Influence of High reactive Metakaolin (HRM) on flexural strength of Concrete in combination with self-curing agents

N.T.Suryawanshi, S.B.Thakare, R.K.Jain, Pedram Saremi

Abstract: The present study is directed to understand contribution of High reactive Meta kaolin in combination with self-curing agents on flexural strength of concrete of higher strength. Earlier studies revealed that ordinary Portland cement can be replaced by HRM and optimum replacement level is 10 %. It was also observed that compressive was found improved at the same replacement level. This optimum replacement level may get vary and mainly depends on the water cent ratio of mix. This study include experimental program to find out compressive strength of concrete of low water cement ratios varies in between 0.32 to 0.42.Result showed that the water cement ratios, it was found that w/c 0.38 provides compressive strength nearly equals to target mean strength and observed declined for other w/c ratios. The concrete produced of low water cement ratios likely to shrink in early days; this is because of insufficient water for hydration process. This is the reason due to which strength obtained for 0.32, 0.34, and 0.36 is not up to the mark. Hence in this research attempt was made to enhance strength of such low water cement ratios by addition of super absorbent polymers like Poly acrylic acid. No external curing is employed. The poly acrylic acid (PAA) is white granular powder has been tried as self -curing agent. It absorbs water, swells and releases water slowly during hydration process. From the experimentation it was observed that due to the addition of PAA, the compressive as well as flexural Strength of such low water cement is get enhanced and is about 90% of strength of control mix (water cured). Study also proposes relation between avg. flexural strength and w/c for different curing conditions with degree of confidence more than 90 %. Hence research promotes internal curing method for high strength concrete for low water cement ratios.

Keywords: High strength concrete, high reactive Meta kaolin, Poly acrylic acid, Flexural strength, super plasticizer etc.

I. INTRODUCTION

High-reactivity Metakaolin (MK) is one of the recently developed supplementary cementing materials for high-performance concrete. It is manufactured by thermal treatment on kaolin clays, the temperature is in between 700-900 ^{0}c.At high temperature crystaliine structure get destroy and Metakolin (MK) will get develop, which is an amorphous alumina silicate. MK phase react with $Ca(OH_2)$ and for secondary calcium silicate hydrate (C-S-H) gel.It would help to improve concrete performance. Previously, researchers have shown a lot of interest in MK as it has been found to possess both pozzolanic and micro filler characteristics (Poon et al. 2001). Use of mathematical modelling was also used successfully for producing self-compacting concrete of higher strength (Dvorkin et al. 2012).However, limited test data are available regarding the performance of the commercially available MK and Indian cements in the case of concrete of higher strength in the country (Basu P.C.2003,Basu et al. 2000, Pal et al. 2001, Patil and Kumbhar 2012). The study include addition of Meta kaolin in variation from 5% to 15% and its effect on strength and durability properties was examined it was estimated that 10 % replacement level was the optimum level in terms of compressive strength. The replacement above 10% levels decreases the strength properties. Indirect tensile strength and elastic modulus values have also found to be improved. (P.Dinkar et. al. 2013). Earlier study showed that w/c below 0.4 possess low permeability hence entry to water by external curing will be limited. It would result in ineffective curing. Water cement between 0.36-0.42 might not provide enough water for hydration process and some additional water required whereas w/c below o.36 might not provide enough space for hydration. (Mindess ,2003;Gaston Espinoza –Hajazin et al.,2012).The use of water-soluble poly vinyl alcohol, poly acrylic as an internal curing agent in concrete mixtures in lower percentages (0.02 to 0.04 percentages) has been found to be water retentive and enhanced compressive strength of Metakaolin based high strength concrete. (Nagesh T. Suryawanshi, 2018)

The objective of this study was to evaluate the effect of high reactive Metakaolin on the strength enhancement of high strength concrete of low water cement ratios varies from 0.32 to 0.38.It also includes to check its properties in bending by addition with poly acrylic acid under air dry curing condition (No water is applied externally) for curing purposeto the journal, rectification is not possible.

II. EXPERIMENTAL INVESTIGATION

It includes production of high strength concrete by partially replacing cement by 10% and it was for all water cement ratios.

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It also consist of addition of self -curing agent, 0.02 % of poly acrylic acid in Metakaolin based high strength concrete of low water cement ratios. The following section describes the types of materials used and procedures adopted.

