregates such as (PS) polystyrene, (PET) polyethylene terephthalate (Jadaun, et al., 2023). Except for (PVC) polyvinyl chloride, which has a detrimental effect on health owing to the emission of harmful chloride, a new technique to mixing has been used to all forms of polypropylene (PP) and polyethylene (PE) (Ahmadinia et al., 2012; Modarres and Hamedi, 2014; Yuetan et al., 2021). The proliferation of plastic materials has been a major driver of the ever-mounting non-biodegradable Municipal Solid Waste (MSW) problem worldwide (OECD, 2018). (OECD, 2018; Madhavan et al, 2010). Plastic materials are available in eight (8) primary polymer varieties, PPP is one of the most popular plastic materials (Dawei, 2012). Plastic manufacturing is increasing regularly owing to its excellence strength to weight ratio, ease of assuming diverse forms, liquid impermeability, and low cost, among other factors. It is common in the textile, consumer products, transportation, and construction industries. While plastics offer convenience, their production cycle, from manufacturing to disposal, poses significant

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environmental risks, including greenhouse gas emissions, water contamination, and ecological hazards (OECD, 2018). Unfortunately, despite its detrimental environmental impact, approximately 10-12% of municipal solid waste containing plastic is incinerated, releasing a harmful chemicals like dioxins, furans, mercury, and polychlorinated biphenyls (PCBs) into the air. Landfills are already overburdened with garbage, and wastes are being incinerated, with plastic bags providing high mortality rates. The need for effective alternatives to solve them needs to be prioritised (Verma, et al 2016). The infrastructure sector largely relies on the conventional method of concrete production, which utilizes cement, granite, and sand as the primary ingredients. The escalating costs of materials have hampered the construction of housing and other infrastructures especially in third-world countries such as Nigeria. As a result, engineering feedback is essential to apply low-cost, locally accessible materials to achieve the required criteria, as well as to produce a cleaner environment with reduced construction expenses (Olutoge, 2010). The table below presents a summary of the diverse plastic categories and their respective recovery rates. Despite producing a staggering 32.5 million tonnes of plastic in total, only 3 million tonnes were recycled, resulting in a dismal recycling rate of just over 9% (Mahmood and Kockal 2020).

Table I: In 2013, the following plastic types and amounts were discovered in MSW throughout the United States (EPA 2015)

		Recovery		
Plastic Types	The type of Plastic	1000 tonnes	% Recovery	Discards 1000 tons
PET (Polyethene terephthalate)	4680	930	19.9	3750
HDPE (High-density polyethene)	5580	570	10.2	5010
PVC (Polyvinyl chloride)	900	Neg	Neg	900
PLA (Polylactic acid)	50	Neg	Neg	50
LDPE (Low-Density Polyethylene)	7460	470	6.3	6990
PP (Polypropylene)	7400	40	0.5	7360
PS (Polystyrene)	2270	30	1.3	2240
Other resins	4180	960	23	3220
Total plastic in MSW	32520	3000	9.2	29520

Using polypropylene waste in concrete invariably solves the problem of disposal of plastic product waste while also lowering the cost of readily available building materials. The possibility of using rubber particles concrete combination to create a reduced cost, composite light brick materials which was more resistant to heat was investigated. According to the information obtained, the mechanical parameters met all relevant international specifications. The results of the experiments showed that replacing strong-level rubber particles with ordinary sand aggregates did not result in a sudden fracture even after failure loads (Paki and Bulent, 2008). Packaging and labelling, textiles (ropes, thermal wear, and carpets), stationery, plastic products and reusable containers of various sorts, laboratory gadgets, vehicle parts, and polymer banknotes are all examples of polypropylene's vast range of uses making it the second most used commodity (Hisham, 2016). As illustrated in Figure 1, the substantial rise in plastic waste generation depicted by Geyer et al. (2017) indicates that a vast amount of waste generated from plastic was discarded globally in 2015. PP plastic ranked fourth in terms of waste generation, following the industrial sector, packaging, and LD plus LDPE, all of which were strongly influenced by primary plastic consumption. Packaging emerges as the primary culprit behind plastic waste generation, accounting for a remarkable 50% of the global total. In stark contrast, construction-oriented plastics boast an impressive average lifespan of 35 years. In 2015, an alarming 74% (302 million tonnes) of the staggering 407 million tonnes of primary plastics produced globally ended up in landfills, a stark reminder of the urgent need for sustainable waste management practices (Ritchie and Roser, 2018).

