INVESTIGATION ON THE PROPERTIES OF CONCRETE REPLACING CEMENT AND NATURAL SAND WITH METAKAOLIN AND ROBO SAND ABSTRACT

Zubair Ahmad Khan[1], V S Sagu[2]

[1]M. Tech Scholar, [2]H.O.D
Parnnath Parnami institute of management and technology Hisar

***Abstract*: Concrete is the most extensively used construction material in the world, which consumes natural resources like lime, aggregates and water. The worldwide production of cement has greatly increased, due to this production environmental pollution increases with emission of CO_2 gas. To reduce this effect cement was replaced by some supplementary materials like Metakaolin, Fly ash, Bottom Ash, Ground Granulated Blast Furnace Slag (GGBS) and Rice Husk etc.. In this content Metakaolin was a pozzolanic material used in wide range in replacement of cement. Metakaolin is dehydroxylated aluminum silicate, due to its pozzolanic activity the strength properties and durability properties of concrete increases and reduction in Porosity and Permeability also. Now-a-day's availability of natural sand is constraint, so alternative material called ROBO Sand (having similar properties as that Natural Sand) is used in place of Natural sand to study the fresh and hardened properties of concrete. In this present investigation cement is replaced partially with metakaolin in varying percentage i.e. 0%, 5%, 10%, 15% and 20% and natural sand with 50% ROBO sand to get the different concrete mixes. The fresh and mechanical properties of concrete i.e. workability (slump test) and compressive strength, split tensile strength and flexural strength at 7 days, 28 days and 90 days are studied of the different concrete mixes and results are compared with conventional concrete.**

***Keywords*: concrete, metakaolin, robo sand, Compressive Strength, Split Tensile strength, Flexural strength**

INTRODUCTION

Concrete is a composite material which is predominantly used all over the world. It is obtained by mixing cementing materials, aggregates and water in required quantities. The word "concrete" is originates from the Latin verb "concretus" which means to grow together. The strength characteristics of concrete depends upon the properties of constituent of material and their combined action. In the production of cement CO_2 gas emission is more, due to these results in damage of natural climatic conditions. To reduce the consumption of cement partial replacement of cement with some supplementary cementitious materials like Metakaolin, fly-ash, bottom ash, rice husk, GGBS and silica fume etc., are used in concrete mix. Metakaolin is a dehydroxylated form of clay mineral Kaolin. Stone having high percentage of kaolinite are known as china clay (or) kaolin was traditionally used in manufacture of porcelain i.e. ceramic material. Metakaolin reacts with $Ca(OH)_2$ one of the bi-product of hydration reaction of cement and results in C-S-H gel , which results in increasing strength of the concrete. By replacing cement with Metakaolin increase in strength and durability and reduces the porosity in concrete and permeability also. Fine aggregate is one of the important constituent material as far as strength characteristic of concrete is concerned. Increase in demand and decrease in natural sources of fine aggregate for the production of concrete has resulted in the need to identify new sources of fine aggregate. River sand which is most commonly used as fine aggregate in the production of concrete and mortar poses the problem of acute shortage in many areas. At the same time increasing quantity of ROBO sand (Crusher sand) is available from crusher waste. The disposal of ROBO sand (Crusher sand) is a serious environmental problem. If it is possible to use ROBO sand in making concrete and mortar by partial replacement of natural river sand, then this will not only save the cost of construction but at the same time will solve the problem of disposal of this dust. Concrete made with this partial replacement can attain the same compressive strength, comparable tensile strength and flexural strength. For satisfactory utilization of this alternative material, the various phases of examination have to be technical feasibility, durability of processed concrete and economic feasibility. With the ongoing research being done to develop appropriate technology and field trials tomonitor the performance and assessment of concrete quality with use of this alternative materials i.e. MK and RS will become more viable.

Objective of Present Study

The research work is entitled as " aims to improve the strength characteristics of concrete by partial replacement of cement with Metakaolin and Natural sand with Robo sand. The objectives of the research work are outlined as below.

1. To determine the physical properties of OPC 43-grade cement, Metakaolin, Natural sand, ROBO sand (Crusher sand) and Coarse aggregates.
2. To determine the mix design for M25 grade concrete.
3. To determine the fresh property i.e. workability of M25 grade concrete by partially replacing cement with metakaolin

and Natural sand with ROBO sand.

