SELF COMPACTING CONCRETE WITH QUARRY DUST AS PARTIAL REPLACEMENT FOR FINE AGGREGATE AND FLYASH FOR CEMENT WITH FIBRE REINFORCEMENT

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Abstract - *SCC is a type of concrete that can be placed in the form work and it passes through any obstruction by its own weight and does not require any vibration. The process of making concrete structures compact by its own weight is known as Self Compacting concrete. These structures are compacted without vibration. Modern application of SCC is focused on high performance, better and more reliable and uniform quantity. Recognizing the lack of uniformity and complete compaction of concrete by vibration, researches at the university of Tokyo, Japan, started in late 1980's to develop SCC . By the year 2000, the SCC has become popular in Japan for prefabrication products and ready mixed concrete. The present study focuses on utilization of quarry dust and fly ash in SCC as a partial replacement of fine aggregate and cement respectively. Quarry dust, a by-product from the crushing process during quarrying activities is one of such materials. In recent days there were also been many attempts to use Fly Ash, an industrial by product as partial replacement for cement to have higher workability, long term strength and to make the concrete more economically available. The present experiment is carried out to investigate the fresh and hardened properties of Self Compacting Concrete with 50 percentage of quarry dust as a replacement for fine aggregate and fly ash as partial replacement of cement at various percentages. Steel fiber is also added in the concrete to improve the properties in certain ratio. In this project, an attempt has been made to study the fresh and hardened properties such as flow ability, passing ability, compressive, tensile and flexural strength of Self compacting concrete.*

Key Words: Self compacting concrete, Fly ash, Quarry dust, Steel fibers, Super plasticizer, compressive strength, split tensile strength, flexural strength.

1. INTRODUCTION

Self compacting concrete is a concrete which can be placed and compacted under its self weight with no vibration effort. It has high workability that it can flow under its own weight. Self-Compacting concrete is a recent development in the construction industry. Since its first development in Japan during mid 1980's, SCC has gained wider acceptance in Japan, Europe and USA due to its inherently distinct advantages. Although there are visible signs of its gradual acceptance in the Middle East through its limited use in construction, Saudi Arabia has yet to explore the feasibility and applicability of SCC in new construction. SCC is first used in Panipat Thermal Power Plant in Haryana in India. Several European countries recognized the significance and potential of SCC developed in Japan. During 1989, they founded European federation of natural trade association representing producers and applicators of specialist building product (EFNARC).The utilization of SCC started growing rapidly. EFNARC, making use of broad practical experience of all members of Europe federation with SCC, has drawn up specification and guidelines to provide a frame work for design and use of high quality SCC during 2001. Most of the information particularly test method given in the chapter is based on specification and guidelines for SCC given by EFNARC .SCC has been described as "the most revolutionary developments in concrete construction for several decades". Originally developed in Japan to offset a growing shortage of skilled labour, it has proved to be beneficial. Quarry dust which is generally considered as a waste material after the extraction and processing of rocks can be used as a replacement for fine aggregate. Fly ash is a pozzolanic material which can be used as partial replacement for cement. Steel fibers can be provided in concrete which may arrest the crack growth

2. LITERATURE REVIEW

K.S. Johnsirani and Dr. A. Jagannathan (july 2015) presents an experimental investigation on self compacting concrete (SCC) with various of both fly ash and silica fume. Partial replacements of fly ash, silica fume and combination .Also the study made with fully replacement of natural sand by quarry dust. After various replacements, cube and cylinder specimens are cast and cured. The specimens are cured in water for 3, 7 & 28 days. The slump, V-funnel and L-Box test are carried out on the fresh SCC and in harden concrete compressive strength and split tensile strength values are determined. An attempt have been made to study the properties of such SCCs and to investigate the suitability of various replacements of fly ash, silica fume and quarry dust to be used in SCC. The compressive Strength and Split Tensile Strength result of SCC with various Partial replacement of cement by Fly Ash and Silica Fume Shows that the 20% replacement of Fly Ash, 15% replacement of Silica Fume and combination of 10% Fly Ash and 15% Silica Fume gives maximum Compressive Strength and Split Tensile Strength. And finally the 100% replacement of River Sand by Quarry Dust result shows that increase in compressive strength when compare to 100% sand and increase in Split Tensile strength of 23.68% when compare to 100% sand.

