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A Study on Effective Utilization of Quarry dust in Self Compacting Concrete with Admixtures

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ABSTRACT: Self-compacting concrete is a type of concrete that gets compacted under its self weight. It is commonly abbreviated as SCC and defined as the concrete which can be placed and compacted into every corner of formwork, purely by means of its self weight by eliminating the need of either external energy input from vibrators or any type of compacting effort. SCC was originally developed at the University of Tokyo, Japan in collaboration with leading concrete contractors during late 1980. The intention behind developing this concrete was the concerns regarding the homogeneity and compaction of cast-in-place concrete with in intricate, of paste (i.e. highly reinforced structures and improvement of overall durability, quality of concrete due to lack of skilled labours). In the present investigation, high strength SCC obtained by 53 grades of cement, quarry dust, coarse aggregates, fine aggregates and chemical admixtures like super plasticizers. The size of aggregates used is 12.5 mm and cement content is replaced by using fly ash in volume. Since the quarry dust is cheaply available, in this project the sand is partially replaced by quarry dust by 0, 20, 40, and 60 percentages.

KEYWORDS: Self-compacting concrete, Quarry dust, Admixtures, Workability, Durability

I. INTRODUCTION

Self-compacting concrete is highly flowable and cohesive enough to handle without segregation. It is also referred as Self Levelling Concrete, Super Workable Concrete, Self Consolidating Concrete, High Flowable Concrete, and Non Vibrating Concrete. Hoshimoto, experimentally visualized and explained the concrete flow blocking mechanism of heavily reinforced section during pouring of concrete. They reported that the blockage of the flow of concrete due to a narrow cross section occurs due to contact between coarse aggregate in concrete during the time of concrete placement. When concrete flows between reinforcing bars, the relative location of coarse aggregate is changed. Developing self-flowing materials such as SCC requires careful control of other factors to ensure high workability. The morphology, particle size distribution, and inter particle spacing of the aggregates are also important factors dictating the flow properties of fresh concrete. Unfortunately, from a practical standpoint, the particle morphology is largely uncontrollable. The particle size distribution of the aggregates, however, can be controlled by adjusting the percentage of fine and coarse particles.

II. RELATED WORK

N.P.Rajamane et al (2013), Well proportioned and larger content of paste and mortar portions give high deformability to fresh SCC mix , which has also high resistance to segregation. These properties (Okamura and Ozawa, 1995 and 2000) could be achieved by, Limited aggregate content, Low water / powder ratio (by volume) and adding super plasticizer. In SCC, gravity provides the energy for compaction. Coarse aggregate requires high amount of energy for compaction and hence, limiting its content will help SCC to become self-consolidating. Cohesion in the mix is

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achieved by a viscous paste, which enables the concrete to flow through obstacles such as reinforcement without segregation. High deformability of the mix is obtained by addition of a compatible Super plasticizer. Champion and Joist (2006), SCC is produced with standard, readily available concrete components. The mix proportioning is based upon creating high degree of flow ability while maintaining a low water cement ratio (< 0.50). This can be achieved through the use of new HRWR admixtures combined with stabilizing agent to ensure homogeneity of. Previously, this flow ability could only be achieved with higher water contents ($w/c > 0.70$), which will result in low strength. Specially designed HRWR can achieve the flowing properties required to obtain a SCC. Proper gradation of aggregate and the composition and combination of different cementitious components are the key elements in achieving the required properties of SCC. The points to be noted here are, w/c ratio equal to regular plasticized concrete, assuming the same required strength, Higher volume of fine aggregate than most plasticized concrete, for example cement, fly ash and mineral fines, Optimized gradation of aggregate and High dosage of HRWR by weight of cement. Dr. Rakesh Kumar and M.V.B.Rao (2016), the ingredients for SCC are similar to other plasticized concrete. It consists of cement, coarse aggregate and fine aggregate, water and mineral and chemical admixtures. Similar to conventional concrete, SCC can also be affected by physical properties of materials and mixture proportioning. The mixture proportioning is based on creating a high degree of flow ability while maintaining a low w/c ratio (< 0.50).

III. OBJECTIVE OF THE WORK

Objective of the present investigation is to develop Self Compacting Concrete and to study its characteristics in both fresh and hardened state.