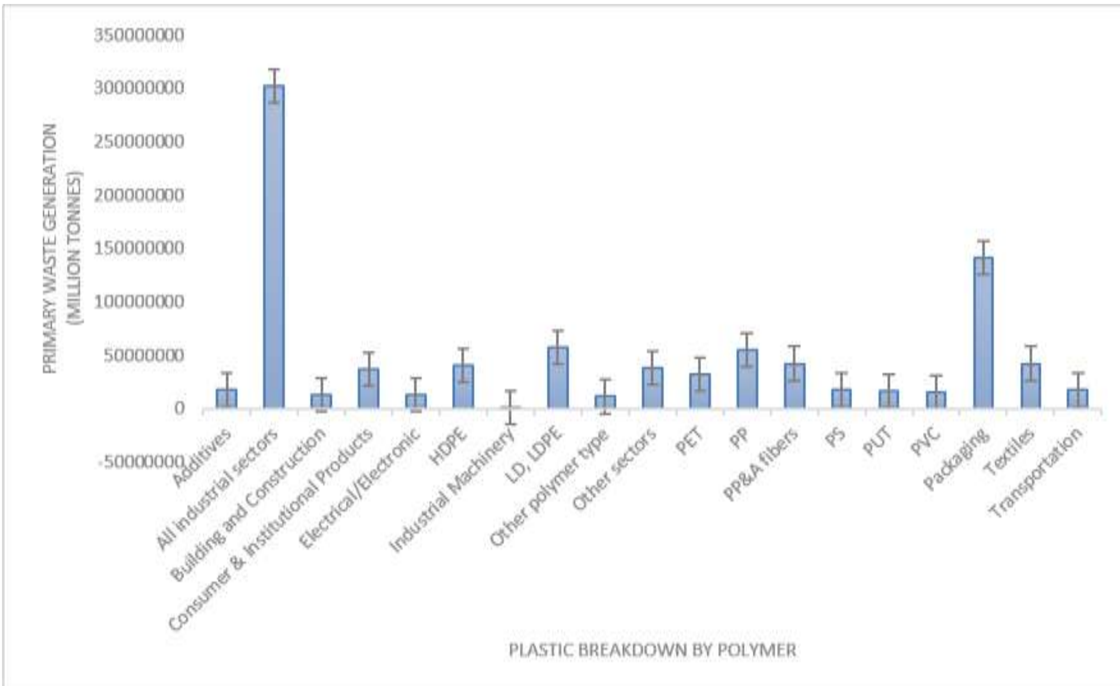

Fig. 1. The global plastic waste production in 2015 (Kershaw, 2011)

Plastics can be disposed of in sanitary landfills or in dump sites or the local habitat if they are not managed. Roughly 2500 metric tonnes of plastics are now in use, accounting for over 30% of all plastics manufactured between 1950 and 2050. 800 million tonnes (12%) of the 8,300 million tonnes of recovered plastic trash produced were burnt, and 600 million tonnes (9%) were recycled. Remarkably, 10% of this salvaged material was recycled once again. Figure 2 illustrates that more than 60% of all plastic produced is thrown away, with 4900 Mt ending up in landfills and the environment. From this discarded volume of plastic waste 600 Mt were PP&A fibres (Roland et al., 2017)

