Experimental Investigation of Partial Replacement of Metakaolin, Silica Fume and M-Sand based Concrete

Dakshnamoorthy. D¹, Gunasekaran. P², Vivekanananthan.C³, Kavitha.A⁴, Saravanan.G⁵
¹,²,³,⁴,⁵Post Graduate Student, Department of Civil Engineering, Prist University, Trichy-Thanjavur Highway,Vallam, Thanjavur, INDIA

ABSTRACT

The addition of pozzolanic materials on concrete may reduce the usage of cement on the concrete. Some pozzolanic materials like metakaolin, silica fume are used at certain percentage instead of cement. The sand plays the vital role on the concrete, but now a day due to some socio-economic problems the production of natural sand was reduced at the same time the cost of natural sand was increased. To balance this problem there would be a suitable replacement for the sand is needed. Such replacement is the Manufacturing sand, simply called as M-sand. Hereby the metakaolin and silica fume are added instead of cement at certain percentage and M-sand is used instead of natural sand at 100%. The metakaolin and silica fume are added on the cement individually as well as mixed state in different combinations. The main theme of this project is to find the strength and durability characteristics of the hardened concrete at these host materials on the concrete on various proportions.

Keywords--- Metakaolin, Silicon, Sorptivity test

I. INTRODUCTION

Concrete is the very basic and important construction material used widely. On the concrete is cement is the important material. In the past few years, many research and modification has been done to produce concrete which has the desired characteristics. The addition of some pozzolanic materials were reduces the usage of cement on concrete considerably and also increases the strength and durability characteristics of the concrete. Some of the pozzolanic materials like metakaolin, silica fume are used instead of cement at certain percentages. Another important material used on the concrete was fine aggregate. The best suitable substituent for the sand is M-sand. These materials were having the different nature of characteristics.

II. INTRODUCTION FOR MATERIALS

There were three different host materials are used instead of the cement and the fine aggregate. They are metakaolin, silica fume and M-sand respectively. The details of those materials are given below.

1. Metakaolin

Metakaolin is one of the innovative clay products developed in recent years. It is produced by controlled thermal treatment of kaolin. It is obtained by the calcinations of pure or refined kaolinitic clay at a temperature between 650°C and 850°C, followed by grinding to achieve a fineness of 700-900 m²/kg exhibits high pozzolanicity. Metakaolin can be used as a concrete constituent, replacing part of the cement content since it has pozzolanic properties. The size of the metakaolin used here was 3 μm.

2. Silica fume

Silica fume is a highly reactive pozzolanic material primarily composed of silicon dioxide (SiO₂) in non-crystalline form. It is a light to dark grey or bluish green-grey powder produced by an electric arc furnace during the manufacture of silicon or ferrosilicon alloy. It has a spherical like fly ash, but it is 100 times smaller, with an average diameter size of 0.1 μm.

3. M-SAND

The M-sand is manufactured from the waste of crushed large size aggregates. The physical properties of sand provide greater strength to the concrete by reducing segregation, bleeding, honeycombing, voids and capillary. M-Sand helps the concrete structures withstand extreme environmental conditions and prevents the corrosion of reinforcement steel by reducing permeability,
moisture ingress and freeze-thaw effect increasing the durability of concrete structures.

4. Cement

The cement is the important material of the concrete. The cement used for this experiment is Pozzolana Portland cement is used. Specific gravity cement is 3.15.

5. Coarse Aggregate

Next to the cement coarse aggregate is another important material. The 20mm aggregates were firstly sieved through 20mm sieve. The specific gravity is 2.825 and its Fineness modulus was 7.68%.

6. Fine aggregate

The fine aggregate may decides the strength, workability, durability of the both fresh and hardened concrete. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. But the sand is only used for the making of the control concrete.

III. CONCRETE DETAILS

Here we used the high performance concrete M40 concrete was used.

