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Developing Concrete Materials from Waste Plastics

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ABSTRACT

The goal of this research was to look into the possibility of fiber reinforced Recycled Aggregate Concrete made from Recycled PET Bottles Waste (RPET) and Recycled Woven Plastic Sack Waste (RWS) (RAC). Construction and Demolition Trash (CDW) and plastic waste are fast increasing in volume and becoming a nuisance for many countries. The current study aims to reduce the amount of solid waste as a good waste management solution while also protecting the environment. On the basis of mechanical characteristics and concrete durability, the effects of RWS and RPET fibers on RAC were assessed. In alkaline settings, the experimental results showed that RPET and RWS fibers have a good alkali resistance. The use of Silica Fume (SF) and RPET fiber increased compressive strength by 3.6–9% and tensile strength by 11.8–20.3 percent tensile strength of splitting. The post-cracking behaviour of RAC was improved using RWS and RPET fiber. RPET fiber contributed more to the enhancement of RAC characteristics than RWS fiber, despite the fact that RWS fiber has a higher tensile strength than RPET fiber.

Keywords Mechanical characteristics, Shear strength, Silica Fume, Recycled aggregate concrete (RAC), Recycled woven plastic sack fiber (RWS), Recycled PET bottle fiber (RPET)

1.Introduction

Due to the amazing growth of the building sector in recent decades, annual concrete demand has risen to almost 15 billion tones, requiring approximately 20 billion tones of aggregate. Rapid urbanization, infrastructure decommissioning, wars, natural disasters, and human activities have all resulted in large amounts of construction and demolition waste. The increased use of CDW has negative consequences for the environment. CDW is expected to account for roughly 40% of global trash (Silva et al., 2014), which is becoming a burden for many countries and posing waste management issues (Tam et al., 2015). As a result, recycling CDW as a new aggregate source for concrete (specifically, recycled concrete aggregate (RCA)) is becoming increasingly popular. Because of its viability, as well as its environmental and economic benefits, it has gotten a lot of attention. Thousands of studies have demonstrated the feasibility of recycling CDW into concrete products (Li et al., 2017a, 2017b; Xuan et al., 2017). Recycled Aggregate Concrete (RAC) has lower mechanical and durability qualities than Natural Aggregate Concrete (NAC) (Bravo et al., 2017; Ho et al., 2018). Adding admixture, increasing the amount of cement, employing fiber, removing attached mortar, and reinforcing adherent mortar are only a few of the techniques that have been devised to improve the quality of RAC. Many approaches improved the compressive strength of RAC, making it equivalent to NAC (Pepe et al., 2016; Silva, 2016). Despite the increase in compressive strength, RAC's tensile strength has remained relatively unchanged in contrast to compressive strength. This is one of the hindrances to applying RAC to construction structures. Furthermore, concrete is a brittle, low-tensile-strength material, and RAC is even more brittle than NAC (Carneiro et al., 2014). Steel fibers can be used as a reinforcement dispersed throughout the cementitious matrix to improve the tensile strength of concrete. Concrete fibers can effectively reduce fracture formation and improve brittle characteristics (Yin et al., 2015) some circumstances, utilizing fibers in RAC improves concrete's tensile strength, modulus of elasticity, and toughness while also strengthening it (Ahmadi et al., 2017). (Silva et al., 2005). Steel fiber, glass fiber, natural fiber, and synthetic fiber are the four basic types of fibers that can be used to reinforce concrete (Yin et al., 2015). Plastic fibers are synthetic fibers like PP, HDPE, PET, nylon, PE, PVC, PVA, or hybrid fiber (a mix of plastic fiber and steel fiber) that can be used to replace steel fiber. Plastic fibers can be either newly made or recycled. Plastic material use has expanded fast over the world, from roughly 1.5 million tonnes in 1950 to around 322 million tonnes in 2015. PET is the most frequently used plastic and is found in food bottles, containers, and packages. Around half a trillion bottles are tossed each year; a million bottles are discarded every minute around the world, and this number is expected to rise by 20% by 2021. Unfortunately, PET bottles are discarded at a higher rate than they are recycled. Furthermore, the usage of woven plastic sacks for packaging industrial products, food preservation and distribution, and other things such as rice, wheat, pulses, tea, coffee, beans, peanuts, sugar, cement, fertilizers, urea, plastic, polymers, plastic pellets, and other items has constantly expanded. Littering, unlawful landfilling, and incineration of plastic trash such as PET bottles and woven plastic bags progressively lead to major environmental problems (Sharma and Bansal, 2016). Recycling PET bottle waste and woven plastic sack waste as fiber in concrete is one way to reduce the amount of plastic waste. Because of its environmental benefits, the use of recycled PET bottle fiber (RPET fiber) in NAC has been intriguing. The use of PET fiber reinforcing concrete is a noteworthy contribution to environmental sustainability because PET bottles take more than 100 years to totally decompose (Silva et al., 2005). PET fibers in cement mortar were reported to be alkali resistant by Ochi et al. (2007).

