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Investigation on High Strength Fiber Reinforced Concrete with Silica Fume and Metakaolin as a Partial Replacement of Cement

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ABSTRACT

In reviewing technology advances through the centuries it is evident that material developments plays a key role in. Considerable efforts are still being made in every part of the world to develop new construction materials. In the construction industry, concrete technology is heading towards entirely new era by the use of Silica Fume, Metakaolin, and Steel Fibres in concrete. While conventional concrete has poor tensile strength, low resistant to tensile cracking, so its capacity to absorb energy is limited. The weakness in tension is conventionally overcome by strengthening their matrix with steel and more recently by reinforcing with fibrous materials. Concrete when mixed with fibres, give fibrous concrete. The mechanical property of fibrous concrete is superior to that of ordinary concrete. Silica Fume and Metakaolin will be evaluated for use as supplementary cementitious material in cement based system, the performance of Silica fume and Metakaolin mixtures will be compared to controlled mixtures and mixtures incorporating Silica fume and Metakaolin as partial replacement for cement.

The manifold benefits of usage of Silica Fume, Metakaolin and Steel Fibres in concrete are now well recognised. To improve the usage of Silica Fume, Metakaolin and Steel Fibres in structural concrete studies on aspects such as compressive strength, split tensile strength and flexural strength of Silica Fume, Metakaolin fibre reinforced concrete are to be undertaken which will spread its usage. Hence, in the present experimental investigation, high strength concrete of M70 is tried using Condensed silica fume (CSF) and Metakaolin (MK) as partial replacement by weight of cement. Steel fibres having aspect ratio of 50 are also used at 2% as total volume of concrete.

Key words- ***High strength reinforced concrete, silica fume, met kaolin, steel fiber, compressive strength, Split tensile strength, flexural strength.***

1. INTRODUCTION

Concrete is one of the most extensively used construction materials in the world, with two billion tons placed worldwide each year. Concrete can generally be produced of locally available materials, can be cast into a wide variety of structural configurations and requires minimum maintenance during service. In its production and use, no poisonous substances are emitted. The found in abundant all over the world. The only ecological disadvantage of concrete is the emission of carbon-di-oxide (Co2) gas during production of cement clinker, have brought about pressure to reduce the cement consumption through the use of supplementary materials.

Supplementary cementitious materials (SCM's) are finely ground solid materials that are used to replace part of cement in concrete mixtures, these materials react chemically with hydrating to form a modified paste microstructure. In addition to their positive environmental impact, SCM's may possess pozzolanic or latent hydraulic reactivity or a combination of these. The term Pozzolan refers to siliceous materials which in finely divided form and in the presence of water will react chemically with calcium hydroxide (CH) to form cementitious compounds.

2. LITURATURE REVIEW

Many researchers have studied the effect of replacement of Portland cement by Metakaolin, Silica fume and also fibre addition on the mechanical and durability properties of ordinary Portland cement concrete.

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Vikas Srivastava:
Nowadays there is an increasing trend of utilization of waste/non-conventional materials in cement and concrete matrices. These materials are often used as a part replacement of cement reducing the cost of construction and help to overcome the deficiencies associated with the use of Ordinary Portland Cement (OPC) alone. Also, these materials generally improve the strength of cement/concrete matrices and other quality aspects. Metakaolin is a waste/non-conventional material which can be utilized beneficially in the construction industry. Metakaolin inclusion increases the compressive, tensile, flexural and bends strength and modulus of elasticity of concrete considerably; however, the workability is slightly compromised. In his work presents the review of investigations carried out to find the suitability of Metakaolin in production of concrete. He concluded that Metakaolin reduces workability. However, in certain cases with appropriate doses of plasticizers the effect is not much. The gain in compressive strength is improved depending upon the replacement level of OPC by Metakaolin. The Metakaolin inclusion generally improves tensile strength, flexural strength, bond strength and modulus of elasticity.

Brief Summary of Literature Review;-The use of Metakaolin and Silica fume in concrete as replacement of cement resulted in: Pozzolanic materials like Metakaolin and Silica fume when used as cement replacement materials in concrete improves the properties of concrete due to the more consumption of $Ca(OH)_2$, better pore refinement, micro filling action, more resistant to permeability, Early gain of strength, higher pozzolanic reaction and also helps in reducing the consumption of cement. This leads to saving of natural resources and reduction in the emission of greenhouse gases like Co_2.

The above existing literature indicates that many researchers have studied the few strength properties of ordinary Portland cement concrete using Metakaolin and Silica fume as cement replacement material. In the present experimental investigation, high strength concrete of M70 is tried using condensed Silica fume and Metakaolin as partial replacement at 5%, 10% and 15% by weight of cement. Steel fibres having aspect ratio of 50 at 2% of the volume of concrete are also used.

