www.rsya.org

Sustainable Construction Materials

Vol 2, Issue 1, Jan-Jun 2022
www.rsya.org/scm

Concrete with Rock Sand Filler and Based on Metakaolin: Experimental Analysis

Parvez Islam*, Zikri Ahmad, Noor Begum

Sunway University, Jalan Universiti, Bandar Sunway, 47500 Petaling Jaya, Selangor, Malaysia)
**Corresponding author:* parvezislam.sunway@yahoo.com

Abstract. Porous concrete may perform worse when subjected to high rates of settling and shrinkage. The objective of this study was to use Metakaolin and rock sand to reduce voids in concrete and enhance performance. As an additional cementitious ingredient, metakaolin has been shown to be a good addition to cement concrete. The most often utilised concrete additives are those that have metakaolin as a component. Due to its widespread accessibility in our country, using metakaolin in cement concrete may have financial benefits. Metakaolin was to be substituted at a rate of 5 percent, 10 percent, 15 percent, 20 percent, and 25 percent by weight of cement. Concrete's strength and durability are evaluated using cubes and cylinders that have been cast. In 15 percent MK-based concrete, an increase in compressive strength of 47.55 percent, 27.88 percent, and 47.52 percent was recorded over 7, 28, and 90 days, respectively.

INTRODUCTION

The most common building material used worldwide is concrete [1], [2]. It is only second to water as the most frequently used material, producing about six billion tonnes annually [3]–[5]. This is because there are many raw materials used in cement manufacture, cement has a relatively low value, and concrete is malleable and adaptable in terms of producing the shapes needed for structural components. The use of additional materials to reduce the need for cement has been resisted because to environmental effects, including harm from CO2 emissions and material extraction during cement production [6]-[9]. These resources could include industrial waste, byproducts, and less-energetic materials. A rise in the incidences of major concrete building degradation are additional factors that contribute to these stresses [10]–[12]. In order to address these challenges, other environmental issues relating to the disposal of waste industrial by-products, as well as economic issues, mixtures of Portland cement (PC) and pozzolans are increasingly being used in structural concrete [13], [14]. Pozzolana is a name that was previously used to characterise naturally occurring calcined earths and volcanic ashes that react with lime in the presence of water at room temperature [12], [15]– [17]. Any aluminous or siliceous materials that, when roughly separated and exposed to water, chemically react with calcium hydroxide to generate cementitious materials are now included in the term. Fly ash, rice husk ash, and silica fumes are all considered to be pozzolana. Pozzolan utilisation results in effective reporting of advantages such reduced temperature rise, increased durability, and increased strength. Although this number is rarely higher than 20% in completely developed concrete, Portland cement releases CH at a rate of about 28 percent of its own volume when fully hydrated[18]. The Portlandite reacts with the extra pozzolan to produce more calcium silicate hydrates. The portlandite created by the hydration of PC offers little in the way of strength and may shorten the life of the concrete. Its removal through pozzolan interaction may result in a greater improvement in the concrete's toughness and durability. The amount of industrial by-products with pozzolanic properties that are released globally far outweighs the amount that is now used, and it is generally believed that use will increase as more people become aware of the environmental benefits of utilising it. It will assist in addressing upcoming maintenance and environmental protection concerns. In the long run, there are compelling arguments for continuing to partially replace cement in concrete and mortar with waste and other less energy-intensive processed materials having pozzolanic properties. The use of calcined clay in the context of metakaolin (Mk) as a pozzolanic addition for concrete and mortar has received a lot of interest in recent years. Much focus has been given to the removal of CH, which is produced during the hydration process and is associated with decreased durability. Eliminating CH increases strength due to the extra cementing phases created by CH's interaction with MK, which also improves alkali silica reactivity and sulphate resistance. High-purity kaolin clay is calcined at temperatures between 600°C and 800°C to create MK. Direct forms of alumina and silica are involved, and they will interact with the CH. The use of clay-based pozzolans in concrete and mortar has mostly been motivated by improved material availability and durability. Additionally, depending on the type of clay and the calcining temperature, strength can be increased, particularly in the early stages of curing.

