STRENGTH STUDY ON LATERITE CONCRETE WITH AND WITHOUT SILICA FUME

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Abstract— Concrete is the one of the most widely used man-made material. Concrete is a composite material composed of coarse aggregate bonded together with fluid cement which hardens over time. Most concretes used are lime-based concretes such as Portland cement concrete. Cement and aggregates are the basic needs for any construction industry. Sand is a prime material used for preparation of mortar and concrete and which plays a major role in mix design. Now a day’s erosion of rivers and considering environmental issues, there is a scarcity of river sand. The non-availability or shortage of river sand will affect the construction industry. Hence there is a need to find the new alternative material to replace the river sand. M-Sand is one of the major alternatives to river sand. But it’s over exploitation causes serious environmental issues. Many researchers are finding different materials to replace fine aggregate and one of the major materials is locally available soil. Laterite soil is one of the easily available local soils and using different proportion of this available soil along with M-sand the required concrete mix can be obtained.

This paper presents a review on the study of effect of silica fume on laterised concrete (concrete in which the fine aggregate is replaced with laterite soil). Initially the optimum percentage of laterite soil is determined. Then with optimum percentage of silica fume, replacement of fine aggregate with locally available laterite soil with different percentages (10%, 20%, 30% & 40%) is done. Tests on workability, compressive strength, flexural resistance, split tensile strength and modulus of elasticity were conducted on specimens. The result is then compared with that of laterised concrete and control concrete. Silica fume improves the bonding as well as compressive strength of concrete. Properties of laterite soil are as good as the regular river sand and M-Sand.

Keywords— laterite soil; silica fume; cementitious material; locally available soil, alternative material

I. INTRODUCTION

Concrete is a commonly used construction material due to its structural stability and strength performance. Now a days, concrete constructions are more costly and creating many environmental problems. In order to make the concrete construction more environmental friendly, we have to reduce the use of harmful constituents in concrete. Mineral admixture are widely used in concrete for various reasons especially for reducing the amount of cement required for making concrete which shows to a reduction in construction cost and make the constructions more eco-friendly. Moreover most pozzolanic materials are by-product materials. The use of these materials shows the reduction in waste, freeing up valuable land, save in energy consumption to produce cement and save the environment. Durability of Portland cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, fire or another process of deterioration. In other words, cement concrete will be termed durable, when it keeps its form and shape within the allowable limits, while exposed to different environmental conditions.
The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative material in the civil construction industry. Unfortunately, production of cement involves emission of large quantities of carbon-dioxide gas into the atmosphere, a major contributor for green house effect and the global warming. Hence it is inevitable either to search for another material or partly replace it by some other material. Substantial energy and cost savings can result when industrial by products are used as a partial replacement of cement. Addition of silica fume to concrete has many advantages like high strength, durability and reduction in cement production. When pozzolanic materials are incorporated to concrete, the silica present in these materials react with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C – S – H), which improve durability and the mechanical properties of concrete.

River sand has been used as one of the major components of concrete due to the ready availability and its well-graded nature with the sand grains of different sizes well distributed. River sand is mainly used for all kinds of civil engineering constructions. The excessive excavation of river sand is becoming a serious environmental issue. Hence it is necessary to explore possible alternatives to minimize the use of river sand. A number of attempts have been made to replace the river sand with other materials which are waste in the environment and to utilize those materials which are disposed without being used. Manufactured sand is one of the major alternatives to river sand. But it’s over exploitation causes serious environmental issues. Laterite soil is one of the easily available local soils and using different proportion of this available soil along with manufactured sand the required concrete mix can be obtained.

In this thesis work the optimum percentages of silica fume and laterite soil that can be used for replacing cement and fine aggregate respectively are finding out. The properties of concrete in fresh and hardened states are studied. An experimental program is carried out to explore its effects on workability, compressive, flexural, split tensile strength and modulus of elasticity of concrete. The focus of a good national development is to look inwards with intent to mobilize all natural resources for economic purposes.

II. LITERATURE REVIEW

Asiedu Emmanuel and Agbenyega Allan (2014) [2] This paper focuses on the utilisation of laterite fines as replacement for sand in the production of Sandcrete bricks as masonry units. With a mix ratio and a water/cement ratio of 1:6 and 0.50 respectively, batches with 0% (control specimens), 10%, 20%, 30%, 40% and 50% laterite fines replacing the sand were adopted in this study. In all, 96 bricks were cast, tested and compared with those of conventional Sandcrete bricks (control specimens). Tests studied were density, compressive strengths (wet and dry) and water absorption. Data results revealed that the laterite fines used could satisfactorily replace the sand up to 30% for the production of structural masonry units even though bricks need to be protected when used in waterlogged areas or below ground level.

