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Experimental Investigations on Partial Replacement of Cement with Fly Ash, Silica Fume and Partial Replacement of Sand with Quarry Sand in Concrete

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ABSTRACT

Fly ash is the waste generated by industries which is responsible for causing environmental as well as health problems due to dumping and disposal. This research describes the accessibility of using the thermal industry waste in concrete production as partial replacement of cement. By formulation of concrete with the use of fly ash as a supplementary cementitious material was tested as an alternative to conventional concrete. The fly ash has been replaced 50% by weight of cement for M30 mix. Concrete mixtures were produced, tested and compared in terms of compressive and with the conventional concrete. These tests were carried out to determine the mechanical properties for the tests for compressive strength at 7 days, 14 days and 28 days taken at room temperature. Quarry dust is used to reduce the demand of natural sand by using quarry waste . By partially replacing the quarry sand with the natural sand, the effect of strength and workability of concrete has been studied. This paper reports the experimental study and investigated the partial replacement of natural sand with quarry dust. It has been found that the partial replacement of quarry dust with natural sand has a significant effect to enhance the compressive strength . Quarry dust has been replaced 40% with the natural sand.Silica fume has major impact on industries. It is an experimental study to determine the nature of silica fume and its impact on the properties of conventional concrete. By partially replacing the cement with silica fume, the strength parameters of concrete have been studied. Silica fume has been replaced by 15% of cement, by weight for cube. By partially replacing cement with Silica fume, investigation has been carried out and its effect on the important parameters of concrete such as strength and workability has been studied. It has been found that partial replacement with silica fume has a significant effect in the compressive strength of cubes. We are investigating the potential of using fly ash, quarry sand and silica fumes its effect on the strength and workability of concrete. Attempts for improving the properties of concrete with respect to strength and durability.

Keywords: Concrete, Sand, cement, Fly Ash, silica fumes, quarry dust (QD), Compressive Strength, supplementary cementitious materials, Ordinary Portland cement (OPC), Partial replacement, slump cone test, thermal industry waste.

I. INTRODUCTION

Presence of waste materials in the environment can directly cause environmental problem , So the reuse of waste material is necessary. The Waste can be used to produce new products so that natural resources are used more efficiently and effectively. The industrial wastes which are dumped in the nearby land through

which the natural fertility of the soil is spoiled. Fly ash is the finely divided mineral residue resulting from the combustion of ground or thermal power plant e.g. Koradi plant . The utilization of waste materials in cement and concrete industry reduces the environmental problems of power plants and decreases electricity generation costs. Cement with fly ash reduces the permeability of concrete. fly ash contributes in a various ways like durability and strength and also increases the setting time of concrete. The pozzolanic reaction removing the excessive calcium hydroxide, which can be produced by the cement reaction. In the present experimental investigation, the fly ash has been used to study the effect on compressive strength on M25 grade of concrete. Some of the countries are facing various problems in the supply of natural sand . the expertise of the construction industry is investigating the other alternative in order to reduce the demand of natural sand . Now a days the natural river sand has became scarce and very costly. Hence we are forced to think of alternative materials .A quarry is a type of open pit mine in which dimension stone, rock , construction aggregate, riprap, sand, gravels or slate is excavated from ground . The quarry dust may be used in the pace of natural river sand fully or partially. Another alternative is by using quarry waste to replace the use of natural sand . Natural sand in many parts of the country is not graded properly and has excessive silt . On the other hand, quarry dust does not contain silt or organic impurities and can be produce to meet desired gradation and fineness as per requirement. Consequently quarry sand improves the strength of concrete. A comparatively good strength is expected when quarry sand is replaced partially or fully with or without concrete admixtures. The particles which are passing through 4.75mm sieve are called as quarry dust. Silica fume is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production.. it is also known as micro silica, non-crystalline polymorph of silicon dioxide. It's particles size less than 1 micron and with an average diameter of about 0.1 microns, The use of silica fume as a pozzolana in proper quantity taken in percent can enhance various properties in conventional concrete such as cohesiveness, strength, permeability and durability. Silica fume concrete is appropriate in places where low permeability and high abrasion resistance are of great importance. It is also appropriate in such places where very high cohesive mixes are required to avoid segregation and bleeding. The main objective of this study is to find the impact of partial replacement of Silica fume with cement on the strength characteristics of concrete. 15 percent of replacement has been considered for partially replacing cement with silica fume. M25 concrete grade is designed with replacement of silica fume .

