

A Study on Strength of Concrete by Partial Replacement of Cement with Metakaolin and Fine Aggregate with Stone Dust

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ABSTRACT: This paper presents an experimental investigation on the strength properties of concrete prepared by the partial replacement of cement with Metakaolin (MK) with varying percentages 10%, 15%, 20% and fine aggregate is partially replaced with Stone Dust (SD) at 30%, 60% and 100%. The combined influence of Metakaolin and Stone Dust on compressive strength, split tensile strength, flexural strength and modulus of elasticity of M30 grade of concrete is investigated. The test results of concrete prepared using various combinations of Stone Dust and Metakaolin are compared with that of controlled concrete. Based on the test results, it can be observed that the concrete prepared with a combination of 15% Metakaolin and 60% Stone Dust possesses improved properties compared to the controlled concrete.

KEYWORDS: Metakaolin, Stone Dust, Partial Replacement, Compressive Strength, Split Tensile Strength, Flexural Strength and Modulus of Elasticity.

I. INTRODUCTION

Concrete is a mixture of binding material, coarse aggregate and fine aggregates and water. It is a versatile construction material due to its reasonable cost and easy availability. The increase in the various construction activities utilizes more natural resources like sand and coarse aggregate. During the process of coarse aggregate production in crushing plants, huge quantity of stone dust is produced which is considered worth less for any substantial use. This stone dust being a waste material, an attempt has been made for the use of stone dust as partial replacement of sand for the preparation of concrete. This will result in conservation of natural resources up to some extent. The presence of stone dust in concrete increases the water demand. Every year 200-400 tons of stone dust is generated by the stone crusher plants and is dumped as waste leading to serious environmental and dust pollution. So it is necessary to dispose the stone dust waste quickly and efficiently. An experimental program was carried out to determine the influence of stone dust on the strength properties of concrete. The manufacture of cement results in CO₂ emission and as a consequence of the green house effect. Hence, one of the solutions to the problem is to reduce the consumption of cement and utilize Pozzolana materials for the preparation of concrete. Previous studies indicates that the use of Fly Ash, Silica Fume, Metakaoline, Ground Granulated Blast Furnace Slag as partial replacement of cement. Metakaolin is a supplementary cementitious material with pozzolanic and micro-filler characteristics. Metakaolin when used as a partial replacement substance for cement in concrete, reacts with Ca(OH)₂ one of the by-products of hydration reaction of cement and results in additional C-S-H gel which results in increased strength. Hence, by partially replacing Portland cement with Metakaolin not only reduces carbon dioxide emission into the atmosphere but also increases the service

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life of buildings. In this experimental investigation the influence of Metakaolin and Stone Dust on strength properties of concrete are investigated.

II.OBJECTIVE

The objective of the present research work is to study the influence of the combined application of Metakaolin and Stone Dust on various strength properties of concrete. Cement is replaced with 10% 15% and 20% of Metakaolin by weight and Fine aggregate is replaced with 30%, 60%, and 100% of Stone Dust by weight. The Compressive Strength, Split Tensile Strength, Flexural Strength and Modulus of Elasticity of concrete are to be obtained and the results are compared with the controlled concrete.

III.EXPERIMENTAL PROGRAMME

A. PROPERTIES OF MATERIALS

B. CEMENT

In the present investigation Ordinary Portland cement (OPC) of 53 Grade confirming to IS specifications was used.

C. FINE AGGREGATE

Locally available river sand confirming to IS specifications was used as the fine aggregate for the preparation of concrete. The properties of fine aggregate are shown in Table 1.

Table 1: Properties of Fine Aggregate

S.No	Property	Values
1	Specific Gravity	2.56
2	Fineness Modulus	2.60
3	Grading of Sand	Zone – II

D. COARSE AGGREGATE

Coarse aggregate of nominal size 20 mm and 12.5 mm, obtained from the local quarry confirming to IS specifications was used. The properties of coarse aggregate are shown in Table 2.

Table 2: Properties of Coarse Aggregate

S.No	Property	Result
1	Specific Gravity	2.61
2	Water Absorption	0.40 %

E. STONE DUST:

The stone dust used in the investigation is obtained from the quarry at Chandragiri near Tirupati, Andhra Pradesh. The properties of Stone dust are shown in Table 3.

Table 3: Properties of Stone Dust

S.No	Property	Result
1	Specific Gravity	2.55
2	Fineness Modulus	3.3
3	Grading	Zone – I

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F. METAKAOLIN

Metakaolin used in this present experimental study is obtained from ASTRRA chemicals, Chennai. Physical and chemical properties of the Metakaolin are shown in the Table 4 and Table 5.

