IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 21, Issue 4, Ser. II (Jul - Aug 2019), PP 74-83
www.iosrjournals.org

Strength and Durability Properties of Metakaolin with Partial Replacement of Cement

N. Ravi[1], P. Bhavani[2]
[1]*M.tech student Roll no- 17961D8710, Lenora Engineering College, Rampa chodavaram, E.G.Dist, AP, India.*
[2] *Assistant Professor, Department of Civil Engineering, Lenora Engineering College,Rampachodavaram, E.G.Dist, AP, India.*
Corresponding Author: N. Ravi

Abstract: *Metakaolin Is A Relatively New Material In The Concrete Industry Is Effective In Increasing Strength Reducing Sulphate Attack And Improving Air-Void Network. Pozzolanic Reactions Change The Microstructure Of Concrete And Chemistry Of Hydration Products By Consuming The Released Calcium Hydroxide (Ch) And Production Of Additional Calcium Silicate Hydrate (C-S-H) Resulting In An Increased Strength And Reduced Porosity And Therefore Improved Durability. In The Production Of Portland Cement About 1 Ton Of Co2 Is Produced For Every Ton Of Cement. Adding Metakaolin To Portland Cement Will Reduce The Final Amount Of Co2 Developed In Relation To Pure Cementitious Binders. With The Environmental Concerns Developed In Recent Years, More Environmental Friendly Cements Are Produced Adding Ground Slag, Fly Ash Or Other Minerals. Metakaolin Is So Far The Only Product Which Will Reduce The Co2 Output And Accelerate The Setting. Metakaolin (Mk) Is An Amorphous Material Obtained By Heating Kaolin In The Temperature Range 550 And 850 °C. Metakaolin Consists Pozzolanic Properties And Reacts With Calcium Hydroxide Gives A Product Similar To C-S-H, Obtained From Portland Cement. Metakaolin Can Be Used As A Energy Saving Binders In Tropical Or Subtropical Countries Where Kaolin Precursor Is Widely Available.In This Study Mechanical And Durability Properties Were Discussed And Evaluated. All The Strength Properties Were Determined And Compared With The Standards. Metakaolin Acts As A Accelerating Admixture In Promoting Cement Hydration In Concrete. Relatively Finer And Highly Pozzolanic Metakaolin As A Partial Replacement Of Cement Produces Pore Structure Modification, Reduces Porosity And Pore Size Refinement In The Hardening Pastes And Concretes.*

Keywords: *Metakaolin, Pazzolanic, Mechanical Properties, Durability Properties, Admixture.*

Date of Submission: 26-07-2019 Date of Acceptance: 12-08-2019

I. Introduction

1.1 General

The use of High Performance Concrete (HPC) for building construction is increasing day to day. HPC exhibits significant high compressive strength than normal strength concrete. The use of HPC gives an advantage in durability ease of placement, and reduces creep and shrinkage as well as increase compressive, shear, tensile strength. The response of HPC in strengths is differ from normal strength concrete is due to different interaction between the internal phases which is governed not only for the cement paste composition and strength but also by the proposition and the strength of aggregate.

1.2 Metakaolin

Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Metakaolin is a valuable admixture for concrete/cement applications. Rocks that are rich in kaolinite are known as china clay or 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, is a relatively new material in the concrete industry is effective in increasing strength reducing sulphate attack and improving air-void network. Pozzolanic reactions change the microstructure of concrete and chemistry of hydration products by consuming the released Calcium Hydroxide (CH) and production of additional Calcium Silicate Hydrate (C-S-H) resulting in an increased strength and reduced porosity and therefore improved durability.

Table 1.1 Properties of Cement and Metakaolin

Chemical composition	Cement %	Metakaolin %
Silica (SiO_2)	34	54.3
Alumina Al_2O_3	5.5	38.3
Calcium oxide CaO	63	0.39
Ferric oxide (Fe_2O_3)	4.4	4.28
Magnesium oxide (MgO)	1.26	0.08
Potassium oxide (K_2O)	0.48	0.50
Sulphuric anhydride	1.92	0.22
LOI	1.3	0.68
Specific gravity	3.15	2.5
Physical Form	Fine Powder	Powder
Colour	Grey	Off white

1.3 Advantages of Metakaolin Using in Concrete

- Reduced permeability (including chloride permeability)
- Reduced potential for efflorescence**,** which occurs when calcium is transported by water to the surface where it combines with carbon dioxide from the atmosphere to make calcium carbonate, which precipitates on the surface as a white residue
- Increased resistance to chemical attack
- Increased durability
- Reduced effects of Alkali-Silica Reactivity
- Enhanced workability and finishing of concrete
- Reduced shrinkage due to particle packing making concrete denser
- Improved color by lightening the color of concrete making it possible to tint lighter integral color
- High performance, high strength, and lightweight concrete
- Precast and poured mold concrete
- Fiber - cement and ferro cement products

1.4 Scope of the Present Work

The following tests are proposed to be conducted to evaluate the strength and durability properties of Metakaolin in concrete. The test results are compared with equivalent grade control concrete.

