An Experimental Investigation on the Characteristics of Metakaolin in Concrete

Akhil S [1], Praveen S [2],
[1], [2] P.G Scholars,
Department of Civil Engineering,
James College of Engineering & Technology,
Nagercoil, Tamil Nadu, India,

Bhagavathi Pushpa T [3], Jegan J [4]
[3]Associate Professor,
[4] Professor & Head,
Department of Civil Engineering,
University College of Engineering,
Ramanathapuram, Tamil Nadu, India

***Abstract:-* Cement concrete is the most widely used material for various constructions. Properly designed and prepared concrete results in good strength and durability properties. Even such well designed and prepared cement concrete mixes under controlled conditions also have certain limitations because of which the above properties of concrete are found to be inadequate for special situations and for certain special structures. Hence variety of admixtures such as fly ash, Silica fume, rise husk ash and stone dust etc., are used along with cement in certain percentages to enhance the properties of the regular cement concrete. Hence an attempt has been made in the present investigation on replacement of cement with recent new pozzolinic material of Metakaolin up to certain percentages. To attain the setout objectives of the present investigations, the grade of concrete M 20 mix case have been taken as reference concrete. Hardened concrete is tested for strength properties such as Cube Compressive strength, Split Tensile Strength, Modulus of Rupture and Youngs Modulus of Elasticity. The variations of above strengths with variation in different % of Metakaolin have been studied.**

1. INTRODUCTION

High performance concrete has been used in various structures all over the world since last two decades. In Indian high performance concrete is about a decade old with major applications in the construction at nuclear power Plants. Recently a few infrastructure projects have also be specific application of high performance concrete. The development of high performance concrete (HPC) has brought about the essential need for additives, both chemical and mineral to improve the performance of concrete. Most of the developments across world have been supported by continuous improvement of these admixtures.

1.1 Role of SCM's In High Performance Concrete

Supplementary cemetitious materials (SCM's) are a must to produce high performance concrete along with a cost efficient chemical admixture. Metakaolin one of the SCM's which can significantly improve the performance as well as strength of Portland cement based. Metakaolin, also known as high reactive Metakaolin (HRM) is more often used in colour industrial floorings than structural concrete. There are a few applications of Metakaolin concrete for structural application. IS 456-2000 has recommended for use in improving the concrete properties. Metakaolin is obtained by calcinations of pure or refined kaolintic clay at a temperature between 6500c and 8500c, followed by grinding to achieve a fineness of 700 to 900m2/kg. The average particle size of Metakaolin is 1.5µm. Metakaolin, available in our country indigenously, is used for paint industries, but scarcely for concrete applications. If this resource can be tapped for concrete application, the cost of high-performance concrete the cost of high-performance concrete can be brought down significantly.

2. PROPERTIES OF METAKAOLIN CONCRETE

A number of laboratory studies have been conducted to study the behavior of concrete with replacement and addition of Metakaolin to cement in concrete.

2.1 Physical Properties

Table.1 Properties of Metakaolin

Physical Properties of Metakaolin Concrete	
Average particle size, µm	1.5
Residue 325 mesh (%max)	0.5
B.E.T. surface area m2/gm	15
Pozzolan reactivity MgCa (OH)2/gm	1050
Specific gravity	2.5
Bulk density (gm/1lt.)	300+ or -30
Brightness	80+ or -2
Sio2 + Al2O3 +Fe2O3	96.88%
Cao	0.39%
Mgo	0.08%
Tio2	1.35%
Na2o	0.56%
K2o	0.06%
Li2o	Nil
L. I. O.	0.68%

2.2 Pozolanic Reactivity

Metakaolin is a lime – hungry Pozolanic that reacts with free calcium hydroxide to form stable, insoluble, strength – adding, cemetitious compounds. When Metakaolin – HRM (AS2) reacts with calcium hydroxide (CH), a cement hydration by products, a Pozolanic reaction takes place where by new cemetitious compounds, (C2ASH8) and (CSH), are formed. These newly formed compounds will contribute cemetitious strength and enhanced durability properties to them system in place of the otherwise weak and soluble calcium hydroxide.

