STUDY ON M25 AND M30 GRADE CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN

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Abstract- Now a days the partially replacement of Ordinary Portland cement with pozzolana has been increasing widely. Most commonly used pozzolana are fly ash, silica fume, metakaolin, and ground granulated blast furnace slag. A pozzolana is a material which, when combined with calcium, exhibits cementitious properties. Pozzolana are commonly used as an addition to cement concrete mixture to increase the long-term strength and other material properties of cement concrete and in some cases to reduce the material cost of concrete. Recent researched aimed at energy conservation in the cement and concrete-industry has in part, focused on the use of less energy intensive materials such as fly ash, slag and silica fume. Of the some attention has been given to the use of natural pozzolana like Metakaolin as possible partial replacement for cement. Amongst the various methods used to improve the strength, Durability and resisting power of the temperature, and to achieve high performance of the concrete, the use of Metakaolin a relatively new approach, the chief problem with its extreme fineness and high water requirement when mixed with cement.

I. INTRODUCTION

The most common cementitious materials that are used as concrete constituents, in addition to Portland cement, are fly ash, ggbs, silica fume, and Metakaolin .Presently, the use of pozzolanic materials such as Metakaolin (MK) in Portland cement is becoming more common. They save energy, conserve resources and have many technical benefits.

Metakaolin, produced by controlled thermal treatment of kaolin, can also be used as a concrete constituents, since it has pozzolanic properties. Metakaolin is a manufactured pozzolanic mineral admixtures which significantly enhance many performance characteristics of cement based mortars, concrete and related products. The use of pozzolanic materials in the manufacturing of the concrete has a long, successful history. Most pozzolans used in the world today are by products from other industries, such as coal fly ash, blast Furnas slag, rice husk and silica fume .As such there has been relatively little work done with regard to manufactured, optimized and engineered pozzolanic materials which are specially intended for use in Portland cement based formations. The use of Metakaolin and various chemical admixtures have staple in gradients in the production of concrete with designed strength in excess of 7500psi (>50Mpa).

Among the various methods used to improve the durability of concrete against high temperature and achieve high performance of concrete the use metakaolin is relatively new approach. The partial replacement of ordinary Portland cement with pozzolanic materials can be advantageous in increasing the stability against high temperature, mortar or concrete if the proper curing regime is adopted. The due to the fact that the Calcium hydroxide produced by the cement hydration react with pozzolana and produce additional gel which has a pore blocking effect and therefore alters the pore structure and the strength. In addition there is a reduction of calcium Hydroxide (CH) which leads to improved resistance to sulphate attack and alkali-silica reactions.

2. Review of Literature:

AndreaBoddy, *et al*., (2001)

The investigations carried out by the above author revealed that the temperature rise in MK-PC mortars (above 5% MK and up to at least 15% MK) greater than that in equivalent PC mortars (other than at very low MK levels).The increase in heat evolution during initial hours of hydration was resulted from the combined effect of accelerated portland cement hydration and pozzolanic reaction.

Badogiannis *et al*., (2004):

In their investigation, the effect of Metakaolin on concrete, kaolin was thermally treated at defined conditions, and the produced Metakaolin was super fine ground. For comparison, a commercial Metakaolin of high purity was used and the strength development of Metakaolin concrete was evaluated using the K- value (efficiency factor). The produced Metakaolin as well as the commercial one imported similar behavior with respect to the concrete strength.

Bai *et al*., (1999):

Metakaolin has been proved has an effective replacement for the cement. Research work has shown that the incorporation of metakaolin in concrete significantly enhance early strength, it also increase resistance demonstrated by the performance of mortar bars exposed to 5% sodium Sulphate solution But the increase in replacement of Metakaolin results in the increase in the demand of water and thus the workability of concrete reduced.

Brooks *et.al*., (2000):

After studying the effect of silica fume, Metakaolin, fly ash and ground granulated blast furnace slag on setting times of high strength concrete they concluded that there was increase in the retarding effect upto 10% replacement of cement by metakaolin and as the percentage replacement is increased, the retarding effect is reduced.