The main objectives of the study are:

- To investigate the strength properties of the concrete with Metakaolin
- To fulfill the need of cement in the society and use of alternative resources
- To evaluate the effectiveness of the Metakaolin in the concrete
- To study the durability characteristics of Metakaolin concrete
-

II. Literature Review

2.0 Theory

Several researchers conducted various tests regarding Metakaolin. Following some literatures explained about properties of Metakaolin and its performances in concrete.

Dinkar et al. (2013) investigated MK and cement designed for a low water/binder ratio of 0.3, high strength and high performance concretes can be developed and compressive strengths of more than 100 MPa can be realized. The optimum replacement level of OPC by MK was 10 %, which gave the highest compressive strength in comparison to that of other replacement levels. It was due to the dilution effect of partial cement replacement. These concretes also exhibited a 28-day splitting tensile strength of the order of 5.15 % of their compressive strength and showed relatively high values of modulus of elasticity. Splitting tensile strengths and elastic modulus results have also followed the same trend to that of compressive strength results showing the highest values at 10 % replacement. As far as the durability properties are concerned, local MK found to reduce water permeability, absorption, and chloride permeability as the replacement percentage increases. This may be due to the filler effect of MK particles which has substantially reduced the permeability or porosity of the concrete.

Khatib et al. (2012) carried out Replacing cement with around 20% MK causes a substantial enhancement in compressive strength of mortar. This enhancement in compressive strength can reach a value around 50% compared with the control. Beyond 30% MK the compressive strength starts to reduce. However the maximum value of ultrasonic pulse velocity occurs at around 10% MK.

Nikhil and Ajay Hamane (2015) explained about the Plain concrete is a brittle material and fails suddenly. Addition of Metakaolin and Fly ash to concrete changes its brittle mode of failure into a more ductile one and improves the concrete ductility.The compressive strength and flexural strength of concrete increases with Metakaolin and fly ash content. It is true up to 15% replacement if we replace cement by more than 15% strength starts reducing. Therefore it always preferable to use Meta kaolin & Fly ash with 10% replacement of cement and it gives us better result.

Saravanan et al. (2014) investigated the use of Metakaolin, as pozzolanic material for partial replacement in producing high strength concrete. The increase in Metakaolin content improves the compressive strength and split tensile strength up to 20% cement replacement. 20% cement replacement by Metakaolin is superior to all other mixes. The strength of all Metakaolin concrete mixes over shoot the strength of OPC.

Vijay Shankar and Suji (2014) investigated the optimum percentage (0, 2.5,5,7.5,10,12.5 & 15 %) of Metakaolin as a partial replacement for cement together with partial replacement of natural river sand with quarry dust at (0, 10, 20, 30, & 40), results in the production M40 grade mixes. From the experimental results it is proved that, Quarry Dust can be used as alternative material for the fine aggregate (sand). Metakaolin can be used as one of the alternative material for the cement used for producing HPC. Based on the results the compressive and split tensile strengths are increased by mixing of Metakaolin with Quarry Dust. The compressive strengths are 16%,16% 10%,10%,10% and 10% at the period of 7,14,28 ,56, 90 and 120days and the increase in the split tensile strength is 16% and 12%at the period of 28 & 56 days, by replacing 10% of cement with Metakaolin and 30% of sand with Quarry Dust with 3% Super Plasticizers.

III. Materials

3.1 MATERIALS USED

The following are the materials used in the investigation. Cement (opc 53 grade), metakaolin, fine aggregates, coarse aggregates, super plasticizer.

3.2 MATERIALS PROPERTIES

Materials used for the preparation of concrete in the present investigation are shown below. Ordinary Portland Cement (OPC) of 53 grade was used in this research. Cement was purchased from the same source throughout the investigation. While storing cement, care was taken to avoid contact with moisture.

3.2.1 Cement

OPC of 53 Grade confirming to IS: 12269 - 2004 was used in the investigation. The specific gravity of cement was 3.10. The properties of cement explain below Table 3.1

Table 3.1 Physical characteristics of cement

No.	Properties	Test Method	Test Results	Limitation As per IS 12269-2004
1	**Normal Consistency (in %)**	Vicat Apparatus (IS: 4031Part - 4)	33%	30 -35 %
2	**Specific Gravity**	Sp. Gr. bottle (IS: 4031Part - 4)	3.12	≤ 3.15
3	**Initial Setting Time**	Vicat Apparatus (IS: 4031 Part - 5)	40 Min	>30
4	**Final Setting time**		220 Min	<600
5	**Fineness of cement**	Sieve test on 90μ Sieve (IS: 4031 Part -1)	5.00%	< 10%

3.2.2 Fine Aggregate

Locally available river sand passing through 4.75 mm IS sieve conforming to grading zone-II of IS: 383-1970 was used. The specific gravity of fine aggregate was 2.54.

Table 3.2 Physical characteristics of FA

Sl. No.	Physical Properties	Code of Practice	Results
1	Specific gravity	IS: 2386 Part 2-1963	2.50
2	Fineness modulus	IS: 383-1970	2.81
3	Bulking	IS: 2386 Part 2-1963	10%
4	Bulk density(kg/m3)	IS: 2386 Part 2-1963	1432(Loose), 1600(Rodded)

3.2.3 Coarse Aggregate

Coarse Aggregates with a maximum size of 20 mm from a local source having the specific gravity of 2.7 conforming IS: 383-1970 was used.

