PERFORMANCE OF FLY-ASH, SILICA FUME AND RICE-HUSK ASH IN CONCRETE

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***ABSTRACT*: Bond strength is one among the important property of hardened concrete. Bond between the reinforcement and concrete influences the behavior of structural concrete in many respects. The quality and quantity of ingredients used for making the concrete affect the bond strength of concrete. The addition of mineral admixtures like fly ash, silica fume, rice husk ash etc. into the cement by means of replacing the cement content is nowadays considering as an important matter for protecting the environment against any hazardous situations and also recycling the waste by-products into an effective manner. But, the addition of mineral admixtures affects the structural system of cement and also in concrete. It also leads to the variations in the properties of concrete both fresh and hardened state. With these in mind, the bond strength variations of ternary blended concrete were examined in this experimental investigation and compared with the normal strength concrete. The class F type Fly Ash (FA) was used for making the binary blended concrete. In addition to that Silica Fume (SF) and Rice Husk Ash were (RHA) considered for developing the ternary blended concrete.**

I.INTRODUCTION

1.1 General

1.1.1 Pozzolanic materials

The use of pozzolanic materials is as old as that of the art of concrete construction. It was recognized long time ago, that the suitable pozzolans used in appropriate amount, modify certain properties of fresh and hardened mortars and concretes. Ancient Greeks and Romans used certain finely divided siliceous materials which when mixed with lime produced strong cementing material having hydraulic properties and such cementing materials were employed in the construction of aqueducts, arches, bridges etc.

A number of structures stand today as evident of the superiority of pozzolanic cement over lime. They also attest the fact that Greeks and Romans made real advance in the development of cementitious materials.

It has been amply demonstrated that the best pozzolans in optimum proportions mixed with Portland cement improves many qualities of concrete, such as:

1. Lower the heat of hydration and thermal shrinkage
2. Increase the water tightness
3. Reduce the alkali-aggregate reaction
4. Improve resistance to attack by sulphate
5. Lower susceptibility to dissolution and leaching
6. Improve workability
7. Lower costs

In addition to these advantages, contrary to the general opinion, good pozzolans will not unduly increase water requirement or drying shrinkage. Pozzolanic materials are siliceous and aluminous materials, which in themselves possess little or no cementitious value, but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide liberated on hydration, at ordinary temperature to form compounds, possessing cementitious properties. On hydration of tri-calcium silicate and di-calcium silicate, calcium hydroxide is formed as one of the products of hydration.

This compound has no cementitious value and it is soluble in water and may be leached out by the percolating water. The siliceous or aluminous compound in a finely divided form reacts with the calcium hydroxide to form highly stable cementitious substances of complex composition involving water, calcium and silica. Generally, amorphous silicate reacts much more rapidly than the crystalline form. It is pointed out that calcium hydroxide, otherwise a water soluble material is converted into insoluble cementitious material by the reaction of pozzolanic material.

The reaction can be shown as Pozzolanic materials + calcium hydroxide + water → C-S-H (Gel)

Fly ash, widely used pozzolanic materials, is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electrostatic precipitator. Fly ash was first used in large scale in the construction of Hungry Horse dam in America and the approximate amount of 30 percent by weight of cement. Later, it was used in Canyon and Ferry dam etc. In India, Fly ash was used in Rihand dam construction replacing cement up to about 15 percent. The use of fly ash as concrete admixture not only extends technical advantage to the properties of concrete but also contributes to the environmental pollution control.

1.1.2 Durability of concrete

Concrete durability is a subject of major concern in many countries. Number of international seminars are held on concrete durability and numerous papers written on failures of concrete structures. In the recent revision of IS 456 of 2000, one of the major points discussed deliberated and revised is the durability aspects of concrete.

One of the main reasons of deterioration of concrete in the past is that too much emphasis is placed on concrete compressive strength. It is now recognized that strength of concrete alone is not sufficient, the degree of harshness of the environmental conditions to which concrete is exposed over its entire life is equally important. Therefore, both strength and durability have to be considered explicitly at the design stage. It is interesting to consider yet another view point regarding strength and durability relationship. Among the many factors that governs the durability and performance of concrete in service, type of cement receives greater attention. Durability of concrete is its resistance to deteriorating agencies to which it may be exposed during its service life, or which inadvertently, may reside inside the concrete itself. The deteriorating agencies may be chemical-sulphates, chlorides, CO_2, acids, etc, or mechanical causes like abrasion, impact, temperature etc. The steps to ensure durable concrete encompass structural design and detailing, mix proportion and workmanship, adequate quality control at the site and choice of appropriate ingredients of concrete. Type of cement is one such factor.