3. PROBLEM DEFINITION, OBJECTIVES AND METHODOLOGY

The raw materials needed for the manufacture of Portland cement (PC) are available in most parts of the world, and the energy requirements for its production may be considered to be relatively modest. Nevertheless the use of alternative binders or cement replacement materials has become a necessity for the construction industry because of the economic, environmental and technological benefits derived from their use. Furthermore recent years have seen increased concerns regarding the depletion of raw materials, energy demands and the consequent environmental damage. These concerns have led to wider utilization of existing cement replacement materials and further search for other less energy intensive materials. Many of these mineral admixtures are industrial by-products, and are considered as waste. When used as a partial cement replacement material, typically in the range of 20 to 40% by mass, the energy and cost savings are substantial. From an environmental point of view mineral admixtures are playing an undisputed role. They are responsible for substantial “environmental unloading” because their disposal can be hazardous to the environment and higher utilisation of them can result in reduction of greenhouse gas emissions attributed to the cement industry.

Methodology

Recognizing in need for utilization of Silica fume and Metakaolin in concrete, the present investigation is taken up with an aim to establish or 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.

1.The materials have been collected from a specific location and properties have been studied.
2.Using these properties, mix design is carried out with suitable w/c ratio of M70 grade concrete.
3.Required slump is obtained experimentally by slump cone test.
4.Concrete cubes were casted to study the compressive strength of concrete. Then the cubes were tested in compression testing machine

5.The compressive strength of the concrete will be determined by using 150 mm concrete cube specimens. The specimens will be tested at 3, 7, 14 and 28 days age, in 200 tons capacity hydraulic type compression-testing machine. The cube compressive strength will be obtained by considering the average of three specimens at each age.

Objectives

1.To study the slump property of concrete.
2.To study the strength properties such as compressive strength, split tensile strength and flexural strength of M70 grade of concrete while replacing Silica fume as a partial replacement at 5%, 10% and 15% by weight of cement.
3.To study the strength properties such as compressive strength, split tensile strength and flexural strength of M70 grade of concrete while replacing Silica fume as a partial replacement at 5%, 10% and 15% by weight of cement with addition of steel fibres at 2% by volume of concrete.

4. CHARACTERIZATION OF CONSTITUENT MATERIALS

The two major components of fibre-reinforced cement composites are the matrix and the fibre. The matrix generally consists of Portland cement, aggregates, water and admixtures.

1. Ordinary Portland Cement
2. Fine aggregate
3. Coarse aggregate
4. Water
5. Mineral admixture
6. Chemical admixture
7. Steel fibres

Silica fume

CORNICHE SF brand SILICA FUME a 25 kg bag which is an ultra-fine powder, and light to dark grey in colour supplied by MILLENIUM BUILDING SYSTEM, BENGALURU is used in the present experimental study.

Metakaolin

Metakaolin is another pozzolanic material which is manufactured from selected kaolins, after refinement and calcination under specific conditions. Metakaolin used 25 kg bag which is manufactured by Specialty Minerals LTD, Baroda.

Chemical admixture

Super plasticizer GLENIUM B244 of M/s. BASF Construction Chemicals (I) Pvt. Ltd, confirming to IS: 9103: 1999 has been used.

Steel Fibres

The fibres of M/S SHAKTHIMAN MSC 6030 which conforms with ASTM A820 have been used. The fibres used are Crimped End Fibres shown with the following characteristics as provided by manufacturer.

5.EXPERIMENTAL INVESTIGATIONS

This test was carried out for determining the workability of concrete. The method of testing was done as per IS 1199-1959. The dimensions of the mould are as shown in Fig 5.1. Steel tamping rod of 16 mm in diameter, 0.6 m long and rounded at one end was taken. The internal surface of the mould was thoroughly cleaned and free from superfluous moisture and any set concrete before commencing the test. The mould was place on a smooth, horizontal, rigid and non-absorbent surface (levelled metal plate). The mould was held firmly while concrete is filled. The mould was filled in four layers, each approximately one-quarter of the height of the mould. Each layer was tamped with twenty-five strokes of the rounded end of the tamping rod. The strokes were distributed in a uniform manner over the cross-section of the mould and in the second and subsequent layers. After the top layer was tamped excess concrete was struck off and levelled with a trowel. The mortar leaked out between the mould and the base plate was cleaned. The mould was removed from the concrete immediately by raising

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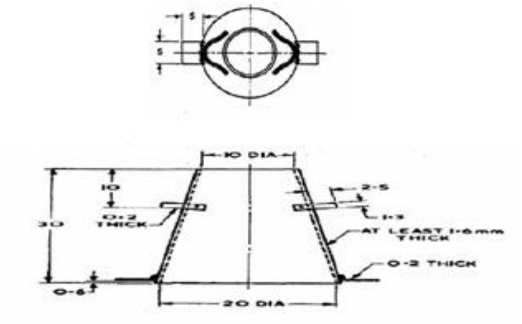
it slowly and carefully in a vertical direction. Slump was measured (in mm) immediately by determining the difference between the height of the mould and that of the highest point of the specimen being tested. The operations were carried out at a place free from vibration or shock, and within a period of two minutes after sampling.



