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Use of Metakaolin as Pozzolanic Material and Partial Replacement with Cement in Concrete (M30)

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***Abstract*— To achieve sustainability in construction world number of substitutions materials are used. Metakaolin is widely used green pozzolanas. Metakaolin is calcinied clay (koalite). It is obtained from raw material i.e. Kaolin Clay (very fine, white). There is very little emission of carbon dioxide whiles the production of Metakaolin as compared to cement hence it is called as green pozzolanas. The chemical properties of cement were compared with Metakaolin, so that we can replace cement with Metakaolin. In this study partial replacement of cement with Metakaolin at 0%, 3%, 6%, 9% and 12% was done. Mix design was prepared with grade M30 concrete. The compressive strength and split tensile strength of concrete was achieved at 12% addition of Metakaolin. Earlier research also indicate that effect of blended Metakaolin on the properties of cement such as consistency, setting time, soundness remains within the acceptable ranges at different standards. It also solve ecological and environmental problems because cheaper production of Metakaolin and more durable. Therefore this paper provides a scope for more research which is required for green and durable concrete.**
***Keywords*—Metakaolin, M30 grade concrete, compressive strength and split tensile strength analysis.**

I.INTRODUCTION

Concrete can be made with OPC (Ordinary Portland cement) or PPC (Pozzolanas Portland cement).Among the above two, PPC is widely used in the construction world. Concrete is a mixture of cement, fine aggregates (size less the 4.75mm), coarse aggregates (size more than 4.75mm) and water. Production of cement among all other constituents of concrete is harmful for environment because during the manufacturing of cement there is large emission of CO2 i.e. 3%-5%. In this study the main pozzolanas used was Metakaolin. The prefix ‘Meta’ in the term is used to denote change and Kaolin is stone having higher percentage of Kaolinite also known as china clay or kaolin. It was traditionally used in the manufacturing of porcelain i.e. ceramic material.

Metakaolin is written as $Al_2Si_2O_7$ or $Al_2O_3.Si_2O_2$. It is obtained from raw material such that Kaolin Clay (very fine, white and clayey). Metakaolin is also used as an admixture to produce high strength concrete. It is also known as green pozzolanas because during the production of Metakaolin there is very little emission of carbon dioxide. MK is Silica based product that on reaction with Ca(OH)2, produces CSH (secondary calcium silica hydrate) gel at ambient temperature like cement. MK also contains alumina that reacts with CH to produce additional alumina containing C4AH13, C2ASH8 and C3AH6. .Metakaolin is easily available in Gujarat, Maharashtra and Bombay etc. Metakaolin used in this process has following physical properties assured by the merchants:

Size of grains = 1µ to 13µ
Specific gravity = 2.57g/cm2 and
pH = 6.3

In this research work first all 4 cubes, 4 cylinder i.e. 12 for each varying percentage of MK for 7, 14 & 28 days strength calculations with conventional concrete using the quantities as calculated in Table No.19 and Table No.20 were casted. Then the cement was partially replaced with MK by weight. The percentage replacement of MK was varied i.e. 0%, 3%, 6%, 9% and12%. 72 Standard cubic specimens of size 150 mm (four sample for each percentage of Metakaolin were casted for the compressive strength of concrete and 72 standard cylindrical moulds of size 100mm diameter and 200mm height (four sample for each percentage of Metakaolin and marble powder) were casted for split tensile strength of concrete and was kept under curing for 7, 14 days & 28 days of age.

II.LITERATURE REVIEW

Sabir B.B. et.al (2014) described the partial replacement of cement with the Metakaolin in concrete and mortar which cause great improvement in the pore structure and hence resistance of concrete to harmful solutions. This paper also demonstrated clearly that MK is very effective pozzolanas and result in enhanced early strength with no detriment to, and some improvement in the long term strength of mortar and concrete. It greatly improves the resistance to the transportation of water and diffusion ions which lead to degradation of matrix.