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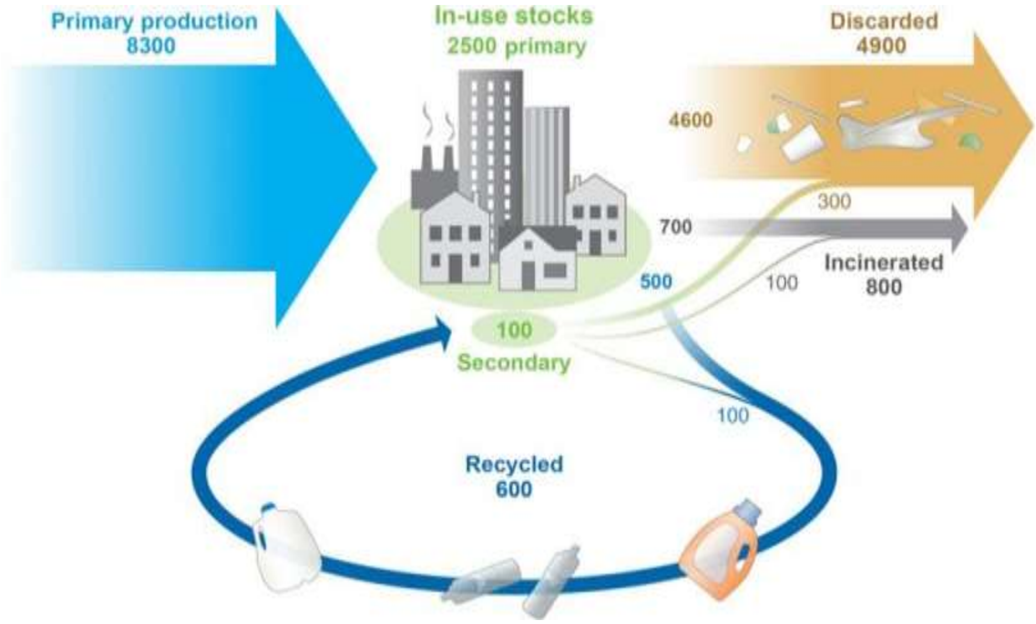

Fig. 2. 7,800 million metric tonnes of polymer resins, artificial fibres, and compounds were produced, used, and disposed of globally between 1950 and 2015 (Geyer et al. 2017).

Batayneh et al. (2007) investigated the influence of soil plasticity on concrete's workability. A concrete mixture that contained up to 20% microscopic particles was created in order to partially replace fine aggregates. The study's results showed that when the plastic particle concentration increased, the study's results fell. Utilizing 0% plastic particles and a 20% replacement resulted in a significant decrease in concrete slump to 25% of its original state. The study examined the generation of PPP waste from MSW following ASTM D5231-92-2016 and evaluated the physico-mechanical characteristics of concrete utilizing recycled PPP in accordance with ACI 213-2014.

II. MATERIALS AND METHOD

Materials

a) Materials for concrete cube casting

Lafarge Powermax Premium Technical Portland limestone cement (42.5N) was used which conforms to NIS 444–1 (2014). The sand underwent a meticulous cleaning process to eliminate clay and other impurities, followed by a three-day air-drying period to eliminate moisture. This rigorous preparation ensured that the sand met the stringent requirements of BS EN 12620 (2014). The coarse aggregate which consisted of granite for the concrete was supplied by a quarry located in Alabata, Ogun State, Nigeria, which had a maximum size of 12 mm that passed through 14mm sieve, which conformed to BS EN 12620 (2014). Polypropylene plastic (PPP), which is medicine prescription waste polypropylene plastic bottle was obtained from Funaab health centre. The particles were irregularly shaped and ranged in size from 2 to 5 millimetres, which allowed them to pass through a 4.75 millimetre mesh sieve. Impurity-free fresh water obtained from the Civil Engineering department at FUNAAB was employed for the mixing and curing of the concrete to ensure optimal results.

b) Materials for wastes characterization

The materials and equipment utilized for the task included sorting containers, a sorting platform, waste collection bags, a digital hanging weighing scale, and personal protective equipment (PPE) consisting of hand gloves, a face mask, and a laboratory cloth. The sorted wastes were weighed in batches with a digital hanging weighing scale. The process of waste collection and separation is shown in Figs. 3 (a)-(d).

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Fig. 3: Waste collection and separation process (a) Samples of waste collected and separated, (b) Sorting containers, (c) Sorting platforms and (d) Digital hanging weighing scale.

Method

a) Crushed plastics preparation

The medicine prescription waste polypropylene plastic bottles in Fig. 4a were obtained from the FUNAAB health centre and taken to the crushing factory at Ijebu Ode where it was sorted out into various grades. The sorted PPP material was fed into the mechanical waste plastic crusher (Fig. 4b), which pulverised the PPP into granules (Fig. 4c). The Pulverized granules were collected at the bottom chamber of a 10-horsepower high speed crusher. The pulverised material was then passed into water to remove contaminants and harmful materials such as sand and small pebbles which were collected at the bottom of the tank. The pulverised material, which floated on water, was scooped off. The material was then sun dried for 3 days. A 4.75 mm sieve was used to separate the dried powdered PPP material into various particle sizes. The sieved materials were then individually packaged and sealed in plastic bags for transportation back to the FUNAAB laboratory.