Ghutke & Bhandari (01)examine the Influence of silica fume on concrete. Results showed that the silica fume is a good replacement of cement. The rate of strength gain in silica fume concrete is high. Workability of concrete decreases as increase with% of silica fume. The optimum value of compressive strength can be achieved in 10%replacement of silica fume. As strength of 15%replacement of cement by silica fume is more than normal concrete. The optimum silica fume replacement percentage varies from 10 % to 15 %replacement level.

Alok (02) write A Research Paper on Partial Replacement of Cement in M-30 Concrete from Silica Fume and Fly Ash. Replacement levels of OPC by Silica Fume were 0%, 2.5%, 5%and 7.5%where replacement levels of Ordinary Portland cement by Fly Ash were 0%, 5%, 10% and 15% by weight. 1% super-plasticizer was used in all the test specimens for better workability at lower water cement ratio and to identify the sharp effects of Silica Fume and Fly Ash on the properties of concrete. Water-cement ratio was kept 0.43 in all cases.43.1 N/mm2 was the maximum compressive strength which was obtained at replacement level of 7.5% by weight of SF and 20% by weight of FA with cement.6.47 N/mm2 was the maximum flexural strength which was obtained at replacement level of 7.5% by weight of SF and20% by

weight of FA with cement.2.573 N/mm2was the maximum split tensile strength which was obtained at replacement level of 7.5% by weight of SF and 20% by weight of FA with cement.

Sasikumar & Tamilvanan (03) Performed an Experimental Investigation on Properties of Silica Fumes as a Partial Replacement of Cement main parameter investigated in this study is M30 grade concrete with partial replacement of cement by silica fume 0%, 25%, 30%, 40% and 50%. The normal consistency increases about 40% when silica fume percentage increases from 0% to 25%.The optimum 7 and 28-day compressive strength has been obtained in the 25 % silica fume replacement level. Also, the split tensile strength is high when using 25% silica fume replacement for cement.

Amarkhail (04) observed Effects of Silica Fume on Properties of High-Strength Concrete. He found that up to 10% cement may be replaced by silica fume without harming the concrete workability. Concrete containing 10% silica fume replacement achieved the highest compressive strength followed by 15% silica fume replacement with a small difference. Concrete with 15% silica fume content achieved the highest flexuralstrength.10% and 15% silica fume content as replacement of cement were found to be the optimum amount for significantly enhancement of compressive strength and flexural strength respectively.

Abdullah Anwar et al (05) their studies tell that Fly ash is rich in cementitious industrial wastes and has great potential to replace Portland cement. Their studies tell that 28 days compressive strength of Mix can be achieved with a replacement of 30% of fly ash with the cement. When the percentage of replacement is increased the water/ binder ratio gets reduced, thereby, increasing the compressive strength.

Marthong and T.P. Agrawal(06) studied about compressive strength, durability and shrinkage of concrete and their Test results shows that, inclusion of fly ash generally improves the concrete properties up to certain percentage of replacement in all grades of OPC.

Samaresh Pan (07) founded that replacements of cement by fly ash have resulted in considerable variation in the properties of fresh concrete. Incorporation of fly ash in concrete increased the cohesiveness of the mix, prevented segregation and resulted in reduced bleeding. Fly ash concretes have been found to be amiable to compaction than the control mixes. Higher percentages of fly ash can cause a change in color of the mix.

Alvin Harison et al (08) conducted a peculiar study on the utilization of materials which can fulfill the expectations of the construction industry in different areas. In this study cement has been replaced by fly-ash accordingly in the range of 0%, 10%, 20%, 30%, 40%, 50%, 60% by weight of cement for M-25 mix with 0.46 water cement ratio. Concrete mixtures were produced, tested and compared in terms of compressive strength. It was observed that 20% of replacement of Portland pozzolana cement (PPC) by fly-ash strength is increased marginally (1.9% to 3.2%) at 28 days and 56 days respectively. It was observed that upto 30% replacement of PPC by fly-ash strength is almost equal to the referral concrete after 56 days. PPC gained strength after 56days curing because of slow hydration process.

G.Balamurugan*, Dr.P.Perumal (09) founded that Concrete acquires maximum increase in compressive strength at 50% sand replacement by quarry sand The percentage of increase in strength with respect to control concrete is 24.04 & 6.10 in M20 and M25 respectively.

Chitlange and Pajgade (10) It is observed that there is consistent increase in the strength of plain concrete when natural sand is fully replaced by quarry dust.

Nanda et al. (11).The investigation proposes that the stone dust can be replaced up to 50% without any

effect on mechanical and physical properties and the economical saving will be 56%.

Chandana Sukesh (2013) in his study published in the International Journal of Innovative Technology and Exploring Engineering, says that ideal percentage of the replacement of sand with quarry dust is 55 percent to 75 percent in case of compressive strength.