Table 3.3 Physical characteristics of CA

Sl. No.	Physical properties	Code of Reference	Results
1	Specific gravity	IS: 2386 Part 3-1986	2.65
2	Water absorption	IS: 2386 Part 3-1986	0.15%
3	Bulk density (kg/m^3)	IS: 2386 Part 3-1986	1366 (Loose) 1439 (Rodded)
4	Finesse Modulus	IS: 2386 Part 2-1963	6.02
5	Impact value	IS: 2386 Part 3-1986	9.76%
6	Loss Angle Abrasion	IS: 2386 Part 3-1986	35.4%
7	Flakiness Index	IS: 2386 Part 3-1986	14.06%
8	Elongation Index	IS: 2386 Part 3-1986	62.4%

3.2.4 Metakaolin

Metakaolin is a relatively new material in the concrete industry and it is effective in increasing strength, reducing sulphate attack and improving air-void network. Pozzolanic reactions change the microstructure of concrete and chemistry of hydration products by consuming the released Calcium Hydroxide (CH) and production of additional Calcium Silicate Hydrate (C-S-H), resulting in an increased strength and reduced porosity and therefore improved durability. All the properties of Metakaolin explained in Table 1.1.

3.2.5 Super Plasticizer

Super Plasticizers to be added to cement concrete at the time of mixing so as to achieve the desired property in concrete, in the plastic or hardened state. Poly-carboxylate Ether Super plasticizer obtained from Chemcon tech SYS was used. It conforms to IS: 9103 – 1999 and its specific gravity was 1.2.

IV. Experimental Investigations

4.1 Introduction

This deals with the details about development of mixes, preparation of test specimens, the various strength and durability studies conducted including its procedures. Trial mixtures were prepared to obtain target strength more than 60 N/mm^2 for the control mixture at 28 days and the w/c ratio for all the mixtures were kept at 0.32 to 0.40. The details of the mixture (MK0, MK5, MK10, MK15 and MK20) were employed to examine the influence of low w/c ratio on concretes containing MK on the mechanical and durability properties. The slump of fresh concrete found as 100 mm – 120mm. The mix proportions for conventional and quantity based partial replacement OPC by Metakaolin presented in Table 4.1

Table 4.1 Details of Mix Proportions

Ingredients	**OPC 0%MK**	**5% MK**	**10% MK**	**15% MK**	**20% MK**
Cement (kg/m^3)	510	485	460	435	410
Metakaolin (kg/m^3)	0	25	50	75	100
Fine Aggregates (kg/m^3)	806	806	806	806	806
Coarse Agg. 20 mm to 4.75mm (kg/m^3)	1122	1122	1122	1122	1122
Super plasticizer (kg/m^3)	3.0	3.25	3.6	3.8	4.0
Slump (mm)	120	110	115	105	100
Water (kg/m^3)	162	162	162	162	162
w/c ratio	0.32	0.33	0.35	0.37	0.40

4.4 Mechanical Properties of Concrete

The test program considered the cast and testing of concrete specimens of cube (150mm) and (150 x150mm). The specimen was cast M60 grade concrete using OPC, Natural River sand and coarse aggregate (20mm to 4.75mm) and Metakaolin. Each three numbers of specimens made to take the average value. The Specimens removed from cube after 24hrs. The specimens were allowed to the curing periods. Tests were conducted to ascertain the strength criteria in concrete are described below in detail.

4.5 Durability

The durability is the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Due to the denser binder matrix and the reduced chemical and physical deterioration the durability of cementitious systems is greatly increased. Depending on the application an engineer must design a concrete of different degrees of durability and properties which depend on the exposure given by the environment, e.g. water salt water etc With metakaolin the durability can be improved to the needed levels to find the suitable durability to extend the life time of a concrete. Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Different concretes require different degrees of durability depending on the exposure environment and properties desired. For example, concrete exposed to tidal seawater will have different requirements than an indoor concrete floor. Concrete ingredients, their proportioning, interactions between them, placing and curing practices, and the service environment determine the ultimate durability and life of concrete. Tests were conducted to ascertain the resistance of developed concrete to sulphate attack, Temperature attack etc.

5.1.1 Compressive Strength

The Compressive Strength compared to control specimen with various percentages of Metakaolin. Compressive Strength results of specimens presented in Table 5.1. The seven day Compressive Strength varied between 45 and 55 N/mm^2. The 28 day strength varied between 61 and 73 N/mm^2. The 20% replacement MK mixture exhibited lower strengths comparatively than the other MK percentages. All the concrete s including the control achieved their target strength of 60 N/mm^2 at 28 days and all the concretes achieved strength of more than 70MPa. Fig. 5.1 presents the relation between Compressive Strength and MK percentages at 7 and 28 days. The highest for the MK15 mixtures achieving strength of 72.7 N/mm^2 at 28 days. This clearly shows the replacement level of 15% was the optimum Compressive Strength is concerned. After 28 days the compressive strength for MK 5% increases in 4.36%, when compared to control specimen. The compressive strength for 10%, 15% and 20% increases in 13.73%, 17.45% and 12.44% respectively. MK 15% increases in higher strength, when compared to all other mixes. But MK 20% decreases in 4.26% from MK 15%. So MK 15% is the best proportion for add in cement.

