EXPERIMENTAL STUDY TO DETERMINE THE FEASIBILITY OF REPLACING NATURAL RIVER SAND BY WASTE FOUNDRY SAND IN CONCRETE PAVERS

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ABSTRACT

The disposal of waste foundry sand (WFS) in landfills not only occupies open lands, but is also an environmental concern. Disposing or reusing WFS in scientific and environment friendly ways is the need of the hour. This paper investigates the suitability of replacing natural river sand (NRS) by WFS in the manufacture of pavers for non-traffic applications as per Indian Standards. In this study, pavers were manufactured by the rubber mould method of casting. The specimens were tested for various physical and mechanical properties by replacing NRS by WFS in percentages of 0, 25, 50, 75 and 100 by weight. The properties of the specimens that were tested are water absorption, compressive strength, flexural strength, tensile splitting strength and abrasion resistance as per IS 15658: 2006. From the experimental results, it was found that NRS can be replaced by WFS up to 50% by weight.

Key words: Natural river sand (NRS), waste foundry sand (WFS), pavers.


1. INTRODUCTION

Sand is one of the commonly used materials for making moulds in the metal casting industries (foundries) worldwide. This sand which has a high silica content is called foundry sand. The binder in this sand is either clay or chemically active compounds. Foundry sand is recycled and reused several times before being rendered unfit for further recycling. At this stage, foundry sand is discarded and termed as spent or waste foundry sand (WFS). As per 50th
World Casting Census published by Modern Castings, USA in December 2016, India is the 2nd largest castings producer, producing an estimated 10.77 million tonnes of various grades of castings as per international standards [1]. Consequently, the production of WFS in India is also significant. There are about 7000 foundries operating all over India out of which 142 are located in the Belagavi cluster, Karnataka. Belagavi cluster alone produces 450 tonnes of WFS per day which is disposed into landfills and low lying areas in and around Belagavi city which may lead to pollution of soil and ground water [2]. Due to scarcity of open land, there is an immediate need for innovative methods of disposing or reusing the WFS.

Concrete is the most widely used construction material as of now. Due to the exponential growth in construction industry in the last two decades and due to the ban imposed on sand mining, the demand for NRS, which is used as fine aggregate in concrete, has led to illegal NRS mining activities. As such, there is a need to develop alternatives that can replace NRS. For all the above reasons, use of WFS in concrete as a replacement of NRS could be an alternative to dumping of WFS in the landfills. The use of pavers has witnessed an increase in the past few years and their applications mainly include landscaping and construction of pavements. Hence, use of WFS in the manufacture of pavers can be thought of as one of the means to utilize WFS beneficially, thereby reducing the load on landfills and over exploitation of NRS.

In the present study, experimental tests were carried out to determine the physical and mechanical properties of concrete pavers, manufactured by replacing NRS by WFS and employing rubber moulds for casting. The parameters considered in the feasibility study include water absorption, compressive strength, flexural strength, split tensile strength and abrasion resistance as per IS 15658: 2006 [3].

2. LITERATURE REVIEW

From their experimental studies on mechanical properties like compressive strength, tensile splitting strength, flexural strength and modulus of elasticity of concrete, obtained by replacing river sand by used-foundry sand, Siddique et al. concluded that the optimum percentage of replacement is 30%. From the marginal increase observed in all the properties, the authors concluded that foundry sand can be used in making good quality concrete and other construction materials [4].

Siddique and Singh carried out study on abrasion resistance and strength properties of concrete by replacing river sand by waste foundry sand up to 20%. From the results, it was concluded that there was a significant increase in abrasion resistance of concrete containing waste foundry sand. It was also found that the concrete containing WFS showed an increase in 28-day compressive strength of 8.3 – 17%, tensile splitting strength 3.6 – 10.4%, modulus of elasticity 1.7 – 6.4% and showed continuous improvement up to the age of 365 days [5].