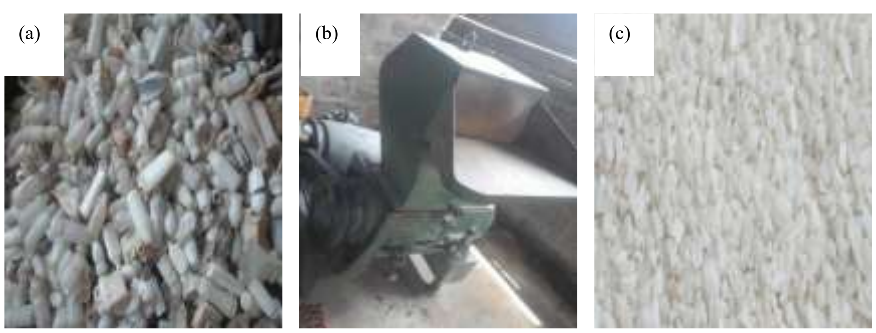

Fig. 4. Crushed plastic preparation includes (a). Polypropylene plastic prescription medical bottles before pulverisation, (b) crushed PPP with Waste plastic crusher and (c) granulated polypropylene plastic particles

b) Waste Characterization

The amount of sorting samples needed to reach the appropriate degree of data accuracy was determined in accordance with ASTM D5231-92-2016 using Eqn 1. The collected waste samples were sorted into four (4) waste categories, which were infectious waste, general waste (paper, plastic films, polypropylene plastic bottles medical prescription bottle, food scraps) chemical waste and radioactive waste categories. The mass fraction of each waste category was obtained using Equation 2, Equation 3 and Equation 4.

$$n = \left[\frac{t^{*}.s}{e.\bar{X}}\right]^2 \qquad 1$$

where,
n = sorting sample quantity
s = estimated standard deviation
e = precision level desired
X¯= estimation of the mean
t* = the t-statistic corresponding to the specified level of certainty of the student

$$W_i = W_g - W_t \qquad 2$$

$$mf_i = \frac{W_i}{\sum_{i=1}^{j} W_i} \qquad 3$$

$$P_i = mf_i \times 100 \qquad 4$$

where,
Wg = gross weight of container and individual waste component
Wt = tare weight of container
Wi = weight of individual waste component

mfi = the relative amount of each waste component in the overall waste composition
Pi = the fractional part of the total waste mass contributed by each individual waste component
j = number of waste components.

c) Batching of test samples

The batching by weight approach was utilized, and five batches were prepared, one for each of the five replacement levels. PPP granules were partially incorporated in place of sand in the concrete mixture at 0, 2.5, 5.0, 7.5, and 10%, denoted as PPP0, PPP2.5, PPP5, PPP7.5, and PPP10. For each of the five batches, one cube, one cylinder and one beam specimen were cast and tested at each of the three curing ages (7, 21 and 28 days), giving a total of 5 replacement levels x 3 specimen types x 3 curing ages = 45 specimens, consistent with the total reported in the Abstract. [Author to confirm: as currently described this design provides a single specimen per replacement level, specimen type and curing age, with no true replicates; if additional duplicate specimens were in fact cast and averaged, please state the actual replicate count here and in Table V/Figs. 9-11, since replicate data are needed to support the statistical analysis requested elsewhere in this review.] A 0.55 water/cement ratio was used for a 1:2:4 cement: sand: granite mix proportion in order to reach the desired compressive strength of 25 MPa for the concrete. Table II displays the proportions of each sample that were combined by mass.

