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# EFFECT OF JUTE FIBER AND RECYCLED COARSE AGGREGATES ON THE COMPRESSIVE STRENGTH AND POROSITY OF CONCRETE

*[a]Hafiz Kamran Jamil*, [b]Faisal Shabbir*

[a, b] Department of Civil Engineering, University of Engineering and Technology, Taxila, Pakistan.
kamranjamil894@gmail.com faisal.shabbir@uettaxila.edu.pk
*Corresponding author: Email ID: kamranjamil894@gmail.com

***Abstract-*** In construction, concrete is mostly used for different projects. The drawback of plain cement concrete is that it is strong in compression but weak in tension. Nowadays, a lot of effort is made to minimize this problem by using additives e.g. fibers and cementitious material. Moreover, recycled coarse aggregates (RCA) are seeking more attention towards substituting natural coarse aggregate (NCA) because of their related economic benefits and sustainable development. Hence, this paper examines the combined influence of jute fiber (JF) and recycled coarse aggregates (RCA) on the concrete properties. In this investigation, the length of JF is kept at 10 mm. Two types of mixes are investigated i.e. with 0% RCA (control mix) and 100% RCA. In each of these mixes, 0%, 0.30%, and 0.60% of jute fiber (JF) by volume of concrete are used. The mechanical and durability properties are evaluated by compressive strength test and porosity test respectively. This investigation shows that the addition of 0.30% of JF has a positive influence whereas the addition of 0.60% has a negative influence on the mechanical property of concrete in both 0% RCA and 100% RCA cases. In both cases (0% RCA and 100% RCA), the compressive strength is slightly improved up to 0.30% of fibers but upon further increase of the fibers, the compressive strength is decreased. While in the durability test, the concrete porosity increases with the increasing quantity of JF and RCA in both 0% RCA and 100% RCA cases. In a higher dosage of fibers (0.60%), the effect of porosity is more as compared to lower dosages.

***Keywords-*** Durability properties, Jute fiber, Mechanical property, Recycled coarse aggregates.

## 1 Introduction

Concrete is mostly used in structures due to its high compressive strength, low maintenance, and economical as compared to other materials. To improve its construction (mechanical and durability) properties, many researchers have been working on the addition of cementitious materials and natural fibers. This composite material is called fiber reinforced concrete. These natural fibers can be divided into three groups i.e. plant, mineral, and animal fibers. Plant fibers possess higher strength than other fibers and are investigated by different researchers [1]. According to Banthia [2], the compressive strength of concrete is increased by the addition of plant fiber. In this paper, jute fiber (JF) is used to increase the mechanical and durability properties of concrete. Islam et al. [3] used different amounts of JF and concluded that the small amount (0.25%) of JF has a positive effect on concrete properties. Dayananda N et al. [4] uses different dosages and different curing ages of JF and concluded that the addition of 0.4% JF has a positive effect on concrete and with the increase in curing age, the mechanical properties of JF reinforced concrete mix increase.

Recently, many countries are facing problems with the dumping of construction and demolition (C&D) waste due to a shortage of land. According to Akhtar [5], 3 billion tons of C&D waste are generated in 40 major countries. The volume of natural coarse aggregates (NCA) in concrete is 50-75% normally. So recycled coarse aggregates (RCA) derived from C&D waste are used to minimize the problem and to lessen the dependence on the NCA. The partial or full replacement of NCA with RCA can assist to solve the problems related to the shortage of landfills and pollution. Kwan et al. [6] indicated that the compressive strength of concrete is almost identical in the case of concrete which is made of 30% RCA and NCA concrete, and compressive strength is decreased by 20% when 100% RCA is used. In China, Li et al. [7] used RCA successfully in different structural and pavement applications and shown the positive response of RCA in civil engineering. Hoffman et al. [8] also showed the RCA sustainability in different concrete structures applications and indicated the corresponding variation in concrete properties.

The literature shows that there are rare studies on the effect of JF with RCA keeping the mechanical and durability aspects into account. For this purpose, this paper shows the behavior of JF reinforcement on the performance of concrete with RCA. In this research, two different types of mixes are made from 0% RCA (reference mix) and 100% RCA, and in every mix, 0%, 0.30%, and 0.60% of JF by volume of concrete are used. The results show that 0.30% JF has a positive effect on the properties of concrete in all cases.

