International Journal of TechnoChem Research
ISSN:2395-4248 www.technochemsai.com
Vol.04, No.01, pp 20-26, 2018

Experimental Studies On Strength And Durability Aspects Of Metakaolin Based Cement Concrete

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Abstract : Metakaolin is one of the widely developing cementitious material used as an admixture to produce high strength concrete and is used for maintaining consistency of concrete. In the case where sufficient or poor curing concrete structures like the sea shores, underground structures get affected by loss of compressive strength, permeability and durability, use of metakaolin proves to be very useful to modify the properties of concrete. This project deals with the properties of concrete by replacement of metakaolin. The mix were obtained by replacing 0, 5, 7.5, 10, 12.5, 15 percent mass of cement by metakaolin. Finally, required specimens were tested to investigate the behaviour such as compressive strength and durability. The test result indicates optimum quantity of metakolin usage tend to increase the strength of concrete when compared with conventional one.
Key words: Target mean strength, characteristic compressive strength, tolerance factor, cement, sp. Gravity, w/c.

Introduction

Concrete is the most widely used construction material. Addition to improvement in strength, concretes with very low w/c ratios get improved characteristics, such as higher fluidity, elastic modulus, flexural strength, lower permeability, improved abrasion resistance, and better durability[6]. However, by using super plasticizer we began to decrease the w/c ratio as fluid modifiers for normal-strength concretes[2]. They increase the long term performance of concrete with reduced permeability and enhanced durability. Mineral admixtures such as fly ash, rice husk ash, metakaolin, silica fume etc. are most commonly used in the production of concrete mixes for obtaining higher performance and economy[7]. High reactivity materials like metakaolin, which is a relatively newer material in the concrete is effective in increasing the compressive strength[3-5]. It reduces the sulphate attack and enhances air-voids in concrete [9]. Addition of these materials improves the strength and durability aspects of concrete[7]. Cement is not replaced by either steel slag or ceramic waste, because the maximum limit of total addition of performance improver such as fly ash, Granulated slag, Silica fume, Lime stone, rice husk ash, Metakaolin is 5 % during the manufacturing process of ordinary Portland cement as per IS 269- 2013[10]. The decrease in the early compressive strength of ground granulated blast furnace slag is compensated by Metakaolin[1]. These efforts included the utilisation of supplementary cementations materials such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin as alternative binders to Portland cement[8].

Naturally available Si-Al minerals, low calcium fly ash, metakaolin and combination of GGBS and metakaolin have been studied as source materials[14]. V. Kannan and K. Ganesan has investigated on Chloride and chemical resistance of self compacting concrete containing rice husk ash and Metakaolin[11]. Cement can be partially replaced by a number of mineral admixtures such as fly ash, silica fume, metakaoline etc., which have certain properties related to that of cement. By adding the Nano materials, concrete composites with superior properties can be produced[15]. Some of the commonly used SCM are fly ash, silica fume (SF), GGBS, rice husk ash and metakaolin (MK), etc.

Metakaolin is obtained by the calcination of kaolinite. It is being used very commonly as pozzolanic material and has exhibited considerable influence in enhancing the mechanical and durability properties of concrete[12]. The high performance of concrete can be achieved by replacing partially of cement with mineral admixtures like Metakaolin (MK), Ground Granulated Blast Furnace Slag (GGBS). By using these mineral admixtures leads to lowering the global warming[18]. Usage of high reactive Metakaolin and Flyash, as an admixture and mix design was prepared with 29% of coarse aggregate, replacement of cement with Metakaolin and class F flyash, combinations of both and controlled SCC mix with 0.36 water/cementitious ratio (by weight) and 388 litre/m3 of cement paste volume[16]. Crushed granite stones of size 16 mm and 12.5 mm used with a blending 60:40 by percentage weight of total coarse aggregate[19]. Among these coal fly-ash, blast furnace slag, rice hull ash, silica fume, or metakaolin are the most common ones[17]. Bentonite is a form of metakaolin clay (i.e. clay that has gone through heat process to be in its powder form) that consists of a primary mineral called montmorillonite which gives it properties[13]

Objective

The aim of this paper is to study the variations in strength-durability characteristics of high strength concrete mix by partial replacement of cement with different percentages of metakaolin along with super plasticizer.

