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# Glass Fiber Effect on Mechanical Properties of Eco- SCC

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## ABSTRACT

Sustainable Construction encouraging the use of recycled materials and implies adoption of fewer natural resources in buildings and other infrastructure. In this paper Quarry Dust (QD) is used as partial replacement for River Sand (RS) to make Self Compacting Concrete (SCC) of grade M40. Glass fiber is used as strengthening material to the developed concrete. The present study mainly focused to develop Eco-SCC using QD. In this study it was found that, for developing Eco-SCC, what is the optimum dosage of replacement of QD in RS. Fresh properties of SCC are satisfying the EFNARC specifications and also target strength is achieved. Further it is concluded that, with the glass fiber addition there is an improvement in the split and flexural strength values.

## INTRODUCTION

Self-compacting concrete (SCC) is a type of concrete having high flowing nature and able to compact under its own weight. Having the property of high fluid nature, it is easy for placing in difficult situations and the sections with congested and heavy reinforcement. Use of SCC can also help minimize noise pollution on the worksite that is induced by vibration of concrete. The time required for place large sections is significantly reduced by using of SCC. [1,2]. Slump test is a Conventional method of measuring workability of concrete. Workability of concrete represents the ease with which concrete can be transported, placed and compacted. As the concrete technology progresses with the advent of more fluid concretes like pumpable concrete, self-compacting concrete, it is necessary to measure the flow properties of concrete. In general, in developing countries, the demand of natural sand is quite high, to satisfy the rapid infrastructural growth, in this situation developing country like India facing shortage in good quality natural sand [5].

Optimum utilization of available resources, reduction in wastage of material/energy, overuse controlling and guaranteeing that the resources are kept for the future generations without complete utilization are the methods to accomplish sustainability in construction successfully[4].Effective utilization of waste materials like Quarry Dust(QD) as a replacement for expensive and environment friendly River sand (RS),which is becoming extinct quickly now a days because of irregular and over usage, is one of the best method of achieving sustainability in construction .At the same time using of such materials also reduces the disposal problems as these are posing environmental threats [5].

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Quarry Dust is a residue, tailing or other non-voluble waste material obtained after extraction and processing of rocks to form fine particles less than 4.75mm. It is abundantly available (produced on an average 200 million tons per annum) and is posing landfill disposal problems, health hazard and environmental issues. Generally, QD is used in highways as surface finishing material in large scale, also used in light weight prefabricated elements and also in manufacturing of hollow blocks.[6, 7]. The utilization of Quarry Dust had reached more than 60% of its total production in the industrialized nations like France, Australia, Germany and UK. At the same time QD also increasing the workability and strength parameters of concrete [8,9]. The physical and chemical properties of QD are shown in Tables 1 and 2.

**Table.1 Physical properties of QD & RS**

| Property | Quarry Dust | River Sand |
|---|---|---|
| Specific gravity | 2.55-2.60 | 2.62 |
| Bulk relative density (kg/$m^3$) | 1730-1810 | 1460 |
| Absorption (%) | 1.25-1.50 | Nil |
| Moisture content(%) | Nil | 1.50 |
| Fine particles less than 0.075 mm(%) | 12-15 | 06 |
| Sieve analysis | - | Zone – IV |

**Table 2. Chemical Composition of QD & RS**

| Constituent | Quarry Dust | River Sand |
|---|---|---|
| $SiO_2$ | 62.48 | 80.78 |
| $Al_2O_3$ | 18.72 | 10.52 |
| $Fe_2O_3$ | 06.54 | 01.75 |
| CaO | 04.84 | 03.22 |
| Mgo | 02.58 | 00.80 |
| $Na_2O$ | Nil | 01.35 |
| $K_2O$ | 03.20 | 01.25 |
| $TiO_2$ | 01.24 | Nil |
| Loss of Ignition | 00.50 | 00.35 |

## RESEARCH SIGNIFICANCE

In the present study, mechanical properties of Eco-Friendly Fiber Reinforced Self Compacting Concrete (Eco-FRSCC) with QD used as partial replacement for River Sand (RS) and fly ash as partial replacement for cement are evaluated. The mix proportion suitable for Eco-FRSCC accommodating finer filler materials was developed modifying the existing Nansu's method of mix design [10]. The fly ash available locally was used as a partial replacement for cement in optimum dosages for improving the strength and workability properties of Eco-FRSCC.

