Experimental Investigation on Performance of Fly ash and Quarry Dust in a Concrete

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Abstract- **This paper presents the results of an experimental investigation carried out to evaluate the compressive strength and transverse strength of 1:3 mortar mixes in which natural sand was replaced with 20%, 50%, and 100% quarry dust by weight which were further modified by partially replacing cement with four percentages (15%, 20%, 25%, and 30%) of low calcium fly ash. The compressive strength was determined at 3, 7, 28, and 50 days of age while transverse strength was determined at 28 and 50 days age. Test results revealed that the combined use of quarry rock dust and fly ash exhibited excellent performance due to efficient microfilling ability and pozzolanic activity. The majority of fly ash produced in India is low calcium fly ash. The use of fly ash as admixture in cement mortar/concrete not only extends technical advantages to the properties of cement mortar/concrete but also contributes to the environmental pollution control.**

Key words- Quarry dust ,fly ash, compressive strength, transverse strength.

I INTRODUCTION

Out of various cementing materials, fly ash is the most widely used material worldwide. Fly ash is the byproduct of the combustion of pulverized coal in thermal power plants. According to the American Concrete Institute (ACI) Committee 116R, fly ash is defined as "the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gasses from the combustion zone to the particle removal system." Worldwide, the estimated annual production of coal ash in 1998 was more than 390 million tons. The main contributors for this amount were China and India. Only about 14 percent of this fly ash was utilized, while the rest was disposed in landfills. By the year 2010, the amount of fly ash produced worldwide is estimated to be about 780 million tons annually. Fly ash, if not utilized, may present environmental concerns, and its storage/disposal will be expensive. The majority of fly ash produced in India is low calcium fly ash. The use of fly ash as admixture in cement mortar/concrete not only extends technical advantages to the properties of cement mortar/concrete but also contributes to the environmental pollution control.

Further, Hundreds of stone crushing plants in our country generate several thousand tons of quarry dust every day. This quarry dust is considered to be solid waste material. If it is possible to use this in making mortar/concrete by replacement of river sand, then it will solve the problem of its disposal. Moreover, the utilization of quarry dust, which can be called as manufactured sand after removal of micro fines below 150 micron size by sieving, has been accepted in the industrially advanced countries of the West as the river sand, which is one of the constituents used in preparation of cement mortar/concrete, has become highly expensive and scarce. Usage of quarry dust as partial replacement to river sand/natural sand further modified by partial replacement of pozzolanic materials like fly ash is receiving more attention these days as their use generally improves the properties of cement/concrete.

A large volume of literature is available in area of use of supplementary cementitious materials in mortar/concrete as partial replacement for cement. Many researchers indicated that low calcium fly ash (class F) improves the interfacial zone microstructure. Class F fly ash contains less than 20% of lime (CaO) and is pozzolanic in nature. Fly ash from the bituminous and anthracite coals is referred to as ASTM class F fly ash or low calcium fly ash. It consists of mainly an aluminosilicate glass and has less than 10 percent of CaO. Tikal sky et al. concluded on the basis of their research study that concrete containing fly ash as a cement replacement (0 to 35%) on an equal weight basis displayed improved long term compressive, flexural strength. The variation of strength with age was also discussed by Wischers and Kuhlmann, Dhir et al., Malhotra, and Berry et al . Ganesh Babu and Siva Nageswara Rao evaluated the cementing efficiency of fly ash in concrete at the different ages of 7, 28, and 90 days and at percentage replacement levels ranging from 15 to 75%. In general, it was observed that fly ash exhibits very little cementing efficiency at the early ages and acts rather like fine aggregate (filler), but at later ages the pozzolanic property becomes effective leading to a considerable strength improvement. Numbers of significant results have been reported on the use of quarry dust as partial replacement for fine aggregate. Quarry dust, a byproduct from the crushing process during quarrying activities, is one of those materials that have recently gained attentions to be used as concreting aggregates, especially as fine aggregates. Quarry dust has been used for different activities in the construction industry, such as road construction and manufacture of