Table 4: Physical Properties of Metakaolin

Properties	Value
Density (gm/cm ³)	2.17
Bulk density (gm/cm ³)	1.26
Particle shape	Spherical
Colour	Half-white
Specific gravity	2.1

Table 5: Chemical Properties of Metakaolin

Constituents	Values
Silica	53%
Alumina	43%
Iron Oxide	0.5%
Calcium Oxide	0.1%
Sulphate	0.1%
Sodium Oxide	0.05%
Potassium Oxide	0.4%

G. WATER

Water used for casting and curing of concrete test specimens is free from impurities which when present can adversely affect the strength of concrete.

B. CONCRETE MIX PROPORTION

M30 grade of concrete was designed as per the Indian Standard code of practice. The various combinations of the ingredients required for one cubic meter of concrete are shown in Table 6.

Table 6: Quantities of Ingredients per cum of M30 Grade Concrete

S.No	Cement (%)	Meta kaolin (%)	Stone Dust (%)	Water (lit)	Cement (kg)	Meta kaolin (kg)	Fine Aggregate (kg)	Stone Dust (kg)	Coarse Aggregate (kg)
1	100	0	0	146.25	325	0	710	0	1262
2	100	0	100	146.25	325	0	0	710	1262
3	100	0	60	146.25	325	0	284	426	1262
4	100	0	30	146.25	325	0	496	213	1262
5	90	10	30	146.25	292.50	32.50	496	213	1262
6	85	15	30	146.25	276.25	48.75	496	213	1262
7	80	20	30	146.25	260.00	65.00	496	213	1262
8	90	10	60	146.25	292.50	32.50	284	426	1262
9	85	15	60	146.25	276.25	48.75	284	426	1262
10	80	20	60	146.25	260.00	65.00	284	426	1262

C. TEST SPECIMENS

Concrete test specimens consist of 150 mm × 150 mm × 150 mm cubes, cylinders of 150 mm diameter and 300 mm height and 100 mm × 100 mm × 500 mm prisms. Concrete cubes were tested at different curing periods 3, 7, 28, 56 and 90 days to get the compressive strength. Cylindrical specimens were also tested at the age of 28 days to obtain the split tensile strength of concrete. The prisms were tested to obtain the flexural strength of concrete. The rate of loading is as per the Indian Standard specifications.

IV. RESULTS AND DISCUSSION

A. COMPRESSIVE STRENGTH

The variation of the cube compressive strength with age of M30 grade concrete for various combinations of Stone Dust and Metakaolin for different curing periods is shown in Fig.1, Fig.2 and Fig.3. The cube compressive strength indicates the average of three test results. It can be observed that the compressive strength of concrete containing Stone Dust and Metakaolin exhibits more strength than the control concrete up to 15% of Metakaolin and with further increase in Stone Dust the strength decreases for the given Stone dust content.

