# EXPERIMENTAL STUDY OF PROPERTIES OF RECYCLED AGGREGATE CONCRETE WITH THE ADDITION OF GLASS FIBERS

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***ABSTRACT****: Investigation of the properties of Recycled aggregate concrete with the addition of glass fibers was done in this research work. For this purpose normal concrete cubes and glass fibers concrete cubes were prepared. Glass fibers were used at different ratios with the replacement of cement. Cubes having a size of 6" x 6" x 6" were prepared and cured in curing tank. After curing the cubes were tested at the compression testing machine after 14, 21 and 28 days. The loading rate was set at 200 Kpa per second. The ratios of glass fibers used were 3%,6%, and 10%. Compressive strength of both normal and glass fiber cubes was compared after 14, 21 and 28 days. The finding of this research shows that the addition of glass fibers reduces the workability of recycled aggregate concrete. Flexure and tensile strength of recycled aggregate concrete also improved with the addition of glass fibers. Lesser permeability also results after the addition of glass fibers into the recycled aggregate concrete. Cracking and bleeding also reduce after the addition of glass fibers into the recycled aggregate concrete. Future work is recommended for the effect of glass fibers on different grades of concrete at different w/c ratios. Also, the effect of admixture on Glass fiber added recycled aggregate concrete can also be studied*

**Keywords:** Constituents of concrete; glass fiber; Concrete cubes; Compressive strength; Workability of concrete.

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## . INTRODUCTION

Concrete is the most manufactured material in the world and has an impact on the environment. There is no alternative to this material within the world context. An increase in industry activities has an enormous increase in the production of waste material all over the world. The creation and disposal of non- decaying material like bricks, gravel, etc. have problems for the environment and for a construction site as well as in developing countries. Crushing of this waste at the site with the potable crusher to minimize the cost of construction and transportation of this causes environmental problems. In most developing countries the use of technology is increasing day by day. Therefore a need exists to promote the reduction of the impact of concrete on the environment, guaranteeing at the same time that it is technological and economic advantages remain valid. Due to the development of technology, recycled concrete aggregate is used in concrete due to technical, economical and has less impact on the environment. Recycled concrete has reduced the consumption of primarily used aggregate in the industry and in the civil engineering constructions. The use of recycled concrete opens a new way to reuse of materials in the building industry. This utilization of recycled concrete aggregate is a solution for the excess of waste material, provided the desired final product quality is reached. This reduces the consumption of landfills for concrete waste. To employ the recycled aggregate derived from concrete waste in a reinforced concrete structure, properties as compression resistance, recycled aggregate crushing resistance and concrete modulus of elasticity can give information on understanding behavior and provide direction for new product reliability. The use of fiber-reinforced concrete has increased in building structures because the fibers in concrete may improve the toughness, flexural strength, tensile strength, and impact strength as well as failure of

mode of concrete. Glass fibers have various applications in concrete like crack control, prevent coalescence of cracks and change the behavior of the material by bridging of fibers across the cracks. Ductility is provided by fibers reinforced cement composites because fibers bridge crack surfaces in other words.

## 2. OBJECTIVES

The main objectives of this research work were as follows:

- To study the properties of glass fiber reinforced concrete and normal concrete.
- To differentiate between the strength of normal concrete and glass fiber reinforced concrete.
- To determine the workability of concrete with or without glass fibers.
- To reduce the cost of construction by using the waste of concrete as recycled aggregate.
- To make the environmentally friendly construction from concrete waste.
- To optimize the maximum use of waste concrete as aggregate with glass fibers.

## 3. LITERATURE REVIEW

- **Yanweerasak et al.**[1]studied the effect of recycled aggregate quality on the bond behavior and shear strength of reinforced concrete members. They concluded that the bond strength of both natural and recycled concrete increased with a decrease in water-to-cement ratio but not for the full spectrum of ratio values. Furthermore, the shear behavior of reinforced concrete beams with natural and recycled concrete is very similar, but the results depend on the size of the beams.
- In their research, **Kim et al.** [2] performed a study on the properties of recycled aggregate concrete and its production facilities. Equipment was developed to improve the quality of recycled aggregate to increase the use of that aggregate for environmental improvement purposes. The results showed improvements in the air volume, slump, compressive strength, freezing and thawing resistance, and drying shrinkage.
- An investigation on the use of recycled concrete aggregates originating from a single ready-mix concrete plant was performed by **Anastasiou et al.**[3]Crushed hardened concrete from test specimens (HR) and from returned concrete (CR) were tested for their suitability as Concrete aggregates, and cement sludge fines (CSF) originating from the washing of concrete trucks

were tested as filler. Both HR and CR can be considered good-quality recycled aggregates, especially when the coarse fraction is used. Furthermore, HR performs considerably better than CR both as coarse and as fine aggregate. CSF seems to be a fine material with good properties as a filler, provided that it is properly crushed and sieved through a 75 µm sieve.

