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PERFORMANCE OF METAKAOLIN AND SUPER PLASTICIZER IN FIBER-REINFORCED CONCRETE

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Abstract: The fiber reinforced concrete is relatively a new construction material developed through extensive research and development works. The addition of fibers in to concrete has been found to improve several properties like tensile strength, crack resistance, impact strength and wear resistance etc. In this article an approach has been made to study strength properties of FRC with metakoline. The mix adopted was 1:1.63:3.313 by mass and w/c of 0.5 with inclusion of 1% fiber content by volume. The study mainly oriented towards the replacement of cement by metakaolin with different percentages. Also test have been conducted to study the effect of super plasticizer on fiber reinforced metakaolin concrete. From the results it is observed that, the use of super plasticizer improves the compressive, split and flexural strengths and 10% metakaolin mix shown superior performance among different mixes.

Keywords: Compressive strength, Split tensile strength, Flexural strength, Fibers, Metakaolin

I. 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 of nuclear power plants. Recently a few infrastructure projects have also been 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. Supplementary cementitious materials (SCM's) are a must to produce high performance concrete along with a cost efficient chemical admixture. Metakaolin (MK) one of the SCM's, which can significantly improve the performance as well as strength of portland cement based concrete. 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 and 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 650°C and 850°C, followed by grinding to achieve a fineness of 700 to 900 m^2/kg. The average particle size of metakaolin is 1.5μm metakaolin, available in our country indigenously, is used for paint industries, but limited works for concrete applications. If this resource tapped for concrete application, the cost of high-performance concrete can be brought down significantly. Metakaolin is a lime-hungry pozzolan that reacts with free calcium hydroxide to form stable, insoluble, strength-adding, cementitious compounds. When metakaolin-HRM (AS_2) reacts with calcium hydroxide (CM), a cement hydration by products, a pozzolanic reaction takes place whereby new cementitious compounds, (C_2ASH_8) and (CSH), are formed. These newly formed compounds will contribute cementitious strength and enhanced durability properties to the system in place of weak and soluble calcium hydroxide. Unlike other chemically available pozzolanic materials, metakaolin is a quality controlled, manufactured material and 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 calcium hydroxide. From the previous lookup works it is discovered that, partial substitution of cement with MK is discovered to improve the compressive strength of concrete (Wild et al., 1996, 1997, Sabir et al., 2001, Khatib, 2008). However, both MK and silica fume contributes in strength development. MK is surprisingly cheaper than silica fume and may additionally have greater software in high overall performance concrete. Caldarone et al. (1994) confirmed that concrete made with 5%10% MK as partial substitute of CEM 1 had better electricity at a long time up to 365 days than the control and even 10% higher strength than concrete containing silica fume. The energy enhancement is likely to be due to the giant floor place of MK which fills the pores, the acceleration of cement hydration due to giant surface area, and the pozzolanic reaction of MK with calcium hydroxide (Wild et al., 1996). The filler effect is immediate, the acceleration of cement hydration takes region at some stage in the first 24 hours, and the pozzolanic response makes the most extend in strength someplace between 7 and 14 days of age (Wild et al., 1996). The fine contribution made through MK does no longer continue past 14 days, irrespective of the replacement level. This end result used to be now not validated by using other researchers (Ding and Li, 2002). Wild et al. (1997) later showed that the use of MK with larger particular floor area (15 m^2 /g as a substitute of 12 m^2 /g) reduces the age at which most energy enhancement occurs in MK mortars. The maximum compressive strength takes place at around 7 days for the finer MK as antagonistic to 14 days. This shows the have an impact on of fineness on reaction rate. An amplify in the surface place has led to faster response and greater rate of energy evolution. It be noted, however, that the alternate in particle measurement did no longer affect the long-term (e.g., 90 days) strength. However, Ding and Li (2002) discovered that both MK and silica fume had been high quality in growing strength past 14 days. On the different hand, Aboubakar et al. (2013) confirmed that typically the incorporation of calcined kaolin reduces strength and this is partly due to the uncooked materials used which have impurities. Flexural strength (modulus of rupture) research have investigated the have an impact on of MK on modulus of rupture (MOR). Dubey and Banthia (1998) examined the influence of MK on flexural strength of high-performance steel fiber-reinforced concrete. The MOR was determined to make bigger in the presence of MK for concrete with and barring fibers. Dubey and Banthia (1998) located that the overall performance of fiber-reinforced concrete beyond the peak for was once superior when MK was present. In other words, MK incorporation served to expand toughness. Also, there is enhancement in flexural energy with the amplify in MK replacement. The most value of flexural strength was got at 15% MK as cement replacement (Khatib and Hibbert, 2001, 2005). This is incredibly in agreement with the results acquired on the flexural behavior of reinforced concrete containing MK (Khatib and Khalaf, 2007).