# 2 Experimental Procedures

## 2.1 Materials

### *2.1.1 Binder*

Ordinary portland cement (OPC) of grade 53 was used as a binder in this investigation. This OPC is according to ASTM C150 [9] and it is type 1. The general characteristics of OPC are given in table 1.

***Table 1. General properties of OPC***

| Chemical composition | Percentage (%) | Physical characteristics | Results |
|---|---|---|---|
| $SiO_2$. | 22.7 | (SG) Specific gravity | 3.13 |
| $Al_2O_3$ | 5.15 | (SS) Specific surface | 318 ($m^2$/kg) |
| $Fe_2O_3$ | 3.95 | Consistency | 28.75 (%) |
| CaO | 63.85 | Initial setting time | 175 (min) |
| MgO | 2.71 | Final setting time | 240 (min) |
| $SO_3$ | 3.03 | Soundness | No |
| $Na_2O$ | 0.23 | 28 days $f_c^/$ (compressive strength) | 43.95 MPa |
| $K_2O$ | 0.85 | Fineness | 94% |
| Ignition loss | 0.65 | -- | -- |

### *2.1.2 Aggregates*

Originally Lawrencepur natural siliceous sand was used as fine aggregates (FA) in all mixes. Locally available natural coarse aggregate (NCA) of Margalla brand natural crush was used in this research. The chemical and physical properties of fine and coarse aggregates are given in table 2. RCA was obtained manually by crushing concrete cylinder having compressive strength in the range of 30-35 MPa. After crushing, these recycled coarse aggregates were sieved according to the size of NCA. The maximum and minimum sizes of NCA and RCA were kept constant as shown in figure 1. The gradation curve of aggregates is shown in figure 2. All aggregates (fine and coarse) used in this experiment follow the ASTM standard specification [10]. The general properties of aggregates are given in table 2.


*Figure 1: Recycle coarse aggregates (RCA) and natural coarse aggregates (NCA)*

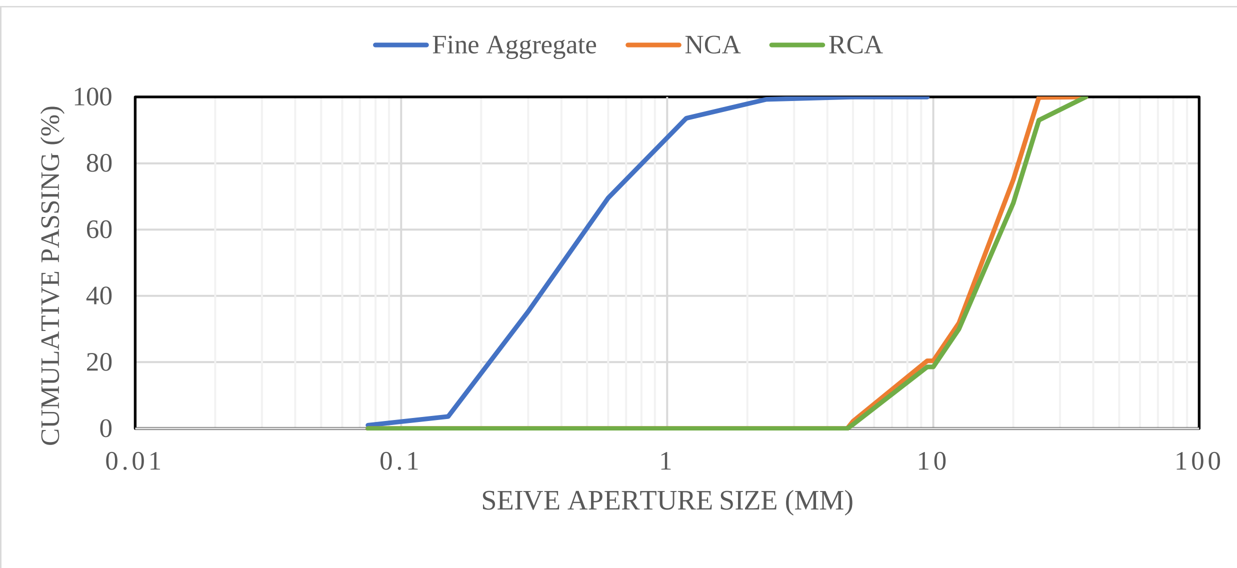


*Figure 2: Gradation curve of aggregates*

***Table 2. General Properties of aggregates***

| Properties | FA | NCA | RCA |
|---|---|---|---|
| Max. nominal size (mm) | 4.75 | 25 | 25 |
| Min. nominal size (mm) | 0.075 | 4.75 | 4.75 |
| Saturated surface dry water absorption (%) | 0.62 | 1.04 | 6.5 |
| Bulk Density (kg/m$^3$) | 1638 | 1602 | 1360 |
| Specific gravity | 2.67 | 2.73 | 2.27 |

### *2.1.3 Jute fibers*

Locally available jute fibers were used in this experiment. The jute fibers were cut into 10 mm length as shown in figure 3. Table 3 shows the typical properties of JF.