However, in an alkaline or sulfuric acid environment, the compressive strength of concrete reinforced with recycled PET fibers reduced. The compressive strength and elastic modulus of concrete containing recycled PET fiber decreased as the fiber content increased, but the ultimate strength and relative ductility of recycled PET fiber concrete beams were significantly higher than those without fiber PET bottle fibers reinforcing NAC could boost the ductility of concrete. Although the essential features of three RPET fiber reinforced NAC have been thoroughly investigated, few researchers have focused on the performance of RAC incorporating RPET fiber when using 100 percent coarse RCA.

Nonetheless, these researchers did not explore the use of mineral admixtures and mixing techniques to improve the characteristics of RAC, which had a significant impact on the performance of RAC containing RPET fiber. Meanwhile, the compression behaviour of RPET reinforced polymer concrete with 100% natural aggregate and 100% RCA revealed different failure causes (Jo et al., 2008). With the growing trend of using RAC for construction sites, it's important to look into the performance of RAC that contains RPET fiber and mineral admixture. Fiber reinforced concrete provides a bridge between broken surfaces, which is one of its benefits. In this work, the post-cracking performance of RAC reinforced with RPET fiber is taken into account. Polyethylene (PE) or Polypropylene (PP) are two types of woven plastic sacks that are resistant to alkali, acid, and degreasing agents. Weaved plastic bags' strength and durability make them reliable for confining and transporting a variety of commodities. In general, woven plastic sack garbage was collected, cleaned, and recycled in the same way that other types of plastic waste was. However, a simpler way of recycling it as fiber in concrete material could potentially replace this task. Carneiro et al. (2014) examined RAC reinforced with steel fiber using recycled steel fiber. The positive assessment of recycled woven plastic sack fiber (RWS fiber), enhanced RAC's performance capacity has received little attention. As a result, the current study suggests recycled woven plastic bag waste as a new type of fiber for RAC construction. Silica Fume (SF) has been shown to fill RCA fractures and convert Calcium Hydroxide (CH) into C-S-H gel in RAC (Kou et al., 2011) to improve RAC characteristics (Meyer, 2009). Furthermore, SF has been shown to control and counteract the alkali silica reaction to reduce concrete expansion over a lengthy period of field observations (Boddy et al., 2003). As a result, despite its higher cost than Portland cement, adopting SF to improve RAC performance is being actively investigated. SF improved the compressive strength of RAC by around 30.95 percent, with 15% SF by weight of cement replacing fine aggregate in RAC Katz (2004) used SF to create a coating on the surface of RCA, resulting in a 15 percent improvement in compressive strength 4 after 28 days. Bui et al. (2018) looked into the different percentages of SF (3, 5, and 7%) in RAC. When SF was coupled with sodium silicate in the treatment approach, the mechanical and durability qualities of RAC improved dramatically. has discovered that 5% SF in RAC combinations is more favourable to enhancing certain RAC features. In addition, modified concrete mixing procedures using SF for improving RAC performance have been developed, which coat a small coating of SF on the surface of RCA as a way to treat RCA to improve its performance strength and durability of RAC (Li et al., 2009; Tam et al., 2005; Tam and Tam, 2008, 2007). As a result, the purpose of this study is to see how the addition of 5% SF and the new mixing procedure affect RAC containing RPET and RWS fiber. The goal of this research is to reduce solid waste by recycling CDW as aggregate, recycling plastic waste as fiber, and adding silica fume to RAC as a mineral admixture. This study examines the mechanical and durability qualities of RAC reinforced with RPET or RWS fiber and 100 percent coarse RCA to help researchers better understand how RAC with RPET and RWS fiber performs at varying fiber contents. Silica fume is used in RAC mixtures to improve the qualities of the RAC while taking into account modified mixing techniques.