2.3 Cement Hydration Process

$$OPC + H_2O \rightarrow CSH + CH$$

2.4 Pozzolanic Reaction Process

$$AS_2 + CH + H_2O \rightarrow C_2ASH_8 + CSH$$

Unlike other chemically available Pozzolanic materials Metakaolin is a quality controlled, manufactured material, it is a by-product of unrelated industrial process. Metakaolin has been engineered and optimized to contain a minimum of impurities and to react efficiently with cements hydration by-product calcium hydroxide.

3. MATERIALS USED

3.1 Cement

Ordinary Portland cement of 43 grade cement of RAMCO brand conforming to IS: 8112- 1970 was throughout the work. The specific gravity is 3 and fineness 4.52 %.

3.2 Fine Aggregate

Locally available Natural River Sand confirming to grading Zone – II of table of IS: 383- 1970 has been used as fine aggregate. The specific gravity is 2.7, and fineness modulus is 3.77

3.3 Coarse Aggregate

Machine crushed granite confirming to IS: 383-1970 (23) consisting 20mm maximum size of aggregates have been obtained from the local quarry. It has been tested for specific gravity i.e., 2.73.

3.4 Metakaolin

The Metakaolin is obtained from the Private Company at Vadodara in Gujarat. The specific gravity of Metakaolin is 2.54. The Metakaolin is conformity with the general requirements of pozzolana.

3.5 Super Plasticizer

Conplast p211 is a chloride free water reducing admixture based on selected sugar reduced lignbosulphonats. It is supplied as a brown solution which instantly disperses in water. This produces higher levels of workability for the same water contain. Allowing benefits such as water reduction and increased strengths to be taken to be taken. This specific gravity is 1.18 to 1.19 at 2500c; fluoride content is less than 0.05% by weight.

3.6 Water

Portable water has been used it this experimental program for mixing and curing

4. METHODOLOGY

In the present investigation M_{20} grade concrete has been used. The mix of concrete is designed as per the guidelines of IS 10262[8] ,subsequently mixes were prepared with a partial replacement of cement by Metakaolin at percentages of 7.5, 10, 12.5, 15 and 17.5 for cubes and cylinders and 0, 5, 10, 15, 20, 25 for beams ,by weight of cement water ratio of 0.5 and constant dosage of 200 ml suerplasticizer for 1 bag of cement is used.

Manual mixing is adopted throughout the experimental work. First the materials cement, Metakaolin, fine aggregate and coarse aggregate are weighed exactly, cement and Metakaolin are mixed first. Then to C.A. & F.A., cement Metakaolin mixture is added and thoroughly mixed. A solution is prepared by adding the required dosage of suerplasticizer to about 10% of water required for the concrete mix to be used at the added and mixed well. The balance of water is then added to the concrete in small quantities and uniformly mixed. At this stage, the solution containing suerplasticizer is added to the concrete and is again thoroughly mixed until there is uniform colour.
The beams are cast I the steel molds of size 150 x150x600 mm (internal). First the moulds are, oiled. Later the mixed concrete poured into the moulds and compaction is done by using table vibrator. Similarly cubes (150x150x150mm) and cylinders (fire 150mmdia and 300 long) are also cast. The specimens are demoulded curing is done for a period of 28 days. The cube specimens were tested for compressive strength, the cylinder specimens were tested for Young's Modulus and split tensile strength and the beam specimens were tested for flexural strength.

5. TEST RESULTS AND DISCUSSIONS

5.1 Influence of Metakaolin on Compressive Strength of Concrete

Referring to Table 2 and Fig 1 the compressive strengths of the mix M_{20} ie. Without mixing of Metakaolin are 39.407N/mm^2 for 28 days respectively. In the present investigation the Metakaolin has been used as replacement to cement up to a maximum of 17.5%. When Metakaolin is used as admixture in different percentages the strength is increased .For e.g., with 7.5% replacement of cement by Metakaolin the compressive strength at 28 days is 47.11 N/mm^2 and there is an increase of compression strength by 8.53%. Considering 10% replacement, the compressive strength is 51.259 N/mm^2 there is an increase in compressive strength by 15.3%. With 17.5% replacement, the compressive strength is 42.222 N/mm^2, and the decrease in compressive strength by 2.8%. From this strength it is clear that there is no advantage in using Metakaolin beyond 10%. Hence, 10% Metakaolin can be taken as the optimum dosage, which can be mixed as a partial replacement to cement for giving maximum possible compressive strength at any stage

