

Study on Mechanical Properties of Concrete on Partial Replacement in Cement with Metakaolin, Fly Ash and Fine Aggregate with Ceramic Waste Powder

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ABSTRACT:This study is aimed to determine the engineering properties with the replacement of Cement with Metakaolin & Fly Ash and Fine Aggregate with Ceramic Waste Powder. Ordinary Portland cement is by far the most important type of cement. The most important benefit of ordinary Portland cement is faster rate of development of strength. As the demand of blended cement is increasing day by day, the manufacture of ordinary Portland cement is decreasing all over the world on account of lower energy consumption, environmental pollution, economic and other technical reasons. The best effective way to reduce the environmental impact is to use mineral admixtures, as a cement and aggregate replacement both in concrete and mortar, which will have the potential to reduce costs, conserve energy and minimizes the waste emissions In the concrete mixture, cement can be replaced by Supplementary cementation materials (SCM) which are finely ground solid materials. Present study investigates the use of Metakaolin and fly ash as partial replacement of cement and ceramic waste as partial replacement of fine aggregate on M30 grade concrete with different percentages i.e. M0, M1, M2, M3, M4, M5, M6. The various tests such that compressive strength test, split tensile strength test and flexural strength test are conducted. The detailed study is carried and presented here.

KEYWORDS:Compressive Strength, Tensile Strength, Flexural Strength, Metakaolin, Fly Ash, Ceramic Waste.

I. INTRODUCTION

The most important element of the infrastructure and also a durable construction material is cement that is used both in mortar and concrete. In general, in design of concrete mix, cement, fine aggregates and coarse aggregates are being used since long back, that plays a crucial role in designing the grade of concrete. But now a days there is a scarcity in aggregates. So, some new materials which are locally available for low cost have to introduced for replacing the fine aggregates, coarse aggregates and as well as cement to get the same strength. Cement is widely noted to be most expensive constituents of concrete. For minimizing the use of cements and reducing the construction cost, the construction industry is searching for a suitable and effective waste product. However, the environmental impact of cement is becoming a growing concern because about 2.5 % of total worldwide industrial waste emissions is due to cement manufacturing. The effective way for reducing the environmental impact is with the use of mineral admixtures, as an additive and replacement in cement and mortar with partial cement and river sand, which has the potential in reducing costs, conserving energy and minimizes the waste emissions. From manufacturing units and by demolition of constructions due to human daily habits, huge amount of solid wastes are being generated. Researchers are working on solid waste as partial replacing substances based on the locally available industrial wastes such as Fly ash, Sugarcane bagasse ash, Blast furnace slag, Rice husk ash, Palm oil fuel ash, Wheat straw ash, Silica fumes, Metakaolin, waste Ceramic tiles, glass powder, over burnt bricks, coconut shells, etc. are being used as supplementary cement and fine aggregate additive and replacement materials. When cement is added with these pozzolanic materials, the silica in these

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materials reacts with free lime released during the hydration of cement, thus forming the additional calcium silicate hydrate as new hydration products and improves the mechanical properties of concrete formulation. Use of cheaper material without loss of performance is very crucial to the growth of developing countries. The present study is to understand the behaviour and performance of the waste ceramic tiles powder which is used as the partial replacement of fine aggregate by 10%, 15% and 20% say M1, M2 and M3 respectively and combined partial replacement of ceramic waste as fine aggregate and Metakaolin and Fly ash as the partial replacement of cement by 10% & 0%, 15% & 5% and 20% & 10% say M4, M5 and M6 respectively. For analysing the suitability of these waste ceramic tile powder and Metakaolin in concrete mix M30 the compressive strength test, split tensile strength test and flexural strength tests for 7 and 28 days are conducted for all mixes.

II. MATERIALS USED

METAKAOLIN

Metakaolin is one of recently developed mineral admixture used to replace a part of cement in the manufacture of cement of HPC. It is manufactured by pozzolanic material. Metakaolin is a mineral admixture which confirms class-N pozzolanic specifications. By heating purified kaolin clay within specified temperature range 650-900°C. The water processed, refined and dried kaolin is thermally activated to make highly reactive Metakaolin.