***Table 3. Typical properties of JF***

| Parameters | Results |
|---|---|
| Fiber length (mm) | 10 |
| Fiber diameter (mm) | 0.02-0.05 |
| Bulk density (kg/m$^3$) | 1450 |
| Ultimate tensile strength (MPa) | 490 |
| Young Modulus (GPa) | 26 |

*Figure 3: Jute fiber (JF)*

### *2.1.4 Water and plasticizer*

Fresh tap water was used in all the concrete mixes. High-range plasticizer Sikament 515 was used to attain the required slump in all mixes. This plasticizer contains the properties of type F according to ASTM C494 [11] standard.

## 2.2 Concrete mixes composition

In this analysis, two cases have been studied i.e., with 0% RCA and 100% RCA. A total of six mixes were prepared with three various fractions of JF (0%, 0.30%, and 0.60%) having 0% RCA and three various fractions of JF (0%, 0.30%, and 0.60%) having 100% RCA. The first mix is the control mix (reference mix), which contains 0% JF and 0% RCA. The 0% RCA mixes are made according to ACI 211-91[12] for 30 MPa cylinder compressive strength, while 100% RCA mix cases, the RCA is used as a substitution of the volume of NCA. The value of slump and the water-cement ratio is 75-100 mm and 0.45 respectively for all the mixes. Table 4 shows the details for all concrete mixes.

***Table 4. Detail of mix proportion***

| Mixture | RCA | JF (kg/m$^3$) | OPC (kg/m$^3$) | Sand (kg/m$^3$) | NCA (kg/m$^3$) | RCA (kg/m$^3$) | Water (kg/m$^3$) | Slump (cm) |
|---|---|---|---|---|---|---|---|---|
| R0JF0(Ref) | 0 | 0 | 439 | 660 | 1107 | 0 | 193 | 88 |
| R0JF0.30 | 0 | 4.35 | 439 | 660 | 1107 | 0 | 193 | 98 |
| R0JF0.60 | 0 | 8.7 | 439 | 660 | 1107 | 0 | 193 | 82 |
| R100JF0 | 100 | 0 | 439 | 660 | 0 | 940 | 193 | 85 |
| R100JF0.30 | 100 | 4.35 | 439 | 660 | 0 | 940 | 193 | 80 |
| R100JF0.60 | 100 | 8.7 | 439 | 660 | 0 | 940 | 193 | 91 |

The mixing is carried out into two stages in a mechanical mixer. In the first stage, aggregates are mixed with the help of half of the water for 4 min, then fibers, cement, and the remaining half of water are inserted in the next stage, and the mixing is continued for 6 min. The total time of mixing is 10 min. Kurad et al. [13] adopted a similar method of mixing. After completion of mixing, the value of the slump is recorded by the slump cone apparatus. Table 4 reveals that the range of slump values is 75-100 mm.

# 3 Specimen Preparation and Testing Method

In all mixes, the mechanical property is calculated by compressive strength test while durability property is calculated by porosity test. For the compressive strength test, cylinder specimens of (150 mm diameter × 300 mm height) sizes were cast according to the ASTM C39/C39M-14 [14] standard. In the case of the porosity test, concrete discs of 50 mm thickness and 100 mm diameter were cast according to ASTM C642 [15] standard. These types of discs were produced from cylinders of 100 mm diameter and 200 mm height with the help of a stone cutter after curing. All the cylinders were left to be set in molds for 48 hours after casting. After de-molding, the curing of these cylinders is done for 28 days in normal water. After curing, these cylinders were cut into discs using a stone cutter and subjected to testing. Three specimens of each mix are cast and the average of these three is used to determine the results.

