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Experimental Comparison of Normal Plain Concrete and Recycled Aggregate Concrete Addition with Coconut Fiber and Chemrite-530 SP

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ABSTRACT

Concrete is a versatile and widely used construction material that has been in existence for centuries. Waste concrete comes from demolished concrete structures and has appeared as a worldwide challenge in recent years. Rather than disposing of waste concrete in landfills, it can be recycled and used for various purposes to protect natural resources and minimize environmental pollution. Managing waste has become important, because of an increase in the demand for natural resources as well as the amount of waste products produced during construction and demolition, both of which have exerted enormous pressure on the environment. Environmental studies that cover waste material recycling and reuse are becoming increasingly important today. Environmental pollution is thought to be best solved by using waste that was collected from demolished buildings, or natural resources, cleaned, and then reduced to aggregate form. Construction expenses are rising today, and the gradual influence on the environment has driven researchers to accept natural fibers, such as coconut fiber, for reinforcing concrete. Normal plain concrete cubes, cylinders, as well as coconut fiber cubes and cylinders were prepared. Coconut fibers are used at different ratios. A very small amount of admixtures called super-plasticizers is added to the concrete mix. As a result of their addition, the mixture becomes significantly more workable, and the water/cement ratio or even the amount of cement is lowered. Their performance is determined by the type of super-plasticizer SP used, the composition of the concrete mixture, the time of addition, and the temperature conditions at the time of mixing and concreting. The primary goal of the research study was to compare the characteristics of recycled concrete aggregate, RCA combined with natural Coconut fiber CF and SP Super plasticizer Chemrite-530 to those of Normal Plain Concrete under Compressive-Strength and Splitting-Tensile strength.

Keywords: concrete waste, demolition concrete, coconut fiber waste, super-plasticizer, compressive strength, tensile strength.

INTRODUCTION

The world's most manufactured material, concrete has an effect on the environment. In the modern era, there is no substitute for this content. Global waste production has significantly increased as a result of increased industrial activity. It has been observed by Günçan that the waste recycled aggregates increases the mechanical properties of concrete such as density, compressive strength, and modulus of elasticity. On the negative side, the toughness of concrete decreases with the increase in recycled aggregate (Günçan, 1995). Only a useful recycling process would make it possible to dispose of waste in an environmentally friendly manner, a challenging problem in the modern world. The authors propose that removing the debris from demolished buildings in order to obtain waste concrete aggregates (WCA) that can be used again in the production of concrete may well be a partial solution to environmental pollution (Topçu & Şengel, 2004).

An investigation was conducted to explore the feasibility of substituting natural coarse-aggregate with recycled concrete aggregate in structural concrete. The inquiry involved the process of crushing and grading concrete debris collected from multiple landfills and demolition sites in Cairo. The study utilized various aggregates, including natural sand, dolomite, and broken concretes from diverse sources (Wagih et al., 2013).

Another study by Kumar & Kesvan aimed to investigate the utilization of coconut fiber and coconut fiber ash in a concrete grade mix and evaluate the behavior of the resulting concrete matrix incorporating these coconut-based constituents. Compressive, tensile, and flexure properties of basic strength tests were examined. In the cement concrete mix, coconut fiber were added a rate of 5%, and coconut fiber ash at a rate of 15%. Sea water was included to the mixture in addition, and the mix's structural characteristics were determined. There appears to be a positive increase in the base strength properties of the mix with the addition of this coconut fiber and ash component, as well as an acceptable outcome when applied to the structure (Kumar & Kesavan, 2020).

Since coconut processing produces coconut fiber as a byproduct, it is relevant to this discussion. The mechanical, physical, and deformation characteristics of fiber reinforced concrete reinforced with coconut fibers, as well as the effects of the fiber percentage. Concrete was used to create the samples, and its compressive strength ranged from 40 to 50 MPa after 28-days, samples, and its compressive strength ranged from 40 to 50 MPa after 28 days. For compression and axial compression, the increase in mechanical indicators was 24% and 26%, respectively, and for tensile bending and axial tension, it was 42% and 43%. The maximum compression and tension strains increased by 46% and 51%, respectively. There was a 16% increase in the elastic modulus (Ahmad et al., 2020).