Biju Mathew, Benny Joseph & C. Freeda Christy (2013) [3] conducted a study that, natural M- Sand was replaced with laterite at the rate of 10%, 20% and 30 % by weight for design mix of M25 controlled concrete. A total of 36 specimens prepared to determine the cube compressive strength, and flexural strength. From the studies, addition of laterite reduces workability in concrete. Compressive strength decrees with increases in percentage of laterite replacement with sand. The flexural strength has only slight variation with controlled concrete. Laterite of 20 % by weight of sand content has shown the best results, thus indicating possibility of using laterite as a partial replacement.

J. Santhiyaa Jenifer and S. Ramasundarm (2015) [8] studied the physical properties of laterite namely specific gravity, particle size distribution and density. An attempt was made to use of
laterite as a fine aggregate in concrete. The quantity of laterite varies from 0% to 100% at interval of 25% in this study. The 1:1.5:3 mix of concrete is used for determining the mechanical strength and durability characteristics. The density of laterite mixed concrete increases when percentage of laterite increases. The results of laterite sand mixed concrete are compared with conventional concrete. At 50 percentage replacement of sand by laterite sand produces high compressive strength. The tensile and flexural strength increases when the percentage of laterite sand increases.

Vishal S. and Pranita S. Bhandari (2014) [10] here an attempt is made to partially replace Portland cement by silica fume. The main objective of this research work was to determine the optimum replacement percentages of silica fume. To fulfill the objective various properties of concrete using silica fume have been evaluated. Further to determine the optimum replacement percentage comparison between the regular concrete and concrete containing silica fume is done. It has been seen that when cement is replaced by silica fume compressive strength increases up to certain percentage (10% replacement of cement by silica fume). But higher replacement of cement by silica fume gives lower strength.

III. OBJECTIVE & SCOPE OF THE WORK

The scope of this study is more about the determination of the strength of concrete with replacement of M-Sand by laterite and find out the effect of silica fume on concrete in which fine aggregate is replaces with laterite soil. This study will therefore introduce new alternatives for fine aggregate.

IV. TESTS OF MATERIALS

<table>
<thead>
<tr>
<th>Materials</th>
<th>Tests</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement [OPC 43]</td>
<td>Specific gravity</td>
<td>3.2</td>
</tr>
<tr>
<td>Fine aggregate [M-sand]</td>
<td>Specific gravity</td>
<td>2.61</td>
</tr>
<tr>
<td>Fine aggregate [Laterite soil]</td>
<td>Specific gravity</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>Clay content [%]</td>
<td>8</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>Specific gravity</td>
<td>2.77</td>
</tr>
<tr>
<td></td>
<td>Water absorption [%]</td>
<td>0.5</td>
</tr>
</tbody>
</table>

4.1 Silica fume

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Chemical requirements</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SiO₂</td>
<td>92</td>
</tr>
<tr>
<td>2</td>
<td>Moisture content</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3</td>
<td>Loss on ignition[Max]</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Alkalies as Na₂O</td>
<td>&lt;1</td>
</tr>
<tr>
<td>5</td>
<td>pH value</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 3. Silica fume physical analysis results

<table>
<thead>
<tr>
<th>Physical Analysis</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specific surface, m²/g</td>
</tr>
<tr>
<td>2</td>
<td>Maximum % retained on IS 45 micron Sieve</td>
</tr>
<tr>
<td>3</td>
<td>Compressive strength at 7 days as percentage of control sample[N/mm²]</td>
</tr>
</tbody>
</table>
4.2 Super plasticizer

In this investigation super plasticizer- CONPLAST-SP 430 was used to improve the workability of concrete. The properties of super plasticizer are shown in Table 4.

<table>
<thead>
<tr>
<th>Table 4. Properties of super plasticizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply form</td>
</tr>
<tr>
<td>Colour</td>
</tr>
<tr>
<td>Specific gravity</td>
</tr>
<tr>
<td>Usage</td>
</tr>
<tr>
<td>Chloride content</td>
</tr>
</tbody>
</table>

V. EXPERIMENTAL INVESTIGATION

5.1 Overall Scheme of Experimental Investigation

The mix proportion for M30 concrete designed as per provisions in IS Codes were considered for this investigation. In this study the parameters considered are workability, cube compressive strength, flexural strength and split tensile strength. To study the effect of silica fume on laterised concrete initially mixes having fine aggregate replaced with laterite soil of different percentage was prepared and its optimum amount was also determined. Then concrete mixes are prepared with optimum amount of silica fume and fine aggregate is replaced with different percentages of laterite soil. The results are then compared.

5.2 Materials Used

Ordinary Portland cement 43 grades, locally available good quality M-Sand of specific gravity 2.61 passing through 4.75mm IS sieve conforming to zone II, coarse aggregate of specific gravity 2.77, laterite of specific gravity 2.56, Silica fume and Potable water were used for making the various concrete mixes considered in this study.

