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Feasibility study of strength and durability performance of paver blocks using RHA and WFS

R Ganesh [1], A Sheerin Farzana [2], P Ponkarthikeyan [3], J Jacob [4]
[1, 2, 3] Assistant Professor, [4]P.G Student,
Department of Civil Engineering Kamaraj College of Engineering and Technology,
Virudhunagar, Tamilnadu,
e-mail: [1]anbuganesh11@gmail.com, [2]sheerinfarzana39@gmail.com,
[3]ponkarthikeyancivil@kamarjengg.edu.in, [4]jackprakash3@gmail.com

Abstract— **In this industrial world, recycling material plays an important role to preserve natural sources. The main focus of this research is to study the strength of paver block using waste industrial materials. Metal foundries use large amounts of molding sand for casting process. Foundries successfully recycle and reuse those sand many times. The foundry sand is removed from foundry when the sand can be no longer reused. Foundry sand can be used in concrete to improve its strength and other durability factors. Rice Husk Ash (RHA) is the pozzolanic waste generated from Rice milling Industries. Blending of a large amount of RHA is being done in large extents in the manufacture of cement and cementitious products. This paper deals with the study of strength and durability characteristics of RHA and WFS replaced paver block. Cement concrete cubes were casted to determine the optimum percentage replacement of cement and fine aggregate with RHA and WFS. Optimum results were found for the replacement of 15% RHA with total mass of cement and 20% WFS with total mass of fine aggregate. From the obtained optimum results, paver blocks were casted with 15% cement replacement with RHA and 20% sand replacement with WFS. Tests were performed for water absorption test, flexural strength, impact test, abrasion resistant test, compressive strength and split tensile strength for replacement levels of rice husk ash and waste foundry sand at different curing periods (28-days & 60-days). Test results shows increase in strength and durability performance of the paver blocks. From the test results it can be concluded that Manufacturing of bricks and paver blocks using combination Rice Husk Ash and Waste Foundry Sand is feasible and economical.**

Keywords— ***Rice Husk Ash, Waste Foundry Sand, Partial Replacement, Paver Block, Durability***

I. INTRODUCTION

Concrete and natural river sand plays a vital role in the construction industry. Use of the natural resources as a major ingredient of concrete costs high and good quality natural river sand is not available now-a-days. As the natural resources takes millions of years for its formation and is not renewable, an alternative option should be found out. The environmental factors and pressure of utilizing waste materials from industry have also play a major role in new developments in the field of construction.

Foundry sand is high quality silica sand that is a byproduct from the production of both ferrous and nonferrous metal casting Industries. Most of the metal industries prefer sand casting system. In this system mould made of uniform sized, clean, high silica sand is used. After casting process foundries recycle and reuse the sand several times but after sometime it is discarded from the foundries known as waste foundry sand. The application of waste foundry sand to various engineering sector can solve the problems of its disposal and harmful effect to environment.

Rice husk is an agricultural residue which is also known as rice hull is a by-product of rice milling product. The partially burnt husk produced from the milling plants will contribute to environmental pollution when used as a fuel and efforts are being made to overcome this environmental issue by utilizing this material as a supplementary cementing material. RHA is rich in silica content and can be used as a potential cement replacement material.

II. SELECTION OF MATERIALS:

A. Cement

Ordinary Portland Cement of 53 Grade conforming to IS 8112-1989 [13] with specific gravity 3.16 was used.

B. Course Aggregate

Coarse aggregates used was crushed angular aggregates of normal size 20 mm with specific gravity 2.81 and fineness modulus 3.57.

C. Fine Aggregate

Fine aggregate used was river sand with specific gravity 2.73, passing through 4.75mm sieve and falling under zone III as specified in IS 383-1978 [10]. Fineness modulus 0.57

D. RHA & WFS

The RHA used for blending was grey in colour with specific gravity 2.5. The specific gravity of WFS 2.20

E. Water

Ordinary potable water conforming to IS456-2000 [11] was used for casting and curing.

III. Mix Design

The concrete mix proportion for M20 concrete was arrived based on IS10262-2009 [14] method and it was given in Table 1.

TABLE I. MIX PROPORTION FOR M30 CONCRETE

Materials/ m3 of Concrete	**Water**	**Cement**	**FA**	**CA**
Kg	191.61	383	594.59	1242.58
Mix	0.5	1	1.55	3.24

IV. Experimental Program

The main objective of this investigation is to study the strength and durability performance of paver blocks using RHA and WFS. Concrete cubes were casted with various percentage replacements of cement with Rice husk ash and Fine aggregate with Waste Foundry Sand. The optimum results were obtained at 15% replacement of cement with Rice Husk Ash and 20% replacement of Fine aggregate with Waste Foundry Sand. Paver blocks were casted for this obtained optimum value.

