

# Waste Foundry Sand as a Replacement for Fine Aggregate in High Strength Solid Masonry Blocks

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**ABSTRACT:** The management of solid industrial waste is of big global concern nowadays. The majority of industries are not interested in the treatment and safe disposal of industrial waste due to its high cost involvements, causing environmental and other ecological impacts. The disposal of waste foundry sand is of prime importance due to the big volume produced from the foundries all over the world. Moreover solid masonry blocks which are widely used in construction purposes are structurally inferior to burnt clay bricks. This also has a disadvantage that it cannot be used for load bearing and seismic resistant structures. This paper mainly targets on two solutions: making of commercially available solid masonry blocks to high strength so that it can be used in load bearing structures and replacement of fine aggregate in these blocks with waste foundry sand. Although many studies have been formulated using waste foundry sand in concrete, no such study has been reported so far with solid masonry blocks. Design of blocks were made following IS: 10262(2009) guidelines and testing of blocks were satisfied using IS: 2185(1979). It was inferred that about 20 to 30 percent of replacement of fine aggregate to waste foundry sand gave good results for all practical purposes. This study also aims to encourage industries to start commercial production of concrete products using waste foundry sand.

**KEYWORDS:** High strength solid masonry blocks, waste foundry sand, chemically bonded foundry sand, compressive strength

## I. INTRODUCTION

Natural sand has been used widely in construction activities and is diminishing day by day. At present due to the unavailability of natural sand, manufactured sand produced from quarries are widely used for mass production of concrete. Very soon in the near future there will be a scarcity for manufactured sand also. Use of recycled products is the new trend in industry and researchers are keen to find a new material that fit for the right purpose. Here waste foundry sand can be effectively utilized as partial or full replacement of natural sand or manufactured sand. Waste foundry sand (WFS) is a by-product of the metal casting industries generated from the released moulds for casting after several reuses [1]. Foundry sand is basically high quality silica sand. Depending upon the type of binders used, waste foundry sand or used foundry sand can be classified into green sand and chemically bonded sand. In green sand the binder used is bentonite whereas in chemically bonded sand it is mainly of organic system [2]. Due to the chemicals present in the binders the disposal of waste foundry sand for land filling may cause adverse environmental and ecological impacts. Due to high treatment cost, foundry industries are not much interested to invest on the safe disposal of waste sand. As per present disposal practices, the waste foundry sand which is dumped on barren land cannot be recovered. So the waste foundry sand should be used for other beneficial applications to reduce its adverse effects. In this study the properties of high strength concrete masonry blocks with partial replacement of waste foundry sand to fine aggregates are examined. This alternate use is also advantageous in saving of natural resources like river sand, which is in threat of depletion. It can also save the natural rock deposits to some extent as nowadays manufactured sand

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

are used in abundance instead of natural sand. The energy requirement for the waste foundry sand is also a minimum compared to the manufactured sand. By the efficient use of this waste foundry sand total construction cost can be reduced substantially.

## II. RECENT INNOVATIONS USING WASTE FOUNDRY SAND IN CONSTRUCTION ACTIVITIES

At present waste foundry sand obtained from foundry industries are used in structural fills such as filling embankments, in road construction as filling material for sub bases etc.[3]. Latest innovations prove it can also be used in normal concrete as a replacement for fine aggregate for certain level of replacement [2, 4, 5]. A peripheral research has also been carried out by incorporating waste foundry sand on paving units [6]. Waste foundry sand in self compacting concrete was another milestone achieved in research field [7, 9]. High strength concrete was also set up using waste foundry sand [8]. All these experiments were made either on concrete, or its properties. But no such report has been presented so far distinguishing the significance of using waste foundry sand in commercial products such as concrete masonry blocks.

## III. RESEARCH SIGNIFICANCE

At present the commercially available blocks are of very inferior quality both in strength and durability. Main objective of this study was that if blocks of higher strength and durability can be obtained by the use of partial or full replacement of waste foundry sand total cost of the cost of construction of residential buildings can be reduced.

