EXPERIMENTAL INVESTIGATION BY REPLACEMENT OF METAKAOLIN AND COPPER SLAG IN CONCRETE

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Abstract - In recent days sustainability and resource efficiency are the major challenges faced by the construction industry. Due to rapid growth in construction, increases demand for cement and fine aggregate. This project involved in finding efficient way of replacing conventional usage by replacing cement by metakaolin and replacing fine aggregate by copper slag. The properties and characteristics of cement, fine aggregate, copper slag and metakaolin was studied through various literatures. In this work planned to use, M40 grade of concrete for concrete mix design for replacing fine aggregate with different proportions like 25%, 50% of copper slag and replacing of cement with different proportions by 7.5%, 10%, of metakaolin to increase strength and workability of concrete. Therefore it is recommended that 50% copper slag can be used as replacement of sand with 7.5% and 10% of metakaolin is used in order to optian good strength and durability properties.

Key Words: Copper slag, metakaolin, High Strength, Increased Durability.

1. INTRODUCTION

1.1 General

Rapid growth of industrialization gives rise to variety of by-products. Disposal of waste materials are quite hazardous. Hence it became essential to find a better way to reuse these by-products. Many researches found that concrete made with wastes and by-products acquires excellent properties than the conventional concrete in terms of strength, performance and durability. In this project, copper slag and metakaolin are taken to investigate its sustainability as a replacement materials while making concrete.

Concrete is a supreme material for the construction which has resulted in large scale manufacturing of cement. Various researchers proven that production of cement produces heavy environmental pollution due to emission of CO_2 gas. So metakaolin can be a better alternative for supplementary cementing material which is used to make a high strength concrete and increases the durability of the concrete.

Copper slag is a by-product obtained during smelting and refining of copper which is best suited for replacing sand. The construction field is the only area where the safe use of waste materials like copper slag is possible. Copper slag increases the compressive strength and split tensile strength. It also reduces water consumption as compared with sand.

1.1 OBJECTIVES

The main objective of this study is to determine the best percentage of Metakaolin replacement in cement and best percentage replacement of sand by Copper slag.

1.2 SCOPE

The scope of this project is to make use of Copper slag as a replacement of sand as it has properties similar to sand and also to make use of Metakaolin as a cement replacement material.

2. LITERATURE REVIEW

1. **Guruvignesh.**NMetakaolin can be used as a replacement for cement as it has properties similar to cement. Flexural strength of the concrete can be increased with 15% replacement of cement by Metakaolin, 100% replacement of Waste glass and Copper slag for fine aggregate. Usage of copper slag as a replacement for fine aggregate increases the density of the concrete. Replacement by 15% Metakaolin gives 40% more compressive strength when compared with conventional concrete. Replacement of fine aggregate by 100% waste glass and 100% Copper slag gives 12% and 25% more compressive strength than conventional concrete respectively.

2. **Ping Duan, Wei chen, Chunhua shen** With the addition of GGBS and metakaolin, pore structure In concrete is optimized and pore size distribution is more Reasonable, ITZ becomes denser, compressive strength of concrete increases gradually and durability aspects are enhanced. The improving effect is in the sequence: compound of metakaolin and GGBS> metakaolin >GGBS. There are close relationships between microstructure and durability. Concrete with higher ratio of fine porosity, reasonable pore size distribution, and higher micro hardness Has corresponding higher compressive strength, lower carbonation depth, lower chloride migration coefficient ,Lower weight loss and relative dynamic modulus of elasticity.

3. Rajkumar. R, Akkineni Surya Teja, Pandia Rajan. R

The addition of Metakaolin along with cement has increased the compressive strength of the concrete when compared to the conventional concrete. The more effective percentage of replacement with metakaolin seems to be between 10% and 15%. The replacement of Copper slag in fine aggregates also shows much improved compressive strength when compared to control mix. The more effective percentage of replacement seems to be between 50% and 60%However the flexural strength of the concrete used with Slag shows decreased strength when compared to the control concrete and the reduction is at the order of about around 7.5%.The addition of Slag in concrete has shown increased water absorption percentage when compared to control.