Table 5.1 Compressive Strength in N/mm^2

Age of test	**0% MK**	**5% MK**	**10% MK**	**15% MK**	**20% MK**
7 days	45.1	50.9	51.9	54.8	51.4
28 days	61.9	64.6	70.4	**72.7**	69.6
Increased	-	4.36%	13.73%	**17.45%**	12.44%

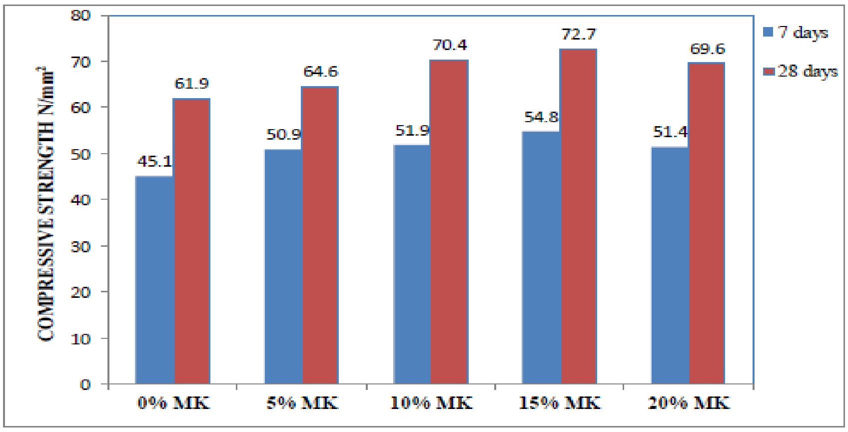


Fig 5.1 Variation of Compressive Strength

5.1.2 Split Tensile Strength

From the results Split Tensile Strength also exhibited the highest strength at MK15 mixture. The Split Tensile strength for MK 5% increases in 8..82%, when compared to control specimen. The Split Tensile strength for MK 10%, 15% and 20% increases in 14.70%, 20.56% and 11.76% respectively. MK 15% increases in higher strength, when compared to all other mixes. But MK 20% decreases in 7.31% from MK15%. So MK 15% is the best proportion for add in cement. The split tensile strength and various mix concrete test values are presents in Table 5.2 and variation of split tensile strength shown in Fig 5.2

Table 5.2 Split Tensile Strength in N/mm^2

Age of test	**0% Metakaolin**	**5% Metakaolin**	**10% Metakaolin**	**15% Metakaolin**	**20% Metakaolin**
28 days	3.4	3.7	3.9	4.1	3.8

Increased	-	8.82%	14.7%	20.56%	11.76%

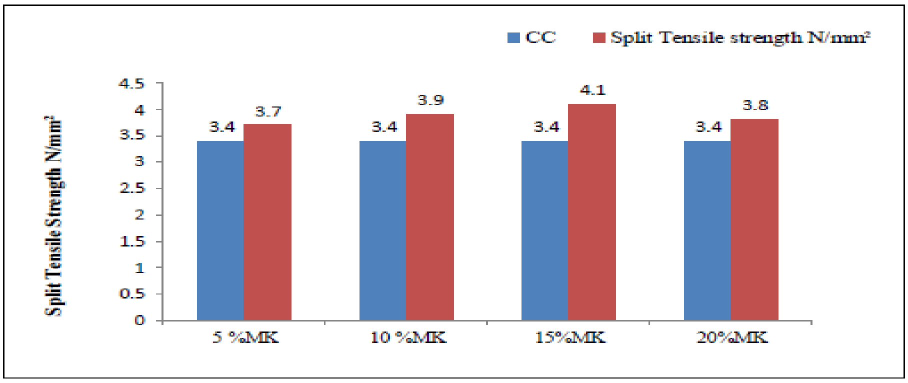


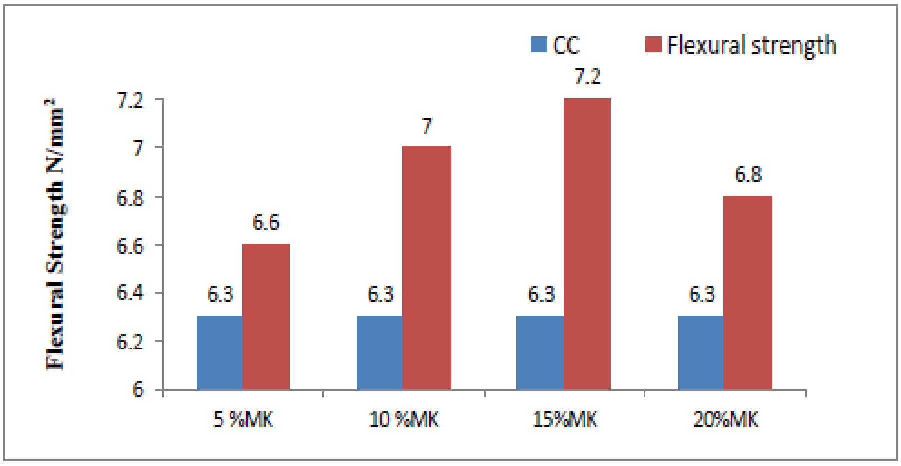
Fig 5.2 Variation of Split Tensile Strength for Metakaolin Concrete