- **Yang** [4] analyzed the effect of different types of recycled concrete aggregates (RCAs) on the equivalent concrete strength and drying shrinkage properties. A total of six mixes were proportioned using the modified equivalent mortar volume (EMV) method with three RCAs. The test results show that the concrete with RCAs produced from concrete sleepers exhibited compressive strength, Young's modulus, and flexural strength values equivalent, within 2% variation, to those values of the companion natural aggregate concrete. In other mixes, compressive strength was found to decrease to 11–20%. For 100% replacement, Young's modulus increased up to 10% and the drying shrinkage increased up to 8%, while for 50% replacement, Young's modulus decreased up to 8% and the drying shrinkage dropped up to 4%.
- **Duan et al.**[5] used artificial neural networks (ANNs) to determine the significance of aggregate characteristics on the mechanical properties of recycled aggregate concrete (RAC). The results show that water absorption has the most important effect on aggregate characteristics, further affecting the compressive strength of RAC, and that combined factors including concrete mixes, curing age, specific gravity, water absorption, and impurity content can reduce the prediction error of ANNs to 5.43%. Moreover, for elastic modulus, water absorption, and specific gravity, they are the most influential, and the network error with a combination of mixes, curing age, specific gravity, and water absorption is only 3.89%.
- **Wang et al.**[6] presented a material characterization for sustainable concrete paving blocks. Five types of waste materials were used in this project, including recycled concrete coarse aggregate (RCCA), recycled concrete fine aggregate (RCFA), crushed glass (CG), crumb rubber (CB), and ground granulated blast-furnace slag (GGBS). Using either RCCA or RCFA can decrease the blocks' strength and increase their water absorption. The suggested incorporation levels of RCCA and RCFA are 60% and 20%, respectively. Adding CG to the concrete paving blocks as a type of coarse aggregate can improve their strength and decrease their water absorption.
- **Khaldoum Rahal and el (2005)**[7]The experimental study on some of the mechanical properties of recycled aggregate concrete (RAC) as compared to those of the conventional normal aggregate concrete (NAC). Studies waste concrete was obtained from two buildings under demolition. The concrete with cylinder compressive strengths between 25 and 50 Mpa, the modulus of elasticity of RAC was only 3% lower than that of NAC. The coefficient of variation ranged from 2.16% to 3.27% with an average of 2.73% for RAC and between 1.87% and 4.18% with an average of 2.60 for NAC. The 28 days compressive strength for all five mixes was achieved except for the 40 and 50Mpa RAC where the observed strength was slightly lower than the target strength.
- **Yogesh Iyer Murthy and el (2012)**[8]carried out a study on the compressive strength, flexural strength and workability of concrete containing varying proportions of glass fiber as replacement of fine aggregate. 25 micrometers in diameter and 5cm long are used for the preparation of standard M30 grade concrete by replacing fine aggregate by fiber up to 1.5%. The increase in compressive strength is nominal while the flexural strength increased significantly as expected with the increase in the percentage of glass fiber. The reduction in a slump with the increase in glass fiber content. The flexural strength of a beam with 1.5% glass fiber shows an almost 30% increase in the strength compared to the beam with 0% glass fiber. In this research concrete with glass fiber is made cost-effective and solves the problem of disposal, to make the environment greener.

## 4. EXPERIMENTAL PROGRAM

### 4.1. Preparation of Test Specimens

Concrete was prepared from the materials according to the specified ratio derived from the mix design and casting was done in the concrete slab as shown in figure.1. First of all

**Fig. 1 Preparation of concrete**

**Fig. 2 Compacted concrete sample**

the recycled concrete was crushed to the desired size and shape and then placed fine aggregate ascend above the aggregate at the end cement were placed. After this, all ingredients were mixed to each other by thrice times and then add the water according to the w/c ratio. The water to cement ratio of 0.5 was used in the mix design. Before poured the concrete, cubes were oiled from the inner side. To achieve the strength of cubes better poured the concrete in the cubes in 3 layers and each layer was compacted by 25 strokes of the rod as shown in figure.2.(due to unavailability of the vibrating table or compacting machine).

36 cubes of other cubes were also prepared as follows the same procedure of above described. 9 cubes of normal concrete and 27 cubes of fiber reinforced concrete were prepared at a different ratio like 3%,6% and 10% of 9 each cube as shown in table 1.