Chi-Sun Poon *et.al*., (2003):

An experimental investigation was conducted to evaluate the performance of metakaolin (MK) concrete at elevated temperatures up to 800 °C. Eight normal and high strength concrete (HSC) mixes incorporating 0%, 5%, 10% and 20% MK were prepared. The residual compressive strength, chloride-ion penetration, porosity and average pore sizes were measured and compared with silica fume (SF), fly ash (FA) and pure ordinary Portland cement (OPC) concretes. It was found that after an increase in compressive strength at 200 °C, the MK concrete suffered a more severe loss of compressive strength and permeability-related durability than the corresponding SF, FA and OPC concretes at higher temperatures. Explosive spalling was observed in both normal and high strength Metakaolin concretes and the frequency increased with higher Metakaolin contents.

Curcio, (1998):

In their investigation, super-plasticized mortars containing Metakaolin as 15% replacement of cement and with a water/binder ratio of 0.33 have been characterized with four commercially available Metakaolin samples have been studied and compared to silica fume. Three out of four Metakaolin samples showed improvement in compressive strength at early ages, when compared to SF, but at 90 days and later the difference is reduced. The difference in the compressive strength between the specimens with micro fillers and control decreases after 28 days, because of a smaller slowdown of the hydration rate in the control. This can be related to the fineness of the micro-filler in the specimens with Metakaolin. At 90 and 180 days Metakaolin and silica fume specimens gave similar strengths.

David, (2008):

Investigated the effect of using Metakaolin and flyash as partial replacements with cement on the rate of heat evolution during hydration. It was observed that adding flyash to Portland cement enhanced the Portland cement hydration in the very early stages of hydration, but at extended periods an increase in flyash replacement causes a systematic reduction in heat output. When combining Metakaolin and flyash in ternary blending, the Metakaolin has a dominant influence on the heat output versus time profiles.

3. Methodology

In this present experimental work Metakaolin has been used as a admixture in cement. The methodology of the investigation is as follows:

The materials required for the concrete mix were collected from different sources. Then those materials were tested to know all the properties of materials.

The present investigation has been undertaken to compare the M25 & M30 grade of concrete by partial replacement of cement with Metakaolin in different percentages i.e. 0%, 5%, 10%, 20%. The main parameter investigated was comparison of strengths of M25 & M30 grade of concrete.

In this study, M25 & M30 grade of concrete mix was done as per IS: 10262-2009. In this mix design constant water cement ratio of 0.50 with targeted slump of 25-75mm by the replacement of 0%, 5%, 10%, 20% of cement with Metakaolin was maintained.

Based on the design mix the concrete mix is prepared, slump cone test & compaction factor test was conducted on fresh concrete for knowing workability of concrete. The specimens of standard cubes (150mmX150mmX150MM) 9No.s, Standard prisms (100mm x 100mm x 500mm) 3No.s and Standard cylinders of (150mm diameter 300mm height) 3Nos are cast for each cycle.

A total number of 120 specimens were to be casted, out of which specimens to be cured for 7 days, 14 days & 28days.

All the cubes casted will be cured for 7 days, 14days & 28 days with placing an identity mark on each cube for identity in a curing tank. All the cubes after completion of curing period will be tested for its compression strength, Split Tensile strength and Flexural Strength.

4. MATERIALS

4.1. Cement:

Cement is a generic name that can apply to all binders. The chemical composition of the cements can be quite diverse but by far the greatest amount of concrete used today is made with Portland cements. For this reason, the discussion of cement in this thesis is mainly about the Portland cement. Portland cement, the basic ingredient of concrete, is a closely controlled chemical combination of calcium, silicon, aluminum, iron, and small amounts of other ingredients to which gypsum is added in the final grinding process to regulate the setting time of concrete. Lime and silica make about 85% of the mass. Common among the materials used in its manufacture are limestone, shells, silica sand and iron ore. Each step in the manufacturing of Portland cement is checked by frequent chemical and physical tests in plant laboratories. The finished product is also analyzed and tested to ensure that it complies with all specifications. The term 'portland' in Portland is originated in 1824 when an English mason obtained a patent for his product.