MATERIALS USED

Brick Cement

According to IS: 8112- 2013[19], metakaolin-based cement concrete with a specific gravity of 3.14 and initial and final setting periods of 65 and 288 minutes, respectively, was created in this experiment using grade 43 OPC. a wish to use Pozzolans in a specific amount to replace cement in order to improve the quality of cement concrete examples. 6.51 percent was discovered to be the cement's fineness.

Metakaolin

CO2 emissions are reduced when Metakaolin is used as a weight substitute for cement in concrete sample. Metakaolin is a white clay made of calcium-rich lime stone and dolomite. In comparison to cement, metakaolin has a finer particle size dispersion. The physical analysis of metakaolin powder is displayed in Table 1. The chemical make-up of metakaolin and Ordinary Portland Cement (OPC) is displayed in Table 2. Metakaolin's use in concrete greatly lessens the harmful effects of carbon emissions on the environment. It not only enhances the micro properties of the concrete but also lowers carbon dioxide emissions and aids in garbage disposal. Additionally, by limiting the porosity of the structures, its use in cement concrete aids in reducing the effects from outside sources.CO2 emissions are reduced when Metakaolin is used as a weight substitute for cement in concrete sample. Metakaolin is a white clay made of calcium-rich lime stone and dolomite. In comparison to cement, metakaolin has a finer particle size dispersion. The physical analysis of metakaolin powder is displayed in Table 1. The chemical make-up of metakaolin and Ordinary Portland Cement (OPC) is displayed in Table 2. Metakaolin's use in concrete greatly lessens the harmful effects of carbon emissions on the environment. It not only enhances the micro properties of the concrete but also lowers carbon dioxide emissions and aids in garbage disposal. Additionally, by limiting the porosity of the structures, its use in cement concrete aids in reducing the effects from outside sources.CO2 emissions are reduced when Metakaolin is used as a weight substitute for cement in concrete sample. Metakaolin is a white clay made of calcium-rich lime stone and dolomite. In comparison to cement, metakaolin has a finer particle size dispersion. The physical analysis of metakaolin powder is displayed in Table 1. The chemical make-up of metakaolin and Ordinary Portland Cement (OPC) is displayed in Table 2. Metakaolin's use in concrete greatly lessens the harmful effects of carbon emissions on the environment. It not only enhances the micro properties of the concrete but also lowers carbon dioxide emissions and aids in garbage disposal. Additionally, by limiting the porosity of the structures, its use in cement concrete aids in reducing the effects from outside sources.

Table 1: Chemical Composition of Cement and Metakaolin

Chemical composition	SiO_2	Al_2O_3	CaO	Fe_2O_3	MgO	Na_2O	K_2O	LOI
OPC (%)	26.95	8.51	45	4.52	1.12	0.16	0.03	2.63
Metakaolin (%)	52	46	0.09	0.6	0.03	0.14	0.03	0.50

Fine and Coarse Aggregate

According to IS383: 2016[20], the fine aggregate used in the current experiment was angular natural sand from a river in zone 3 with a specific gravity of 2.59. 10- and 20-mm coarse aggregates were used in this experiment in proportions of 2:3 of the total quantity of coarse aggregate, respectively.

Rock Sand

Rock sand minerals (P) LTD in Andhra Pradesh provided the rock sand for purchase. Rock sand has been acknowledged as a superior alternative to river sand for a variety of significant reasons. Due to the homogenous size and shape of the sand particles, the building has less porosity and is more rigid and strong. There are no organic or inorganic pollutants in the sand, making it more weather-resistant and durable. The cubic shape of the sand particles minimises the amount of cement and water used by 4 to 5 percent each. Currently, a mix of 50 percent rock sand and 50 percent river sand has been used in the current study. This method is used to examine the change in compressive and split tensile strength.

