Properties of Steel Fiber Reinforced Concrete with Metakaolin (MK) as Admixture

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Abstract - *During cement production, work has been conducted to examine the effect of metakaolin (MK) substitution with cement strength due to associated environmental pollution and to preserve virgin raw materials for future generations, and yet at the same time, utilizing the approachability of additional cementing materials such as metakaolin-an engineered material. In this study, the strength characteristics of Metakaolin concrete with and without crimped steel fiber have been tested. Reinforced concrete with short random fibers has been identified by monitoring the origin length/dia. propagation of fractures to enhance the strength of cementitious matrices. Steel fibers have contributed to mechanical qualities by minimizing the crack development inside concrete blocks and so improving concrete strength at all testing ages. Results show that the flexural strength of M60 concrete increases with 1.5 percentages of fiber content and strength-effectiveness at aspect ratio 60 is observed to be maximum.*

Key Words: Metakaolin (MK), Mechanical properties, Strength Steel fiber reinforced concrete

1. INTRODUCTION

Concrete is a fabricated material that is most extensively in construction throughout the world. Even during thiese COVID times the construction is in swing with high rise air conditioned buildings structures made of concrete. In concrete, the aggregates are bonded together by the cement mixed with water. With the advancement of technology and the increased field of application of concrete and mortars, the strength, workability, durability, and other characteristics of ordinary concrete can be made suitable for any situation. For this, definite proportions of cement, water, fine aggregate, coarse aggregate, mineral admixtures, and chemical admixtures are required. Concrete has become so popular and indispensable because it's inherent in concrete brought a revolution in applications of concrete. Concrete has unlimited opportunities for innovative applications, design, and construction techniques. Its great versatility and relative economy in filling a wide range of needs have made it a very competitive building material. With the advancement of technology and the increased field of applications of concrete, the strength, workability, durability and other characteristics of the ordinary concrete need modification to make it more suitable for suitable situations. To overcome various problems encountered in the construction field and to achieve better performance in an aggressive environment, the use of high-performance concrete is becoming more popular. The addition of fibers along with mineral admixture in concrete makes matrix strengthened and results in, increase of strength characteristics. Metakaolin presents comparable performance to the ones with other mineral Admixtures in terms of mechanical properties as well as permeability and durability properties. Moreover, the utilization of metakaolin is also environmentally friendly due to the reduction of CO_2 emission to the atmosphere by decreasing portland cement consumption.

2. Background

Metakaolin is not a byproduct. It is obtained by the calcination of pure or refined Kaolinitic clay at a temperature between 650 0C and 850 0C, followed by grinding to achieve a fineness of 700-900 m2/kg. The resulting material has high pozzolanic. Metakaolin is manufactured from pure raw material to strict quality standards. They may also contain active components (such as sulfur compounds, alkalies, carbon, reactive silica) which can undergo delayed reactions within the concrete and cause problems over prolonged periods. Metakaolin is a new material in India and is still a matter of R&D investigations. The suitability of raw materials in India for the production of structural grade Metakaolin has not been explored in great detail. The possibility of producing structural grade concretes using Metakaolin mixes and conventional concreting tools has not been well established in the Indian context as most of the studies have been confined to miniature specimens. When concrete materials are used in construction they should be durable to withstand a highly aggressive environment. In earlier days the strength of concrete was only considered in the design mix procedures, but after the introduction of IS: 456-2000 the importance is focused on durability. Although Metakaolin was introduced during the 1980s, no exhaustive research data are available towards durability. Presently Metakaolin is more expensive than Portland cement, as is Silica Fume, even though moderately low temperatures are required for its processing and its overall production cost is significantly less than that of Portland cement. 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 concerning pure cementitious binders. With the environmental concerns developed in recent years, more environmentally friendly cement is produced adding ground slag, fly ash, or other minerals. Metakaolin is so far the only product that will reduce the CO_2 output and accelerate the setting.