Table II: Proportions of batch mixing for PPP concrete substitute

% Replacement	Cement (Kg)	Sand (Kg)	Granite (Kg)	PPP (Kg)
0.00	4.75	9.50	19.00	0.00
2.50	4.75	9.27	19.00	0.24
5.00	4.75	9.03	19.00	0.48
7.50	4.75	8.79	19.00	0.71
10.00	4.75	8.55	19.00	0.95

Test of Materials

The specific gravity of sand and PPP was determined using BS 1377–2 (1990). The density determination was performed adhering to the guidelines specified in British Standard EN 12350–6: (2009). The slump test was conducted in accordance with British Standard EN 12350–2, 2000. The calculation of the compaction factor followed (BS 1881, 2001). Following the guidelines established by BS EN 12390-3, 2009, the compressive strength testing was carried out in the Concrete Laboratory of the Department of Civil Engineering at FUNAAB utilising the 600 kN power Zhejiang Tugong Universal Testing Machine, as shown in Fig. 5a. As illustrated in Fig. 5b, the split tensile force of cylinder shape having dimension sizes of 100 mm in diameter and 300 mm in length was assessed in accordance with the recommendations specified in BS EN 12390-6: 2019. The beam specimen underwent flexural strength testing for PPP0, PPP2.5, PPP5, PPP7.5, and PPP10, as depicted in Fig. 6c. in accordance with the 2019 edition of BS

EN 12390-5. The one-point loading test approach was used to examine the flexural behaviour of beams measuring 150 mm by 150 mm by 750 mm.

Fig. 5. The mechanical test includes (a). Hardened cube concrete tested by a Universal testing machine, (b) Hardened cylindrical concrete tested by a Universal testing machine, and (c) Hardened reinforced concrete beam tested by a Universal testing machine

III. RESULTS AND DISCUSSIONS

Waste Characterization Result

The overall waste characterization data as shown in Fig. 6 revealed that general wastes comprising food, PPP, paper, plastic films, which was the most generated waste component, had a rate of 4.45kg/day (75%). Infectious wastes comprising wastes from surgery on patients, tissues exposed to blood or other bodily fluids, materials and instruments that had contact with an infectious person's excreta had a rate of 0.8913kg/day (15%). Chemical wastes that comprised wastes from laboratory reagents, film developer, expired disinfectants, solvents had a rate of 0.2971kg/day (5%). Radioactive waste, including metal wastes, which comprised batteries, broken thermometers, unused liquids from radiotherapy, unused liquids from patients treated or tested with open radionuclides, polluted glassware, soaked paper, urine, or excreta had a rate of 0.2971kg/day (5%). General waste was further broken down to 43% food waste, 21% plastics, 12% paper/cardboard, 5% liquids, 4% textiles, 2% glass, 1% metals and 12% others. The 21% plastics fraction was sorted further and confirmed to consist entirely of PPP medicine-prescription bottles. The overall waste characterization results collated from the FUNAAB health center revealed that 0.9345 kg/day of PPP was generated from an overall daily general waste rate of 4.45kg/day (75% total waste generated).

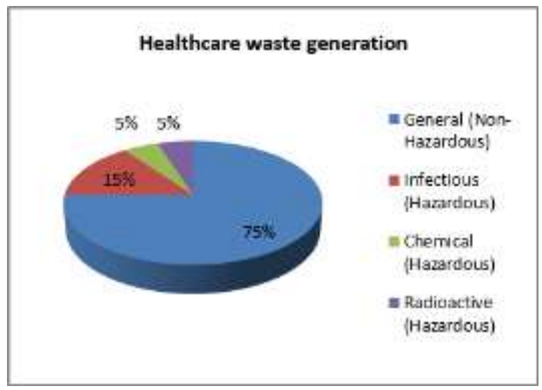

Fig. 6. Overall waste components generated from FUNAAB health centre.

3.1 Physical Tests

a) Specific gravity result

Table III: Specific gravity of cement, sand, PPP granules and granite.

Properties	Cement	Sand	PPP granules	Granite
Specific Gravity	3.14	2.6	0.97	2.7

Sand has a specific gravity of 2.6, whereas recycled polypropylene waste has a specific gravity of 0.97, which is far less dense than sand shown in Table III revealed that recycled Polypropylene waste was lighter than the sand, when sand (fine aggregate) was partially substituted with recycled plastic, the resulting concrete was lighter (polypropylene).

Table IV: Quantifying the mass of material per cubic metre of concrete mixture.