The toughness qualities of RAC including recycled fiber are used to evaluate the post-cracking behaviours. Furthermore, the study investigates the alkali resistance of RPET and RWS fiber in various alkaline solutions as well as in RAC.

2 MATERIALS

2.1 CEMENT AND SILICA FUME

Silica fume and cement JSW Company provided Portland cement type I. The cement has a density of 3.15 g/cm3. Table 1 shows the chemical composition of Portland cement and silica fume (SF) to maintain the specifications' integrity.

Table 2.1 Chemical composite of materials for concrete (%)

MATERIAL	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO
Cement	1.07	0.78	3.47	22.63	0.42	62.57
SF	1.13	1.11	3.04	94.05	0.92	0.31
NA	4.39	2.43	16.87	58.40	0.68	7.46
RAC	2.69	1.83	12.52	62.56	1.30	12.01

2.2 AGGREGATE

Natural coarse aggregate (NA) was obtained in the crushed stone quarry.

Table 2.2 Aggregate mixing

Compositions	% by weight
Old concrete, cement	90.4
PET Fine aggregate	6.2
Woven plastic	2.7
Powder Glass	1.5
Total	100

In Miyagi Prefecture, Japan, RCA formed from CDW of ancient concrete structures was delivered by a local recycling aggregate manufacturing plant and crushed by a mobile machine. A visual examination approach was used to assess the composition of RCA, which was reported Old concrete, mortar, and stone are the basic components of RCA. Table 2.2 shows that the results are consistent with previous findings on RCA components. Table 2.1 lists the chemical constituents of aggregate.

Table 2.3 Properties of natural aggregate and recycled concrete aggregate

Aggregate Properties	**Fine Aggregate**	**Natural Aggregate**	**RAC**
Relative density	2.67	2.83	2.41
Apparent relative density	2.78	2.91	2.64
Relative density oven-dry	2.61	2.79	2.27
Water absorption(%)	2.44	1.29	6.50

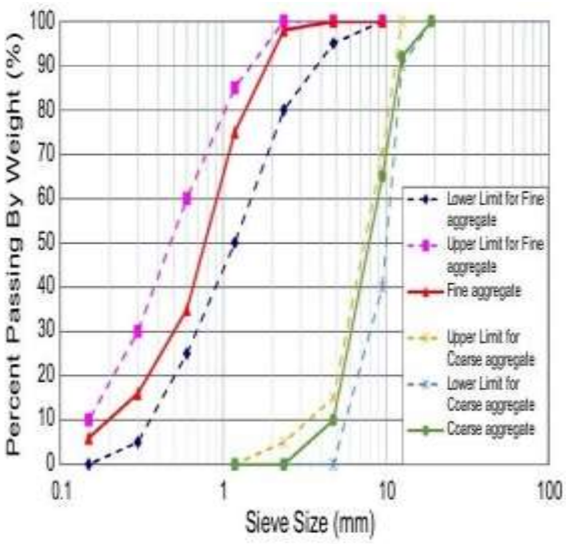


Figure 2.1(Gradation distribution of coarse and fine aggregate)

2.3 RECYCLED WOVEN PLASTIC SACK

Researchers investigated the potential performance of PET fibers made from PET bottles in order to lower fiber manufacturing costs. Before cutting, waste PET bottles and weaved plastic sacks were gathered and washed. Second, using a manual process in the laboratory, waste PET bottles and woven plastic bags were used to create fiber with the necessary diameters as shown in Fig. 2.2.

