Fracture Toughness of Concrete by using Recycle Aggregates in Addition with S2 Glass Fiber

Anshul Garg, Nitish Kumar Jha, Pushpendra Kumar Sharma

Abstract: The scarcity in conventional material to prepare concrete and a demand of reuse of demolished or abandoned waste of concrete structure gives a reason to study the ways of using more amount of recycled aggregates. Various studies reviewed the use of recycled aggregates but to a maximum limit of 50% whereas use glass fibers gave a better response to mechanical and chemical properties of concrete 1. For concrete the occurrence of cracks and pores is uncertain and it is important to investigate whether they are intact or not. The durability of the fracture tests depends on the ductile nature of concrete structures under load. It was found that there is a need to assess the strength of the concrete at fracture of the critical point. The present study aims at finding out how far the ductility of concrete with recycle aggregates can be improved by the addition of S2 glass fibers in terms of fracture toughness by varying the fiber content. The research work consist of replacement of recycle aggregates with five different mixes of concrete as 40, 60, 70, 80 & 100% and in each five mixes the addition of S2 glass fiber with 0.25%-1% by its weight with an increment of 0.25% is done. 3 point bending test on notched beams were conducted for determination of critical stress intensity. The tests were performed as per the guidelines of International Union of Laboratories and Experts in Construction Materials, Systems and Structures (RILEM) 5. The research paper gives idea about optimum percentage of recycle aggregates and S2 glass fiber that can be used in concrete structures casting taking in account the study of fracture toughness.

Keywords: Fracture Toughness, Critical Stress Intensity, RILEM, Crack propagation, S2 glass fiber

I. INTRODUCTION

Concrete is for most part versatile material utilized in the turf of structural designing. Reusing concrete is a feasible alternative to enhance the interest on great characteristic assets and breaking point the measure of waste arranged in landfills. Estimating the compressive or elasticity just won't ensure the exhibition of the solid structure attributable to the communication of the material conduct, previous splits and geometry of the structure. The solid fracture properties can give more portrayal of the potential burden conveying limit of the material in a given basic system. Since concrete is a composite material, the nearness of breaks and pores inside cement can't be controlled. So it gets important to research whether these splits are steady or not.

6. Fracture mechanics is a significant technique for examining solid conduct under static stacking. The fracture execution of reused total cement with expansion of S2 glass fiber has not been assessed to date in the writing and could give further understanding to the material execution when utilized for concrete. Research on fracture properties of different solid blends has discovered a noteworthy advantage with expansion of fiber fortification to plain concrete. Most of writing recommends the quality of cement containing reused solid total (RCA) is not exactly coarse total cement even at low water/bond proportions. A few nations have seen the reusing of development and destruction squander as another structure material as one of the primary objectives over terms of reasonable structure conduct. Numerous analysts have submitted their work to depict the properties of reused total, the base necessities for their utilization in concrete and the properties of reused total cement. Past examinations likewise show that glass strands are solid constituents and the utilization of glass filaments prompts an expansion in concrete flexural quality. Among the accessible glass fiber, S2 glass fiber has expanded solid quality. The utilization of strengthened cement with reused total S2 glass fiber will consequently have most extreme quality and effectiveness. The goal of this exploration was to initially decide the fracture properties of a regular concrete as contrasted and reuse total cement what's more with S2 glass fiber with comparable blend constituent and degree.

II. METHODOLOGY

The experimental study consists of evaluating materials and preparing a regular M25 grade strength concrete with a total aggregate size of 20 mm. S2 glass fibers having an aspect ratio of 150-200 in volume fractions of 0.25%, 0.5%, 0.75% and 1% and recycle aggregates with five different mixes as 40, 60, 70, 80 & 100% replacement were used for the study. The experimental system consists of a three-point bending test on volume 500x100x100 mm notched beam samples with an initial 30 mm notch depth and 3 mm width for all 400 mm period mixes and all the test are done as per guidelines of RILEM. The details of the specimen for the fracture test are shown in Fig. 1. The deflection was distinguished using dial gauge through testing.

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According to the RILEM 5., the fracture toughness is determined using equation (1) as the critical stress intensity $K_{ic}$.

$$K_{ic} = \frac{3FS_{\text{max}}}{2BW^2} f(\alpha)$$

Where, $K_{ic}$ = critical stress intensity (MPa√m), $F_{\text{max}}$ = max. load (N), $S$, $W$ and $B$ are the span, depth, and width in mm respectively of the testing beam.