From above past research works, it is observed that main intension has been taken place on replacement of cement with MK and results are also encouraged to use as replacement material to cement. But the effect of superplasticizer and low strength steel fibres (black steel wire) along with different %MK replacements, not noticed in previous research works. Hence in this view the experimental program planned to evaluate the effect of superplasticizer and fiber with combination of MK in concern with compressive, split and flexural strengths. For the present experimental investigation the following materials used and for each material few necessary specifications are presented below.

II. MATERIALS USED

Cement: Ordinary portland cement of 43-grade cement of Rajasree brand conforming to IS:8112-1989 was throughout the work. The sp. gr. is 3, and the fineness 4.52%.

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 sp gr is 2.7, and fineness modulus is 3.77.

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

Metakaolin: The metakaolin is obtained from the 20 Microns Limited Company at Vadodara in Gujarat. The specific gravity of metakaolin is 2.54. The metakaolin is in conformity with the general requirements of Pozzolana and properties are presented in Table 1.

Table 1: Physical and Chemical properties of metakaolin

Sl.No	Physical property		Chemical property	
	Parameter	Numerical value	composition	Numerical value (%weight)
1	Average particle size, µm	1.5	Sio_2+ Al_2O_3 + Fe_2O_3	96.88%
2	Residue 325 mesh (% max)	0.5	Cao	0.39%
3	B.E.T. surface area m^2/gm	15	Mgo	0.08%
4	Pozzolan reactivity mgca $(OH)^2$/gm	1050	Tio_2	1.35%
5	Specific gravity	2.5	Na_2o	0.56%
6	Bulk density (gm/1 lt.)	300+ or – 30	K_2O	0.06%
7	Brightness	80+ or – 2	L.I.O	0.68%
8	Physical foam	off-white powder		

Fibers: Black steel wire (in general it may called as binding wire) of 1.0 mm diameter is used for this investigation. Aspect ratio of the fiber is 50. The length of the fiber is to be maintained as 50 mm. The tensile strength of the fiber is 300 Mpa. The fibers are cut to the required length by using shear cutter.

Superplasticizer: Conplast P211 is a chloride free-water reducing admixture based on selected sugar-reduced lignosulphonates. It is supplies as a brown solution which instantly disperses in water. This produces higher levels of workability for the same water content, allowing benefits such as water reduction and increased strengths to be taken.

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The specific gravity is 1.18-1.19 at 25°C chloride content is less than 0.05% by weight.

Water: Portable water has been used in this experimental program for mixing and curing.

III. METHODOLOGY

In the present investigation M20 grade concrete is taken and it is designed as per the guidelines given in IS 10262, subsequently mixes were prepared with a partial replacement of cement by metakaolin (MK) at percentages of 0,5,10,15,20 and 25 by weight of cement. For all mixes water cement ratio of 0.50 and mild steel black wire of 1.0 mm dia with length 50mm is used as fiber. Constant dosage of 200 ml suerplasticizer for 1 bag of cement is used and manual mixing is adopted throughout the experimental work. First the materials cement, metakaolin, fine aggregate, coarse aggregate and fibres are weighed exactly, cement and metakaolin are mixed first. Then to C.A and F.A., cement metakaolin mixture is added and throughly mixed.