## EXPERIMENTAL PROGRAM

The experimental work plan was done in two phases. In the first phase of work plan, an optimum dosage of QD is arrived to develop Eco-SCC by satisfying the fresh properties and compressive strength. In the second phase, the mechanical properties of such optimized Eco-SCC were investigated. In continuation of the studies on Fibrous Eco-SCC are also presented.

### Materials Used

Ordinary Portland cement of 53 grade (compressive strength not less than 53 MPa) was used in the study. The cement was selected as per Indian Standard Code IS: 12269-1987 [11]. The fly ash from local source was used and the property of fly ash is confirming to Indian Standard Code IS: 3812-1981 [12] of Indian Standard Specification for Fly Ash for use as Pozzolana and Admixture. The specific gravity was 2.05. Fine aggregate (F.A) was standard natural river sand procured locally as per Indian Standard Code IS-2386 [13] and Quarry Dust (QD) was used as replacement for natural river sand. Crushed granite was used as Coarse Aggregate (C.A). The aggregate was properly graded through standard sieves before using in concrete works [14].As a partial replacement of cement locally available fly ash was used. Polycarboxylic either based superplasticizer (water reducing admixture) and to improve workability properties, Viscosity Modifying Agent (VMA) was added in optimum dosage. The Glass fiber is Cem-Fil Anti Crack and its Specific gravity is 2.6, length of the fiber is close to 12 mm, and the Specific surface area is 105 m2 /kg [15,16].

## Methodology

The experimental program was designed to study the mechanical properties of Eco-SCC & Eco-FRSCC made with concrete of M40 grade with partial replacement of QD for river sand. The compressive strength, split tensile & flexural strength properties were determined. The plan of work consisted of casting and testing Self Compacting Concrete cubes (150*150*150mm), cylinders(150mmΦ & 300mm height) and prisms(100mm *100mm*400mm) with different QRD dosages of 0%, 10%, 20%, 30%, 40% & 50% as replacement for natural sand. The optimum dosage of 40% of QRD was finalized and with this dosage as constant for Eco-SCC and for fibrous Eco-SCC mixes 1.00 Kg/m3 of Glass Fiber was used. While fixing the mixes, Nansu method of mix design adopted for Eco-SCC & Eco-FRSCC and the details are shown in Table 3[10].

**Table 3: Details of Mix Proportions for M40 grade SCC & Eco-SCC**

| Designtion | Cement(Kg) | Fly Ash(Kg) | Coarse Aggregate (Kg) | Fine Aggregate (Kg) | | Water (Lit ) | S.P (% ) | VMA(%) |
|---|---|---|---|---|---|---|---|---|
| | | | | RS | QD | | | |
| Mix-A | 430 | 150 | 707 | 850 | - | 198 | 0.85 | 0.20 |
| Mix-B | 430 | 155 | 707 | 765 | 85 | 198 | 0.87 | 0.25 |
| Mix-C | 430 | 160 | 707 | 680 | 170 | 198 | 0.91 | 0.25 |
| Mix-D | 430 | 165 | 707 | 595 | 255 | 198 | 0.94 | 0.25 |
| **Mix-E** | **430** | **170** | **707** | **510** | **340** | **198** | **0.98** | **0.25** |
| Mix-F | 430 | 175 | 707 | 472 | 472 | 198 | 1.25 | 0.30 |

## Development of Self Compacting Concrete (SCC)

Filling ability, passing ability and resistant to segregation in required amount are the key properties of Fresh SCC must possess. To satisfy these conditions Europe Guidelines (EFNARC) for Self Compacting Concrete [17] has devised certain test procedures and specifications. The slump flow equipment (Figure.1(a)) is currently widely used in concrete construction practice, and the method is very simple and straightforward. Thus, the slump flow combined with T50 was selected as the first priority test method for the filling ability of SCC [18]. The V-funnel (Figure.1(b)) test are recommended as second priority alternatives to the T50 measurement. L-box test is used to measure the passing ability of fresh Self Compacting Concrete (Figure.1(c)). The fresh properties of the Eco-SCC mixes are showed in Table 4.