The nominal maximum aggregate size for both NA and RCA coarse aggregate gradations is 12.5 mm. Natural stone was crushed to make fine aggregate.

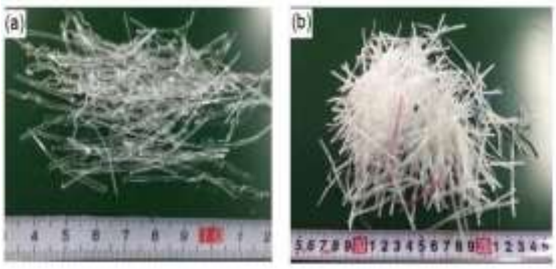


Figure 2.2 a) Recycled PET bottle fiber b) Recycled woven plastic sack fiber

The PET bottle was chopped into lengths of 50–60 mm and widths of 2–3.5 mm. The woven plastic bag was cut into 50–60 mm lengths and then separated to produce fiber with 2.5–3 mm widths. Because the woven plastic sack was weaved in two directions from many plastic threads or strands (warp and weft). At room temperature, the fibers were washed and dried. The physical and durability qualities of fibers in alkali conditions were determined before they were introduced to the concrete. $Ca(OH)_2$ solution (pH = 12.30), NaOH solution (pH = 13), and three different hydrated concrete solutions with pH values of 12.43, 12.61, and 12.79, respectively, were used to submerge the fibers in five distinct alkaline solutions fiber's tensile strength was measured before and after immersion at 28, 180 days.

2.4 MIXTURE DESIGN

For building types such as pavement, slabs, and substructure walls, the ACI 211.1 (reapproved 2009) standard is used to develop concrete mixtures for both NAC and RAC with a w/c ratio of 0.45 and the appropriate slump. These construction types have slump values ranging from 25 to 75 mm. Different volumes of RPET and RWS fiber were used to make the mixes. The concrete's intended compressive strength after 28 days was 30 MPa. During the proposed mixing technique, 5 percent silica fume was blended into the RAC mixture to coat RCA particles, which was determined depending on the amount of cement. The concrete mix proportions were represented in table 2.4.

Table 2.4 Mixing Proportion of RAC

Notation	Water	Cement	Coarse RAC
NAC	206.15	428.89	-
RAC	213.00	428.89	899.19
RAC-5SF	213.00	428.89	899.19
RAC-5SF-0.25WS	213.00	428.89	899.19
RAC-5SF-0.5WS	213.00	428.89	899.19
RAC-5SF-0.75WS	213.00	428.89	899.19
RAC-5SF-0.25PET	213.00	428.89	899.19
RAC-5SF-0.5PET	213.00	428.89	899.19
RAC-5SF-0.75PET	213.00	428.89	899.19

2.5 SPECIMEN PREPARATION

As shown in Fig. 5.3, this study provided a mixing process for RAC incorporating silica fume for the aim of filling pores and cracks with cementitious materials, resulting in a denser concrete structure and higher strength. Another purpose of the research was to see if the mixing technique might coat RCA with pozzolanic powder (silica fume) to improve the workability of fresh RAC. During the concrete mixing process, the water for concrete is separated into numerous sections and poured into the mixer at different periods. In the laboratory, the researchers mixed concrete with a small portable concrete mixer.

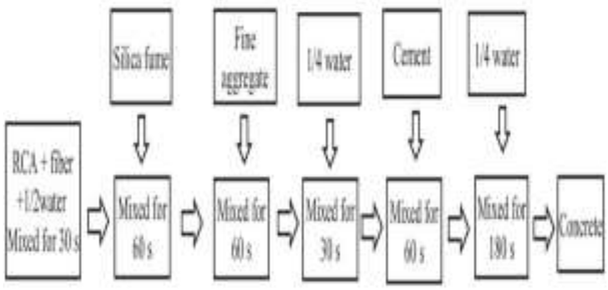


Figure 2.3. Mixing procedure of RAC containing fiber.