5.1.3 Flexural Strength

The Flexural strength compared to control specimen with various percentages of Metakaolin. When compared to control specimen the Flexural strength for MK5% increases 4.76%. The Flexural strength for MK 10%, 15% and 20% increases 11.11%, 14.28% and 7.94% respectively. MK 15% gave high flexural strength. But 20% of MK decreases in 5.55% from MK15%. So MK 15% is the best proportion for add in cement. The Flexural strength and various mix concrete test values are presents in Table 5.3

Table 5.3 Flexural Strength in N/mm^2

Age of test	0% Metakaoline	5% Metakaoline	10% Metakaoline	15% Metakaoline	20% Metakaoline
28 days Flexural Strength	6.3	6.6	7.0	7.2	6.8
Increased	-	6.6%	11.11%	7.2%	6.8%



5.3 Variation of Flexural Strength to Replacement of Metakaolin in concrete

5.1.4 Water Absorption Test

Water absorption is used to determine the amount of water absorbed under specified condition. Factors affecting water absorption include: type of plastic, additive used, temperature and length of exposure. The data sheds light on the performance of the materials in water or humid environments. In this study, a total no of 6 cubes each for the control and cement replacement levels of 0%, 5%, 10%, 15% and 20% were produced respectively. For the compressive strength, 150mm x 150mm x 150mm cubes mould were used to cast the cubes and 2 specimens were tested for each age in a particular mix (i.e. the cubes were crushed at 7 and 28 days respectively). All freshly cast specimens were left in the moulds for 24 hours before being de-molded and then submerged in water for curing until the time of testing.

Table 5.4 Water Absorption for Metakaolin

MK %	Wet Weight W1 in Kgs	Dry Weight W2 in Kgs	% of Absorption	% of Average
0%	8.50	8.45	0.59	0.47
	8.45	8.41	0.47	
	8.55	8.52	0.35	
5%	8.45	8.40	0.47	0.49
	8.15	8.10	0.49	
	8.25	8.20	0.48	
10%	7.80	7.75	0.50	0.51
	8.65	8.60	0.51	
	8.50	8.44	0.49	
15%	8.75	8.70	0.53	0.54
	8.35	8.30	0.54	
	8.45	8.38	0.55	
20%	7.80	7.75	0.56	0.56
	8.65	8.50	0.55	
	8.50	8.43	0.57	

5.1.5 Sulphate Attack

There is limited information in the literature on the resistance of concrete with MK to sulfuric acid attacks. A 5% sodium sulfate solution was used in which concrete cubes were immersed for a period of 12 months. It was reported that the cubes that contained 10% and 15% MK with a water- binder (w/b) ratio of 0.5 have the maximum expansion of 0.10% and 0.07% after the 12 month immersion period.

By replacing regular Portland cement with different amounts of MK, the tri-calcium aluminate hydrate phase will be diminished in the concrete matrix and aside from that, more CH is consumed by the pozzolanic reaction of MK and more C-S-H will be produced in the hydration phase. Thus, all of these will ultimately result in an enhanced resistance of concrete to the sulfate solution.

Table 5.5 Acid Resistance test for M60 grade concrete

Replacement Level	Normal compressive Strength at 28 days	After Acid attack Compressive Strength in N/mm^2		
		28 Days	56 Days	90 Days
MK 0%	61.9	68.0	66.8	65.0
MK 5%	64.6	69.5	69.0	67.8
MK 10%	70.4	66.2	66.0	65.0
MK 15%	72.7	64.0	63.5	62.0
MK 20%	69.6	62.7	62.0	59.0

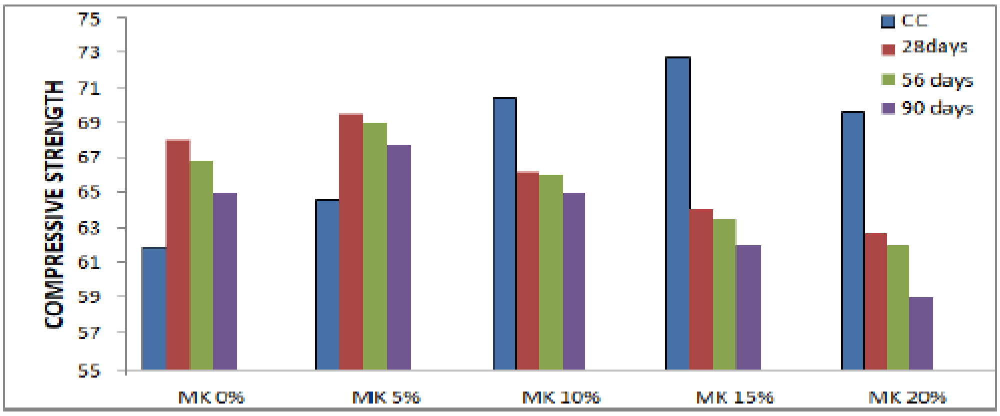


Fig 5.4 Residual Compressive strength After Acid Attack

5.1.6 Influence of Elevated Temperature

The concrete cubes were subjected for elevated temperature of 100°C, 200°C, 300°C and 400°C for one hour, two hours and three hours duration, respectively. Afterwards they were tested under Compression Testing Machine to determine their residual strength at 28 days and 90 days. The residual compressive strength after the test is shown for M60 concrete in below Table 5.6