Dr. G. Balamurugan and Dr. P. Perumal (December 2013) presents an experimental study presents the variation in the strength of concrete when replacing sand by quarry dust from 0% to 100% in steps of 10%. M20 and M25 grades of concrete are taken for the study keeping a constant slump of 60mm. The compressive strength of concrete cubes at age of 7 and 28 days is obtained at room temperature. Split tensile strength and flexural strength of concrete are found at the age of 28 days. From the test results it is found that the maximum compressive strength, tensile strength and flexural strength are obtained only at 50%replacement. This result gives clear picture that quarry dust can be utilized in concrete mixtures as a good substitute for natural river sand at 50% replacement with additional strength than control concrete.

L. Rama Prasad Reddy et.al (0ctober 2014) investigated on their work, Fiber Reinforced Self-Compacting Concrete (FRSCC) for replacements of Natural Sand (NS) with Quarry Rock Dust (QRD) was developed independently. A relationship is developed between the tensile strength and compressive strength, flexural strength and compressive strength of FRSCC for replacements of NS with QRD for M40 Grades of Concrete. The values of Compression, Split, and Flexure of FRSCC with and without glass fiber for different replacements of NS with QRD were also compared with the Indian Standard Codal Provisions. The 28 days Target compressive strength could be achieved in case of M40 grade at 40% replacement of QRD in NS. This means quarry rock dust aggregate concrete is in no way inferior to natural aggregate concrete but the replacement percentage may be restricted. There is also an increase in compressive strength, flexural strength and split tensile strength of quarry rock dust aggregate concrete with fiber additions.

3. MATERIALS AND ITS PROPERTIES

3.1 Cement

The cement in broad sense can be described as a material with adhesive and cohesive properties, which is capable of binding mineral fragment into compact mass. There are several types of cements available in market. Among them ordinary Portland cement (OPC) of 53 grade conforming to IS 1226:1978 is used in our study.

Table-1: properties of cement

S. No	Description	value
1	Specific gravity	3.15
2	Standard consistency	30%
3	Initial setting time	54 min
4	Final setting time	570 min

3.2 Fine aggregate

Fine aggregate increases the volume of concrete and thus makes it cheaper. It fills the voids in concrete and gives density to concrete. It makes the mass homogeneous and improves the strength of concrete. The hardening process of concrete results from the chemical reaction between silica and cement constituents. The fine aggregate with maximum size of 4.75 mm is used.

Table -2: Properties of Fine aggregate

S. No	Description	Value
1	Specific gravity	2.62
2	Fineness modulus	3.21
3	Zone	III

3.2 Coarse aggregate

For structural concrete the common coarse aggregate used is crushed hard stone. Coarse aggregate with maximum size of 12mm was used.

Table -3: Properties of coarse aggregate

S. No	Description	value
1	Specific gravity	2.82
2	Fineness modulus	6.68
3	Impact value	23%
4	Nominal size	12mm

3.3 Water

Water used for should be free from impurities. Potable water with PH value 7 was used for mixing throughout this experiment.

3.4 Fly ash

Class F Fly ash was used in the present job. Fly ash, a principal by-product of the coal-fired power plants, is well accepted as a pozzolanic material. Hence this may be used either as a component of blended Portland cement or as a mineral admixture in concrete. It is generally observed that a partial substitution of Portland cement by fly ash in a mortar or concrete mixture reduces the water requirement for obtaining a given consistency.