Fig -1: Metakaoline

In this study, two different steel fibers which have the same diameter and different length of hooked-end were used. The properties of fibers were given in Table 1.

Fig -2: Crimpled steel fibres.

Table -1: Properties of fibres.

Specimen	Length (mm)	Diameter (mm)	Aspect ratio (l/d)
SF 1	45	0.75	60
SF 2	60	0.75	80

3. Experimental program

Many researchers have studied the properties of ordinary Portland cement concrete and steel fibre reinforced concrete using fly ash, silica fume, as cement replacement materials. Less research has been done work using Metakaolin as cement replacement materials in steel fibre reinforced concrete. This study deals with the details about the development of mixes, preparation of test specimens, the various strength and durability studies conducted including its procedures. Trial mixtures were prepared to obtain a target strength of more than 60 N/mm2 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 was found as 100 mm – 120mm. The main objective was to investigate the effect of the replacement of cement by metakaolin in varying percentages on the mechanical properties of concrete. and to investigate the effect of Hooked end steel fibers with the same dia and different aspect ratios on flexural strength of high-performance concrete. To solve the global warming problem, efforts are being made to reduce the use of Portland cement in concrete. In this direction, the specimens were tested to evaluate to assess the performance of Meakaolin concrete in terms of strength. This includes the use of auxiliary cementing materials such as metakaolin for Portland cement. The strength parameters were studied by conducting a compressive strength test, flexural strength test, and splitting tensile strength test.

4. Results and discussion

The obtained test results for geopolymer concrete are compared with the flexural strength values for control cement concrete. The test results of the concrete specimen are discussed below and presented in Table 1. The strength tests were carried out at age of 28 days. The 28-day compressive strength varied between 61 and 71 MPA. The highest for the MK10 mixtures achieving strength of 71 MPA at 28 days. Split tensile strength exhibited the highest strength at MK 10 mixture. The range of flexural strength of concrete varies from 7.9 MPa to 10 MPa.MK 10% gave high flexural strength. So we may conclude that MK 10% is the best proportion for add-in cement.

Table -2: Strength in (MPA).

% of Metakaolin	Compressive Strength (MPA) 28 days	Tensile Strength (MPA) 28 days	Flexural Strength (MPA) 28 days
0% MK	61	4.1	5.6
5% MK	65	4.6	6.5
10% MK	71	5.1	7.9
15% MK	69	4.3	7.1
20% MK	67	4	6.9

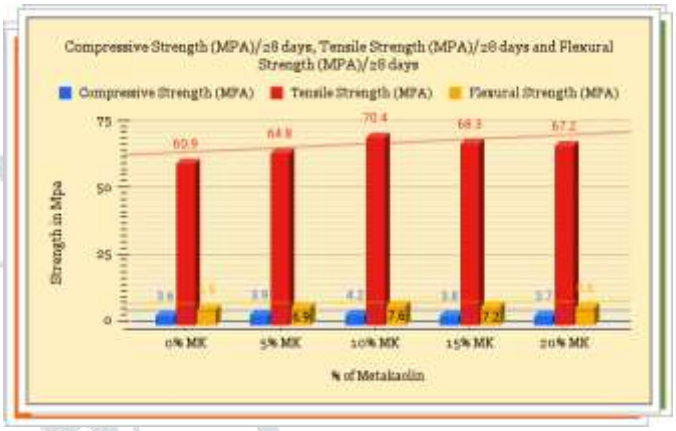

Fig -3: Comparison between different Strength results.

In Table 2 we investigated that the percentage of 10 % metakaolin gives higher strength as compared to 5 %, 15 %, and 20 % of metakaolin mixed with concrete in all strength respectively so we adopted 10 % metakaolin to mix with 1% & 1.5 % hooked steel fiber at different aspect ratio in concrete.

Table -3: Flexural Strength of concrete mix with additives.