Kannan V and Ganesan K. **(2014)** proposed research on the durability properties of self-compacting concrete (SCC) containing rice husk ash (RHA),Metakaolin (MK) and a combination of MK and RHA (1:1 ratio) were evaluated and their relationships were discussed. The durability properties of the various mixtures were studied. The results showed that SCC blended with RHA and a combination of RHA and MK showed a considerable improvement in durability than unblended SCC (100% OPC).

Patil S.N. et.al (2014) deals with the use of Metakaolin which is having good pozzolanic activity and is a good material for the production of high strength concrete. Use of MK is getting popularity because of its positive effect on various properties of concrete. They carried out their tests by replacing 7% to 15% of the cement with Metakaolin and when use of MK is less than 10%, and then the benefits are not fully realized so at least 10% Metakaolin should be used. Values of compressive strength of concrete with Metakaolin after 28 days can be higher by 20%. Dosage higher than 15% of Metakaolin causes decrease of workability. Sai A.V.S.K and Rao K.B. (2014) described partial replacement of cement with quarry dust and Metakaolin which are having silica used as admixture for making concrete. First quarry dust was used as partial replacement of cement and after that Metakaolin was used as replacement. Results were found that quarry dust and Metakaolin usage in partial replacement to cement can be made.

Varma D.V and Rao G.V. (2014) did partial replacement of cement is done to observe the compressive strength of M70 grade concrete. The results conclude that, the use of Metakaolin Concrete (MKC) has improved the performance of concrete under various conditions.

Khatib J.M. et.al (2013) studied the compressive strength, density and ultrasonic pulse velocity of mortar containing high volume of Metakaolin (MK) as partial substitution of cement. In this paper up to 50% of MK was used to replace cement in increment of 10%. After De-molding, specimens were cured in water at 20°C for a total period of 28 days. The density seems to reduce with the increase of MK content especially at MK content above 30%. The strength increases as the MK content increases up to about 40% MK with a maximum strength occurring at 20% where the strength is 47% higher. At 50% the strength start reducing, 10% and the 30% MK mixes exhibit an increase in strength of around 37%.

John N. (2013) investigates the effects of Metakaolin on strength of concrete. The inclusion of Metakaolin results in faster early age strength development of concrete. For all Metakaolin admixed concrete overs the strength of OPC. Mixed with 15% Metakaolin is superior to all other mixes. The increase in Metakaolin content improves the compressive strength, Split Tensile Strength and Flexural Strength up to 15% replacement. Arunakanthi E. et.al (2013) described the effect of chemical environment on High performance concrete with Metakaolin in which Ordinary Portland cement is partially replaced by 20% of Metakaolin by weight and chemical environment is simulated by subjecting the concrete to different concentrations of Magnesium sulphate in de-ionized water during mixing and curing. The results indicate that the compressive strength and split tensile strength decrease with the decrease in concentration of Magnesium sulphate when compared with concrete without Magnesium sulphate in mixing and curing water.

Srivastava V. et.al (2012) did experimental investigations to find the suitability of silica fume and Metakaolin combination in production of concrete. The optimum doses of silica fume and Metakaolin in combination were found to be 6% and 15% (by weight) respectively, when used as part replacement of ordinary Portland cement. The 28 day compressive strength of concrete generally increases with the Metakaolin content up to its optimum content, at all the Silica fume contents, and there after declines. The slump is found to decreases with increase in Metakaolin content at all the Silica fume contents considerably

III.MATERIALS AND METHODOLOGY

A.Materials used

Cement: Ordinary Portland cement of grade 43 is adopted for this work. The brand of cement used was Ultra Tech OPC with grade 43. The cement was gray and free from lumps.

Aggregates: In this research work fine aggregates used was river sand zone II and coarse aggregates used were crushed stones. These materials were easily available from local market.