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MATERIALS: The ordinary Portland cement of 53 grade confirming IS 12269:1987, commercially available Metakaolin supplied by 20 micron ltd. Vadodra, Gujrat. SEM (scanning electron microscopy) test was conducted on the MK and PAA. **Fig. 1a, 1b** and **Fig. 2a, 2b** shows typical shape and crystal size with high magnifying power.

Crushed stone metal of basaltic nature procured and used as coarse aggregate. The maximum size of 20 mm and satisfies I.S. 2386 requirement. Well-graded river sand obtained locally and of maximum size 4.75 mm (confirms I.S. 383) was used as fine aggregate. Laboratory test conducted to find out specific gravities of both type of aggregate. It was observed that specific gravity of the coarse aggregate and fine aggregate are 2.65 and 2.60 respectively. The super plasticizer trade name MYK SAVEMIX SP111 was used to improve workability. Its dose was adjusted from 0 to 1.5 % by the weight of cement to get desired slump in between 50-100 mm.

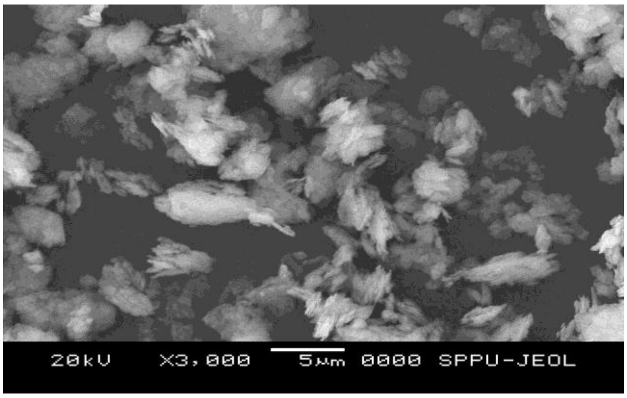

Fig.1a Image of MK (5µm)

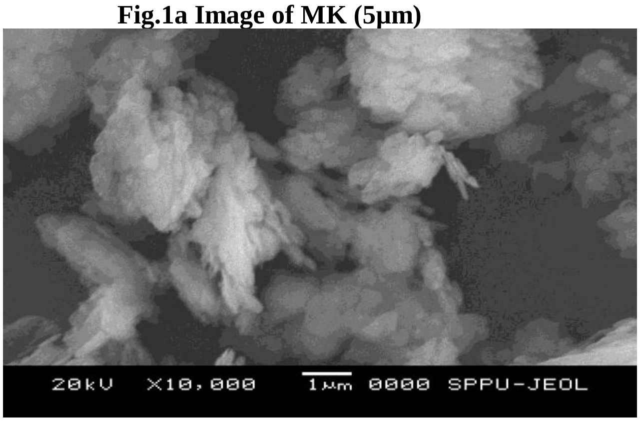

Fig.1b Image of MK (1µm)

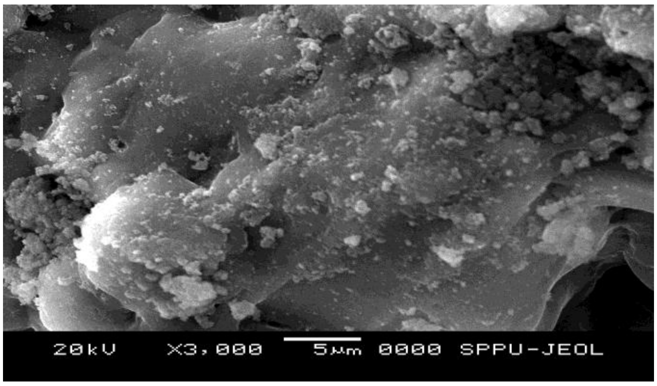

Fig.2a Image of PAA (5µm)