Waste coconut fiber, which is the byproduct of processing coconut fiber to make fiber, is typically just thrown away or burned. This waste still possesses fiber qualities with diameters ranging from 0.2 to 0.7 mm in the range of 5 to 7 cm. The goal of this study was to process waste to produce fiber for use as organic fiber in fiber-reinforced concrete. In the study, diameters of 0.32 mm, 0.35 mm, 0.37 mm, 0.49 mm, and 0.65 mm were used. Tensile strength was tested and the chemical composition was further examined. The findings indicated that cellulose, hemicellulose, and lignin make up the fiber's chemical composition (Delarue, 2017). In general, the recycled aggregate concrete with admixtures performed better mechanically than the reference mixes with a less active super-plasticizer or without admixtures. Therefore, it is asserted that if super-plasticizers are used to lower the water-cement ratio of the concrete, the mechanical performance of concrete made with fine recycled concrete aggregates can be as good as that of conventional concrete.

(Kanema et al., 2016) investigated the shrinkage behavior of new earth concrete that has been mixed with different volumes of recycled concrete aggregates (RCA). There were two preparation methods used: in situ (industrial) and laboratory (manual). A one-dimensional model was used to assess shrinkage, 2D image analysis approach. As RCA percentages increase, shrinkage decreases. Shrinkage is impacted by industrial vibration as well. Super-plasticizer is added to decrease the appearance of cracks without affecting overall shrinkage. To assess the effects of RCA, mechanical tests were conducted. The addition of RCA increases the compressive strength while maintaining bending tensile strength.

OBJECTIVES

The primary objectives of the research are as follows:

- investigate the qualities of demolished waste recycled aggregate concrete (RCA) reinforced with coconut fiber;
- distinguish between normal concrete and coconut fiber-reinforced concrete;
- reduce construction waste in landfills;
- produce environmentally friendly concrete from the waste of construction and natural sources.

MATERIALS

Concrete is made from the materials describe below.

Cement

The process of making portland cement involves fine-grinding portland clinkers with a small amount of gypsum to regulate the setting time. It possesses adhesive qualities as well as binding properties to connect the materials together. In this experimental program, Pakistan-based company BEST-WAY cement is used, and different tests were performed like Fineness modulus, Density of Cement, as well as Initial and final setting time of cement shown in Table 3 below.

Coarse aggregates and fine aggregates

Aggregate is the most important component of concrete. It provides the concrete body or form, reduce shrinkage, and also has economic consequences. Fine aggregates and coarse aggregates are the two kinds of aggregates. Coarse aggregates are those that are primarily held on the 4.75mm I.S. sieve, whereas fine aggregates flow through the 4.75mm sieve. Recycled aggregates are processed via a 10 mm and 20 mm I.S sieve in this study. Recycled concrete aggregate is acquired from the demolished concrete slab and concrete columns, as shown in Figure 1.

Coconut fibers

This experimental work includes processed coconut fiber. Fiber treatment eliminates dust particles and other impurities that have been left on the fiber to improve the surface of contacting between the fiber and the mix, leading to a stronger bond between the reinforcement and the concrete to reach maximal high strength. The fiber length is 50mm (5cm), shown in Figure 2, and properties are presented in Table 1.

Figure 1. Recycling of aggregate

Figure 2. Coconut fiber threads

CHEMRITE-530

High-performance concrete additive Chemrite-530 is used to maintain slump and reduce water content. For creating free-flowing concrete with substantial water reduction, Chemrite-530 is a very effective liquid super-plasticizer. Over an extended length of time, it offers excellent slump retention. It is utilized in pre-stressed concrete bridges, cantilever structures, walls, columns, and piers, as well as slabs and foundations. It is also used in pre-cast concrete parts. Increased workability makes pouring concrete easier. Less effort is needed for concrete to compact, which makes the concrete mix's cohesiveness better. This super-plasticizer is Sulfonated Naphthalene based polymer and brown liquid. Chemrite-530 complies with ASTM C949 type A, F, and G.

