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Analysis the Metakaolin Cement Concrete by Conducting a Scientific Enquiry with an Emphasis on The Rock Sand Infill

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Abstract: *Concrete with pores may perform poorly when subjected to high rates of shrinkage and settlement. This study sought to determine whether rock sand and metakaolin could aid in the reduction of voids in concrete. Metakaolin has proven to be a great extra cementitious ingredient in cement concrete. Among the additives used most frequently in concrete are metakaolin and its properties. Because metakaolin is widely available in our country, using it in cement concrete may have economic benefits. The percentages of 5, 10, 15, 20, and 25% by weight of cement that were to be substituted with metakaolin were to be used. Concrete's strength and longevity are evaluated using casting cubes and cylinders. Compressive strength in 15% MK-based concrete rose by 47.55 percent, 27.88 percent, and 47.52 percent after 7, 28, and 90 days, respectively.*

Keywords: Metakaolin, Rock Sand, Compressive Strength, Tensile Strength, Concrete

INTRODUCTION

The material that is used for construction the most frequently all over the world is concrete [1, 2]. When it comes to the most frequently used material, it is only second to water in terms of production, with approximately six billion tonnes being produced annually [3, 5]. This is due to the fact that cement production requires a large quantity of raw materials, the low value of cement, and the fluidity and adaptability of concrete in the fabrication of structural component shapes. All of these factors contribute to the formation of cement. The utilisation of auxiliary materials to lessen the consumption of cement has been hampered by environmental concerns regarding the emission of carbon dioxide and the extraction of materials during the production of cement [6, 9].

In addition to byproducts and waste from industrial processes, these resources may also include materials that require less energy to produce. An additional factor that contributes to these pressures is an increase in the number of instances that involve significant concrete building degradation [10], [12]. Additionally, in order to address these issues, as well as additional environmental concerns regarding the disposal of waste industrial by-products and economic concerns, Portland cement (PC) and pozzolan mixes are becoming increasingly routinely utilised in structural concrete [13], [14]. The term "pozzolana" has been used in the past to refer to naturally occurring calcined earths and volcanic ash that undergo a reaction with lime when it is present in the presence of water at room temperature [12], [15], and [17]. The definition of cementitious materials has recently been expanded to encompass any aluminous or siliceous materials that, when roughly separated and exposed to water, undergo a chemical reaction with calcium hydroxide to produce cementitious materials. The category of pozzolana includes a variety of substances, including fly ash, rice husk ash, and silica fumes. Pozzolans offer a number of beneficial properties, including a reduction in temperature rise, an increase in durability, and a higher strength when they are applied. This quantity is rarely higher than 20 percent in fully developed concrete [18], despite the fact that Portland cement produces CH at a rate of approximately 28 percent of its own volume when it is fully hydrated. The reaction between Portlandite and the additional pozzolan results in the formation of additional calcium silicate hydrates. The portlandite that is produced when PC is hydrated has a low strength and has the potential to shorten the life of the concrete. The removal of it through pozzolan contact has the potential to improve the durability and strength of the concrete. The amount of pozzolanic industrial by-products that are released around the world is significantly higher than the amount that is currently being used, and it is generally accepted that the use of these by-products will increase as more people become aware of the positive effects that using them has on the environment at large. Future environmental and long-term maintenance requirements will be easier to meet as a result of this effort. In the long run, there are compelling arguments in favour of using waste and other processed materials with pozzolanic qualities that require less energy to process in order to partially replace cement in concrete and mortar. There has been a significant amount of interest in the utilisation of calcined clay in the construction industry in recent years. A pozzolanic additive, also known as metakaolin (Mk), is utilised in the production of concrete and mortar. CH, which is formed during the hydration process and has been associated with lower durability, has been eliminated, which has received a great deal of attention. CH has been associated with lower durability. The removal of CH not only enhances the reactivity of alkali silica and the resistance to sulphate, but it also increases the strength of the material. This is because the interaction of CH with MK results in the formation of additional cementing phases. Calcination of high-purity kaolin clay at temperatures ranging from 600 to 800 degrees Celsius is the process that results in the production of MK. It is important to note that the CH is involved in the interaction of direct forms of alumina and silica. Using clay-based pozzolans in concrete and mortar is beneficial for a number of reasons, the most important of which are improved durability and material availability. Strength can be increased depending on the type of clay and the temperature at which it is calcined, particularly in the beginning stages of the curing process [32-33]. In recent years, there has been a significant increase in the amount of attention that has been devoted to the utilisation of alternative materials in the making of concrete. This is a direct result of concerns regarding the environment as well as the hunt for environmentally responsible building approaches. The calcined clay component known as metakaolin has recently gained popularity as an ingredient that is desired for use in cementitious systems. As a result of its higher mechanical qualities and durability features in comparison to conventional concrete formulations, it is a prospective addition to cementitious systems. The goal of this study is to investigate the properties of cement concrete that is based on metakaolin. This will be accomplished through the utilisation of a complete scientific investigation. To be more specific, the inquiry will focus on the utilisation of rock sand as a material for filling in openings. The use of rock sand, which can be acquired from natural sources such as granite or basalt, has the potential to enhance the performance of concrete mixtures while also making them more environmentally friendly.

