

An Experimental Investigation on Various Properties of Concrete by Partial Replacement of Cement with Metakaolin and Sand with Vermiculite

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ABSTRACT: The present research work has been carried out to evaluate the feasibility of utilization of Vermiculite as fine aggregate in concrete and Metakaolin as Partial Cement Replacement to enhance the strength characteristics of concrete. The concrete mix design is done for M35 grade concrete. The mix is prepared for different combinations of 5%, 10% & 15% of replacement of Fine Aggregate by Vermiculite with 5%, 10% & 15% of Metakaolin as Partial Cement Replacement. The mechanical & Durable properties were compared with control mix. Results of Compressive strength, Split Tensile Strength, Flexural Strength, Modulus of Elasticity & Chlorine Attack tests will be compared and tabulated.

It can be observed that the compressive strength of concrete prepared by replacing Vermiculite (V) & Metakaolin (M) as replacement of Fine Aggregate and Cement exhibits improved Compressive Strength individually. Combined application of Vermiculite (10%) & Metakaolin (10%) shows 20.24% improved Compressive Strength compared to Controlled Concrete. Same combination gave improved results in all Mechanical and Durability properties. There is 14% increase in Split Tensile strength, 15.14 % in Flexural Strength and 10.14% in Modulus of Elasticity.

KEYWORDS: Vermiculite, Metakaolin, Partial Replacement, Particle Packing and Strength of Concrete, Combination and Strength of Concrete.

I. INTRODUCTION

The advance in the open field of Construction Industry represents a huge step towards for making cement mortar a high tech material with enhanced characteristics. The material like sand is becoming scarce as huge amounts of construction works is taken up as the population is growing on year by year. In India, especially Andhra Pradesh which was recently separated from Telangana is posing a wide need for expression of several structures at capital and other urban centers. Therefore, alternative material for sand like vermiculate is to be assessed analyzed and recommended as a desirable material for construction works. Mortar is a broadly used construction substance for different types of construction due to its stability and strength. The exercise, operation as well as the strength of mortar, built in the period of the last half of the century with an arrangement of ordinary Portland cement and fine aggregate. The fine aggregate is one of the primary ingredients used for the production of mortar and has no alternative in the civil construction industry. The search for any such materials, which can be used as an option or as a supplement for fine aggregate should lead to more benefits.

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II. OBJECTIVE

The main objective of the present experimental investigation is to obtain the 1. Effect of combined application of Metakaolin (MK) and Vermiculite (V) on Compressive Strength, Flexural Strength and Split Tensile Strength of concrete. □ Dosages of the Metakaolin used is 5%, 10 % & 15 % of the total cementitious material.

- Dosages of the Vermiculite used are 5 % , 10 % & 15 % of the Fine Aggregate.
- Conventional Concrete
- Vermiculite (5%) + Metakaolin (5%)
- Vermiculite (5%) + Metakaolin (10%)
- Vermiculite (5%) + Metakaolin (15%)
- Vermiculite (10%) + Metakaolin (5%)
- Vermiculite (10%) + Metakaolin (10%)
- Vermiculite (10%) + Metakaolin (15%)
- Vermiculite (15%) + Metakaolin (5%)
- Vermiculite (15%) + Metakaolin (10%)
- Vermiculite (15%) + Metakaolin (15%)

III. EXPERIMENTAL INVESTIGATION

3.10 PROPERTIES OF MATERIALS

3.11 CEMENT

In the present investigation Ordinary Portland Cement (OPC) of 53 Grade confirming to IS specifications was used. The properties of cement are shown in Table.1.

Table 1. Properties of Cement

S. No	Characteristics	Test results	Requirements as per IS 12269 – 1987
1	Fineness (retained on 90- μ m sieve)	5.94 %	<10%
2	Normal Consistency	33 %	--
3	Initial setting time of cement	54 min 's	30 minutes (minimum)
4	Final setting time of cement	470 min 's	600 minutes (maximum)
5	Expansion in Le-chatelier's method	4 mm	10 mm (maximum)
6	Specific gravity	3.14	3.10 – 3.25

3.12 FINE AGGREGATE

Locally available river sand confirming to IS specifications was used as the fine aggregate in the concrete preparation. The properties of fine aggregate are shown in Table.2.

