An Experimental Study on Partial Replacement of Cement and Fine Aggregate with Industrial Waste in Concrete Paver Blocks

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Abstract. The present experimental investigation reports the relative results of flexural and compressive strength of conventional uni-paver concrete blocks of M-40 grade with the paver blocks produced by the combined partial replacement of the cement and fine aggregate with fly ash and pond ash respectively. Incorporation of these industrial products resulted in the saving of cement subsequently an overall saving of about 10% in the economy per each paver block production, while not compromising with its performance in respect to its strength aspect. The paver block considered in this experimental work is of zig-zag shape specimen of size 201 mm × 100 mm × 80 mm. Initially, fine aggregate and cement were replaced in percentages of 5, 10, 15 and 20 separately with pond ash and fly ash respectively. Later on, both fine aggregate and cement were replaced and the performance of paver block is evaluated in terms of its mechanical properties.

1. Introduction

Due to the special benefits associated with the interlocking paver blocks from the point of view of operational and environmental constraints they are being extensively used all over the world especially in the locations of footpaths, parking areas, airport runways, entrance to offices, driveways, parkways, small and medium market roads, container yards etc. [1-2]. To make the production of such concrete paver blocks more economical utilization of industrial waste as a partial replacement of the fine aggregate and cement is a good alternative. This also simultaneously solves the problem of disposing these wastes. In recent times, many researches are attempting to evaluate the effective use of these industrial wastes in terms of their modified mechanical properties and the feasibility of their economical production. Effective use of waste glass and copper slag as a partial replacement of fine aggregate in the concrete paver blocks was examined in the recent investigations. Results indicated that up to 30% these industrial wastes can be used without affecting the mechanical properties of paver blocks [3-4]. Through the experimental investigations, it was concluded that crushed stone dust can be successfully utilized as a partial replacement for sand in the preparation of concrete paver blocks [5-6]. Previous researchers evaluated the feasibility of utilization of waste tire crumb rubber and PVC plastic...
material as partial replacement of fine aggregate in precast concrete paver blocks. Results showed that up to 15-20% these wastes can be employed without any loss in strength properties [7-8]. Earlier investigations also reported the feasibility of partial replacement of cement by various mineral admixtures namely run-of-station ash (60%), plasterboard gypsum (5%), ground granulated blast-furnace slag (55%), and cement bypass dust (25%) without significant influence on the strength and durability properties [9].

2. Experimental analysis

2.1. Materials characterization
In this experimental study 53 grade Ordinary Portland Cement confirming to IS: 12269-1999 was used for casting of concrete paver blocks. For the cement the physical properties are provided in Table.1. Class F Fly ash and pond ash are collected from the nearby source NTPC Visakhapatnam, India. The Pond ash particle size is varying between 1.18 mm and 150 \( \mu \)m. Specific gravity is found to be 2.25. The fineness and specific gravity of class F fly ash sample was determined as 361 m\(^2\) / kg and 2.05 respectively. Chemical composition of fly ash sample is presented in Table.2. For fine aggregate locally available sand which confirms to Zone III, having a specific gravity of 2.64 is used. Particle size of fine aggregates lies in between 4.75 mm and 150 \( \mu \)m. Coarse aggregate of maximum nominal size 12 mm with a specific gravity and water absorption as 2.72 and 0.45 % is used. A water-reducing admixture, Sikament FF, having a relative density of 1.25 and pH range of 8-12 is also used in the production of paver blocks.