A. Impact resistant test

The impact resistance of the specimen is determined by using drop weight method of Impact test recommended by ACI committee 544 procedures. The size of the specimen recommended by ACI committee is 152 mm diameter and 63.5 mm thickness and the weight of hammer is 4.54 Kg with a drop of 457mm. The specimens placed on the base plate with the finished face up and positioned within four lugs of the impact testing equipment. The bracket with the cylindrical sleeve is fixed in place and the hardened steel ball is placed on the top of the specimen within the bracket. The drop hammer is then placed with its base upon the steel ball and held vertically. The hammer is dropped repeatedly. The number of blows required for the first visible crack to form at the top surface of the specimen is to be the first crack was based on visual observation (N1). Ultimate failure is defined in terms of the number of blows required to open the cracks in the specimens (N2) sufficiently to enable fractured pieces to touch three of the four positioning lugs on the base plate. The impact energy delivered to the specimens are calculated by each impact is calculated as follows:

EI = Nmgh

Fig. 1. Impact test apparatus

B. Water absorption test

B1. Saturation

The test specimen is completely immersed in water at room temperature for 24 * 2 h. then the specimen removed from the water and allowed to drain for 1 min by placing them on a 10mm or coarser wire -mesh. 'Visible water on the specimens shall be removed with a damp cloth.The specimen shall be immediately weighed and the weight for each specimen noted (W_w).

B2. Drying

Subsequent to saturation, the specimens shall be dried in a ventilated oven at 107 + 7°C for not less than 24 h and until two successive weighing at intervals of 2 h show an increment of loss not greater than 0.2 percent of the previously determined mass of the specimen. The dry weight of each specimen shall be recorded (W_d).

Percentage of water absorption = $\frac{w_w - w_d}{w_d}$ X 100

C. Abrasion Resistant Test

The weight of the specimen shall be noted. Both prior to the abrasion test and after every four cycles. The grinding path of the disc of the abrasion testing machine shall be evenly strewn with 20 g of the standard abrasive powder as per IS 1237. The specimen shall be fixed in the holding device such that the testing surface faces the grinding disc. The specimen shall be centrally loaded with 294±3 N. The grinding disc shall be run at a speed –of 30 rpm. The disc shall be stopped after one cycle of 22 revolutions. The test cycle shall be repeated 16 times, the specimen being turned 90° in the clockwise direction and spreading of 20 g of abrasive powder on the testing track after each cycle. The abrasive wear of the specimen after 16 cycles of testing shall be calculated as the mean loss in specimen volume, Δv, from the equation:

$$\Delta v = \frac{\Delta m}{PR}$$

D. Compressive strength test

The dimensions and plan areas of the specimens are determined. The blocks shall be stored for 24 * 4 h in water maintained at a temperature of 20 ± 5"C. The bearing plates of the testing machine shall be wiped clean. The specimens are aligned with those of the bearing plates. The load shall be applied without shock and increased continuously at a rate of 15 ± 3 N/mm2/min until no greater load can be sustained by the specimen or delamination occurs. The maximum load applied to the specimen shall be noted in N.

Compressive strength = Maximum load / Plan area

Fig. 2. Compressive strength on paver blocks

E. split tensile strength

The test is carried out along the longest splitting section of the specimen, parallel and symmetrical to the edges, in such a way that the distance of the splitting section to any side face is at least 0.5 times the thickness of the specimen over at least 75 percent of splitting section area. The splitting section shall be chosen in such a way that the greatest total proportional section length satisfying the distance requirement is obtained. d) In case the section of the specimen is square, hexagonal or circular in plan, the splitting section shall be chosen in such a way that it is the shortest length passing through the centre of the plan area.

The tensile splitting strength of the test specimen is calculated from the equation:

$$T = 0.637 (k) \times \frac{P}{S}$$

Fig. 3. Spilt tensile strength on paver blocks

F. flexural strength test

The load shall be applied from the top of the specimen in the form of a simple beam loading through a roller placed midway between the supporting rollers. The load shall be increased continuously at a uniform rate until the specimen fails, and the maximum load applied shall be recorded to the nearest N.