The present study includes the following:

1. To develop a suitable mix with the required rheological characteristics of Self Compacting Concrete with partial replacement of sand by quarry dust
2. To determine the workability and strength parameters of self compacting concrete with partial replacement of sand by quarry dust and to obtain the optimum percentage of quarry dust and optimum dosage of the super plasticizers used

IV. MATERIAL STUDY

IV.I BINDING MATERIAL

Ordinary Portland cement of 53Grade is used throughout this investigation. Laboratory tests are conducted as per testing methods recommended by Indian standards and the important properties of cement are given below in table 1.

Table 1: Physical Properties of OPC

Grade of Cement used	Ordinary Portland cement, 53 grade
Specific Gravity of Cement	2.88
Normal Consistency	36%
Initial Setting Time	150 minutes
Final setting time	260 minutes

IV.II QUARRY DUST

Aggregate crushers produce significant amounts of crusher dust during the process of producing 10-20 mm nominal size aggregates. Utilization of stone crusher dust, a waste material, has not been made in concrete. The reason for this is the greater specific surface area, excess of material smaller than $150 \mu\text{m}$ and the associated increase in water demand of concrete. However, with the availability of high range water reducers, the increased water demand of the crusher dust can be accommodated without increasing the water-cement ratio. In order to obtain the grain size distribution of quarry dust, sieve analysis is performed in sieve shaker and the results are presented in table 2. Based on these results, S-curve is plotted and represented figure 1.

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Table 2: Properties of Quarry dust tested in sieve shaker

Sieve size (mm)	Weight of particles retained (g)	Percentage retained	Cumulative percentage retained	Percentage passing
10	-	-	-	100
4.75	-	-	-	100
2.36	-	-	-	100
1.18	67	12	12	88
600	98	19.6	31.6	68.4
300	89	17.8	49.4	50.6
150	112	22.4	71.8	28.2
Pan	141	28.2	100	-

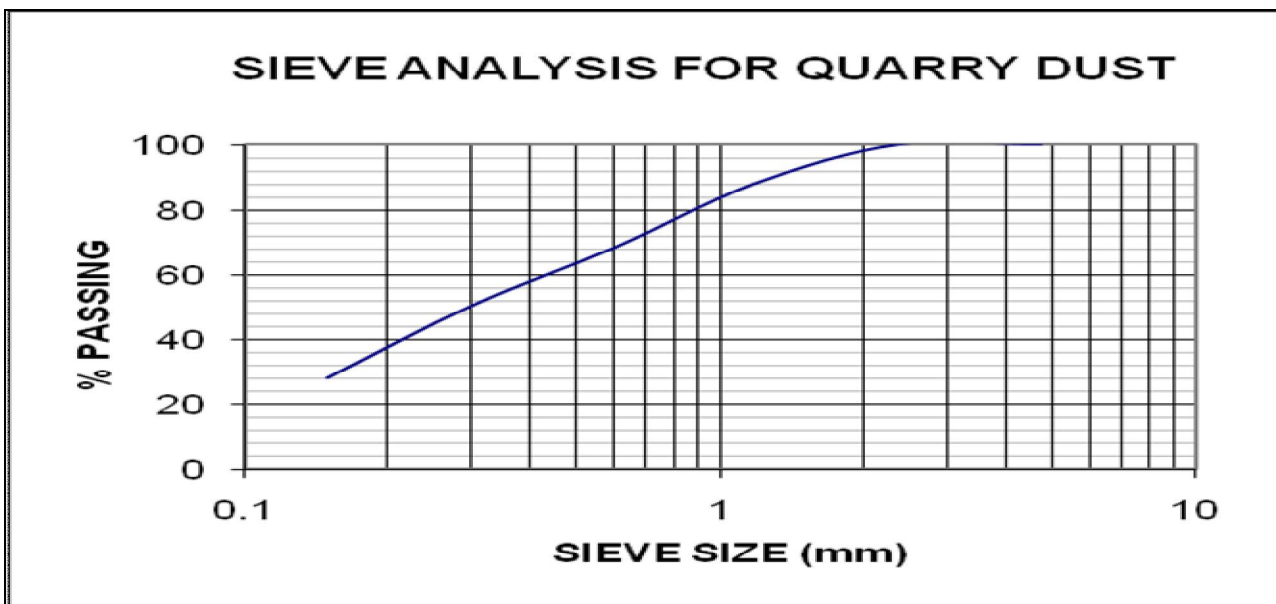


Fig 1: Particle size distribution curve for quarry dust to study its particle size variation and fineness tested in laboratory under ordinary field conditions

IV.III COARSE AGGREGATE

Crushed granite aggregate with a maximum nominal size of 12 mm and bulk density 1510 Kg/m³ (loose state) and 1600 Kg/m³ (rodded state) have been used.