Basar and Nuran carried out study on effect of waste foundry sand as partial replacement of river sand in ready mix concrete (RMC). River sand was replaced by waste foundry sand from 0 – 40% and the physical and mechanical properties were studied. For concrete containing waste foundry sand they concluded that, the density of concrete decreased and water absorption was found to increase, whereas the compressive strength, tensile splitting strength and modulus of elasticity showed a decrease in values for concrete of all ages. However it was found that at 20% replacement the mechanical and physical properties were satisfactory as per the Turkish Standards [6].
Prabhu et al. carried out study to evaluate the utilization of foundry sand as a replacement for fine aggregate in concrete production. The replacement percentages in their study varied from 0 – 50% and the samples were tested for their physical and mechanical properties. From the study they concluded that the compressive strength for 20% replacement by foundry sand showed a decrease in value by 2.1%, which was close to the compressive strength of concrete without replacement. They concluded that 20% of river sand can be replaced by foundry sand without affecting the strength values of concrete significantly [7].

3. MATERIALS AND METHODOLOGY

3.1. Materials

Cement
Ordinary Portland cement (OPC) - 43 Grade conforming to IS 8112: 2013 was used in the pavers.
Properties:
- Normal consistency: 38%
- Initial setting time: 75 minutes
- Final setting time: 205 minutes
- Specific gravity: 3.14

Fine Aggregates
Fine aggregates conforming to Table 4 of IS 383: 2016 belonging to Zone II was used.
Properties:
- Fineness modulus: 2.858
- Specific gravity: 2.63
- Silt content: 4.09%

Coarse Aggregates
Aggregates (10 mm down size) conforming to Table 2 of IS: 383-2016 was used.
Properties:
- Specific gravity: 2.7
- Waste foundry sand

WFS belonging to Zone II as per IS 383: 2016 was obtained from one of the metal casting industries, located in Udyambag, Belagavi, Karnataka.
Properties:
- Fineness modulus: 2.75
- Specific gravity: 2.38
- Silt content: 12.58%

Chemical Admixture
High range water reducing admixture confirming to IS 9103: 1999, ASTM C-494 Type F.

White Cement and Dolomite Powder
White cement and dolomite powder were used in the top wearing surface of the pavers.
Experimental Study to Determine the Feasibility of Replacing Natural River Sand by Waste Foundry Sand in Concrete Pavers

Water
Water confirming to IS 456: 2000 was used in the concrete mix.

3.2. Methodology
Pavers were casted using rubber moulds. The specimens were tested for various physical and mechanical properties by replacing NRS by WFS in percentages of 0, 25, 50, 75 and 100 by weight. Pavers were manufactured for non-traffic conditions and the minimum compressive strength of pavers required as per IS 15658: 2006 is 30 N/mm². The concrete mix was designed as per IS 10262: 2009 for a target strength of 38.25 N/mm² [8].

Tests conducted on pavers to determine:
Physical properties:
Water absorption as per Annexure C of IS 15658: 2006

Mechanical properties:
- Compressive strength as per Annexure D of IS 15658: 2006
- Tensile splitting strength as per Annexure F of IS 15658: 2006
- Flexural strength as per Annexure G of IS 15658: 2006
- Abrasion resistance as per Annexure E of IS 15658: 2006

4. EXPERIMENTAL RESULTS AND DISCUSSIONS
4.1. Water Absorption of Pavers

Table 1 Water absorption of pavers

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Percentage replacement</th>
<th>Average water absorption (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>4.96</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>5.64</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>5.90</td>
</tr>
<tr>
<td>4</td>
<td>75</td>
<td>6.20</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>6.89</td>
</tr>
</tbody>
</table>

Figure 1 Variation in water absorption of pavers with percentage replacement of NRS by WFS
Water absorption of the pavers was found to increase with increase in percentage of WFS in the concrete mix (Fig. 1). This increase in water absorption can be attributed to the excess silt content in WFS.

As per IS 15658: 2006, the maximum water absorption value in pavers permitted is 6%. Pavers up to 50% replacement satisfied this criterion.