Fibers are dispersed uniformly and the whole mix is ultimately mixed well. A solution is prepared by adding the required dosage of superplasticizer to about 10% of water required for the concrete mix to be used at the added and mixed well. The balance of 60% water is then added to the concrete in small quantities and uniformly mixed. At this stage, the solution containing superplasticizer is added to the concrete and is again thoroughly mixed untill there is uniform colour. The beams (30 numbers) are cast in the timber moulds of size 150 x 150 x 750mm. Similarly 30 cubes (150 × 150 × 150 mm) and 30 cylinders (150 mm dia and 300 mm long) are also cast. The specimens are demoulded after 24 hours from moulds and all speciments are under gone to curing for 28 days. The cube specimens were tested for compressive strength, the cylinder specimens were tested for split tensile strength and the beam specimens for flexural strength. The fiber reinforced concrete (wet state) and testing of cube, cylinder and beams can be viewed in figure 1.

Concrete mix with fibre in wet state	Cube testing	Cylinder testing	Beam testing

Fig 1: Wet mix of fiber reinforced concrete and testing of cube, cylinder and beam

IV. TEST RESULTS AND DISCUSSION

The results obtained from the experimental investigation are presenting below along with discussion of results.

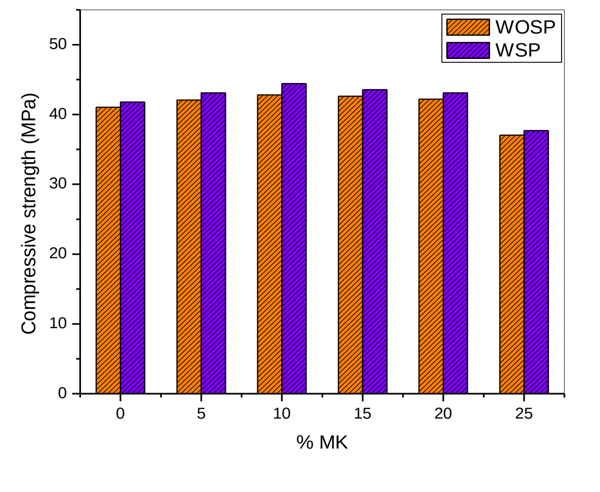
Compressive Strength

The compressive strength of metakaolin fibrous concrete cubes of all is shown in the Table 2 and figure 2. From this it is noticed that, from 0 to 10% of metakaolin the compressive strengths are increasing and later for later percentages it is decreasing. Among all different mixes the mix with 10% shown higher compressive strength of 42.81Mpa and it is 4.34% higher than with 0% metakaolin mix. This type of trend is observed for superplasticizer mix also. The mix 10%MK with super plasticizer shown 6.37 and 3.78% higher than with 0%MK in combination of with and without super plasticizer. From overall strength results it is ascertain that, the superplasticizer mixes shown higher strengths compared with without super plasticizer mixes.

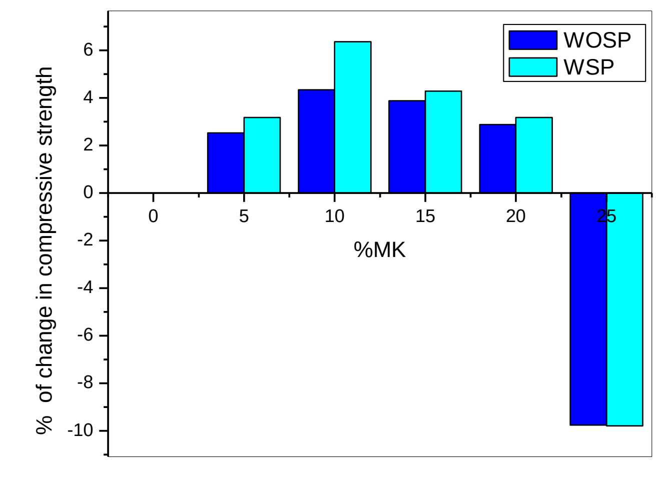
By addition of superplasticizer for different mixes the mixing of ingredients is uniform and also the fibers does not subjected to baling action. Moreover during the casting time the workability is good compared with mixes without super plasticizer, in fact the superplasticizer does not act as strength enhancer, but it improves workability and cohesiveness of mix. This might be the reason for enhance of strengths for super plasticizer mixes than without superplasticizer addition mixes.