4. Jagtap. A,Mohan. N As the metakaolin in concrete increases workability decreases. As there is a reduction in fineness modulus of cementatious material, quantity of cement paste available for providing lubricating effect is less per unit surface area of aggregate. As the percentage replacement of cement with metakaolin increases strength of concrete increases up to 15%.

5. Kasu Naveena, K. Anantha Lakshmi The strengths achieved in concrete made with percentage use of GGBS and MK achieved high strengths when compared with cement. Super plasticizer named is used to attain workability and water cement ratio. At 28 days curing, the 30% replacement of cement with GGBS and MK gave very high strength. From the above experimental results, it is proved that GGBS can be used as an alternative material for cement, reducing cement consumption and reducing the cost of construction. Use of industrial waste products saves the environment and conserves natural resource.

6. P. Dinakar, Pradosh K. Sahoo, and G. Sriram

This study presents the effect of incorporating metakaolin (MK) on the mechanical and durability properties of high strength concrete for a constant water/binder ratio of 0.3. MK mixtures with cement replacement of 5, 10 and 15 % were designed for target strength and slump of 90 MPa and 100 ± 25 mm. From the results, it was observed that 10 % replacement level was the optimum level in terms of compressive strength. Beyond 10 % replacement levels, the strength was decreased but remained higher than the control mixture. Compressive strength of 106 MPa was achieved at 10 % replacement. Splitting tensile strength and elastic modulus values have also followed the same trend. In durability tests MK concretes have exhibited high resistance compared to control and the resistance increases as the MK percentage increases. This investigation has shown that the local MK has the potential to produce high strength and high performance concretes.

7. M.Narmatha, Dr.T.Felixkala From the experimental results presented in this study, the following conclusions can be drawn: Compared to the control mix, there was a slight increase in the Concrete density of nearly 5% with the increase of copper slag content, whereas the workability increased rapidly with increases in copper slag percentage. Addition of up to 50% of copper slag as sand replacement yielded comparable strength with control mix.

3. MATERIALS TO BE USED

CEMENT

Cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them

S. No	Properties	Value
1	Specific Gravity	3.15
2	Standard Consistency	26%
3	Initial Setting Time	43 minutes
4	Final Setting Time	510 minutes

together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Concrete is the most widely used material in existence and is only behind water as the planet's most-consumed resource.

Constituent	Composition (%)
CaO	40 - 52
SiO2	10 - 19
FeO	10 - 40 (70 - 80% FeO, 20 -30% Fe2O3)
MnO	5 - 8
MgO	5 - 10
Al2O3	1 - 3
P2O5	0.5 - 1
S	< 0.1

M-SAND

Manufactured is an alternative for river sand. Due to fast growing construction industry, the demand for sand has increased tremendously, causing deficiency of river sand in most part of the world. Due to depletion of good quality river sand for the use of construction, the use of manufactured sand has been increased. Another reason for use of M Sand is its availability and transportation cost.

S. No	Properties	Value
1	Specific Gravity	2.68
2	Percentage of voids	25.50%
3	Fineness Modulus	2.876
4	Bulk Density	1670 kg/m3

5	Water Absorption	1.30%

COARSE AGGREGATE

Coarse aggregate is mined from rock quarries or dredged from river beds, therefore the size, shape, hardness, texture and many other properties can vary greatly based on location. Even materials coming from the same quarry or pit and type of stone can vary greatly. Most generally, coarse aggregate can be characterized as either smooth or rounded (such as river gravel) or angular (such as crushed stone).

S.No	Properties	Value
1	Specific gravity	2.76
2	Fineness Modulus	5.67
3	Bulk Density	1507.5 kg/m3
4	Water Absorption	0.80%

METAKAOLIN

Metakaolin is the anhydrous calcinated form of the clay mineral kaolinite. Minerals that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The particle size of metakaolin is smaller than cement particles, but not as fine as silica fume. Considered to have twice the reactivity of most other pozzolans, metakaolin is a valuable admixture for concrete/cement applications. Replacing portland cement with 8–20% (by weight) metakaolin produces a concrete mix that exhibits favorable engineering properties, including: the filler effect, the acceleration of OPC hydration, and the pozzolanic reaction. The filler effect is immediate, while the effect of pozzolanic reaction occurs between 3 and 14 days.