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Table 2. Properties of Fine Aggregate

S.No	Property	Value
1	Specific Gravity	2.62
2	Fineness Modulus	3.05
3	Bulk Density (Loose)	14.50 kN/m ³
4	Grading of Sand	Zone – I

3.13 COARSE AGGREGATE

Crushed granite metal of nominal size 20 mm and 10 mm obtained from the local quarry and confirming to IS specifications were used. The properties of coarse aggregate are shown in Table.3. The coarse aggregate used for the preparation of concrete is a combination of 20 mm and 10 mm size aggregates in ratio 1.5: 1.0.

Table3. Properties of Coarse Aggregate

S.No	Property	Result
1	Specific Gravity	2.67
2	Bulk Density (Loose)	14.80 kN/m ³
3	Water Absorption	1.2 %
4	Fineness Modulus	7.52

3.14 VERMICULITE

The vermiculite used for this work was obtained from Om Santhi Enterprises, jogipalli, SPSR Nellore (Dt). The vermiculite applies to a group of mineral is characterized by their power to inflate into a long, worm –like strands when heated. It's Physical and Chemical Properties are as shown in Table 4 & Table 5.

Table 4. Physical Properties of vermiculite

S.No	Physical Property	Value
1	Melting Point (in Degrees)	1330
2	Specific Heat (1 Kj / Kg. k)	1.08
3	Specific Gravity (Crude)	2.5
4	Mohs Hardness (Crude)	1-2
5	pH (ISO787-9)	7-8
6	% loss at 105 ⁰ (expanded product)	< 0.5
7	% loss at 1000 ⁰ (expanded product)	< 6
8	Colour	White, Yellow, Brownish Black
9	Category	Phyllo Silicates

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Table 5. Chemical Properties of vermiculite

S.No	Chemical Content	%
1	Silicon	39.4
2	Magnesium	25.2
3	Aluminium	8.8
4	Potassium	4.5
5	Iron	4
6	Calcium	1.8
7	Carbonate	1.4
8	Titanium	0.8
9	Fluorine	0.5

3.15 METAKAOLIN:

Metakaolin is obtained by calcination of pure or refined kaolin clay at a temperature between 6500C and 8500C, followed by grinding to achieve a fineness of 15000 m²/kg. The specific gravity is found as 2.50. The resulting material has high pozzolanic property. The properties of Metakaolin are shown in Table 6.

Table 6. Pozzolanic Reactivity Properties of Metakaolin

Material	Pozzolanic Reactivity mg Ca(OH) ₂ per g
Blast furnace slag	40
Calcined paper waste	300
Micro silica, silica fume	427
Calcined bauxite	534
Pulverized fuel ash	875
High reactivity Metakaolin	1050

3.16 WATER

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

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3.17 CONCRETE MIX PROPORTION

The concrete mix design was proposed by using Indian Standard for control concrete. The grade was M35. The mixture will be prepared with the cement content of 350 kg/m³ and water to cement ratio of 0.45. The mix proportion of materials is 1:2.12:3.39 as per IS 10262-2009.

3.20 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 cube specimens were tested at 3, 7, 28, 56 & 90 days of curing to obtain the compressive strength of concrete. Cylindrical specimens were tested at the age of 28 days to obtain the compressive strength, split tensile strength and Modulus of Elasticity of concrete. The prisms were tested at the age of 28 days to obtain the flexural strength of concrete. The rate of loading is as per the Indian Standard specifications. Acid attack test is also performed for durability.

IV. RESULTS AND DISCUSSIONS

4.10 COMPRESSIVE STRENGTH

The variation of the cube compressive strength with the age of M35 grade concrete prepared using the various proportions of Vermiculite and Metakaolin is shown in Fig.1. The Cube Compressive Strength of Controlled Concrete is compared with various proportions of Vermiculite (5%, 10% & 15%) and Metakaolin (5%, 10% & 15%) with different proportions of Vermiculite are represented in Fig No. 1. It can be observed that the Concrete with Vermiculite (10%) & Metakaolin (10%) expresses higher Compressive Strength compared to other mixes.

