

Influence of quarry sand on the properties of high strength concrete containing low calcium fly ash

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Abstract: - Influence of the presence of higher percentage of fine particles in quarry sand on the mechanical properties of high strength concrete containing fly ash has been discussed in the present paper. A high strength concrete of grade 50 MPa has been designed with conventional aggregates. From this mixture proportion, the sand content has been replaced with varying percentage of quarry sand (50 percent and 100 percent). The quarry sand selected for the study had the highest percentage of finer particles among the different samples considered. For each such modified mixture proportion, the cement content has been further modified by replacing it with different percentages of fly ash (10 percent to 45 percent). A total of 15 sets of mixes have been considered for the present study. It could be concluded from the study that, the higher percentage of fine particles in quarry sand does not affect significantly the engineering properties of high strength concrete when river sand is replaced with 50percent quarry sand along with a 25 percent replacement of cement with fly ash. Compared with conventional concrete, the said combination will yield an economical concrete also.

Keywords: - Quarry Sand; fly ash; high strength; concrete; mechanical properties

I. INTRODUCTION

Most widely used fine aggregate for making conventional concrete is the natural river sand. However river sand is scarce due to several reasons. Mining of river sand causes environmental threats such as lowering of river beds, lowering of water table, sinking of bridge piers, subsidence of river banks etc.. Hence, it is desirable to obtain a substitute material for river sand that is economical compared to the cost of river sand.

Quarry wastes, an end product from stone crushing process, is not being used for any application other than filling low lying area. Due to the scarcity of natural river sand, attempt has been made by many investigators to consider quarry waste as a substitute for river sand in concrete [1-7]. The higher percentage of fine particles in quarry waste is being removed by washing with water and this washed quarry waste is named as quarry sand.

Fly ash, a waste product, is being effectively used as a partial substitute for cement in concrete and extensive study has been carried out in the past and its effectiveness has been well established [9-15]. Though the inclusion of fly ash in concrete gives many benefits, such inclusion causes a low rate of early strength development due to its relatively slow hydration process. Nevertheless, fly ash causes an increase in the workability of concrete. Study on the influence of the combined use of fly ash and quarry sand in concrete is significant due to the fact that, there are still concerns primarily due to the presence of possible higher fine content and its related influence on the behavior of such concrete. Even though quarry waste is washed to get quarry sand, the effectiveness in the removal of finer particles is still doubtful. Further, the acceptability of quarry sand in high strength concrete is yet to be established. Hence, the present paper focuses on the impact on the presence of higher fine contents in quarry sand on the mechanical properties of high strength concrete containing fly ash as partial substitute for cement.

