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Strength and Durability of High Performance Concrete Using Quarry Dust

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Abstract - *Concrete is probably the most extensively used construction material in the world. It has been in use for centuries in various type of structure due to its versatile nature. Increase in demand and decrease in supply of aggregate for the production of concrete motivated to identify new source of aggregates. So we use other materials to replace the appropriate amount of aggregates and study was made on quarry dust. The objective of this study is to find the suitability of using quarry dust in concrete and to compare its properties with that of the conventional concrete. Hence a simple mix design procedure has been developed especially for M60 grade concrete. In this work, the feasibility of the usage of quarry dust as 60:40 proportion of substitution of natural sand i.e. (quarry dust replaces 60% of natural sand) in concrete. Silica fume is added as mineral admixture by 10% and 20% of weight of cement and steel fiber used in different percentage (0.5%, 1.0%, and 1.5%) to increase the tensile strength. Tests were conducted for 3, 7 and 28 days to study the compressive, tensile and durability test of concrete also conducted. From the result it was found that addition of silica fume will increase the compressive strength, steel fibre will increase the tensile strength. Addition of 1% steel fibre is found as optimum from the experimental results.*

Keywords - High performance Concrete, Quarry dust, Strength, Workability, Mechanical properties.

1. INTRODUCTION

Concrete is a widely used material in the world. Based on global usage, it is placed at second position after water. Fine aggregate is an essential component of concrete. The most commonly used fine aggregate is natural river or pit sand. The global consumption of natural sand is very high due to the extensive use of concrete owing to rapid infrastructural growth. In this situation, the construction industries of developing countries are in stress to identify alternative materials to lessen or eliminate the demand for natural sand. So, quarry waste fine aggregate could be an alternative of natural sand. It is a byproduct generated from quarrying activities involved in the production of crushed coarse aggregates. Quarry waste fine aggregate, which is generally considered as a waste material after the extraction and processing of rocks to form fine particles less than 4.75mm, causes an environmental load due to disposal problem. Hence, the use of quarry waste fine aggregate in concrete mixtures will reduce not only the demand for natural sand but also the environmental burden. Moreover, the incorporation of quarry waste fine aggregate will offset the production cost of concrete. In brief, the successful utilization of quarry waste fine aggregate will turn this waste material into a valuable resource. Unfortunately, limited research has been conducted to explore the potential utilization of quarry waste fine aggregate in concrete mixtures. Usually, Quarry Rock Dust is used in large scale in the highways as a surface finishing material and also used for manufacturing of hollow blocks and lightweight concrete prefabricated Elements. Use of Quarry rock dust as a fine aggregate in concrete draws serious attention of researchers and investigators.

2. LITERATURE REVIEW

Ganesan (2009) reported that volume fraction of steel fibre to be used are 0.5, 1.5, 2.0%. For M60 compaction factor ranges from 0.88 to 0.92. Indira P V (2009) reported that the standard mix design methods cannot be directly applied to HPC since various additional parameters are to be considered simultaneously. ACI 211 was a recommended code to made a mix proportioning of HPC. Subramanian, Kalaiarasu (2008) reported that the workability of concrete decreases as percentage of silica fume in concrete increases. Raman, Md. Safiuddin and Zain (2007) indicated that quarry waste did not significantly affect the non-destructive properties of the concretes except initial surface absorption. Dynamic modulus of elasticity, ultrasonic pulse velocity, and initial surface absorption varied linearly with compressive strength. Moreover, dynamic modulus of elasticity and ultrasonic pulse velocity were well-correlated. Ilangovan and Nagamani (2006) reported that Natural Sand with Quarry Dust as full replacement in concrete as possible with proper treatment of Quarry Dust before utilization. Quarry waste fine aggregate was used in presence of silica fume. The overall test results revealed that quarry waste fine aggregate can be utilized in concrete mixtures as a good substitute of natural sand. It is found that the compressive, flexural strength and durability studies of concrete made of quarry rock dust are nearly 10% more than the conventional concrete. Sahu, Sunil Kumar and Sachan (2003) reported significant increase in compressive strength, modulus of rupture and split tensile strength when 40 percent of sand is replaced by Quarry Rock Dust in concrete. Nagaraj (2000) studied that the consumption of cement content, workability, compressive strength and cost of concrete made with Quarry Rock Dust. The mix design proposed shows the possibilities of ensuring the workability by wise combination of rock dust and sand, use of super plasticizer and optimum water content. Hudson(1997) reported that the strength of Quarry Rock Dust concrete is comparatively 10-12 percent more than that of similar mix of Conventional Concrete. Also the result of this investigation shows that drying shrinkage strains of Quarry Rock Dust concrete are quite large to the shrinkage strain of Conventional Concrete. However, at the later age, they have shown equal strain than Conventional Concrete. Durability of Quarry Rock Dust concrete under sulphate and acid action is higher inferior to the Conventional Concrete Permeability Test results clearly demonstrates that permeability of Quarry Dust concrete is less compared to conventional concrete. Nagaraj and Zahinda Banu (1996) produced concrete using the rock dust as an alternative to natural sand. They studied the effect of rock dust on the strength and workability of concrete.

