

# Experimental Study on Performance of Concrete Using Partial Replacement of Cement by Metakaolin

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**Abstract** - Test results were obtained for normal concrete, concrete with partial replacement of cement by Metakaolin, concrete with partial replacement of cement by Metakaolin and Steel Slag, accelerated curing results of concrete with partial replacement of cement by Metakaolin. For Compressive Strength cubes of size 100 mm x 100 mm x 100 mm were cast and tested at 7, 21, and 28 days of curing period. The addition of 15% of Metakaolin as replacement to cement shows optimum enhancement in properties of concrete, with increase in Strength parameters as high as 48% in comparison to control mix. Hence Metakaolin up to 15% replacement can be utilized as a partial replacement to cement in binary blend as well as ternary blend with Steel Slag for high Strength, accelerated Strength and high durability concrete.

**Keywords:** Metakaolin, durability concrete, Steel Slag, Compressive Strength, supplementary cementitious material.

## I. INTRODUCTION

The most exceedingly used man-made building material in the world is concrete. Nowadays, concrete is being used on a large scale due to the rapid growth of the construction industry worldwide. Concrete is a predetermined proportion of cement, fine aggregate, coarse aggregate and water produced to achieve desired strength at the specific age. Concrete constituents are obtained from different sources, differing in their physical, chemical and reactive characteristics. This requires the study of concrete ingredient properties and concrete characteristics. Recent advances in the construction sector have dramatically increased the usage of concrete. It has become the second-largest consumed material in the world next to water. By using such a massive amount of concrete results in huge demand for cement and other raw materials. Due to this, the global demand of cement has reached about 5 to 7 billion metric tons every year. In the production process of OPC natural resources (Limestone) are getting exhausted at a faster rate and greenhouse gases are released in to the atmosphere by consuming huge energy during calcination of cement. During the cement manufacturing process, about 7%

to 8% of man-made CO<sub>2</sub> emission is released into the atmosphere.

In order to overcome this problem and to control the impact on the environment, the researchers are in search of finding alternative materials which can replace cement. In blended concrete, admixtures replace the cement to a major extent due to their strength gaining capacity, high resisting nature, durability and lower cost. In addition, the greenhouse gases are reduced, which are produced in the manufacturing of cement, resulting in a reduction of pollution. Concrete with Binary, Ternary and Tetra nary blending of admixtures provides significant benefits over the mix containing only OPC. The partial substitute of cement by admixtures not only reduces the production cost of concrete but also the addition of admixtures with cement has a beneficial effect on workability, the heat of hydration and permeability of concrete. The proportional use of a combination of different admixtures not only develops strength but also improves the overall durability of concrete. Mineral admixtures are the materials added to improve the properties and performance of concrete before or during mortar or concrete mixing. Mineral admixtures are generally natural or by-product materials also referred as Supplementary Cementitious Materials (SCM). Mineral admixtures are added for improving fewer short term and more long-term properties [5][6][7].

The usage of supplementary cementitious materials for the production of blended concrete is one of the main focused areas in concrete research. Proper material selection and dosage of the admixture are the key factors that affect the concrete performance. When the concrete is subjected to loading, the failure area lies either in the hydrated cement paste or in the interface between the cement paste and the aggregate particles, i.e., Interfacial Transition Zone (ITZ) of concrete. In the case of traditional concrete, the interfacial transition zone of concrete will be very weak and the failure occurs in ITZ of concrete [8]. Whereas in blended concrete the combination of different admixtures helps to strengthen the ITZ and improves the strength and durability of concrete. The cementitious materials used to manufacture of blended concrete should be inexpensive and of superior quality. Most of the mineral admixtures that have been studied so far are of

micro-size which helps to fill the cement pores. In order to reduce the cost of SCC, one of the alternatives is the use of additions like industrial waste or by-products, such as Fly Ash, Silica Fume, Ground Granulated Blast Furnace Slag (GGBS), Rice Husk Ash.