4.2. Compressive Strength of Pavers

Table 2 Compressive strength of pavers

<table>
<thead>
<tr>
<th>Sl. no</th>
<th>Percentage replacement</th>
<th>Average compressive strength at 28 days (N/mm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>52.56</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>48.47</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>45.65</td>
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<td>4</td>
<td>75</td>
<td>35.38</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>34.10</td>
</tr>
</tbody>
</table>

Figure 2 Variation in compressive strength of pavers with percentage replacement of NRS by WFS

- The compressive strength of pavers reduced with increase in the percentage replacement of WFS in the concrete mix (Fig. 2).
- It was observed that the desired target strength (38.25 N/mm$^2$) was achieved up to 50% replacement and then, beyond this point the compressive strength fell below the required target strength.
- Also, a steep decline in compressive strength was observed when more than 50% of NRS was replaced by WFS.
- From the discussion above it can be inferred that 50% is the optimum percentage of replacement in terms of compressive strength of pavers.
4.3. Flexural Strength

Table 3 Flexural strength of pavers

<table>
<thead>
<tr>
<th>Sample</th>
<th>Percentage replacement</th>
<th>Load, P (kN)</th>
<th>Flexural strength, ( F^* = \frac{3P_1}{2bd^2} ) (N/mm(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>4.62</td>
<td>3.50</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
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<td>3.32</td>
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<tr>
<td>3</td>
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<td>3.95</td>
<td>2.99</td>
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<tr>
<td>4</td>
<td>75</td>
<td>3.45</td>
<td>2.62</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>3.00</td>
<td>2.28</td>
</tr>
</tbody>
</table>

* Clause G5 – Annex G IS 15658: 2006

Figure 3 Variation in flexural strength of pavers with percentage replacement of NRS by WFS

- Flexural strength of the pavers was found to decrease with increase in percentage of WFS in the concrete mix (Fig. 3).
- As per IS 15658: 2006, the minimum breaking load in flexure for pavers in non-traffic applications is 2 kN. It was observed that this criterion is satisfied for all percentage replacements.

4.4. Tensile Splitting Strength

Table 4 Tensile splitting of pavers

<table>
<thead>
<tr>
<th>Sl. no</th>
<th>Percentage replacement</th>
<th>Average Tensile Splitting Strength (N/mm(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>11.27</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>8.05</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>5.33</td>
</tr>
<tr>
<td>4</td>
<td>75</td>
<td>4.76</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>4.18</td>
</tr>
</tbody>
</table>
Variation in tensile strength of pavers with percentage replacement of NRS by WFS

- Tensile splitting strength of the pavers was found to decrease with increase in percentage the percentage of WFS in the concrete mix (Fig. 4).
- A steep decline in strength was observed up to 50% replacement, beyond which the rate of fall was found to decrease.

4.5. Abrasion Resistance

Table 5 Abrasion resistance of pavers

<table>
<thead>
<tr>
<th>Sl. no</th>
<th>Percentage replacement</th>
<th>Loss of volume in (mm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1149.60</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>1241.68</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>1913.86</td>
</tr>
<tr>
<td>4</td>
<td>75</td>
<td>2048.11</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>2404.08</td>
</tr>
</tbody>
</table>

Variation in abrasion resistance of pavers with percentage replacement of NRS by WFS

- Abrasion resistance of the pavers is found to decrease with increase in percentage of WFS in the concrete mix (Fig. 5).
Experimental Study to Determine the Feasibility of Replacing Natural River Sand by Waste Foundry Sand in Concrete Pavers

- As per IS 15658: 2006, the permissible loss of volume under abrasion of pavers should be between 1000 mm$^3$ – 5000 mm$^3$. This criterion is satisfied for all percentage replacements.

5. CONCLUSIONS

- From the experimental results it can be inferred that WFS can be used as a partial replacement for NRS in the manufacture of concrete paving units for non-traffic applications.
- Considering the physical and mechanical acceptance criteria as per IS 15658: 2006, WFS can replace NRS upto 50% by weight.
- Belagavi, being one of the major foundry clusters, produces 450 tonnes of WFS per day. Utilizing this waste in the manufacture of pavers will reduce the load on the landfills, soil pollution and ground water pollution due to leaching of heavy metals, thus making it environmentally viable.
- Using WFS in the manufacture of pavers will reduce illegal mining and over exploitation of NRS.

REFERENCES