5.3 Mix Design

M30 concrete mix was designed as per IS 10262-2009. The mix obtained as per IS code design is of proportion 1: 1.579: 2.5: 0.45. The quantity required for 1m³ concrete as given in Table 5. For all replacement level, the same mix ratio for normal concrete was followed.

5.4 Preparation of Test Specimen

Slump test and compaction factor tests was conducted for each mix to assess the workability. Concrete cubes (150mm) for determining compressive strength, beams (100 mmx100mmx500mm) for determining flexural strength and cylinders for split tensile strength are casted. Concrete cube specimens were tested at 7 and 28 days to obtain the compressive strength of concrete.

VI. EXPERIMENTAL RESULTS AND DISCUSSION

6.1 Optimization of laterite soil

6.1.1 Workability.

Compaction factor test and slump test are conducted for finding the workability of the concrete. The workability of all the mixes were assessed as per the IS 1199:1959 specification. The workability of the concrete is decreased with increase in laterite soil content. The workability reduced below the target value after 20% replacement.

<p>| Table 5. Slump test values of mixes having fine aggregate replaced with laterite soil |</p>
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Mix</th>
<th>Slump value [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A₀₀₀</td>
<td>105</td>
</tr>
<tr>
<td>2</td>
<td>A₀₁₀</td>
<td>104</td>
</tr>
<tr>
<td>3</td>
<td>A₀₂₀</td>
<td>101</td>
</tr>
<tr>
<td>4</td>
<td>A₀₃₀</td>
<td>97</td>
</tr>
<tr>
<td>5</td>
<td>A₀₄₀</td>
<td>93</td>
</tr>
</tbody>
</table>

**Figure 1. Slump test values of mixes having fine aggregate replaced with laterite soil**

**Table 6. Compaction factor for mixes having fine aggregate replaced with laterite soil**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Mix</th>
<th>Compaction factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A₀₀₀</td>
<td>0.97</td>
</tr>
<tr>
<td>2</td>
<td>A₀₁₀</td>
<td>0.95</td>
</tr>
<tr>
<td>3</td>
<td>A₀₂₀</td>
<td>0.94</td>
</tr>
<tr>
<td>4</td>
<td>A₀₃₀</td>
<td>0.89</td>
</tr>
<tr>
<td>5</td>
<td>A₀₄₀</td>
<td>0.86</td>
</tr>
</tbody>
</table>

**Figure 2. Compaction factor for mixes having fine aggregate replaced with laterite soil**

The workability for mixes having 10% and 20% replacement by laterite soil is almost nearer to the control mix.

### 6.1.2 Strength Study

- Compressive Strength

**Table 7. Compressive strength of mixes having fine aggregate replaced with laterite soil**
Figure 3. Compressive strength of mixes having fine aggregate replaced with laterite soil

The result shows that the compressive strength increases with increase in laterite soil content up to 20%. The target strength is achieved at 10& 20% replacement levels. The maximum strength is observed at 20% of replacement by laterite soil. After that the strength decreases below the strength of control concrete.

6.2 Optimization of laterite in optimum replacement of silica fume

6.2.1 Workability.

Compaction factor test and slump test are conducted for finding the workability of the concrete. The workability of all the mixes were assessed as per the IS 1199:1959 specification.

Table 8. Slump test values of mixes with optimum percentage of silica fume and variable percentage of laterite soil

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Mix</th>
<th>Slump value [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A0,0</td>
<td>105</td>
</tr>
<tr>
<td>2</td>
<td>A10,10</td>
<td>102.5</td>
</tr>
<tr>
<td>3</td>
<td>A10,20</td>
<td>101</td>
</tr>
<tr>
<td>4</td>
<td>A10,30</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>A10,40</td>
<td>98</td>
</tr>
</tbody>
</table>
Figure 4. Slump test values of mixes optimum percentage of silica fume and variable percentage of laterite soil

Table 9. Compaction factor values of mixes optimum percentage of silica fume and variable percentage of laterite soil

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Mix</th>
<th>Compaction factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A₀,₀</td>
<td>0.97</td>
</tr>
<tr>
<td>2</td>
<td>A₁₀,₁₀</td>
<td>0.95</td>
</tr>
<tr>
<td>3</td>
<td>A₁₀,₂₀</td>
<td>0.94</td>
</tr>
<tr>
<td>4</td>
<td>A₁₀,₃₀</td>
<td>0.92</td>
</tr>
<tr>
<td>5</td>
<td>A₁₀,₄₀</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Figure 5. Compaction factor values for mixes optimum percentage of silica fume and variable %percentage of laterite soil

Considering the workability of the replaced concrete, the workability decreases with increase in Laterite soil content. Super plasticizers are added to maintain the workability without changing the water cement ratio. The compaction factor for 10% and 20% Laterite soil are almost nearer to the ordinary mix after the addition of super plasticizers.
6.2.2 Strength Study

- Compressive Strength
  In this section laterite soil of different percentage added with optimum replacement of silica fume for the fine aggregate in concrete.