IV.IV SAND

Fine aggregate used for the study should be properly graded to give the minimum voids ratio and shall be free from deleterious materials like clay, silt content and chloride contamination. Locally available sand passing through 4.75mm sieve with fineness modulus of 3.416 and specific gravity 2.57 which falls under grading zone II were used for the entire investigation.

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IV.V CHEMICAL ADMIXTURES

A high performance concrete super plasticizer Glenium B233, based on modified polycarboxylic ether is used to reduce water cement ratio for a required workability. The physical properties of Glenium B233 obtained from BASF construction chemicals are shown in Table 3.

Table 3: Properties of Glenium B233

Physical Properties	Limits
Colour	Yellowish liquid
Relative density	1.09 ± 0.01
pH	7 ± 1

Glenium B233 is a ready to use admixture that is added to the concrete at the time of batching. The maximum effect is achieved when it is added after the addition of 50 to 70 % of the water and it must not be added to the dry materials.

V. EXPERIMENTAL STUDY

V.I SELF COMPACTABILITY OF FRESH CONCRETE

The method for achieving self compactability involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and mortar when the concrete flows through the confined zone of reinforcing bars. Okamura and Ozawa have employed the following methods to achieve self compactability

1. Limited aggregate content
2. Low water-powder ratio
3. Use of super plasticizer

V.II WORKABILITY TESTS

To study the fresh concrete properties of self compacting concrete based on the parameters defining the fresh concrete, many different test methods have been developed in an attempt to characterize the property of Self Compacting Concrete. The following tests are conducted to determine the properties of self compacting concrete.

Slump Flow Test

The slump flow is used to assess the horizontal free flow of Self Compacting Concrete in the absence of obstruction. This method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the filling ability of concrete. This test gives good assessment on the filling ability of the concrete and some indication of resistance to segregation. The acceptance limit for slump flow should be between 500 and 800 mm.

V-Funnel Test

The equipment consists of a V-shaped funnel. The test is used to determine the filling ability of the concrete with a maximum aggregate size of 20mm. The funnel is filled with about 12 litres of concrete and the time taken for it to flow through the apparatus measured. V-Funnel flow time, T_f should be less than 6 seconds.

L-Box Test

The test assesses the flow of the concrete, and also the extent to which it is subject to blocking by reinforcement. The apparatus consists of a rectangular-section box in the shape of an 'L', with a vertical and horizontal

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section, separated by a moveable gate, in front of which vertical lengths of reinforcement bars are fitted. Blocking ratio is to be greater than 0.8.

U-Box Test

This Test is also called as “box-shaped” test. The test is used to measure the passing ability of Self Compacting Concrete. The apparatus consists of a vessel that is divided by a middle wall into two compartments. An opening with a sliding gate is fitted between the two sections. Reinforcing bars with nominal diameters of 13 mm are installed at the gate with centre-to-centre spacing of 50 mm. This creates a clear spacing of 35 mm between the bars. The left hand section is filled with about 20 litres of concrete then the gate lifted and concrete flows upwards into the other section. The height of the concrete in both sections is measured. It provides a good direct assessment of filling ability. The filling height should be in between 0 – 30 mm.

V.VI HARDENED CONCRETE TESTS

Compressive Strength Test

The main aim is to determine the compressive strength of concrete specimen. The test specimens, cubical in shape of size 150 x 150 x 150 mm. Compression tests are made at recognized (28 days) ages of the test specimens. Specimens cured in water are tested immediately on removal from water and while they are still in wet condition. The bearing surfaces of the testing machine are wiped clean and the cubes are placed in the compression testing machine in such a manner that the load is applied to opposite sides of the cubes as cast. The axis of the specimen is carefully aligned with the centre of thrust of the spherically seated plate. The spherically seated block is brought to bear on the specimen and the load is applied without shock and continuously at a rate approximately 140 kg/cm²/minute until failure of the specimen. The maximum load applied to the specimen until failure is recorded.

Split Tensile Strength Test

The objective of this test is to find the splitting tensile strength of concrete cylinders. The specimens shall be cylindrical in shape, 150 mm in diameter and 300 mm long. The test is made at 28 days. This is an indirect method of finding tensile strength of concrete. This is also sometimes referred as “Brazilian Test”. One of the plywood strips is cantered along the centre of the lower pattern. The wet cylinder specimen is placed on the strip horizontally with its axis perpendicular to the loading direction. The second plywood strip is then placed lengthwise on the cylinder centrally. The load is then applied without shock and increased continuously at a rate to produce approximately a splitting tensile stress of 14 to 21 kg/cm²/min until failure

Flexural Strength Test

The aim of this test is to determine the flexural strength of the concrete specimen. The specimens in the form of beams 100 x 100 x 400 mm in size are used and are supported on rollers. The specimen is placed in UTM, in such a manner that load shall be applied to the upper most surface, as cast in the mould, along two lines spaced 13.3 cm apart. The load shall be applied without shock and increased at rate such that, the extreme fibre stress increases at approximately 7 kg/mm²/min, until failure occurs.