Specimen	% of Steel Fiber	Aspect ratio (l/d)	Flexural Strength (MPA) 28 days	Increase (%)
10 % MK	0	0	7.9	
10% MK + SF 1	1	60	10.69	33.55
		80	9.79	21.05
10% MK + SF 2	1.5	60	11.92	45.92
		80	10.78	31.57

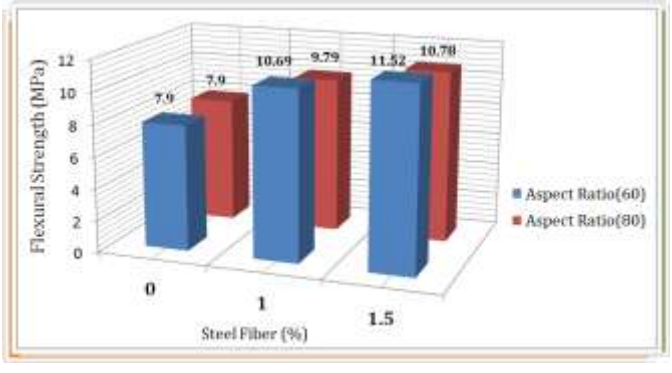

Fig -4: Flexural strength of concrete mixed with 10% metakaolin and hooked steel fiber of different aspect ratios.

The Flexural Strength values are determined in the laboratory for concrete mixed with metakoline and hooked steel end fiber are shown in Table 2 and it is clear that the flexural strength of concrete decreases as the steel fiber aspect ratio content increases with 10% of metakaolin. Maximum flexural strength of mixed concrete is with 10% metakaolin at a hooked steel end fiber aspect ratio (60) with the replacement of 1.5% of steel fiber at 28 days. The variation of flexural strength of concrete with 10% metakoline and various of hooked steel fiber with both aspect ratios is depicted in figure 4.

5. Conclusions

Metakaolin is waste that could be utilized in a concrete structure and its addition in concrete in the current study showed improvement in the compressive strength, split tensile strength and flexural strength up to 10% cement replacement. The maximum replacement level of metakaolin ash is 10% for M60 grade of concrete strength for 28 days curing period. It shows that the addition of 10 % metakaolin has a significant effect on the strength characteristics of the mixes. Also, the Flexural strength of M60 concrete increases with 1.5 percentages of fiber content and strength-effectiveness at aspect ratio 60 is observed to be maximum i.e. 11.52 MPA than the control concrete at 28 days. The short fibers provided higher flexural strength development than long fibers incorporated concretes with an increase in volume fraction. The level of improvement was more pronounced for MK concretes than plain ones. This difference in the behavior of steel fiber reinforced concretes may be attributed to the dispersion and orientation of the steel fibers within the concrete. The results encourage the use of Metakaolin along with the addition of additives like hooked steel fibers as well with different percentages and different aspect ratios, which also reflected that less cement and concrete having better strength properties than ordinary concrete can be generated by this mix.

REFERENCES

[1] Güneyisi, E., Gesoğlu, M., Akoi, A.O.M. and Mermerdaş, K., 2014. Combined effect of steel fiber and metakaolin incorporation on mechanical properties of concrete. *Composites Part B: Engineering*, *56*, pp.83-91.

[2] Garg, R., Garg, R., Chaudhary, B. and Arif, S.M., 2021. Strength and microstructural analysis of nano-silica based cement composites in presence of silica fume. *Materials Today: Proceedings*.

[3] Sawant, R.M. and Ghugal, Y.M., 2015. Recent trend: Use of metakaolin as admixture: A review. *American Journal of Engineering Research*, *4*(12), pp.8-14.

[4] Kansal, C.M. and Goyal, R., 2021. Analysing mechanical properties of concrete with nano silica, silica fume and steel slag. *Materials Today: Proceedings*.

[5] Kansal, C.M. and Goyal, R., 2021. Effect of nano silica, silica fume and steel slag on concrete properties. *Materials Today: Proceedings*.

[6] Bindiganavile, V. and Banthia, N., 2001. Fiber reinforced dry-mix shotcrete with metakaolin. *Cement and Concrete Composites*, *23*(6), pp.503-514.