FLY ASH

Fly Ash has a numerous advantage for use in concrete, it is a residual material of energy production using coal, which has been found to have numerous advantage for use in concrete. The advantages of Fly Ash includes improved workability, permeability reduction, increased ultimate strength, reduced bleeding, better surface and reduced heat of hydration. Depending on the coal and coal combustion process, several types of fly ash are produced. Fly Ash has been classified into two classes. It is the residues that is generated in combustion that consists of fine particles which arises from flue gases. Fly ash is produced during combustion of coal in terms of Industrial Context.

CERAMIC WASTE

The ceramic waste is one of the mineral admixture used as a partial replacement of cement and aggregates. It is available in different sizes and shapes. The ceramic waste is durable, hard and highly resistant to biological, chemical and physical degradation forces. Due to the pozzolanic property of ceramic waste the durability is increased.

III. LITERATURE REVIEW

The study of **A.V.S.Sai. Kumar, Krishna Rao B (2014)** [1] "A Study on Strength of Concrete with Partial Replacement of Cement with Quarry Dust and Metakaolin". It was observed that the compressive strength at the age of 28 days reached its target mean strength. The degree of workability was found to be almost same.

The study of **SatyendraDubey, Rajiv Chandak, R.K. Yadav (2015)** [2] "Experimental Study of Concrete with Metakaolin as Partial Replacement of OPC". The addition of metakaolin in the concrete as partial replacement of OPC increases the 28 days compressive strength significantly.

P. R. Wankhede & V. A. Fulari[3] studied an effect of fly ash on properties of concrete. The study has been carried out for M25 grade of concrete and tested for 7 days, 14 days, 28 days of curing. Cubes had been casted by replacing 0%, 10%, 20% & 30% cement with fly ash by weight. This paper also studied the variation in slump in different W/C ratio and the research concluded that slump loss of concrete increases with the increase in W/C ratio of concrete. Concrete with 10% & 20% replacement of cement with fly ash shows good compressive strength for 28 days for 0.35 W/C ratio. But in case of 30% replacement of cement with fly ash, compressive strength of concrete decreases.

The study of **Hitesh Kumar Mandavi, Vikas Srivastava, V.C. Agarwal (2015)** [4]. "Durability of Concrete with Ceramic Waste as Fine Aggregate Replacement". It is observed that, compressive strength of concrete made using ceramic waste increased with replacement level (up to 40%). Optimum replacement level of fine aggregate with ceramic waste is 40%.

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IV. CONVENTIONAL CONCRETE MIX DESIGN PROCEDURE

In the present investigation mix proportioning is done using BIS method for M30 grade concrete.

Characteristic compressive strength (f_{ck}) - 30 N/mm²

Type of cement/ grade of cement - OPC 53 grade

Specific gravity of cement - 3.15

Specific gravity of sand - 2.74

Specific gravity of coarse aggregate - 2.78

Bulk density of sand - 1600 kg/m³

Bulk density of coarse aggregate - 1500 kg/m³

The concrete mix has to be designed for a somewhat higher target average compressive strength (σ_{ck}).

$$\sigma_{ck}^1 = \sigma_{ck} + t \times s$$

s = standard deviation, and t = a statistic, depending upon the accepted proportion of low results and the number of tests; for large number of tests

- a) Volume of concrete = 1 m³
- b) Volume of cement = (386.36 / 3.13) x (1 / 1000) = 0.123 m³
- c) Volume of water = (170 / 1) x (1 / 1000) = 0.17 m³
- d) Total volume = [1 - (0.123 + 0.170)] = 0.707 m³
- e) Weight of Coarse aggregate = 0.707 x 0.65 x 2.78 x 1000 = 1277.55 Kg
- f) Weight of Fine aggregate = 0.707 x 0.35 x 2.74 x 1000 = 678.01 Kg

Cement Kg	Fine aggregate Kg	Coarse aggregate Kg	w/c ratio
386.36	678.01	1277.55	170
1	1.75	3.31	0.44

Procedure:

Casting of Specimens

The standard cast iron moulds are used for casting. The moulds are cleaned of dust particles and the bolt and nuts are well tightened to avoid the water loss. The moulds are applied with mineral oil on all sides before concrete is poured in to the moulds. The moulds are placed on a level platform. For Compressive strength test – Cube, For Split tensile strength – Cylinder and for flexure strength – Prism is used. An average of three specimens is taken for all mixes.