MIX DESIGN AND WATER TO CEMENT RATIO

In the current investigation, an M20 mix design was adopted. For all concrete samples, the water to binder ratio was held constant at 0.04. Table 2 displays the concrete mix design in detail.

Table2: Mix Design of concrete

Precursor (kg/m^3)	0% MK	5% MK	10% MK	15% MK	20% MK	25% MK
Cement	492.9	468.25	443.61	418.96	394.32	369.67
Metakaolin	--	24.65	49.29	73.94	98.58	123.23
Fine Aggregate	568.38	568.38	568.38	568.38	568.38	568.38
Coarse Aggregate	1055.55	1055.55	1055.55	1055.55	1055.55	1055.55
Water	197.16	197.16	197.16	197.16	197.16	197.16

Compressive Strength

Using a compression testing machine, the concrete sample's compressive strength was evaluated on a 150x150x150 mm cube specimen. The specimen was initially cured for 7, 28, and 56 days in the deep pond. The samples were sun dried prior to testing at the appropriate curing times.

Split Tensile Strength

Using a compression testing equipment, a specimen measuring 150 mm by 300 mm was used to test the cylinder's split tensile strength. The cylinder's projection was modified in accordance with IS:456 requirements.

RESULTS & DISCUSSION

Compressive Strength

The compressive strength graph is depicted in Figure 1. For 7, 28, and 90 days, respectively, the compressive strength can be considered to steadily rise up to 15% MK replacement. However, after 90 days of curing, the strength of the 20 percent MK-replaced concrete outperformed all other categories. According to Fig. 1, the compressive strength of the 20 and 25 percent MK mixtures was higher and more similar to the control and other mix proportions. In 15 percent MK-based concrete, an increase in compressive strength of 47.66%, 27.80%, and 47.53% was noted over the course of 7, 28, and 90 days, respectively. Compressive strength, however, declines as MK fraction continues to fluctuate. Experimental results showed that switching from 50% river sand to rock sand increased compressive strength by up to 15% MK replacement. Additionally, it was discovered that 20 percent MK concrete's compressive strength increased after 90 days of curing. All blends were lowered in strength after reaching this point.

Split Tensile Strength

Figure 2 shows how the cement concrete's split tensile strength changed after 7, 28, and 90 days. Here, it can be seen that the 20 percent MK concrete had a higher split tensile strength than the others during the 28-day curing period. However, during the 90-day testing period, the 20% and 25% MK replacements show a comparable strength phenomena. In experiments, it was discovered that 20 percent MK-based concrete showed an increase in strength of 41.03, 54.90, and 58.16 percent in comparison to control specimens at 7, 28, and 90 days, respectively.