Table -4: Properties of Fly ash

S. No	Description	Value
1	Specific gravity	2.67
2	Colour	grey

3.5 Quarry dust

Locally available quarry dust is used for this project. Quarry Rock Dust can be defined as residue, tailing or other non-voluble waste material after the extraction and processing of rocks to form fine particles less than 4.75mm. Quarry dust is fine rock particles. When boulders are broken into small pieces quarry dust is formed. It is gray in color and it is like fine aggregate. Quarry dusts are produced during the extraction and processing of aggregates.

3.6 Steel fibers

Steel Fibers are added to SCC in order to avoid micro cracks in concrete which eventually reduces the strength of the concrete. The Steel fiber used in our study has an aspect ratio of 50.

3.7 Super plasticizer

The super plasticizer used in our project is Conplast-SP 430. It is a high performance super plasticizer intended for applications where increased workability and high fluidity is required.

4. MIX DESIGN

The mix design is done as per the EFNARC guidelines. As there is no standard proportioning method is available for self-compacting concrete various trial mixes are done as per the guidelines and finally mix proportion is achieved. Table 5 shows the mix proportions of the self- compacting concrete. Mix designations are used such as F10QD50 represents replacement of cement at 10% and replacement of Quarry dust with the addition of steel fibers.

Table -5: Mix proportions of SCC

Materials	OPS CC	F10 QD5 0	F20 QD5 0	F30 QD5 0	F40 QD 50
Cement(Kg/m^3)	500	450	400	350	300
Fly ash (Kg/m^3)	0	50	100	150	200
Fine aggregate(Kg/m^3)	868.92	434.46	434.46	434.46	434.46
Quarry dust(Kg/m^3)	0	434.46	434.46	434.46	434.46
Coarse aggregate(Kg/m^3)	802.08	802.08	802.08	802.08	802.08
Water(Lit/m^3)	200	200	200	180	180
Super plasticizer (Lit/m^3)	7.5	8.1	7.2	7	6
Steel fibers	1 %	1%	1%	1%	1%

5. FRESH PROPERTIES OF SCC

5.1 Slump flow test

The slump flow measures the flow spread. It indicates the free, unrestricted deformability within a defined flow distance. The slump cone has 20 cm bottom diameter, 10 cm top diameter and 30 cm in height. Fill the cone with the sample from the bucket without any external compacting action such as rodding or vibrating. The surplus concrete above the top of the cone should be struck off, and any concrete remaining on the base plate should be removed. After a short rest (no more than 30 seconds), lift the cone perpendicular to the base plate in a single movement, in such a manner that the concrete is allowed to flow out freely without obstruction from the cone. The subsequent diameter of the spread is measured in two perpendicular directions.

5.2 T50cm Slump flow test

The procedure for this test is same as for slump flow test. When the slump cone is lifted start the stop watch and find the time taken for the concrete to reach 500 mm mark. This time is called T_{50} time. This is an indication of rate of speed of concrete. A lower time indicates greater flow ability.

5.3 L-Box test

Fill the vertical part of the L-box with fresh concrete. Now the sliding gate is lifted and the concrete flows from the vertical part to the horizontal part. The height of the section at the end of the horizontal section represents h_2 (mm) and the height of the vertical section represents h_1 (mm). The ratio of h2/h1 is known as blocking ratio.

5.4 V-Funnel test

The V-funnel flow time is the period a defined volume of SCC needs to pass a narrow opening and gives an indication of the filling ability of SCC provided that blocking and/or segregation do not take place; the flow time of the V-funnel test is to some degree related to the plastic viscosity. Fill the funnel completely with a representative sample of SCC without applying any compaction or rodding. Remove any surplus of concrete from the top of the funnel using the straight edge. Open the gate after a waiting period of (10 ± 2) seconds. Start the stopwatch at the same moment the gate opens. Look inside the funnel and stop the time at the moment when clear space is visible through the opening of the funnel. The stopwatch reading is recorded as the V-funnel flow time. Do not touch or move the V-funnel until it is empty.