# 4 Results

## 4.1. Mechanical Property

### *4.1.1. Compressive strength test*

The compressive strength test is conducted after curing as shown in figure 4. Figure 5 shows the values of the compressive strength test of all mixes with different quantities (0%, 0.30%, and 0.60%) of JF. With the increasing percentage of fibers in the case of 0% RCA and 100% RCA, a similar trend in compressive strength has been observed. As the fiber percentage increases, the compressive strength is increased in both cases of RCA. Similar observations have been observed by [3] [14]. Ali et al. [16] show that by adding fibers, the compressive strength is increased up to a certain limit then the compressive strength is decreased. In this paper, the compressive strength is increased up to 0.30% of fibers but upon further increases of fibers, the compressive strength is decreased in both cases as shown in figure 5. This is because of the addition of excessive fibers, honeycombing, and voids are created in the case of 0.60% of fibers. These types of defects decrease the internal strength of concrete. At 0.30% JF, the compressive strength of concrete made with 0% RCA is greater than the reference mix (R0JF0). Compared to reference (R0JF0), the compressive strength is increased by 8% at R0JF0.30. However, by looking at the standard distribution of the results, it can be noted that the strength increase is not much significant. Therefore, it can be said that compressive strength is not compromised up to 0.30 % of JF in the concrete as compared to the control mix.

The value of compressive strength in the case of R100JF0 is lower than the reference mix (R0JF0). Compared to reference (R0JF0), the compressive strength is reduced by around 22% at R100JF0. This shows that the recycled coarse aggregates (RCA) have less strength than natural coarse aggregates (NCA). The maximum compressive strength achieved at R0JF0.30 is 31 MPa but in the case of R100JF0.30, it was 25 MPa.

It is concluded that as the jute fiber (JF) percentage increases, the compressive strength is not compromised up to 0.30% of jute fibers (JF) in both cases but on further percentage increases, the compressive strength is decreased. The average maximum compressive strength is achieved at R0JF0.30. Therefore, 0.30% of JF quantity is the optimum quantity for the compressive strength of concrete. It is also observed that the RCA mixes have less compressive strength than the NCA mixes. This is because of the lesser density of RCA than NCA, therefore compressive strength is affected negatively by equal volume replacement with NCA.

