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Mix design of concrete by replacing cement with Silica Fumes and Fly Ash

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ABSTRACT

*Concrete is the most versatile construction material because it can be designed to withstand harshest environments while taking on most inspirational forms. Nowadays, most concrete mixtures contain**s**upplementary cementitious material (SCM). This supplementary cementitious consist of fly ash natural pozzolans, silica fumes, Ground Granulated Blast Furnace Slag (GGBFS). Among these entire SCMs silica fume is most successful because it enhances both strength and durability of concrete to such extent that model design rules call for the addition of silica fumes for design of high strength Concrete.*

In the present work of series of tests were carried out to make comparative studies of various mechanical properties of concrete mixes prepared by using ordinary Portland cement (OPC) of 43 grade cement. The mixes are modified by 7.5%, 10%, and 12.5% of silica fumes in replacement. After optimising the percentage of silica fume, the silica fume is then blended with fly ash, keeping the percentage of cement fix. The properties studied are 7 days and 28 days compressing strength; 28 days split tensile strength and 28 days flexural strength.

Key words: *Fly Ash, Silica fume, Compressive Strength*

I.INTRODUCTION

Concrete is a mixture of cement, sand, course aggregate and water. In construction, cement concrete remains the main construction material which is used in construction industries, other than brick, clay, mud, glass, wood and many more. Thus, there is a need to eliminate the amount of cement which is used in construction with some other constituents hence, fly ash and silica fumes are the best replacement. Then se of SCM in concrete construction not only prevent these materials to check the pollution but to also to enhance the properties of concrete in fresh and hydrated state.

Fly ash, a by-product from thermal power stations, has been used successfully to replace Portland cement up to 30% by mass, without adversely affecting the strength and durability of concrete [1–5]. In some cases, large volume of fly ash (>40%) is used to achieve the desired concrete properties and lower the cost of concrete production [6,7]. The fly ash concrete system offers a holistic approach that can help us to achieve the goals of meeting the rising demands for concrete, enhancement of concrete durability with little or no increase in cost (in some instances reduced cost), and ecological disposal of large quantities of the solid waste products from coal-fired power plants [8]. Several laboratory and field investigations involving concrete containing fly ash had reported to exhibit excellent mechanical and durability properties [9–12]. However, the pozzolanic reaction of fly ash being a slow process, its contribution towards the strength development occurs only at later ages and, hence, the early strength of fly ash concrete is significantly reduced [13,14]. This is a barrier for the application of fly ash concretes in precast industries, where formwork turnover time is significantly reduced with slow strength development. Therefore, it is of prime importance to improve the early strength of fly ash concretes for realisation of full benefits of fly ash to precast industries. Different approaches have been used to accelerate the pozzolanic reaction of fly ash and, thereby, to increase the early strength of concrete containing fly ash. These include: mechanical treatment (grinding), accelerated curing and autoclaving and chemical activation (alkali and sulphate activation) [15–20]. However, alkali activation used in concrete may lead to alkali–silica reaction [21], while the sulphate activation may impair the durability of concrete due to the formation of large quantities of ettringite.

II.LITERATURE REVIEW

Chatterjee (2011) reported that about 50 % of fly ash generated is utilised with present efforts. He also reported that, one may achieve up to 70% replacement of cement with fly ash when high strength cement and very high reactive fly ash is used along with the sulphonated naphthalene formaldehyde super plasticizer. He reported improvement in fly ash property could be achieved by grinding and getting particles in sub micro crystalline range.

Bhanumathidas, &Kalidas (2002) with their research on Indian fly ashes reported that the increase in ground Fineness by 52% could increase the strength by 13%. Whereas, with the increase in native fineness by 64% the strength was reported to increase by 77%. Looking in to the results it was proposed that no considerable improvement of reactivity could be achieved on grinding a coarse fly ash. Authors also uphold that the study on lime reactivity strength had more relevance when fly ash is used in association with lime but preferred pozzolanic activity index in case of blending with cement.

Subramaniam, Gromotka, Shah, Obla& Hill (2005) investigated the influence of ultrafine fly ash on the early age property development, shrinkage and shrinkage cracking potential of concrete. In addition, the performance of ultrafine fly ash as cement replacement was compared with that of silica fume. The mechanisms responsible for an increase of the early age stress due to restrained shrinkage were assessed; free shrinkage and elastic modulus were measured from an early age. In addition, the materials resistance to tensile fracture and increase in strength were also determined as a function of age. Comparing all the test results authors indicated the benefits of using ultrafine fly ash in reducing shrinkage strains and decreasing the potential for restrained shrinkage cracking.

Poon, Lam & Wong (1999) from their experimental results concluded that replacement of cement by 15% to 25% by fly ash results in lower porosity of concrete and plain cement mortars. Literature discussed has shown improvement in the workability and durability of concrete by partial replacement of cement with fly ash.

However 28 days strength was reported to be lower by replacement of cement with fly ash, than concrete without replacement of cement with fly ash. Analysing the literature it is seen than grinding of fly ash is less effective. This may be due to destruction of spherical shape of fly ash which is helpful in increasing workability and reducing voids. Grinding cost also offsets partial cost advantage of cheaper fly ash over cement. Low reactivity of low lime Indian fly ashes as compared to high lime fly ash restricts use of higher volumes of fly ashes for cement replacement. Lower reactivity of fly ash makes it urgent to develop a method for replacing higher volumes of cement with fly ash without grinding or activation of fly ash.

