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Investigation towards Strength Properties of Hardened Concrete by the use of Metakaolin as a Mineral Admixture

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ABSTRACT: In this paper, the impact of Metakaolin (MK) on mechanical properties of hardened concrete is examined. Metakaolin can be utilized as a solid constituent, since it also constitute some level of pozzolanic properties. In this investigation, blending of Metakaolin with different percentage of 6%, 7% and 8% have been adopted for M 25 grade of concrete. In order to achieve a desired workability (75-100 mm slump value), despite of choosing a lower w/c ratio (w/c ratio = 0.45), super plasticizer (SP) of 0.7 % (by weight of cement) has been added in the mix. Depending on the various parameters adopted during experimental programme, testing for mechanical properties of concrete has been carried out. The results obtained for different strength parameters (compressive strength, split tensile and flexure strength) for hardened concrete shows a considerable increase in strength parameters for 28 days of curing lying in range of 4 - 6 % at an optimum percentage of 8 % addition of MK. A least effect on split tensile has been observed with the addition of Metakaolin in the concrete. This approach of waste utilization in the concrete thereby reduces the hazardous effect of cement on the environment as well as leading to a cost effective production of concrete. However, the present study also opens a door for more advanced research towards assessing the effect of Metakaolin on the properties of concrete when used in with other waste materials up to a higher degree of blending.

KEYWORDS: Metakaolin, Compressive Strength, Split Tensile Strength, and Flexure Strength.

I. INTRODUCTION

Metakaolin has a pleasant appearance, which is white in shading contrasted with greyish dark by Z. Hashim and R. Hamid [4]. The utilization of pozzolanas for making concrete considered as an efficient ingredient, as it permits the lower cement consumption, thereby enhancing the quality and durability properties of the concrete. Metakaolin when utilized as a partial replacement substance for cement in concrete, it reacts with Ca(OH)_2 one of the by-products of hydration reaction of cement and results in additional C-S-H gel, which increased the strength [1]. The use of SCM materials in concrete has been associated with the refinement of the concrete pore structure. This in turn could affect the properties of concrete in the fresh and hardened states, including strength, deformation and durability performance by R. Sharma et al. [7].

Metakaolin is a valuable pozzolanic material, it is athermally activated alumina-silicate material obtained by calcining kaolin clay within the temperature range of 700-850°C [5]. Metakaolin is unique when compared with common pozzolans or different sorts of manufactured pozzolans in such a way that it requires an arrangement of procedures to

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get pozzolanic property. Metakaolin is a thermally initiated alumina-silicate material acquired by calcining kaolin earth inside the temperature range 650– 800 °C [6].

The impact, for example, increments of strength at a beginning stage, imperviousness to sulphate attack and alkali silica reaction (ASR) every one of these marvels are enhanced by the pozzolonic response of MK with Calcium Hydroxide [8]. The moderately fine particles of MK with their smaller scale filler capacity assumed a critical part in enhancing the interfacial transition zone. Consideration of MK can upgrade the quality of solidness states of cement [9]. The substitution of MK in mortar yielded better mechanical properties, brings down energy utilization and CO₂ liberation and furthermore spares up to 40% of clinker, when compared with the execution of control mortar [10]. Inclusion of MK can improve the quality of toughness states of cement, the quality expanded with the prolongation of curing period for 14 days [11].

The amount of MK included in concrete depends upon the result needs. It has been demonstrated that replacement of 5% to 9% of MK had increased the early strength of concrete; replacement of 10% to 15% of MK had increased the imperviousness to chemicals and chloride particle and substitution of more than 15% of MK had increased the capacity to control the efflorescence in concrete [3]. According to the literature, the research work on Metakaolin is focused on two main areas. The first is the impact of the kaolin structure on the kaolinite to metakaolinite transformation, while the second one concerns the pozzolanic behaviour of metakaolinite and its impact on solid properties. Although there is a contradiction in numerous incomplete points, the learning level is agreeable and consistently extended [2].