Table 1. Physical properties of OPC-53 grade ((IS 12269-1999))

| Specific gravity | Fineness | Consistency | Initial setting time | Final setting time |
|-----------------|----------|-------------|----------------------|--------------------|
| 3.15            | 7%       | 31%         | 140 min              | 31 min             |

Table 2. Chemical composition of Fly ash

| Chemical composition (%) | SiO\(_2\) | Al\(_2\)O\(_3\) | Fe\(_2\)O\(_3\) | Na\(_2\)O | MgO | CaO | SO\(_3\) |
|--------------------------|----------|----------------|----------------|------------|-----|-----|--------|
| Fly ash                  | 61.24    | 25             | 8.71           | 0.09       | 0.09| 4.42| 0.49   |

2.2. Mixture design
Trial tests are performed in achieving a concrete mix of strength corresponding to M-40 grade. According to the guidelines of IRC 44 and IS 15658:2006 the mixture proportions details are finalized. The mixture proportions of the M-40 grade and the mix designations of all remaining mixes, prepared by partially replacing fine aggregate and cement are represented in Table.3 and Table.4. Fine aggregate (F\(_{\text{agg}}\)) and Cement (OPC) in the conventional concrete paver block mixes are partially replaced by Pond ash (PA) and Fly ash (FA) respectively in percentages of 5, 10, 15 and 20 %.

Table 3. Mix proportions (kg/m\(^3\))

| Mix ID | Cement | Fine aggregate (F\(_{\text{agg}}\)) | Coarse aggregate | Water | Chemical admixture | Water/Cement |
|--------|--------|-----------------------------------|------------------|-------|-------------------|-------------|
| M\(_0\)-0 | 443    | 822                               | 1051             | 161.78| 2.21              | 0.365       |
Table 4. Mix Designations

| Mix ID   | F<sub>Agg</sub> : PA | OPC : FA |
|----------|----------------------|----------|
| M<sub>5-0</sub> | 95:5                | 100:0    |
| M<sub>10-0</sub> | 90:10               | 100:0    |
| M<sub>15-0</sub> | 85:15               | 100:0    |
| M<sub>20-0</sub> | 80:20               | 100:0    |
| M<sub>10-5</sub> | 90:10               | 95:5     |
| M<sub>10-10</sub> | 90:10               | 90:10    |

2.3. Specimen preparation and test procedures
All the raw materials which are stored separately are weighed for accuracy and transferred into the mix in the sequence of: coarse aggregate, fine aggregate, cement, and pigment of the desired color.

First these materials are mixed for about three to four minutes. Later, additional water is added along with the admixture and again mixed again for about three to four minutes. After measuring the slump it was transferred to moulds of zig-zag shape. In order to maintain identical slump the admixture content is slightly adjusted. The size of moulds used is 201 mm × 100 mm × 80 mm. The moulds later vibrated for about 15 seconds and then they are kept undisturbed for 24 hours. After this period specimens are de-moulded and kept in water for the curing process to take place until the time of testing. Both the flexural and compressive strength tests were performed in accordance with IS 15658:2006. The specimens during the testing are arranged as shown in Figure 1 and the average value of compressive and flexural strengths for four paver blocks was evaluated.

3. Results and discussions
The compressive strength and flexural strengths of concrete paver blocks are evaluated at 3, 7 and 28 days are evaluated and the average of four specimens is reported as the respective strength. The compressive and flexural strengths of all mixes are discussed below. Figure 2 delineates the comparison between average 3, 7 and 28 days compressive strength of concrete paver blocks with 5, 10, 15 and 20% replacement of aggregate fines by pond ash and the average compressive strength of conventional concrete paver blocks.
It can be observed that up to 15% replacement of fine aggregate by pond ash there is an increment in the compressive strength of paver blocks at 3, 7 and 28 days when compared to the conventional concrete paver blocks. The maximum gain in the compressive strength is found to be at 10% replacement of aggregate fines by pond ash. The rate of increment in the average 3, 7 and 28 days compressive strength of paver blocks is found to be 18, 12 and 11% respectively at 10% of replacement of fine aggregate. At 20% replacement there is a decline in the average 28 days compressive strength and the rate of decrement is found to be 10% when compared to the conventional concrete paver blocks. Interestingly, except for 20% replacement by pond ash the average compressive strength of paver blocks at 3, 7 and 28 days is greater than conventional concrete paver blocks wherein the sand alone is used as fine aggregate. Figure 3 represents the flexural strength variation of concrete paver blocks when the fine aggregate is replaced by the pond ash in percentages of 5, 10, 15 and 20%. It can be noted that at 5% replacement of pond ash the flexural strength is improved compared to the paver blocks made from conventional concrete.