TEST ON MATERIALS

The creation of concrete specimens includes cubes and cylinders according to the ASTM Standard. Tests on the specimen were performed in a lab. Details about materials, such as cement, fine aggregate, and coarse aggregate are discussed in Table 2.

Test on ordinary portland cement

Various cement tests were undertaken and executed in the laboratory and the results are presented in Table 3.

Test on aggregates

The primary ingredient of concrete corresponds to aggregates. It comprises up to 70 to 80 percent of the entire volume of concrete as well as affects the qualities and properties of various concretes. Various properties of fine aggregate are shown in Table 4.

Table 1. Properties of coconut fiber threads

Sr. no.	Properties	Values
1	Length mm	50
2	Apparent density mg/m^3	1.42
3	Water absorption %	140

- Specific gravity test on the coarse and fine aggregate test.
- Bulk density test on the coarse and fine aggregate test.
- Sieve analysis on the coarse and fine aggregate test.

EXPERIMENTAL PROGRAM

Mix design

M15-grade concrete mix designs were intended and concrete cubes as well cylinders were prepared. Casting was done in the concrete lab using the ingredients and ratios determined by the mix design to create concrete. The coarse aggregate was crushed to the desired size and shape, and then the fine aggregate was placed as sand above the crushed coarse aggregate. Cement, sand, and aggregate mix design ratios for normal plain concrete were 1:2:4, respectively, with a water-cement (W/C) ratio of 0.5. The mix design for coconut fiber recycled aggregate reinforced concrete was the same as that for normal plain concrete, with the exception of the following changes. To make concrete workable, different lengths and contents of fibers were added, and water was gradually added to avoid bleeding. At the same time, the same mass of aggregates was deducted. All materials were taken mass of cement. All specimens were created, vibrated, and dried in a controlled environment in a wet chamber. The amount of cement was set at 300 kg/m^3, sand 450 kg/m^3 and coarse aggregate was 900 kg/m^3. SP containing

Table 2. Materials

Sr. no.	Materials	
1	Cement	Ordinary Portland cement
2	Fine aggregate	Fine sand which is passed through 4.75 mm sieve
3	Coarse aggregate	Aggregates which are passing through 10 mm and 20 mm sieve
4	Coconut fiber	Fiber washed with the length of 5 cm
5	Water	Drinking water Ph 7 value
6	Super-plasticizers	Chemrite-530 (brown liquid)

Table 3. OPC tests results

Sr. No.	Property	Values obtained
1	Initial-setting time	42 min
2	Final-setting time	485 min
3	Density	3.099 g/cc
4	Fineness	5.2%

Table 4. Properties of fine aggregates

Sr. No.	Properties (fine aggregate)	Values obtained
1	Specific gravity	2.78
2	Bulk density	1.69 g/cc
3	Fineness modulus	2.43

compositions comprised 3.5 kg/m^3 of SP. The coconut fiber strips were fully covered in coconut oil, precisely cut into 5 cm lengths, and sun-dried for around 24 hours. The mixture was then mixed, and a consistent color was formed. All ingredients were combined and water was added in accordance with the w/c ratio. The mix design used a water-cement ratio of 0.5 for concrete. To prevent bleeding, care must be kept in gradually adding water. The super-plasticizer (Chemrite-530) was added to the concrete to increase the setting time and make the concrete workable. It also reduces the shrinkage and cracks of concrete, In order to obtain good workability as shown in Figure 3.

Before pouring the concrete, the molds were oiled from the inside. To achieve the strength of cubes better poured the concrete in the cubes in three layers, each of which was compacted by 25 rod strokes as shown in figure 4. Total of 12 cubes and 12 cylinders of concrete including Normal and RAC were prepared according to the same procedure described above. The 3 cylinders and cubes consist of normal concrete and the remaining cubes were prepared at different ratios like 3%, 6%, and

Figure 3. Mixing of concrete

Figure 4. Casting of concrete

10% of Coconut fiber to the total weight of cement. Each ratio had a set of 3 cubes for the test.

