

Potential of Recycled Biaxially Oriented Polypropylene Pellets as Fine Aggregates for Concrete

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ABSTRACT – Plastic waste aggregates (PWA) are replacing aggregates in civil engineering projects. Waste in concrete has environmental and economic benefits. This study investigates the method of substituting aggregate for a workable concrete mix. It may be a greener option for concrete manufacturing and aggregate use in construction. This study used hand-mixing to prepare M20 mix concrete using hybrid fine aggregates. The recycled BOPP pellets to sand ratio were varied at 10:90 and 0:100. The slump value and compressive strength (CS) of the concrete block were compared with the one prepared with 100% sand to determine the workability and strength of the concrete. The workability and compressive strength of the concrete were reduced with the addition of BOPP aggregates. Yet, the slump higher than 20 mm and CS of ~26 MPa showed promising application for M20 concrete. Camera images supported the results.

1. INTRODUCTION

Construction, the largest industry in many countries and the largest consumer of raw materials, is a prospective sector where Plastic Waste (PW) might be beneficially employed for various uses. PW is a versatile material that may be used as an aggregate in cementitious and asphalt mixtures, filler, insulation, and other civil building materials. Despite its enormous potential for building construction, PW's use and development are currently entirely limited [1]. PW must, however, fulfil the application's mechanical and durability standards to be employed in construction. In addition to being a useful construction material, PW should be affordable and sustainable to promote its use over other materials [1]. Several studies have been conducted on plastic aggregate use as a sand substitute in conventional concrete in recent decades [2-4]. They have demonstrated their potential to improve concrete qualities such as flexural strength, flexibility, density, and heat resistance [3]. PWA is typically inferior to concrete's compressive strength and modulus E (Fc). It

was claimed that the quantity of PWA decreased the modulus, E. When the sand was replaced with polyethylene terephthalate (PET) aggregates at 7.5 percent volume, E was reduced by 13–31 percent in mixtures. This condition is expected because PET aggregates have a far lower E value than normal mineral aggregates [4]. As stated by a study conducted by Almeshal et al. [3], the most often used plastic aggregates in concrete are polyvinyl chloride (PVC), polyethylene terephthalate (PET), polystyrene (PS), and low-density polyethylene (LDPE). However, there has been little investigation into the potential of PWA of biaxially-oriented polypropylene (BOPP) as a building aggregate. As a result, this project will focus on using recycled BOPP (rBOPP) as fine aggregates in the M20 concrete mix.

2. METHODOLOGY

M20 concrete mixes, according to Table 1 were hand-mixed. The sand was laid on the platform, and cement was poured over it. In a dry condition, the sand and cement are thoroughly mixed with shovels numerous times until the material achieves an equal colour and is streak-free. The calculated amount of coarse aggregates, together with the rBOPP, was placed in a homogeneous layer on top of the mixture and well-mixed. 75% water was poured into the depression and stirred using shovels. Finally, the remaining water was added, and the mixing procedure was repeated until the concrete had a consistent colour. The overall duration for concrete mixing should not exceed 3 minutes. The slump test measured concrete consistency and fluidity and indicated a more workable concrete mix with high water content following the BS1881:part 102 specifications. Then, the fresh concrete mix was filled in 100x100 cm mould and repeatedly rammed to produce a homogenous cube. After condition and curing in water (Figure 2), the cubes were tested for 7, 14 and 28 days of compressive strength following B.S. EN 2390-3:2019. The compression test was performed at room

temperature using a Hydraulic Press Compression Machine. The fractured concrete mixes were investigated using the OM analysis to determine the aggregate distribution in the concrete mix.