MATERIALS USED

Metakaolin

A concrete sample that contains metakaolin as an alternative to cement that is lightweight results in a reduction in the amount of carbon dioxide emissions. Metakaolin is a white clay that is based on dolomite and contains a high concentration of calcium. The particle size distribution of metakaolin is more finely spread than that of cement. The results of the physical analysis of metakaolin powder are reported in Table 1. Both ordinary Portland Cement (OPC) and metakaolin are broken down into their respective chemical components in Table 2. The use of metakaolin in concrete contributes to a significant reduction in the detrimental effects that carbon emissions have on the environment. Not only does it enhance the micro characteristics of the concrete, but it also helps with the disposal of waste and results in a reduction in carbon dioxide emissions. The use of this material in cement concrete simultaneously reduces the porosity of structures, which in turn reduces the impact of external factors.

Cement

A specific gravity of 3.14 and initial and final setting times of 65 and 288 minutes, respectively, were achieved by using 43 grade OPC in the production of metakaolin-based cement concrete, as stated by the International Standard 8112-2013[19]. One of the goals is to improve the quality of cement concrete specimens by substituting a specific quantity of pozzolans for cement. There was a 6.51 percent fineness found in the cement, according to the findings [25-21].

Fine and Coarse Aggregate

On the basis of IS383: 2016[20], the fine aggregate that was utilised in this investigation was angular natural sand that was obtained from a zone 3 river and had a specific gravity of 2.59. For the purpose of this investigation, coarse aggregates with a size of 10 and 20 millimetres were utilised in a proportion of 2:3 of the total quantity of coarse aggregate [28-31].

Table 1: Chemical Composition of Cement and Metakaolin

Chemical composition	SiO_2	Al_2O_3	CaO	Fe_2O_3	MgO	Na_2O	K_2O	Others
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	0.5

Rock Sand

The rock sand was supplied by Rock Sand Minerals (P) LTD, which is located in Andhra Pradesh. Rock sand has been acknowledged as a superior alternative to river sand for a number of different reasons. Sand particles are uniform in size and shape, which results in the building having less porosity and being more robust and stronger than it would have been otherwise. Considering that it does not contain any organic or inorganic pollutants, sand is more resistant to the elements and more long-lasting. The cubical shape of the sand particles results in a reduction of four to five percent in the amount of cement used and four to five percent in the amount of water used. During the course of this investigation, rock sand and river sand were each responsible for fifty percent of the total. The method in question is utilised to investigate the changes that occur in compressive and split tensile strength.

MIX DESIGN AND WATER TO CEMENT RATIO

In the current investigation, the M20 mix design was utilised. A constant ratio of 0.4 was maintained for the water-to-binder ratio across all of the concrete samples. Table 2[20-22] provides a comprehensive design of the concrete mix that has been developed.

Compressive Strength

For the purpose of determining the compressive strength of a concrete sample, a compression testing machine was utilised on a cube specimen that measured 150 millimetres in length, 150 millimetres in width, and 150 millimetres in height. For the purpose of curing the specimen, it was placed in a deep pond for seven, twenty-eight, and fifty-six days respectively throughout the process. The samples were sun-dried before being put through the testing process so that they could be evaluated for the various curing times [23–25].

Table2: Mix Design of concrete

Precursor (kg/m3)	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

Split Tensile Strength

With the assistance of a compression testing machine, a specimen that was 150 millimetres in length and 300 millimetres in width was subjected to an investigation of its split tensile strength. For the purpose of conforming to the requirements of IS:456, the protrusion of the cylinder was altered in some way [23–25].

TEST RESULTS & DISCUSSION

Compressive Strength

The compressive strength graph is shown in Figure 1. After 7, 28, and 90 days, there is a gradual improvement in compressive strength, ultimately attaining 15% MK replacement. The 20 percent MK replacement concrete's strength was greater than all other categories after a 90-day curing time. Figure 1 illustrates that the mix proportions with 20% and 25% MK had a higher compressive strength compared to the control and other mix proportions. Compressive strength rose by 47.66 percent, 27.80 percent, and 47.53 percent in concrete with 15% MK basis after 7, 28, and 90 days, respectively. However, the compressive strength of the material diminishes with changes in the MK fraction. Tests revealed a 15% MK replacement gain in compressive strength when 50% river sand was substituted for rock sand. It was also shown that the compressive strength of 20% MK concrete increased after 90 days of curing. All blends become weaker after hitting this point.