building materials, such as lightweight aggregates, bricks, tiles, and autoclave blocks. Researches have been conducted in different parts of the world, to study the effects of incorporation of quarry dust into concrete. Galetakis and Raka studied the influence of varying replacement proportion of sand with quarry dust (20, 30, and 40%) on the properties of concrete in both fresh and hardened state. Safiuddin et al investigated the influence of partial replacement of sand with quarry dust and cement with mineral admixtures on the compressive strength of concrete whereas Celik and Marar investigated the influence of partial replacement of fine aggregate with crushed stone dust at varying percentages on the properties of fresh and hardened concrete. Ghrici et al, Chindaprasirt et al, Curcio and DeAngelis, and Misra investigated the effect of shape and size of fine aggregate on the strength of cement sand mortars and the possibility of replacing sand by crushed stone dust. The water requirement and the compressive strength are found higher for crushed stone dust as compared to that for conservative sand samples for same grading and mix proportions. deLarrard and Belloc studied the influence of aggregate on the compressive strength of normal- and high-strength concrete while Goble and Cohen observed the influence of aggregate surface area on mechanical properties of mortar. Baali et al studied the mechanical response of mortar made with natural and artificial fine aggregates.

In the present investigation low calcium fly ash, a supplementary cementitious material, is used to improve the mechanical characteristics, namely, compressive strength and transverse strength of mortar using quarry dust as fine aggregate.

II LITERATURE REVIEW

G. Balamurugan , Dr. P. Perumal, et al (Nov, 2013)

This 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. Concrete acquires maximum increase in compressive strength at 50 % sand replacement. When compared with concrete with only river sand, the amount of increase in strength is 19.18% and 5.21% for M20 and M25 respectively.

Dr. R. CHANDAK et al (Nov, 2010)

"optimization of fly ash in concrete" published in 2004 world coal ash (w.o.c.a) may 4-7, 2009 found that high lime fly ash in concrete increases the strength of concrete. the test done by them indicated that replacing proportions of cement with high lime fly ash would provide improved strength and a most effective solution.**Obadakayali**" high performance brick from fly ash" published at 2005 world coal ash (w.o.c.a) April 11- 15, 2005 concluded that the results were indicative of the satisfactory performance of the fly ash brick as load bearing element the mechanical properties of fly ash bricks have exceeded those of standard load bearing clay bricks there is evidence that the micro structural feature of the surface of fly ash is rougher texture.This characteristic is responsible for increase bond strength the density of fly ash brick is lessusing fly ash provides much saving of money. **Tuntunlu faith** (et.al) "utilization of fly ash in manufacturing of building bricks" published in 2001 international ash utilization symponium, center of applied energy research, university of kentucky, paper 13 concluded that material for the production of building is not only a viable alternate but also a solution to a difficult and expansive disposable problem.

MOHAMMED A . ELSAGEER, STEVE GMILLAD (ET AL)

" strength development of concrete containing coal fly ash under different curing temperature condition" published in 2009 world coal ash (w.o.c.a) conference may - 4-7, 2009 in lenington, u.s.a concluded that flyash concrete was observed to be similar to that of an equivalent portland cement concrete at standard curing tempratyre (20 degree centigrade up to 32 days. at 40 degree centigrade and 50 degree centigrade, the strength development of concrete is similar to that of an equivalent Portland cement concrete at early stages their work indicates that fly ash concrete could be used in projects when early strength is required.

TARUN R. NAIK (et al)

" high early strength containing large quantities of fly ash concluded thatconcrete mix with type c flyash can be used with confidence to produce high early strength as the amount of fly ash used in a mix increases, the water required for the same workability decreases. Fly ash improves the workability if the concrete.(5)

AMIT MITTAL (et al)

"experimental study on the use of fly ash in concrete" concluded that,, as fly ash content increase there is reduction in the strength of concrete.

RAJAMANI. N.P et al in (2006)

studied on this work, a prediction equation was proposed which estimates the 28 days compressive strength of fly ash concrete and can also be used to modify any basic cement concrete mix so that the concretes with and without replacement of fly ash have similar strength. The prediction equation also considers the different levels of replacement of sand and fly ash with fine aggregate at sand replacements of 20, 40, 60 % were prepared. Actual fine aggregate quantity added was varied from 1.0 to 1.6 times the quantity of sand replaced to study the effect of higher quantity of fly ash in concrete. Compressive strength of these mixes was determined at 7, 28 days. They reached their target mean strength and compared with proposed prediction equation.

PROF. CHANDRAKANT B SHAH et al (2009) ,
their study was aimed in finding the trends due to replacement of Portland cement by processed fly ash of compressive strength of standard 70.7 mm mortar cubes at the ages of 3, 7, 28, 56 and 90 days. The percentage replacements were 40, 45, 50 and 55 respectively. Test showed that although the initial strengths were lower than that for only OPC, for mix at later age, the results were close to that of OPC. The study showed that replacement of OPC 53 grade cement by processed fly ash up to 55 to 60 % would be possible.