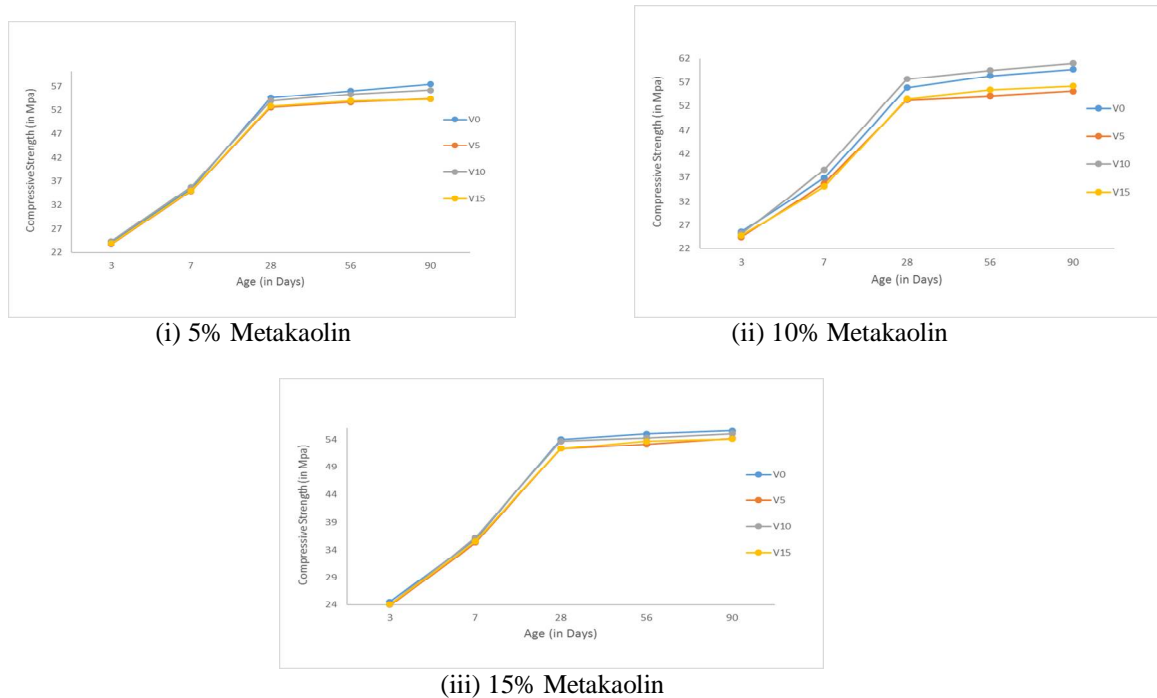


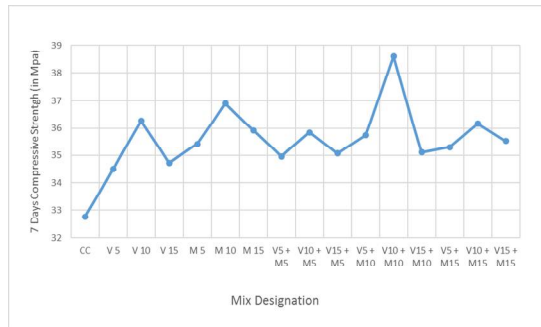
Fig. 1. Variation of Cube Compressive Strength of M35 Grade Concrete with age for different percentages of Vermiculite and Metakaolin.

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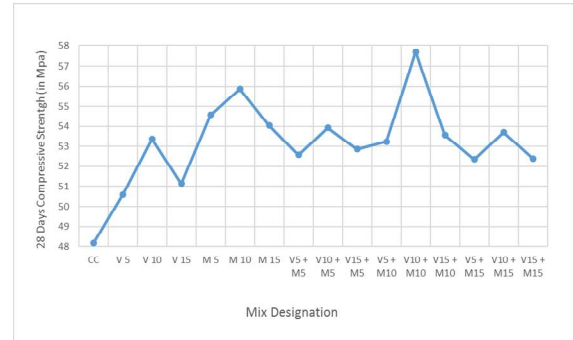
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(i) 7 Days Compressive Strength



(ii) 28 Days Compressive Strength

Fig. 2. Variation of 7 – Days & 28 Days Cube Compressive Strength of M35 Grade Concrete for different percentages of Vermiculite and Metakaolin.