**Figure1. Self Compacting Concrete Acceptance Tests**

(a) (b) (c)

## Table 4. SCC and Eco-SCC mixes Properties at Green State

| Sl. No. | Designation | Slump Test | | V Funnel Test | | L Box Test | | | EFNARC Specifications |
|---|---|---|---|---|---|---|---|---|---|
| | | Harizontal-Flow (mm) | T50 (time in Sec) | Time for complete discharge Sec | T 5 min in Sec | Time For 0-200 mm spread | Time for 0- 400 mm spread | H2/H1 | |
| 1 | Mix-A | 720 | 4.52 | 10.00 | 12.50 | 3.80 | 6.00 | 0.95 | satisfied |
| 2 | Mix-B | 710 | 4.71 | 10.50 | 13.00 | 3.80 | 6.00 | 0.90 | satisfied |
| 3 | Mix-C | 705 | 4.82 | 10.65 | 13.25 | 3.91 | 6.25 | 0.87 | satisfied |
| 4 | Mix-D | 705 | 4.95 | 10.67 | 13.30 | 4.02 | 6.34 | 0.85 | satisfied |
| **5** | **Mix-E** | **690** | **5.10** | **10.78** | **13.45** | **4.28** | **6.50** | **0.83** | **satisfied** |
| 6 | Mix-F | 600 | 8.00 | 14.00 | 18.04 | 6.00 | 14.00 | 0.70 | Not satisfied |

## Fresh and hardened Properties of SCC & Eco-FRSCC

In the first Phase, ten mix proportions as shown in Table 3 are taken up and SCC with M40 grade concrete covering mixes with different proportions of quarry rock dust in concrete were considered (Mix-A to Mix-F). The fresh properties of SCC and Eco-SCC based on EFNARC specifications are shown in Table 4. In the second phase, FRSCC & Eco-FRSCC mixes are developed by considering the known optimum dosage of 1.0 kg/m3 of glass fiber [15]. The mix proportions details and fresh properties of FRSCC and Eco-FRSCC are shown in Tables 5 and 6 respectively. The companion cube specimens of standard dimensions 150mm x 150mm were casted and tested. Table 5 shows the details of the Eco-SCC mixes with introduction of glass fibers in optimized mixes ie., Mix-A, Mix-F.

## Testing of Specimens

Universal Testing Machine (UTM) of capacity 3000KN was used for testing the specimens under standard load rate control. While testing, precautions were taken to ensure axial loading. Specimens were tested for compression, split, flexure and for modulus of elasticity. For flexural strength standard three point loading was adopted as per Indian Standard Code IS: 516 [19]. The modulus of elasticity of concrete was determined using compressometer setup and tested under UTM.

## Table 5: FRSCC & Eco-FRSCC Mix proportion Details

| Designtion | Cement(Kg) | Fly Ash(Kg) | Coarse Aggregate (Kg) | Fine Aggregate (Kg) | | Glass Fiber (Kg) | Water (Lit ) | S.P (% ) | VMA(%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | NRS | QRD | | | | |
| Mix-G | 412 | 166 | 707 | 944 | - | 1.00 | 193 | 1.6 | 0.25 |
| Mix-H | 412 | 177 | 707 | 564 | 378 | 1.00 | 193 | 1.75 | 0.30 |