Table 2: Compressive Strength

Sl.No	Percentage of Metakaolin (MK)	Compressive Strength (N/mm^2)		% of change in WSP mix compared to WOSP mix
		Without Super plasticizer (WOSP)	With Super plasticizer (WSP)	
1	0	41.03	41.77	1.80
2	5	42.07	43.1	2.45
3	10	42.81	44.43	3.78
4	15	42.62	43.56	2.21
5	20	42.21	43.10	2.11
6	25	37.03	37.68	1.76



Compressive strength vs %MK



% of change in compressive strength with respect 0%MK

Fig 2: Compressive strength

Split Tensile Strength

The split tensile strength results are presented in Table 3, from the results it is noticed that, herein also the trend of compressive strengths is showing for split tensile strengths. Among different MK mixes the mix with 10%MK shown maximum split tensile strength of 4.43MPa and this is 9.93% higher than the 0%MK mix. By comparing the different mixes, the mixes with SP showing higher strengths than the mixes without SP. The mix with 10%MK and with SP shown 4.39% higher strength than reference mix i.e., 0%WSP mix. By comparing the WSP mixes with corresponding WOSP mixes, all are exhibited higher percentages of enhancement in strength and it is ranging from 2.03 to 8.33%. Highest percentage of enhancement is noticed to 15%MK and lesser percentage of strength observed to 10%MK mix. The behavior of split tensile strengths are shown in figure 3.

Table 3: Split tensile strength

Sl.No	Percentage of Metakaolin(MK)	Split tensile Strength (N/mm^2)		% of change in WSP mix compared to WOSP mix
		Without Super plasticizer (WOSP)	With Super plasticizer (WSP)	
1	0	4.03	4.33	7.44
2	5	4.25	4.40	3.53
3	10	4.43	4.52	2.03
4	15	4.08	4.42	8.33
5	20	3.91	4.10	4.86
6	25	3.60	3.70	2.78

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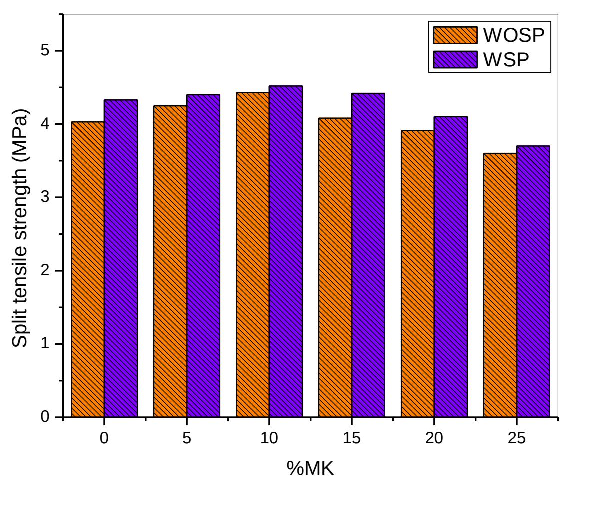
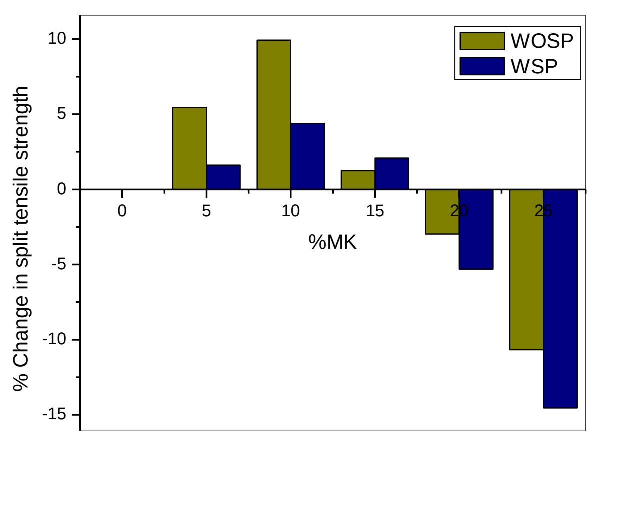


Split tensile strength vs %MK



% of change in split tensile strength with respect 0%MK

Fig 3: Split tensile strength

Flexural Strength

The ultimate flexural strength metakaolin fibrous reinforced concrete beams increases with the increase in the percentage of metakaolin up to 10% and then decreases with the addition of percentage of metakaolin content (Table 4). 10%MK-WOSP mix shown 3.12% higher failure load than 0%MK-WOSP and in similarly line, the 10%MK-WSP mix shown 7.08% higher failure load than 0%MK-WSP.

