Effect of Metakaolin And Banana Fibre in High Strength Concrete

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ABSTRACT
The extensive experimental investigations carried out and the discussion on strength and durability are presented. The relative performance of Banana fibre reinforced concrete as compared to the plain concrete has been highlighted. The compressive strength of Banana fibre reinforced concrete has shown considerable increase relative to the reference concrete, 0.25% fibre content with 10% of metakaolin. Flexural strength of Banana fibre reinforced concrete is also maximum, when the fibre is 0.25%, with an aspect ratio 70 when compared to the 50 and 30 aspect ratio of fibres. Compressive, flexural and split tensile strength of Banana Fibre Reinforced Concrete are maximum at 0.25% fibre content with addition of 10% of metakaolin to the volume of cement. And also the compressive strength obtained at 0.25% fibre content is 68 N/mm² and it’s 18.62% higher than the reference concrete strength. The maximum flexural strength obtained at 0.25% fibre content is 6.4 N/mm². This is 17.64% higher than the reference concrete strength. The maximum split tensile strength attained at 0.25% fibre content is 4.93 N/mm², which is 15.18% higher than the reference concrete strength. Workability decreases, as the percentage of metakaolin increases. The maximum compressive strength obtained is 70.4N/mm at 10% replacement of OPC with metakaolin, which is 20.2% higher than the reference strength. From the above study, the best mix proportion was chosen at 10% replacement of metakaolin.

KEYWORDS: Metakaolin & Banana fibre, Tensile strength, Flexural behavior.

INTRODUCTION

METAKAOLIN CONCRETE
Cementation properties, Calcium Hydroxide are liberated during the hydration of Portland cement. Lately, there has been much interest in the use of High Reactivity Metakaolin (HRM) as a supplementary cementing material, produced by calcining purified kaolin clay in the temperature of 700° C.

\[ \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O} \rightarrow \text{Al}_2\text{O}_3\cdot3\text{SiO}_2 + 2\text{H}_2\text{O} \]  \[1\]

HRM (\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2) is a poorly crystallized white powder with a high pozzolanic reactivity, when HRM reacts with calcium hydroxide, a pozzolanic reaction takes place whereby new cementations compounds are formed. These newly formed compounds will contribute...
cementations strength and enhanced Durability properties to the system in place of the otherwise weak and soluble calcium hydroxide. The use of (HRM) with (strength and durability of steel fiber reinforced concrete due to reduction of permeability)²

However, environmentalists concern both in terms of damage caused by the extraction of raw material and CO₂ emission during cement manufacture have brought pressures on researchers for the reduction of cement consumption by partial replacement of cement by supplementary materials. These materials may be naturally occurring, industrial wastes or byproducts that require relatively less energy to manufacture. The other concerns contributing to these pressures are the incidents involving serious deterioration of concrete structures³

In addressing these concerns and other environmental issues relating to the disposal of waste industrial by products because of economic advantages, mixtures of Portland cement and pozzolans are now very commonly used in concrete production ⁴. Originally the term pozzolan was associated with naturally formed volcanic ashes and claimed earths, which react with lime at ambient temperatures in the presence of water. The admixtures in the form of siliceous aluminous materials which, in finely divided form and in the presence of water, will react chemically with calcium hydroxide Ca(OH)₂ to form compounds that possess cementations properties⁵

This generalized definition covers waste products such as fly ash (FA), rice husk ash and silica fume (SF). Portland cement, if fully hydrated, produces calcium hydrate (CH) which does not make a significant contribution to strength and can be harmful to concrete durability. The complete elimination (or) partial reduction of (CH) with the reaction of pozzolan results in stronger and durable concrete. Because of these technical advantages over the last few decades, there has been increasing and widespread utilization of FA, SF and natural zeolite in concrete. The volume of industrial by products with pozzolanic properties, produced worldwide exceeds their current utilization and it is widely believed that their utilization will increase with increasing realization of the environmental benefits associated with such use. This will immensely help in the protection of environment and leads to sustainable construction.