3. MATERIALS

3.1 Cement

The Ordinary Portland cement was used in this study conforming to IS: 8112-1989. The specific gravity of cement is 3.15. The initial and final setting times were found as 26 minutes and 120 minutes respectively. Standard consistency of cement was 31%.

3.2 Fine aggregates

The river sand is used as fine aggregate conforming to the requirements of IS: 383-1970, having specific gravity of 2.68 and fineness modulus of 2.52 has been used as fine aggregate for this study.

3.3 Coarse Aggregate

Coarse aggregate obtained from local quarry units has been used for this study, conforming to IS: 383-1970 is used. Maximum size of aggregate used is 20mm with specific gravity of 2.63 and fineness modulus of 6.11 has been used.

3.4 Quarry Dust

The quarry dust used for this investigation work is obtained from the quarry near tindivanam in Tamil Nadu. The quarry dust passing through 4.75 mm retained on 150 micron IS sieves are taken. Specific gravity of 2.617 and fineness modulus of 2.706 has been used.

3.5 Silica Fume

The specific gravity of silica fume is 2.2. It consists of 0.1 to 1 micron sized fine, smooth spherical glassy particles with fineness of 20m^2/gm conforming to ASTM C1240-1999 standards.

4. EXPERIMENTAL PROCEDURE

Mix proportions were arrived at for M60 grade of HPC trial mix based on the above formulated mix design procedure by adding 15% of the mass of cement with silica fume at a W/C ratio of 0.29 and a super plasticizer namely, CONPLAST SP430 was used at 2% by weight of a cements for obtaining workable concrete. The mixes were designated in accordance with IS: 10262-2009. However, as the steel fibres were added to the HPC, the workability was found to decrease. Percentage replacement of Quarry dust (Q: S =60:40) with partial replacement of 15% of silica fume and addition of steel fibre of various proportions (0.5%, 1.0%, 1.5%).A total of 36 concrete cubes, 36 concrete cylinders and 12prismswere casted. The specimens were demoulded after 24 hours and curing was done for different age of testing. They were tested for their strength properties on 3, 7, 28th day confirming to IS: 516-1959.

Table -1: Details of Mix Proportions of Concrete

Water	Cement	Fine aggregate	Coarse aggregate	Silica fume	Super plasticizer
139.2	497.17	602.91	1193.24	74.57	9.94
0.29	1	1.21	2.40	15%	2%

Table -2: Compressive strength of cubes on 3, 7 and 28 Days in 10% of silica fume

% of Replacement	Cube Compressive Strength (N/mm2)		
	3 days	7 days	28 days
CC	31.86	42.67	63.48
steel fibre 0.5%	34.31	45.12	65.93
steel fibre 1.0%	38.83	47.64	66.45
steel fibre 1.5%	37.72	45.53	63.34