Tensile Strength

Figure 2 shows the variation in cement concrete's split tensile strength after 7, 28, and 90 days. After 28 days of curing, the 20% MK concrete had a higher split tensile strength than the other concretes. Nonetheless, during the 90-day testing period, comparable strength phenomena are observed in the replacements of 20 and 25 percent MK. Comparing 20 percent MK-based concrete to control specimens after 7, 28, and 90 days revealed increases in strength of 41.03 percent, 54.90 percent, and 58.16 percent, respectively.

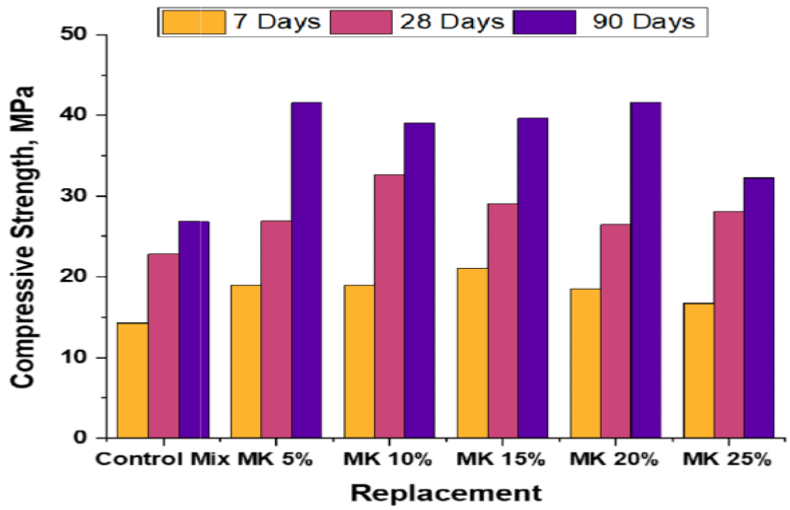

Fig 1 Compressive Strength

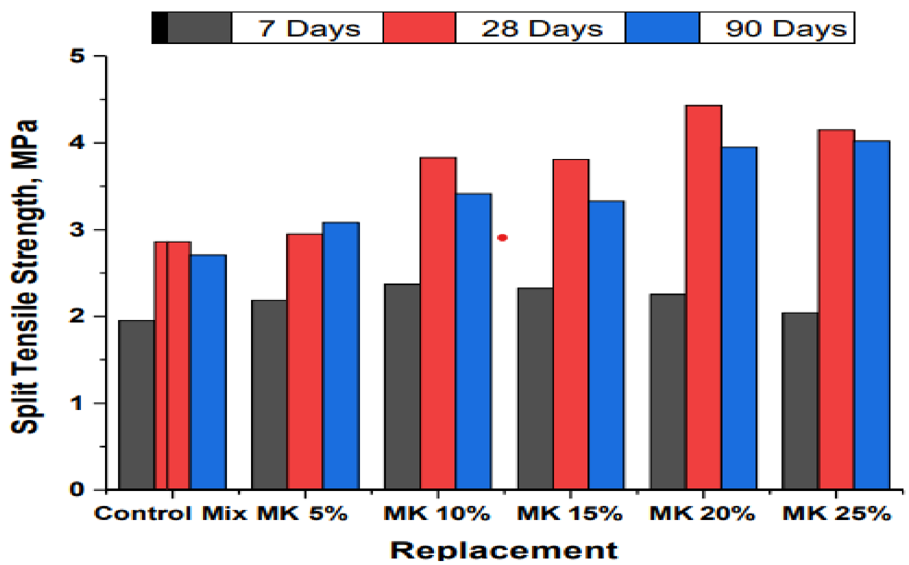

Fig 2 Split Tensile Strength of MK Replaced Cement Concrete

CONCLUSION

There is a reduction in porosity in concrete that contains metakaolin. As a consequence of this, concrete that is composed of metakaolin possesses a compressive strength that is superior to that of normal concrete. Metakaolin has the potential to improve the compressive strength of the calcium silicate hydrate (C-S-H) link. If the amount of metakaolin in the concrete is increased any further, the inert material in the concrete will grow, which will result in a decrease in the split tensile and compressive strengths of the concrete. After 28 days, the compressive strength of 15 percent MK replacement is higher than that of 20 percent MK replacement; however, after 90 days, the compressive strength of 20 percent MK replacement is higher than that of 15 percent MK replacement. It is possible to increase both the compressive strength and the split tensile strength of the material by substituting some of the rock sand with river sand. Twenty-five percent MK concrete showed a rise in its split tensile strength after a period of 28 days. In spite of this, the strength of the MK concrete was approximately 25 percent weaker after it had been allowed to dry for ninety days. The compressive strength of 15 percent MK-based concrete increased by 47.55 percent, 27.88 percent, and 47.52 percent, respectively, after 7, 28, and 90 days. On the other hand, the split tensile strength of 20 percent MK-based concrete increased by 41.03 percent, 54.90 percent, and 58.16 percent, respectively, after the same amount of time had passed.

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