II. MATERIALS & METHODOLOGY

MATERIALS USED

Cement: In the present investigation, Ordinary Portland Cement (OPC) of Birla Samrat is used. Testing of cement as per the specification given by IS 269-2015. The values obtained by laboratory testing appeared to be almost similar to the values provided by the manufacturer. The properties of cement obtained by testing the sample are given in the Table 1:

Table 1: Properties of Cement

Properties	Observed value
Fineness	2.73%
Normal Consistency	28%
Specific Gravity	3.14
Initial Setting Time	95 minutes
Final Setting Time	225minutes

Aggregate: Natural river sand 'Jamuna' as a Fine Aggregate component in concrete was used in this study. However, smashed stone as coarse aggregate acquired from Banda (UP) of 20 mm and 12.5 mm ostensible size were used in the concrete mixing. Testing of cement as per the specification given by IS 383-1970. The properties details for Fine Aggregate and Coarse Aggregate are depicted in the Table 2:

Table 2: Properties of Aggregate

Properties	Fine Aggregate	Coarse Aggregate	
		12.5 mm	20 mm
Fineness Modulus	2.78%	6.80%	8.36%
Specific Gravity	2.74	2.74	2.61
Water Absorption	1.4%	0.40%	0.56%

Metakaolin: The Metakaolin was obtained from "ASTRAA CHAMICALS", Chennai. The colour of Metakaolin was off-white. The details of the physical and chemical properties for Metakaolin has been provided by the manufacturer itself and are illustrated in Tables 3:

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Table 3: Physical properties of Metakaolin

Physical Properties	Results
Physical State	Powder
Odour	Odourless
Colour	White
Bulk Density	0.50 gm/cc
Specific Gravity	2.63
Water Absorption	66.80 ml/100 gm
Oil Absorption	64.00 ml/100 gm

Table 4: Chemical properties of Metakaolin

Chemical Properties	Results
Silica (SiO ₂)	52.86%
Alumina (Al ₂ O ₃)	44.10%
Ferric Oxide (Fe ₂ O ₃)	0.45%
Titanium Oxide (TiO ₂)	0.36%
Calcium Oxide (CaO)	0.28%
Magnesium Oxide (MgO)	0.20%
Pottasium Oxide (K ₂ O)	0.20%
Sodium Oxide (Na ₂ O)	0.25%
Loss on Ignition	0.85%

Superplasticizer: Superplasticizer (SP) “Auramix 400” complies with IS 9103-1999(2007) and ASTM C94 type G from Fosroc Chemicals was used as a chemical admixture. In this study, the dose of SP is constant throughout the experiment, 0.7 % (by weight of cement).

III. EXPERIMENTAL METHODOLOGY

In this study M25 grade of concrete was used. According to IS: 10262-2009, Concrete mix proportioning we were figured that for one meter cubic volume of concrete, we require distinctive elements are as follows-

Table 5: Quantities per unit volume of concrete

Cement (kg/m ³)	Fine Aggregate (kg/m ³)	Coarse Aggregate (kg/m ³)	
		12.5 mm	20 mm
350	856	485	687

The final mix proportion was 1:2.44:3.26 at fixed water cement ratio of 0.45. The specimen concrete was tested for mechanical properties of concrete (compressive, flexural and split tensile strength) in hardened state after 28 days of water curing. For compressive strength 12 cubes of size (150 mm × 150 mm × 150 mm), for flexure strength 4 beams of size (100 mm × 100 mm × 500 mm) and for split tensile strength 12 cylinders of size (75 mm × 150 mm) were casted.

A total of 3 cubes, 3 cylinders and 1 beam have been kept under one mix, for which the volume with 18% wastage of material was calculated as 0.02019 m³. Finally, the quantities of each mixes for different ingredients are illustrated in Table 6. Different mixes were designated as M0 with no blending of Metakaolin (control mix), M1 with 6% blending,

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M2 with 7% blending and M3 with 8% blending of Metakaolin have been used in this study in order to get rid of any experimental mishap.