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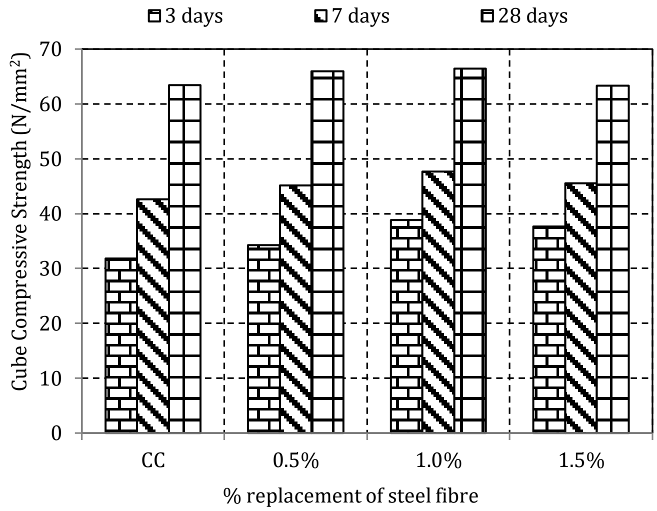

Chart -1: Compressive strength of cubes on 3, 7 and 28 Days

Table -3: Compressive strength of cubes on 3, 7 and 28 Days in 20% of silica fume

% of Replacement	Cube Compressive Strength (N/mm2)		
	3 days	7 days	28 days
CC	37.73	48.87	63.01
steel fibre 0.5%	40.18	51.32	67.46
steel fibre 1.0%	44.71	53.84	69.92
steel fibre 1.5%	43.59	51.73	71.5

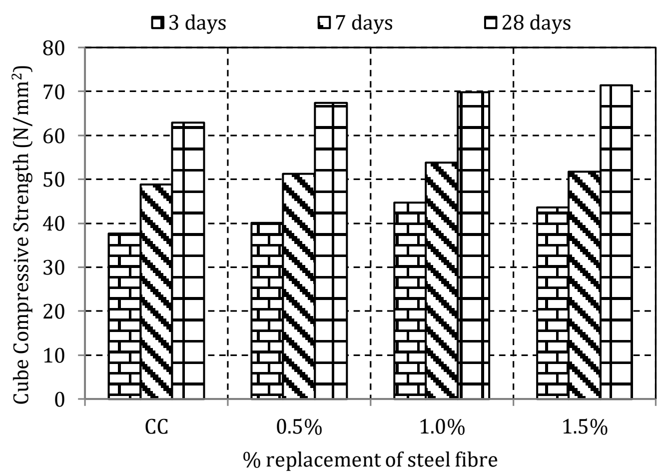

Chart -2: Compressive strength of cubes on 3, 7 And 28 Days

Table -4: Split tensile strength of cubes on 3, 7 and 28 Days in 10% of silica fume

% of Replacement	Split tensile strength(N/mm²)		
	3 days	7 days	28 days
CC	1.45	2.73	4.01
steel fibre 0.5%	1.52	2.96	4.4
steel fibre 1.0%	2.29	4.31	6.33
steel fibre 1.5%	1.92	3.74	5.56

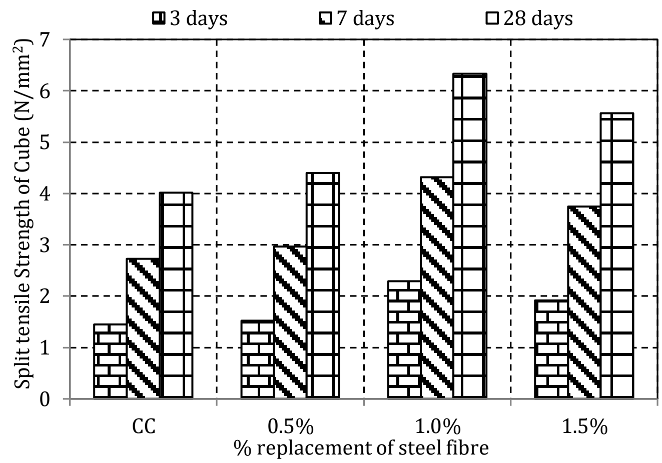

Chart -3: Split tensile strength of cubes on 3, 7 and 28 Days

Table -5: Split tensile strength of cubes on 3, 7 and 28 Days in 20% of silica fume