P. M. SHANMUGAVADIV et al (2010)
have shown from water permeability test that permeability reduced with increase in proportion of manufactured sand. This may be due to less voids present in concrete with manufactured sand showing better bonding between the aggregate and cement paste. Results of rapid chloride penetration test shows that chloride ion penetrability is high for concrete with natural sand while it is reduced using manufactured sand. They attribute this due to coarser grain size of manufactured sand resulting in better packing of particles. They suggest that 70% of manufactured sand in concrete is the optimum replacement for natural sand for better results.

III MATERIALS AND METHODOLOG

Fly ash, quarry dust and the materials required for the concrete are collected from the nearby sources; the various materials required are cement, quarry dust and water. The various materials collected are prepared and batch casting. Materials that are used for making concrete were tested before casting the specimens. The properties obtained from the testes were used in mixed design. The preliminary tests are conducted for the following materials.

- fine aggregate
- fly ash
- quarry dust
- Cement

IV PROPERTIES OF MATERIAL

1. Cement
The cement used was Ordinary Portland Cement (43 grade). The various laboratory tests conforming to Indian standard specification, IS: 4031-1996 specification, were carried out and the physical properties are shown in
Table 1: Physical properties of cement

2. Fly Ash
Low calcium fly ash samples taken from Kahalgaon Thermal Power Plant, NTPC were used in this study. Fly ash shown in Figure 1 was not processed and was used as received. The sample satisfied the requirements of IS: 3812 (Part I). The physical and chemical properties as supplied by the Kahalgaon Thermal Power Plant, NTPC are shown in Tables 2 and 3.

Table 2: Physical properties of fly ash.

Sl. number	Physical properties	Observed values
1	Specific gravity	2.51
2	Initial setting time	45 Min
3	Final setting time	280 Min
4	Consistency	35%

Table 3: Chemical properties of fly ash.

3. Quarry Dust
The quarry dust used in this study was used as a partial replacement for fine aggregate and was obtained locally. The sample of quarry dust, shown in Figure 2, was analyzed in terms of physical properties and is presented in Table 4. The sieve analysis results are presented in Table 5.
Table 4: Physical properties of quarry dust and natural sand.

Table 5: Sieve analysis of quarry dust.

IS sieve designation	Weight retained (kg)	Percentage of weight retained	Cumulative percentage of weight retained	Percentage of fineness by weight
4.75 mm	0.40	0.040	4.00	96
2.36 mm	0.025	0.065	6.50	93.50
1.18 mm	0.117	0.182	18.20	81.80
600 micron	0.152	0.334	33.40	66.60
300 micron	0.443	0.777	77.70	22.30
150 micron	0.170	0.947	94.70	5.30

4. Sand
Ordinary sand from river Sone having fineness modulus of 2.60 was used. Sand after sieve analysis (Table6) conforms to zone II as per IS: 383-1970.

Table 6: Sieve analysis of fine aggregate.

IS sieve (mm)	Weight retained (Kg)	Cumulative weight (Kg)	Percentage retained	Percentage passing	Remarks
4.75	0.034	0.034	3.4	96.6	
2.36	0.026	0.060	6	94	
1.18	0.140	0.200	20	80	Sand zone II as per IS: 383-1970 CLAUSE 4.3 Table 4
600	0.162	0.362	36.2	63.30	
300	0.425	0.787	78.7	21.30	
150	0.185	0.972	97.2	2.30	

V SUMMARY AND FUTURE WORK

The results of compressive strength test show the variation of compressive strength of all the mixes at different ages. Examining the strength at 3 days and 7 days of age it can be seen that increasing the quarry dust content from 0% to 100% has caused minimal increase in compressive strength for fly ash content of 0%. However, examining the strength at 28 days and 50 days of age it can be seen that the rate of increase in compressive strength decreases when natural sand was replaced by 50% and 100% quarry dust. This decrease is significant when natural sand is completely replaced by quarry dust. The decrease in compressive strength is almost 13% and 10% as compared with the strength of reference mix (QC1) at 28 and 50 days. Mix proportion QC2 revealed an increase of compressive strength up to 6% at both 28 days and 50 days as compared to reference mix while the increase was 4% in case of mix proportion QC3 when compared to reference mix QC1. This may be due to the fact that 20% replacement of natural sand by quarry dust may show the optimum reaction with optimum filler capacity. It can be concluded that 20% replacement of natural sand by quarry dust will yield the maximum strengths for cement mortar. Figure 5 represents the variation of compressive strength at 28 and 50 days for mortar mixes of QC series with different percentages of quarry dust.

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