BANANA FIBER
Banana plant not only gives the delicious fruit but it also provides textile fiber, the banana fiber. It grows easily as it sets out young shoots and is most commonly found in hot tropical climates. All varieties of banana plants have fibers in abundance. These fibers are obtained after the fruit is harvested and fall in the group of bats fibers. This plant has long been a good source for high quality textiles in many parts of the world

FIBRE REINFORCED CONCRETE
In the past, attempts were made to impart improvement in tensile properties of concrete members by using conventional reinforcing steel bars and pre-stressing techniques. Although
both these methods improved the tensile strength of the concrete members, there is no increase in the inherent tensile strength of concrete.

Under loading, the micro cracks present in concrete propagate and open up, owing to the effect of stress concentration and also additional cracks form in places where there are minor defects. The development of such minor cracks is the main cause of inelastic deformation of concrete.

It has been recognized that the additions of small, closely spaced and uniformly dispersed discontinuous discrete fibres to concrete would substantially improve its static and dynamic properties. This type of concrete is known as fibre reinforced concrete. The concept of fibre reinforcement is to use the deformations of the matrix under stress to transfer load to the fibre. The static and dynamic strength can be improved if the fibres are strong, stiff and loaded to fracture, provided there is a minimum fibre volume fraction\(^7\)

Fibres currently being used in concrete can be broadly classified into two types:

i) Low modulus, high elongation fibres such as nylon, polypropylene, polyethylene, etc. which possess the capacity of large energy absorbing characteristics but cannot impart strength improvement. However, they impart toughness and resistance to impact and explosive loading\(^8\)

ii) High strength, high modulus fibres such as steel, asbestos and carbon which produce strong composites, their high modulus impart strength, stiffness and dynamic properties to the composite\(^9\)

**REVIEW OF LITERATURE**

**Sabir.B.B et al (2007)** carried out a study on the utilization of Metakaolin as pozzolanic material for mortar and concrete and mentioned about the wide range application of Metakaolin in construction industry .They reported that the usage of Metakaolin as a pozzolana will help in the development of early strength and some improvement in long term strength. They mentioned that Metakaolin alters the pore structure in cement paste mortar and concrete and greatly improves its resistance to transportation of water and diffusion of harmful ions which lead to the degradation of the matrix

**Jian-Tong Ding et al (2007)** Experimentally found out the effects of Metakaolin and Silica Fume on the properties of Concrete. Experimental investigation with seven concrete mixtures of 0, 5, 10, and 15% by mass replacement of cement with High Reactivity Metakaolin or Silica fume, at a water cement ratio of 0.35 and a sand-to-aggregate ratio of 40% was carried out. The effect of Metakaolin or Silica fume on the workability, strength, shrinkage, and resistance to chloride penetration of concrete was investigated. The incorporation of both Metakaolin and Silica fume in concrete was found to reduce the free drying shrinkage and
restrained shrinkage cracking width. It is also reported that the incorporation of Metakaolin or Silica fume in concrete can reduce the chloride diffusion rate significantly.

**Badogiannis, E et al (2008)** Evaluated the effect of Metakaolin on concrete. Eight mix proportions were used to produce high-performance concrete, where Metakaolin replaced either cement or sand of 10% or 20% by weight of the control cement content. The strength development of Metakaolin concrete was evaluated using the efficiency factor (k value). With regard to strength development the poor Greek Metakaolin and commercially obtained Metakaolin yielded the same results. The replacement with cement gave better results than that of sand. When Metakaolin replaced cement, its positive effect on concrete strength generally started after 2 days, whereas in case of sand it started only after 90 days. Both Metakaolin exhibited very high k-values (close to 3.0 at 28 days) and are characterized as highly reactive pozzolanic materials that can lead to concrete production with excellent performance.