**Table.1 Combinations**

| Sr no | Fibers percentage | Cement | Fine Aggregate | Recycled Aggregate |
|---|---|---|---|---|
| 1 | 0% | 100% | 100% | 100% |
| 2 | 3% | 97% | 100% | 100% |
| 3 | 6% | 94% | 100% | 100% |
| 4 | 10% | 90% | 100% | 100% |

### 4.2. Test Performed

After 24 hours of casting the cubes were demoulded and properly cured for 14, 21 and 28 days in curing tank. After 14,21 and 28 days of curing the cubes were dragged out of the curing tank and allowed to dry for 24 hours to make them ready for testing. After that, the cubes were tested in the compressive testing machine of 3000 kN Capacity as shown in figure 4. The machine was manually set to apply the load at the rate of 200 Kpa/s while the area of the cube was 22500 $mm^2$ as shown in Fig 3. The compressive strength of the cubes was found to be on 3 specimens of each group according to the design mix and curing of cubes in the curing tank.


**Fig. 3 Setting Area and Load Rate**

**Fig. 4 Compression Testing Machine & Placed Cubes**

## 5. RESULTS AND DISCUSSION

### 5.1. Experimental observations

Recorded data in terms of loads was used to plot bar charts to represent the values of compressive strength from that it is obvious that the maximum strength in compression carried by the concrete cube was 14.1 Mpa. Moreover, the behavior of concrete cube up to failure was noticed to be almost linear. As well as the failure mode of concrete cubes is concerned, it was failed in shear as shown in Fig.9 which is brittle failure of the concrete cube. Table 2 shows the values of compressive strength of Normal concrete and graphical representation of compressive strength is shown in figure 5. Table 3 shows the compressive strength of recycled concrete with 3% glass fibers and the graphical representation of the compressive strength of recycled concrete with 3% glass fibers is shown in figure 6. Table 4 shows the compressive strength of recycled concrete with 6% glass fibers and the graphical representation of the compressive strength of recycled concrete with 6% glass fibers is shown in figure 7. Table 5 shows the compressive strength of recycled concrete with 10% glass fibers and graphical representation of the compressive strength of recycled concrete with 10% glass fibers is shown in figure 8.

### 5.2. RESULTS

**Table.2 Compressive strength of Normal Concrete**

| Type of Concrete | Compressive Strength (MPa) | Curing Days | | |
|---|---|---|---|---|
| | | 14 | 21 | 28 |
| Normal | sample 1 | 10.6 | 10.5 | 14.1 |
| Normal | sample 2 | 10.9 | 12.2 | 13.8 |
| Normal | sample 3 | 10.5 | 10.8 | 14.2 |

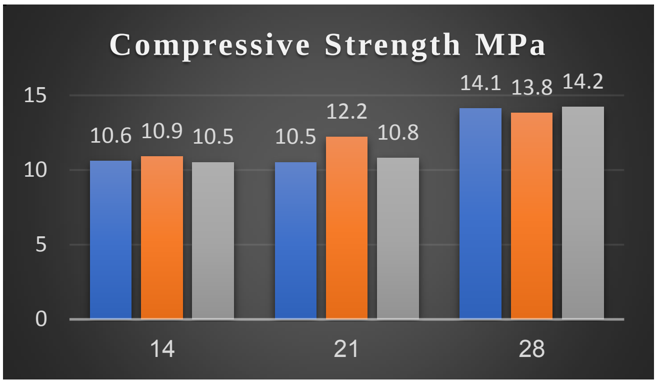


**Fig. 5 Graphical representation of Compressive strength of Normal Concrete**

**Table 3. Compressive strength of Recycled aggregate concrete with 3% Glass fibers**

| Amount of glass fiber | Sample No. | Compressive strength (Mpa) | | |
|---|---|---|---|---|
| | | 14 | 21 | 28 |
| Fiber 3% | Sample 1 | 6.7 | 6.1 | 8.2 |
| Fiber 3% | Sample 2 | 6.3 | 6.1 | 8.4 |
| Fiber 3% | Sample 3 | 6.9 | 6.4 | 8.4 |