COPPER SLAG

Granulated copper slag (or) copper slag which is a byproduct of metallurgical operations in Sterlite industries (India) Ltd., Tuticorin was used for the experimental investigation. For every tone of metal production, about 2.2 ton of waste slag is generated. During the past two decades, attempts have been made by several investigators and copper producing units all over the world to explore the possible utilization of copper slag. The physical and mechanical properties of granulated copper slag shows that it can be used to make products like coarse and fine aggregates, cement, fill, ballast, roofing granules, glass etc

5 Mix Design: The study uses the design mix M40 grade of concrete using 53 grades OPC in the study. The Mix design was performed as per IS 10262: 2019. The water cement ration for mix is 0.36. The following mix proportion was obtained from the mix design.

Table -1: MIX DESIGN(CEMENT;SAND;AGGREGATE)

Cement	Sand	Aggregate
439	662	1256
1	1.51	2.86

6 Casting & Curing: For compressive strength the standard size of cube mould is 150 mm × 150 mm × 150 mm used. Lime is used as a partial replacement of cement to prepare lime concrete in this study. Amount of lime used in this study is 5, 10, 15, 25 and 35% by weight of cement. After casting, each cube should be marked with a legible identification on the top of cubes. Leave the sample undisturbed for 24 hours. After the 24 hours, the moulds are opened and immersed in water for curing till the day of testing. Ponding method was used for curing. Testing is done after 3, 7, 28 days. Three cubes were prepared for each specimen.

7. Testing

7.1 Compressive Strength: Compressive strength is the maximum compressive stress that under a gradually applied load, a given solid material can sustain without fracture. Compressive strength is carried on cubes i.e. 150 mm × 150 mm × 150 mm specimens. Concrete's compressive strength mostly depends on the concrete mix design, quality of concrete, cement strength, water cement ratio, curing etc. It is also affected by the other factors such as mixing of concrete, placing of concrete, curing of concrete as well as quality of concrete ingredients. The compressive strength of concrete was found by universal testing machine of 1000 kN capacity.

Compressive Strength = P/A

Where, P = Compressive load in kN and A = Area of cube

8. RESULT AND DISCUSSION

Average strength of 3 specimens was taken as compressive strength at 7 days and 28 days

TABLE 1 : COMPRESSIVE STRENGTH CONCRETE

	Conventional	CS-25/	CS-25/	CS-50/	CS-50/
mix	mix 1	mix 2	mix 3	mix 4	mix 5
7 days	31.00	23.80	26.21	31.55	29.77
28	39.27	35.55	40.29	47.55	42.81

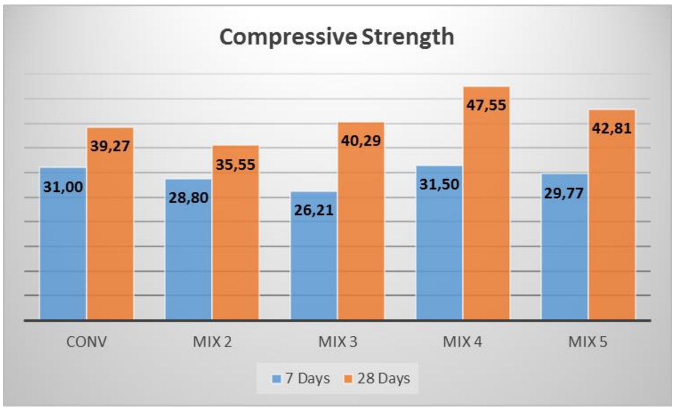

FIGURE 1. COMPRESSIVE STRENGTH CONCRETE

From the above Figure 1 the compressive strength of concrete at 7 and 28 days are compared. Above graph says that optimum compressive strength is obtain by adding of 50% copper slag can be used as replacement of sand with 7.5% and 10% of metakaolin so we accured good strength and durability.

9. CONCLUSIONS

1)From the above it is evident that in addition to that the metakaolin and Copper slag plays a vital role in construction industry.

2) The compressive strength of concrete at 7 and 28 days are compared. Above graph says that optimum compressive strength is obtain by adding of 50% copper slag can be used as replacement of sand with 7.5% and 10% of metakaolin so we accured good strength and durability.

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