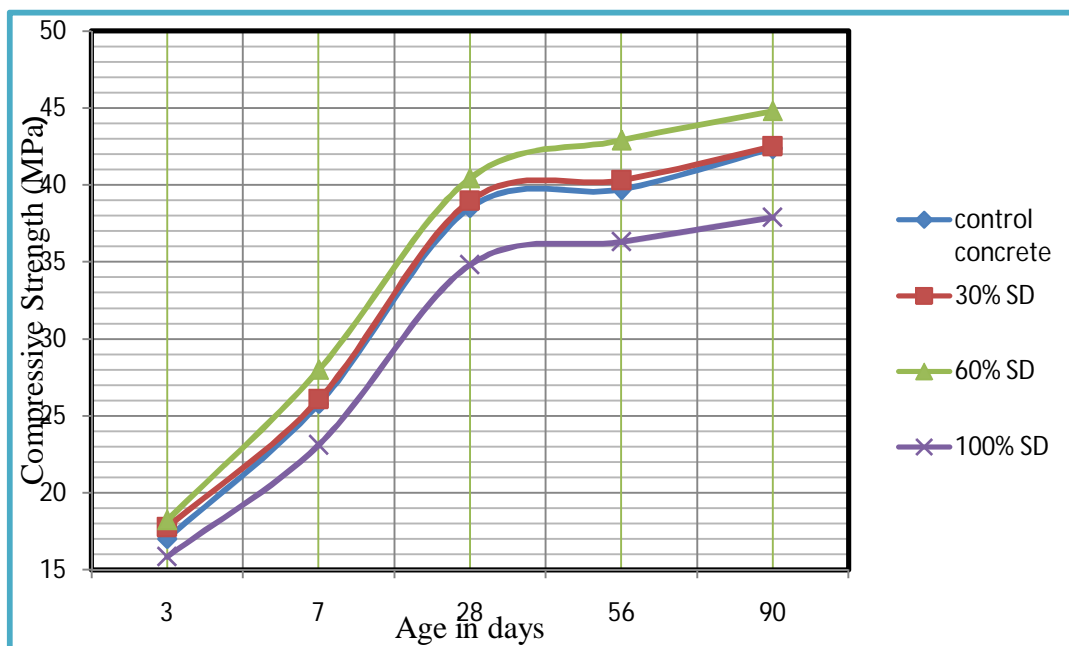


Fig. 1: Variation of Compressive Strength of Concrete with different percentages of Stone Dust

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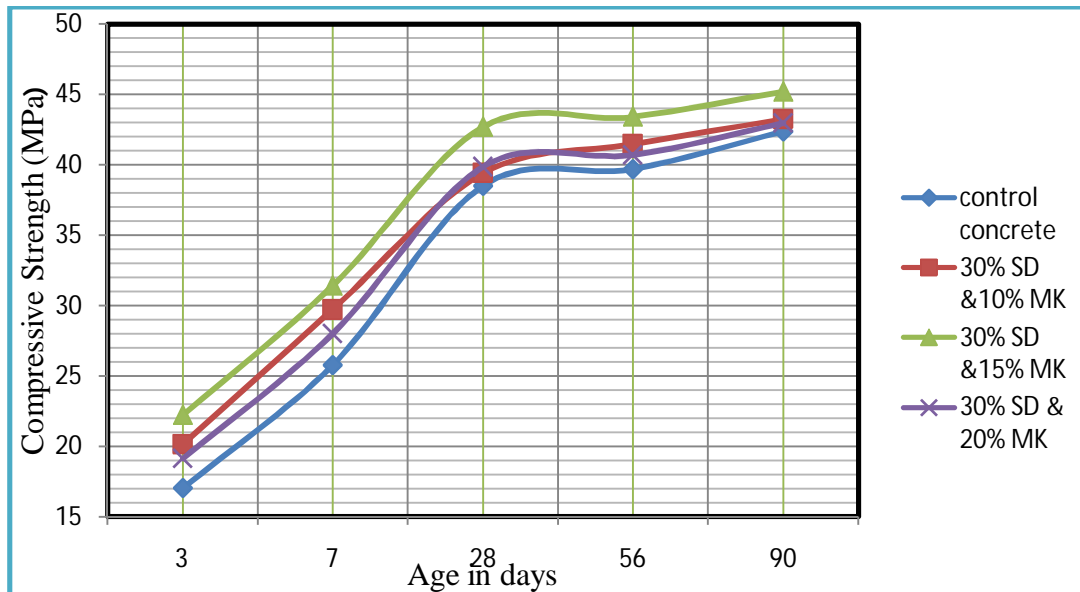


Fig. 2: Variation of Compressive Strength of Concrete containing 30% Stone Dust and Different percentages of Metakaolin

The cube compressive strength indicates the average of three test results. It can be observed that the compressive strength of concrete containing Stone Dust and Metakaolin exhibits more strength than the control concrete up to 15% of Metakaolin and with further increase in Stone Dust the strength decreases for the given Stone dust content.