- To compare the compressive strength and sulphate resistance of control concrete with that of concrete made by replacing cement with metakaolin.

Materials and Their Properties

- **Cement***:* In this experiment Portland pozzolanic cement (PPC) with fly ash and the S_c is 3.15
- **Fine Aggregate:** River sand of size less than 4.75 mm and the S_{fa} is 2.63
- **Coarse Aggregate***:* Crushed aggregate available from nearby quarry sources. Good grading aggregate passing through 20mm IS sieve and retained on 12.5mm.
- **Water:** Potable fresh water has been used for mixing and curing.
- **Super Plasticizer*:*** A high range of water reducing agent **GLENIUM B233** was used. It was used in the range of 700ml per bag.
- **Acid*:*** The acid used in the investigation is H_2SO_4 of 3% concentration.
- **Metakaolin*:*** The mineral admixture metakaolin ($Al_2Si_2O_7$) is used in varying proportions.

Table -1 Physical Properties of Metakaolin

PROPERTY	VALUE
Sp. Gravity	2.6
Physical form	powder
Colour	white

Table -2 CHEMICAL COMPOSITION OF METAKAOLIN

Ingredients	% By Weight
SiO2	51.52
Al2O3	40.18
Fe2O3	1.23
CaO	2
MgO	0.12
K2O	0.53
TiO2	2.27
Na2O	0.08

Table – 3 Mix Ratio Details

Water	Cement	Fine Aggreagte	Coarse Aggregate
185.47	463.5	437.68	1245.7
0.40:	0.1:	0.94:	2.68

Methodology

Determination of Effective Water - Cement Ratio

The effective water – cement ratio for the mix design was determined by conducting slump test. The slump test was conducted by using slump cone apparatus for the design mix ratio with a water- cement ratio of 0.35. The water cement ratio was gradually increased in small proportions until the slump obtained to the optimum range (75-100 mm). Super plasticizer of 14 ml was added for every 1 kg of cement. After successive tests the effective water – cement ratio of 0.38 was adopted.

Mixing Procedure

The Portland pozzolanic cement was replaced at the rate of 5%, 7.5%, 10%, 12.5%, 15% of that of metakaolin. The water to cement ratio of 0.38 was adopted for all the mixes. The super plasticizer of 14ml was added for every 1kg of cement.

Casting and Testing of Test Specimens

The compressive strength test for each mix of 3 concrete cubes of size 150X150X150 mm were casted. The moulds have been removed after 24 hours and the specimens were kept in a clean water tank. The specimens were tested for 28 days' compressive strength test. For acid attack test, for each mix 3 concrete cubes were casted. The moulds were removed after 24 hours and the specimens were kept in water with H_2SO_4 concentration of 3%. The specimens have been tested after a period of 28 days.

Figure .1 Compression testing machine

Figure .2 Concrete cube subjected to sulphate attack

Results and Discussion

For Compressive Strength

The compressive strength of control 5%, 7.5%, 10%, 12.5% and 15% of metakaolin imparted specimens were tested after their specific age of curing. The air dried specimens were tested in Compression Testing Machine (CTM) by the application of compressive loads uniformly on the specimens of dimension150mm x 150mm x 150mm. The obtained failure load in KN is noted and the mean compressive strength of the specimens was taken into consideration for analysis of Compressive Strength.

Mean Compressive Strength

The following table contains the mean compressive strength in MPa obtained from compressive strength of 3 specimens each of control, 5%, 7.5%, 10%, 12.5% and 15% Metakaolin with water-cement ratio of 0.38.