The ratio of the concrete is 1:1.49:3.25.
The water Ratio is 0.49
The mean Target strength is 48.25 N/mm²

IV. EXPERIMENTAL PROCEDURES

The main aim of this experiment is to find the strength and durability characteristics of the concrete with metakaolin, silica fume and M-sand combination. Those materials are used on concrete at certain combinations; they are given as follows,

1) COMBINATION 1:
Instead of Cement and sand,
(1) Metakaolin and M-sand replacement-10% &100%
(2) Metakaolin and M-sand replacement-20% &100%
(3) Metakaolin and M-sand replacement-30% &100%

2) COMBINATION 2:
Instead of Cement and sand,
(1) Silica fume and M-sand replacement -10% &100%
(2) Silica fume and M-sand replacement -20% &100%
(3) Silica fume and M-sand replacement -30% &100%

3) COMBINATION 3:
Instead of Cement and sand,
(1) Silica fume and M-sand replacement -10% &100%
(2) Silica fume and M-sand replacement -20% &100%
(3) Silica fume and M-sand replacement -30% &100%

V. TEST TO FIND STRENGTH:

COMPRESSIVE AND TENSILE STRENGTH TEST:

Concrete was made on that different combinations and the cubes and cylinders are casted, then the specimens are cured under normal condition as per IS recommendation and they are tested at 7 days and 28 days to determine the compressive and Tensile strength of the concrete and compared with the test results of conventional concrete are shown in table 1 and 2

COMPRESSIVE STRENGTH:

<table>
<thead>
<tr>
<th>s.no</th>
<th>Description</th>
<th>Average Compressive strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>7 days (10%</td>
</tr>
<tr>
<td></td>
<td>Metakaolin</td>
<td>25.2</td>
</tr>
<tr>
<td></td>
<td>Silica fume</td>
<td>24.8</td>
</tr>
<tr>
<td></td>
<td>Metakaolin+ silica fume</td>
<td>24.3</td>
</tr>
<tr>
<td></td>
<td>Control concrete</td>
<td>29.5</td>
</tr>
</tbody>
</table>

Table: 1 Average compressive strength after of 7 and 28 days
**TENSILE STRENGTH**

Table 2: Average Tensile strength after of 7 and 28 days

<table>
<thead>
<tr>
<th>s.no</th>
<th>Description</th>
<th>Average Tensile strength (N/mm²)</th>
<th>7 days</th>
<th>28 days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>10%</td>
<td>20%</td>
</tr>
<tr>
<td>1.</td>
<td>Metakaolin</td>
<td>23.5</td>
<td>22.8</td>
<td>23.1</td>
</tr>
<tr>
<td>2.</td>
<td>Silica fume</td>
<td>22.8</td>
<td>21.9</td>
<td>21.5</td>
</tr>
<tr>
<td>3.</td>
<td>Metakaolin + silica fume</td>
<td>21.4</td>
<td>20.7</td>
<td>23.4</td>
</tr>
<tr>
<td>4.</td>
<td>Control concrete</td>
<td>28.3</td>
<td></td>
<td>41.6</td>
</tr>
</tbody>
</table>

**VI. TEST TO FIND DURABILITY**

There were two types of tests are done to find the durability characteristics of the concrete. They are as follows,
1. Sorptivity test
2. Porosity test

**1. Sorptivity test**

For this test the specimens are made in cylindrical shape. The diameter of the cylinder was 100mm and the height was 50mm. The cylinders are made on the above combinations and they are cured for two days. After curing the cylinders are made dried for a day and the dry weight was taken. Then half of the cylinder from top was sealed with tape and the cylinder was partially immersed on the water. Then the weight of the specimen was taken at 1min, 2min, 4min, 8min, 16min,...Period intervals up to 6 hours. By such values the sorptivity values are calculated for all combinations like the given table. This is the sorptivity value table for metakaolin 10% and M-sand 100%. This is the test procedure to find the durability of the concrete by the sorptivity method as per the ASTM Designation C1583-13

Table 3: Sorptivity values for metakaolin 10% and M-sand 100% (Dry weight = 1146g)