RESULTS ANALYSIS

Slump test on concrete

This test method is used in the lab to figure out the slump. It measures a decrease in the height of concrete when the mold is lifted up. The Concrete workability was evaluated using the slump test. The results that were concrete included 2 inches (50 mm) fall in true slump shown in Figure 5.

Compression test on normal plain concrete

The mean value obtained from three readings was 14.06 N/mm^2 at 28 days strength. It is known as the compression strength test results of normal concrete, shown in Table 5 and Figure 6.

Compressive-strength of coconut fiber reinforced concrete

This volume of concrete has varied amounts of coconut fiber reinforcement 3%, 6%, and 10% added to the volume of concrete. However, low operability is noted when the fiber is added to the mixture. In order to create a concrete mixture with the appropriate operability, super-plasticizers were thus added to cement in various proportions. After 24 hours of casting, the cubes and cylinders were demolded and thoroughly cured in a curing tank for 14, 21, and 28 days. After 14, 21, and 28 days of curing, the cubes and cylinders were removed from the

Figure 5. Slump of concrete

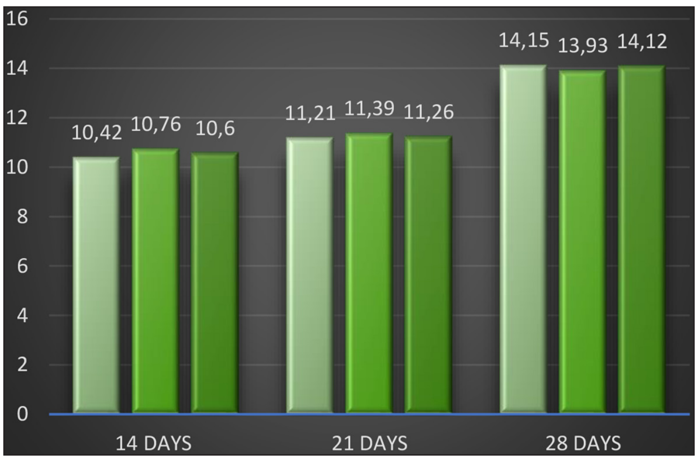

Figure 6. Compressive-strength of normal plain concrete

curing tank and left to dry for 24 hours for testing. The cubes were then tested in a 3000KN compressive testing machine. The compression testing equipment was manually adjusted to apply the loading at a rate of 250 KPa/s, while the area of the Cube was 22500 mm^2 (150×150×150 mm) shown in Figure 7. Three specimens from each group, the compressive strength of the cubes was determined according to the design mix and curing of cubes in the curing tank. The compressive strength was examined and the values obtained are shown in Table 6. Compressive strength at 14 days age 21 and 28 days, with 3, 6, and 10% of coconut fiber is shown in Tables 6, 7, and 8. The graphical representation of compression at 14, 21, and 28 days of

Table 5. Compression test result of normal plain concrete

Specimen	W/C Ratio	Slump height (mm)	14 days age curing result N/mm^2	21 days age curing result N/mm^2	28 days age curing result N/mm^2
1	0.5	15	10.42	11.21	14.15
2	0.5	20	10.76	11.39	13.93
3	0.5	50	10.60	11.26	14.12

Table 6. Compression test result of 3% coconut fiber and SP mix

Specimen	W/C Ratio	Slump height (mm)	% coconut fiber added	14 days age curing result N/mm^2	21 days age curing result N/mm^2	28 days age curing result N/mm^2
1	0.5	40	3	7.42	7.82	8.33
2	0.5	50	3	7.46	7.83	8.56
3	0.5	60	3	7.63	7.82	8.34

Table 7. Compression test result of 6% coconut fiber and SP mix

Specimen	W/C Ratio	Slump height (mm)	% coconut fiber added	14 days age curing result N/mm^2	21 days age curing result N/mm^2	28 days age curing result N/mm^2
1	0.5	40	6	6.83	6.45	6.98
2	0.5	50	6	6.83	6.76	7.09
3	0.5	60	6	6.56	6.43	7.12

Figure 7. Compression testing cube failure

age curing is shown in Figures 8, 9, and 10. The compression strength is calculated by the following formula,

$$fc = \frac{P}{A} \quad (1)$$

where: P – compression load, A – area of Cube Specimen.