4.2. Aggregates:

Aggregates generally occupy 70 to 80% of the volume of concrete and can therefore be expected to have an important influence on its properties. They are granular materials derived for the most part from natural rock and sands. Moreover, synthetic materials such as slag and expanded clay or shale are used to some extent, mostly in light weight concrete. In addition to their use as economical filler, aggregates generally provided concrete with better dimensional stability and wear resistance. Based on their size, aggregates are divided into coarse and fine fractions. The coarse aggregate fraction is that retained on the 4.75mm sieve. While the fine aggregate fraction is that passing the same sieve.

4.2.1. Fine Aggregate:

The locally available river sand was used as fine aggregate in the present investigation .The sand is pre from clayey matter, salts and organic impurities .The sand is tested for its various properties like specific gravity, fineness modulus, bulk density etc in accordance with IS 2386-1963.Fine aggregate passing through 4.75 mm IS sieve and retained on 0.075mm IS sieve was used. It confirms to grading zone-11 of IS 383-1970. The specific gravity and fineness modulus are found to be 2.50 and 2.79.

Fig.4.1: Fine Aggregate

4.2.2. Coarse Aggregate:

Machine crushed angular granite metal of maximum size of 20mm retained on 4.75mm I.S sieve conforming to IS 383-1970 was used in the present investigation .It is free form impurities such as dust, clay particles and organic matter etc. The coarse aggregate is also tested for its various properties.

Fig.4.2: Coarse Aggregate

4.3. Metakaolin:

Metakaolin is a dehydroxylated form of the clay minerals kaolinite. Rocks that are rich in kaolinite are known as china clay are kaolin, traditionally used in the manufacture of porcelain. The particle size of metakaolin is smaller than cement particles, but not as fine as silica fume. Metakaolin (MK) is a pozzolanic material. It is obtained by the calcination of kaolinite clay at a temperature ranging between 500°C and 800°C. The raw material input in the manufacture of metakaolin is kaolin.

Metakaolin enhances the strength and durability of concrete through primary actions which are the filler effect, the acceleration of ordinary Portland cement (OPC) hydration and the pozzolanic reaction with calcium hydroxide (CH). Found that the filler effect is immediate, the acceleration of OPC hydration has its major impact with in the first 24 h and the maximum effect of pozzolanic reaction occurs between 7 and 14 days. It was concluded that the optimum replacement level of OPC by MK to give maximum long term strength is about 20% by weight.

Fig.4.3: Metakaolin

5. TESTS ON MATERIALS

The materials used in the experimental work namely cement, metakaolin, fine aggregate and coarse aggregate (20mm, 10mm) have been tested in laboratory for use in mix designs. The details are presented below.

5.1 Cement:

Ordinary Portland cement of 43 grade- was used in this investigation.

5.1.1. Specific Gravity of Cement:

Specific gravity of the cement is calculated by using Le-Chatlier's flask method or by density bottle method.
Cement specific gravity: 3.15 (Density bottle method)

5.1.2. Fineness Test on Cement:

Fineness test on cement can be calculated by sieve test or air permeability method, in commercial cement it is suggested that there should be about 25 to 30% of particles less than 7 microns in size.
Fineness of test cement**: 92%**

5.1.3. Initial and Final Setting Time Test on Cement:

Initial and final setting test on cement is obtained by Vicat's apparatus, for the initial setting time of the cement Vicat's needle should penetrate to a depth of 33 to 35mm from the top, for final setting time the Vicat's needle should pierce through the paste more than 0.5mm.
We need to calculate the initial and final setting time as per IS: 4031 (part 5) **–** 1988.
Initial setting time of test cement: **90 mins**
Final setting time of cement: 3 hrs 30 mins **(210 mins)**

5.1.4. Standard Consistency Test:

The Standar0d consistency test of cement paste is defined as that consistency which will permit vicat's plunger having the 10mm diameter and 50mm length to penetrate to a

depth of 33 to 35 from the top of the mould. The basic aim is to find out the water content required to produce a cement paste of standard consistency as specified by the IS: 4031 (part 4) **–** 1988.