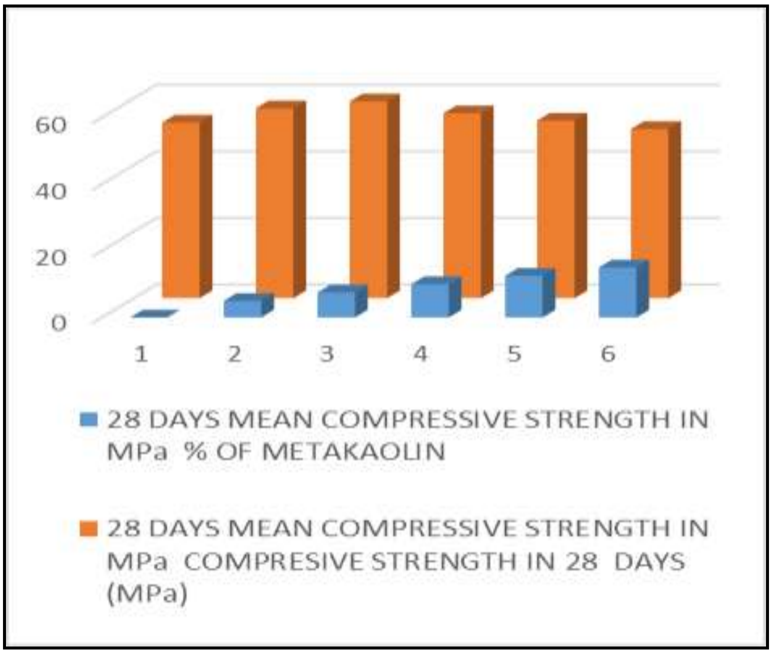

Figure. 3 Graph showing compressive strength with various percentage of metakaolin

The above graphical representation denotes the compressive strength of control specimen as well as specimens with various percentage of Metakaolin. The Compressive Strength of control specimen is 52.70 MPa and for 5% -M, 7.5%-M, 10%-M, 12.5%-M and 15%-M specimens obtained are 56.96, 59.04, 55.48, 53.26 and 50.74 respectively.

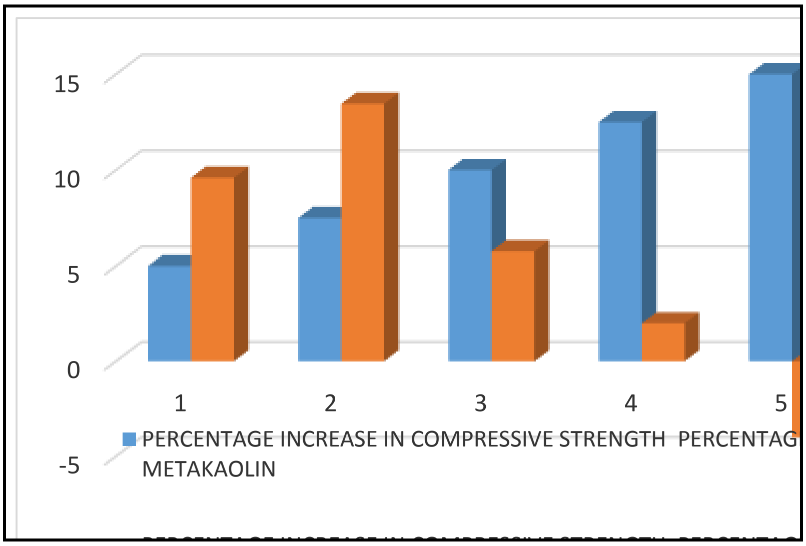

Figure.4 Percentage of compressive strength

Sulphate Attack Test

The compressive strength of control, 5%, 7.5%, 10%, 12.5% and 15% of metakaolin imparted specimens which subjected to sulphate solutions were tested after their specific age of curing. The air dried specimens were tested in Compression Testing Machine (CTM) by the application of compressive loads uniformly on the specimens of dimension 150mm x 150mm x 150mm. The obtained failure load in KN is noted and the mean compressive strength of the specimens was taken into consideration for analysis of Compressive Strength.