$f(\alpha)$ is geometry factor, which depends on the ratio of the notch depth/crack length ($a$) to the depth ($W$) of the beam. In case $S = 4W$ as applied in the current study, $f(\alpha)$ can be as shown in equation 2.

$$f(\alpha) = \frac{[1.99-a(1-a)/[2.15-3.93a+2.7a^2]]}{\sqrt{W(1.4a)/(1-a)1.5}}$$

The materials utilized for the investigation are Ordinary Portland Cement of Grade 43, locally available river sand utilized as fine aggregates, reused aggregates of demolished structures, coarse aggregates of 20 mm and S₂ glass fiber of 15 mm length and 0.1 mm width, Master Glenium B233 as super plasticizer and water of drinking quality.

Table- I: Physical Properties of Cement

| Properties          | Data obtained | Standard Data |
|---------------------|---------------|---------------|
| Normal consistency  | 33.5%         | 26% - 33%     |
| Initial setting time| 49 min        | 30 minimum    |
| Final setting time  | 242 min       | 600 maximum   |
| Fineness            | 4.65%         | ≤ 10%         |
| Specific gravity    | 3.12          | 3.15          |

Table- II: Physical Properties of Aggregates

| Name               | Water Absorption | Specific Gravity |
|--------------------|------------------|-----------------|
| Coarse Aggregates  | 0.556%           | 2.69            |
| Fine Aggregates    | 0.9%             | 2.59            |
| Recycled Aggregates| 7.92%            | 2.34            |

Mix design of M25 grade concrete was carried out as per IS 10262-2019 11. Straight type S₂ glass fiber with an aspect ratio of 150 was used in the experimental study which has Magnesium alumino silicate glass without CaO. The mix was confirmed based on a slump of 75 mm and 28 day cube compressive strength of 33.55 MPa. The final mix proportions and mix designations are shown in Table III and IV respectively.

A. Casting of Specimens

The moulds have been fitted for the beam test. For conducting fracture examination, specimens with and without recycled aggregates & S₂ glass fiber are casted. For each combination, two samples were cast i.e. a total of 42 specimens of beams were cast. The samples of concrete beams were left without disruption until a hardened condition was reached. After 2 hours, the notch system was removed and after 24 hrs. the samples were submerged in water for 28 days.

Fig. 1. Details of Fracture Test Specimens

Table- III: Mix Proportion as per IS 10262:2019 11

| Material | Cement | Fine aggregates | Coarse Aggregates | Water |
|----------|--------|-----------------|-------------------|-------|
|          | 435.41 | 736.12          | 1035.29           | 191.6 |
| Ratio    | 1      | 1.69            | 2.377             | 0.44  |

Table- IV: Mix Designations and Percentages of Materials Added or Replaced in Concrete in Kg/m³

| SN | Description | % replacement of coarse with recycled aggregates | % volume of S₂ glass fiber |
|----|-------------|-----------------------------------------------|---------------------------|
| 1  | CR0G0       | 0                                             | 0                         |
| 2  | CR40G0.25   | 40                                            | 0.25                      |
| 3  | CR40G0.5    | 40                                            | 0.5                       |
| 4  | CR40G0.75   | 40                                            | 0.75                      |
| 5  | CR40G1.0    | 40                                            | 1.0                       |
| 6  | CR60G0.25   | 60                                            | 0.25                      |
| 7  | CR60G0.5    | 60                                            | 0.75                      |
| 8  | CR60G0.75   | 60                                            | 1.0                       |
| 9  | CR60G1.0    | 60                                            | 1.0                       |
| 10 | CR70G0.25   | 70                                            | 0.25                      |
| 11 | CR70G0.5    | 70                                            | 0.5                       |
| 12 | CR70G0.75   | 70                                            | 0.75                      |
| 13 | CR70G1.0    | 70                                            | 1.0                       |
| 14 | CR80G0.25   | 80                                            | 0.25                      |
| 15 | CR80G0.5    | 80                                            | 0.75                      |
| 16 | CR80G0.75   | 80                                            | 1.0                       |
| 17 | CR80G1.0    | 80                                            | 1.0                       |
| 18 | CR100G0.25  | 100                                           | 0.25                      |
| 19 | CR100G0.5   | 100                                           | 0.5                       |
| 20 | CR100G0.75  | 100                                           | 0.75                      |
| 21 | CR100G1.0   | 100                                           | 1.0                       |

