International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 07, July-2015

Strength and Duriabilty Properties of Concrete with Partial Replacement of Cement with Metakaolin and Marble Dust

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***Abstract* — In this study partial replacement of cement has been done at 0%,3%,5%,9%,12%,13% with MK(Metakaolin) and 0%,10%(constant) with MP (Marble Powder). Compressive as well as tensile strength of concrete made with MK-MP has been compared with conventional concrete of grade M30. Durability of concrete was also analyzed with RCMT(Rapid chloride Migration Test). Result shows that there is a gain of strength with the addition of MK and MP. The optimized strength value of concrete was achieved for both compressive as well as split tensile strength at 9%MK and 10%MP.**

RCMT shows that with the increase of addition of Metakaolin and Marble powder, there is a decrease in rate of penetration of chloride ions, hence good durability as compared to standard concrete

Keywords — Metakaolin; marble dust; strength; duriabilty; RCMT.

I. INTRODUCTION

In construction Industry, consumption of cement is increasing day by day as well as cost is also increasing so to reduce the consumption of cement, partial replacement with Metakaolin and Marble powder was done in this study. Metakaolin is a calcinied clay and easily available in Gujarat, Maharashtra & Bombay etc. It is a Dehydroxylated form of the clay mineral Kaolinite. Stone having higher percentage of Kaolinite are known as china clay or kaolin, was traditionally used in the manufacture of porcelain i.e. ceramic material. The particle size of Metakaolin is smaller than cement particles.

Marble dust is obtained from cutting and manufacturing industries of marble. In India near about 3500 metric tons of marble dust slurry per day is generated. So, Marble dust is very easily available with very less cost. Some of industries used to wash out this marble powder with water in natural streams which cause water pollution and is harmful for our environment.

So, it is advisory to use marble dust as partial replacement with cement as it has properties similar to cement and one of good pozzolanas. Similarly use of MK leads to Green concrete, because during production of MK there is no emission of carbon dioxide, also MK is good admixture for high early age strength, known as HPC etc.

Since there is large emission of carbon dioxide in manufacturing of cement and clinker, results in 3-5% increase in greenhouse gasses and global warming.

II. LITERATURE REVIEW

Abdullah Anwar et.al (2014)[1]: In this paper the authors represented that Marble Dust Powder has replaced the (OPC & PPC) cement of 0%, 5%, 10%, 15% 20%, & 25% by weight & M-20 grade concrete was used. Concrete is M30. mixtures were developed, tested and compared in terms of compressive strength to the conventional concrete. The purpose of the investigation is to analyze the behavior of concrete while replacing the Marble Dust Powder with Different proportions in concrete. The result obtained for 28-day compressive strength confirms that the optimal percentage for replacement of cement with marble dust powder is about 10% for (PPC) and (OPC). This will post less on the production of carbon dioxide and solving the environmental pollution by cement production there by enhances the urban surroundings.

Sanjay N. Patil et,al(2014)[2]: The paper 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. Literature Review shows that optimal performance is achieved by replacing 7% to 15% of the cement with Metakaolin and when use of MK is less than 10% , 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 of 15% of Metakaolin causes decrease of workability. So increasing amount of perceptual proportion of Metakaolin in concrete mix seems to require higher dosage of super plasticizer to ensure longer period of workability.

J.M. Khatib et.al(2012)[3]: In the paper author 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%.

Prof. P.A. Shirule et.al (2012)[4]: The paper described the feasibility of using the marble sludge dust in concrete production as partial replacement of cement. The Compressive strength of Cubes & Split Tensile strength of Cylinders are increased with addition of waste marble powder up to 10% replaced by weight and it was also observed that 10% replacement gave optimum percentage of strength .

B.B.Sabir et.al (2001)[5]: The paper described the partial

replacement of cement with the Metakaolin in concrete and mortar, which causes great improvement in the pore structure and hence resistance of concrete to harmful solutions. The paper also demonstrated clearly that MK is very effective pozzolanas and result enhanced early strength with no detriment to, and some improvement in the long term strength. Mortar and concrete were observed as great improvement in resistance to the transportation of water and diffusion ions which lead to degradation of matrix.

III. EXPERIMENTAL PROGRAMME

A. Concrete Mix Design (M30)

Design Stipulations

(1) Characteristic comp. strength required
In the field at 28 days =38.25 Mpa
Level of quality control Good

(a) 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			

IV. PREPARATION AND CURING OF SPECIMEN

In this research work 72 Standard cubic specimens of size 150 mm (four sample for each percentage of Metakaolin and marble powder) were casted for the compressive strength of concrete and 72 standard cylindrical mould 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, For RCMT, 30 Specimen of 10cm diameter and 20 cm height(4 sample for each percentage of MK-MP) were casted and was kept under curing for 7, 14 days & 28 days of age.