## II. LITERATURE SURVEY & BACKGROUND

Jian-Tong Ding et al (2020) experimentally found out the effects of Metakaolin and Silica Fume on the properties of Concrete. Experimental investigation with seven concrete mixtures of 0, 5, 10, and 15% by mass replacement of cement with high-reactivity Metakaolin or Silica fume, at a water cement ratio of 0.35 and a sand-to-aggregate ratio of 40% was carried out. The effect of Metakaolin or Silica fume on the workability, strength, shrinkage, and resistance to chloride penetration of concrete was investigated. The incorporation of both Metakaolin and Silica fume in concrete was found to reduce the free drying shrinkage and restrained shrinkage cracking width. It is also reported that the incorporation of Metakaolin or Silica fume in concrete can reduce the chloride diffusion rate significantly. The performance of Silica fume was found to be better than Metakaolin.

Badogiannis. E et al (2021) evaluated the effect of Metakaolin on concrete. Eight mix proportions were used to produce high-performance concrete, where Metakaolin replaced either cement or sand of 10% or 20% by weight of the control cement content. The strength development of Metakaolin concrete was evaluated using the efficiency factor (k value). With regard to strength development the poor Greek Metakaolin and commercially obtained Metakaolin yielded the same results. The replacement with cement gave better results than that of sand. When Metakaolin replaced cement, its positive effect on concrete strength generally started after 2 days where as in case of sand it started only after 90 days. Both Metakaolin exhibited very high k-values (close to 3.0 at 28 days) and are characterized as highly reactive pozzolanic materials that can lead to concrete production with excellent performance.

Nabil M. Al-Akhras (2022) carried out an investigation by replacing cement with Metakaolin to find out the durability of concrete against sulphate attack. Three replacements of cement with Metakaolin (5, 10 and 15% by weight) were done with water cement ratio of 0.5 and 0.6. After the specified days, the samples were immersed in 5% sodium sulphate solution for 18 months. The effect of metakaolin addition proved to be beneficial in improving the resistance of concrete to sulphate attack. Metakaolin with water cement ratio of 0.5 exhibited better results in sulphate resistance than 0.6. Autoclaved cured specimens had better resistance against sulphate than moist cured specimens.

Abid Nadeem et al (2023) made an investigation on the chloride permeability of high strength concrete and mortar specimens containing varying proportions of Metakaolin (MK) and Fly ash at elevated temperatures. A total of seven concrete and three mortar mixes were tested after exposing each mix to 200, 400, 600 and 800°C. In concrete, the dosage levels of MK were 5, 10 and 20% and for Fly ash the dosage levels were 20, 40 and 60%. In mortar, the dosage level of Metakaolin and Fly ash was 20%. All concrete specimens investigated in this study had a minimum compressive strength of 85 MPa.

## III. OBJECTIVE

The introduction of Metakaolin is to modify concrete properties in both fresh and hardened states; the following progressive specific objectives are required to study.

- To evaluate concrete workability, strength and durability for a 'concrete mix with accelerator (Metakaolin)'.

## IV. RESULT

### Mechanical Properties

The mechanical properties of concrete are mainly consisting of strength parameters. In this research, compressive strength and flexural strength tests were conducted.

Compressive strength of concrete is one of the most important mechanical properties, as it indicates the ability of concrete to withstand axial loads. It is the maximum stress that a concrete sample can withstand before failure under a compressive load. Compressive strength is a key factor in the design of concrete structures. Engineers use it to determine the load-bearing capacity of concrete elements.

Table 1: Compressive strength test results of Metakaolin concrete mixes for 0.25 water cement ratio

Compressive Strength (MPa)		
Mix Details	For 0.25 w/c ratio	
	7 Days	28 Days
NC	40	49
MK-5	46	60
MK-10	52	69
MK-15	56	73
MK-20	48	64
MK-25	44	56