Table 10. Compressive strength of mixes with optimum percentage of silica fume and variable percentage of laterite soil

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Mix</th>
<th>percentage of laterite</th>
<th>7\textsuperscript{th} days compressive strength (N/mm\textsuperscript{2})</th>
<th>28\textsuperscript{th} days compressive strength (N/mm\textsuperscript{2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A\textsubscript{0,0}</td>
<td>0</td>
<td>25.2</td>
<td>38.7</td>
</tr>
<tr>
<td>2</td>
<td>A\textsubscript{10,10}</td>
<td>10</td>
<td>33</td>
<td>42</td>
</tr>
<tr>
<td>3</td>
<td>A\textsubscript{10,20}</td>
<td>20</td>
<td>36</td>
<td>45</td>
</tr>
<tr>
<td>4</td>
<td>A\textsubscript{10,30}</td>
<td>30</td>
<td>29</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>A\textsubscript{10,40}</td>
<td>40</td>
<td>25</td>
<td>37.2</td>
</tr>
</tbody>
</table>

Figure 6. Compression value of mixes with optimum percentage of silica fume and variable percentage of laterite soil

- Split Tensile Strength

Table 11. Split tensile strength of mixes with optimum percentage of silica fume and variable percentage of laterite soil

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Mix</th>
<th>% of laterite</th>
<th>7\textsuperscript{th} day Split tensile strength (N/mm\textsuperscript{2})</th>
<th>28\textsuperscript{th} days Split tensile strength (N/mm\textsuperscript{2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A\textsubscript{0,0}</td>
<td>0</td>
<td>2.85</td>
<td>3.83</td>
</tr>
<tr>
<td>2</td>
<td>A\textsubscript{10,10}</td>
<td>10</td>
<td>4</td>
<td>5.1</td>
</tr>
<tr>
<td>3</td>
<td>A\textsubscript{10,20}</td>
<td>20</td>
<td>4.9</td>
<td>5.5</td>
</tr>
<tr>
<td>4</td>
<td>A\textsubscript{10,30}</td>
<td>30</td>
<td>3.3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>A\textsubscript{10,40}</td>
<td>40</td>
<td>2.5</td>
<td>3.6</td>
</tr>
</tbody>
</table>
Figure 7. Split tensile strength of mixes with optimum percentage of silica fume and variable percentage of laterite soil

- Flexural Strength

Table 12. Flexural strength of mixes with optimum percentage of silica fume and variable percentage of laterite soil

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Mix</th>
<th>% of laterite</th>
<th>7th day Flexural strength (N/mm²)</th>
<th>28th day Flexural strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A0,0</td>
<td>0</td>
<td>2.9</td>
<td>4.45</td>
</tr>
<tr>
<td>2</td>
<td>A10,10</td>
<td>10</td>
<td>3.7</td>
<td>4.85</td>
</tr>
<tr>
<td>3</td>
<td>A10,20</td>
<td>20</td>
<td>4</td>
<td>5.1</td>
</tr>
<tr>
<td>4</td>
<td>A10,30</td>
<td>30</td>
<td>3.5</td>
<td>4.6</td>
</tr>
<tr>
<td>5</td>
<td>A10,40</td>
<td>40</td>
<td>3</td>
<td>3.9</td>
</tr>
</tbody>
</table>

Figure 8. Flexural strength of mixes with optimum percentage of silica fume and variable percentage of laterite soil

VII. CONCLUSION

The experimental investigation was carried out to study the effect of silica fume on concrete in which the fine aggregate is partially replaced with laterite soil.

- The optimum percentage replacement of cement with silica fume was found to be 10%.
- The workability of concrete mix reduced below the target value when laterite soil exceeds 20%.
- The optimum percentage replacement of fine aggregate with laterite soil was found to be 20%. And the compressive, split and flexural strength are 4.65%, 9.66% and 5.62% higher than that of control mix.
• The mixes having optimum percentage of silica fume and laterite soil of 20% and 30% are found to be preferable for use in construction purposes.
• Silica fume addition in laterised concrete improves the compressive strength by 16.28% than control mix and 11.11% than laterite concrete without silica fume.
• Split tensile strength improves 43.6% than control and 30.95% than laterised concrete.
• Flexural strength improves 14.61% than control mix and 8.5% than laterised concrete.

REFERENCES