The results shown that WSP mixes are superior to WOSP mixes for all replacements of MK. Among mixes the WOP mixes showed superior performance than WOSP mixes and the percentage of variation is varied from 0.89 to 6.22 and maximum and minimum variations was noticed to 20%MK and 0%MK mixes. For 10% MK mix the enhancement is noticed as 4.76%.

From compressive, split and failure flexural loads, noticed that the mix with 10%MK shown higher strengths compared with other mixes and it can be consider as optimum replacement to cement. At this stage residual calcium hydroxide can react with MK and forms additional CSH gel, it leads to enhance the strength and addition of superplasticizer to MK mixes gives uniform mix among the ingredients (enhances the workability).

The pictorial representation of flexural strengths and its variations are shown in figure 4.

Table 4: Flexural Strength

Sl.No	Metakaolin %	Flexural Strength (Mpa)		% of change in WSP mix compared to WOSP mix
		Without Superplasticizer (WOSP)	With Superplasticizer (WSP)	
1	0	4.48	4.52	0.89
2	5	4.50	4.75	5.56
3	10	4.62	4.84	4.76
4	15	4.58	4.80	4.80
5	20	4.50	4.78	6.22
6	25	4.36	4.40	0.92

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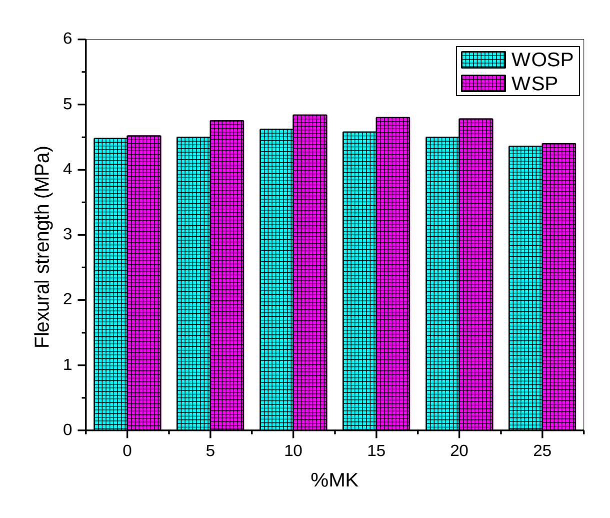

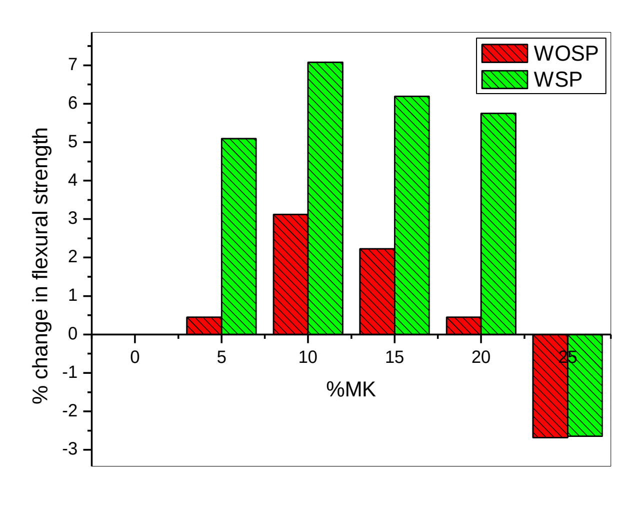

Flexural strength vs %MK	**% of change in flexural strength with respect 0%MK**

Fig 4: Flexural strength

V. CONCLUSION

From the experimental investigation it is concluded that, the use of 10% metakalone as replacement to the cement in concrete is found as optimum. The addition of superplasticizer for concrete is enhances the cube compressive, split and flexural strengths. For10% MK mix without use of superplasticizer the compressive, split and flexural strengths are increased by 4.34, 9.93 and 3.12% when compared with reference mix (0%MK). In similar way for addition of superplasticizer mixes the same strengths are increased by 6.37, 4.39 and 7.08% respectively compared to reference mix. 10%MK with super plasticizer mix showed 3.78, 2.03 and 4.76% of increment in compression, split and flexural strengths compared with 10%MK without superplasticizer.

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