Table 3:Material Analysis

% Replacement of MK →	0%	3%	5%	9%	12.50%	13%
% Replacement of MP→	0%	10%				
Cement (kg)	9.24	8.04	6.99	6.08	5.29	4.61
Sand (kg)	9.96	9.96	9.96	9.96	9.96	9.96
Coarse aggregate(kg)	22.84	22.84	22.84	22.84	22.84	22.84
Metakaolin (kg)	0	0.00277	0.00402	0.00629	0.00761	0.00688
Marble powder (kg)	0	0.92	0.92	0.92	0.92	0.92
w/c Ratio	0.4	0.40	0.40	0.40	0.40	0.40

IV. RESULT AND DISCUSSIONS

A. Strength Analysis: Compressive & Tensile strength:

Compressive and split tensile strength of concrete is tested at different percentage of MK and MP from 0% to 13 % MK and 0% &10% MP (constant). For compressive strength of concrete, 72 cubes was casted with four samples of each percentage variation of MK & MP. The Compressive strength of concrete has been tested at 7 days, 14 days and 28 days of curing for Initial gain in strength of concrete, median gain of strength in concrete and final strength of concrete respectively. Compression testing machine is used for testing the compressive strength of concrete. At the time of testing the cube is taken out from water and dried and then tested keeping the smooth faces in upper position. Similarly, For Split tensile Strength 72 cylinder of 15cm and 20cm height was prepared at different percentage addition of MK&MP at 7,14 and 28 Days of curing. The strength of concrete is very much dependent up on curing i.e. the hydration reaction .The type and amount of cement used in concrete determines the hydration reaction. In this study Ultra Tech OPC 43 grade of concrete is used. The result analysis of compressive strength and split tensile strength with partial replacement of cement by MK & MP is shown in Table 1 for all different percentage of MK-MP at 7,14 and 28 days of curing.

A. COMPRESSIVE STRENGTH TEST :

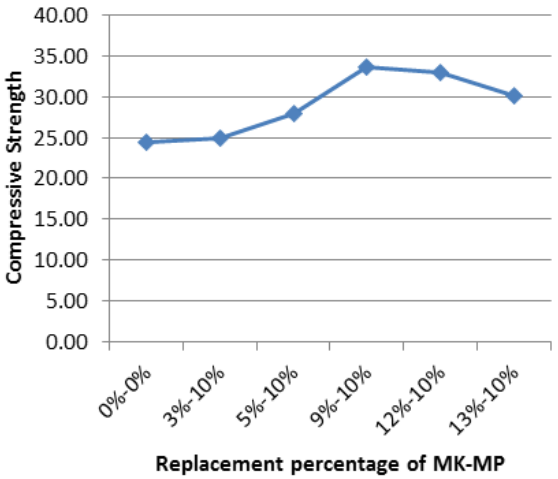

Fig 1: 7-Days compressive strength Analysis

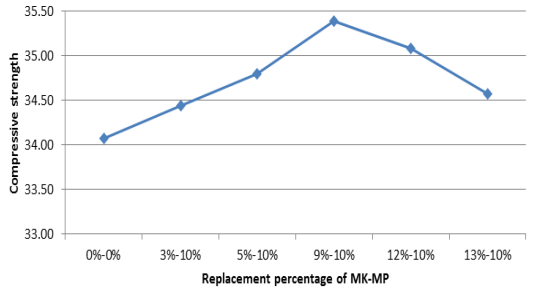

Fig 2 : 14-Days Analysis of Cube

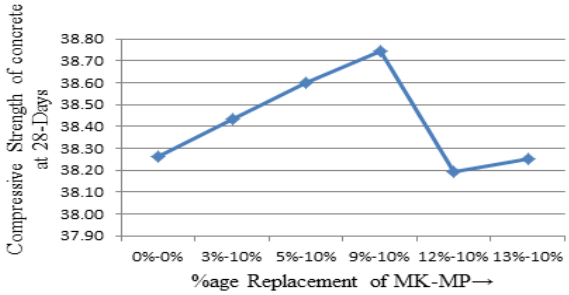

Fig 3: 28 Days analysis of cube

From above results it is cleared that maximum compressive strength is obtained at 9%MK and 10% MP.

