STUDY ON PERFORMANCE OF QUARRY DUST AS FINE AGGREGATE IN CONCRETE

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ABSTRACT

The suitability of quarry dust as alternative material for the river sand in concrete manufacturing is studied. M25 grade concrete was prepared with 0%, 20%, 40%, 60%, 80% partial replacement of sand with quarry dust. The physical properties of quarry dust namely specific gravity; water absorption; silt content; and fineness modulus were measured using standard tests. This was followed by compression, split tensile and bending tests on cubes, cylinders and RC beams respectively to study the strength of concrete made of quarry rock dust. The results were compared with the conventional concrete (0%). The results showed that with increasing proportion of quarry dust, the strength increased to peak value (at 40%) followed by a subsequent drop in strength and a decreased workability.

Key Words: *Quarry dust, compressive strength, split tensile strength, reinforced-concrete.*

INTRODUCTION

Quarry dust is the residue of particles in the size range of 0 – 4.75mm obtained as a byproduct in the later stages of crushing of igneous rock, sedimentary rock or gravel.

It is produced in natural stone processing plants.It is currently used in road highway construction as a surface finishing material. It is also used in manufacture of hollow blocks and lightweight concrete blocks.

Quarry dust is cheap. Worldwide natural stone industry offers an output of 68 million tonnes of the processed product (dust or slurry) annually. In 2006, the European Union alone accounted for 39.2% of total amount, assuming the leadership of the sector, followed by Asia, which owed its comfortable share of 37% contributed by China and India.

The earliest research was conducted by Celik et al., 1996 on crusher dust formed during the process of comminution of rock into crushed stone or crushed sand. They investigated the effects of varying dust content from 0 to 30% of fine aggregates on the physical and mechanical properties of fresh and hardened concrete. They reported an increase in compressive strength and flexure strength upto 10% dust content, followed by a gradual decrease with increasing dust content.

Sivakumar et al., 2011 studied the mechanical properties of cement mortar and concrete by replacing fine aggregates with quarry dust. They reported a 11.8% increase in compressive strength of cement mortar cubes with 100% replacement of sand with quarry dust. They also reported a 17.45% and 15.25% increase in compressive strength and split tensile strength of concrete. Shyam Prakash et al., 2016 studied strength of concrete with replacement of sand with quarry dust ranging for 0-100%. They reported increase in concrete compressive strength for upto 40% replacement followed a decrease from 50% replacement onwards.

Ho et al., 2002 studied the performance of granite fines and limestone powder for use in self-compacting concrete. Shakir et al., 2013 studied a novel flowable method of brick production using quarry dust, billet scale and fly ash with improved durability and compressive strength.

With regards to workability, they reported that due to its higher surface area quarry rock dust consumes more water . Raman et al., 2011 used quarry dust as partial replacement for sand in quantities ranging from 10% to 40%. They reported a decrease in compressive strength and also a decrease in workability with increasing quarry dust content.

EXPERIMENTAL PROGRAMME

The present work investigates the effect of using quarry dust as partial replacement for sand on the compressive strength and splitting tensile strength for M25 grade concrete. It identifies the trend in variation of these strengths with increasing replacement. The optimum replacement for which strength is maximized is found for this test batch. The flexural behavior of reinforced concrete beam specimen with increasing proportion of quarry dust in fine aggregates is also investigated and compared with control reinforced concrete beam.

The following materials have been used throughout this investigation. Normal potable drinking water was used in the experiments. Portland Slab Cement (PSC) was stored in airtight drums when it is not in use during the test period to minimize the effect of weathering. Specific gravity of this cement was found to be 2.98. Crushed granite stones in size range of 10 mm and 20 mm were collected. Specific gravity of these coarse aggregates was found to be 2.73 and water absorption was found to be 0.68%.

The physical properties of the quarry dust collected from the source were determined and compared with sand as illustrated in table 1.