Young's Modulus Test

The aim of this test is to draw the stress-strain characteristics of the concrete and to find the Young's modulus of concrete. The concrete specimen is a cylinder of 150 mm diameter and 300 mm height. Assemble the top and bottom frame of the compressometer by keeping the spacers in position. Keep the pivot end on the screws. Adjust the screws and lock them in position. Keep the tightening screws of the top and bottom frames unscrewed. Keep the cylinder on a level surface. Place the compressometer centrally on the specimen so that the tightening screws of the bottom and top

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frames are at an equal distance from the ends. Screw the tightening screws so that the compressometer is held on the specimen. Remove the spacers by unscrewing the spacer screws. Place the specimen with compressometer on the lower plate of the compression testing machine. Set the dial gauge and take the initial reading. Start applying the load at a uniform rate and note the dial gauge reading for every load increment. To get the actual deformation divide the dial gauge readings by two. Calculate the stress-strain values for every load increment and plot them. Draw the tangent to the stress-strain curve at the initial point and find its slope, which gives the value of Young's modulus.

VI. TEST RESULTS

VI.I. WORKABILITY TEST RESULTS

The investigation is carried out by varying the quarry dust content by replacing sand and the super plasticizer dosage. In this investigation the cement content is kept as 550 kg/m^3 and all mixes have been tested in order to achieve the self compacting concrete characteristics. Table 4 gives the details of the workability test results with different super plasticizer dosage taken for the investigations.

Table 4: Fresh concrete test results

Specimen Index	Glenium B233 (%)	Quarry Dust (%)	Slump value (mm)	V Funnel Test (sec)	U-Box Test (mm)	L-Box Test (H2/H1)
QD1	0	0	No Significance	No Significance	No Significance	No Significance
QD2	0	20	No Significance	No Significance	No Significance	No Significance
QD3	0	40	No Significance	No Significance	No Significance	No Significance
QD4	0	60	No Significance	No Significance	No Significance	No Significance
QD5	5	0	No Significance	No Significance	No Significance	No Significance
QD6	5	0	No Significance	No Significance	No Significance	No Significance
QD7	5	0	430	No Significance	No Significance	No Significance
QD8	5	0	470	No Significance	No Significance	No Significance
QD9	10	0	580	9	No Significance	No Significance
QD10	10	20	540	7	42	0.54
QD11	10	40	585	6	38	0.76
QD12	10	60	610	4	24	0.9

VI.II. HARDENED CONCRETE TEST RESULTS

Once the fresh properties of SCC are assessed, the mixes are casted in specimens such as prisms, cylinders and beams in order to assess the mechanical properties of hardened concrete and the table 5 shows the test results for the SCC mixes with and without replacement of quarry dust obtained at 28 days of curing.

Table 5: Test results of hardened concrete

Specimen Index	Glenium B233 (%)	Quarry Dust (%)	Compressive Strength (Mpa)	Flexural Strength (Mpa)	Split Tensile Strength (Mpa)	Youngs Modulus (Mpa)
QD1	0	0	56.8	5.63	3.97	20428
QD2	0	20	58.85	6.78	4.44	23546
QD3	0	40	66.55	7.45	5.27	27424

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QD4	0	60	48.60	4.75	3.05	21830
QD5	5	0	52.40	5.14	3.78	19142
QD6	5	0	47.74	4.19	2.96	17097
QD7	5	0	50.26	4.34	4.03	20823
QD8	5	0	37.45	2.65	3.61	23825
QD9	10	0	41.20	3.92	4.54	26940
QD10	10	20	32.82	2.15	4.28	21329
QD11	10	40	42.59	4.94	3.71	22342
QD12	10	60	47.74	5.24	4.16	24000

VI.III. COMPARISON OF STRENGTH FOR DIFFERENT MIXES

From the results of hardened concrete testing, it is observed that the strength of concrete increases with increase in percentage replacement of quarry dust up to 40% and there after the strength is reduced and this comparison of strength for different mixes with quarry dust alone from 0% to 60% is shown in figure 2.