B. SPLIT TENSILE STRENGTH:

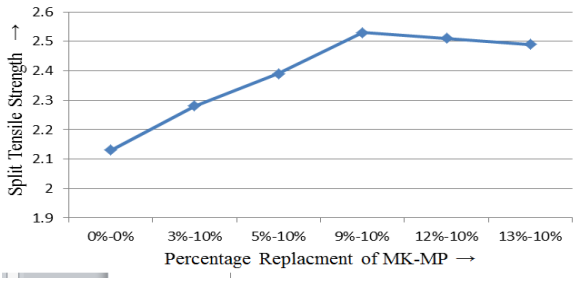

Fig 4: 7-Days Split Tensile Strength of Concrete

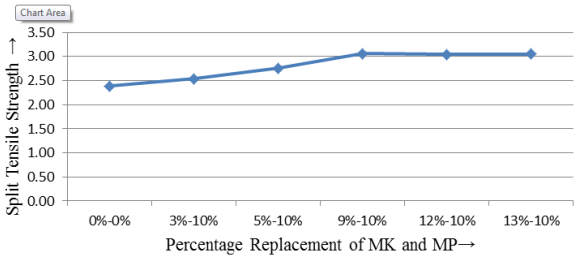

Fig 5: 14-Days Split Tensile Strength

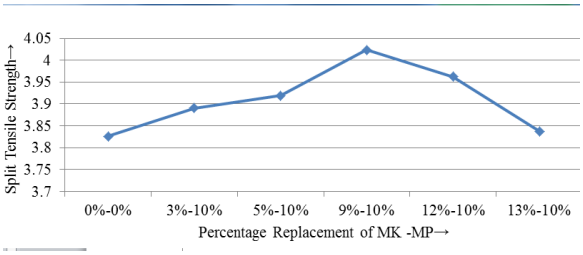

Fig 6: 28-Days Split Tensile Strength of Cylinder

Fig 7 : Testing of specimen

C. Durability Analysis RCMT

Durability of concrete is an important factor for the durability of concrete structures. Now Days, The properties of Metakaolin as high-quality pozzolanic materials are investigated by several researchers. Rapid Chloride Migration Test (RCMT) at 7 and 28 Days was performed on specimen for calculation of chloride ion penetration and kept at 60V of current for 18hrs, In addition, microstructure of the cement pastes incorporating Metakaolin and MP was studied by EDAX tests. The percentages of Metakaolin that replace PC in this research are 0%, 3%,5%,9%,12% and 13% by mass and MP as 0%(standard concrete) and 10 %.

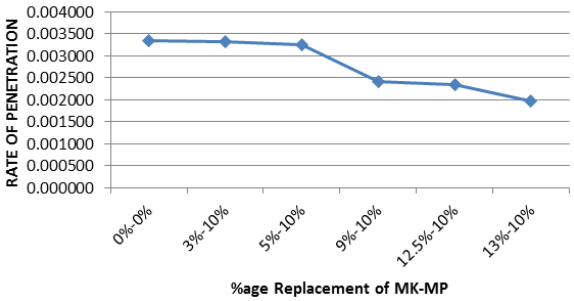

Fig 8 :7-Days Analysis of Rate of Penetration

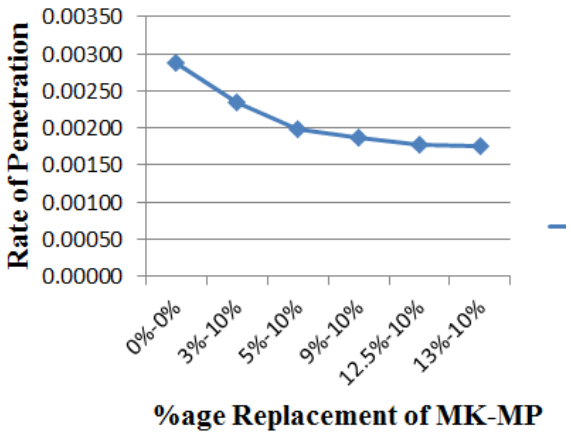

Fig 9 : 28-Days Analysis of Rate of Penetration

Hence from above result we can say durability of concrete goes on increase with addition of MK-MP.

CONCLUSIONS

1. The replacement of cement with 9%MK and 10% MP, give better results better for strength as shown in Fig 3 and Fig 6.
2. If the percentage of MK is increased above 9% keeping the percentage of MP as10%, there is reduction in strength of concrete.
3. The permeability test shows that there is decrease in permeability of concrete with the increase in amount of Metakaolin and Marble powder addition as shown in fig 9.
4. The optimum percentage for replacement of cement with Metakaolin and Marble powder was 9% and 10 % respectively for both cubes and cylinders. After 9%MK & 10% MP, compressive strength as well as split tensile strength starts decreasing.
5. There is decrease in strength after 9% replacement of MK and 10% replacements of MP but durability properties go on increase with increase in percentage of MK-MP.
6. Use of Metakaolin and Marble powder give GREEN CONCRETE.
7. Use of MK and MP save our environment, since during the production of MK and MP there is no emission of carbon dioxide.
8. RCMT results shows that concrete made of addition of MK-MP has very less rate of penetration of chloride ions. Hence Rate of penetration goes on decrease with increase of percentage of MK-MP in concrete as shown in fig 9. So we can say more durable concrete is obtained.

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