Split tensile test

The specimens were allowed to dry for 24 hours after being removed from the curing process before testing. The specimens of concrete were tested in the tensile machine at a load of 1.2 MPa/s. The size of cylinder specimens was 150mm diameter and 300 mm length of . The split-tensile strength of cylinders was evaluated on three specimens from each group. The experiment was carried out in accordance with ASTM C 496-86 shown in Figures 11 and 12.

$$fsplit = \frac{2p}{\pi DL} \quad (2)$$

where: P – compression load (KN), D – diameter of cylinder, L – length of cylinder.

Results of the split tensile test were shown in Table 9 with average values of 3%, 6%, and 10% of coconut fiber. A graphical re-presentation of split tensile strength between normal plain concrete is shown in Figure 14.

RESULTS

Compression strength test

Reinforced concrete is poured with 3%, 6%, and 10% of coconut fiber CF added in cement, to obtain the value and compressive strength of plain cement concrete. From Tables 6, 7, and 8 the trend is observed that when adding 3% of coconut fiber the maximum average compressive strength of concrete is 8.41 MPa at 28 days age, 6% coconut fiber average compressive strength at 28 days age is 7.063 MPa and 10% addition of fiber average compressive strength at 28 days age is 5.82 MPa. It was further observed that each specimen from a different group achieved maximum strength at 28 days of age. When additional fiber is added, pressure resistance values are substantially lower compared to normal plain concrete. The creation of transition zones causes a weak area around the fiber making the sample weak. The difference between plain concrete and fiber-added recycled aggregate concrete is shown in Figure 13.

Figure 8. Compression-strength of concrete cube specimen with 3% of Coconut fiber concrete

Figure 9. Compression-strength of concrete cube specimen with 6% of coconut fiber concrete

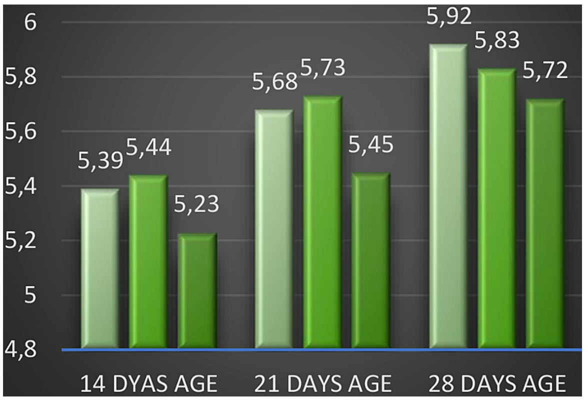

Figure 10. Compressive strength of concrete with 10% coconut fiber concrete

Split tensile strength test

The splitting tensile tests were carried out in accordance with ASTM C-496 and values are

Figure 11. Splitting tensile test on cylinder specimen

Figure 12. Splitting tensile test specimen failure

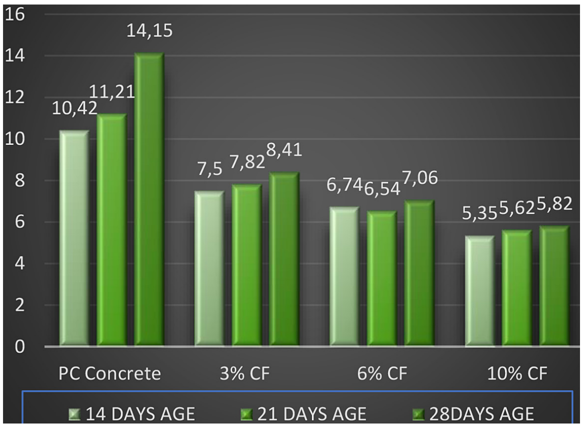

Figure 13. Comparison of compression strength between plain cement concrete and 3%, 6% and 10% coconut fiber concrete