III.MATERIALS

Cement

The most popular construction material till date is cement in the form of concrete. The use of cement in construction is very old. Cement has proved its efficiency in terms of its sufficient strength, economic cost, less time of construction and finally good durability. Moreover, the growth of a country is adjudged through its infrastructural facilities. Hence, construction industry has always been in boom and has seen rapid development in recent past. Cement Concrete with large volumes of fly ash needs to be used in construction activities for the benefits discussed later in this paper.

Fly ash

Fly ash is the fine residue produced from the combustion of pulverized coal in electric and steam generating plants. In India, thermal power plants are the main source for producing electricity. Though attempts are being made to find solutions for cleaner production of electricity, but still there is a long way to go and we may depend on traditional coal burning thermal power plants for quite some more time (50-100 years). As a rough estimate, approximately 115 million tons of fly ash are being produced annually from thermal power plants in India. However, only 40 million tons of fly ash are used annually in various engineering applications. The use of small percentages of fly ash in a variety of civil engineering works is being carried out mainly for economical reasons. Fly ash, being available, at negligible or no cost is taking place of cement, a costly construction raw material with the aim - one, to solve the problem of disposal of fly ash in environment and two, to get some financial benefit. However, researchers abroad, especially in developed countries, have proved that fly ash in high volumes can safely be used in concrete and results in better pump ability and long term durability. The use of fly ash in concrete has increased in last 20 years considerably.

Silica fume

Silica fume is also known as micro silica or condensed silica fume, is used as an artificial pozzlanic admixture. It is a material resulting from reduction of quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. Chemical composition of silica fume contains more than 90 percent silicon dioxide other constituents are carbon, Sulphur and oxides of aluminium, iron, calcium, magnesium, sodium and potassium. The physical composition of silica fume diameter is about 0.1 micron to 0.2 microns, Surface area about 30,000 m^2/kg and Density varies from 150 to 700 kg/m^3.

Fig.1:Ordinary Portland Cement

Fig.2: Fly Ash

Fig.3: Silica fume

Fig.4: Course Aggregate (12.5mm)

Fig.5: Course Aggregate (20mm)

Material Properties

To obtain the best percentages of mixed proportions, separate casting of test specimens was conducted concrete materials were mixed as per standard of IS: 10262. OPC was used and it's physical and chemical properties are tabulated below. The physical and chemical analysis of the constituents of silica fume and fly ash are tabulated below. The properties of course aggregate and fine aggregate are also tabulated below. Here we have used both 12.5mm and 20mm size of course aggregate.

Property	River sand
Specific gravity	2.67
Loose density	1.57g/cc
Rodded density	1.72 g/cc
Grading zone	II

Table 1: Properties of fine aggregate

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Property	Coarse aggregate
Specific gravity	2.67
Density	1.47 g/cc

Table 2: Properties of course aggregate

Properties	Ordinary Portland Cement	Silica Fume	Fly Ash
Specific Gravity	3.12	2.24	2.855
Fitness	370 m^2/Kg	20400 m^2/Kg	423 m^2/Kg
Consistency	26%	-	42%
Initial Setting Time (Min.)	27	-	-
Final Setting Time (Min.)	529	-	-
Bulk Density	-	240 Kg/m^3	-
SiO_2	21.02%	91.4%	53.92%
Al_2O_3	5.68%	1.1%	21.0%
Fe_2O_3	3.53%	0.3-0.5%	3.9-4.3%
MgO	1.1%	1.3%	2.2%
CaO	62.25%	0.7%	4.0%
SO_3	3%	-	0.6%
Na_2O	0.15%	0.8%	-
K_2O	0.35%	0.5%	-
TiO	-	-	0.98%
C	-	0.9%	18.92%
S	-	1.8%	-
Loss of Ignition	1.05%	2.4%	1.9%

Table 3: Properties of cement, fly ash and silica fume

Testing Program

The compressive strength is measured using cube specimens. The size of the cube specimen is 150 mm × 150 mm × 150 mm. In this investigation nine numbers of cubes were cast for each mix and each three cubes were cured in normal water for 7, 14 and 28 days. During curing period, the samples were stored in a place free from vibrations and in relatively moist air at temperature range from 25 – 27^{0}C. After 24 hours the mould is removed and marked with symbol to identify later and finally cured under clean fresh water.

IV.CONCLUSION

Fly ash concrete is most important building material for the sustainable construction and consumption of large volume of fly ash. Literature discussed in the present paper has given an overview of advantages of fly ash concrete to increase workability and durability of concrete. The literature surveyed has also listed the slower strength gain at early ages as major problem in making fly ash concrete very popular in the Indian construction industry which is only focused on short term strength gain. A detailed mix design procedure along with conformation of results for designing fly ash concrete to achieve required strength at 28 days is needed. It is must to shift contractors focus on economical and durable fly ash concrete even if higher days of curing are required. The replacement of cement with silica fume is environment friendly in nature. One of the biggest benefits of using silica fume is reduction in CO_2 emissions, which is the main cause of Green – house effect.

From the complete investigation and the results of this work, it may be recommended that blending of silica fume and fly ash should not be done to increase the strength characteristics of concrete. Silica fume alone is enough to enhance the quality. Use of silica fume is economical and also eco – friendly in nature.

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