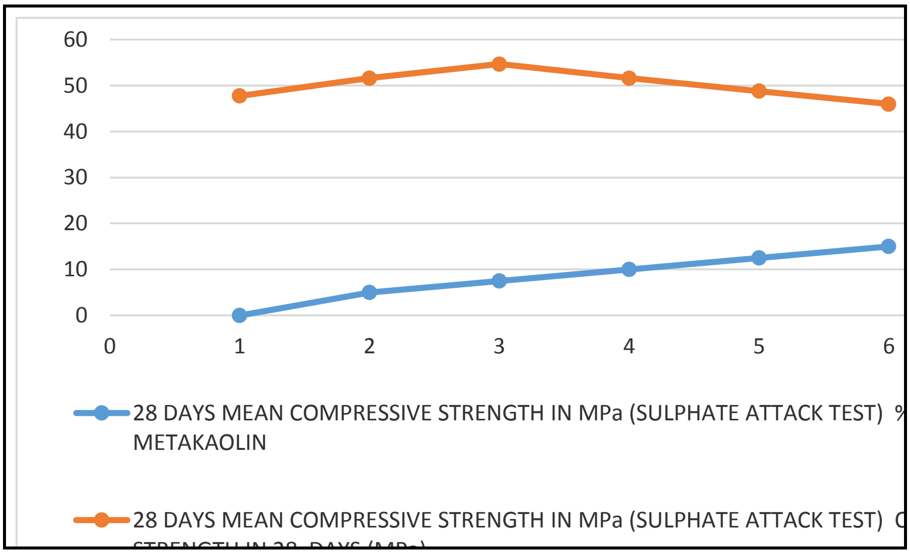

Figure .5 Graph showing compressive strength (sulphate attack) with various percentage of metakaolin

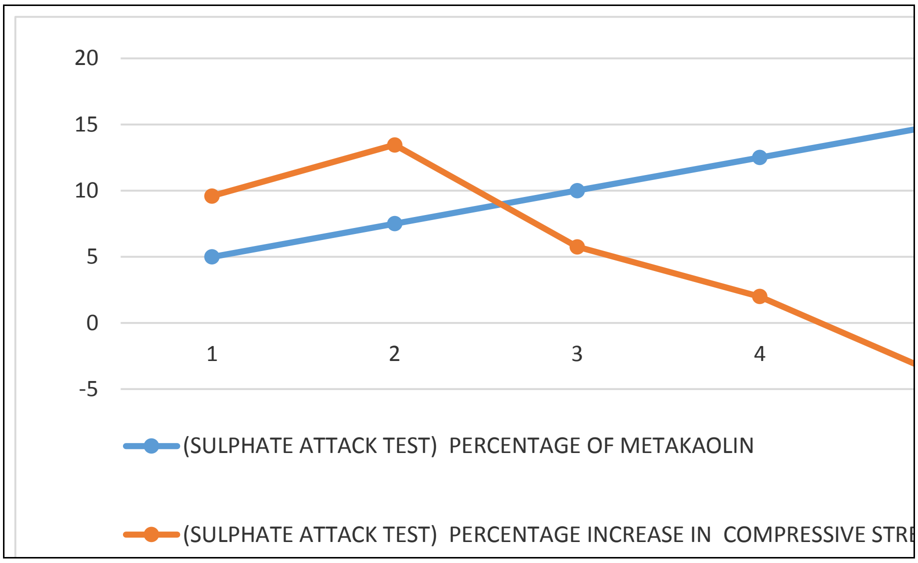

Figure .6 Graph showing percentage of metakaolin Vs increase of compressive strength

Inference and Conclusion

The compressive strength of concrete cubes increases by the addition of metakaolin. It proves better results compared with control concrete. The compressive strength of concrete increases with the increase in metakaolin content to 7.5 % and then there is a slight decline in strength for ratios of 10%, 12.5% and 15%. The maximum strength is obtained in 7.5% of metakaolin. This is the optimum percentage of metakaolin available to react with calcium hydroxide. which accelerates the hydration of cement and forms C-S-H gel. It was also observed that replacement of cement with metakaolin showed better resistance against to sulphate attack. Therefore, the optimum amount of metakaolin can be used as a partial replacement of cement in concrete.

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