International Journal of Advanced Technology in Engineering and Science www.ijates.com
Volume No.03, Issue No. 05, May 2015 ISSN (online): 2348 - 7550

A STUDY OF HIGH STRENGTH FIBRE REINFORCED CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH SILICA FUME AND METAKAOLIN

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ABSTRACT

Civilisation is a part of human life, and technology is advancing rapidly from centuries. Many efforts are made so far in developing of new construction materials. In the construction industry, concrete technology plays a vital role. The usage of supplementary cementitious materials such as Silica fume, Metakaolin and steel fibres in concrete is a new history in the technology. Normally conventional concrete is poor in tensile strength, having low resistance in tensile cracking. This weakness can be overcome by the usage of steel and reinforcing with fibrous material. The mechanical property of fibrous concrete is superior to that of conventional concrete.

In the study, Silica fume and Metakaolin are used as partial replacement of cement, and steel fibres of aspect ratio 50 are used at 2% of total volume of concrete to investigate the strength of concrete. The properties of partially replaced cement are studied based on workability and compressive strength of concrete.

Keywords: Admixtures, Fibre Reinforced Concrete, Metakaolin, Silica Fume, Steel Fibres

I. INTRODUCTION

In Civil Engineering construction field concrete is one of the most commonly used construction material throughout the world. Its production is greatly increased worldwide. In the production of concrete no poisonous substances are emitted but emission of carbon dioxide Co_2 gas is more in the production of cement clinker. This is making significant contribution to greenhouse gases thereby causing environmental pollution. This is the only ecological disadvantage in the production of cement. This effect can be reduced by reduction of cement consumption by using supplementary cementitious materials (SCM's).

Supplementary cementitious materials (SCM's) are finely grounded solid materials which are used to part replacement of cement in concrete mixtures. SCM's may be naturally occurring, manufactured or man-made waste. SCM's may posse's pozzolanic or latent hydraulic reactivity or combination of both of these.

Pozzolan term refers to siliceous materials which are in finely divided form. In the presence of water pozzolons react with calcium hydroxide (CH) chemically to form cement compounds. Pozzolans can be either natural or industrial origin. Natural pozzolans contains volcanic ash and diatomaceous earth. Some examples of artificial pozzolans are Metakaolin (MK), Silica Fume (SF), Fly ash (FA), Ground granulated blast furnace slag (GGBS), Rice husk ash (RHA). Metakaolin is obtained by thermal activation of ordinary clay and kaolinitic clay. It is processed with water to remove the impurities to make 100% reactive pozzolan. Silica fume is obtained from

the effluent gases produced in the manufacturing of silicon metal and alloys. By using the supplementary cementing pozzolanic materials the strength parameters of concrete can effectively enhanced.

Huge quantities of these by-products are wasted either in low-value applications such as landfills, road sub bases or simply disposed by stockpiling and ponding. Recent research has shown that blending of pozzolanic materials with Portland cement improves the several advantages such as lowering the heat of hydration, increased anti-corrosion characters, impermeability, and durability of concrete. Cost reduction of Portland cement can be obtained by using supplementary cementing pozzolanic materials such as Silica Fume, Metakaolin, Rice husk ash, etc. All these are industrial and Agro-wastes. The disposal of these wastes is of top most importance. Instead of useless disposal of these pozzolanic by-products, if they are blended with Portland cement, its advantages are great.

Cement replacement with certain percentage of Silica fume, Metakaolin without sacrificing strength of concrete is one of the ways of reducing the content of cement. The fact is that strength of concrete can be increased by the use of these materials.

1.1 Silica Fume

Silica fume (SF) is a very efficient and effective pozzolanic material. Silica fume also called by different names as Micro Silica, Condensed Silica fume, Silica dust, and Fumed Silica. SF should not be used in concrete indiscriminately, but it should be limited for specialized applications to get full advantage of its unique properties. Few years ago Silica fume was only a waste product. With so many researches now the price of Silica fume varies from half to twice the price of normal Portland cement. One can get full advantage in the production of high strength concrete by the effective replacement of cement by Silica fume.