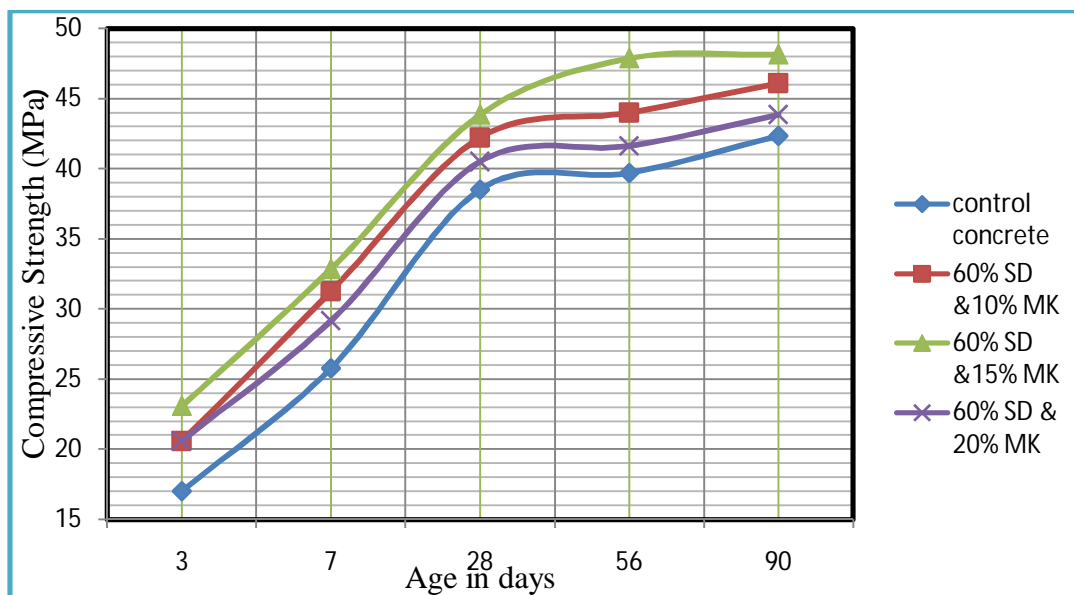


Fig. 3: Variation of Compressive Strength of Concrete containing 60% Stone Dust and Different percentages of Metakaolin

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B. SPLIT TENSILE STRENGTH

The variation of split tensile strength of M30 grade of concrete with Metakaolin and various percentages of Stone Dust is shown in Fig. 4. The split tensile strength of concrete initially increased up to 15% of Metakaolin for any given percentage of Stone Dust and beyond which the strength decreases with increase in the Metakaolin. It can also be observed that at a combination of 15% of Metakaolin and 60% Stone Dust maximum split tensile strength can be obtained.

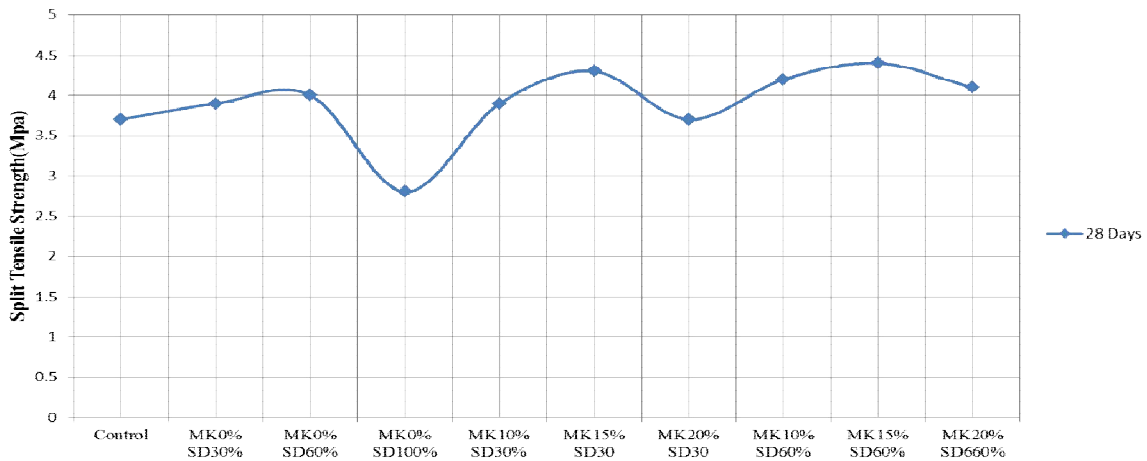


Fig. 4: Variation of Split Tensile Strength of M30 Grade of Concrete with different percentages of Metakaolin and Stone Dust

C. FLEXURAL STRENGTH

The variation of flexural strength of M30 grade of concrete containing various percentages of Stone Dust and Metakaolin is shown in Fig 5. The flexural strength of concrete initially increases up to 15% of Metakaolin for different percentage of Stone Dust and then with further increase in the Metakaolin the flexural strength decreases. Hence, the recommended combination for maximum flexural strength is 15% of Metakaolin and 60% Stone Dust.