Table 5.6 Variations of Compressive Strength with Different Temperatures

		Compressive strength in N/mm^2

Replacement Level	**Temperature in ° C**	**1 hour**		**2 hours**		**3 hours**	
		28 Days	**90 Days**	**28 Days**	**90 Days**	**28 Days**	**90 Days**
MK 5 %	100	68.2	73	67	72.25	65	71
	200	67.5	72.5	66	71	63	69.5
	300	66.7	71.7	65	70	60.8	67
	400	65	70	63.8	69	58	65
MK 10 %	100	69.8	75	68	74	66.2	72.5
	200	69	74	67	73	65	71
	300	68	72.7	65.2	72	63	69
	400	67	71	63	70	61.2	67
MK 15 %	100	67.5	72	66	71	64.2	69
	200	67	71	66	69.5	64.2	68
	300	65.5	69.5	64	68	62	66.2
	400	64	68	63	67	61	65
MK 20 %	100	65.5	71	64	70	62	68
	200	65	70	64	69	61.8	67
	300	64	69	62	67.5	60	65
	400	63	67.8	60	65	58	63
CC	100	67	73.5	66	72	64	70
	200	65	72	65	70	62.8	67.5
	300	63.5	71	63	69	60	65
	400	61	69.8	61	67	57	62

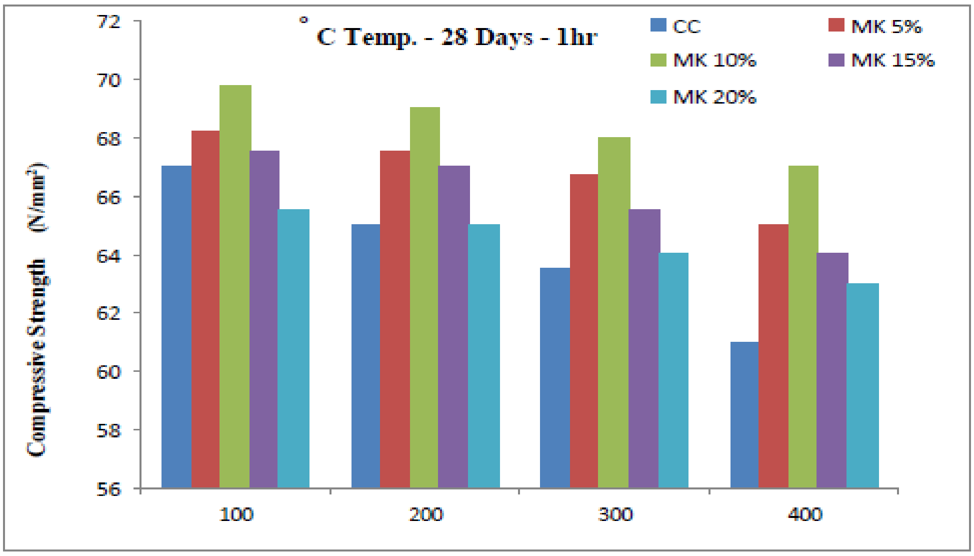


Fig 5.5 Variation of compressive strength after exposing to elevated temperature for 1 hour duration for 28 days

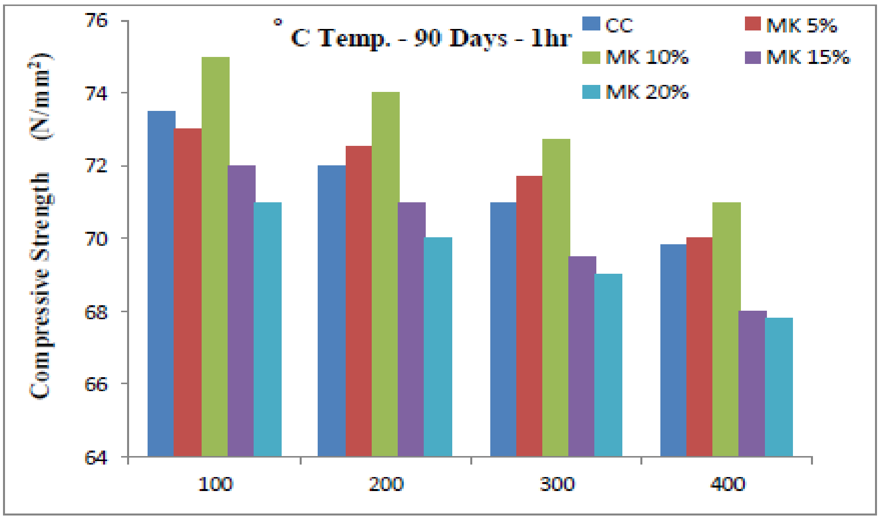


Fig 5.6 Variation of compressive strength after exposing to elevated temperature for 1 hour duration for 90 days