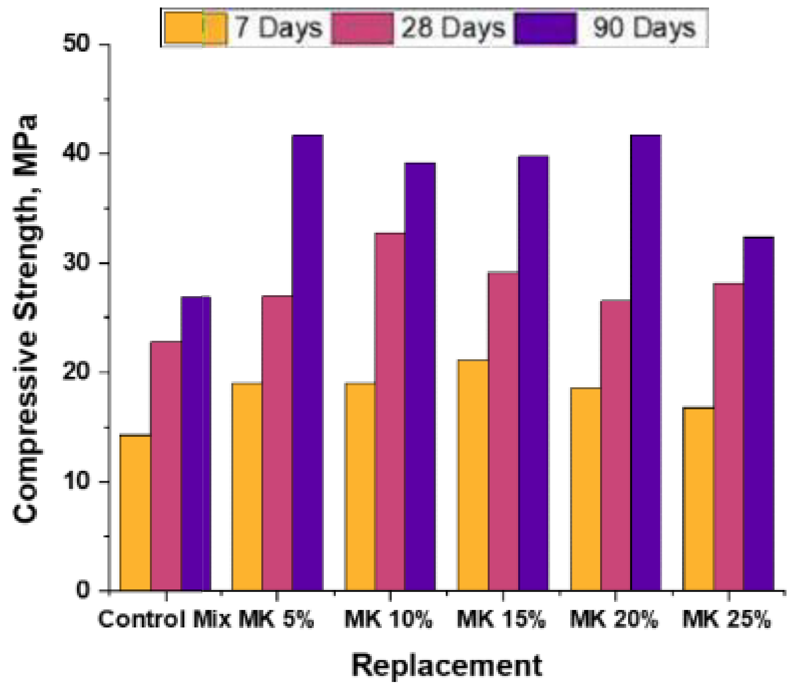

Figure 1: Compressive Strength of OPC and MK based Cement Concrete

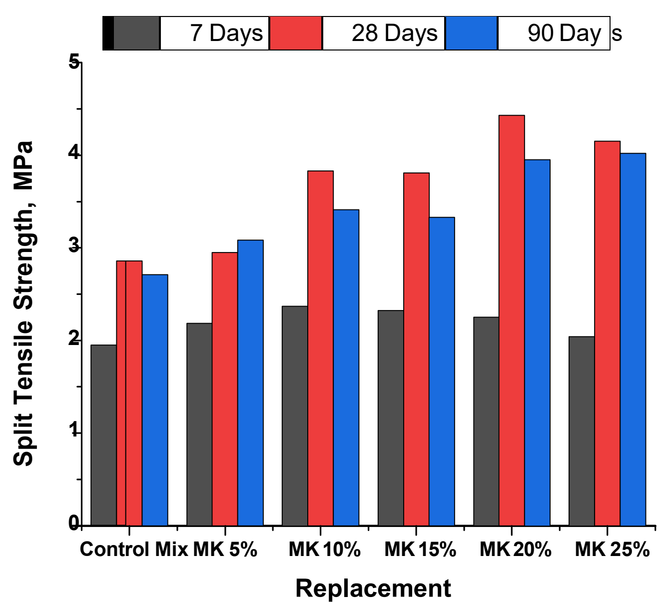

Figure 2: Split Tensile Strength of MK Replaced Cement Concrete

CONCLUSION

From the study, the following findings may be made:

Metakaolin use in concrete reduces the concrete's porosity. As a result, metakaolin-based concrete has stronger compressive strength than regular concrete. The strength of the calcium silicate hydrate (C-S-H) link, which is what gives metakaolin its higher compressive strength, can be increased. The inert substance in concrete will rise as we add more metakaolin, lowering the concrete's compressive and split tensile strengths. Among all replacement percentages, 15% MK replacement showed greater compressive strength over the course of 28 days, whereas 20% MK replacement showed greater compressive strength over the course of 90 days. Compressive strength and split tensile strength increase when river sand is partially substituted with rock sand. At 28 days, 20% MK concrete shows superior split tensile strength. However, during the 90-day curing period, it was somewhat close to 25% of the strength of MK concrete. 15 percent MK-based concrete experienced increases in compressive strength of 47.55, 27.88, and 47.52 percent at 7, 28, and 90 days, respectively, whereas 20 percent MK-based concrete experienced split tensile strength increases of 41.03, 54.90, and 58.16 percent at 7, 28, and 90 days, respectively.

REFERENCES

[1] P. Sharma, N. Sharma, P. Singh, M. Verma, and H. S. Parihar, "Examine the effect of setting time and compressive strength of cement mortar paste using iminodiacetic acid," Mater. Today Proc., Apr. 2020, doi: 10.1016/j.matpr.2020.04.336.

[2] Kardam, V. K., Sharma, P., & Sharma, N. (2023, July). Reviewed mechanical properties of sugarcane bagass eash replacement of cement in concrete. In *AIP Conference Proceedings* (Vol. 2721, No. 1). AIP Publishing.

[3] Singh, A. K., Singh, P., Sharma, P., & Sharma, N. (2023, July). Environmental effects of cement production: A review. In *AIP Conference Proceedings* (Vol. 2721, No. 1). AIP Publishing.

[4] C. L. Wong, K. H. Mo, S. P. Yap, U. J. Alengaram, and T. C. Ling, "Potential use of brick waste as alternate concrete-making materials: A review," J. Clean. Prod., vol. 195, pp. 226–239, 2018, doi: 10.1016/j.jclepro.2018.05.193.