Compression Test:

The compressive strength of concrete i.e. ultimate strength or concrete is defined as the load which causes failure of the specimen divided by the area of the cross section in uni-axial compression, under a given rate of loading. To avoid large variation in the results of compression test, care should be taken during the casting of the test specimens and loading as well. It is however realized that in an actual structure, the concrete at any point is in a complex stress condition and not in uni-axial compression. However it is customary to conduct the test in uni-axial compression only. Concrete under tri-axial state can offer more resistance and will fail only after considerably large deformations. The use of 150mm cubes have been made as per I.S code of practice IS 456-2000. The advantage of selection of IS 516-1959 cube as the standard test specimen is that two plane and parallel surfaces can always be found between which the load can be applied. The cubes were tested in 200 tons capacity compressive testing machine. Placed the specimen in the machine then apply the continuously, uniformly and without shock. The rate of loading is continuously adjusted through rate control valve by hand to 400 kN/minute. The load is increased until the specimen fails and record the maximum load carried by specimen during the test.

Split tensile Strength

The split tensile strength of the concrete is defined as the load which causes failure of the specimen divided by the area of the cross section in uni-axial compression, under a given rate of loading. To avoid large variation in the results of Split test, care should be taken during the casting of the test specimens and loading as well. The specimen is placed horizontally in the testing machine and the rate of loading is continuously adjusted through rate control valve by hand to 400 KN/minute. The load is increased until the specimen fails and record the maximum load carried by specimen during the test.

Flexural Test

The standard sizes of the specimen are 15x15x70 cm. They are tested immediately on removal from the water whilst they are still in wet condition. The bearing surfaces of the supporting and loading rollers are wiped clean, and loose sand or other material removed from the surfaces of specimen where they are to make contact with the rollers. The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 13.3cm apart. The axis of the specimen is carefully aligned with the axis of the loading device. no packing is used between the bearing surfaces of the specimen and the rollers. The load is applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 0.7 kg/cm2/min i.e. at a rate of 180 kg/min. The load is increased until the specimen fails and the maximum load applied to the specimen during the test is recorded. If any value falls below 5 N/sq-mm, the mix design shall be reviewed. Plate 8 shows failure of flexural beam member.

6.MIX DESIGN OF M70 CONCRETE AND DESIGN OF REINFORCED CONCRETE BEAM

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with object of producing concrete of certain minimum strength and durability as economically as possible. For the present work a grade of concrete M70 suggested to be used in any RCC members is adopted. Mix design is based on IS: 10262:2009.Tests on trial mixes have been carried out. Finally a mix proportion that gives required 28 days cube compressive strength with minimum cement content and required workability of 50 to 150mm is selected.

7.RESULTS AND DISCUSSIONS

In the present experimental investigation, high strength concrete of Grade M70 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% as total fibre percentage of the volume of concrete. Cubes, cylinders and beams were cast with M70 grade concrete design mixes. The results can be discussed under the following heads.

Conclusion

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 properties of concrete can be enhanced by introducing the steel fibres.

1.High strength fibre reinforced concrete mix has been produced with addition of condensed Silica fume and Metakaolin as mineral admixtures.

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

3.The compressive strength of high performed concrete after 28days of curing with 5%, 10% and 15% of Silica fume and Metakaolin has been increased by 2.01%, 4.01% and 2.19% for Silica fume and 1.86%, 2.26% and 1.73% for Metakaolin.

4.It has been observed from the test results, the split tensile strength has been increased at 10% replacement of Silica fume and Metakaolin with 2% of steel fibres.

5.From the experimental results it has been observed that the appreciable improvement in compressive strength, split tensile strength and the flexural strength has observed with 10% of silica fume and 2% of steel fibres.

6.By the addition of steel fibres in high strength concrete with different percentage of mineral admixtures, the flexural strength has been improved in all the mix.

Scope for future work

1. Strength of concrete incorporating different replacement ratio of Metakaolin and Silica fume can be determined.

2. Strength of concrete incorporating different mineral admixtures can be determined.

3. Strength of concrete with different types of fibers can be determined.

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