Table 2 Cube Compressive Strength of Concrete with % of Metakaolin

S. No	% of Metakaolin	7days (N/mm^2)	28days (N/mm^2)
1	0	39.407	43.407
2	7.5	39.407	47.111
3	10	41.185	51.259
4	12.5	39.111	45.63
5	15	38.667	44.148
6	17.5	38.111	42.222

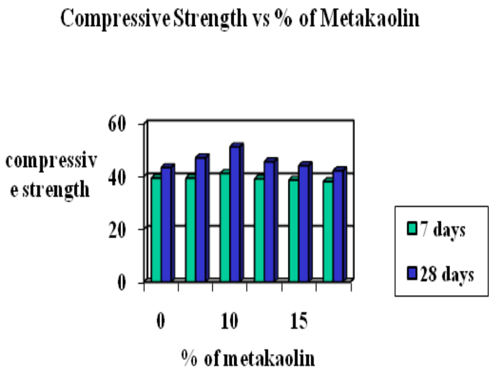

Figure 1 Compressive Strength Vs % of Metakaolin

5.2 *Influence of Metakaolin on Split Tensile Strength of Concrete*

In the case of split tensile strength (Table No 3 and Fig 2) the 28 days value without Metakaolin is 2.971N/mm^2. When 7.5% replacement is used the split tensile strength is 3.16 N/mm^2. There is increase in strength by 6.3%. The split tensile strength at 28 days with 10% replacement is 3.1124 N/mm^2 showing an increase of strength by 27%. With 17.5% replacement the strength for 28 days is 3.1124 N/mm^2. There is increase in strength by about 4.8% only. Hence, it is advisable to use 10% as replacement. Hence the optimum percentage of Metakaolin is again 10% only even in the case of split tensile strength.

Table 3 Split Tensile Strength of Concrete with % of Metakaolin

S. No	% of Metakaolin	7days (N/mm^2)	28days (N/mm^2)
1	0	2.871	2.971
2	7.5	3.065	3.160
3	10	3.208	3.773
4	12.5	3.208	3.348
5	15	2.971	3.490
6	17.5	2.971	3.112

5.3 *Influence of Metakaolin on Modulus Of Rupture of Concrete*

In the case of rupture (Table No 4 and Fig No 3) the 28 days value without Metakaolin is 3.84 N/mm^2. When 5% replacement is used the flexural strength is 4N/mm^2. There is increase in strength by 4.17%. The flexural strength 28 days with 10% replacement is 4.216 N/mm^2 showing an increase of strength by 37.6%. With 15% replacement the strength for 28 days is 3.9N/mm^2. There is increase in strength by about 1.56%. Hence it is advisable to use 10% Metakaolin as replacement. For other percentage there is decrease in strength with respective to 0% of Metakaolin. Hence the optimum percentage of Metakaolin is again 10% only even in the case of flexural strength. At optimum percentage the beam shows the higher stiffness this can be observed in Fig 5.