4. To study the effect of Metakaolin and ROBO sand on hardened properties compressive, Split tensile and Flexural strength of concrete at 7, 28 and 90 days.

5. Comparing the results with conventional concrete mix.

LITERATURE REVIEW

Metakaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous alluminosilicate that is reactive in concrete. Like other Pozzolans (fly ash and silica fume are two common Pozzolans), metakaolin reacts with the calcium hydroxide (lime) byproducts produced during cement hydration. Calcium hydroxide accounts for up to 25% of the hydrated Portland cement, and calcium hydroxide does not contribute to the concrete's strength or durability. Metakaolin combines with the calcium hydroxide to produce additional cementing compounds, the material responsible for holding concrete together. Less calcium hydroxide and more cementing compounds means stronger concrete. Metakaolin is very fine and highly reactive, gives fresh concrete a creamy, nonsticky texture that makes finishing easier. Efflorescence, which appears as a whitish haze on concrete, is caused when calcium hydroxide reacts with carbon dioxide in the atmosphere. Because metakaolin consumes calcium hydroxide, it reduces efflorescence. From the experience up to 10-15% of metakaolin can be replaced instead of cement and up to 50% replacement of natural sand with ROBO sand gives better strength results.

Venu Malagavelli et al. (2010) have studied about the characteristics of M30 concrete with partial replacement of cement with Ground granulated blast furnace slag (GGBS) and sand with the ROBO sand (crusher dust). 43 grade OPC was used to prepare concrete mix. Sand was replaced by crusher dust from 0-30% at increment of 5% and cement by GGBS 40-60%. The cubes and cylinders were cast and tested for both compressive and tensile strength. Admixture also added to enhance the required workability. The w/c ratio was fixed as 0.42. From the test results it was found that if sand only replaced by crusher dust then maximum compressive and tensile strength was obtained at 30% replacement. For GGBS in place of cement and crusher dust for sand used simultaneously then maximum strength was obtained at 50% and 25% materials respectively. It was concluded that GGBS and ROBO sand can be utilized as partial replacement materials.

M. R. Chitlange et al. (2010) study shows that mixes with artificial sand as fine aggregate gives consistently higher strength than the mixes with natural sand. The sharp edges of the particles in artificial sand provide better bond with cement than the rounded particles of natural sand resulting in higher strength. The excessive bleeding of concrete is reduced by using artificial sand.

Hemant Chauhan et al. (2011) made an attempt to use industrial wastes like activated Fly ash, Iron Oxide and Metakaolin as supplementary Cementitious materials in various proportions. Using these mineral admixtures with OPC cement, five different types of concrete mixtures were prepared and same were used to find compressive strength of concrete cubes at 3,7,14,28 and 56 days. When OPC was replaced up to 42% with Metakaolin, it gives strength up to 40.67 N/mm^2 at a water cement ratio of 0.40 and at 0.55 ratios, it gave strength up to 25.47 N/mm^2 at 56th day. They reported that it was possible to make the concrete economical by 42% replacement of cement with different percentages of mineral admixtures like Fly ash (30%), Metakaolin (10%) and iron oxide (2%).

B.B. Patil and P.D.Kumar et al. (2012) performed an experiment on strength and durability properties of High performance Concrete incorporating High reactive Metakaolin. High performance concrete is latest development in concrete. The present work deals with the properties normally workability, compressive strength and durability of M60 grade High Performance concrete with different percentages of Metakaolin. Finally they concluded that the Workability and Strength properties of High Performance Concrete mixes improved by incorporating reactive Metakaolin up to 7.5% of weight of cement.

Mukesh and charkha (2012) have conducted experiments on concrete to study the effect of the flexural and tensile strength with partial replacement of ingredients. 40% sand was replaced by crushed stone dust and cement was replaced by fly ash from 0- 40% at increment of 10%. Flexure and split tensile tests were conducted in M20 mix using PPC. From the test results it was observed that the maximum flexure and split tensile strength were obtained 0% fly ash and 40% sand replacement. If the cement was replaced by fly ash then flexure and split tensile strength were reduced. So the optimum fly ash content was 0% for PPC cement. It was concluded that crushed stone dust can be partially used as fine aggregate with conventional river sand in concrete.