S.No.	Cube (mm)	Cylinder (mm)	Prism (mm)
1	150 x 150 x 150	150mm dia x 300mm	100 x 100 x 500

Curing Of Specimens

After casting for about 24 hours the specimens are left in the moulds undisturbed at room temperature. The specimens are then removed from the moulds and immediately kept in normal water for curing. The specimens are fully immersed in the water. In this experimental study the specimens are left in curing for 7 days and 28 days.

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Fig. 1: Curing of Specimens

Compression Testing Machine

The compression testing machine used for testing the cube specimens is of standard make. The capacity of the testing machine is 2000 KN. The machine has a facility to control the rate of loading with a control valve. The plates are cleaned and oil level is checked, and kept ready in all respects for testing. After the required period of curing, the cube specimens are removed from the curing tubs and cleaned to wipe off the surface water. It is placed on the machine such that the load is applied centrally. The smooth surfaces of the specimen are placed on the bearing surfaces. The top plate is brought in contact with the specimen by rotating the handle. The oil pressure valve is closed and the machine is switched on. A uniform rate of loading 140 kg/sq.cm/min.



Fig.2: Compressive Strength Testing Machine

Split Tensile Strength Test on Concrete Specimens

The test consists of applying a compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the compressive platens. Due to the compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter as obtained from an elastic analysis. Specimens were removed from the moulds after 24 hours and cured. After curing, Cylinder specimens of different percentages of ceramic waste and metakaolin were tested under compression testing machine in accordance with IS:516 after a curing period of 7 days & 28 days. After required curing period the cylinder specimens are removed from the curing tubs and cleaned to wipe off the surface water. Draw diametrical lines on each end of the specimen using a suitable device that will ensure that they are in the same axial plane. Determine the diameter of the test specimen by averaging three diameters, Determine the length of the specimen by averaging at least two length measurements. Position the bearing strips, test cylinder, and supplementary bearing bar by means of the aligning jig, and centre the jig so that the supplementary bearing bar and the centre of the specimen are directly beneath the centre of thrust of the spherical bearing block. Apply the load continuously and without shock, at a constant rate within the range 689 to 1380 kPa/min (100 to 200 psi/min) splitting

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tensile stress until failure of the specimen, record the maximum applied load indicated by the testing machine at failure, note the type of failure and the appearance of the concrete.



Fig.3: Split Tensile Testing Machine

Flexural Strength Test on Concrete Specimens

The flexural strength is expressed as Modulus of Rupture in psi (MPa) and is determined by standard test methods ASTM C 78 (third-point loading) or ASTM C 293 (centre-point loading). The Modulus of Rupture determined by third-point loading is lower than the Modulus of Rupture determined by centre-point loading, Specimens were removed from the moulds after 24 hours and cured .After curing, Prism specimens of different percentages of ceramic waste and metakaolin were tested under flexural test machine in accordance for 7days, 28 days. After required curing period the cylinder specimens are removed from the curing tubs and cleaned to wipe off the surface water whilst they are still wet. The test specimen shall be placed in the machine correctly centred with the longitudinal axis of the specimen at right angles to the rollers. The load shall be applied at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens. Note the value of reading.

V. RESULTS AND DISCUSSIONS

Compressive Strength Studies:

For Compressive strength test standard cube size of 150mm x 150mm x 150mm are used. An average of three specimens is taken for all mixes after a curing period of 7 days & 28 days.

Compressive Strength at 7 Days (MPa)

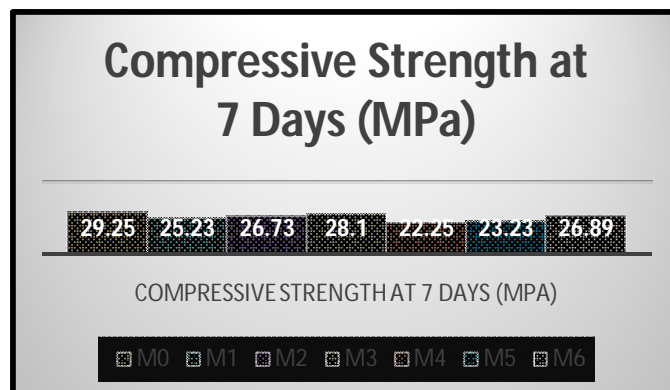


Fig. 4: Compressive Strength at 7 days

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The 7 day compressive strength of concrete with different percentages of Metakaolin, Fly Ash and Ceramic waste are shown in Fig.4. M1, M2, M3, M4, M5 and M6 is decreased by 0.06%, 0.17%, 0.23%, 1.78%, 0.25% and 1.45% compared with M0 control concrete mix.