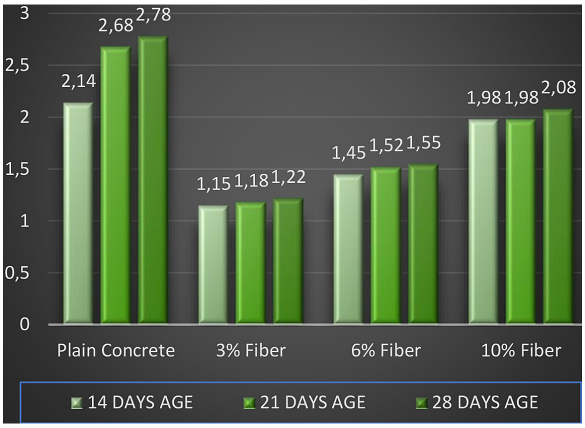

Figure 14. Comparison of splitting tensile strength between normal plain concrete and 3%, 6%, and 10% coconut fiber concrete

Table 8. Compression test result of 10% of coconut fiber and SP mix

Specimen	W/C Ratio	Slump height (mm)	% coconut fiber added	14 days age curing result N/mm^2	21 days age curing result N/mm^2	28 days age curing result N/mm^2
1	0.5	40	10	5.39	5.68	5.92
2	0.5	50	10	5.44	5.73	5.83
3	0.5	60	10	5.23	5.45	5.72

Table 9. Split tensile test result of 3%, 6%, 10% of coconut fiber and SP mix

Specimen	W/C Ratio	Slump height (mm)	% coconut fiber added	14 days age curing result N/mm^2	21 days age curing result N/mm^2	28 days age curing result N/mm^2
1	0.5	50	Plain Concrete	2.14	2.68	2.78
2	0.5	40	3	1.15	1.18	1.22
3	0.5	50	6	1.45	1.52	1.55
4	0.5	60	10	1.98	1.98	2.08

obtained shown in Table 9. The normal plain concrete average of 14, 21, and 28 days age splitting tensile strength was 2.53 MPa. The maximum splitting tensile strength of 3% coconut fiber reinforced concrete was 1.18 MPa, with 6% addition of Fiber was 1.50 MPa, and with 10% of coconut fiber the average splitting tensile strength was 2.01 MPa. After the results were obtained, it is observed that when ratio of coconut fiber is increased splitting tensile strength is increased 10% of addition of coconut fiber at 28 days, age curing the splitting tensile-strength slightly increased because interlocking of coconut fiber with recycled aggregates.

CONCLUSIONS

The following conclusions were drawn from experimental data for concrete samples incorporating fibers and recycled aggregate in various volumetric ratios. Concrete workability is reduced when coconut fiber is added. The recycled aggregate concrete containing coconut fiber increased splitting tensile strength when percentage of coconut fiber is increased. Compressive strength is decreased when percentage of coconut fiber is high. Maximum amount of coconut fiber should not be more than 2%. High quantity of coconut fiber causes segregation of concrete. Concrete with fiber added to it experienced a decrease in crack occurrence and their widening. Additionally, the presence of fiber changed the collapse pattern from brittle to ductile. The properties can be increased or decreased depending on coconut fiber length and percentages of coconut fiber. Compression and splitting tensile strength are influenced by the type, surface, and crushing strength of the coarse aggregates, the replacement ratio of RA, and the quantity and type of super-plasticizer. Since recycled concrete aggregate is not commonly used in Pakistan, at least 30% to 40% recycled aggregate can be used, rather than the 100% recycled coarse aggregate, to achieve the desired results that were obtained in the conducted experimental work to reduce the cost of civil works.

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