II. MATERIALS

2.1. Cement: The most common cement used is an Ordinary Portland Cement (OPC). The Ordinary Portland Cement of 53 grade confirming to IS 12269: 2013 It constitutes only about 20 percent of the total volume of concrete mix; it is the active portion of binding medium and is the only scientifically controlled ingredient of concrete.

Table 1. properties of cement

Sr.no	Physical property of cement	Result	Requirements as per IS: 12269:2013
1.	Specific gravity	3.15	3.10 - 3.15
2.	Soundness (Le Chatelier's)	9.5	10
3.	Initial setting time (hours, min)	35min	30 min. minimum
4.	Final setting time (hours, min)	178 min	600 min. maximum
5.	Compressive strength- 3 days	26.51 N/mm^2	27 N/mm^2
6.	Compressive strength- 7 days	38.49 N/mm^2	37 N/mm^2
7.	Compressive strength- 28 days	52.31 N/mm^2	53N/mm^2

2.2. Coarse aggregate: -The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate. Locally available coarse aggregate having the maximum size of 20 mm was used in this work. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The aggregates were tested as per IS: 2386 (Part 4) - 1963.

Table 2. properties of coarse aggregate

Sr.no.	Characteristics	Value
1	Color	Grey
2	Size	20mm
3	Shape	Angular
4	Specific gravity	2.80

2.3. Fine aggregate: -

The aggregates most of which pass through 4.75 mm IS sieve are termed as fine aggregates. According to size, the fine aggregate may be described as coarse, medium and fine sands. Depending upon the particle size distribution IS: 383-1970 has divided the fine aggregate into four grading zones (Grade I to IV). The grading zones become progressively finer from grading zone I to IV. In this experimental program, fine aggregate was locally procured and conformed to Indian Standard Specifications IS: 383-1970. The sand was sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and conforming to grading zone II. It was coarse sand light brown in color. Sieve analysis and physical properties of fine aggregate are tested as per IS:383-1970 and results are shown in below Table.

Table 3. properties of fine aggregate

Sr.no.	Characteristics	value
1	Specific gravity	2.65
2	Bulk density(kg/m3)	1.3
3	Fineness modulus	2.62
4	Water absorption	0.02

2.4. Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Water cement ratio used is 0.467 for M25.

2.5. Fly ash:

Table 4. properties of fly ash

Sr. No	properties	value
1.	Specific Gravity	1.90-2.55
2.	Specific surface (m^2/kg)	392
3.	Bulk density(gm/cm^3)	0.994
4.	color	Whitish grey

2.6. Silica fume:

Table 5. properties of silica fumes

Sr. No.	Physical property of Silica fume	result
1.	Specific gravity	2.2
2.	Bulk density(kg/m3)	130-430
3.	Particle size(μm)	<1
4.	Fineness(m^2/kg)	15000-30000

2.7. Quarry sand:

Table 6. properties of quarry sand

Sr.no	Properties	values
1.	Specific of gravity	2.57
2.	Fineness modulus	2.41
3.	Density	1.85gm/cc
4.	Void ratio	0.42

III. DESIGN MIX METHODOLOGY

A mix M25 grade was designed as per IS10262:2009 and the same was used to prepare the test samples. The design mix proportion is shown in table

Table 7. Concrete Design Mix Proportion

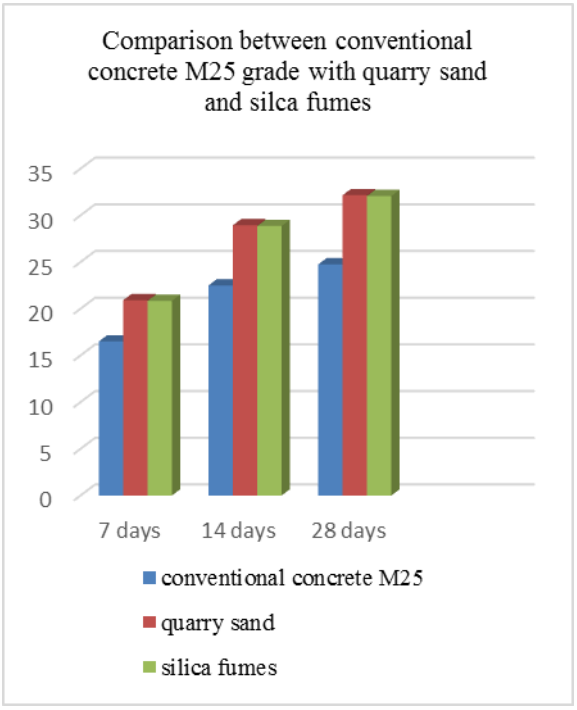
Sr No	Material replace	Concrete type	Concrete Design Mix Proportion (By Weight)				Replacement %
			W/C Ratio	C (kg)	FA (kg)	C.A. (kg)	
1	Fly ash	M30	0.5	1	1.3	3.2	50
2	Quarry sand	M25	0.467	1	1.5	2.696	40
3	Silica fumes	M25	0.467	1	1.5	2.696	15