Table 1: Comparison of Properties of Sand and Quarry Dust

Property	Sand	Quarry Dust
Specific Gravity	2.55	2.57
Water Absorption	1.65	3.62
Silt content	2.13	4.08
Fineness modulus	2.50	2.92

Compressive Strength

The compressive strength is used to measure overall quality of concrete and thus as an indication of other properties relating to the deformations or durability. 150 mm cube is cast and tested as per IS 516:1959. The curing was done by immersion in water tanks kept in the laboratory. Thee cubes were tested under the Compressive testing machine and the average compressive strength of three cubes each were evaluated at 7 days and 28 days.

Figure 1: Experimental Setup for Compressive Strength of concrete

Split Tensile Strength

Concrete is not usually expected to resist direct tensile forces because of its low tensile strength and brittle nature. However, tension is important with regard to cracking which is a tensile failure. 150 x 300 mm cylinders are cast with the same concrete. The cylinder is prepared and tested according to IS.516-1959. A minimum of three cylinders is tested for each group of mix.

Figure 2: Experimental Setup for Split Tensile Strength of concrete cylinder

Test on RC Beams with Quarry Dust Concrete

The beams are 150 mm wide and 200 mm deep and 1400 mm long for an effective span of 1200 mm. The Longitudinal reinforcement comprised 3 number of 8mm diameter bars of Fe 500 grade at bottom and 2 number of 8mm diameter bars at top. Two-Legged stirrups of 8mm mild steel bars are provided at 150 mm on centre. The beams are designed(M_{25} grade concrete and Fe 415 grade steel) pertaining to a two-point load of 20 kN spaced at 400 mm as shown in the figure below. The beams are under-reinforced, and the effect of compression steel was not considered in the design.

The mix design for M25 is based on IS 10262:2009. Maximum/minimum cement content and maximum water to cement ratio used in the concrete is based on IS-456:2000. Maximum size of aggregates used is 20mm. Sica admixture is used and design is done targeting a slump of 60mm and taking into account the various properties of materials like cement, sand, coarse aggregates. We adopt water-cement ratio of **0.43.** The mix proportions for M25 comes out to be **1:1.33:2.73 (**cement:FA:CA).