## Table 6. Fresh Properties of M40 grade FRSCC and Eco-FRSCC

| Sl. No. | Grade of Concrete | Slump Test | | V Funnel Test | | L Box Test | | | EFNARC Specifications |
|---|---|---|---|---|---|---|---|---|---|
| | | H-Flow (mm) | T50 (time in Sec) | Time for complete discharge Sec | T 5 min in Sec | Time For 0-200 mm spread | Time for 0- 400 mm spread | H2/H1 | |
| 1 | Mix-G | 712 | 4.65 | 10.45 | 12.67 | 4.00 | 7.50 | 0.93 | Satisfied |
| 2 | Mix-H | 685 | 5.23 | 10.96 | 13.29 | 4.37 | 6.80 | 0.81 | Satisfied |

# DISCUSSION OF TEST RESULTS

Table 7 shows the details of the various mechanical properties viz., compressive strength, split strength, flexural strength and modulus of elasticity for SCC (Mix-A), Eco-SCC (Mix-E), FRSCC (Mix-G) and ECO-FRSCC (Mix-H). Based on earlier studies, the optimum fiber content utilized throughout the experimental work. As detailed before in the first stage, the optimum replacement value of QD (Quarry Dust) in RS (River Sand) of SCC fixed as 40% based on experimental results.

## Table.7 Glass Fiber Effect on Strength values of M40 Grade SCC & Eco-SCC

| Sl. No. (1) | Designation (2) | Compressive Strength (Mpa)(3) | Split Tensile Strength (Mpa)(4) | Flexural Strength (Mpa)(5) | Split/√Comp. (6) | Flexure/√fck (7) |
|---|---|---|---|---|---|---|
| 1 | Mix-A | 49.24 | 3.80 | 4.29 | 0.54 | 0.68 |
| 2 | Mix-G | 50.12 | 4.11 | 4.73 | 0.58 | 0.75 |
| 3 | Mix-E | 48.65 | 3.74 | 4.10 | 0.54 | 0.65 |
| 4 | Mix-H | 49.68 | 4.18 | 4.69 | 0.59 | 0.74 |

## Compressive Strength of Eco- Fiber Reinforced Self Compacting Concrete

The 28 days compressive strength values are shown in Table 7 for M40 grade concretes. The target compressive strength could be achieved in all the said mixes. With replacement of QD in RS, the compressive strength has decreased but was always above the target strength with 40% QD replacement. This gives a conclusion that quarry rock dust based concrete is not inferior to normal concretes if proper proportions are adopted as replacements. It is also observed that, there is an improvement of compressive strength marginally with the addition of fibers (Fig.2).

## Split Tensile Strength of Eco- Fiber Reinforced Self Compacting Concrete

The tensile strength of concrete is relatively much lower than its compressive strength because concrete develops tension quickly with crack propagation. The decrease is more so in case of quarry rock dust based self compacting concrete. Hence, it is important to improve the tensile strength of such a concrete. The split tensile strength of QD (fine aggregate in concrete) based SCC decreases with increase in the dosage of replacement of QD in RS, while fibers improve the behaviour as shown in Table 7. This is as high as 10 % in normal self compacting concrete and 11.83 % with a 40% QD based self compacting concretes. The variation of split tensile strength with QD as fine aggregate replacement and with fiber additions for M40 grade concrete is shown in Fig 3. Column 6 of Table 7 shows the ratio of split tensile strength to square root of compression for M40 grade for optimum replacement (ie 40%QD) in RS without and with optimum dosage of glass fiber additions.

