Stone crusher dust as a fine aggregate in Concrete for paving blocks

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ABSTRACT

Concrete paving blocks are ideal materials on the footpaths for easy laying, better look and finish. In this paper, a parametric experimental study for producing paving blocks using crusher dust is presented. Some of the physical and mechanical properties of paving blocks with fine aggregate (sand) replaced by various percentages of crusher dust are investigated. The test results show that the replacement fine aggregate by crusher dust up to 50% by weight has a negligible effect on the reduction of any physical and mechanical properties while there is a saving of 56% of money. The percentage of saving was less but highly beneficial for mass production of paving blocks. The shaving would be more if the sand availability is at a greater distance. This also reduces the burden of dumping crusher dust on earth which reduces environmental pollution.

Keywords: Paving block, Stone crusher dust.

1 Introduction

A lot of face-lift is being given to roads, footpaths along with roadside. Concrete paving blocks are ideal materials on the footpaths for easy laying, better look and finish. Cement concrete paving blocks are precast solid products made out of cement concrete. The product is made in various sizes and shapes viz. rectangular, square, and round blocks of different dimensions with designs for interlocking of adjacent paving blocks. The raw materials require for manufactures of the product are Portland cement and aggregates which are available locally in every part of the country. Market potential cement concretes paving blocks find applications in pavements, footpaths, gardens, passengers waiting sheds, bus-stops, industry and other public places. The product is commonly used in urban areas for the above applications. Hence, the unit may be set up in urban and semi-urban areas, near the market.

A concrete mix of 1:2:4 (cement: sand: stone chips) by volume may be used for cement concrete paving blocks with water to cement ratio of 0.60. The concrete mix should not be richer than 1:6 by volume of cement to combined aggregates before mixing. Fineness modules of combined aggregates should be in the range of 3.6 to 4.0. All the raw materials are placed in a concrete mixer is rotated for 15 minutes. Till now Indian standard has not given any specification on cement concrete paving blocks. However, the specification laid down in IS 2185 (Part-1) specification for concrete masonry units: Part I for Hollow and solid concrete blocks, may be used as general guidelines for meeting the quality parameters. Quality parameters like actual proportion of the individual raw materials, ratio of coarse
aggregates to fine aggregates, water to cement ratio, good finish, accuracy in size and shape, and compression strength after curing are the some of the important parameters that should be checked periodically to ensure good quality of the product.

Raman et al., 2005 studied the effect of quarry dust and found that the partial replacement of river sand with quarry dust without the inclusion of fly ash resulted in a reduction in the compressive strength of concrete specimen. It has also been reported that the reduction in the compressive strength of quarry dust concrete was compensated by the inclusion of fly as into the concrete mix. Reddy and Reddy, 2007 reported an increasing compressive strength by use of rock flour as fine aggregate instead of river sand. Ilangovana et al., 2008 reported strength of quarry rock dust concrete was comparably 10-12 % more than that of similar mix of conventional concrete.

Hameed and Sekar, 2009 studied effect of crushed stone dust as fine sand and found the flexural strength increases than the concrete with natural sand but the values decreases as percentage of crusher dust increases. It has been reported by Reddy and Reddy, 2007 from their experimental study on use of rock flow and insulator ceramic scrap in concrete that the rock flow when used as fine aggregate increases the modulus of rapture thus the flexural strength. From the study of green concrete posses containing quarry dust and marble sludge powder it has been reported that the split tensile strength of green concrete was 14.62% higher at 7days and 8.66 %higher at 28 days. But split tensile strength was found to be lesser by 10.41% at 3 days than controlled concrete.

Hameed and Sekar, 2009 also reported the resistance of Green concrete containing crusher dust against sulfate attack (Mg SO$_4$ and Na$_2$SO$_4$ ) is higher than the conventional concrete. Also they have reported acid resistance ( H$_2$SO$_4$ ) is higher than the conventional concrete. The durability of quarry rock dust concrete under sulphate and acid action is higher than the conventional concrete.

Similarly water Absorption found to be more in the concrete containing crusher dust$^2$. The overall workability value of quarry rock dust concrete in terms of slump as well as compaction factor was less in comparison to conventional concrete(Ilangovana et al., 2008). As reported by (Hameed and Sekar, 2009) the slump value increases (Workability increases), if concrete is mixed with quarry dust as well as marble sludge due to presence of marble sludge powder

2 Experimental Programme

Paving block specimens (figure 1) of sizes 0.25mx0.20mx0.05m, made of concrete with cement, fine aggregate (sand/coarser dust) and coarse aggregate in the ratio (1:2:4) by weight are casted with following replacements of sand.