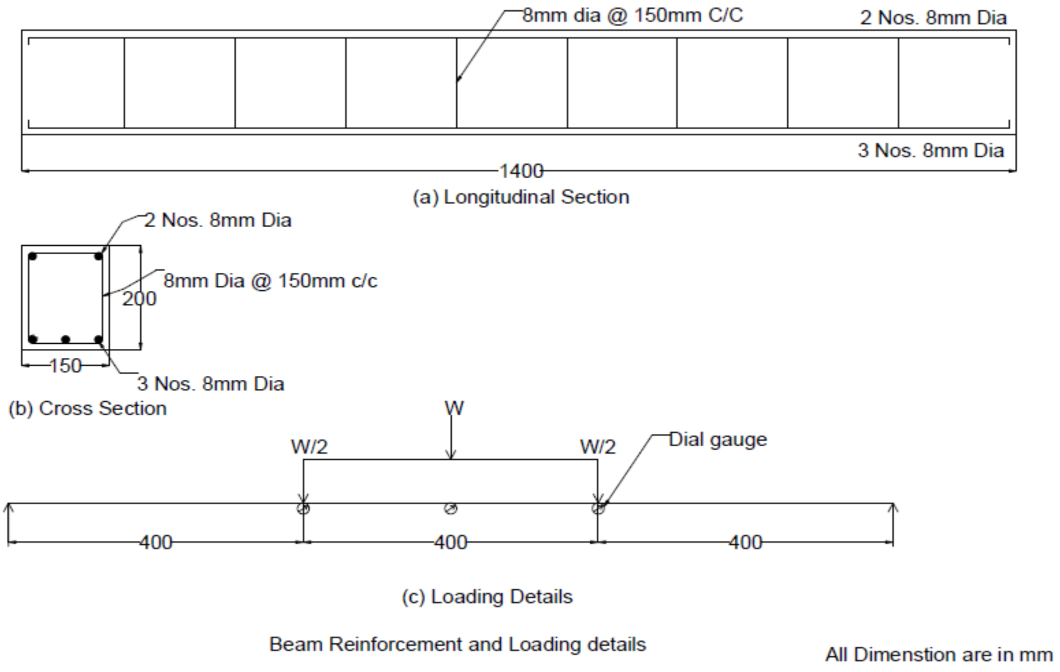

Figure 3: Detailing and load set up of reinforced concrete beam

RESULTS AND DISCUSSION

Slump Test

The slump values in case of 20%, 40% and 60% replacement by quarry dust in concrete were 70mm, 67mm and 62 mm respectively. However, the slump value in case of 80% and 100% replacement were 38mm and 28mm respectively. This indicates workability with 80% and 100% replacement by quarry dust is lower as compared to 20%, 40% and 60% replacement.

Compressive Strength

Three cubes were cured for 28 days and the average compressive strength was obtained. The results are shown in table 2 and figure 4

The compressive strength increased with increase in percentage replacement of quarry dust upto 40% after which the strength reduced with increase in amount of quarry dust. There was a considerable decrease in compressive strength in case of 80% and 100% replacement. The given graph below shows the variation of compressive strength with different percentage replacements by quarry dust.

Split Tensile Strength

Three cylinders each having diameter 150 mm and height 300 mm were cured for 28 days and tested to determine the average split tensile strength. The trend for split tensile strength was similar to that obtained in the compressive strength. The maximum split tensile strength was obtained for 40% quarry dust proportion.

Table 2: Compressive strength at 28 days

Quarry Dust as replacement for sand	Specimen	Weight(in kg)	Load(in kg)	Compressive Strength(MPa)	Average Compressive Strength (MPa)
0%	1.	8.30	60500	26.37	26.74
	2.	8.32	61500	26.81	
	3.	8.34	62000	27.03	
20%	4.	8.26	62000	27.25	27.76
	5.	8.36	63500	27.69	
	6.	8.48	65000	28.34	
40%	7.	8.22	67000	29.21	29.79
	8.	8.26	68500	29.87	
	9.	8.32	69500	30.30	
60%	10.	8.32	64000	27.90	27.47
	11.	8.28	62000	27.03	
	12.	8.30	63000	27.47	
80%	13.	8.32	43500	18.97	18.97
	14.	8.12	42000	18.31	
	15.	8.40	45000	19.62	
100%	16.	8.48	49000	21.36	21.44
	17.	8.42	48500	21.15	
	18.	8.56	50500	21.80	