<table>
<thead>
<tr>
<th>s.no</th>
<th>T (s)</th>
<th>√T (s)</th>
<th>Q mm²</th>
<th>A mm²</th>
<th>Q/A mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2.</td>
<td>60</td>
<td>7.745</td>
<td>1000</td>
<td>7854</td>
<td>0.127</td>
</tr>
<tr>
<td>3.</td>
<td>120</td>
<td>10.954</td>
<td>1000</td>
<td>7854</td>
<td>0.127</td>
</tr>
<tr>
<td>4.</td>
<td>240</td>
<td>15.491</td>
<td>1000</td>
<td>7854</td>
<td>0.127</td>
</tr>
<tr>
<td>5.</td>
<td>480</td>
<td>21.908</td>
<td>1000</td>
<td>7854</td>
<td>0.127</td>
</tr>
<tr>
<td>6.</td>
<td>960</td>
<td>30.983</td>
<td>2000</td>
<td>7854</td>
<td>0.254</td>
</tr>
<tr>
<td>7.</td>
<td>1920</td>
<td>43.817</td>
<td>3000</td>
<td>7854</td>
<td>0.381</td>
</tr>
<tr>
<td>8.</td>
<td>3840</td>
<td>61.967</td>
<td>3000</td>
<td>7854</td>
<td>0.381</td>
</tr>
<tr>
<td>9.</td>
<td>7680</td>
<td>87.635</td>
<td>4000</td>
<td>7854</td>
<td>0.509</td>
</tr>
<tr>
<td>10.</td>
<td>15360</td>
<td>23.935</td>
<td>5000</td>
<td>7854</td>
<td>0.636</td>
</tr>
<tr>
<td>11.</td>
<td>30720</td>
<td>75.271</td>
<td>6000</td>
<td>7854</td>
<td>0.763</td>
</tr>
<tr>
<td>12.</td>
<td>61440</td>
<td>247.87</td>
<td>6000</td>
<td>7854</td>
<td>0.763</td>
</tr>
</tbody>
</table>
Thus the sorptivity coefficients for all combinations are shown on the chart below.

Thus the above chart shows that metakaolin 10% and M-sand 100% shows less value, so this combination shows the high durability characteristics.

2. Porosity test

For this test the specimen is be in the cylindrical shape as like the specimen given on sorptivity test with same dimensions. The cylinders are cured for two days. After this process, the cylinder is dried for a day at room temperature. Then the cylinders are made allowed for curing on boiled water. The constant temperature of 21°C heated water is used. The cylinders are kept in the hot water for two days. After this curing the cylinder is allowed to cool and the weight of the specimen is taken. Then by proper calculation methods given in ASTM.
THE SORPTION COEFFICIENT = \(4.72 \times 10^{-2}\) N/mm²

Thus the above chart shows that metakaolin 10%, silica fume 10% and M-sand 100% absorbs less percentage of voids, so this combination shows the high durability characteristics.

VII. RESULTS AND DISCUSSIONS

There were different tests are conducted on the concrete with various host material and the results of those tests are given below.

Compressive strength

Thus the compressive strength test results of the combination Metakaolin and M-sand replacement-10% &100% was greater than the control concrete.

The compressive strength of this combination is 42.4 N/mm²

Tensile strength

Thus the tensile strength test results of the combination Metakaolin and M-sand replacement-10% &100% was greater than the control concrete.

The tensile strength of this combination is 42.1 N/mm²

Sorptivity test

Here the combination Metakaolin 10% and M-sand 100% on concrete having the value 0.0472×10-2, this combination may absorbs the least water. This shows the Hardened concrete which absorbs less water may have high durable characteristics.

Porosity test

The result of the porosity shows that the Metakaolin, Silica fume 10% and M-sand 100% on concrete having the value of 16.33%, and this combination may have fewer amounts of pores and this may shows the increase of durability of the concrete. This combination is best to increase the durability.

VIII. CONCLUSION

Thus this project finalizes that the replacement is a good idea to reduce the usage of cement, because of the economic situation. At the same time the replacement should provide good strength and stability characteristics.

By the way metakaolin provides good strength, because it was a clay material, so it reduces the pores and air voids. This results in the high strength and durability. At the same
time, the usage of the M-sand is best suitable replacement of the natural sand. Due to the human activities the production of the natural sand was reduced. But M-sand was not like that it May available still aggregate was used. It was economical, as well as it was eco-friendly and also not affected by the chemical activities.

REFERENCES