[5] E. M. R. Fairbairn, B. B. Americano, G. C. Cordeiro, T. P. Paula, R. D. Toledo Filho, and M. M. Silvoso, "Cement replacement by sugar cane bagasse ash: CO2 emissions reduction and potential for carbon credits," J. Environ. Manage., vol. 91, no. 9, pp. 1864–1871, 2010, doi: 10.1016/j.jenvman.2010.04.008.

[6] Verma, P., Mahadeven, V., Sharma, P., Sharma, N., & Parashar, A. K. (2023, July). Application of nano technology in civil engineering and future trends: A review. In *AIP Conference Proceedings* (Vol. 2721, No. 1). AIP Publishing.

[7] Kumar, A., Agrawal, A., Mistry, M., & Sharma, P. (2023, July). Experimental study of the geopolymer concrete with elevated temperature. In *AIP Conference Proceedings* (Vol. 2721, No. 1). AIP Publishing.

[8] T. S. Ng, Y. L. Voo, and S. J. Foster, "Innovative Materials and Techniques in Concrete Construction," Innov. Mater. Tech. Concr. Constr., pp. 81–100, 2012, doi: 10.1007/978-94-007-1997-2.

[9] R. Andrew, "Global CO2 emissions from cement production," 2017. doi: http://doi.org/10.5281/zenodo.831455.

[10] Singh, P., Serawat, A., Singh, B., & Sharma, P. (2023, July). The impact of sandstone

fines on the effectiveness of concrete. In *AIP Conference Proceedings* (Vol. 2721, No. 1). AIP Publishing.

[11] A. M. Halahla, M. Akhtar, and A. H. Almasri, "Utilization of Demolished Waste as Coarse Aggregate in Concrete," Civ. Eng. J., vol. 5, no. 3, p. 540, 2019, doi: 10.28991/cej-2019-03091266.

[12] Y. Karim, Z. Khan, M. S. Alsoufi, and M. Yunus, "A Review on Recycled Aggregates for the Construction Industry," Am. J. Civ. Eng. Archit., vol. 4, no. 1, pp. 32–38, 2016, doi: 10.12691/ajcea-4-1-5.

[13] A. Al Kourd and A. Hammad, "CEMENT and CONCRETE TECHNOLOGY," pp. 1–155, 2010, doi: 10.1016/j.jneb.2011.02.016.

[14] J. Borger, R. L. Carrasquillo, and D. W. Fowler, "Use of recycled wash water and returned plastic concrete in the production of fresh concrete," Adv. Cem. Based Mater., vol. 1, no. 6, pp. 267–274, 1994, doi: 10.1016/1065- 7355(94)90035-3.

[15] D. L. N. B. Jayawardane, U. U.P.A.S, W. W.M.N.R., and P. C.K., "Physical and Chemical Properties of Fly Ash based Portland Pozzolana Cement," Civ. Eng. Res. Exch. Symp. 2012, pp. 8–11, 2012.

[16] "Fly Ash, Slag, Silica Fume,and Natural Pozzolans," in Design and Control of Concrete Mixtures, 1996, pp. 57–72.

[17] A. Benyahia, "Comparative study of effect hot climate and conventional water on strength development of SFR - SCMs using natural pozzolana replacement," Asian J. Civ. Eng., pp. 1–9, 2019, doi: 10.1007/s42107-019- 00176-4.

[18] Hamada, H., Alattar, A., Tayeh, B., Yahaya, F., & Thomas, B. (2022). Effect of recycled waste glass on the properties of high-performance concrete: A critical review. *Case Studies in Construction Materials*, *17*, e01149.

[19] IS:8112, "Ordinary Portland Cement, 43 Grade - Specification," New Delhi, India, 2013.

[20] IS:383., "Coarse and fine aggregate for concrete- Specifications," Indian Stand., vol. Third Revi, no. January, pp. 1–21, 2016.