Materials (PPP)	Mix Ratio	EMC	Specific Gravity	MVM	MM
2.50%	0.025	1.25	0.97	0.001 m^3	8.1 kg/m^3
5%	0.05	2.5	0.97	0.003 m^3	16.2 kg/m^3
7.50%	0.075	3.75	0.97	0.004 m^3	24.4 kg/m^3
10%	0.1	5	0.97	0.005 m^3	32.5 kg/m^3

EMC = Equivalent Mass of cement 50kg Per bag MVM = Materials Volume of materials per m3 of concrete
MM = Mass of Material per m3 of concrete

A PPP mass requirement of 8.1, 16.2, 24.4 and 32.5 kilograms per cubic metre of concrete mix corresponds to a fine aggregate (sand) replacement of 2.5%, 5.0%, 7.5% and 10% respectively, as shown in Table IV. This means that for the daily waste generation of 0.9345 kg/day for PPP from an overall daily general waste rate of 4.45 kg/day in Funaab health centre, it will take approximately 9, 17, 26 and 34 days to accumulate enough PPP waste (8.1, 16.2, 24.4 and 32.5 kg respectively) to produce one cubic metre of concrete at each of these sand replacement levels, given a PPP mass requirement of 8.1, 16.2, 24.4 and 32.5 kg/m3 of concrete mix, at sand replacement levels of 2.5, 5, 7.5 and 10% with PPP respectively.

b) Slump test

Fig. 7. Slump value against percentage of sand replacement with polypropylene in concrete

Figure 7 shows a decreasing trend in the slump value as the percentage of PPP waste in the concrete mix increases. Due to decreased adhesion between the concrete's components, the handling qualities of the concrete deteriorated as the percentage of fine aggregate substituted by PPP waste rose. However, the concrete mix with PPP2.5 was very workable at the same water cement ratio with PPP0. PPP5, PPP7.5 and PPP10 were reasonably workable. These findings indicate that concrete mixtures with a higher percentage of recycled PPP waste necessitate increased water content to achieve adequate workability and flow properties. The results of Gideon et al. (2021), Coppola et al. (2016), and Manjunath (2016), who saw a decline in workability with increasing PET percentages and curing age, are consistent with this conclusion. The result agrees with Aulia (2002) because the introduction of polypropylene fibres accelerated the time to the first and final set time of the concrete and resulted in a slower rate of drying in the concrete as the rate of bleeding reduced.

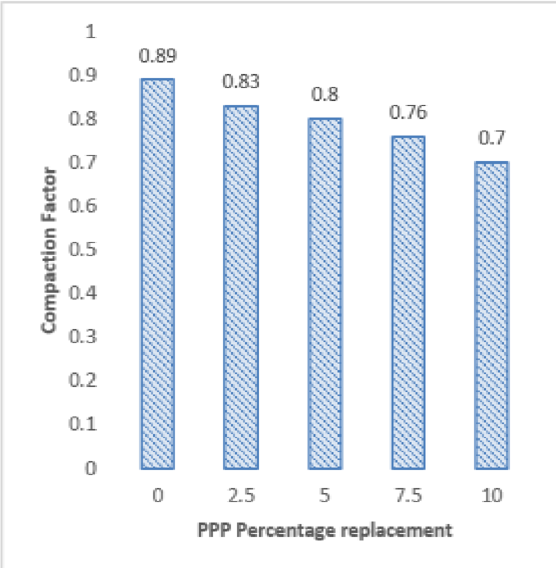

Fig. 8. Compaction factor result for polypropylene mixed concrete

As shown in Fig. 8, the amount of compaction factor declined dramatically as the quantity of PPP in the concrete blend increased. The concrete became less workable as the percentage of PPP sand replaced increased, indicating that the concrete's other components had not been properly incorporated. The slump test findings were supplemented by the compaction factor data, which showed that at 2.5 percent replacement, the concrete mixture achieved the desired workability with the same water-to-cement ratio as the reference specimen, and it was reasonably workable at 5 percent, 7.5 percent, and 10 percent replacement. Consequently, concrete mixes with a higher proportion of reprocessed plastics demanded increased water content to attain satisfactory workability and flow properties. The findings here corresponded with those of (Turkeswari et al., 2021; Rayed et al., 2021; Sifatullah et al., 2020), who found a decrease in workability when the various PET percentages rose with curing age. Previous research done by the following researchers (Rai et al. 2012; Khajuria and Sharma 2019; Gawatre, et al., 2015) showed that adding plastic aggregate to concrete mixes reduced the workability of the concrete.