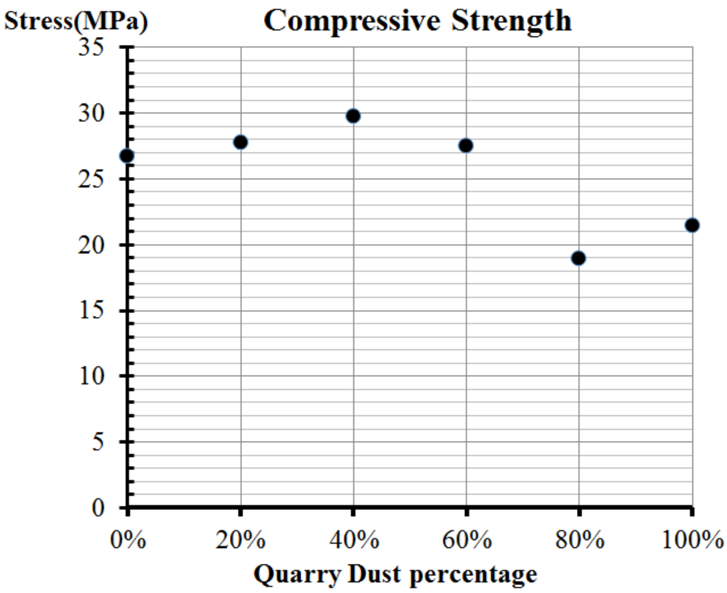

Figure 4: Variation of compressive strength with % increase in quarry dust

Table 3: Split tensile strength at 28 days

Quarry Dust as replacement for sand	Specimen	Weight(in kg)	Load(in kg)	Split Tensile Strength(MPa)	Average Split Tensile Strength (MPa)
0%	1.	13.08	14500	2.01	1.89
	2.	13.06	13500	1.87	
	3.	12.98	13000	1.80	
20%	4.	12.98	16500	2.29	2.15
	5.	12.94	15500	2.15	
	6.	12.90	14500	2.01	
40%	7.	13.22	21000	2.91	2.75
	8.	13.28	19500	2.71	
	9.	13.30	19000	2.64	
60%	10.	13.18	12500	1.73	1.71
	11.	13.20	13000	1.80	
	12.	13.14	11500	1.60	
80%	13.	13.26	16000	2.22	2.10
	14.	13.32	15000	2.08	
	15.	13.18	14500	2.01	
100%	16.	13.36	10000	1.39	1.27
	17.	13.28	8500	1.18	
	18.	13.32	9000	1.25	

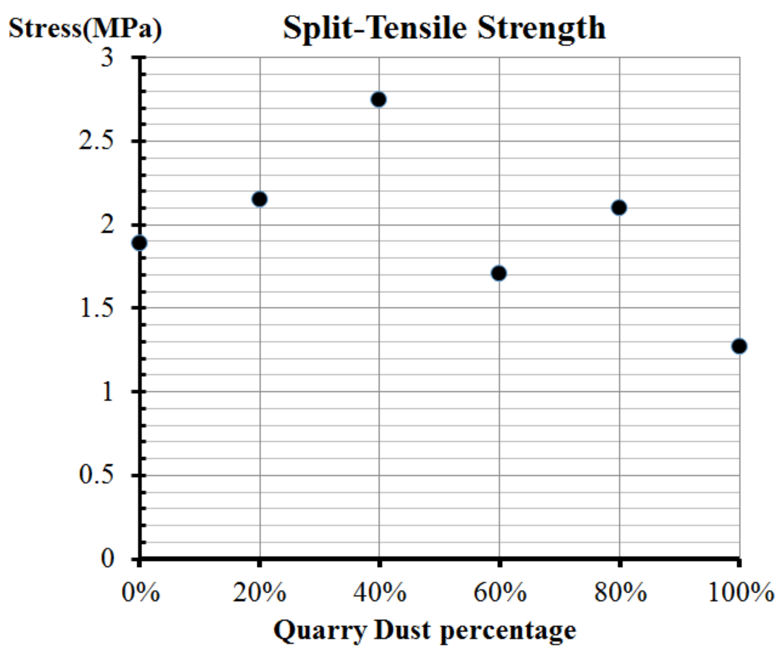

Figure 5: Variation of Average split tensile strength with % increase in quarry dust

Four point bending tests on RC Beams

The beam cast with natural sand as fine aggregate was designated CS-1 (Control Specimen). Four beams QD-20, QD-40, QD-60 were prepared by partial replacement of sand with quarry dust with the percentages being 20%, 40% and 60% respectively. The concrete was compacted using a 25 mm needle vibrator. Four-point bending tests were carried out on these beams using Universal Testing Machine of 500 kN capacity. During the test, the beam deflection was recorded at mid-span and one-third section using dial-gauges for every incremental load of 2.5 kN distributed equally over the two points of load application. The cracks were also visually monitored during the tests. The results on flexural behavior (deflection, and failure modes) were compared in Table 4 and Figure 6. The peak loads for control specimen, QD-20, QD-40 and QD-60 were 90 kN, 110 kN, 120 kN and 110 kN respectively. Flexural cracks were observed at peak loads as shown in Figure 7.