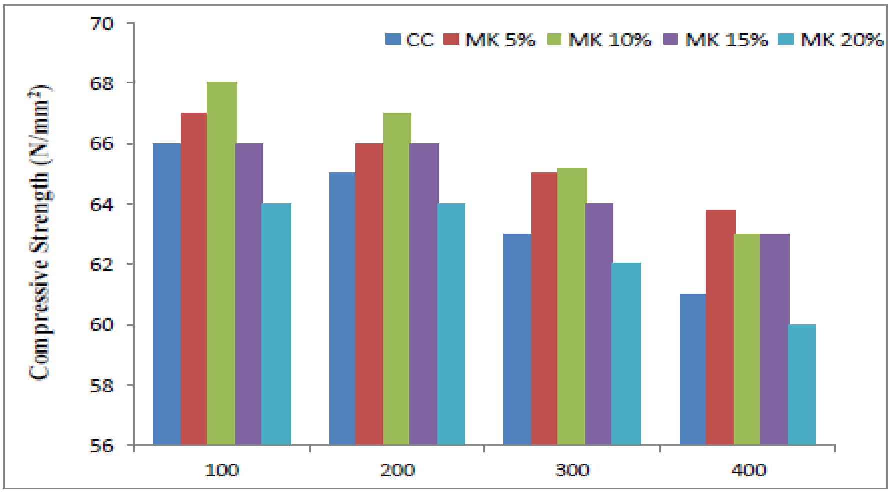


Fig 5.7 Variation of compressive strength after exposing to elevated temperature for 2 hours duration for 28 days

IV. Conclusions

Based on the investigation conducted on the strength and durability characteristics of Metakaolin as the replacement materials blended with high percentage metakaolin with the water demand will be more. Because of the greater fineness of Metakaolin to maintain constant workability, use of plasticizer become necessary. An optimum of 10% to 15% metakaolin gives better strength. The gain in strength of metakaolin concrete with age is normal compared to that of ordinary concrete. Metakaolin helps concrete in having better sulphate resistance.

- Metakaolin can be recommended as useful replacement to enhance the durability of concrete in aggressive environment consisting of sulphates. Cement replacement upto 15% with metakaolin leads to increase in compressive strength, for M60 grade of concrete. From 20% there is a decrease in compressive strength for 7& 28 days curing period. The maximum replacement level of metakaolin ash is 10% to 15% for M60 grade of concrete.
- The optimum replacement level of OPC by MK was 10 % to 15%, which gave the highest compressive strength in comparison to that of other replacement levels; this was due to the dilution effect of partial cement replacement. These concretes also exhibited a 28 days splitting tensile strength of the order of 5.15 % of their compressive strength.
- As far as the durability properties are concerned, local MK found to reduce water permeability, absorption, and chloride permeability as the replacement percentage increases. This may be due to the filler effect of MK particles which has substantially reduced the permeability or porosity of the concrete.
- Consistency of concrete was decreased with the increase in Metakaolin without affecting the compaction of concrete. Metakaolin acts as a accelerating admixture in promoting cement hydration in concrete. Relatively finer and highly pozzolanic metakaolin as a partial replacement of cement produces pore structure modification, reduces porosity and pore size refinement in the hardening pastes and concretes.
- Metakaolin contributes through filler effect and acts as an accelerating admixture to enhance cement hydration at early ages. At later ages, through pozzalanic reactivity Metakaolin contributes to the improvement in the properties of hardened concrete. Partial cement replacement with Metakaolin significantly increases the compressive strength and the degree of strength enhancement increase with the increase of Metakaolin content and w/c ratio. It was general found to reduce with the increase of age.
- Tensile strength and flexural strength of concrete are less improved with the increase of Metakaolin content compared to compressive strength. While chloride permeability, resistance to ASR and sulfate attack is reduced in Metakaolin concrete, the carbonation depth was increased. 10% to 15% of Metakaolin by replacement of cement is sufficient to control ASR related expansion and sulphate attack.

Further Scope

All the basic tests were conducted in Metakaolin with various concrete mixtures. Some other important part of concrete did not touch it.In terms of durability more long term data is necessary to predict how metakaolin-concretes will perform under field conditions.

Resistance to damage from freeze –thaw cycling should be investigated. And also Metakaolin greatly reduced the charge passed in rapid chloride permeability testing, long-term ponding tests may be desirable to fully understand the extent of corrosion resistance that metakaolin can offer.

Sulphate testing should continue until mortar bars have expanded beyond the length of the comparator. Additionally the research should be carried out in future, the seismic effects on structural elements using Metakaolin combined with other pozzolanic materials.