4.20 SPLIT TENSILE STRENGTH

The variation of the Split Tensile strength of M35 grade concrete prepared using the different percentages of Vermiculite and Metakaolin is shown in Fig.3. The Split tensile strength of Control concrete is 4.50 MPa. It is observed that all the replacements & admixtures exhibits improved Strength Characteristics compared to Control Concrete, But the Optimum mix of Vermiculite (10%) & Metakaolin (10%) resulted in significant improvement with 14 % more than Control Concrete

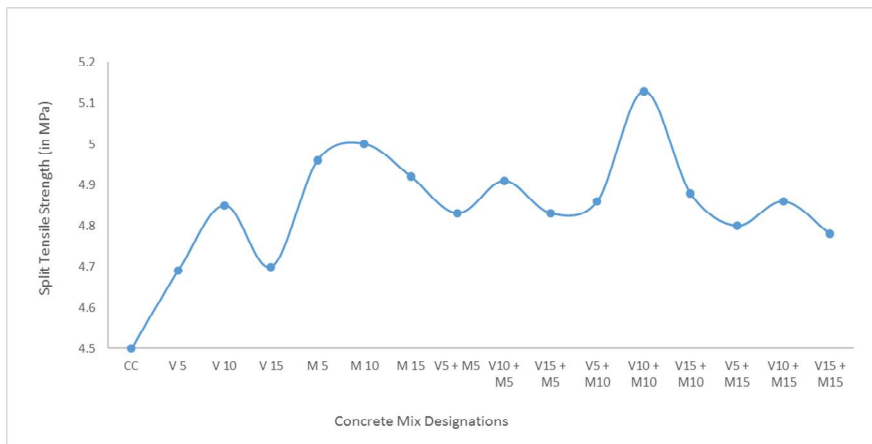


Fig. 3. Variation of Split Tensile strength of M35 grade concrete prepared using the different percentages of Vermiculite and Metakaolin.

4.30 FLEXURAL STRENGTH

The variation of the Flexural strength of M35 grade concrete prepared using the different percentages of Vermiculite and Metakaolin is shown in Fig.4. The Flexural strength of Control concrete is 7 MPa. It is observed that all the replacements & admixtures exhibits improved Strength Characteristics compared to Control Concrete, But the Optimum mix of Vermiculite (10%) & Metakaolin (10%) resulted in significant improvement with 15.14 % more than Control Concrete

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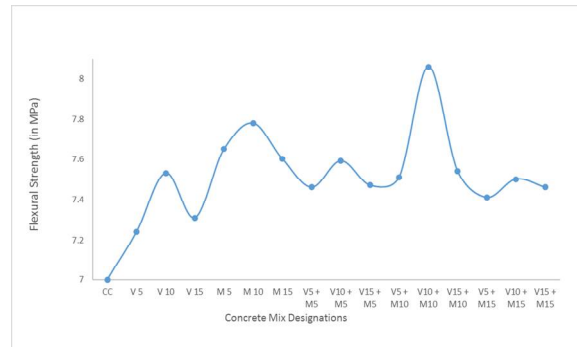


Fig. 4. Variation of Flexural strength of M35 grade concrete prepared using the different percentages of Vermiculite and Metakaolin..