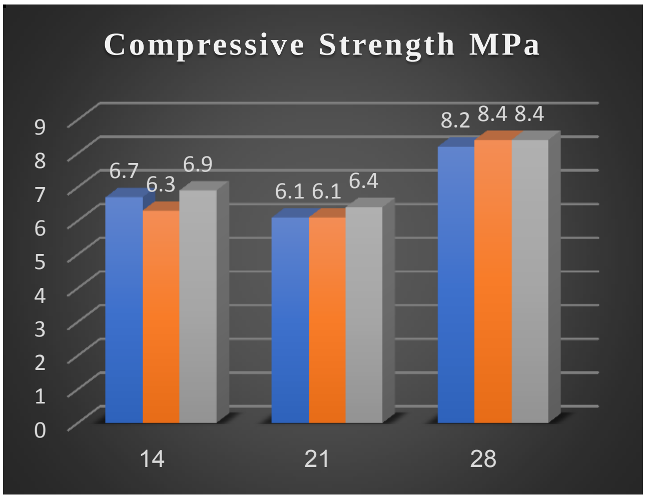


**Fig. 6 Graphical representation of Compressive strength of Concrete with 3% Glass fibers**

**Table 4. Compressive strength of Recycled aggregate concrete with 6% Glass fibers**

| Amount of glass fiber | Sample No. | Compressive strength (Mpa) | | |
|---|---|---|---|---|
| | | 14 | 21 | 28 |
| Fiber 6% | Sample 1 | 5.3 | 4 | 6.4 |
| Fiber 6% | Sample 2 | 5.1 | 5.6 | 6.4 |
| Fiber 6% | Sample 3 | 6.3 | 5.9 | 7 |

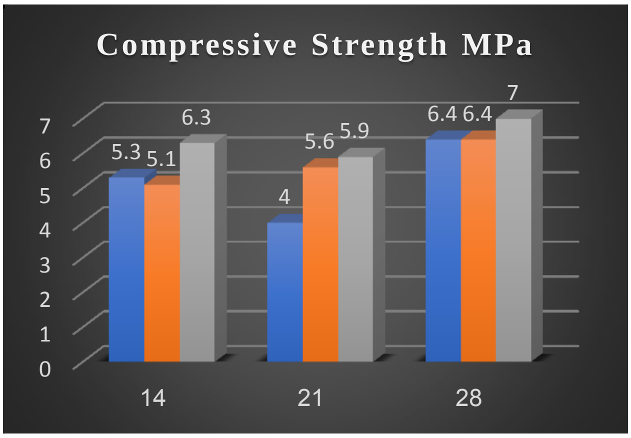


**Fig. 7 Graphical representation of Compressive strength of Concrete with 6% Glass fibers**

**Table 5. Compressive strength of Recycled aggregate concrete with 10% Glass fibers**

| Amount of glass fiber | Sample No. | Compressive strength (Mpa) | | |
|---|---|---|---|---|
| | | 14 | 21 | 28 |
| Fiber10% | Sample 1 | 5.2 | 5.2 | 5.4 |
| Fiber10% | Sample 2 | 4.9 | 4.5 | 5 |
| Fiber10% | Sample 3 | 4.2 | 4 | 4.8 |

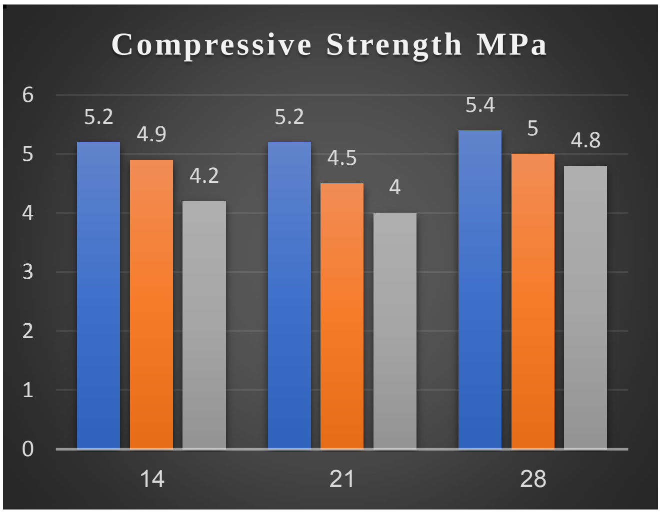


**Fig. 8 Graphical representation of Compressive strength of Concrete with 10% Glass fibers**

**Fig.9 Failure Pattern of Concrete cube**

**Comparison of normal recycled aggregate concrete and concrete containing glass fibers**

The comparison between normal and fiber concrete to determine the effective compressive strength at which percentage of fiber gives better results is shown in table 6 The comparison between the normal and fiber concrete shows that at 3% of fiber given the better results and other ratios reduce the compressive strength of the concrete. Graphical representation of the compressive strengths of both concrete type is shown in figure 10.