c) Density Test

Table V: Calculated density for polypropylene mixed concrete cubes

Percentage Replacement	Average weight (kg) 7 days	Density (kg/m^3) 7 days	Average weight (kg) 21 days	Density (kg/m3) 21 days	Average weight (kg) 28 days	Density (kg/m3) 28 days
0	2.59	2590	2.64	2640	2.7	2700
2.5	2.52	2520	2.56	2560	2.65	2650
5	2.49	2490	2.53	2530	2.6	2600
7.5	2.44	2440	2.5	2500	2.56	2560
10	2.33	2330	2.48	2480	2.5	2500

The data presented in Table V indicates that concrete density exhibited a declining trend as the substitution of sand with polypropylene increased. For 2.5 percent sand replacement with polypropylene, there was a 50 kg/m3 drop in density relative to the control, a 100 kg/m3 significant decrease for 5% replacement, a 140 kg/m3 significant decrease for 7.5 percent replacement, and a 200 kg/m3 significant decrease for 10 percent replacement. This finding shows that substituting sand (fine aggregate) with recycled polypropylene produces a modest reduction in concrete density. However, the resulting densities

(2500-2700 kg/m3) remain well within the normal-weight concrete range and do not approach the equilibrium density of roughly 1840-1920 kg/m3 or below that ACI 213 (2014) specifies for structural lightweight concrete; the mixes investigated here are therefore best classified as normal-weight concrete with a modest density reduction rather than as lightweight concrete. Density reductions of a similar order have been seen in other plastic-modified concretes, such as PET and ethylene-vinyl acetate concrete (Rayed et al., 2021; Gideon et al., 2021).

Mechanical Tests

a) Compressive Strength

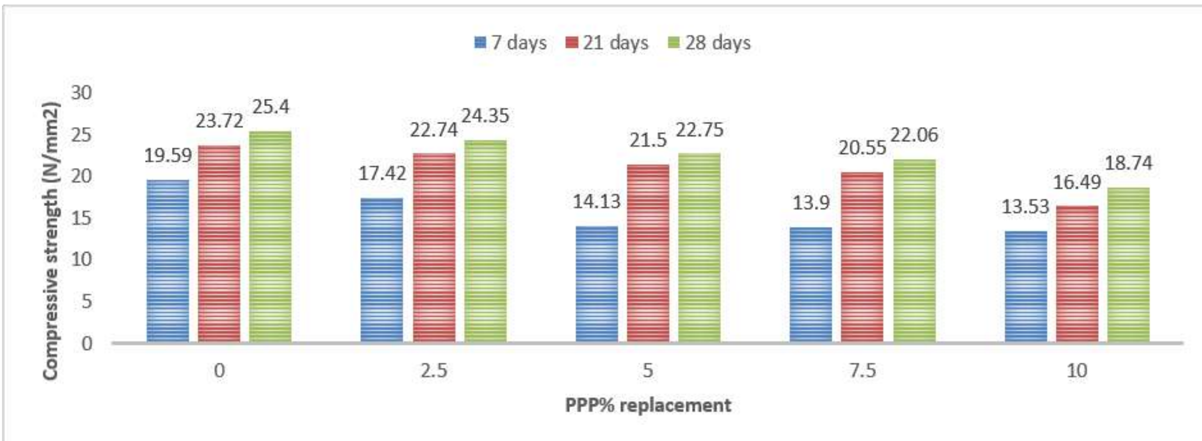

Fig. 9. Impact of PPP replacement level and curing time on concrete compressive strength