The slump apparatus was used to evaluate the slump of the fresh RAC before preparing specimens. The slump test results for RAC mixes were within 25–75 mm of the target value for slump. Concrete was poured into cylindrical steel moulds. According to the Japanese standard JSCE-G 553-2007, the beam-shaped specimens had diameters of 100 350 mm. In comparison to RWS fiber, RPET fiber performed better in RAC. Both RWS and RPET fibers increased the ductility and post-cracking behaviour of RAC. The splitting tensile strength of RAC was improved using RPET and RWS fibers. In comparison to RAC without fiber, the splitting tensile strength of RAC reinforced with RPET fiber increased by, while RWS fiber merely improved the splitting tensile strength of RAC.

3. PREPARATION OF SPECIMEN

3.1 COLLECTION OF MATERIALS

- Waste plastic materials (PET bottles) are collected from the department stores, garbage units and public places like bus stand etc.
- Construction and demolition waste (CDW) are collected from the building demolition sites.
- Woven plastic sacks are collected from the food distribution sites.

3.1 (a) PET BOTTLES

(b) WOVEN PLASTIC SACK

(c) CONSTRUCTION AND DEMOLITION MATERIAL

3.2 PROCEDURE FOR SPECIMEN PREPARATION

3.2.1 FIXING THE PROPORTION OF SAND AND PLASTIC

For the fabrication of concrete block PET plastic, Woven Plasic, silica fume are mixed in different proportions. PET plastic mixed in a ratio of 6.2, Woven sack plastic are mixed in a ratio of 1.5 and the old concrete which taken from domolisition area and cement mixed together in a ratio of 90.4. After the specimen preparation the blocks are gone to be tested after 28 days

Table 3.1 Mixing Proportions

Compositions	**% by weight**
Old concrete, cement	90.4
PET Fine aggregate	6.2
Woven sack plastic	1.5
Silica fume	1.2
Powder Glass	0.7
Total	100

3.2.2 PREPARATION OF MOULD

The mould is prepared by PVC pipe with the diameter is 70mm and the height of 300mm.

Its internally covered by the paper sheets and oil to produce the specimen with better surface finish. PVC will be cost effective and it serve the better surface finish.

3.2 (a) SPECIMEN WHILE PREPARING

(b) PREPARED SPECIMEN

3.3 TEST OF SPECIMEN

3.3.1 COMPRESSION STRENGTH TEST

In this test, the cylindrical block specimen is placed in the UTM. After placing it we fed the load on the blocks without any shock. The load will be gradually increased till the specimen's resistance the load and it breaks down when can't withstand any greater load further. Recording the maximum load applied to the specimen and the values are noted.

FORMULA

Compressive strength = Maximum load applied = F/A

Specimen area

Where, F-Maximum load applied (KN)

A-Specimen Area (mm2)