References

[1]. Abdul Razak, H & Wong, HS 2005, 'Strength Estimation Model for High Strength Concrete Incorporating Metakaolin and Silicafume', *Cement and Concrete Research*, vol. 35, no. 4, pp. 688 - 695
[2]. Adel Azzawi, A, Ahmed Sultan Ali & Husam Risan, K 2011, 'Behaviour of Ultra High Performance Concrete Structures', *ARPN Journal of Engineering and Applied Sciences*, vol. 6 , no. 5, pp. 95 - 109
[3]. Arunakanthi, E & Sudarsana Rao, H 2013, 'Effects of calcium chloride in mixing and curing water on strength of high performance Metakaolin Concrete', *Indian Journal of Research*, vol. 2, no. 9, pp. 91 - 94
[4]. Beulah, M & Prahallada, MC 2012, 'Effect of Replacement of Cement by Metakaolin on the Properties of HPC subjected to Hydrochloric Acid Attack', *International Journal of Engineering Research and Application*, vol. 2, no. 6, pp. 33 - 38
[5]. Dhinakaran, G , Thilagavathi , S & Venkataramana , J 2012, 'Compressive Strength and Chloride Resistance of Metakaolin concrete', *KSCE Journal of civil Engineering* , vol. 16, no. 7, pp. 1209 - 1217
[6]. Dinkar, P, Pradosh, K, Sahoo & Sriram, G 2013, 'Effect of Metakaolin Content on the Properties of High Strength Concrete', *International Journal of Concrete Structures and Materials*, vol. 7, no. 3, pp. 215 - 223
[7]. Jibing Bai & Albinas Gailius 2010, 'Consistency of Flyash and Metakaolin Concrete', *Journal of Civil Engineering and Management*, vol. 15, no. 2, pp. 131 – 135.
[8]. Kannan, V & Ganesan, A 2012, 'Strength and Water Absorption Properties of Ternary Blended Cement Mortar using Rice Husk Ash and Metakaolin', *Scholarly Journal of Engineering Research*, vol. 1, no. 4, pp. 51 - 59
[9]. Khatib, JM, Negim, EM & Gjonbalaj, E 2012, 'High Volume Matakaolin as Cement Replacement in Mortar', *World Journal of Chemistry*, vol. 7, no. 1, pp. 07 - 10
[10]. Musbau Salau, A & Oseafiana Osemeke, J 2015, 'Effects of Temperature on the Pozzolanic Characteristicks of Metakaolin Concrete', *Physical Science International Journal*, vol. 6, no. 3, pp. 131 - 143
[11]. Muthupriya, P, Subramanian, K & Vishnuram, BG 2011, 'Investigation on Behaviour of High Performance Reinforced Concrete Columns with Metakaolin and Flyash as Admixture', *International Journal of Advanced Engineering Technology*, vol. 2, no. 2, pp. 190 - 202
[12]. Nabil, M & AlAkras 2006, 'Durability of Metakaolin Concrete to Sulphate Attack', *Cement and Concrete Research - Elsevier*, vol. 36, no. 1, pp. 1727 - 1734
[13]. Nikhil, K & Ajay Hamane, A 2015, 'Evaluation of Strength of Plain Cement Concrete with Partial Replacement of Cement by Metakaolin and Fly ash', *International Journal of Scientific Research and Education*, vol. 3, no. 5, pp. 3443 - 3450
[14]. Nova John 2013, 'Strength Properties of Metakaolin Admixed Concrete', *International Journal of Scientific and Research Publications*, vol. 3, no. 6, pp. 01 - 07
[15]. Patil, BB & Kumbhar, PD 2013, 'Strength and Durability Properties of HPC incorporating High Reactivity Metakaolin', *International Journal of Modern Engineering Research*, vol. 2, no. 3, pp. 1099 - 1104
[16]. Saravanan, J, Suguna, K & Raghunath, PN 2014, 'Mechanical Properties for Cement Replacement by Metakaolin Based Cocrete', *International Journal of Engineering and Technical Research*, vol. 2, no. 8, pp. 04 - 08
[17]. Shelorkar Ajay, P & Jadhao Pradip, D 2013, 'Strength Appraisal of High Grade Concrete by using High Reactive Metakaolin', *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 2, no. 3, pp. 657 - 663
[18]. Shriram Mahure, H, Mohitkar, V & Ravi, K 2014, 'Effect of Metakaolin On Fresh And Hardened Properties Of Self Compacting Concrete', *International Journal of Civil Engineering and Technology*, vol. 5, no. 2, pp. 137 - 145
[19]. Si-Ahmed, M, Belakrouf, A & Kenai, S 2012, 'Influence of Metakaolin on the Performance of Mortars and Concretes', *International Journal of Civil and Structural and Construction Engineering*, vol. 6, no. 11, pp. 100 - 103
[20]. Srinivasa Rao, P, Sravana, Abdul Rahim, Z & Seshadri Sekhar 2012, 'Durability Studies on Steel Fibre Reinforced Metakaolin Blended Concrete', *AKGEC International Journal of Technology*, vol. 3, no.1, pp. 38 – 43.

N. Ravi. " Strength and Durability Properties of Metakaolin with Partial Replacement of Cement" IOSR Journal of Computer Engineering (IOSR-JCE) 21.4 (2019): 74-83.