% of Replacement	Split tensile strength(N/mm²)		
	3 days	7 days	28 days
CC	2.29	3.65	5.01
steel fibre 0.5%	2.36	3.88	5.4
steel fibre 1.0%	3.13	5.23	7.33
steel fibre 1.5%	2.76	4.66	6.56

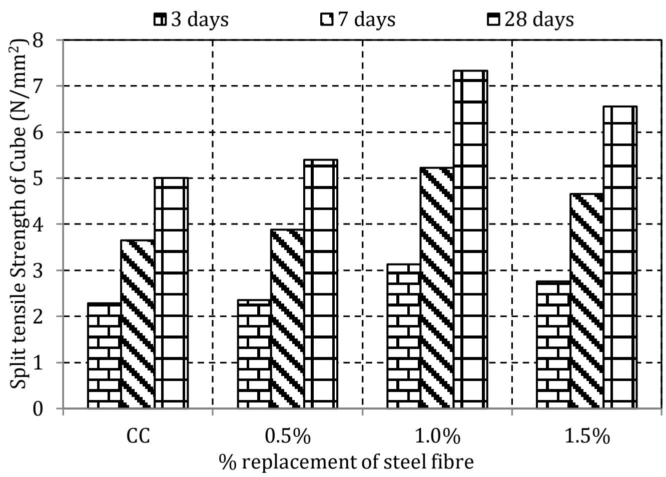

Chart -4: Split tensile strength of cubes on 3, 7 and 28 Days

5.0 DURABILITY TEST

Table -5: Saturated water absorption test in 10% of silica fume

% of Replacement	Flexural strength (N/mm²) 28 days
CC	2.91
steel fibre 0.5%	2.64
steel fibre 1.0%	2.51
steel fibre 1.5%	2.60

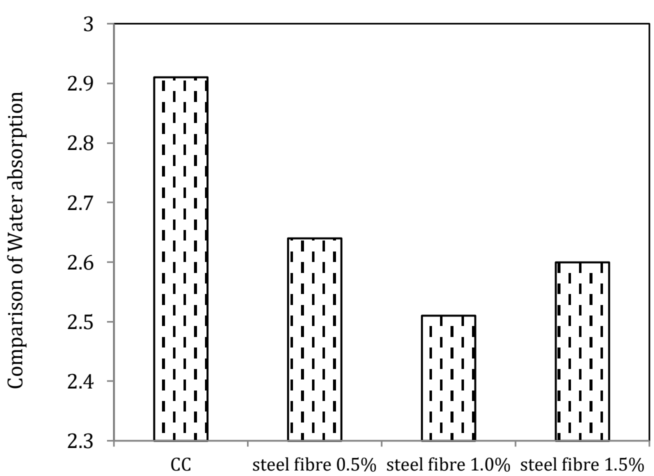

Chart -5: Comparison of Water absorption values at 28th day

Table -6: Saturated water absorption test in 20% of silica fume

% of Replacement	Flexural strength (N/mm²) 28 days
CC	2.91
steel fibre 0.5%	2.89
steel fibre 1.0%	2.70
steel fibre 1.5%	2.82