At 28 days, the compressive strength of concrete mixtures with 2.5, 5, 7.5, and 10% PPP replacement, respectively, reached 24.35 MPa, 22.75 MPa, 22.06 MPa, and 18.74 MPa, as shown in Figure 9. The results obtained from larger percentage replacements were lower than the results obtained from 0% sand substitution with recycled polypropylene, which was the standard concrete blend (control) with 25.4 MPa. The substitution of sand with polypropylene resulted in a decline in compressive strength at all curing stages, while an increase in strength was observed with increasing curing duration. From the results, the strength at all percentage replacements exceeded 17.24 MPa, the minimum compressive strength that ACI 213 (2014) specifies for structural-grade concrete within its 17.24-41.36 MPa structural strength range; since the measured densities (Table V) remain in the normal-weight range, this comparison benchmarks the mixes against ACI 213's strength criterion rather than classifying them as structural lightweight concrete. The PPP blend achieved a compressive strength decline of 4% on the 28th day with the 2.5 PPP% replacement mix. As illustrated in Figure 9, the compressive strength tests conducted on concrete samples containing varying PPP percentages, ranging from 2.5% to 10%, revealed that the addition of 2.5% PPP resulted in a decrease in compressive strength compared to the control mix with 0% PPP. Mehta and Monteiro (2014) stated that other scholars have suggested that the occurrence of van der Waals interactions is responsible for the strength of solidified materials. This refers to physical forces causing adhesion between two solid surfaces, with the amount and character of the adhesive activity governed by the size and type of the surfaces. These Portland cement hydration products adhere firmly to materials with low surface area, including fine and coarse aggregate particles, anhydrous clinker grains, and calcium hydroxide. In the presence of van der Waals forces of attraction, age-related increases in compressive strength are common. The outcome was in line with studies by Albano et al. (2009) and Rayed et al. (2021) that found that adding PET reduced the bonding and compressive strength of PET additions.

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b) Split-tensile Strength

Fig. 10. Split-tensile strength of concrete mix with increasing concentrations of PPP during various curing days.

When recycled polypropylene was added to 2.5, 5, 7.5, and 10% of the sand, respectively, the Split tensile strength decreased to 2.06 MPa, 1.97 MPa, 1.92 MPa, and 1.72 MPa at 28 days (Fig. 10). These were lower in strength compared to conventional concrete blend (control) with a strength value of 2.12 MPa. The results showed that at all curing ages, the inclusion of polypropylene, which was employed in place of sand, decreased the Split tensile strength, whereas the strength increased with the number of days. From 7 days to 28 days, the strength grew practically linearly, indicating that the cement had reached a significant degree of hydration (BS 8110 1985). The decrease in ultimate split tensile strength is consistent with the findings of Khaloo et al (2008), due to a reduction in the adhesive strength between the polypropylene plastic granules' surface and the cement paste (Govind and Purnanand 2022; Sifatullah et al., 2020). The result agreed with Islam and Shahjalal (2021) who stated that the strength initially surged at initial percentage replacement and later reduced as the percentage replacement increased this was because PP is a flexible material with a weak elastic modulus, therefore it can't withstand a lot of force. Furthermore, due to PPA's hydrophobic nature, a substantial amount of free water collects around the transition zone, weakening it, resulting in poorer strength of concrete for increased PP content percentages.

c) Flexural Strength

Fig. 11. Flexural strength of concrete mix with increasing percentages of PPP during various curing days.

The flexural strength rose as the age of curing increased for all % substitutions of polypropylene with fine aggregate, as shown in Fig. 11. PPP2.5, PPP5, PPP7.5, and PPP10 had values of 3.45 MPa, 3.34 MPa, 3.29 MPa, and 3.03 MPa at 28 days, respectively. These were lower in strength compared to conventional concrete mix (control) of 3.53 MPa at PPP0. The flexural strength dropped with the substitution of sand with polypropylene at all curing ages, whereas the strength rose as the number of curing days increased, according to the results. This finding is in consistent with the report of (Togay et al., 2017; Lucolano et al 2013; Ferreira et al., 2012; Sifatullah et al., 2020), who found that as the replacement amount of waste plastic aggregates in concrete rose, flexural strength decreased.

IV. CONCLUSION

This study looked at the effects of replacing sand with PPP, and the relevant conclusions were drawn from the studies:

i. As the amount of PPP grew, compaction factor value, the slump and density reduced.
ii. Concrete with 2.5 percent PPP had stronger compressive, split tensile, and flexural strengths, as well as better bonding within aggregate particles than concrete containing higher percentages of PPP.
iii. The health center waste source had general waste as the highest generation rate of waste generated daily with a mean rate of 4.45kg/day which was 75% of the overall mean waste generation rate.
iv. The partial substitution of fine aggregate with polypropylene, up to 10% replacement, produced a normal-weight concrete with a modest density reduction that met the 17.24 MPa minimum compressive strength ACI 213 (2014) specifies for structural-grade concrete, demonstrating favorable potential as a substitute material for structural components.

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