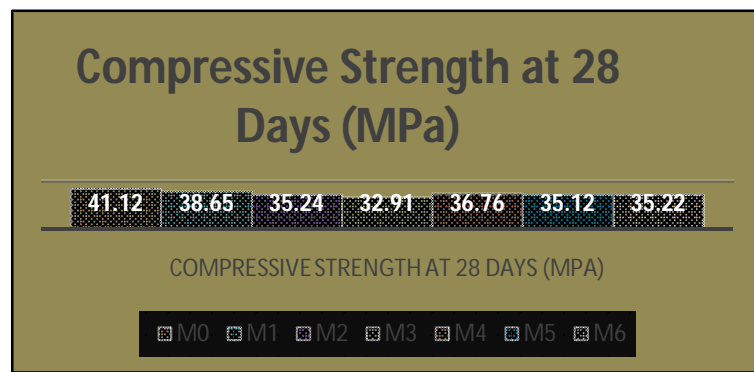


Fig. 5: Compressive Strength at 28 days

The 28 day compressive strength of concrete with different percentages of Metakaolin and Ceramic waste are shown in Fig.5. M1, M2, M3, M4, M5 and M6 is decreased by 2.37%, 1.32%, 2.46%, 4.36%, 6.0% and 4.90% compared with control concrete mix M0.

Split Tensile Strength Studies

For split tensile strength test standard cylinder size of dia 150mm and height of 300mm are used. An average of three specimens is taken for all mixes after a curing period of 7 days & 28 days.

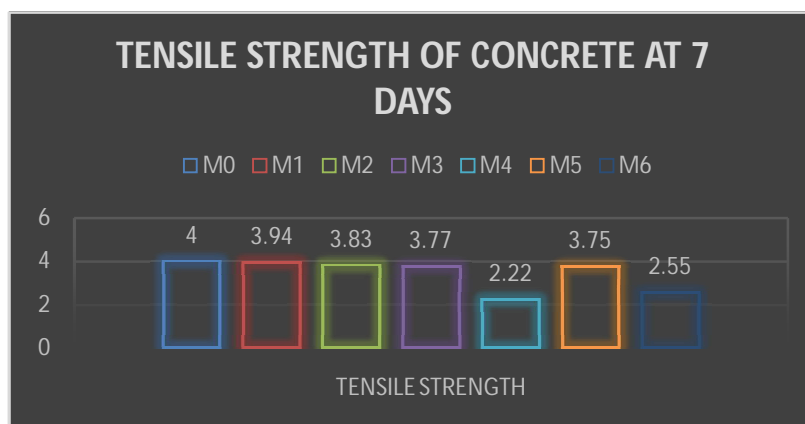


Fig: 6 Split Tensile strength at 7 days Vs % replacement with Metakaolin, Fly Ash & Ceramic waste

The 7 day Split tensile strength of concrete with different percentages of Metakaolin, Fly Ash and Ceramic waste are shown above in Fig.6. M1, M2, M3, M4, M5 and M6 is decreased by 1.50%, 4.28%, 5.75%, 3.50%, 9.0% and 11.5% compared with control concrete mix M0.

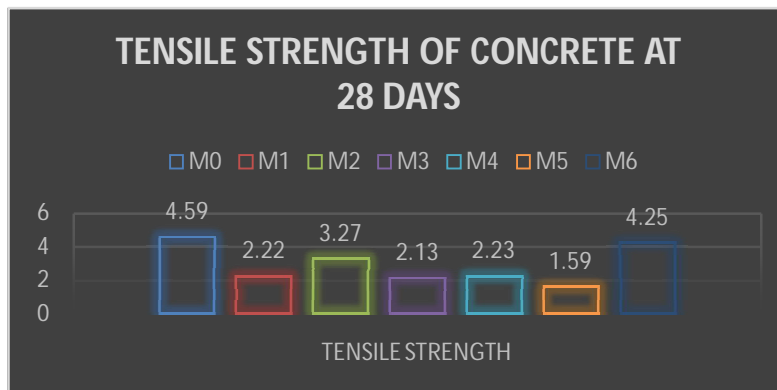


Fig: 7 Split Tensile strength at 7 days Vs % replacement with Metakaolin, Fly Ash & Ceramic waste

The 28 day Split tensile strength of concrete with different percentages of Metakaolin, Fly Ash and Ceramic waste are shown in Fig.7. M1, M2, M3, M4, M5 and M6 is decreased by 1.63%, 0.47%, 3.70%, 3.00%, 4.9% and 7.23% compared with control concrete mix M0.