**Figure 2.** Compressive strength of Concrete Paver blocks with the partial replacement of FA

**Figure 3.** Flexural strength of Concrete Paver blocks with the partial replacement of FA
There is a slight decrement in 7 and 28 days flexural strength of concrete at 10, 15, 20% replacement with pond ash compared to the conventional paver blocks although marginally higher flexural strengths are attained at 3 days curing period. Compared to the conventional blocks the percentage decrements in the average flexural strengths at 28 days are found to be 7.3, 8.2, 8.9 at 10,15 and 20 % replacement of aggregate fines with the pond ash. On the other hand, percentage increments in the average 3, 7, 28 days flexural strengths at 5% replacement are found to be 11, 7.3 and 7.2 % respectively. Figure 4 illustrates the influence of fly ash replacement in the concrete paver blocks wherein 10% of the fine aggregate was replaced with the pond ash. From figure 4, it is clear that as the fly ash replacement increases, there is an increase in the average 28 days compressive strength of concrete paver blocks up to 15%, although at 3 and 7 days, the compressive strengths are marginally low. This may be due to the low heat of hydration arising with the presence of fly ash.

Figure 4. Compressive strength of Concrete Paver blocks with the partial replacement of FA (10%) and cement

At 20% replacement of cement by fly ash, there is a marginal reduction in the compressive strength of paver blocks compared to 15% replacement. The percentage gain in 28 days compressive strength of 10, 15, and 20% replacement is found to be 6, 11 and 4 % when compared to conventional paver blocks. At 3- days curing period, when 15% by weight of cement is replaced with fly ash a decrement of 17% in average compressive strength of paver blocks It can be noticed while at 7 days a marginal increment in the compressive strength was observed. Hence, the maximum gain in compressive strength occurred at 10% replacement of aggregate fines by pond ash and 15% replacement of cement by fly ash.

Figure 5 depicts the flexural strength variation of paver blocks when 10% of the fine aggregate is replaced by pond ash and cement is replaced by fly ash in percentages varying from 5 to 20% in increments of 5%. From Figure 5 it is evident that the flexural strength of the paver blocks with partial replacement of fine aggregate are marginally lower than conventional concrete paver blocks except at 15% replacement of cement by fly ash when the curing period of paver blocks attained 28 days. At this curing period, the highest gain in the flexural strength was found to be 3.5% when compared to the flexural strength of conventional concrete paver blocks. Therefore, similar to the trend of compressive strength, when cement and fine aggregate are replaced by 15% of fly ash and 10% pond ash, respectively better flexural strengths of paver blocks
are achieved compared to the conventional blocks. Figure 6 shows the compressive strength development of paver blocks at the age of 3, 7 and 28 days when fine aggregate and cement are partially replaced with pond ash and fly ash respectively. From Figure 6, it is observed that as the in fly ash content increases the compressive strength of paver blocks is improving, but beyond 15% replacement of cement by fly ash, the compressive strength is dropped down even below the strengths of conventional paver blocks. Addition of fly ash resulted in lesser compressive strengths at 3 and 7 days curing whereas significant strength developments at 28 days are observed. The maximum compressive strength gain occurred when 15% of the cement is replaced by fly ash and 5% of fine aggregate was replaced by pond ash.