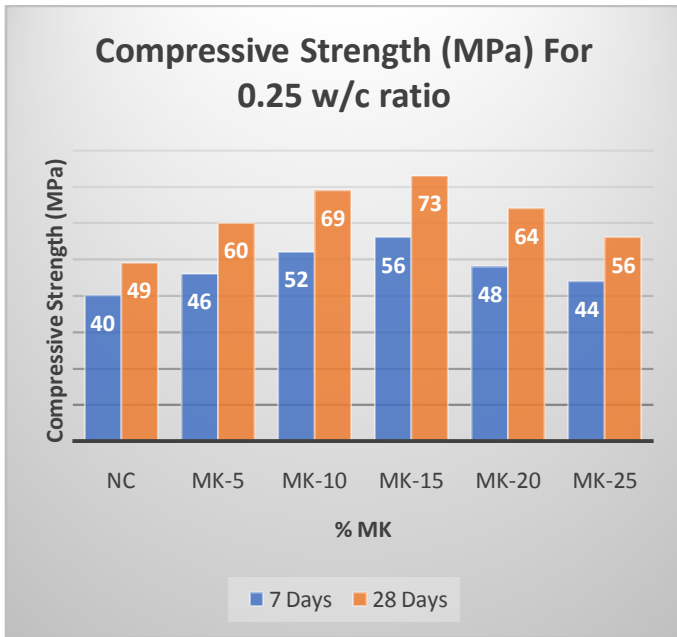


Figure 1: Compressive Strength (MPa) for 0.25 w/c ratio

Table 2: Compressive strength test results of Metakaolin concrete mixes for 0.30 water cement ratio

Compressive Strength (MPa)		
Mix Details	For 0.3 w/c ratio	
	7 Days	28 Days
NC	37	46
MK-5	42	55
MK-10	47	63
MK-15	51	67
MK-20	43	58
MK-25	40	51

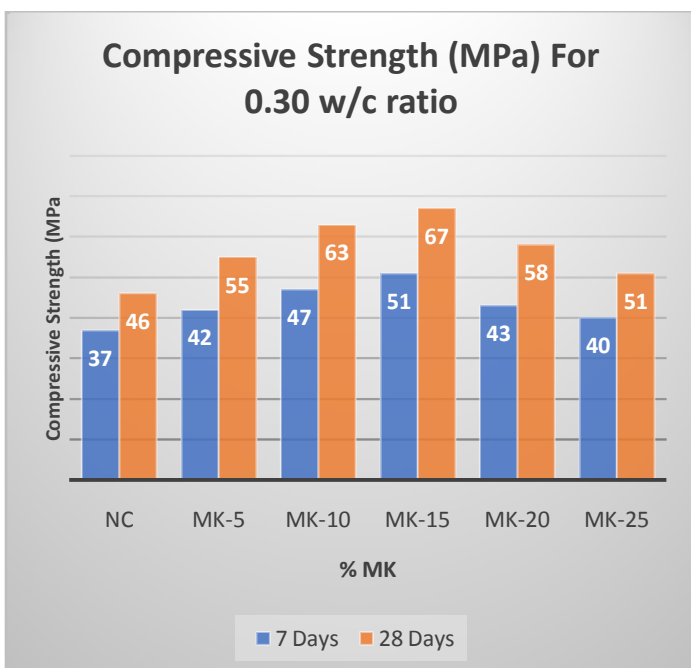


Figure 2: Compressive Strength (MPa) for 0.30 w/c ratio

Table 3: Compressive strength test results of Metakaolin concrete mixes for 0.35 water cement ratio

Compressive Strength (MPa)		
Mix Details	For 0.35 w/c ratio	
	7 Days	28 Days
NC	31	40
MK-5	35	47
MK-10	39	53
MK-15	42	57
MK-20	35	49
MK-25	33	43