**Table 6. Comparison Normal recycled aggregate concrete and concrete containing glass fibers**

| Amount of glass fiber | Compressive strength (Mpa) | | |
|---|---|---|---|
| | 14 | 21 | 28 |
| Normal | 10.67 | 11.17 | 14.03 |
| Fiber 3% | 6.63 | 6.2 | 8.33 |
| Fiber 6% | 6.63 | 5.17 | 6.6 |
| Fiber 10% | 4.77 | 4.57 | 5.07 |

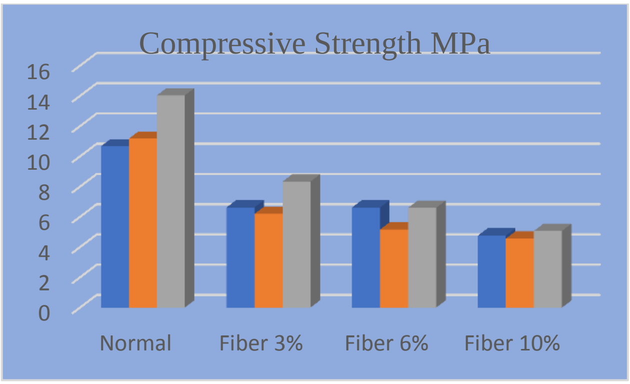


**Fig. 10 Graphical representation of compressive strengths of Normal and Fiberglass added recycled aggregate concrete**

### 5.3. Finding Properties

Properties and characteristics of materials determined using Cement, Sand, RCA. Fibers

1. fineness of cement
2. Consistency of cement
3. Initial and Final Setting Time of Cement
4. Compressive Test of Cement Concrete.

After calculating these properties carefully used them in a mix design to find the strength of concrete cubes.

### 5.4.Establishing Ratio

Using mix design the ratio of materials and w/c ratio is calculated this involves following steps;

**1. Choice of Slump**

The value of the slump is assumed for the purpose of designing a concrete mix. In our case, the value of slump is 1-2 in (25-50mm).

**2. Water to Cement Ratio**

It is calculated keeping in view the importance of using glass fiber, kept 0.5 to 0.6.

**3. Calculation of Cement Content**

When the water content and the w/c ratio is determined, the amount of cement per unit volume of the concrete is found by dividing the estimated water content by the w/c ratio.

**4. Estimation of Coarse Aggregate Content**

The volume of coarse aggregates is found by subtracting the volume of cement, fine aggregate, water and air from the total concrete volume.

**5. Estimation of Fine Aggregate Content**

The volume of fine aggregates is found by subtracting the volume of cement, coarse aggregate, water and air from the total concrete volume.

**6. Adjustment for Moisture in the Aggregate**

To adjust the water amount just decrease the amount of water by surface moisture and increase the amount of aggregate equal to the surface moisture by weight.

### 5.5. Cost Comparison

After designing Concrete cubes, the cost comparison between the materials used for the same application was carried out. While comparing the cost, not only cost of the materials was taken into consideration but also the carriage cost the material to the construction site is also considered. The comparison in Pakistani rupees is given in below Table 7. In the cement, only the actual cost is taken into account due to local availability and other materials the cost of per 100cft is taken which includes material and carriage cost both.

**Table 7.Cost Comparison in PKR**

| Normal Recycled aggregate concrete | Recycled aggregate concrete with glass Fibers |
|---|---|
| Cement = 600/- per Kg | Cement = 600/- per Kg |
| Sand = 1000/- per100 cft | Sand = 1000/- per100 cft |
| Aggregate = 4000/- | Aggregate = 4000/- |
| Cost of labor = 2200/- | Glass Fibers = 1000/- |
| Total = 7800/- | Cost of labor = 2200/- |
| | Total= 8800/- |

### Conclusions and Recommendation for future work

- The addition of glass fibers decreases the workability of concrete.
- The recycled aggregate concrete containing Glass fiber gives higher flexural and split tensile than conventional concrete.
- The recycled aggregate concrete containing Glass fiber has low permeability as compared to normal concrete.
- Max amount of Glass fiber in concrete should not be more than 2%
- High quantity of glass fiber causes segregation in the concrete.
- Placement of the concrete in the cube is also difficult due to fiber
- The Glass fiber decrease cracking and bleeding in the concrete. The use of fiber produces more closely spaced cracks and reduces crack width. Fibers bridge cracks to resist deformation
- The finishing of the concrete surface required more time.
- The size of glass fiber should be as small as possible for easy mixing.
- For future work, the same research can be done for different grades of concrete with different w/c ratios. Also, the Effect of different admixtures on glass fiber concrete needs to be studied.

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