The flexural strength of the specimen shall be calculated as follows

$$f_b = \frac{3pl}{2bd^2}$$

Fig. 4. Flexure strength on paver blocks

V. Results and Discussion

A. Impact test result

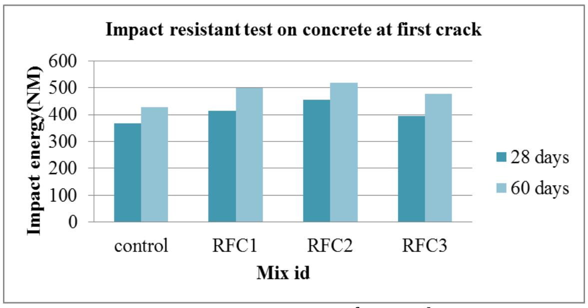

Fig 5: impact resistant at first crack

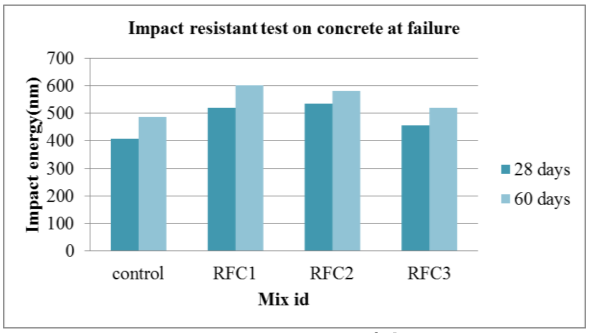

Fig. 6. Impact resistant at failure

Fig 5,6 illustrates the variation of impact resistance of the paver block with 15% replacement of Rice Husk Ash for cement and 20% replacement of foundry sand for Fine aggregate. Graph shows that impact resistance of RFC paver block increases with respect to the control specimen. From the graph it is found that the impact resistance at first crack of the paver block is approximately 15.10% increase in 28 days curing period and 16.74% increase in 60 days curing period when compared to control mixture.

B. Water absorption test for paver blocks

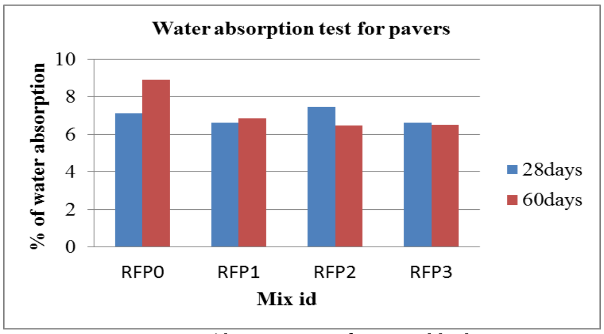

Fig. 7. Water Absorption test for paver blocks

Fig 7 shows the variation of Water Absorption of the paver block with 15% replacement of Rice Husk Ash for cement and 20% replacement of foundry sand for Fine aggregate. Graph shows Water Absorption of RFC paver block decreases with respect to the control specimen. From the graph it is found that the Water Absorption of the paver block decreases approximately 8.29% in 28 days curing period and 15.8% decrease in water absorption in 60 days curing period when compared to control mix.

C. Flexural strength for paver blocks:

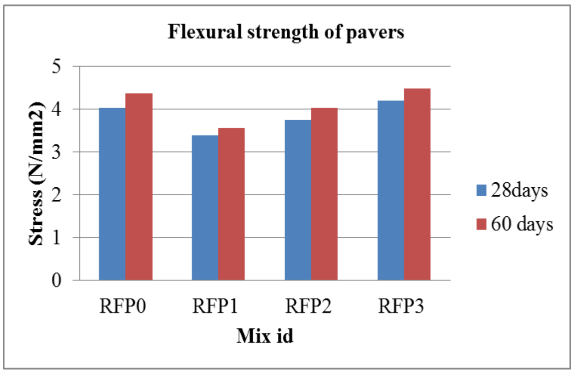

Fig. 8. Flexural strength of paver blocks

Fig 8 shows the variation Flexure strength of the Paver block with 15% replacement of Rice Husk Ash for cement and 20% replacement of foundry sand for Fine aggregate. It is found that addition of Rice Husk ash and Foundry sand increases the density of the paver block hence increase the Flexure strength of the Paver block. The Flexure strength of the Paver block increases approximately 6.36% for 28 days curing period and 7.87% for 60 days curing period.