Two significant aspects in fig.1.1 deserve notice. The first is that the production of Portland Pozzolana Cement (PPC) and Portland Slag Cement (PSC) taken together is greater than that of Ordinary Portland Cement (OPC) which indicates gradual acceptance of such blended cements for structural concrete. The other aspect is that all other varieties, which are required to impart special characteristics of strength development or durability, comprise only one percent. On the phase of it, this will appear to be surprising. In a large country like India where weather, environmental and ground water conditions vary widely in different parts, the need of functionally efficient cements should be large.

This anomaly is resolved to some extent by having ordinary portland cement, which fulfills the intents of more than one specification. These may be called multifunctional or multi-blended cements.

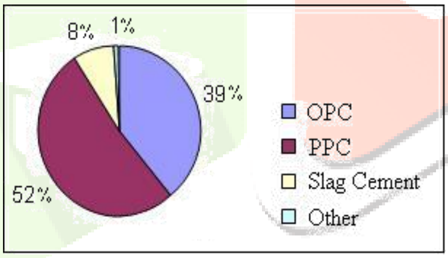

Fig.1.1 Production trend of different varieties of cement in India

Fly ash or ground granulated blast furnace slag can be used in cement and concrete in two different ways. Fly ash or slag can be used in the manufacture of PPC or PSC in the cement plant, by blending or inter-grinding with cement clinkers and gypsum. Alternately, fly ash or ground granulated slag can be added to OPC and other ingredients of concrete in the concrete mixer at the construction site and RMC plant. The prevalent practice in any country depends upon the way the industry has grown.

IS 456 - 2000 recommends the use of blended cement like PPC and PSC, or the mineral admixtures like fly ash, granulated slag and silica fume for improving durability of concrete. Reservations in many agencies in the public sector are also being removed. Recent constructions in many prestigious projects like Delhi Metro, Atomic Power projects and others have used concrete containing fly ash or granulated slag. Use of fly ash and slag are particularly resorted to in case of aggressive foundation conditions.

1.1.3 Use of silica fume and triple-blends

Silica fume is used in India for high performance concrete, requiring high strength, greater impermeability and durability or both. As a result, its use for normal concrete mixes (M_{20} to M_{40} range) has not received due attention. There is much to be gained in using silica fume at about 5 to 7 percent of cement by weight in such mixes. It results in saving of cement content, increased durability and corrosion resistance, higher strength, increased pump ability all of which are vital in every construction.

1.1.4 Bond strength

Bond strength between cement paste and steel reinforcement is of considerable importance. A perfect bond, existing between concrete and steel reinforcement is one of the fundamental assumptions of reinforced concrete. The bond strength arises primarily from the friction and adhesion between concrete and steel. The roughness of the steel surface is also one of the factors affecting bond strength. The bond strength of concrete is a function of compressive strength and is approximately proportional to the compressive strength up to about 20 MPa. For higher strength, increase in bond strength becomes progressively smaller. The bond strength is also a function of specific surface of gel. Cement which consists of a higher percent of C_2S will give higher specific surface of gel, thereby giving higher bond strength. On the other hand, concrete containing more C_3S or the concrete cured at higher temperature results in smaller specific surface of gel which gives lower bond strength. It has been already pointed out that high pressure steam cured concrete produces gel whose specific surface is about 1/20 of the specific surface of the gel produced by normal curing. Therefore, bond strength of high pressure steam cured concrete is correspondingly lower.

Debonding of concrete cover may lead to loss of confinement and reduction of bond strength at interfacial zone between the two materials. In addition, when deformed bars are used, the deterioration of ribs of such bars causes considerable reduction of the interlocking force between the ribs and the surrounding concrete. This seriously affects the primary mechanism of the bond strength between deformed bars and concrete hence the bond strength decreases significantly.

1.1.5 Objectives

The main objective of this project work is to evaluate the bond strength of blended concrete. For this purpose, the mix proportion of normal strength concrete is found using IS code procedure (IS 10262:2009 Recommended guidelines for concrete mix design). The variations in fresh concrete properties of binary and ternary blended concretes are evaluated using various admixtures like fly ash, silica fume and rice husk ash. The variations in compressive strength, tensile strength along with the bond strength of blended concretes are identified. Finally, the effect of rebar corrosion on the behaviour of bond between the reinforcement and concrete is determined.