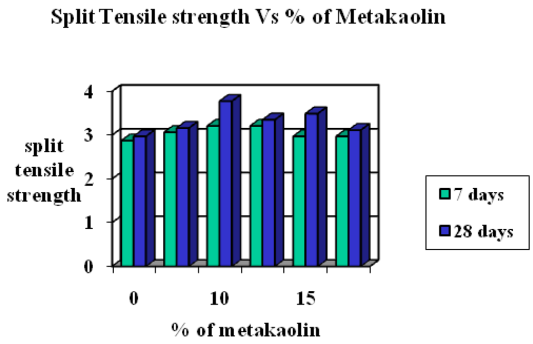

Figure 2 Split Tensile Strength Vs % of Metakaolin

Table 4 Modulus of Rupture with % of Metakaolin

S. No	% of Metakaolin	Flexural Strength (N/mm^2)
1	0	3.84
2	5	4.0
3	10	4.216
4	15	3.9
5	20	3.75
6	25	3.086

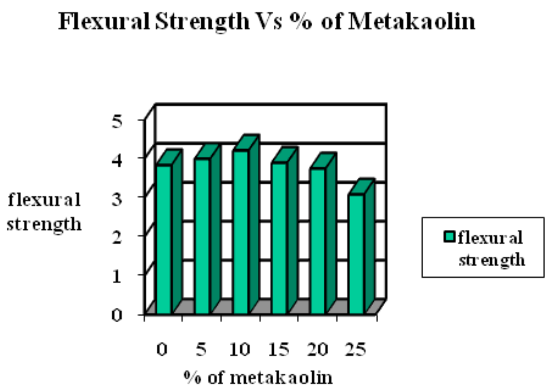

Figure 3 Flexural Strength Vs % of Metakaolin

5.4 *Influence of Metakaolin Percentage on Modulus of Elasticity (E) of Concrete*

In the case of Modulus of Elasticity (Table No 5) the 28 days value without Metakaolin is 28651N/mm^2. When 7.5% replacement is used the Modulus of Elasticity is 30884 N/mm^2. There is increase in strength by 7.79%. The Modulus of Elasticity at 28 days with 10% replacement is 39140N/mm^2 showing an increase of strength by 36.6%. With 17.5% replacement the strength for 28 days is 26992 N/mm^2. There is decrease in strength by about 5.79%. Hence it is advisable to use 10% as replacement. Hence the optimum % allowed Metakaolin is again 10% only even in the case of Modulus of Elasticity. The stress strain curve at 10% replacement of Metakaolin can be seen in Fig.4

Table 5 Modulus of Elasticity of Concrete with % of Metakaolin

S. No	% of Metakaolin	Modulus of Elasticity (N/mm^2)
1	0	28651
2	7.5	30884
3	10	39140
4	12.5	31660
5	15	29425
6	17.5	26992

6. CONCLUSIONS

Based on the present Experimental Investigation, the following conclusions are drawn 10% Metakaolin can be taken as the optimum dosage, which can be by using super plasticizer and mixed as a partial replacement to cement for giving maximum possible compressive strength at any stage. The optimum percentage of Metakaolin is again 10% in the case of Split Tensile Strength, Flexural Strength. The optimum % of Metakaolin is again 10% only in the case of Modulus of Elasticity. Metakaolin addition to concrete leads to decrease in workability which has to be compensated.

REFERENCES

1. A.K. Tiwari & P. Bandyopadyaay Metakaolin for high performance concretes in India. ICI Journal, Vol .4.
2. ASTM C150/C150M-12 Standard Specification for Portland cement.
3. E. Moulin, P. Balnc, D.sorrentino. Influence of key Concrete chemical parameters on the properties of Metakaolin blended cements. Cement & concrete composites 12(2001) P-464- 469.
4. IS 8112-1987 43 Grade OPC Specification.
5. IS 8112-1989 43 Grade OPC Specification.
6. IS 383-1970 Specification for CA & FA.
7. IS 516-1959 Method of Test for Strength of Concrete.
8. IS 5816-1970 Splitting Tensile Strength of Concrete.
9. IS 456-2000 Plain and Reinforced concrete Code of Practice.
10. Jian-Tong Ding and Zongjin Li “Effects of Metakaolin and Silica Fume on Properties of Concrete”.
11. M. S. Morsy, a. M. Rashad and s. S. Shebl, “Effect of Elevated Temperature On Compressive Strength of Blended Cement Mortar”.
12. Mix Design Code Books IS 10262 – 1982.
13. N. Suresh and M. Laxmipathy. Studies on Moungs modulus of Elasticity of plain concrete subjected to sustained elevated temperature. Recent Development in Structural Engg. Published at Roorkee(2001), P:312-318
14. Silica Fume Association: Silica fume manual.38860
15. Sierra Lane, Lovettsville, VA 20180, USA (2005).