*Figure 4: Compressive strength test*

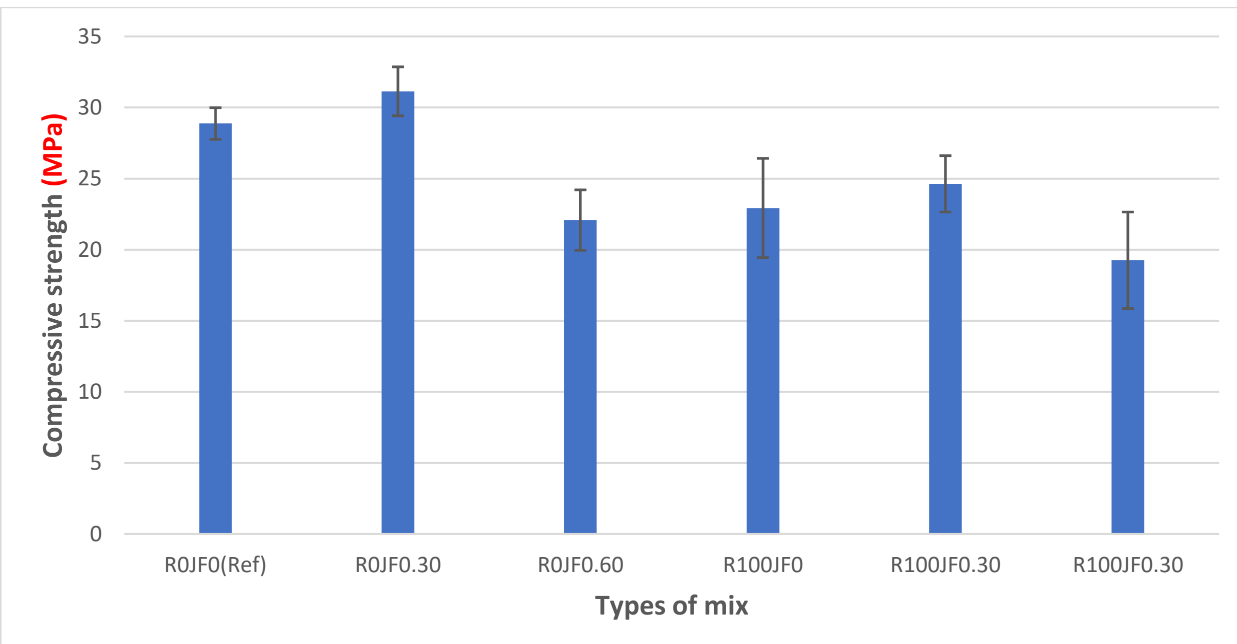


*Figure 5: Graph between compressive strength and type of mix*

## 4.2. Durability Property

### *4.2.1. Porosity*

The porosity of concrete is the measurement of void spaces in concrete. Figure 6 shows that the porosity of concrete mixes increases as the JF and RCA content increases. This is because of the presence of mortar which is adhered to RCA and the high volume of free water in RCA is the major cause of higher porosity. The porosity is significantly increased in higher dosages of JF (>0.30%) in both cases. A similar trend was also shown in the research performed by Ali et al. [16] This is because as the percentages of fibers increase, the compression is not effective due to fibers accumulation.

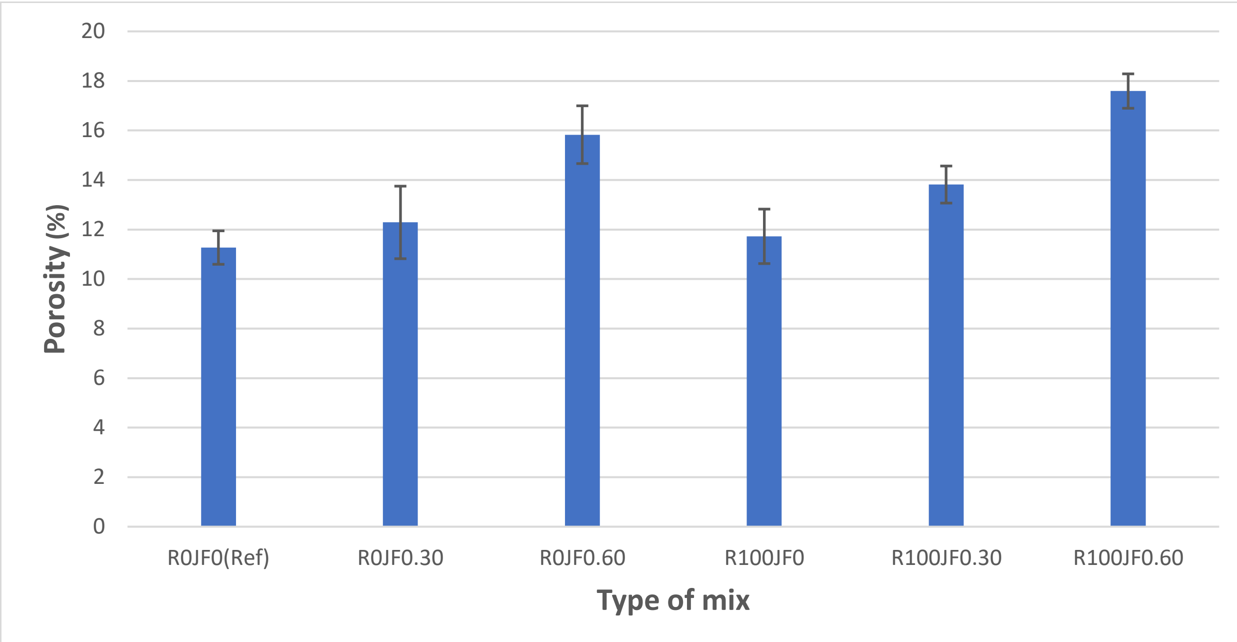


*Figure 6: Graph between porosity and type of mix*

## 5 Conclusion

This research topic investigates the effect of JF on the performance of concrete with RCA. The following conclusion can be drawn as,

- The average compressive strength of the concrete mixes is slightly increased in both cases (0% RCA and 100% RCA) due to the addition of JF as compared to reference mixes. The maximum compressive strength is increased up to 0.30% of fibers but upon a further increase in the percentage of fibers, the compressive strength is decreased.
- The values of porosity increase with the increase of JF and RCA. This is attributed to the fact that as the percentages of fibers increase, the compression is not effective due to fibers accumulation. In the higher dosage of fibers (0.60%), the effect of porosity is more when compared to lower dosages.
- It is concluded that 0.30% is the optimum dosage of fiber for compressive strength of concrete and RCA can be used in concrete where low strength is desired.

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