Vinayak R. Supekar, Popat D. Kumbhar's et al. (2012) study shows the replacement of natural sand by 60% artificial sand results in producing the concrete of satisfactory workability and strength properties. It is also possible to minimize the area of surface cracks of concrete, thus achieving the durable concrete. However, for more than 60% replacement of natural sand by artificial sand causes reduction in compressive strength of concrete mixes with increase in the area of cracks. The replacement of natural sand with artificial sand will help in conserving the natural resources of sand and maintain the ecological balance of the nature.

Dojkov.I et al. (2013) experimentally studied the reaction between Metakaolin-Ca $(OH)_2$-water and Fly ash- Ca $(OH)_2$ - water. It was clear that during the initial period of curing (up to 7 days), Metakaolin combined lime with a very high rate.

This indicated that the overall rate of the reaction taking place in early age of Portland cement -Metakaolin concretes and cement mortars was limited by the hydration of the cement phases. The reaction between Fly ash- $Ca(OH)_2$-water was taking place at a moderate rate in the initial age as compared with Metakaolin-$Ca(OH)_2$-water. The experimental results justified the possible combined use of Metakaolin- Fly ash - Portland cement in concrete industry.

M. Nazeer and R. Arun Kumar et al. (2014) have done experiment on strength studies on Metakaolin Blended High-Volume Fly Ash Concrete. The addition of Pozzolans to concrete will improve some properties like Workability, Later Age Strength and Resistance to sulphate and Chloride attacks. In this work 50% of cement was replaced with class-F Fly Ash and 5%, 10%, 15% and 20% of Metakaolin is also replaced in place of cement for M_{30} grade concrete mix. From this study they concluded as

i) Addition of Fly Ash and Metakaolin in concrete reduces the Workability and is modified by adding Metakaolin.

ii) Mechanical properties of concrete are decreasing by adding Metakaolin about 10% instead of cement.

A.V.S.Sai Kumar and Krishna Rao et al. (2014) carried out a study on Strength of concrete with partial replacement of cement with Quarry Dust and Metakaolin. In this study the replacement of cement with metakaolin and Quarry dust are having silica used as admixtures for making concrete. Initially 25% of Quarry Dust was replaced without loss of standard strength of cement and 2.5%, 5%, 7.5%, 10% and 12.5%

Metakaolin was replaced instead of cement material. Finally they concluded that the slump values are varying compared to normal concrete as 0.79%, 1.6% and 2.4% are reduced for 2.5%, 5% and 7.5% replacement of metakaolin. And compaction factor is also reduced for 0%, 2.5%, 5% and 7.5 and increased for 1.08% for 10% replacement of cement with metakaolin. The compressive and flexural strength are increased up to 10% replacement of Metakaolin and decreased for 12.5% replacement.

Prakash Rao D.S. and Giridhar kumar. V et al. (2014) investigated the concrete with stone crusher dust which is available abundantly from crusher unit at low cost, the test conducted pertain to concrete with reverse sand of strength 28.1mpa and that with granite stone crusher dust of strength 32.8mpa. Test on strength of concrete and on flexural behavior of RC beam under 2 point loading sustained about 6 percent more load.

L. Vyshnavi Sai, T.Yeswanth, M.Sambasiva Rao and Murthy et al. (2015) experimentally found that effect of metakaolin in concrete with partial replacement of cement for M30 grade concrete. Supplementary cementitious materials are finely ground solid materials that are used to replace a portion of cement in concrete mix. Metakaolin is a dehydroxylated aluminium silicate. From the recent research work using Metakaolin it is evident that it is a very effective Pozzolanic material which enhances the strength parameters. Due to this the compressive strength was gradually increased up to 10% replacement of cement and for 20%, 30%, 40% and 70% replacement of metakaolin strength is decreased.

Nikhil K. Kulkarni et al. (2015) evaluated the strength of Plain concrete with partial replacement of cement by Metakaolin and Fly ash**.** In this study replacement of 13 cement with Metakaolin and Fly ash at 0%, 5%, 10% and 15% and the compressive strength and flexural strength test was conducted for 7and 28 days and compared results with normal concrete. Up to 10% replacement of cement with MK and Fly ash strength was increased and for 15% decreased.