## Effect of Fiber on Compressive Strength, Split Tensile strength of SCC & Eco-SCC

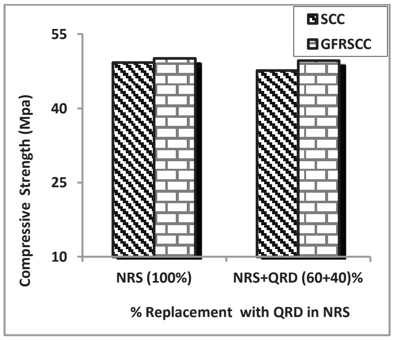


Fig.2

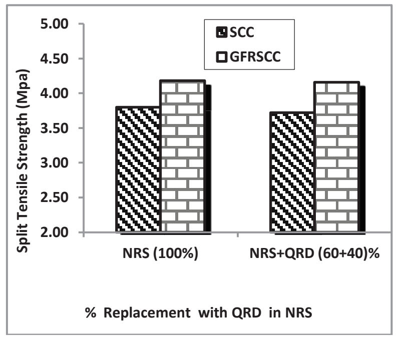


Fig.3

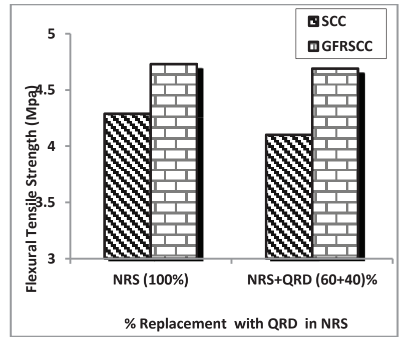


Fig.4

## Flexural Strength of Eco- Fiber Reinforced Self Compacting Concrete

Table 7 and Fig.4 shows the details of flexural strength for M40 grade concretes for optimum replacement of QD in RS for no fiber and Glass Fiber additions. There is an increase in flexural strength of fibrous concretes at 40% QD replacement in RS as compared to no fiber concretes. In case of no fibers and fibrous concretes the flexural strength decreased with increase in the replacements of QD in RS. Column 7 of Table 7 shows the ratio of flexural strength to square root of characteristic strength of concrete (fck). It can be noted that there is a general decrease in the value with increase in the replacement of QD in RS. The values are close to 0.7*sqrt(fck). The value of flexural strength to sqrt(fck) is more for glass fiber concrete.

## Fiber Effect on Modulus of Elasticity of SCC & Eco-FRSCC

A brittle behavior of self-compacting concrete was observed with replacements of QRD for in NS is observed. The fiber addition in such concretes modified the stress-strain behavior of concrete. Based on the stress-strain curves taking the initial elastic portions the Modulus of Elasticity (E) was evaluated as per Indian Standard Code IS: 516-1999 [19]. The values of modulus of elasticity were 30.45 GPa & 29.15 GPa respectively for fiber reinforced self-compacting concrete (using NS as fine aggregate) and Eco-Fiber Reinforced Self Compacting Concrete (using optimum amounts of QD as fine aggregate). It may be concluded that the addition of fiber in general increased the value of the modulus of elasticity of self-compacting concrete. These values were close to 5000*√fck in case of SCC and were higher in case of Eco-FRSCC concretes.

## CONCLUSIONS

From the above study it can be concluded that Quarry Dust (QD) is good alternate materials for replacement of River Sand (RS) and results in an environmental friendly concrete. The following conclusions can be drawn based on the experimental results of this environmental friendly- Fiber Reinforced Self Compacting Concrete (Eco-FRSCC).

1. The 28 day target compressive strength can be achieved with the partial replacements of 40% QD in RS. The results are in support of this environmental friendly fiber reinforced self compacting (Eco-FRSCC) concrete and is no way inferior to results obtained from river sand based self compacting concrete. There is a marginal increase in the compressive strength of Eco-SCC with fiber additions.

2. The split tensile strength in QD based Eco-SCC could be improved with optimum addition of Glass fibers in self compacting concrete. The increase is 10 % in M40 grade FRSCC and 11.83 % in M40 grade Eco-FRSCC.

3. There is an increase in flexural strength of SCC and Eco-SCC with glass fiber additions. The increase is about 10.26 % and 14.39 % respectively in FRSCC (with RS) and Eco-FRSCC (QD 40%) for M40 grade concrete.

4. The relationship between compressive strength , split tensile strength , flexural and characteristic compressive strength with the optimum replacements of QD in RS without and with glass fiber is established for SCC and Eco-SCC.

5. The Modulus of Elasticity values 30.45 GPa and 29.15 GPa respectively for FRSCC and Eco-FRSCC.

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