Table -6: Fresh property test results of SCC

Test methods	**OPSCC**	**F10QD50**	**F20QD50**	**F30QD50**	**F40QD50**
Slump flow test(mm)	650	630	670	680	750
T50 cm slump flow test(sec)	3	3.5	3	2	2.5
L- Box test (h2/h1)	0.90	0.90	0.95	1.0	1.0
V-Funnel test(sec)	10	10.5	11	9	8.5

Table -7: Suggested value of acceptance for different test methods

Methods	**Unit**	**Typical range of values**	
		Minimum	**Maximum**
Slump cone	mm	600	800
T_{50cm} Slump flow	mm	0	10
V-Funnel	Sec	6	12
L-Box	(h_2/h_1)	0.8	1.0

6. PREPARATION OF SPECIMENS

6.1 Casting

Mix is tested in fresh state to suit the requirements of SCC and Specimens are casted for normal SCC and various replacements of fly ash for cement with 50% replacement of fine aggregate with quarry dust and the addition of steel fibers at 1%. Specimens are casted in the mix satisfying the conditions of SCC in the fresh state and are allowed for a curing period of 28 days. As casting of specimens were done soon as mixing was completed, For every different mix 3 set of specimens such as cubes, cylinders, prisms and beams were cast. After casting, all the specimens were stored at the laboratory environment and de moulded after 24 hours.

6.2 Curing

Specimens were cured in water for 7 and 28 days. The water used for curing should be in a PH value of 7.

7. EXPERIMENTAL INVESTIGATIONS ON HARDENED CONCRETE

After curing for a period of 28 days three cubes, three cylinders, three prisms and beams were tested in 7 and 28 days. The tests include Compressive Strength Test, Split Tensile Strength Test, Flexural Strength Test on Prism and Flexural strength test on beam.

7.1 Compressive strength test

Compressive strength test is the most common test conducted on hardened concrete. Cube specimens of size 150mm x 150mm x 150mm were cast for finding the compressive strength after curing for 7 and 28 days. Then the specimen was placed between the jaws of compression testing machine of 2000kN capacity. Compressive load was given till the specimen failed. The failure load was noted as shown in the display of CTM. The compressive strength of three cubes was calculated from the average failure load of cubes.

Fig- 1: Compression strength testing machine

7.2 Split tensile strength test

Split Tensile Strength was used to determine the tensile strength of concrete. Cylindrical specimens of size 150 mm diameter and 300 mm height were used in this test. For each mix 3 specimens were cast and cured for 28days.Tensile strength test was carried out in a 2000 KN capacity compression testing machine in which the specimens were placed in such a way that its axis was horizontal. The load was applied uniformly at a constant rate until failure by splitting along the vertical diameter took place. The failure load was recorded and the splitting tensile strength was computed.

7.3 Flexural strength test on prism

For flexural strength test on prism specimens of dimension 500x100x100 mm were cast. The specimens were cast and were transferred to curing tank wherein they were allowed to cure for 28 days. These flexural strength specimens were tested on Flexural testing machine. Load and corresponding deflections were noted up to failure. In each category three Prisms were tested and their average value is calculated. The flexural strength test is done as per IS: 516-1959.

The flexural strength was calculated as follows

Flexural strength (MPa) = WL/bd^2

Where,

P = Failure load,

L = Length of the specimen,

b = width of specimen=100mm,

d = depth of specimen= 150mm.

Fig- 2: Flexural strength test on prism specimen

7.4 Flexural strength test on RCC beams

For flexural strength test beam specimens of dimension 1600x100x150 mm were cast. The specimens were cast and were allowed to cure for 28 days. The reinforcement with 4 nos of 12mm diameter main bars and 10 nos of 6mm diameter stirups @150 mm spacing is provided. These specimens were tested as per I.S. 516-1959, over an effective span of 1200 mm on Flexural testing machine. Load and corresponding deflections were noted up to failure.