[7] Açikgenç, M., Ulaş, M. and Alyamaç, K.E., 2015. Using an artificial neural network to predict mix compositions of steel fiber-reinforced concrete. *Arabian Journal for Science and Engineering*, *40*(2), pp.407-419.

[8] Akhai, S., Bansal, S.A. and Singh, S., 2020. A CRITICAL REVIEW OF THERMAL INSULATORS FROM NATURAL MATERIALS FOR ENERGY SAVING IN BUILDINGS. *Journal of Critical Reviews*, *7*(19), pp.278-283.

[9] Akhai, S., Mala, S. and Jerin, A.A., 2020. Apprehending Air Conditioning Systems in Context to COVID-19 and Human Health: A Brief Communication. *International Journal of Healthcare Education & Medical Informatics (ISSN: 2455-9199)*, *7*(1&2).

[10] Shinde, P.B., Pawade, P.Y. and Chandak, M.A., 2019. Mixed Influence of Metakaolin (MK) and Steel Fiber on Mechanical Properties of Concrete. In *Smart Technologies for Energy, Environment and Sustainable Development* (pp. 381-390). Springer, Singapore.

[11] Atiş, C.D. and Karahan, O., 2009. Properties of steel fiber reinforced fly ash concrete. *Construction and Building Materials*, *23*(1), pp.392-399.

[12] Sharma, V. and Akhai, S., 2019. Mechanical Behaviour of Fly Ash Reinforced Aluminum Composite Prepared by Casting. *Journal of Advanced Research in Mechanical Engineering and Technology*, *6*(1&2), pp.23-26.

[13] Sharma, V. and Akhai, S., 2019. Trends in Utilization of Coal Fly Ash in India: A Review. *Journal of Engineering Design and Analysis*, *2*(1), pp.12-16.

[14] Moradikhou, A.B., Esparham, A. and Avanaki, M.J., 2020. Physical & mechanical properties of fiber reinforced metakaolin-based geopolymer concrete. *Construction and Building Materials*, *251*, p.118965.

[15] Akhai, S., Singh, V.P. and John, S., 2016. Investigating Indoor Air Quality for the Split-Type Air Conditioners in an Office Environment and Its Effect on Human Performance. *Journal of Mechanical Civil Engineering*, *13*(6), pp.113-118.

[16] Singh, S.K. and Arif, S.M., 2014. Inclusion of coconut coir fiber in soil mixed with coal ash. *International Journal of Research in Engineering and Technology*, *3*(11), pp.209-213.

[17] Thareja, P. and Akhai, S., 2017. Processing Parameters of Powder Aluminium-Fly Ash P/M Composites. *Journal of advanced research in manufacturing, material science & metallurgical engineering 2017; 4 (3&4): 24*, *35*.

[18] Mohanta, N.R. and Samantaray, S., 2019. Study of Combined Effect of Metakaolin and Steel Fiber on Mechanical Properties of Concrete. *Pertanika Journal of Science & Technology*, *27*(3).

[19] Afroughsabet, Vahid, and Togay Ozbakkaloglu. "Mechanical and durability properties of high-strength concrete containing steel and polypropylene fibers." *Construction and building materials* 94 (2015): 73-82.

[20] Gaikwad, G.V. and Ghugal, Y.M., 2019. Experimental Investigation on Metakaolin Modified Fiber Reinforced Concrete. International Research

Journal of Engineering and Technology, Volume: 06 Issue: 08, pp.39-44.

[21] Kamble, M.S.D. and Bogar, V.M., 2019. Experimental Study on Steel Fiber Reinforced Metakaolin Concrete. International Research Journal of Engineering and Technology, Volume: 06 Issue: 07, pp.3623-3636.

[22] Wadhwa, A.S. and Dhaliwal, H.S., 2008. *A Textbook of Engineering Material and Metallurgy*. Firewall Media.