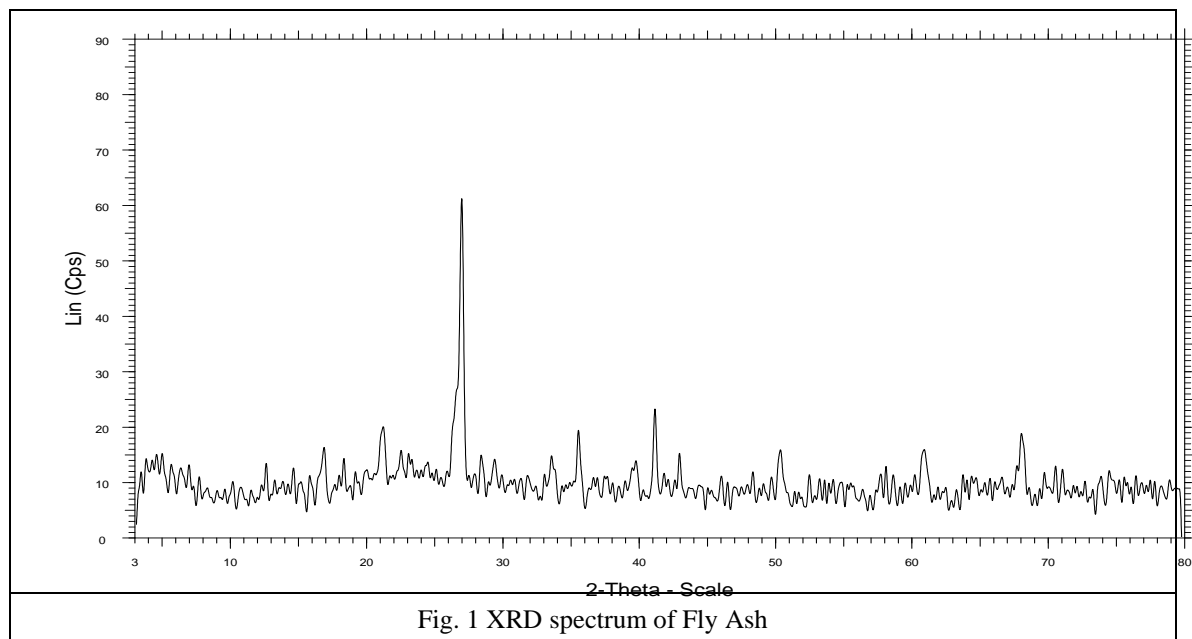
II. EXPERIMENTAL PROGRAM

The present investigation aims to study the influence on the mechanical properties of a typical high

strength concrete made with partial replacement of cement by fly ash when quarry sand is substituted as a replacement for river sand in concrete. The quarry sand considered for the study, has the highest percentage of finer particles among the six different sources considered. A high strength concrete of grade 50 MPa has been designed with conventional aggregates. From this mixture proportion, the sand content has been replaced with varying percentage of quarry sand. For each such modified mixture proportion, the cement content has been further modified by replacing it with different percentages of fly ash.

III. MATERIALS

Ordinary Portland cement of 53 Grade, satisfying the test requirements as per the standard has been used for the present investigation [16]. Fly ash used for the present investigation had a specific gravity of 1.94, fineness of 16.63percent and conforms to the class F classification as per ASTM standard [17]. The XRD spectrum of fly ash used, as shown in Fig. 1, shows that the fly ash selected is mostly amorphous in nature.



Natural River Sand conforming to zone II gradation as per the standard has been used as fine aggregate for the control specimen [18]. Quarry Sand has been collected from six different sources (2 washed and 4 unwashed) Table 1 presents the particle size distribution of the quarry sand collected. From this table, it could be observed that, the quarry sand considered, whether washed or unwashed, has more percentage of finer particles below 150 micron size than the permissible values. Also, it could be seen from Table 1 that, washing is not effective in removing the finer particle from the quarry sand. Out of the samples collected, the sample that contains higher percentage of finer materials has been selected for the present study. The sieve analysis indicated that the quarry sand conforms to zone II of BIS:383 [18].

Table 1 Particle size distribution of quarry sand

IS sieve Size (mm)	Percentage of mass passing					
	QS-1*	QS-2*	QS-3**	QS-4**	QS-5**	QS-6**
4.750	98.2	94.8	97.8	97.4	98	97
2.360	77.8	77.6	76.6	77.2	81	76.8
1.180	58.2	59.4	54.4	58.8	57.2	57.2
0.600	47	56.4	41.8	48.2	43.4	45.2
0.300	20.2	16.6	12.2	21.2	18.6	15.6
0.150	13	10.8	7.8	16.7	14.8	7.6

* - quarry sand washed ; ** - quarry sand unwashed

Crushed granite aggregate of nominal size 20mm has been used as coarse aggregate for the study. Table 2 shows the various physical properties of aggregates relevant to the design of mixture proportion of concrete [19].

Table 2 Physical properties of aggregates

Sl No.	Properties	Aggregate type		
		Fine Aggregate - River Sand	Fine Aggregate - Quarry Sand	Coarse Aggregate
1	Specific gravity	2.49	2.52	2.86
2	Grading zone	II	II	--
3	Fineness modulus	2.89	2.81	--
4	Water absorption (percent)	1.23	1.55	0.33

Sulphonated based admixture with a commercial name Conplast-SP-430 has been used to improve the workability of the concrete. Potable water was used as mixing water.

IV. CONCRETE MIXTURE PROPORTION

A control mix has been designed (BIS:10262 [20]), using river sand as fine aggregate, for a cube strength of 50 MPa and the quantity of different materials required for 1 m³ of concrete is presented in Table 3.