Metakaolin: Metakaolin from Kaolin techniques Pvt. Ltd, Gujarat, having diameter 1µ to 13µ and obtained at the heating temperature of 750oC and flash calcination was done. As from suppliers it was also assured that the Metakaolin has 2.57g/cm2 specific gravity, pH 6.3, with average particle size 3µ, off white colour with reddish tint and also environment friendly.

Water: Clean tap water was used for washing aggregates, and mixing and curing of concretes.

B.Method Adopted

1. Properties of various constituents of concrete viz, cement, fine aggregates, coarse aggregates and Metakaolin were determined, by carrying out various tests.
2. Grade M30 concrete was designed as per IS: 10262-2009, which was used as reference mix.
3. Metakaolin was partially replaced at 3%, 6%, 9% and 12%.
4. Cube and cylinders for 7, 14 and 28 days testing and four sample for each varying percentage was casted,
5. Total 72 cube and 72 cylinders was casted and curing was done.
6. Compressive strength test and split tensile strength test was done.

IV.EXPERIMENTAL PROGRAMME

A.Concrete Mix Design (M30)

Design Stipulations

(1) Characteristic comp. strength required
In the field at 28 days =30 MPa
(2) Level of quality control Good

Test Data for Materials

(1) Specific Gravity of Cement 3.15

TABLE 1: PROPERTIES OF AGGREGATES

Aggregates	Fine Aggregates	Coarse aggregates
Type	River sand (zone II)	Crushed granite
Maximum nominal size	--------	20mm
Specific gravity	2.65	2.70
Bulk density	1.640	1.657
Fineness modulus	2.839	6.414
Free surface moisture(per cent)	1.5	1.0

TABLE 2: DESIGNED VALUES OF MATERIALS

S.No	Item Name	As per Mix Design (kg/m3)	Per unit
1	Cement	479	1
2	Sand	522	1.08
3	Aggregates	1185	2.47
4	Water	192	0.40
Ratio of M30 Designed Mix = 1:1.08:2.47 with water/binder ratio =0.40			

TABLE 3: MATERIAL REQUIRED IN LABORATORY FOR TESTING OF COMPRESSIVE STRENGTH

S.No	Item Name	For Single Cube(kg)	For Four Cube(kg)
1	Cement	2.31	9.24
2	Sand	2.49	9.96
3	Aggregates	5.71	22.84
4	Water	.924lit	3.696lit

Above table shows the result of mix design i.e. designed mix. Hence the designed mix ha proportions as 1:1.07:2.47.

TABLE 4 MATERIAL REQUIRED IN LABORATORY FOR TESTING OF TENSILE STRENGTH

S.NO	Item Name	For Single Cylinder (kg)	For Four Cylinder(kg)
1	Cement	0.911	3.644
2	Sand	0.9843	3.9372
3	Aggregates	2.25	9
4	Water	.3644	1.4576 Lit

With above calculated data cubes were casted at testing was done at 7, 14 and 28 days for compressive as well as split tensile strength test.

V. RESULTS AND DISCUSSION

A.Compressive strength of concrete can be calculated by cube testing. Compressive strength of concrete also defined by compressive strength of concrete at 28days and is directly related to characteristics strength which further depends upon the grade of concrete.

TABLE 5: PARTIAL REPLACEMENT OF CEMENT BY MK (4 CUBICAL MOULD)

Replacement of MK (%)	0%	3%	6%	9%	12%
Cement (kg)	9.24	8.04	6.99	6.08	5.29
Sand (kg)	9.96	9.96	9.96	9.96	9.96
Coarse aggregate(kg)	22.84	22.84	22.84	22.84	22.84
Metakaolin (kg)	0	0.28	0.46	0.83	1.11
w/c Ratio	0.4	0.40	0.40	0.40	0.40