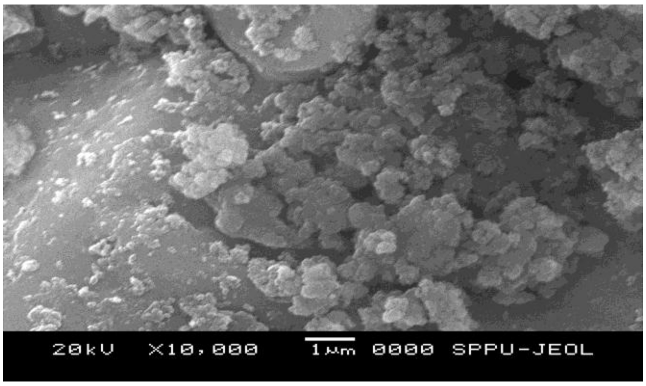

Fig.2b Image of PAA (1µm)

EXPERIMENTAL PROCEDURES

Trial Mix proportions for different water cement ratios were prepared as per IS 10262:2009 to obtain target mean strength of 68.25 N/mm^2 at 28 days. Experimental program conducted in two phases.In first phase five different mixtures of w/c ratios namely 0.32, 0.34, 0.36 and 0.38, 0.4 were employed to examine the influence of high reactive Metakaolin on flexural strength by keeping dose MK constant (10% by the weight of cement).In the second phase to check self-curing possibility and to evaluate effect on flexural strength, PAA was combined with MK for all w/cs.

MIXING AND CASTING DETAILS

All the materials were mixed using a pan mixer. Mixer was fed with materials_in the order of coarse aggregate, cement, MK, sand and PAA in powder form. The materials were mixed dry for 2 minutes. Subsequently three-quarters of the water was added, followed by the Super plasticizer and the remaining water. The mixing was continued for next 5 minute in order to get a homogenous mixture. The specimens were cast from each mixture of size 150 x 150 x150 mm, cubes and of 100 x 100 x 500 mm size beams. All the specimens were cured for three different curing conditions namely Water curing, Self -curing and No curing.

IV . TEST RESULTS AND DISCUSSION

The Cube and Beam specimens were cured for 28 days in different curing conditions and tested under universal testing machine. The results obtained are shown in **Table 1, 2 and 3**.

Table 1 Flexural strength of High strength concrete of low water cement ratios (Water- cured)

WC ratio	Mix Designation	Deflection of beam (mm)	Flexural strength, N/mm^2	Average Flexural strength, N/mm^2
0.4	MK10	0.6	2.62	2.65
	MK10	0.5	2.65	
	MK10	0.5	2..67	
0.38	MK10	0.8	3.55	3.57
	MK10	1.2	3.57	
	MK10	0.7	3.59	
0.36	MK10	0.8	3.42	3.44
	MK10	0.4	3.46	
	MK10	0.7	3.45	
0.34	MK10	1.4	2.98	3.02
	MK10	2.4	3.1	
	MK10	2.2	2.99	
0.32	MK10	0.7	2.43	2.43
	MK10	0.9	2.42	
	MK10	0.8	2.45	

Table 2 Flexural strength of High strength concrete in combination with PA (Self- Cured)

W/C ratio	Mix Designation	Deflection of beam (mm)	Flexural strength, N/mm^2	Average Flexural strength, N/mm^2
0.4	MK10	2.75	5.92	5.89
	MK10	2.67	5.86	
	MK10	2.43	5.89	
0.38	MK10	5.85	7.65	7.64
	MK10	5.28	7.64	
	MK10	5.72	7.63	
0.36	MK10	4.84	7.49	7.51
	MK10	4.45	7.57	
	MK10	4.78	7.48	
0.34	MK10	3.82	7.34	7.37
	MK10	3.91	7.36	
	MK10	4.1	7.42	
0.32	MK10	2.77	6.21	6.24
	MK10	2.93	6.14	
	MK10	2.85	6.37	

Table 3 Flexural strength of High strength concrete in combination with PAA (No Curing)

WC ratio	Mix Designation	Deflection of beam (mm)	Flexural strength, N/mm^2	Average Flexural strength, N/mm^2
0.4	MK10	2.59	5.12	5
	MK10	2.25	4.95	
	MK10	2.47	4..96	
0.38	MK10	4.82	6.72	6.75
	MK10	4.25	6.83	
	MK10	4.15	6.7	
0.36	MK10	3.83	6.67	6.64
	MK10	3.43	6.56	
	MK10	3.77	6.69	
0.34	MK10	2.91	6.2	6.23
	MK10	2.82	6.26	
	MK10	3.24	6.23	
0.32	MK10	2.73	5.45	5.31
	MK10	2.94	5.38	
	MK10	2.65	5.1	