II. LITRATURE REVIEW

Al- Sulaimani.G.J. et.al [1] describes that to simulate the corrosion process direct current was impressed on the bar embedded in the pull out or beam specimen using an integrated system incorporating a small rectifier power supply with an inbuilt ammeter to monitor the current, and potentiometer to control the current intensity. The pull out or beam specimen was placed under water in a fiber glass tank and the direction of the current was arranged so that the reinforcing steel served as the anode while a stainless steel counter electrode was positioned in the tank to act as cathode.

A.K. Mullick [2] describes the characteristics of cementitious systems required to meet the diverse requirements of strength and durability of concrete and highlights the advantages of part replacement of OPC by fly ash, granulated slag and silica fume either singly or in combination in ternary blends. He also said that the compressive strength is required for appropriate strength grade of concrete. For a particular strength of concrete required, higher strength of cement will allow lower cement content in the concrete mix. In India, 53 grade OPC is preferred for most applications involving medium to high strength concrete. Apart from mass concrete, even in general constructions in tropical climates, low heat generation is an advantage, so that the problems associated with hot weather concreting are minimized.

Kyle Styanish et.al [3] have showed that there are two mechanisms by which corrosion may affect the bond between reinforcing bars and concrete.First,most of the corrosion products that accumulate on the bar surface occupy a larger volume than the original uncorroded metal, thereby causing cracking or spalling of the concrete cover. Loss of cover inevitably implies loss of confinement and a reduction in bond strength at the interfacial zone between the two materials. In addition, the surface of the bar becomes covered with corrosion products. This interferes with the development of the bond mechanisms that rely on adhesion on the bar surface

Nabil Bouzoubaa et.al [4] mentioned that the concrete made with ternary system (fly ash and silica fume based) performs better than the concrete made with Portland cement concrete.

Prof. M.S.Shetty [5] has mentioned that a perfect bond, existing between concrete and steel reinforcement is one of the fundamental assumptions of reinforced concrete. The bond strength arises primarily from the friction and adhesion between concrete and steel. The roughness of the steel surface is also one of the factors affecting bond strength. The bond strength of concrete is a function of compressive strength and is approximately proportional to the compressive strength up to about 20 MPa. For higher strength, increase in bond strength becomes progressively smaller. The bond strength is also a function of specific surface of gel. Cement which consists of a higher percent of C_2S will give higher specific surface of gel, thereby giving higher bond strength. On the other hand, concrete containing more C_3S or the concrete cured at higher temperature results in smaller specific surface of gel which gives lower bond strength. It has been already pointed out that high pressure steam cured concrete produces gel whose specific surface is about 1/20 of the specific surface of the gel produced by normal curing. Therefore, bond strength of high pressure steam cured concrete is correspondingly lower.

R.Jayashankar et.al [6] has mentioned that the workability of concrete was decreasing as % of addition of fly ash increasing. The replacement of cement with various percentages (10% and 20%) of fly ash content reduces the bond strength slightly when compared to OPC concrete. When 30% of fly ash is added, the bond strength is decreased suddenly, at the age of 28 days of standard curing.

R.G.Limaye et.al [7] mentioned in their results as the bond strength between reinforcement and concrete interface is the single most vital factor for the performance of reinforced concrete and it reduced to 10 to 15 % of original strength after corrosion study. It is however restricted to 40 to 50% in the corrosion inhibitor added samples.

S.Basker et al [8] mentioned that the effect of rebar corrosion on the behavior of bond is investigated using pull out test to induce desired level of corrosion in rebar specimens were subjected to accelerated corrosion for different corrosion. The behavior of bond was studied for uncorroded and corroded at different corrosion levels. Corrosion of reinforcing steel can greatly influenced the bond between steel and concrete. Concrete specimens were cast and tested in accordance with IS: 2770 (Part -I) 1967.

S.Gopalakrishanan et al [9] said that reinforced concrete is the most extensively used material for construction world wide. A particle substitution of cement by an industrial waste such as fly ash is not only economical but also improves the properties on fresh and hardened concrete and enhances the durability characteristics. Research carried out has established that particle replacement of cement by mineral admixtures such as fly ash and ground granulated blast furnace slag in concrete mixes would help to over come these problems and lead to improvement in the durability of concrete. Mineral admixtures such as fly ash serve as supplementary cementitious materials. The reactive silica component present in them companies with the free calcium hydroxide, liberated during hydration of cement, to form additional calcium-silicate-hydrate (C-S-H), which otherwise would have leached out and increasing the porosity of the cement matrix. The additional C-S-H increases the denseness of the matrix and refines the pore structure. Hence the use of supplementary cementitious materials in concrete can lead to enhanced durability characteristics. It also improves the rheology of the fresh mixes, enhances the strength of concrete and reduces the cost. In the Indian context, maximum economy can be obtained using low cost pozzolanic admixture. A low calcium (class F) fly ash obtained from Ennore Thermal Power Station near Chennai was used to partially replace the 53 grade cement at varying cement replacement levels in a high strength HPC mix. The mechanical and durability properties of these mixes are presented. Cement replacement level of 25% with fly ash (class F) in concrete mixes is found to be optimum level to obtain the compressive strength of 80 MPa at the age of 28 days and about 90 MPa at the age of 90 days. However, higher level of cement replacement is possible if strength at later ages, such as 90 days could be considered for design.