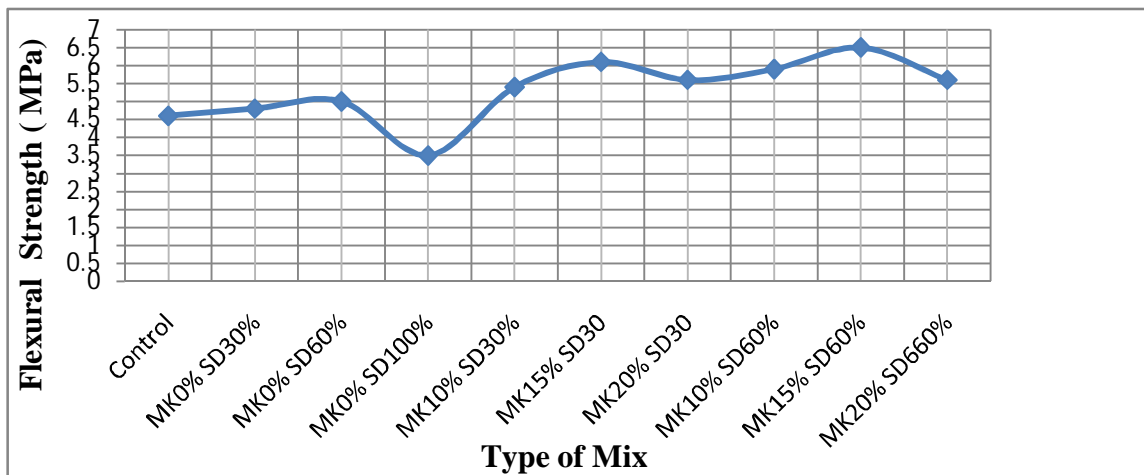


Fig. 5: Variation of Flexural Strength of M30 Grade of Concrete with Different Percentages of Metakaolin and Stone Dust

D. MODULUS OF ELASTICITY

Fig.6 shows the variation of modulus of elasticity of M30 grade concrete with various percentages of Metakaolin and Stone Dust. It can be observed that the modulus of elasticity of concrete increases with Metakaolin for the given content of Stone Dust. The maximum value modulus of elasticity can be obtained at 15% Metakaolin for the given content Stone Dust.

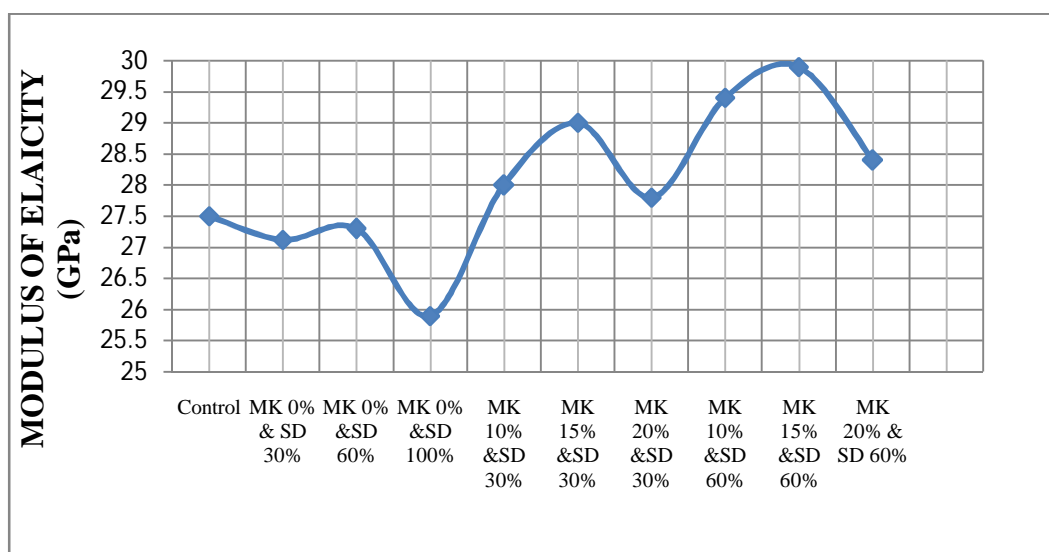


Fig. 6: Variation of Modulus of Elasticity of M30 Grade of Concrete with Different Percentages of Metakaolin and Stone Dust

V.CONCLUSIONS

1. The results of the experimental investigation indicate the combined application of Stone Dust and Metakaolin can be adopted as partial replacement of natural sand and Ordinary Portland cement.
2. Using the test results, it can be concluded that with the increase in the percentage of Metakaolin the various strength characteristics of concrete also increased up to 15%, with further increase in Metakaolin the strength characteristics of concrete are decreased for various percentages of Stone Dust.
3. The increase in various strength characteristics of concrete containing Metakaolin can be attributed to the availability of additional C-S-H gel in the presence of Metakaolin.
4. For a given percentage of Stone Dust as the content of Metakaolin increased the strength properties of concrete also increased up to 15% and then decreased. The optimum results were obtained at 60% of Stone Dust and 15% of Metakaolin.

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