Table 3 Quantity required for 1 m³ of control concrete

Particulars	Quantity
Cement	500 kg
River Sand	400 kg
Coarse Aggregate	1350 kg
Admixture	5 L
Water, L (W/B ratio)	170 L (0.34)

Three concrete groups have been considered in the present study. The concrete group RS corresponds to concrete with 100 percent river sand, RSQS corresponds to concrete with 50percent river sand and 50percent quarry sand and QS corresponds to concrete with 100percent quarry sand. In each group, cement was replaced with fly ash by weight in varying percentages from 15 to 45 with an increment of 10percent. The fly ash content in the mix has been identified by the letter "F" and a two digit number corresponding to the percentage replacement of cement by fly ash. A total of 15 sets of mixes have been arrived at and its identification details are presented in Table 4.

Table 4 Identification details of different mixes

Sl: No	Concrete group	Specimen identification	Material content in concrete			
			River sand (percent)	Quarry sand (percent)	Cement (percent)	Fly ash (percent)
1	RS	RSF00	100	0	100	0
2		RSF15	100	0	85	15
3		RSF25	100	0	75	25
4		RSF35	100	0	65	35
5		RSF45	100	0	55	45
6	RSQS	RSQSF00	50	50	100	0
7		RSQSF15	50	50	85	15
8		RSQSF25	50	50	75	25
9		RSQSF35	50	50	65	35
10		RSQSF45	50	50	55	45
11	QS	QSF00	0	100	100	0
12		QSF15	0	100	85	15
13		QSF25	0	100	75	25
14		QSF35	0	100	65	35
15		QSF45	0	100	55	45

V. RESULTS AND DISCUSSIONS

All values given in the tables are the average of three test results (BIS:516 [21]). The variation of individual test results from the mean value is well within 10 percent. The workability of the fresh concrete was

measured by both slump cone and by compaction factor equipment. The slump value and compaction factor of all the 15 mixes are furnished in Table 5. From Table 5, it could be seen that the 100percent replacement of river sand with quarry sand reduces the slump value by 39percent. However, the addition of fly ash in concrete improves the workability. Hence, a judicious selection of the quantity of fly ash and plasticizer can improve the drawback of the reduced workability of concrete due to the presence of quarry sand in concrete.

Cube compressive strength of test specimen on 7th, 28th, and 90th day has been presented in Table 6. From Table 6, it could be observed that, the rate of early strength development is less in QS group of mixes compared to RS and RSQS groups of mixes. As expected, the strength of concrete reduces with the addition of fly ash in all three groups of mixes (RS, RSQS and QS). However, in all cases, up to a fly ash replacement level of 25percent, there is no much reduction in the 90th day compressive strength of concrete (a maximum of 8percent). It could further be observed that, the partial replacement (50percent) of river sand with quarry sand improves the compressive strength of concrete at all stages of its strength development. However, the influence of quarry sand in concrete is not felt on the 90th day cube compressive strength of concrete. The cylinder compressive strength test results also show a similar behavior.

The split tensile strength of specimen tested in the present investigation is also presented in Table 6. From Table 6, it can be seen that the presence of higher fly ash content in concrete tends to reduce the split tensile strength and the variation is more beyond 35percent replacement level. Further, the addition of 50percent quarry sand in concrete(RSQS) improves the split tensile strength compared to the other two cases (RS and QS). A combined use of fly ash(less than 35percent) and quarry sand (50percent) yields a better tensile strength property in concrete. The flexural tensile strength test results also showed similar trend.