Table 1 Formulation of M20 concretes

Ingredients	M20-NA	M20 -rBOPP
Cement (ratio)	1	1
Water (ratio)	0.5	0.5
Coarse Aggregates	3	3
Fine Aggregates (ratio)		
Sand or Natural Aggregates (wt%)	100	90
Recycled BOPP (wt%)	0	10

3. RESULTS & DISCUSSION

Figure 1 (a) compares the workability between concretes reinforced by natural aggregates (sample M20-NA) and those partially reinforced by recycled BOPP (Sample M20-rBOPP). The relative ease or difficulty of laying and solidifying concrete is referred to as workability. The acceptable slump based on BS 1881:part 102 is 20-100 mm.

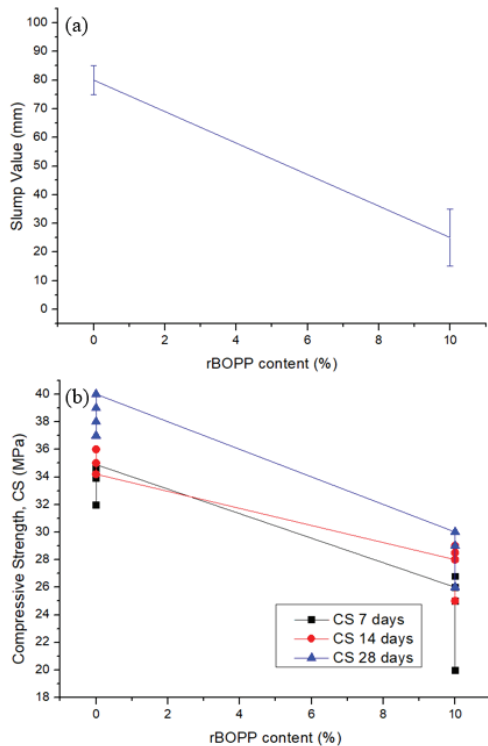


Figure 1 Slump value and compressive strength of the M20 concrete mixtures.

Figure 1(a) shows that the M20-NA showed acceptable workability, whereas the M20-rBOPP showed otherwise. The sample's average slump value falls within the acceptable range, but the produced mixture may have less stability and easily collapse during construction. It could be due to the non-hydrophilic surface of the r-BOPP aggregates and reduced interfacial transition zone. Figure 1 (b) shows the compressive strength of both M20 concretes of 7, 14 and 28 days. The concrete must have a minimum

compressive strength (CS) of 20 N/mm² or 20 MPa after 28 days. The graphs showed a similar pattern of reduction as the one observed in the slump value. The hydrophobic surfaces of rBOPP aggregates cause a thin water film to form over the aggregates, diminishing the M20-rBOPP strength compared to M20-NA. Still, the CS for the M20-rBOPP showed good values with an average higher than 20 MPa even at 7 days. The highest CS at 28 days could achieve 30 MPa. The limited hydrophilic surfaces of the rBOPP could be compensated by the homogenous sizes of the dispersed aggregates between the NA aggregates in the mixture hence giving sufficient CS to the concrete [3]. The fracture surface of the concrete is shown in Figure 2. The whitish rBOPP aggregates are dispersed between the natural aggregates in Figure 2(b).

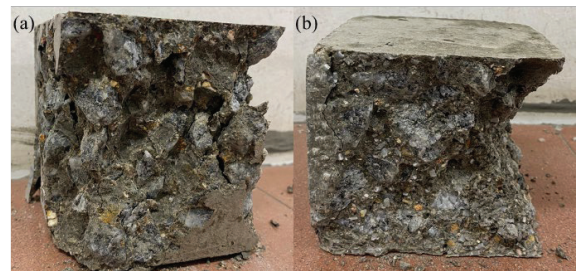


Figure 2 Fractured (a) M20-NA and (b) M20-rBOPP cubes

4. CONCLUSIONS

The workability and compressive strength test conducted on the M20 concrete cubes showed that rBOPP had the promising potential to partially replaced the natural aggregates in construction. The uniformity level of rBOPP aggregates in the concrete mixture influenced the CS values. Further modification to the rBOPP aggregate surfaces could improve their interaction with other elements, enhancing the mechanical properties and concrete's performance.

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