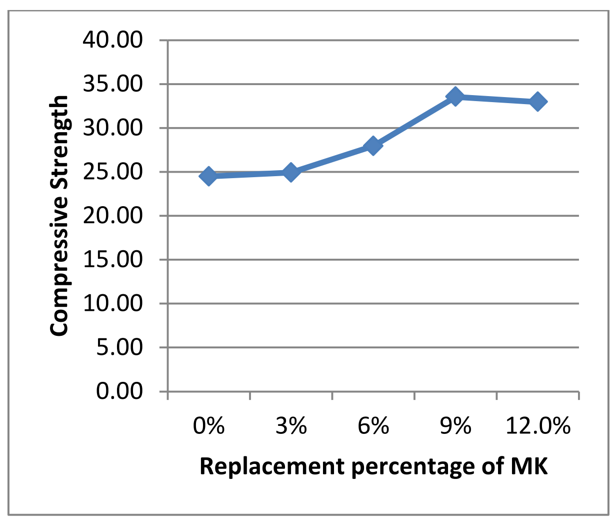

Fig1. 7 Days Compressive Strength Test Results

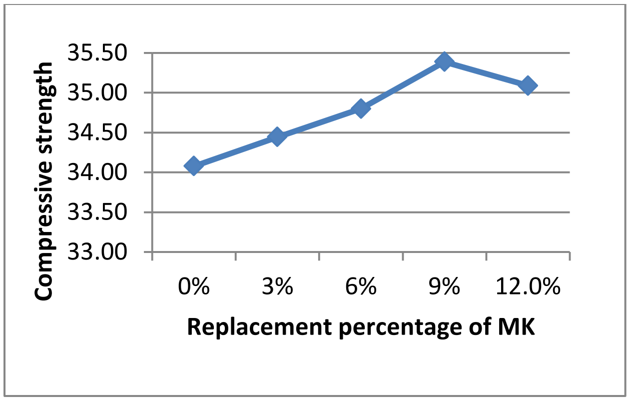

Fig.2 14 Days Compressive Strength Test Results

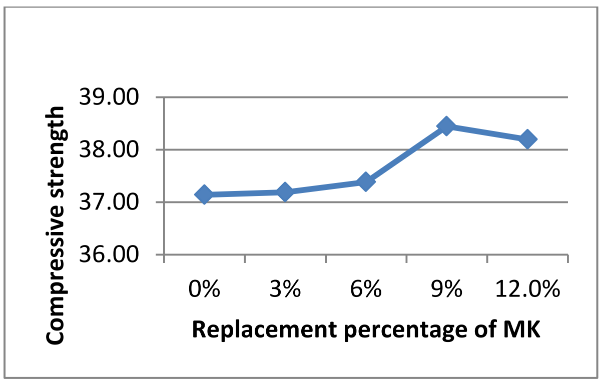

Fig3. 28 days compressive strength test results

In this study 72 cubes were casted and graph was prepared which show that compressive strength increase with the amount of addition of MK till 9% and then decrease was observed. As 7 days, 14 days and 28 days has been conducted to check the gain, in initial strength of concrete, median strength of concrete and final strength of concrete respectively under complete curing.

B.Tensile strength of concrete was analyzed with split tensile strength.

TABLE 6: PARTIAL REPLACEMENT OF CEMENT BY MK(4-CYLINDRICAL MOULD)

Replacement of MK (%)	**0%**	**3%**	**6%**	**9%**	**12%**
Cement (kg)	3.64	3.17	2.76	2.40	2.09
FA (kg)	3.93	3.93	3.93	3.93	3.93
CA(kg)	9	9	9	9	9
Metakaolin (kg)	0	0.109	0.182	0.328	0.437
w/c Ratio	0.4	0.40	0.40	0.40	0.40

Above table give the amount of material needed for cylinder of standard size at different percentage addition of MK in concrete.