**Figure 5.** Flexural strength of Concrete Paver blocks with the partial replacement of FA (10%) and cement

**Figure 6.** Compressive strength of Concrete Paver blocks with the partial replacement of FA (5%) and cement
Figure 7. Flexural strength of Concrete Paver blocks with the partial replacement of FA (5%) and cement

The maximum strength gain in this case is found to be 7.3% when compared to conventional paver blocks. This gain in the strength is relatively lower than the strength gain occurred when 15% of the cement and 10% of the aggregate fines are replaced with fly ash and pond ash respectively. Figure 7 describes the variation in the flexural strength development of paver blocks when 5% of the fine aggregate is replaced by pond ash and fly ash replaces cement in percentages of 5, 10, 15 and 20%. It can be noted from Figure 7 that it at early ages the flexural strength development is low when compared to the conventional paver blocks. A slight increment in the flexural strength is found at 28 days when 15% of cement and 5% of the fine aggregate are replaced with fly ash and pond ash respectively. The maximum flexural strength gain is found to be 1.3% compared to the conventional concrete paver blocks. It can also be noted that this strength is less than the strength attained by paver blocks when 15% of the cement and 10% of the aggregate fines is replaced by fly ash and pond ash respectively.

4. Conclusions
From the experimental investigation conducted on the effective use of industrial wastes i.e. pond ash and fly ash as an alternative source material for fine aggregate and cement, these following conclusions can be made:

- The compressive strength of conventional paver block can be improved by 11% by replacing 10% of aggregate fines by weight with pond ash. The maximum gain in the flexural strength was obtained when 5% of aggregate fines was replaced by pond ash.
- Industrial wastes namely pond ash and fly ash can be effectively used to achieve economy in the production of concrete paver blocks simultaneously improving their mechanical properties.
- Use of 10% pond ash and 15% fly ash as partial replacement of the fine aggregate and cement resulted in an increase in the compressive strength by 11%.
- The maximum gain in the flexural strength of paver blocks was attained when 10% of flash and 15% of cement are replaced by pond ash and fly ash respectively. A maximum increment in the flexural strength was observed to be 3.5% compared to the conventional concrete paver blocks.
- Replacement of 10% of fine aggregate and 15% cement with pond ash and fly ash by weight results in economy savings up to 9.8% for single concrete paper block.

References
[1] Navya G and Rao J V 2014 Experimental investigation on properties concrete paver block with the inclusion of natural fibers Int. Jour. of Eng. Res. and App. 4 pp 34-38
[2] Kumar B R and Rao and J V 2015 Effect of inclusion of glass fibers and fly ash in concrete paver blocks International Journal for Research in Applied Science & Engineering Technology 3 pp 437-443
[3] Nishikant K, Nachiket A, Avadhut I and Sangar A 2016 Manufacturing of concrete paving block by using waste glass material International Journal of Scientific and Research Publications 6 pp 61-77
[4] Kalaiselvi S, Prabhakaran S, Jagadeesan K 2015 An experimental investigation on partial replacement of copper slag as fine aggregate in paver block Int. Jour. of Chem. Tech. Res.10 pp 306-310
[5] Nanda R P, Das A K and Moharana N C 2010 Stone crusher dust as a fine aggregate in concrete for paving blocks International Journal of Civil & Structural Engineering 1 pp 613-620
[6] Gupta A and Tiwari A 2016 Effect on mechanical properties of paver block consist crusher stone dust as fine aggregate with inclusion of steel fiber International Journal for Research in Applied Science & Engineering Technology 4 pp.529-535
[7] Rethinavelsamy B M and Chidambarathanu N 2016 Investigation on precast concrete paver block with waste tyre crumb rubber Road Materials and Pavement Design 17 pp719-736
[8] Mahadevi R, Abirami S, Jananipriya P, Karunya J and Sakthipriya M 2018 An experimental investigation on concrete paver block by using PVC plastic material Int. jour. of mod. Tr. in eng. and res. 5 pp 112-115
[9] Ganjlan Eljalali G and Sudeghi-Pousa H 2015 Reducing cement contents of paving blocks by using mineral waste and by-product materials Journal of Materials in Civil Engineering 27 p 04014106