The flexural strength was calculated as follows

Flexural strength (MPa) = PL/bd^2

Where,

P = Failure load,

L = Unsupported length between the supports= 1200 mm,

b = width of specimen=100 mm, d = depth of specimen= 150 mm.

Fig- 3: Flexural strength test on RCC beam specimen

8. RESULTS AND DISCUSSIONS

8.1 General

The test results of compressive strength, split tensile strength and flexural strength of prisms and beams for various specimens of different replacements of fly ash with the combination of 50% replacement of fine aggregate with quarry dust and the addition of steel fibers at 1 % combinations are discussed in this chapter.

8.2 Compressive strength test

Table 7 and chart 1 show the results of various compression tests. The compression test was conducted on various specimens with different replacements of fly ash for cement with the combination of 50% replacement of fine aggregate with quarry dust and the addition of steel fibers at a certain ratio.

Table -8: Compressive strength test results of concrete cubes

S. No	MIX ID	7 days(MPa)	28 days(MPa)
1	OPSCC	26.50	38.93
2	F10QD50	30.07	43.12
3	F20QD50	27.04	39.59
4	F30QD50	23.28	35.94
5	F40QD50	19.63	31.86

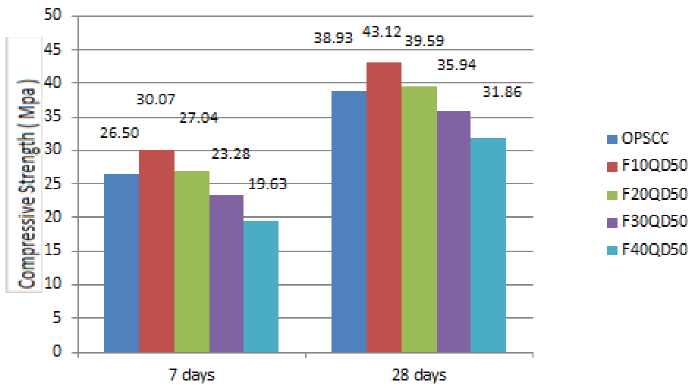

Chart -1: Compressive strength of concrete cubes at an age of 7 and 28days

8.3 Split tensile strength test

Table 9 and chart 2 show the results of split tensile strength for various specimens with different proportions.

Table -9: Split tensile strength results at an age of 28 days

S. No	MIX ID	Split tensile strength(MPa)
1	OPSCC	3.46
2	F10QD50	3.84
3	F20QD50	3.58
4	F30QD50	3.35
5	F40QD50	2.96

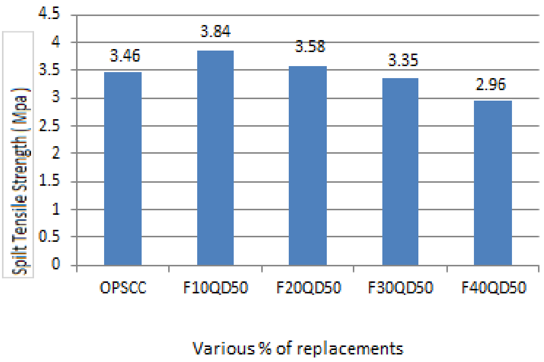

Chart -2: Split tensile strength of concrete cylinders

8.4 Flexural strength of concrete Prisms

The flexural strength was tested for various specimens with different proportion. For each proportion three prisms were tested and their average value is taken. Table 10 and chart 3 shows the flexural strength test results of different prisms at an age of 28 days.