The RC beams with quarry rock dust sustained about 10 to12 percent more strength under two-point loading and developed smaller deflection than the beam with river sand. The better performance of beams with quarry rock dust may be due to the higher strength of concrete. Based on the test results presented it is concluded that quarry rock dust can be adopted in RC concrete structures. However, 80% and 100% replacement of sand by quarry dust in RC beams is not recommendable since the strength was low and the workability was less. More studies are needed in RC Beams with the properties of stress, strain behaviour and finite element model analysis.

Table 4: Load (kN) vs Mid span Deflection (mm) Data for beams under flexural loading

Control Beam (CS) No Quarry Dust		**20% Quarry Dust (QD-20)**		**40% Quarry Dust (QD-40)**		**60% Quarry Dust (QD-60)**	
Load	**Deflection**	**Load**	**Deflection**	**Load**	**Deflection**	**Load**	**Deflection**
0	0	0	0	0	0	0	0
10	0.26	10	0.25	10	0.25	10	0.25
20	0.58	20	0.4	20	0.46	20	0.48
30	0.99	30	0.54	30	0.64	30	0.62
40	1.56	40	0.82	40	0.87	40	0.88
50	2.23	50	1.25	50	1.43	50	1.5
60	3.14	60	2.08	60	1.89	60	1.95
70	3.98	70	2.72	70	2.53	70	2.6
80	4.51	80	3.17	80	3.03	80	3.14
90	5.32	90	3.68	90	3.42	90	4.34
		100	4.13	100	3.95	100	5.34
		110	4.98	110	4.53	110	7.05
				120	5.06		

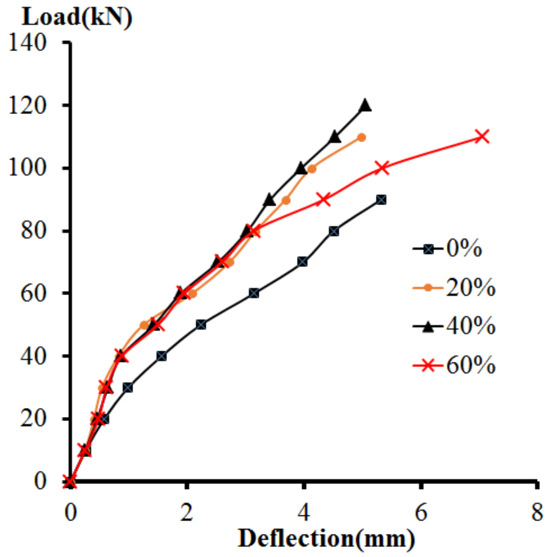

Figure 6: Plot of Load vs Mid-span Deflection for RCC beams for increasing proportion of quarry dust in fine aggregate

Figure 7: Flexure cracks propagating in RC beam under four point bending test.

CONCLUSIONS

1. Slump test studies on quarry rock dust concrete are 11%-13% lower than reference concrete. The workability obtained with 80% and 100% replacement was very low. This might be due to the higher water absorption capacity of quarry dust due to the presence of higher amounts of silt content in quarry dust as compared to sand.

2. With increase in quarry dust proportion of fine aggregates, compressive strength and split tensile strength showed an increasing trend followed by decreasing trend (after reaching peak strength). The present concrete mix gave the highest value at 40% proportion. Also the compressive strength obtained with 60%, 80% and 100% proportions was lower indicating such higher proportions of quarry dust are not recommendable in concrete.

3. The flexural load carried by RC beams with quarry dust proportion of 20%, 40% and 60% of fine aggregate was 10 to12 percent compared to the control RC beam. The better flexural

performance of beams with quarry rock dust may be due to the higher compressive strength and tensile strength of concrete.

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