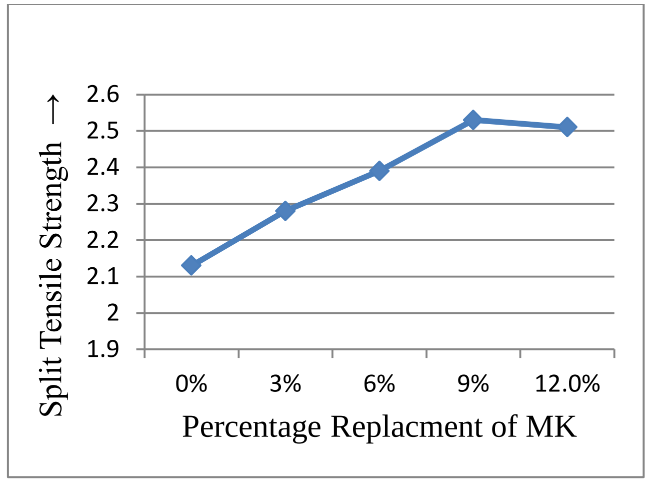

Fig.4 7 Days Split Tensile Strength Test Results

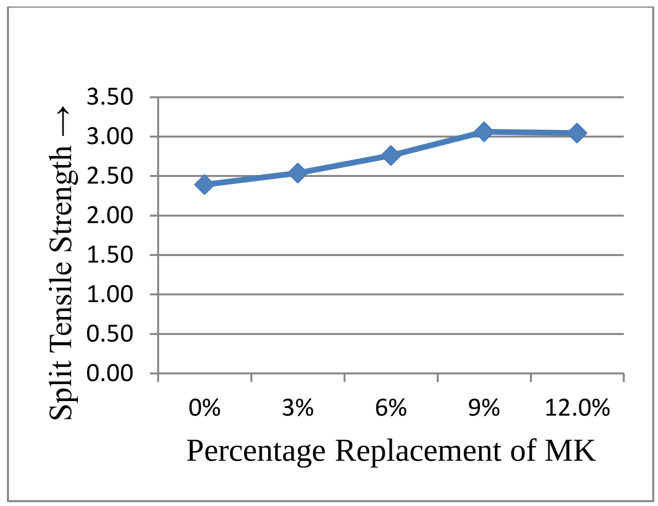

Fig5. 14 Days Split Tensile Strength Test Results

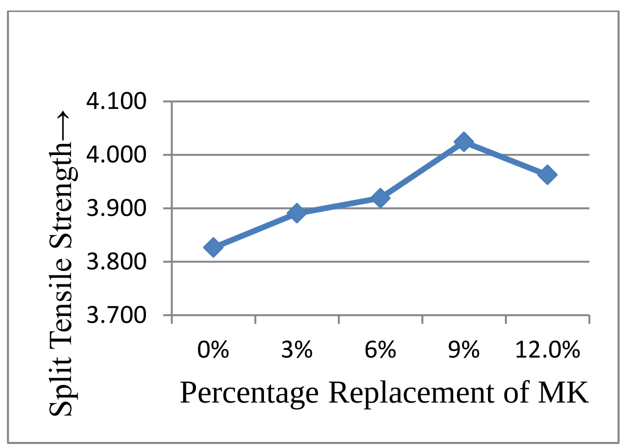

Fig6. 28 Days Split Tensile Strength Test Results

Results show that there was gain in tensile strength with respect to increase in amount of MK. The optimized value is obtained at 9% of MK then there was small continues decrease in strength. There was no use of admixture in this test so there was great saving of money.

VI. CONCLUSION

The replacement of cement with MK up to 9%, give better results from strength prospective. There is regular increase in compressive strength of concrete with increase in partial replacement of MK with cement till 9%, as shown in Fig 1, Fig.2 and Fig. 3. Similarly, increase in split tensile strength of concrete was observed till 9% addition of MK as shown in Fig. 4, Fig.5 and Fig.6 at different interval of ages i.e. 7, 14 and 28 Days respectively. Hence the optimized partial replacement of MK with cement as pozzolanic material was 9% and if the percentage of MK is increased above 9% there was reduction in strength of concrete (compressive as well as split tensile strength) was observed.

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