Replacement of Fine Aggregate by using Recyclable Materials in Paving Blocks

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Abstract: Cement concrete paving blocks are precast hard products complete out of cement concrete. The product is made in various sizes and shapes like square, round and rectangular blocks of different dimensions with designs for interlocking of adjacent tiles blocks. Several Research Works have been carried out in the past to study the possibility of utilizing waste materials and industrial byproducts in the manufacturing of paver blocks. Various industrial waste materials like quarry dust, glass powder, ceramic dust and coal dust are used as partial replacement of fine aggregate and assessed the strength parameters and compared the profit percentages after replacement with waste materials. Quarry dust can be replaced by 20% and beyond that the difference in strength is not much higher but considering cost we can replace upto 40% so that we can get a profit of almost 10%. Similarly we can replace glass powder and ceramic dust by 20% only beyond that there is decrement in strength and even with 20% replacement we can get 1.34% and 2.42% of profit. Coal dust is not suitable for alternative material as fine aggregate as it reduces the strength.

Key words: ceramic dust, coal dust, cost analysis, glass powder, paver blocks, quarry dust

1. INTRODUCTION

Cement concrete paving blocks are precast solid products made out of cement concrete. In general behavior and performance of concrete paver blocks used are mostly governed by properties of materials, water cement ratio, mixing process and curing process. Concrete pavement blocks are best for medium traffic roads, sidewalks, garden paths and public areas and it has excellent durability skid resistance, high strength, choice of colors, elegant appearance and factory controlled quality.

Various waste materials and industrial byproducts can be utilized as alternatives in the manufacturing of paver blocks [9]. In ceramic industry, about 30% production goes as waste. Concrete with non-conventional aggregates such as Ceramic waste and quarry dust were used in concrete to progress the properties of concrete and to reduce cost [3].

Increase in the cube strength to the extent of 3.9% at w/c ratio of 0.46 with replacement of 20% ceramic wastes [5], this study has been conducted through basic experimental research in order to analyze the possibilities of various industrial waste products as fine aggregates in paving blocks.

2. EXPERIMENTAL STUDY

2.1 Materials used:
Natural river sand of Zone II is used, Mix design for M20 grade is considered as per IS 10262:2009. The specific gravity and Sieve analysis of materials used in the study are examined and results are presented below in Fig I and Fig II.
2.2 Details of tests conducted and parameters studied

The present investigations are aimed to study the effect of partial replacement of recyclable material like quarry dust (QD), glass powder (GP), ceramic dust (CrD), coal dust (CD) in concrete. Compressive strength and cost comparisons are carried out for all the samples.

3. RESULTS AND DISCUSSION

3.1 Compressive strength

The standard cubes of (150mm X 150mm X 150 mm) are casted and tested using 2000 KN capacity compressive testing machine. The effect on compressive strength by partial replacement of quarry dust, glass powder, ceramic dust, coal dust in varying percentages from 0% to 40% are presented in table I and fig III to fig VI.

| Table I: Compressive strength values with varying percentages of QD, GP, CrD & CD |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                  | norma mix       | QD 20%          | QD 30%          | QD 40%          | GP 20%          | GP 30%          | GP 40%          | CrD 20%         | CrD 30%         | CrD 40%         |
| 7 days           | 11.93           | 18.22           | 18.67           | 19.5            | 17.78           | 16.00           | 11.11           | 20.00           | 17.78           | 16.00           | 4.44            | 4.00            | 4.44            |
| 14 days          | 17.04           | 25.91           | 25.84           | 26.99           | 24.64           | 22.15           | 15.38           | 27.68           | 24.61           | 22.14           | 6.14            | 5.53            | 6.14            |
| 28 days          | 18.76           | 28.50           | 28.43           | 29.69           | 27.07           | 24.36           | 16.91           | 30.45           | 27.18           | 24.36           | 6.75            | 6.08            | 6.75            |
From the Table no.1 and Figure no. III, IV, V, VI it is observed that by replacing with quarry dust by 20% its compressive strength is about 28.5N/mm² i.e., an increment of 51.92 % and further there is no appreciable increment, where as for glass powder it is observed that there is gradual decrease in compressive strength when replaced. It has preceding values as 27.07N/mm², 24.36N/mm² and
16.91N/mm² even though there is an increment when compared to normal mix initially by 44.29%. Ceramic dust has also had preceding value such as 30.45N/mm², 27.18 N/mm² and 24.36 N/mm² with an initial increment of 62.31% compared to normal mix. Coal has a very less compressive strength compared with all the other pavement blocks.