Table 6: Quantities of different ingredients for different mixes

Mix No.	OPC (kg)	MK (kg)	F.A. (kg)	C. A. (kg)		Water (kg)	S.P. (kg)
				(12.5 mm)	(20mm)		
M0 (0% MK)	7.07	0	15.58	9.52	14.57	3.51	0.049
M1 (6% MK)	6.64	0.42	15.55	9.50	14.55	3.51	0.049
M2 (7% MK)	6.57	0.49	15.55	9.50	14.54	3.51	0.049
M3 (8% MK)	6.50	0.57	15.55	9.50	14.54	3.51	0.049

IV. RESULTS AND DISCUSSION

Effect of Metakaolin on Compressive Strength of Concrete

The test for compressive strength was carried out conforming to IS 516-1959 after 28 days of wet curing. The cubes were tested using Compression Testing Machine (CTM) of capacity 2000 kN. From Fig. 1, the compressive strength for control mix was found as 32.63 N/mm² and keeps on rising as the replacement level is increased. Almost 20 % of increment in strength values (i.e. 39.27 N/mm²) has been observed for replacement cement with 8 % Metakaolin. Slight increase in strength (i.e. 36.51 N/mm² to 37.03 N/mm²) has been seen when the replacement level goes from 6 % to 7 %. A significant improvement in the compressive strength of concrete has been noted by the use of Metakaolin owing to its high pozzolanic activity and void filling ability [9].

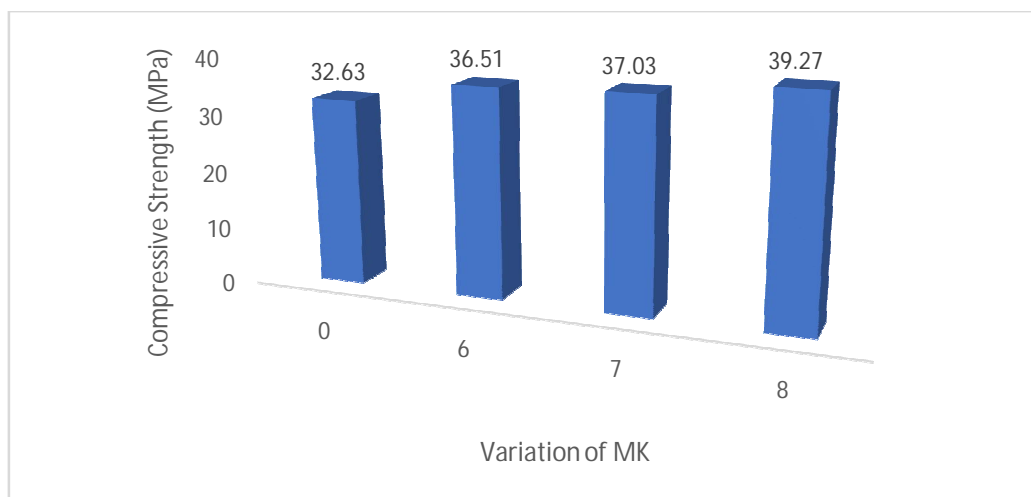


Fig. 1: Variation of Compressive Strength at different replacement level of MK

Effect of Metakaolin on Flexure Strength and Split Tensile Strength of Concrete

The test for flexure as well as split tensile strength was carried out conforming to IS 516-1959 after 28 days of wet curing. The beam specimen for flexure strength was tested using Flexure Testing Machine (FTM) of 100 KN capacity. Fig. 2 shows the variation of flexure values with different degrees of blending with MK. The flexure strength for control mix is noted as 11.75 N/mm². It is clear that the blending of MK shows a little impact on flexure strength. Similar results have been obtained for flexure strength at various replacement levels.