4.40 MODULUS OF ELASTICITY

The variation of the Modulus of Elasticity of M35 grade concrete prepared using the different percentages of Vermiculite and Metakaolin is shown in Fig.5. The Modulus of Elasticity of Control concrete is 29.22 Gpa. It is observed that all the replacements & admixtures exhibits improved Strength Characteristics compared to Control Concrete, But the Optimum mix of Vermiculite (10%) & Metakaolin (10%) resulted in significant improvement with 15.14 % more than Control Concrete

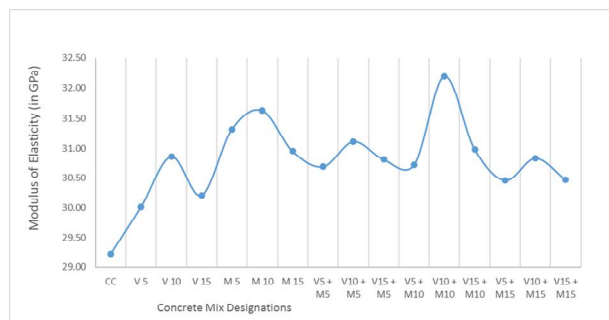


Fig. 5. Variation of Modulus of Elasticity of M35 grade concrete prepared using the different percentages of Vermiculite and Metakaolin

4.50 SULPHATE RESISTANCE

The variation of the Loss in Compressive Strength & Loss of Weight of M35 grade concrete prepared using the different percentages of Vermiculite and Metakaolin is shown in Fig.6. The Loss of Weight (%) is minimum for combined proportion of Vermiculite (10%) & Metakaolin (10%) when compared to other proportions and Control Concrete. The Loss of Compressive Strength (%) is minimum for combined proportions of Vermiculite (10%) & Metakaolin (10%) & Vermiculite (10%) & Metakaolin (15%) when compared to other proportions and Control Concrete

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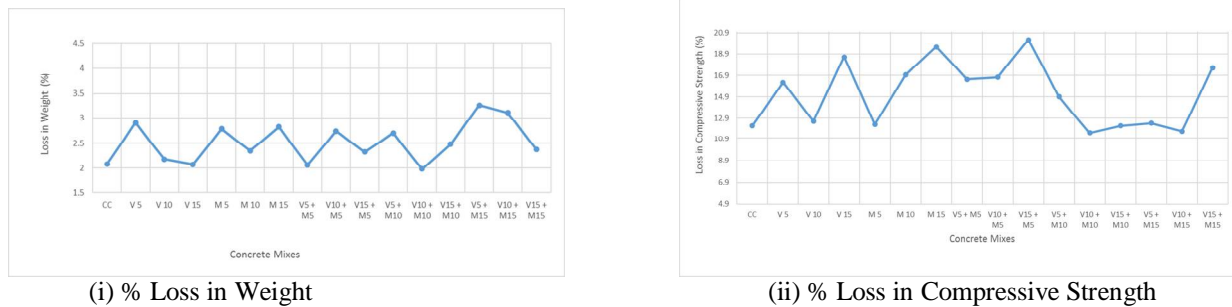


Fig. 6. Variation of Loss in Compressive Strength & Loss of Weight of M35 grade concrete prepared using the different percentages of Vermiculite and Metakaolin

V. CONCLUSIONS

It can be observed that the compressive strength of concrete prepared by replacing Vermiculite (V) & Metakaolin (M) as replacement of Fine Aggregate and Cement exhibits improved Compressive Strength individually. Combined application of Vermiculite (10%) & Metakaolin (10%) shows 20.24% improved Compressive Strength compared to Controlled Concrete. Similar trend can be observed in the case of Split Tensile Strength, There is 14% increase in Split Tensile strength in Concrete with Vermiculite (10%) & Metakaolin (10%) when compared to Control Concrete. The Flexural strength of Control concrete is 7 MPa. It is observed that all the replacements & admixtures exhibits improved Strength Characteristics compared to Control Concrete, But the Optimum mix of Vermiculite (10%) & Metakaolin (10%) resulted in significant improvement with 15.14 % more than Control Concrete. In case of Modulus of Elasticity, Optimum mix of Vermiculite (10%) & Metakaolin (10%) resulted in significant improvement with 10.14 % more than Control Concrete. The Loss of Weight (%) & Loss of Compressive Strength (%) during the Sulphate Attack is minimum for combined proportion of Vermiculite (10%) & Metakaolin (10%) when compared to other proportions and Control Concrete.

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