Table1: Comparison of Finesse of Silica Fume with Various Other Materials

Material	**Finess m^2/kg**
Silica fume	About 20,000
Fly Ash	400 – 700
Portland Cement	300 - 400

Table 2: Chemical Composition of Silica Fume

Constituent	**Percentage (%)**
SiO_2	90-96
Al_2O_3	0.5-0.8
MgO	0.5-1.5
Fe_2O_3	0.2-0.8
CaO	0.1-0.5
Na_2O	0.2-0.7
K_2O	0.4-1.0
C	0.5-1.4
S	0.1-0.4

1.2 Metakaolin

Metakaolin is neither industrial by-product nor a natural available material. MK has great advantage as an SCM since it can increase many properties of concrete and also reduces cementing consumption. Metakaolin is produced by heat-treating of one of the most abundant natural minerals called Kaolin. Kaolin is fine, white clay which is traditionally used in the manufacture of porcelain and as a paper coat. Kaolin name is derived from the name of the Chinese town Kao-ling, which means loosely to "high ridge". MK is commercially available from mid 1990.

Metakaolin reduces the porosity of hardened concrete and the thickness of the interfacial zone is reduced. This improves the adhesion between the aggregate or sand and hardened cement paste. The particle size of Metakaolin is significantly smaller than cement particles. Blending of Metakaolin with Portland cement improves the properties of concrete. Usage of Metakaolin can be more advantageous for preparing stronger and more durable concrete mixes due to above reasons. The performance of concrete is substantially improved by addition of Metakaolin.

TABLE 3: Chemical Properties of Metakaolin

$SIO_2+AL_2O_3+Fe_2O_3$	96.88%
CaO	0.39%
MgO	0.08%
TiO_2	1.35%
Na_2O	0.56%
K_2O	0.06%
Li_2O	NIL

1.3 Steel Fibres

The steel fibres may be square, circular, crescent-shaped and irregular. Round steel fibres are produced by cutting or by chopping wire of diameter 0.10 to 0.30 inches (0.25 mm to 0.76 mm). Steel fibres are produced by melt extraction process.

1.4 Fibre Reinforced Concrete

When compared with traditional reinforced concrete fibre reinforced concrete is rather a new engineering material. Fibre reinforced concrete is a concrete composed of normal setting hydraulic cement, fine aggregates, coarse aggregates and discontinuous discrete fibres with different lengths and different gauges as parameters."

1.5 Chemical Admixture

Concrete is said to be good when it has good workability in fresh state and strong enough in its hardened state. Normally workability and strength not achieved simultaneously by more manipulation of water cement ratio. Improvement in concrete strength and the absence of bleeding and segregation are also important properties to be considered. Such ideal concrete only give good workability produced more quickly for less money affords all round benefits. Such claims can be made with the help of super- plasticizers.

II. EXPERIMENTAL WORK

Recognizing the need of utilization of Silica fume and Metakaolin in concrete, the present investigation is taken up with an aim to understand the behaviour of Silica fume and Metakaolin cement concrete when it is reinforced by steel fibre. Thus the work study is laboratory oriented.

a) The materials are collected from a specific location and properties are studied.

b) Using these properties, mix design of M_{60} grade concrete is carried out with suitable w/c ratio.

c) Using slump cone test required slump is obtained experimentally.

d) To study the compressive strength of concrete cubes were casted and then the cubes were tested in Compression testing machine.

e) Using 150 mm concrete cube specimens the compressive strength of the concrete is determined. The Specimens tested at 3, 7, 14 and 28 days age, in 200 tons capacity hydraulic type compression-testing Machine.

f) Conclusions are drawn based on test results.

2.1 Materials

2.1.1Cement

In the present work, Birla Super 53 Grade OPC has been used.

2.1.2 Fine Aggregate

Clean river sand which is locally available has been used.

2.1.3 Coarse Aggregate

Crushed granite of 20mm maximum size has been used as coarse aggregate. Two different sized coarse aggregates were used. 40% of aggregates are 20mm passing 16mm retained and 60% coarse aggregate are 12.5mm passing and 10mm retained.

2.1.4 Water

In concrete water is an important ingredient. It actively participates in the chemical reaction with cement. The quality and quantity of water is required to look very carefully. In this experimental work for mixing the concrete and for curing the concrete specimen ordinary potable tap water available at laboratory was used.

2.1.5 Mineral Admixtures

The finely grounded solid materials which can be used to replace cement partially can be used as mineral admixtures. Silica fume and Metakaolin are used as mineral admixtures in this project.

2.1.5.1 Silica fume

In the present experimental study silica fume which is an ultra fine powder and light to dark grey in colour is used.