3.1. Casting of Cubes
(As per IS 516:1959)

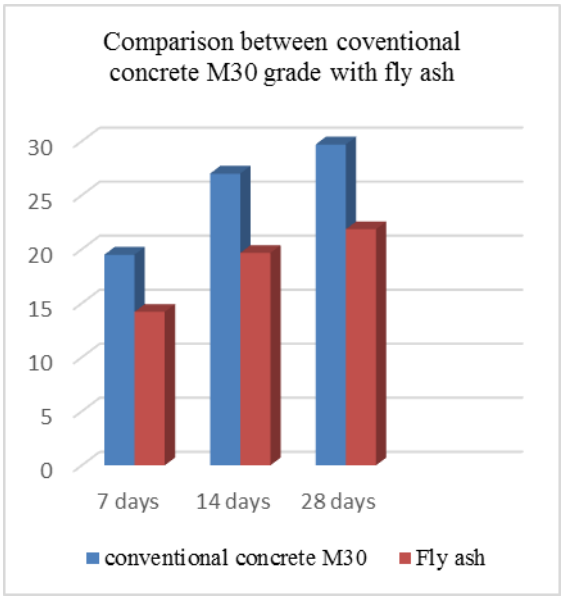
Standard metallic cube moulds (150*150*150 mm)were casted for compressive strength the specimens were demolded after 24 hours and subsequently immersed in water for different age of testing. For each age three specimens were tested for the determination of average compressive and strength.

Table 8. Comparison between conventional concrete M25 & M30 grade with quarry sand silica fumes and fly ash.

Sr. No	Materials	Grade	Average compressive strength for Conventional Concrete (N/mm^2)			Compressive strength for variations		
			7 day	14 day	28 day	7 day	14 day	28 day
1.	Fly ash	M30	19.5	27	29.7	14.21	19.66	21.85
2.	Quarry sand	M25	16.25	22.5	24.75	20.91	28.94	32.16
3.	Silica fume	M25	16.25	22.5	24.75	20.85	28.863	32.07



Graph 1. Comparison between conventional concrete M25 grade with quarry sand and silica fumes



Graph 2. Comparison between conventional concrete M30 grade with fly ash

3.2 Test on Concrete Cubes

3.2.1. Slump Cone Test:

The concrete slump test is an empirical test that measures the workability of fresh concrete. More specifically, it measures the consistency of the concrete in that specific batch. This test is performed to check the consistency of freshly made concrete. Consistency is a term very closely related to workability.

Table 9. slump of materials.

Sr no.	Materials	% Replacing	Slump in mm
1	Fly ash	50	150
2	Quarry sand	40	130
3	Silica fume	15	110

3.2.2. Compression Test

Test was performed on compression testing machine As per IS: 1199:1959. The load was applied axially without shock till the specimen was crushed. Results of the compressive strength test on concrete with and without varying proportions (50%) of fly ash, (40%) of waste marble, (15%) of silica fume replacement at the age of 7days, 14 days and 28 days were noted. The cubes were tested using compression testing machine (CTM). P/A = Compressive stress. Where, P = Load (N) and A = Area (mm^2).

IV. CONCLUSION

Based on limited experimental investigation concerning the compressive &Non-Destructive test, the following conclusions are drawn:

- Compressive strength reduces when cement replaced fly ash at higher percentage (50%).
- Use of fly ash in concrete can save the coal& thermal industry disposal costs and produce a 'greener' concrete for construction.
- Concrete acquires maximum increase in compressive strength at 40% sand replacement by quarry sand.
- According to the value of compressive strength collected, the value is high and it show that quarry dust suitable to use as sand replacement. All the value of compressive strength surpasses the minimum value of compressive strength for normal concrete. So, quarry dust can apply as

sand replacement in concrete mix for M25 Grade in construction industry.

- The optimum strength of cube is gain at 15% replacement for all 7, 14 and 28 days respectively.
- The above conclusion gives clear picture that fly ash can be innovative supplementary cementitious Construction Material but it tends to decrease the compressive strength at high percent (50%) as well as quarry dust can be utilized in concrete mixtures as a good substitute for natural river sand with higher strength at 40% replacement and silica fumes can be used as a partial replacement of cement with 15% replacement.

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