V.Saraswathy et.al [10] found that the activated fly ashes showed improved mechanical properties when compared to unactivated fly ashes. The influence of strength of concrete and mortar by addition of supplementary cementitious materials such as fly ash, silica fume, slag etc., has been analyzed. Replacement level of 10 to 20% of activated fly ashes showed improved mechanical properties including the bond strength of blended concrete .The activated fly ash blended cements may be utilized as a substitute for ordinary portland cement in the construction industry.

III. MATERIAL PROPERTIES

FLY-ASH

Specific gravity of fly-ash is 1.56

RICE-HUSK

Specific gravity of GGBFS is 2.14

SILICA-FUME

Specific gravity of river sand is 2.3

RIVER-SAND

Specific gravity of bottom-ash is 2.36

COARSE-AGGREGATE

Specific gravity of coarse aggregate is 3.10

IV. METHODOLOGY

4.1 Mix Design

Mix Proportion

S.No	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (litre)
1	326	675	1109	179
2	1	2.07	3.40	0.55

4.2 Mix proportion for ternary blended concrete

Ternary blended concrete is the combinations of cement with optimum quantity of fly ash and any one of the admixture of silica fume and rice husk ash. In ternary blended concrete, the quantity of fly ash is constant as per the binary blended calculation. Table.2.5 shows the details of the mix proportion for the ternary blended system.

Mix proportion for ternary blended concrete

S. No	Mix Designation	Cement Content		Mineral Admixture Content (%)					
				Fly Ash		Silica Fume		Rice Husk Ash	
		%	kg/m^3	%	kg/m^3	%	kg/m^3	%	kg/m^3
1	R	100	326.0	-	-	-	-	-	-
2	B	80	260.8	20	65.2	-	-	-	-
3	TS-1	80	247.8	20	65.2	4	13.0	-	-
	TS-2	80	234.8	20	65.2	8	26.0	-	-
	TS-3	80	221.8	20	65.2	12	39.0	-	-
4	TR-1	80	247.8	20	65.2	-	-	4	13.0
	TR-2	80	234.8	20	65.2	-	-	8	26.0
	TR-3	80	221.8	20	65.2	-	-	12	39.0

V. TEST FOR CONCRETE

5.1 Test results for hardened concrete

S.NO	Mix Design	Compressive strength		Durability test 1% HCl acid immerson		Tensile strength (28 days)
		7 days	28 days	7 days	28 days	
1	R	23.67	29.60	20.40	27.42	1.19
2	B	17.67	27.67	15.22	22.55	0.75
3	TS-1	21.67	29.40	18.22	24.17	0.70
	TS-2	19.33	26.93	14.90	20	0.68
	TS-3	17.33	23.17	13.59	18.95	0.65
4	TR-1	19.07	26.63	14.04	20	0.60
	TR-2	17.93	22.13	12.33	18.57	0.57
	TR-3	15.87	19.67	11.66	17.51	0.54

VI. RESULT AND DISCUSSION

The percentage of fly-ash increased the strength of the concrete decreased. Compare to all compositions 0% fly-Ash replacement given maximum strength. Partial replacement of 5 to 25% of cement in concrete is given maximum compressive strength compared to 20% replacement of fly-ash in cement with silica fume act as a admixture 4, 8, 12 %. Also 20% replacement of fly-ash in cement with rice husk act as a admixture 4, 8, 12 % is given less strength. In this project all the compositions reached the target strength of the concrete. So it gives better strength and durability of the concrete

VII. CONCLUSION

Replacement of fly-ash in cement gives good compressive, tensile and durability of the concrete. By using this can able to recycle the waste material and also prevent the demand in construction material. Rice-husk and silica-fume act as a good admixture in concrete. But this composition strength is less compared to ordinary Portland cement concrete. But it reached target m_{20} strength of the concrete. So it can use as a replaced material for cement. These recycled material also used to reduce the environmental effects

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