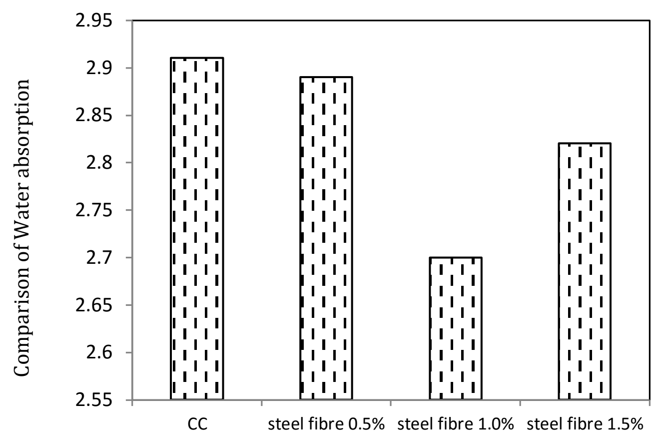

Chart -6: Comparison of Water absorption values at 28th day

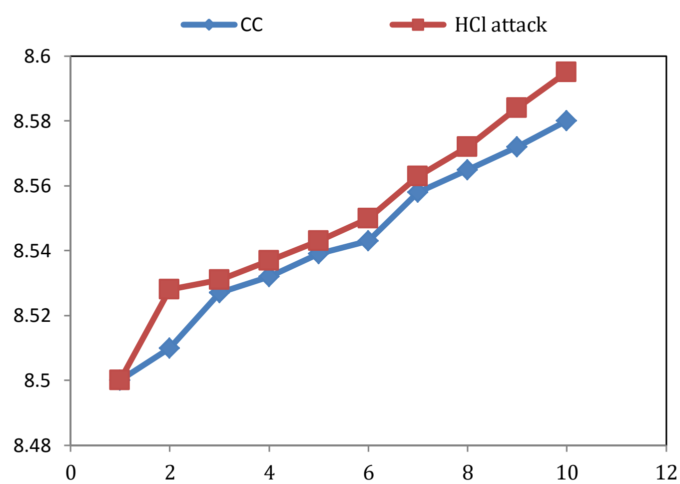

Chart -7: Mass loss of specimen under HCl attack

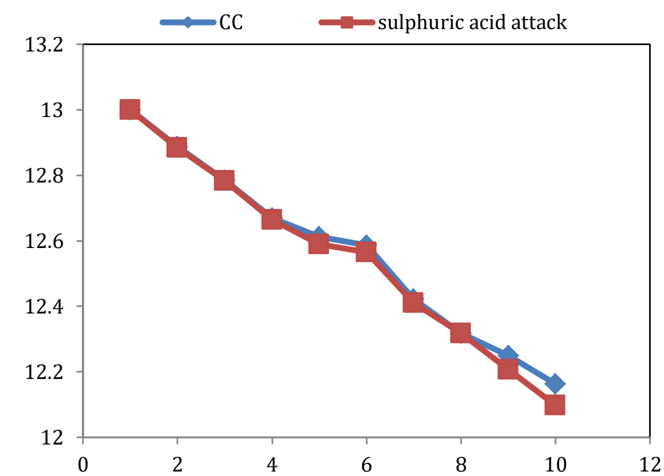

Chart -8: Mass loss of specimen under sulphuric acid attack

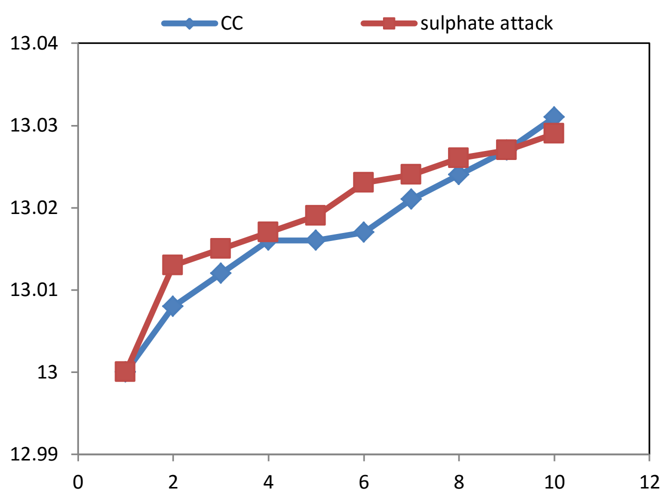

Chart -9: Mass loss of specimen under sulphate attack

6.0 RESULTS AND DISCUSSION

The compressive and split tensile strength of M60 grade concrete mix for quarry dust 60%, silica fume 10%, 20% and different percentage of steel fibre as shown in Table 2, Table 3, Table 4 Table 5. The results for various percentages are discussed below.