Flexural strength Studies

For Flexural strength test standard prism of size 100mm x 100mm x 500mm are used. An average of 3 specimens is taken for all mixes after a curing period of 7 days & 28 days

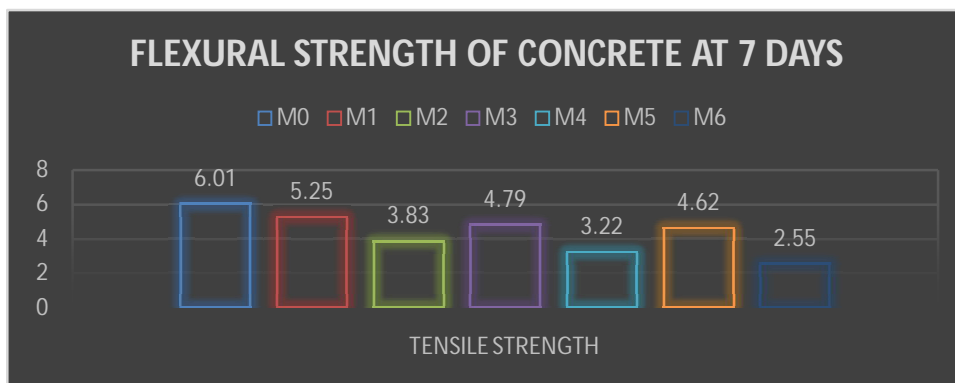


Fig: 8 Flexural strength at 7 days Vs % replacement with Metakaolin, Fly Ash & Ceramic waste

The 7 day Flexural strength of concrete with different percentages of Metakaolin and Ceramic waste are shown in Fig.8. M1, M2, M3, M4, M5 and M6 is decreased by 0.76%, 2.18%, 1.23%, 1.22%, 2.79% and 2.46% compared with control concrete mix M0.

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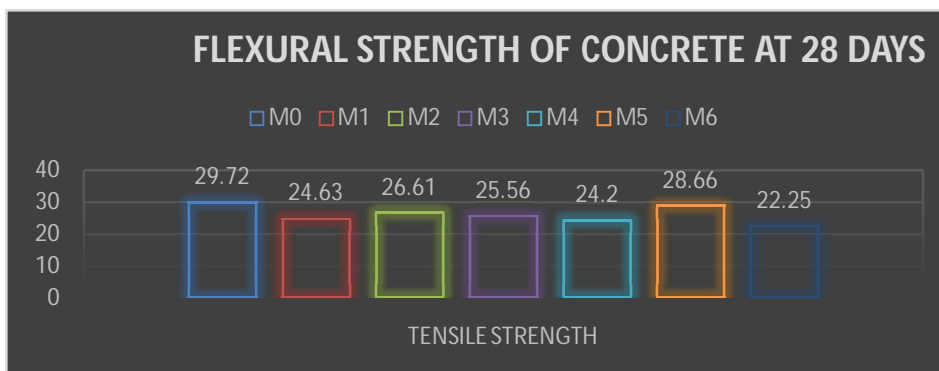


Fig: 9 Flexural strength at 28 days Vs % replacement with Metakaolin, Fly Ash & Ceramic waste

The 28 day Flexural strength of concrete with different percentages of Metakaolin and Ceramic waste are shown in Fig. 9. M1, M2, M3, M4 M5 and M6 is decreased by 5.09%, 3.11%, 4.16% , 5.52% and 7.47% compared with control concrete mix M0.

VI. CONCLUSIONS

- The compressive strength at the age of 7 days and 28 days is less than the conventional mix, but it is slightly more than the target mean strength of design mix M30 grade concrete.
- The split tensile strength at the age of 7 days and 28 days is less when compared to conventional mix,
- The flexural strength at the age of 7 days and 28 days is less when compared to conventional mix, but it is more than that of Modulus of Rupture of design concrete mix M30. By this experimental study we can reduce the cost of concrete. Now a day's river sand price is gradually increasing by replacing it with ceramic waste there will be economical benefit and the natural resource (River sand) is also saved.

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