**EXPERIMENTAL INVESTIGATION**

In this experiment M25 mix concrete is used and the mix design was done as per IS 10262-2009. The cubes of size 100 x 100 x 100 mm³ and cylinders of 150mm diameter and 300mm height are casted for each conventional concrete and Metakaolin and banana fibre replacement of 10%, 12%, and 14% to the weight of cement and tested under compression testing machine. The beam specimens of size 150 x 150 x 700 mm³ are casted with steel reinforcement and bamboo is replaced to the steel reinforcement in the proportion of 25%, 50%, 75% and 100% to the area of steel and metakaolin is replaced for each bamboo reinforcement.

The 4 numbers of 8mm diameter rods are provided as main reinforcement and 8mm diameter stirrups are provided at 140mm center to center in beam specimens. The bamboo sticks were cut into 8mm diameter and coated with asphalt emulsion and replaced to the steel bars. Therefore flexural testing is done in beam specimen under loading frame and the test results are analyzed.

**MATERIALS USED**

The cement used in this experimental study is OPC 43 grade cement from Chettinad Cement Company conforming to specifications of IS 8112:1989. The standard consistency of cement is found to be 30% and the specific gravity is 2.9. The fine aggregate used for this project is river sand obtained from approved suppliers and the coarse aggregate used is crushed rock conforming to specifications of IS 383:1970 and comes under Zone III grade.

The specific gravity of fine aggregate is 2.6 and the coarse aggregate is 2.8. The mature well-seasoned bamboo sticks is used for this study. The properties such as physical and chemical test are tested by as per IS code in IS 6874-2008.
Metakaolin reduces the size of pores in cement paste and transforms many finer particles into discontinuous pores, therefore decreasing the permeability of concrete substantially. Metakaolin increases compressive and flexural strengths. It reduces water permeability and efflorescence. Also it reduces heat of hydration leading to better shrinkage and crack control. So use of Metakaolin has wide scope in its use in HSC Banana fiber is a bast fiber which is collected from the skin or bast surrounding the stem of their respective plant. These fibres have high tensile strength than other fibres. Therefore these fibers are used for durable yarn, fabric, packaging and paper.

MIX DESIGN
The mix design is done for M50 grade of concrete as per the IS 8112. As per the material properties the mix proportion obtained is 1:2.92:6.67. The water cement ratio used for the mix design is 0.4.

RESULTS AND DISCUSSION

COMPRESSIVE STRENGTH
The compressive strength on cube specimens of size 100 x 100 x 100 mm$^3$ are done as per IS 516:1959 codal provisions under the compression testing machine.

![Graph showing Compressive strength results for 7, 14 and 28 days](image)

**Figure-1** Graph showing Compressive strength results for 7, 14 and 28 days

SPLIT TENSILE STRENGTH
The split tensile strength on cylindrical specimens of 150 mm diameter and 300 mm height are done as per IS 5816:1959 codal provisions under the compression testing machine.
FLEXURAL STRENGTH
The flexural strength represents the highest stress experienced within the material at its moment of rupture. The test was done as per IS 516-1959 codal provision.

Figure-3 Graph showing Flexural strength results for 7, 14 and 28 days

FAILURE MODE AND CRACK PATTERN
The cracks at the mid-span opened widely thereafter with the yielding of steel when the beams reached its ultimate load. The failure pattern of the beam specimens was found to be steel reinforced beams.
CONCLUSION

The relative performance of Banana fibre reinforced concrete as compared to the plain concrete has been highlighted. A few specific recommendations based on the assessment/usefulness of the present study, are also given. The compressive strength of Banana fibre reinforced concrete has shown considerable increase relative to the reference concrete, 0.25% fibre content with 10% of metakaolin. Compressive, flexural and split tensile strength of Banana Fibre Reinforced Concrete are maximum at 0.25% fibre content with addition of 10% of metakaolin to the volume of cement. And also the compressive strength obtained at 0.25% fibre content is 68 N/mm² and it’s 18.62% higher than the reference concrete strength.

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REFERENCE