1. For M60 concrete the compressive strength at the end of 3, 7 and 28days for 0.5% of additional of steel fibre in 10% silica fume the compressive strength showed an increasing value of 34.31, 45.12and 65.98N/mm^2 as shown in Table 2.
2. For 20% silica fume in addition of 0.5 % of steel fibre in M60 concrete the compressive strength showed an increasing value of 40.18, 51.32 and 67.46N/mm ^{2} as shown in table 3.
3. A similar trend of increasing value was observed when the steel fibre is increased to 1% in 10% silica fume the maximum value obtained for 3 , 7, 28 days are 38.83, 47.64 , 66.45N/mm^2 as shown in table 2.
4. For 20% silica fume in addition of 1 % of steel fibre in M60 concrete the compressive strength showed an increasing value of 44.7, 53.84 and 69.92N/mm ^{2} as shown in table 3.
5. A gradually increase of 0.5% of steel fibre(1.5%) showed a decreasing trend in 10% silica fume of compressive strength at the end of 3 ,7, 28 days as 37.72 , 45.53 , 63.34N/mm ^{2} as shown in table 2.
6. And for 20% of silica fume the 1.5% addition of steel fibre shows the decreasing value of compressive strength at the end of 3 ,7 ,28 days as 43.59 , 51.73 , 71.5 N/mm ^{2} as shown in table 3.
7. The split tensile strength at the end of 3 , 7 , 28 days of 10 % silica fume in addition of 0.5% of steel fibre showed an increase value of 1.52 ,2.96, 4.4 N/mm ^{2} as shown in table 4.
8. For 20% of silica fume the split tensile strength shows an increased value at the end of 3 ,7 ,28 days are 2.36 ,3.88 ,5.4N/mm ^{2} as shown in table 5.
9. A similar trend of increasing value was observed when the steel fibre is increased to 1% the maximum value obtained in 10% silica fume are 2.29, 4.31, 6.33N/mm ^{2} as shown in table 4.
10. For 20% silica fume when the steel fibre is added to 1% it shows an maximum increasing value at the end of 3 ,7 ,28 days are 3.13 , 5.23 , 7.33N/mm ^{2} as shown in table 5.
11. A gradually increase of 0.5% of steel fibre (1.5%) in 10% of silica fume showed a decreasing trend in the Split tensile strength at the end of 3, 7 and 28 days are 1.92 , 3.72 , 5.56 N/mm ^{2} as shown in table 4.
12. For 20% of silica fume in addition of 1.5% of steel fibre shows an decreasing trend in the split tensile strength at the end of 3 , 7, 28 days are 2.76 , 4.66 , 6.56N/mm ^{2} as shown in table 5.
13. The results of acid attack for the high performance concrete at the age of 28 days are shown for M60 grade of concrete in the chart 7, 8 & 9.

14. From the chart it is clear that the deterioration percentage is 8.5 and 7.85 for M60 grade concrete respectively under HCL attack.

15. The deterioration percentage is10.82 and 10 for M60 grade concrete respective under sulphuric acid attack.

16. And deterioration percentage is 7.65 and 7 for M60 grade concrete respective under sulphate attack.

17. It is clearly proven that the percentage of deterioration of high performance concrete is comparatively lesser than conventional concrete.

CONCLUSION

From Compressive Strength, Split Tensile Strength and the Durability test results it was observed that Quarry dust concrete is better than the Nominal concrete and the replacement of 60% of Quarry dust and 40% of Natural sand and addition of 10% and 20% of silica fume and 1.0% of steel fibres proves to be optimum level to produce High Performance Concrete.

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