Most of the individual residential buildings are made with single storey or twin storey access. Normally these buildings are made using burnt clay bricks or solid concrete blocks utilising its load bearing characteristics. Adopting lesser width concrete blocks enables more room space for the same plinth area and this will be cost effective according to the availability of high strength solid masonry blocks. Hence the main aim was to find out the feasibility of employing waste foundry sand as an ingredient in the manufacture of high strength concrete masonry blocks.

Experimental investigations was carried out to investigate the effect of waste foundry sand (WFS) as partial or full replacement of fine aggregate for the manufacturing of solid concrete blocks . This will be achieved by comparing the parameters such as Block Density, Compressive Strength, Water Absorption, Drying Shrinkage and Moisture Movement with that of blocks made with controlled concrete, utilizing the normal ingredients.

## IV. PHYSICAL COMPOSITION OF WASTE FOUNDRY SAND

Investigations were made on foundry sand procured from Local Foundry near Chavara, Kollam dist., Kerala, India. This type of sand has a peculiarity that it is of chemically bonded nature. Foundry sand obtained directly from foundry is shown in Figure 1. It has to be crushed to usable size before supplying it into concrete making. For laboratory applications it was crushed using manual means. In the case of commercial application aggregate crusher can be engaged. The physical properties of the foundry sand used in this investigation are listed in Table 1 respectively.



Figure 1. a) Waste foundry sand directly taken from site b) Crushed used foundry sand

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Vol. 5, Issue 5, May 2016

Table 1. Physical properties of waste foundry sand

Property	Value
Specific gravity	2.63
Water absorption	1.79%
Bulk density	1440 kg/m <sup>3</sup>
Voids ratio	0.62
Porosity	38.27%

## Moulds Sizes and Specifications

Concrete masonry building units shall be made in sizes and shapes to fit different construction needs. The maximum variation in the length of the units shall not be more than  $\pm 5$  mm and maximum variation in height and width of unit, not more than  $\pm 3$  mm.

- ✓ Length 400, 500 or 600 mm
- ✓ Height 200 or 100 mm
- ✓ Width 50, 75, 100, 150, 200, 250 or 300 mm.[10]

Hence as per the code provisions different sizes can be adopted for manufacturing of blocks. Here 200× 100× 100 mm size blocks were taken for the ease of making and testing. Depending on strength aspects and controlling the factors used in design half sizes of bricks were convenient [10]. For the purpose of experiment five specially designed moulds were fabricated and casted specimens were shown in Figure 2.



Figure 2. Special moulds with casted concrete blocks

## V. MIX DESIGN PROCEDURE

As per IS: 2185 (Part 1) -1979 concrete mix used for blocks shall not be richer than one part by volume of cement to 6 parts by volume of combined aggregates before mixing. Therefore volume batching has been prescribed for the production of concrete for manufacturing concrete masonry blocks. But for comparative study volumetric batching will not give precise results. So the volumes of each ingredient are converted to corresponding weights as per IS 10262(2009) -Indian standard guidelines for mix proportioning [11]. Thus weigh batching is done for the mix. Trial mixes has been prepared with w/c ratio 0.45 and admixtures 0.6%. Code prescribes 1:6 cement to combined aggregate

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ratio. Separate ratios for coarse and fine were not specified in the code. Hence mixing of aggregates was taken on trial basis. Coarse aggregates are taken as 60 % and fine 40% of combined volume. For the experimental work, coarse aggregate passing through 4.75 mm sieve and fine aggregate (M-sand) of zone II specifications was taken. Table 2 indicates the quantity of raw materials required for making of 5 control solid masonry blocks as per theoretical calculation. An allowance of 10% extra material for the wastages due to spillage of concrete mix was also considered

Table 2. Materials for 5 numbers of Control blocks

Material	Theoretical Requirement (kg)	Actual Requirement (with 10% extra for wastage)(kg)
<b>Cement</b>	2.954	3.25
<b>Fine aggregate</b>	8.82	9.71
<b>Coarse aggregate</b>	11.574	12.732
<b>Water</b>	1.493	1.643
<b>Admixture</b>	0.0177	0.1947

Table 3 stipulates materials used in making of 5 blocks for each percentage of replacement for waste foundry sand. Solid concrete blocks blocks after hardening were cured in curing water tank and were kept continuously moist for 14 days. Blocks made after curing is shown in Figure 3.