The result shows that flexural strength of water cured mix for w/c 0.38 is higher than all other w/cs. it is about 11.19 % of target mean strength. The strength obtained of self- cured mix is also about 9.89 % of target mean strength. Both strengths are nearly equal and with difference of 1.3 % only. The strength obtained for no curing condition is only 5.23 % of target mean strength. It should not be considerable strength as compared to other curing condition strength. Result also depicted that as w/c goes below 0.38 the strength as well as deflection found to be decreased also strength obtained for w/c beyond 0.42 shows similar trend.**Fig.3** clearly shows the behavior of flexural strength with respect w/c ratio in different curing conditions.

Study proposes the relationship between w/cs for different curing conditions, shown in **Fig. 4** and the Equations proposed are

For water cured condition

$y = -1030.4\,x^2 + 739.71x - 125.01$, With degree of confidence 92% ------------------ (1)

For self-cured condition

$y = -1007.1\,x^2 + 724.64x - 123.55$, With degree of confidence 91% ------------------ (2)

For Non cured condition

$y = -591.07\,x^2 + 43.0.52x - 74.89$, With degree of confidence 91% ------------------ (3)

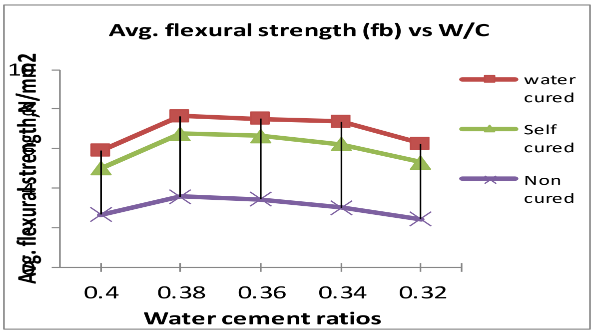

Figure 3 Avg. flexural strength verses w/cs for different curing conditions

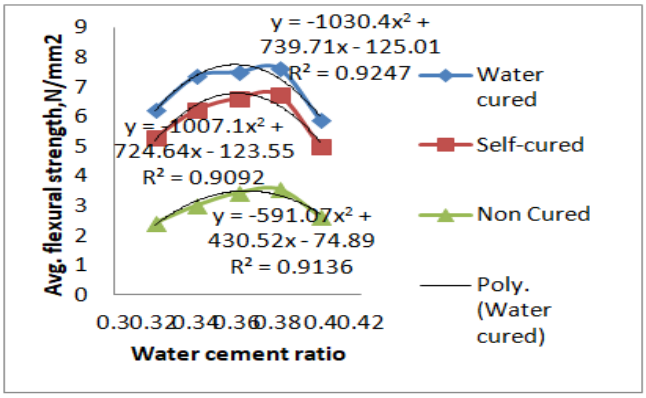

Figure 4 Relationship between Avg. flexural strength and w/cs

IV. CONCLUSION

The following conclusion can be drawn from the current investigation

a) Density (plastic) of cement was decreased by the use of high reactive Metakaolin

b) The concrete of low water cement ratios with optimum 10 % used of MK proved more effective in compressive as well as in flexure.

c) The concrete produced in combination with super absorbent polymers provides considerable flexural strength for all low water cement ratios.

d) Flexural strength obtained for this pozzolana (MK-10 % replacement level) and polymer PAA may not be applicable for the other pozzolanas and polymers.

e) Research proposes the equations that clearly indicate strong relationship between Avg. flexural strength and water cement ratios with degree of confidence more than 90 %.

f) The concrete of low water ratios can be effectively self-cured at room temperature and shows strength enhancement as compared to non- cured mix. Hence study promotes water less curing of high strength mixes.

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Nagesh Suryawanshi is currently an associate professor in the Faculty Engineering. He has about 16 years of experience in teaching field and worked as session chairperson for the national and international conferences He is the subject chairman and worked as member of curriculum design committee of SP Pune university. He is pursuing Ph.D. in civil Engineering from Savitribai Phule Pune University. He received the Master degree in Construction management in 2002.He has presented more than 10 papers in international and national conferences also published papers in peer reviewed journals. His area of interest is advanced construction techniques for sustainability. He has his current research activities include self-curing possibilities of blended concrete and its implementation.

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