Fig. 2. Concrete Mix with Recycle Aggregates and S₂ Glass Fiber
Fig. 3. Notched Beam Specimen for Fracture Test

III. RESULTS & DISCUSSIONS

The specimen was subjected to 3-point bending in simply supported end condition. In order to determine the fracture strength, the 3-point bending tests were performed on beams with 100x100 mm cross section and an effective length of 400 mm. The results of peak load, Crack Length and critical stress intensity are shown in Table V. To represent the behavior of concrete beams due to central load the acquired data is plotted in Fig. 4, 5, 6.

Table V: Results of Fracture Toughness with Different S2 Glass Fiber and Recycle Aggregate on Concrete Beams

| SN | Name    | Peak Load (N) | Crack Length “a” (mm) | Kic (MPa√m) |
|----|---------|---------------|-----------------------|-------------|
| 1  | CR0G0  | 4550          | 53.03                 | 1.59        |
| 2  | CR40G0.25 | 4370        | 54.41                 | 1.37        |
| 3  | CR40G0.5 | 4895         | 51.45                 | 1.71        |
| 4  | CR40G0.75 | 5715        | 50.85                 | 1.99        |
| 5  | CR40G1.0  | 4200        | 55.4                  | 1.47        |
| 6  | CR60G0.25 | 4450        | 53.42                 | 1.56        |
| 7  | CR60G0.5 | 5575          | 51.97                 | 1.94        |
| 8  | CR60G0.75 | 6015        | 50.01                 | 2.09        |
| 9  | CR60G1.0  | 4425        | 53.78                 | 1.55        |
| 10 | CR70G0.25 | 4150        | 55.73                 | 1.45        |
| 11 | CR70G0.5 | 4360          | 54.41                 | 1.53        |
| 12 | CR70G0.75 | 4505        | 53.05                 | 1.57        |
| 13 | CR70G1.0  | 4100        | 55.39                 | 1.44        |
| 14 | CR80G0.25 | 4205        | 54.9                  | 1.47        |
| 15 | CR80G0.5 | 4325          | 54.24                 | 1.51        |
| 16 | CR80G0.75 | 4350        | 54.08                 | 1.52        |
| 17 | CR80G1.0  | 4165        | 55.06                 | 1.46        |
| 18 | CR100G0.25 | 3575        | 64.35                 | 1.26        |
| 19 | CR100G0.5 | 3600          | 62.28                 | 1.27        |
| 20 | CR100G0.75 | 3750        | 60.36                 | 1.32        |
| 21 | CR100G1.0  | 3700        | 60.96                 | 1.30        |

Fracture robustness increased with S2 glass fiber content with 60% recycled aggregate replacement and attained a maximum value for 0.75% fiber content and then decreased. With the introduction of S2 glass fibers, ductility was found to be improved and CR60G0.75 was found to be more ductile. The improvement in ductility was due to the active particle binding and containment. Flexural failure was the pattern of failure observed. Plain concrete beams failed by dividing into 2 halves, whereas GFRC beams only showed narrow cracks and no splitting. The results showed that the overall load and fracture capacity of GFRC beams were significantly increased relative to plain concrete beams.

IV. CONCLUSION

The M25 grade concrete mix has been built with a total 20 mm aggregate volume. The effect of fiber content on concrete’s fresh properties has been studied. The study's main goal was to investigate the effect of S2 glass fibers with recycled aggregates on the behavior of concrete beam fractures.

1. The application of S2 glass fiber in a concrete mix affects the fresh properties of concrete and requires a dosage of 0.25%-0.45% super plasticizer to keep the fresh properties within workable limits.
2. With 60 percent recycled aggregates and 0.75% fiber material, the ultimate load was improved by 32.2 percent and fracture strength by 31.45 percent relative to normal concrete beams.
3. There was a significant increase in the critical load and the fracture parameters of GFRC beams compare to plain concrete beams.
4. The fracture behavior of RAC and traditional concrete is identical under the same degree of concrete grade. If the RCA’s replacement ratio is more than 60%, the strength of the fracture will be decreased by a total of 20%.
5. By including S2 glass fibers, the mode of failure was changed from brittle to ductile flexural process.

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