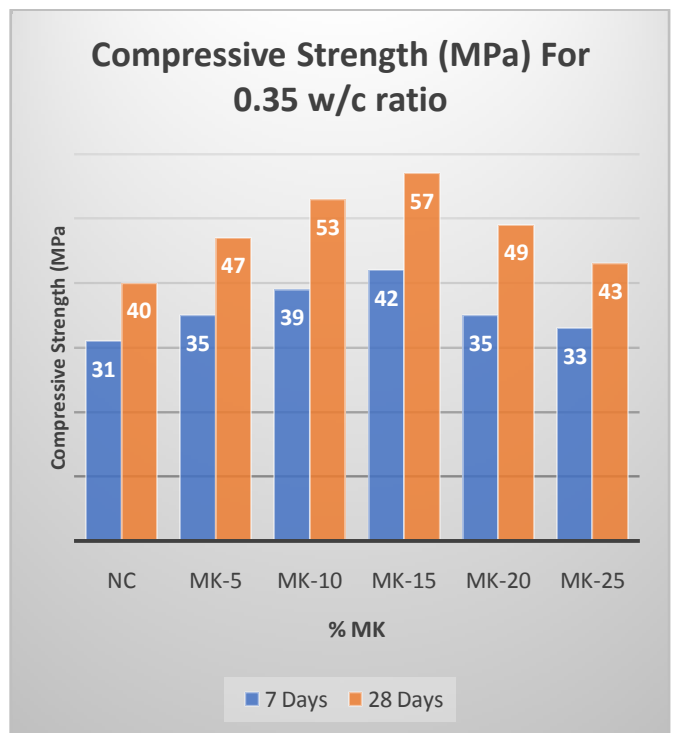


Figure 3: Compressive Strength (MPa) for 0.35 w/c ratio

## V. CONCLUSION

1. The incorporation of Metakaolin as substitute to cement reduces the workability of concrete. There is a maximum of 18.42%, 15.85%, and 10.46% decline in slump values has been noticed in concrete mix containing 25% of Metakaolin as substitute to cement in comparison with control mix for 0.25, 0.30 and 0.35 w/c ratios respectively.
2. The addition of Metakaolin decreases the availability of water in concrete due to its high reactivity and surface area. Also, higher slump values were noticed at 0.35 w/c ratio as compared to lower w/c ratios. Also, the water film thickness reduces with addition of Metakaolin.

## REFERENCES

- [1] Rashad A M. (2013) Metakaolin as cementitious material: History, scours, production and composition –

- A comprehensive overview, Construction and Building Materials, Vol 41, Pp 303-318.
- [2] Siddamreddy Anil Kumar Reddy, Dr. K. Chandrasekhar Reddy (2013) Effect of Fly Ash on Strength and Durability Parameters of Concrete, International Journal of Science and Research, Vol 4, Issue 5.
- [3] Subramani T, Ramesh K.S (2015) Experimental study on partial replacement of cement with fly ash and complete replacement of sand with M sand, International Journal of Application or Innovation in Engineering & Management, Vol 4, Issue 5.
- [4] Syed Afzal Basha, Pavithra.P, Sudharshan Reddy B (2014) Compressive strength of fly ash based cement concrete, International Journal of Innovations in Engineering and Technology, Vol 4, Issue 4.
- [5] Teja Kiran CH, Prudvi K (2016) Strengthening of Concrete by Partial Replacement of Cement with Fly ash and Metakaolin Mix, International Journal of advanced Technology and Innovative Research ,Vol 8, Issue 03, Pp 0459-0463.
- [6] Usha K, Smitha B K (2016) Suitability of Fly Ash in Replacement of Cement in Pervious Concrete, International Journal of Engineering Research and Technology, Vol 5, Issue 8.
- [7] Abid Nadeem Johnny Y N Mok, Salman Azhar, Brian H Y Leung, Gary K W Tse “Comparison of chloride permeability of metakaolin and fly ash concretes and mortars under elevated temperatures” 33rd conference on our world in concrete & structures, Singapore: 25-27 August 2008, <http://cipremier.com/100033057>.
- [8] Jiping Bai, Albinas Gailius “Consistency of fly ash and metakaolin concrete” journal of civil engineering and management 15(2): (2009), pp.131–135.
- [9] Chao Li, Henghu Sun, Longtu Li “A review: The comparison between alkali-activated slag (Si+Ca) and metakaolin (Si+Al) cements” Cement and Concrete Research 40 (2010), pp.1341–1349.
- [10] Eva Vejmelkova, Milena Pavlikova, Martin Keppert, Zbynek Keršner, Pavla Rovnanikova, Michal Ondracek, Martin Sedlmajer, Robert Cerny “High performance concrete with Czech metakaolin: Experimental analysis of strength, toughness and durability characteristics” Construction and Building Materials 24 (2010),pp. 1404–1411.
- [11] Hisham M. Khater “Influence of metakaolin on resistivity of cement mortar to magnesium chloride solution” Ceramics – Silikáty 54 (4), (2010), pp. 325-333.
- [12] Pacheco Torgal F, Arman Shasavandi, Said Jalali “Using metakaolin to improve the compressive strength and the durability of fly ash based concrete” Invaco2: International seminar, innovation & valorization in civil engineering & construction materials, Rabat-Morocco, 23-25 November (2011), ISBN 987-9954-30-595-9.
- [13] Hemant Chauhan “Effect of Activated Flyash in Metakaolin based cement” National Conference on Recent Trends in Engineering & Technology 13-14 May 2011, BVM Engineering College, Gujarat, India.

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