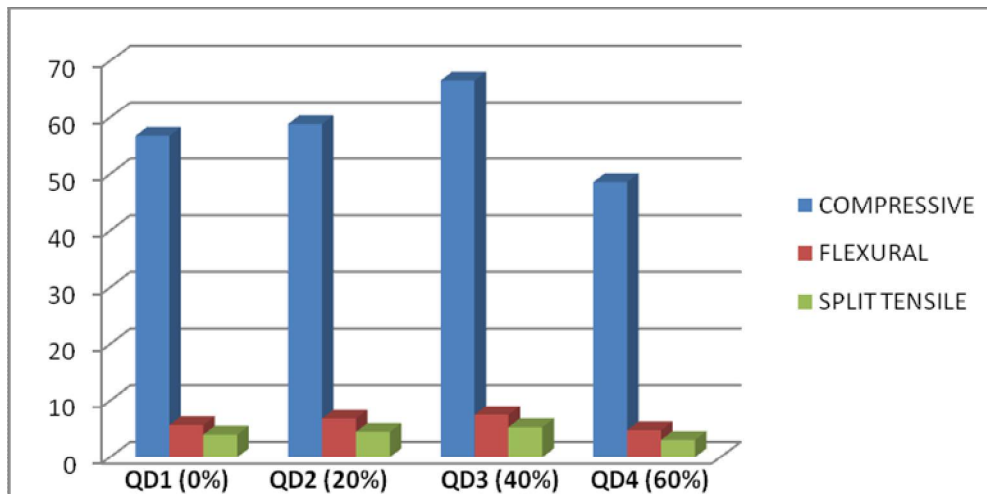


Fig 2: Comparison of strength for concrete mixes

VI.IV. STRESS-STRAIN ANALYSIS

From the tabulated values of young's modulus tests, stress-strain analysis is carried out to assess the modulus of elasticity of the concrete cylinders. Figure 3 represents the analysis for the mix combinations with and without quarry dust replacement.

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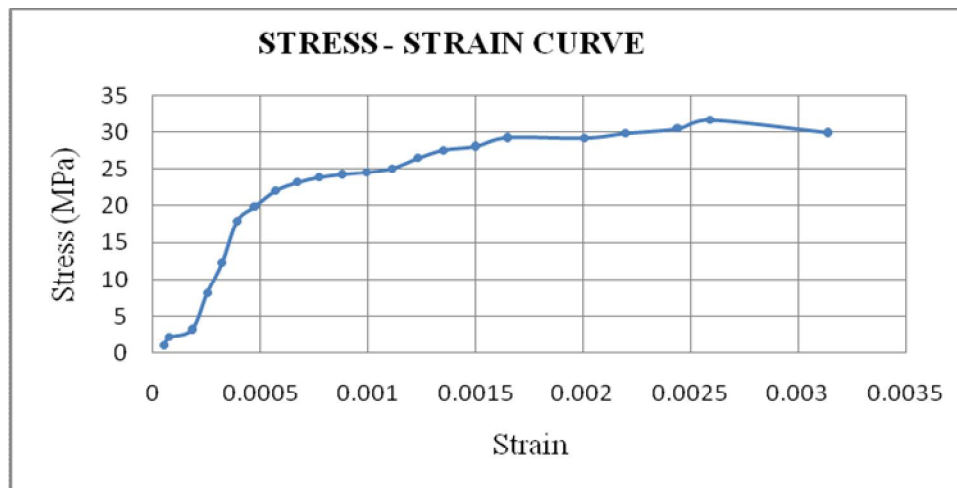


Fig 3: Stress-strain curve for cylinder specimens

VII. CONCLUSION

The experimentation can be summarized as follows.

1. It is observed that while increasing the quarry dust content the workability characteristics has been considerably affected.
2. For 60% replacement of quarry dust, the workability parameters fail to meet the requirements as per the EFNARC guidelines. So it can be concluded that optimum quarry dust replacement content will be around 40%.
3. Throughout the investigation, chemical admixtures the Glenium B233 is used as a water reducing agent
4. The desired properties of SCC were obtained in the combined addition of chemical admixtures. VMA reduces the segregation property of the mix while WRA will help to reduce the bad effects such as bleeding etc.
5. The hardened concrete properties were studied in terms of 28 day strength on cubes, cylinders and prisms. For mix QD12, it is observed that the compressive strength is around 50 MPa . Similarly the other strength parameters such as Split Tensile Strength, Flexural Strength and Young's Modulus were also identified.

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