Table 5 Properties of concrete at fresh stage

Mix Identification Number	Slump (mm)	Compaction Factor
RSF00	90	0.918
RSF15	95	0.920
RSF25	110	0.948
RSF35	120	0.970
RSF45	120	0.965
RSQSF00	70	0.865
RSQSF15	75	0.882
RSQSF25	80	0.895
RSQSF35	85	0.906
RSQSF45	100	0.954
QSF00	55	0.824
QSF15	65	0.862
QSF25	75	0.881
QSF35	85	0.913
QSF45	100	0.934

Table 6 Mechanical properties of concrete tested

Mix Identification	Cube Compressive Strength (MPa)			Split tensile strength (MPa)	Modulus of Elasticity (MPa)
	7 th day	28 th day	90 th day		
RSF00	51.0	57.0	60.0	3.57	35625
RSF15	47.0	54.5	58.0	3.54	34166
RSF25	39.5	52.5	58.5	3.49	32500
RSF35	40.5	49.0	59.5	3.54	28750
RSF45	27.5	43.5	53.5	3.35	26250
RSQSF00	56.0	62.0	63.0	3.64	30625
RSQSF15	48.0	58.0	58.5	3.78	31375
RSQSF25	47.0	55.0	58.0	3.73	30250
RSQSF35	42.5	50.5	56.0	3.78	28750
RSQSF45	28.0	44.5	54.5	3.40	28125
QSF00	47.5	58.0	59.5	3.82	30313
QSF15	42.0	55.0	59.5	3.42	30000
QSF25	35.0	49.5	57.5	3.35	28125
QSF35	33.0	46.0	55.0	3.78	28088
QSF45	30.5	44.0	53.0	3.31	27895

Pull out test was conducted to determine the relative performance in bond strength of different groups of concrete considered. Two samples from each group (RS, RSQS, and QS) with extreme fly ash content (0percent and 35percent) has been considered for the present study. Prism specimens of size 150mm x 150mm x 100mm with a deformed bar of 10mm diameter embedded vertically along the central axis of the specimen were used to determine the bond strength of concrete. The percentage of bond strength of different specimen with respect to the bond strength of conventional concrete is presented in Table 7.

From Table 7, it could be observed that, the bond strength of concrete reduces with the addition of quarry sand in concrete and a 50percent replacement of sand by quarry sand is preferable as against 100percent replacement. Further, it could be observed that, replacement of cement by fly ash by 35percent in a concrete with 50percent river sand and 50percent quarry sand improves the bond strength and is almost close to the bond strength of conventional concrete.

Table 7 Bond strength of typical specimens

Mix Identification	Percentage of Bond Strength	Failure mode
RSF00	100	Steel failed
RSF35	93	Concrete failed
RSQSF00	87	Concrete failed
RSQSF35	98	Steel failed
QSF00	77	Slip
QSF35	70	Concrete failed

VI. CONCLUSIONS

From the experimental investigation carried out, following conclusions could be drawn.

- Quarry sand has higher percentage of finer particles and the process of washing quarry waste will not be effective in removing the finer particles.
- The reduced workability due to the presence of quarry sand in concrete could be overcome by the judicious selection of the quantity of fly ash and plasticizer.
- Strength development in concrete during the early days is influenced by the presence of quarry sand.
- Partial replacement of river sand (50percent) with quarry sand improves the compressive strength of concrete.
- Replacement of cement with 25percent fly ash could make concrete economical and this will not affect the compressive strength of concrete.
- Concrete with fly ash content less than 35percent and 50percent quarry sand content yields a better tensile strength property compared with conventional concrete with or without fly ash.
- Modulus of elasticity of concrete reduces with increase in fly ash content. The rate of reduction is higher (about 9percent) in concrete with river sand when compared with concrete having 100percent quarry sand. The reduction in the modulus of elasticity is more with a fly ash content higher than 25percent.
- Compared with conventional concrete, presence of quarry sand yields a reduced modulus of elasticity. Replacement of quarry sand by 50percent yields better results than 100percent replacement level.
- Bond strength of concrete reduces with the addition of quarry sand in concrete and a 50percent replacement of sand by quarry sand is preferable rather than 100percent replacement. Replacement of cement by fly ash improves the bond strength of concrete containing 50percent quarry sand and 50percent river sand.

Based on the present study, it could be concluded that, the higher percentage of fine particles in quarry sand does not affect significantly the engineering properties of high strength (50 MPa) concrete when river sand is replaced with 50percent quarry sand along with a 25percent replacement of cement with fly ash. Compared with conventional concrete, the said combination will yield an economical concrete also.

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