- Concrete Paving bock Sand 100% and crusher dust 0% - (FC$_0$)
- Concrete Paving bock Sand 75% and crusher dust 25% - (FC$_{25}$)
- Concrete Paving bock Sand 50% and crusher dust 50% - (FC$_{50}$)
- Concrete Paving bock Sand 25% and crusher dust 75% - (FC$_{75}$)
- Concrete Paving bock Sand 0% and crusher dust 100% - (FC$_{100}$)
3. Test Results and Discussion

Samples are prepared for calculating the different mechanical and physical properties of cement as well as fine aggregate in the laboratory and are mentioned below.

3.1 Test results for cement and sand:

- Standard Consistency- 33%
- Initial Setting time- 2Hrs 20 Minutes
- Final Setting Time- 5 Hrs 10 Minutes.

- Specific gravity – 2.85
- Strength of cement-38.32 N/mm² (for 28Days)
- Sand: Fineness Modulus: 2.01, Specific Gravity = 2.62
- Crusher dust: Fineness Modulus: 3.13, Specific Gravity = 2.62

3.2 Test results for paving blocks:

6 sets of samples from each category are prepared for calculating the average values of different mechanical and physical properties of paving and mentioned in Table 1.
Table 1: Different mechanical and physical properties of paving blocks with variation of 
crusher dust replacement with sand

<table>
<thead>
<tr>
<th>Test</th>
<th>(FC₀)</th>
<th>(FC₂₅)</th>
<th>(FC₅₀)</th>
<th>(FC₇₅)</th>
<th>(FC₁₀₀)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 days compressive strength (N/mm²)</td>
<td>35.0</td>
<td>35.0</td>
<td>34.0</td>
<td>33.9</td>
<td>33.7</td>
</tr>
<tr>
<td>28 days flexure strength (N/mm²)</td>
<td>8.4</td>
<td>8.01</td>
<td>7.95</td>
<td>5.55</td>
<td>6.45</td>
</tr>
<tr>
<td>28 days split tensile Strength (N/mm²)</td>
<td>3.36</td>
<td>3.12</td>
<td>3.05</td>
<td>3.36</td>
<td>2.44</td>
</tr>
<tr>
<td>28 days abrasion value (mm)</td>
<td>2.12</td>
<td>2.10</td>
<td>2.11</td>
<td>2.11</td>
<td>2.27</td>
</tr>
<tr>
<td>24 hr. water absorption (%)</td>
<td>1.60</td>
<td>1.55</td>
<td>1.41</td>
<td>1.56</td>
<td>1.33</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>2574.4</td>
<td>2576.9</td>
<td>2676.8</td>
<td>2594.4</td>
<td>2550.0</td>
</tr>
<tr>
<td>Slump value (mm)</td>
<td>95.0</td>
<td>94.0</td>
<td>90.0</td>
<td>87.0</td>
<td>80.0</td>
</tr>
<tr>
<td>30 days weight loss (%) in acid solution (H₂SO₄)</td>
<td>2.01</td>
<td>2.0</td>
<td>1.96</td>
<td>1.95</td>
<td>1.94</td>
</tr>
<tr>
<td>30 days weight loss(%) in alkali solution (NaOH)</td>
<td>1.59</td>
<td>1.60</td>
<td>1.60</td>
<td>1.61</td>
<td>1.57</td>
</tr>
</tbody>
</table>

**Compressive Strength:** - Compressive Strength of the paving blocks are determined in accordance to IS: 2185 (Part-I): 2005 as well as IS15658: 2006. Results for compressive strength of blocks FC₀, FC₂₅, FC₅₀, FC₇₅ & FC₁₀₀ are shown in the graph (Fig.2). The compressive strength for paving block FC₀ and FC₂₅ shows higher and equal strength. But this strength for the blocks FC₅₀, FC₇₅ & FC₁₀₀ are gradually decreased but the variation is very less. Up to FC₅₀ shows highest strength among the blocks containing crusher dust. But all the specimen satisfy the recruitment given in IS : 15658 : 2006 for paving blocks to be used in non-traffic areas. As per above code the minimum grade of concrete as M₃₀. But even M₂₀ concrete is observed to be satisfying above requirement which also satisfy requirement of compressive strength of solid block grade C as per IS: 2185 (Part-I) – 2005.

Figure 2: Graph showing compressive strength with variation of crusher dust replacement
**Flexure Strength:** The flexural strength of paving blocks can be expressed in terms of flexural stress or in terms of breaking load. The flexural strength (Fig. 3) decreases as the percentage of crusher dust increases but all the samples, FC\(_{75}\) as well as FC\(_{100}\) satisfying breaking load specified by IS : 15658 : 2006 even if in heavy traffic condition.