3.2 Cost comparison:
In this analysis the economical variations are compared with the materials involved in the normal pavement block preparation and the replacement block material. Individual costs for each material are added based on the design mix and quantities required for a standard block of 200mm x 100mm are shown in the table II.

| Sl. No | Material | Quantity | Cost of material (Rs) | Calculation | Cost of the material used in the concrete mix (Rs) |
|--------|----------|----------|-----------------------|-------------|-----------------------------------------------|
| 1      | Cement   | 1.82 kgs | 4000/ tonne           | 4x1.82      | 7.28                                          |
| 2      | CA       | 5.45 kgs | 0.96/kg               | 0.96x5.45   | 5.23                                          |
| 3      | FA       | 2.72kgs  | 1/kg                  | 1x2.72      | 2.72                                          |

Let us consider a 1 km pavement of 7.0 m width.
Area of the surface to be covered with pavement blocks = 7000x (1000x1000) = 700000000 mm.
Number of blocks required = 700000000/ (200x100) = 350000.
Total cost of blocks for 1 km pavement = 350000x15.23. = Rs. 5330500 /-

When fine aggregate is replace by the various materials as mentioned earlier the cost of the project can be reduced and the results are furnished in the tables III to VII.

| Percentage replacement | Replacement material cost (Rs) | Cost of the block (Rs) | Overall cost of the pavement construction (Rs) | Variation in cost (Rs) | Profit percentage |
|------------------------|--------------------------------|------------------------|-----------------------------------------------|------------------------|------------------|
| 20%                    | 0.0174                         | 14.81                  | 5183500                                       | 147000                 | 2.76%            |
| 30%                    | 0.0261                         | 14.55                  | 5092500                                       | 238000                 | 4.46%            |
| 40%                    | 0.0522                         | 13.72                  | 4802000                                       | 528500                 | 9.91%            |
Table IV: Cost analysis for paving blocks for fine aggregate replacing with GP

| Percentage replacement | Replacement material cost (Rs) | Cost of the block (Rs) | Overall cost of the pavement construction | Variation in cost (Rs) | Profit percentage |
|------------------------|--------------------------------|------------------------|-------------------------------------------|-----------------------|------------------|
| 20%                    | 0.23                           | 15.026                 | 5259100                                   | 71400                 | 1.34%            |
| 30%                    | 0.44                           | 14.964                 | 5237400                                   | 93100                 | 1.75%            |
| 40%                    | 0.88                           | 14.589                 | 5106150                                   | 224350                | 4.21%            |

Table V: Cost analysis for paving blocks for fine aggregate replacing with CrD

| Percentage replacement | Replacement material cost (Rs) | Cost of the block (Rs) | Overall cost of the pavement construction | Variation in cost (Rs) | Profit percentage |
|------------------------|--------------------------------|------------------------|-------------------------------------------|-----------------------|------------------|
| 20%                    | 0.065                          | 14.861                 | 5201350                                   | 129150                | 2.42%            |
| 30%                    | 0.097                          | 14.621                 | 5117350                                   | 213150                | 4.00%            |
| 40%                    | 0.195                          | 13.904                 | 4866400                                   | 464100                | 8.71%            |

Table VI: Cost analysis for paving blocks for fine aggregate replacing with CD

| Percentage replacement | Replacement material cost (Rs) | Cost of the block (Rs) | Overall cost of the pavement construction | Variation in cost (Rs) | Profit percentage |
|------------------------|--------------------------------|------------------------|-------------------------------------------|-----------------------|------------------|
| 20%                    | 0.353                          | 15.149                 | 5302150                                   | 28350                 | 0.53%            |
| 30%                    | 0.522                          | 15.044                 | 5265400                                   | 65100                 | 1.22%            |
| 40%                    | 1.060                          | 14.769                 | 5169150                                   | 161350                | 3.03%            |

Table VII: Cost comparison normal concrete block with varying percentages of additives

| Percentage replacement | Profit percentage with QD | Profit percentage with GP | Profit percentage with CrD | Profit percentage with CD |
|------------------------|---------------------------|----------------------------|----------------------------|----------------------------|
| 20%                    | 2.76%                     | 1.34%                      | 2.42%                      | 0.53%                      |
| 30%                    | 4.46%                     | 1.75%                      | 4.00%                      | 1.22%                      |
| 40%                    | 9.91%                     | 4.21%                      | 8.71%                      | 3.03%                      |

From the tables III to VII the profit percentage is higher at 40% QD replaced and CrD replaced. Considering the strength there is no appreciable increment in strength when QD % is increased beyond 20% but the profit percentage is higher so QD% can be replaced up to 40% when considering both strength and cost parameters. Similarly while replacing CrD at 20% we got maximum strength and beyond that there is a gradual reduction in strength. Even though there is higher profit percentage at 40% CrD it cannot be used beyond 20%. The analysis shows that the best economical waste product is
quarry dust when compared to other recyclable material in concrete. Almost 10% economical saving for 40% replacement of quarry dust with fine aggregates in concrete paving blocks.

4. CONCLUSIONS
1. By results of specific gravity it was clear that ceramic dust, quarry dust, glass powder have somehow similar specific gravity as normal sand in the range of 2.3 to 3 but coal powder had low specific gravity as 0.8 to 1.4 which is very low among all the materials.

2. Another result was about particle size distribution, glass powder, ceramic dust, quarry dust, coal dust have similar particle size distribution curve when compared to nominal sand as simple ‘S’ curve

3. By replacing with quarry dust by 20% its compressive strength is about 28.5N/mm² i.e., an increment of 51.92 % and further there is no appreciable increment, where as for glass powder it is observed that there is gradual decrease in compressive strength when replaced.

4. Even though there is higher profit percentage at 40% CrD it cannot be used beyond 20% because of decrement in strength of concrete.

5. Considering the strength there is no appreciable increment in strength when QD % is increased beyond 20% but the profit percentage is higher so QD% can be replaced upto 40% when considering both strength and cost parameters.

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