3.3.1.1 PLASTIC MIXED BLOCK CALCULATION

Load (P) = 65KN = 65*103N

Area = π/4(70) 2

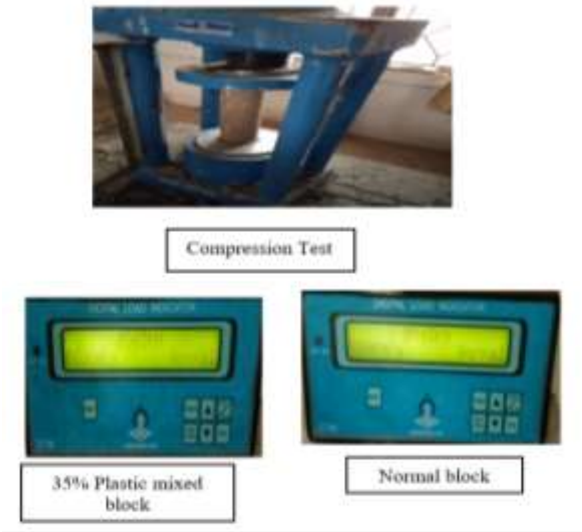
diameter(d) = 70mm

Area = 3.84*103

Compression strength = 65*103 /3.84*103 = 16.92 N/mm2 1N/mm2 = 10.197 kg/cm2

=16.92*10.192

Compression strength = 172.53 kg/cm2



3.3.2 SPILT TENSILE TEST

In this test, the cylindrical block specimen is placed in the UTM. After placing it we fed the load on the blocks without any shock. The load will be gradually increased till the specimen's resistance the load and it breaks down when can't withstand any greater load further. Recording the maximum load applied to the specimen and the values are noted.

3.3.2.1 FOR PLASTIC MIXED BLOCK

FORMULA

Split Tensile Test = 2P/ πLd

Load = P = 40 KN = 40*103 N

Length = L = 300mm

Diameter = d = 70mm

CALCULATION

Split Tensile Test = 2P πLd = 2*(57*103)= 1.72N/mm^2

Π*200*70

1N/mm2 = 10.197 kg/cm2

= 2.59*10.197

Split Tensile Test = 26.43 kg/cm2

Split tensile test

35% Plastic mixed block

Normal block

3.3.4 FIRE RESISTANCE TEST

The standard used for the test is BIS 3809 1979. The plastic alone is readily susceptible if not flammable to elevated temperatures and in case of fire, the sand and plastic mixture may withstand temperatures that plastics alone usually cannot. It has been observed that the structural integrity of the blocks holds very well up to 180°C. In this test we will first heat and maintain the block at the standard testing temperature in the furnace and then we will do the compressive strength test to check whether the properties change or not.

4. RESULT AND DISCUSSION

OVERALL RESULTS

PET bottles which are usually considered as waste can be used as Plastic mixed blocks. These blocks are light in weight, easy to make and provide greater durability as well as strength properties. Plastic blocks provide cost efficiency. Cheaper in comparison to the conventional blocks. Unit weight of the bottle blocks is also less than conventional blocks. Implementation of the study will not lead to give only low-cost housing but, also provide a better way reusing and managing the solid waste like PET bottles. We provide the quality blocks when compare to the conventional block and we prove that our different composites of plastic blocks are strong and withstand the tests we have taken and compare with conventional block. The test we are taken are compression strength test and Split tensile test that has been shown below with theoretically, tables and charts to explain it.

COMPRESSION STRENGTH RESULTS

The results we have got shows us the compression strength of this block is high when compared to the normal block. When compared to normal block may the weight of the brick are less when in turn will decrease the dead weight of the structure.

TEST	NORMAL BLOCKS N/mm^2	25% PLASTIC MIXED BLOCKS N/mm^2	35% PLASTIC MIXED BLOCKS N/mm^2
COMPRESSIVE TEST	12.5 N/mm^2	14.58 N/mm^2	16.92 N/mm^2

SPLIT TENSILE STRENGTH RESULTS

The results we have got shows us the split tensile strength of this block is high when compared to the normal block. When compared to normal block may the weight of the brick are less when in turn will decrease the dead weight of the structure.

TEST	NORMAL BLOCKS N/mm^2	25% PLASTIC MIXED BLOCKS N/mm^2	35% PLASTIC MIXED BLOCKS N/mm^2
SPLIT TENSILE TEST	1.181 N/mm^2	2.182 N/mm^2	2.591 N/mm^2

CONCLUSION

The impacts of recycled woven sack (RWS), recycled PET fiber (RPET) fiber, and Silica Fume (SF) on the mechanical characteristics and durability of recycle aggregate concrete (RAC) were investigated in this study.H. Dilbas, M. Simsek, et.al (2017) from this literature we identified that the combination of Silica Fume (SF) and RPET fiber increased the 3.6–9 % of compressive strength, 16.9–21.5% of elastic modulus, 11.8–20.3% of splitting tensile strength, 7–15% of shear strength of RAC in comparison with RAC samples without fiber. SF and the proposed mixture improved the mechanical properties.

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