D. *Abrasion resistant strength of pavers*

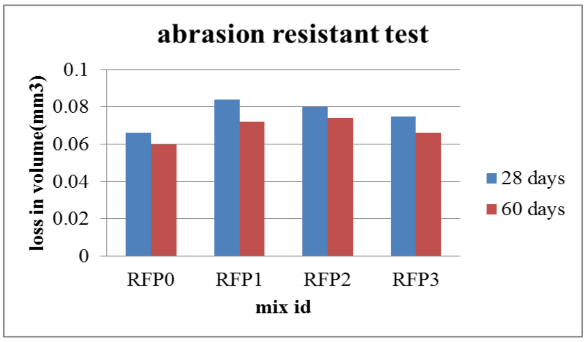

Fig. 9. Abrasion Resistant Test

Fig 9 illustrates the variation Abrasion resistance of the Paver block with 15% replacement of Rice Husk Ash for cement and 20% replacement of foundry sand for Fine aggregate. The Abrasion resistance of the Paver block decreases approximately 20.70% for 28 days curing period and 17.77% for 60 days curing period. It is found that addition of Rice Husk ash and Foundry sand decreases the Abrasion resistance of the Paver block.

E. *Compressive strength of paver blocks*

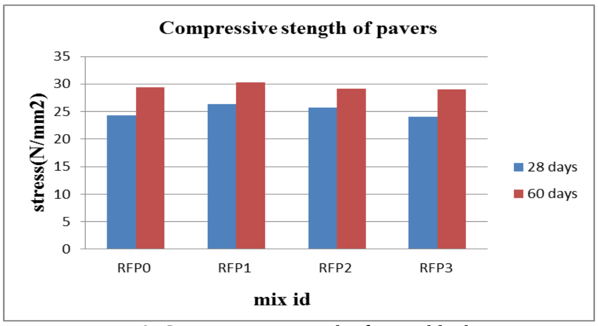

Fig. 10. Compressive strength of paver blocks

Fig 10 illustrates the variation compressive strength of the Paver block with 15% replacement of Rice Husk Ash for cement and 20% replacement of foundry sand for Fine aggregate. The compressive strength of the Paver block increases approximately 25% for 28 days curing period and 32% for 60 days curing period. It is found that addition of Rice Husk ash and Foundry sand increases the compressive strength of bricks and Paver block.

F. *split tensile strength for paver blocks*

Fig 11 illustrates the variation split tensile strength of the Paver block with 15% replacement of Rice Husk Ash for cement and 20% replacement of foundry sand for Fine aggregate. The Abrasion resistance of the Paver block increases approximately 18%for 28 days curing period and 27%for 60 days curing period. It is found that addition of Rice Husk ash and Foundry sand increases the split tensile strength of the Paver block.

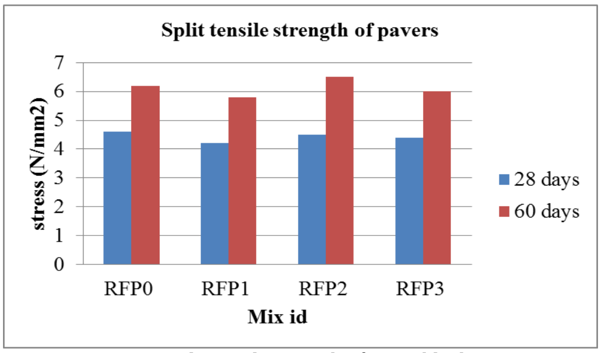

Fig. 11. Split tensile strength of paver blocks

VI. CONCLUSION

The following conclusions are taken from this investigation

In this study, it was found that the optimum level of replacement of rice husk ash (RHA) and waste foundry sand (WFS) 15% of cement and 20% of fine aggregate.

The impact resistance at first crack of the RFP paver block is approximately 15.10% greater than control mixture in 28 days curing period and 16.74% greater than control mixture in 60 days curing period. The compressive strength of the RFP Paver block is greater than control specimen. Replacement of cement (OPC) and fine aggregate (FA) with rich husk ash (RHA) and waste foundry sand (WFS), increases compressive strength than the control specimen in both bricks and paver blocks. The compressive strength of the RFP Paver block increases with curing period.

Split tensile strength of RFP increased by 35% more than the control specimen paver blocks. . Flexural strength results of RFP paver blocks shows that it is suitable for application at Residential driveways, Light vehicles, public pedestrian and light vehicle paths. The use of Rice Husk Ash considerably reduces the water absorption of concrete. Thus, concrete containing Rice Husk Ash can be effectively used in places where the concrete can come in contact with water or moisture. Percentage of Water absorption for paver blocks decreases by 8% at 28days and 11% at 60days. RFP shows good durability improvement rather than the control specimen.

Inclusion of Waste Foundry Sand as sand replacement and Rice Husk Ash as cement replacement significantly improved the abrasion resistance of concrete at all stagesWaste Rice Husk Ash and Waste Foundry Sand can be efficiently used in construction thus leaving the environment safe. The addition of Rice Husk Ash and Waste Foundry Sand in concrete helps in making an economical concrete. Manufacture of paver blocks using a combination Rice Husk Ash and Waste Foundry Sand is feasible.

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