Standard consistency of test cement: **33%**

5.2. Fine Aggregate:

Aggregates smaller than 4.75mm and up to 0.075mm are considered as fine aggregate. The Details of Test Conducted on Fine Aggregate are described below:

5.2.1. Specific Gravity:

The specific gravity of fine aggregate is **2.6445**

5.2.2. Fineness Modulus:

Fineness modulus = 2.09
Fine-aggregates conformed to: **ZONE-II** as per IS: 383-1970

5.3. Coarse Aggregate:

Fineness modulus = 1.81

5.4. Metakaolin:

Properties of Metakaolin

In the present investigation Metakaolin marketed by specialty Minerals,

Table 5.4.1: properties of Metakaolin

PROPERTIES	RESULTS
Average particle size, µm	1.5
Specific Gravity	2.65
Physical form	Off – White Powder
Bulk Density(Kg/m³)	710 kg/m³

6. Experimental Program

The present work focuses on investigating mechanical properties of M25&M30grade cement concrete with partial replacement of cement by Metakaolin by replacing cement viz. 0%, 5%, 10% and 20%. Cubes, cylinders and prisms are tested for compressive strength, split tensile strength and flexural test. All together three mix designations have been casted and each mix comprises of 6 cubes, 3 prisms, 3cylinders are casted and tested for 7, 14, 28days of curing duration.

7. Results & Discussions

Table-7.1: Compressive Strength of Conventional Concrete and Geopolymer (with addition of Metakaolin) concrete

Age of Specimens (Days)	Compressive Strength (N/mm^2)							
	Conventional Concrete		Geopolymer Concrete (with addition of Metakaolin)					
	M25	M30	M25			M30		
			5%	10%	20%	5%	10%	20%
7	21.86	23.61	23.05	24.5	26	29.59	29.33	30.95
14	29.3	33.33	31.3	33.1	36.2	36.11	35.76	37.24
28	32.83	36.63	35	37	40	41.37	43.68	45.32

Table-7.2: Split Tensile Strength of Conventional Concrete and Geopolymer (with addition of Metakaolin) concrete

Age of Specimens (Days)	Split Tensile Strength (N/mm^2)							
	Conventional Concrete		Geopolymer Concrete (with addition of Metakaolin)					
	M25	M30	M25			M30		
			5%	10%	20%	5%	10%	20%
7	1.6	2.19	1.45	1.82	1.94	1.88	1.97	2.11
14	2.1	2.49	2.4	2.2	2.4	2.35	2.48	2.67
28	2.9	3.2	2.9	3.6	3.8	2.94	2.98	3.15

Table-7.3: Flexural Strength of Conventional Concrete and Geopolymer (with addition of Metakaolin) concrete

Age of Specimens (Days)	Flexural Strength (N/mm^2)							
	Conventional Concrete		Geopolymer Concrete (with addition of Metakaolin)					
	M25	M30	M25			M30		
			5%	10%	20%	5%	10%	20%
7	1.95	1.97	2.2	2.55	2.45	2.1	2.61	2.7
14	2.6	3.1	4.1	3.19	3.5	4	3.72	3.83
28	3.9	4	4.4	4.95	5.1	4.5	4.9	5

8. Conclusions

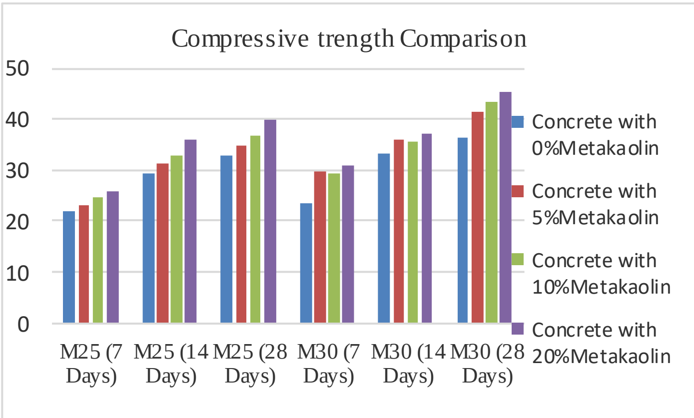

Fig. 8.1: Comparison of Compressive strength of Conventional Concrete and Concrete with Metakaolin