2.1.5.2 Metakaolin

Metakaolin of specific gravity 2.5 in off- white powder is used in the present study.

2.1.6 Chemical Admixture

Super plasticizer based on polycarboxylic ether has been used in the present work.

2.1.7 Steel Fibres

The fibres used are Crimped End Fibres.

2.2. Experimental Investigations

In the present experimental investigation, high strength concrete of Grade M_{60} is studied by using of condensed Silica fume (CSF) and Metakaolin (MK) as partial replacement by weight of cement. Steel fibres having aspect ratio of 50 are also used. The proportion of steel fibres is added at 2% of the volume of the concrete. Cubes were cast with M_{60} grade concrete design mixes.

2.2.1 Compressive Strength Test

Compressive strength test is carried out on 150 mm cubic specimen in a 200 ton capacity compressive testing machine.

Table 4: Compressive Strength of M_{60}grade of Concrete at 28th day

SL No.	Mix Description	Compressive Strength of Cubes in N/mm^2 With replacement % of cement by mineral admixture			
		0%	5%	10%	15%
1	CC	70.01	-	-	-
2	CC+2% Fi	70.56			
3	SF		72.35	73.46	72.76
4	SF+2%Fi		72.56	73.74	72.83
5	MK		71.15	72.36	71.42
6	MK+2%Fi		71.63	72.51	72.08

CC-Conventional concrete, Fi – fibres, SF- Silica fume, MK-Metakaolin

2.2.2 Compressive strength chart of M_{60} grade concrete at 28th day for different combinations

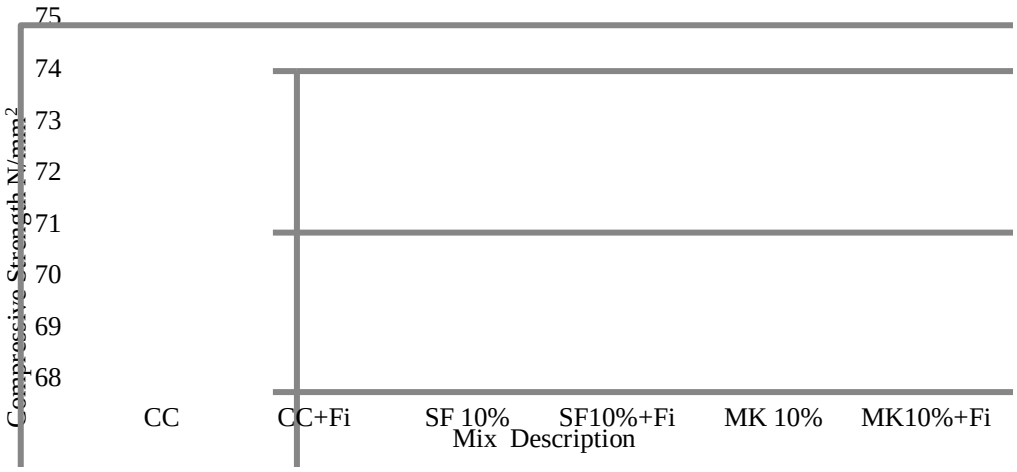

Figure-1. Compressive Strength of Concrete Cubes at 10% Replacement of Cement

III. CONCLUSION

1. It has been observed that with the addition of Silica fume and Metakaolin, the compressive strength of concrete at the age of 28 days has increased with various proportions of the mix. The increase in strength is in

the range of 1.62% to 5.3% for different combinations. However, silica fume concrete gives better result at all ages than Metakaolin concrete.

2. The purpose of introducing Silica fume and Metakaolin by partial replacing cement is to increase strength and performance of the concrete. And also strength and durability of concrete can be enhanced by introducing the steel fibres.

3. The workability of high strength fibre reinforced concrete has been increased by adding Silica fume and Metakaolin with constant quantity of high range water reducing (HRWR) chemical agent.

4. By analysing the experimental results of high strength fibre reinforced concrete, the addition of 10% of Silica fume and 10%Metakaolin with 2% of steel fibres has achieved the maximum compressive strength.

IV. ACKNOWLEDGEMENT

I express my sincere gratitude and thankful to my guide professor K.Rajasekhar for the guidance and encouragement and support in the work.

I sincerely thank to assistant professor K. Krishna murthy, Banglore, and Ragvendra Lab Assistant, BITIT, Hindupur for their support in my work.

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