![Graph showing flexural strength with variation of crusher dust replacement](image)

**Figure 3:** Graph showing flexural strength with variation of crusher dust replacement

**Split Tensile Strength:** Split tensile stress has been done according to IS 15658:2006. The split tensile stress in the normal concrete was found to be higher. Variation of split tensile stress in concrete courting crusher dust between FC\(_{50}\) and FC\(_{75}\) is less. But the sample FC\(_{100}\) shows much lower split tensile stress between normal concrete and concrete containing crusher dust is found to be 9%. As per IS 15658:2006 there is no acceptance limit mentioned but acceptance limited to the specification of the manufacture.

![Graph showing abrasion value with variation of crusher dust replacement](image)

**Figure 4:** Graph showing abrasion value with variation of crusher dust replacement

**Abrasion:** Abrasion test of paving blocks were done in accordance to IS: 15658: 2006. It was found that wearing depth increases with the increase of percentage of crusher dust. Hence
wearing depth is found to be 2.27mm for FC\textsubscript{100} samples. As per IS 1237: 1980 the wearing depth should not exceed 3.5mm of concrete block used for general purpose and should not exceed 2mm. for heavy traffic. As the work contained to the non traffic condition wearing resistance are seems to be satisfactory. The variation up to FC\textsubscript{50} is almost constant (Fig.4).

**Water Absorption:** As per IS: 15658:2006 water absorption of concrete paving block should be less than 7%. But maximum water absorption among all groups was found to be 1.56% in FC\textsubscript{75} which is much less than the requirement also it comply maximum water absorption requirement less than 10% as per IS: 2185 (Part-I) 2005.

**Weight loss in Acid Solution:** From the Weight loss of samples immersed in acid solution (H\textsubscript{2}So\textsubscript{4}) with 1% of water after 30 days it was found the loss in weight in the normal concrete was slightly higher that the concrete containing crusher dust and also weight loss decreases as percentage of crusher dust increases. Difference in weight loss of normal concrete in the concrete containing 100% crusher dust (FC\textsubscript{100}) is found to be 3.5 % approximately. The loss in weight up to FC\textsubscript{50} is insignificant.

**Weight Loss in Alkali Solution:** Weight loss of samples in alkali solution (NaOH) with 4% of water after 30 days in the normal concrete was found to be smaller than the concrete containing crusher dust but differences are very small about 0.6%. It may be due to the crusher dust have greater tendency of reacting with alkali solution than the normal sand i.e. resistance of crusher dust against alkali resistance is less than the normal sand.

**Density:** Density of the normal concrete was found to be less than the density of the concrete containing crusher dust but specific gravity of the sand used for the preparation of concrete was found to be higher than the specific gravity of crusher dust. Density of the specimen FC\textsubscript{100} is found to be less than the normal concrete. The specimen FC\textsubscript{50} &FC\textsubscript{75} shows higher density and it may be due to difference in compaction during casting or may be due to slight variation in homogeneous in the mix. The code IS 2185 (part 1) : 2005 specified for solid concrete block grade C density should not be less than 1800 Kg/m\textsuperscript{3}.

**Flow /Slump (water requirement):** The slump value had been measured during the casting of specimen. The slump value decreases as the percentage of crusher dust increases. This reflects as percentage of crusher dust increases the water requirement increases and thus slump value decreases which may due texture of crusher dust. Generally crusher dust has rough texture than sand. The aggregate having rough texture requires more water for surface weighting. Thus some water is consumed for surface weighting of crusher dust and the net water available get decreases for workability. As per the IS 15658:2006 concrete paving block may be prepared with concrete having zero slumps. If the water requirement increases and slump decreases, addition of crusher dust may solve the problem which will not affect the physical properties.

**3.3 Cost effectiveness:**

It has been seen that a replacement of up to 50% shows negligible variation in mechanical and physical properties. Base upon this cost shaving is calculated. Cost of stone crusher dust including transportation = Rs. 100 per Cum. Cost of Sand (river 20km away) including transportation = Rs. 216 per cum. Variation in transportation cost depending upon location of site and source of sand & crusher dust. It has been seen that there is a shaving of 56% of
money if sand is replaced by crusher dust. The percentage of saving was less but highly beneficial for mass production of paving blocks. The shaving would be more if the sand availability is at greater distance. This also reduces the burden of dumping crusher dust on earth which is eco-friendly.

4. Conclusion

Replacement fine aggregate by crusher dust up to 50% by weight has a negligible effect on the reduction of any physical and mechanical properties like compressive strength, flexural strength, split tensile strength etc. Water absorption is well below the limit as per Indian codes. Durability test shows no variation for different replacements of crusher dust. There is a shaving of 56% of money if sand is replaced by crusher dust. The percentage of saving was less but highly beneficial for mass production of paving blocks. The shaving would be more if the sand availability is at greater distance like hilly area. This also reduces the burden of dumping crusher dust on earth and hence environmental pollution.

5. References