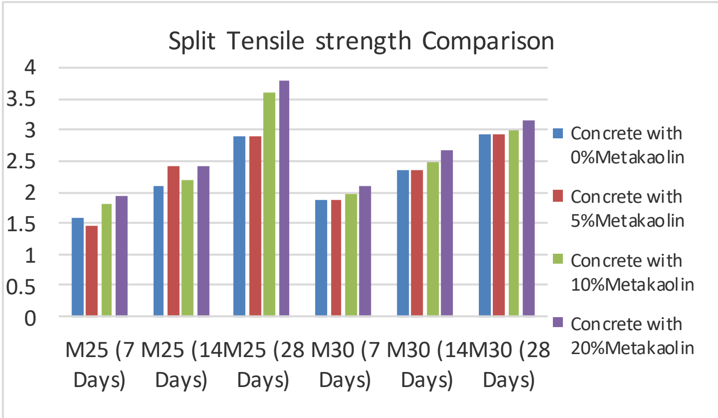

Fig. 8.2: Comparison of Split Tensile strength of Conventional Concrete and Concrete with Metakaolin

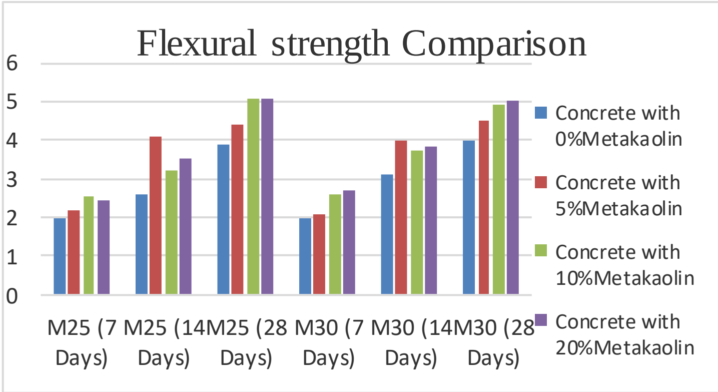

Fig. 8.42: Comparison of Flexural strength of Conventional Concrete and Concrete with Metakaolin

Based on the analysis of experimental results and discussion there upon the following conclusions can be drawn

1. By increasing the grade of Concrete i.e., M25 to M30, strength results are increased.
2. The Compressive strength of concrete increased when cement is replaced by Metakaolin for M25 grade of concrete. At 20% replacement of cement by Metakaolin the concreter attained maximum compressive strength for M25 grade of concrete.
3. The split tensile strength of concrete is increased when cement is replaced with Metakaolin. The split tensile strength is maximum at 20% of replacement.
4. The flexural strength of concrete is also increased when the cement is replaced by Metakaolin. At 20% replacement, the flexural strength is maximum.
5. Compressive strength, Split Tensile strength and flexural Strength of concrete increased more with 20% addition Metakaolin to M30 grade Concrete.
6. After addition of 10% Metakaolin the Split Tensile strength of concrete decreases with grade of concrete. For M30 grade concrete, when compared with M25 grade concrete Split Tensile strength is decreased by 17.22%.
7. After addition of 10% Metakaolin, Flexural strength of concrete decreases with grade of concrete. For M30 grade concrete, when compared with M25 grade concrete compressive strength is decreased by 1.01%.
8. After addition of 20% Metakaolin, Flexural strength of concrete decreased with grade of concrete. For M30 grade concrete, when compared with M25 grade concrete compressive strength is decreased by 1.96%.
9. From experimental results concluded that if we use Metakaolin as a Geopolymer, it can possesses excellent Strength characteristics and durability for aggressive environment compare to conventional concrete.

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