Table -10: Flexural strength test results of concrete prisms

S. No	MIX ID	Flexural Strength(MPa)
1	OPSCC	5
2	F10QD50	6.58
3	F20QD50	5.75
4	F30QD50	4.42
5	F40QD50	3.41

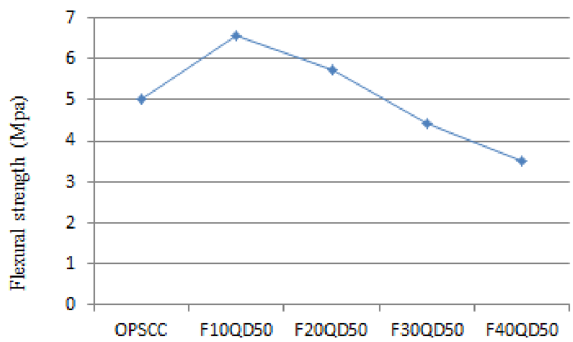

Chart -3: Flexural strength of concrete prism

8.5. Flexural strength of RCC beams

Table 11 and chart 4 shows the flexural strength of reinforced concrete beams at an age of 28 days.

Table -11: Flexural strength test results of RCC beams

S. No	MIX ID	Flexural strength(MPa)
1	OPSCC	35.2
2	F10QD50	38.4
3	F20QD50	36.26
4	F30QD50	34.13
5	F40QD50	30.09

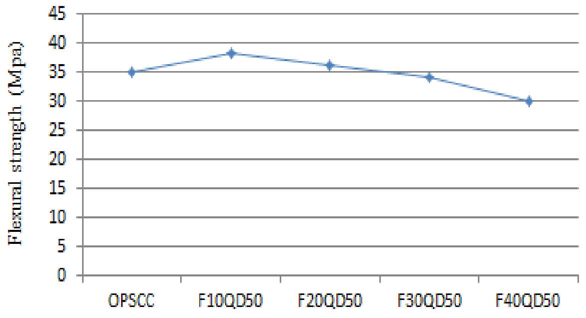

Chart -4: Flexural strength of RCC beams

8.6 Load deflection curve of RCC beams

Table -12: Load deflection curve

SL NO	MIX ID	ULTIMATE LOAD	DEFLECTION
1	OPSCC	66	14.5
2	F10QD50	72	17
3	F20QD50	68	15.6
4	F30QD50	64	14.3
5	F40QD50	58	13.8

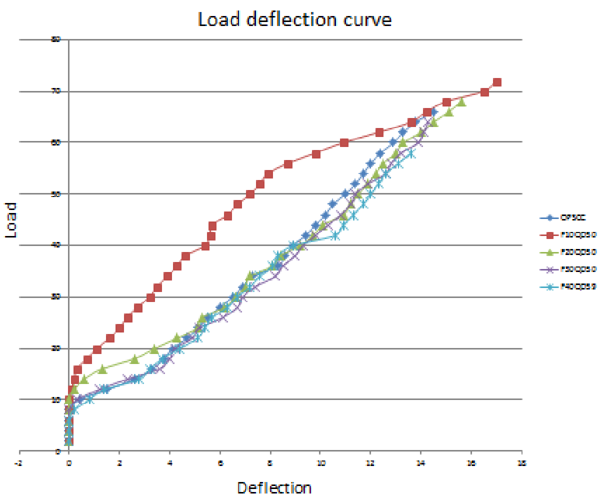

Chart -5: Load deflection curve

9. CONCLUSIONS

- Mix proportion of SCC is derived with various test conforming to the requirements of Self compacting concrete conforming to the acceptance criteria of SCC and EFNARC guidelines
- Fresh property tests are done and the fresh properties of SCC satisfies the requirements of EFNARC guidelines
- The Compressive strength, Split tensile strength and Flexural strength increases with the replacement of fly ash for cement at 10% and 20% with the combination of 50% replacement of fine aggregates with quarry dust and the addition of steel fiber at 1%
- Replacement of fly ash for cement at 30% with the combination of 50% replacement of fine aggregate with quarry dust and the addition of steel fiber at 1% shows considerable results
- The usage Quarry dust reduces the usage of fine aggregate which helps in maintaining the ecological balance thus reducing the consumption of river sand
- The utilization of Fly ash as a partial replacement of cement increases the workability of concrete and also reduces the construction cost with efficient utilization of industrial waste.

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