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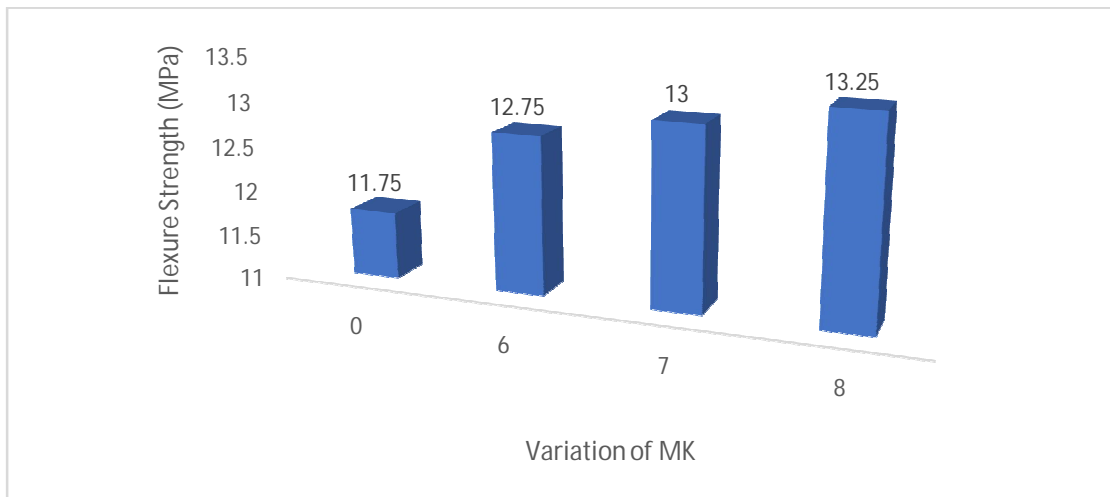


Fig. 2: Variation of Flexure Strength at different replacement level of MK

Similarly, cylindrical samples for split tensile strength was tested using Compression Testing Machine (CTM) of 2000 KN capacity. Fig. 3 shows the variation of split tensile values with different degrees of blending with MK. The split tensile strength for control mix is noted as 2.13 N/mm². From Fig. 3, the maximum tensile strength is observed as 2.41 N/mm² at 28 days of curing. The optimum value of replacement of MK by cement is observed at 8%. Indeed, it can be said that split tensile values will shows an increasing trend from control mix value, when blended with different degrees of replacement level of MK.

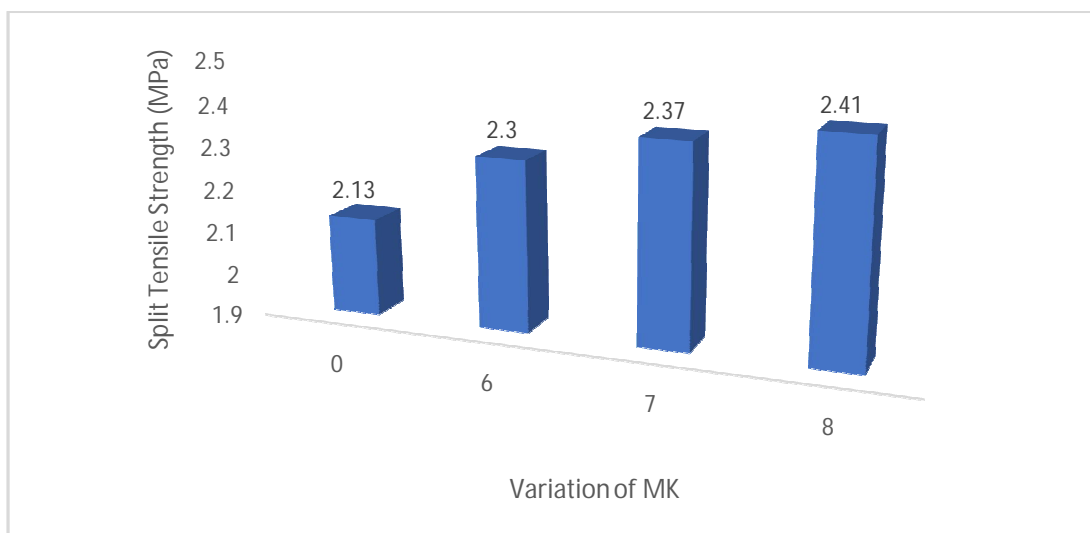


Fig. 3: Variation of Tensile Strength at different replacement level of MK

V. CONCLUSION

Based on the investigation, it is quite clear that mineral admixture like Metakaolin has proved to be the most promising blending material to provide a good quality concrete. The following generalized conclusions can be drawn on the mechanical properties of concrete.

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- The compressive strength of concrete increases with increase in replacement level of MK. The optimum value of replacement of MK is found at 8%.
- The flexure strength of concrete also increases in increasing replacement level of MK. The optimum value of replacement of MK is also found at 8%.
- The optimum value for split tensile strength is obtained at 8% replacement level of MK.

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