Er. Amripal Kaur et al. (2015) studied partial replacement of cement has been done at 0%,3%,5%,9%,12%,13% with MK(Metakaolin) and 0%,10%(constant) with MP (Marble Powder). Compressive as well as tensile strength of concrete made with MK- MP has been compared with conventional concrete of grade M30. Durability of concrete was also analyzed with RCMT (Rapid chloride Migration Test). Result shows that there is a gain of strength with the addition of MK and MP. The optimized strength value of concrete was achieved for both compressive as well as split tensile strength at 9%MK and 10%MP. RCMT shows that with the increase of addition of Metakaolin and Marble powder, there is a decrease in rate of penetration of chloride ions, hence good durability as compared to standard concrete.

A. Anbarasan and M.Venkatesan et al. (2015) performed an experiment on effect of ROBO Sand on strength characteristics of recycled aggregate concrete by adding in different proportions. They added both Recycled and ROBO Sand in 16 set of 6 cubes each were cast and tested. From this they studied that by the combination of 30% Recycled Coarse Aggregates and 100% ROBO Sand. The compressive strength and split tensile strength were increased and for 30%, 50% and 100% proportions of ROBO sand same strength values are observed.

Priyanka A. Jadhava and Dilip K. Kulkarni et al. (2015) study shows the effect of partial replacement of natural sand by manufactured sand on the compressive strength of cement mortar of proportion 1:2, 1:3 and 1:6 with water cement ration as 0.5 and 0.55 are studied. Results are compared with reference mix of 0% replacement of natural sand by manufactured sand. The compressive strength of cement mortar with 50% replacement of natural sand by manufactured sand reveals higher strength as compared to reference mix. The overall strength of mortar linearly increases for 0%, 50% replacement of natural sand by manufactured sand as compared with reference mix (Mix 1). Manufactured sand has a potential to provide alternative to natural sand and helps in maintaining the environment as well as economical balance.

TESTS PERFORMED

- Compressive Strength

- Split Tensile strength
- Flexural strength

Conclusion

On the basis of experimental investigation of the present research study, the following conclusions have been drawn.

1. Workability

The workability of different concrete mixes decreases as compared to the control mix. The workability of the different concrete mixes due to more fineness of MK. The voids present in the concrete are filled with MK. The workability is not affected due to the ROBO sand.

2. Compressive strength

From the test results it has been observed that the compressive strength of different concrete mixes, increases at all ages in comparison of the control mix. The percentage increase are 4.5%, 25%, 30.9%, 18.2% and 8.8% at 7 days, 2.4%, 4.4%, 9.2%, 3% and 1% at 28 days and 2.3%, 4.3%, 9.7%, 2.8% and 0.56% at 90 days as compared to control mix concrete.
The increase in the compressive strength of different concrete mixes is due to the bi-product calcium hydroxide accounts for up to 25% of the hydrated Portland cement. Metakaolin combines with the calcium hydroxide to produce additional cementing compounds, the material responsible for holding concrete together. Less calcium hydroxide and more cementing compounds means stronger concrete.

3. Split Tensile strength

From the test results it has been observed that the Split tensile strength of different concrete mixes, also increases at all ages in comparison of the control mix. The percentage increase are 6%, 10%, 15.2%, 11.9% and 8.8% at 7 days, 2.4%, 8%, 19.16%, 5.3% and 0.6% at 28 days and 2.2%, 7.5%, 17.5%, 5% and 0.5% at 90 days as compared to control mix concrete.

4. Flexural strength

From the test results it has been observed that the Flexural strength of different concrete mixes, increases at all ages in comparison of the control mix. The percentage increase are 2%, 8% and 4% and 8% at 5% and 10% replacement of MK at 28 days after strength is decreasing. Similarly at 90 days 6.7% 11.5% at 5% and 10% replacement of MK and after strength is decreasing. From all the test results it is observed that concrete mix (M3) i.e. with 10% replacement of cement by metakaolin and natural sand with 50% ROBO sand gives better strength as compared with other concrete mixes. As the percentage of Metakaolin increases above 10%, the strength decreases due to its more fineness.

5.1 SCOPE OF FUTURE STUDY

1. Effect Metakaolin may be investigated on the higher grades of concrete.
2. Effect Metakaolin may be investigated on the Durability, reducing efflorescence and chemical attack aspects of concrete.
3. Study may also carried out using recycled coarse aggregates in place of coarse aggregates.
4. Study may also carried out using some other supplementary cementitious materials like Rice husk, GGBS, Fly-ash etc. with replacing cement instead of Metakaolin and natural sand with ROBO sand.

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