Table 3. Materials required for various % of replacement of WFS

Material	%Replacement of Waste Foundry Sand					
	10%	20%	30%	40%	50%	100%
<b>Cement (kg)</b>	3.25	3.25	3.2	3.25	3.25	3.25
<b>Fine aggregate (kg)</b>	8.74	7.76	6.79	5.83	4.86	0
<b>Coarse aggregate (kg)</b>	12.65	12.65	12.65	12.65	12.65	12.65
<b>WFS (kg)</b>	0.94	1.88	2.82	3.75	4.7	9.4
<b>Water (l)</b>	1.729	1.738	1.748	1.755	1.766	1.648
<b>Admixture (ml)</b>	19.47	19.47	19.47	19.47	19.47	19.47



Figure 3. Prepared solid concrete blocks after curing

**VI. EXPERIMENTAL INVESTIGATION AND RESULTS**

Among 20 numbers of blocks, for each percentage of replacement, 8 numbers were used for testing of compressive strength. The strength of the full-size units is considered as that which is calculated from the average measured strength of the segments. For the purpose of acceptance, age of testing the specimens shall be 28 days. Results are plotted in Figure 4

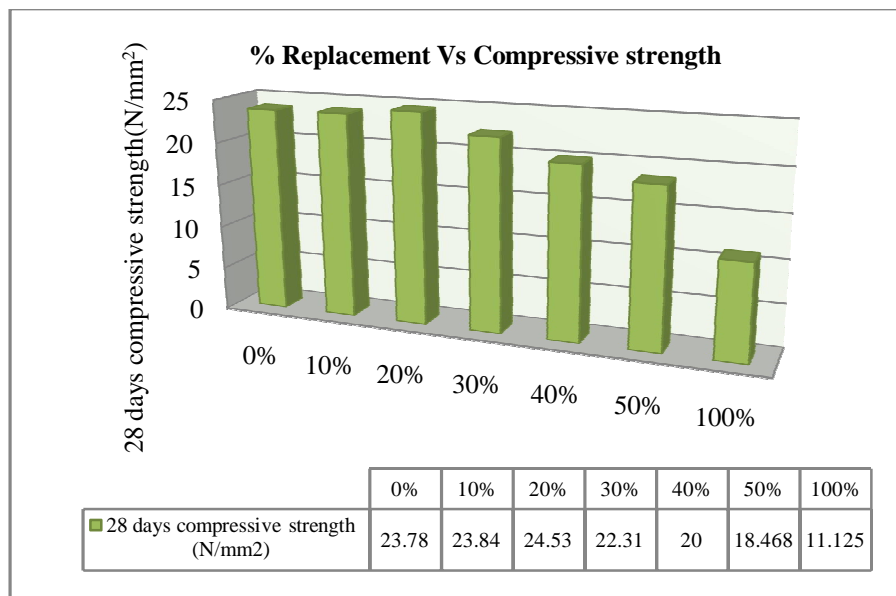


Figure 4. % Replacement of WFS Vs Compressive strength

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Water absorption tests were conducted for three blocks by completely immersing in water at room temperature for 24 hours. Subsequent to saturation, all specimens are dried in a ventilated oven at 100 to 115°C for not less than 24 hours and until two successive weighing at intervals of 2 hours show an increment of loss not greater than 0.2 percent of the last previously determined mass of the specimen. Results are stipulated in Figure 5.

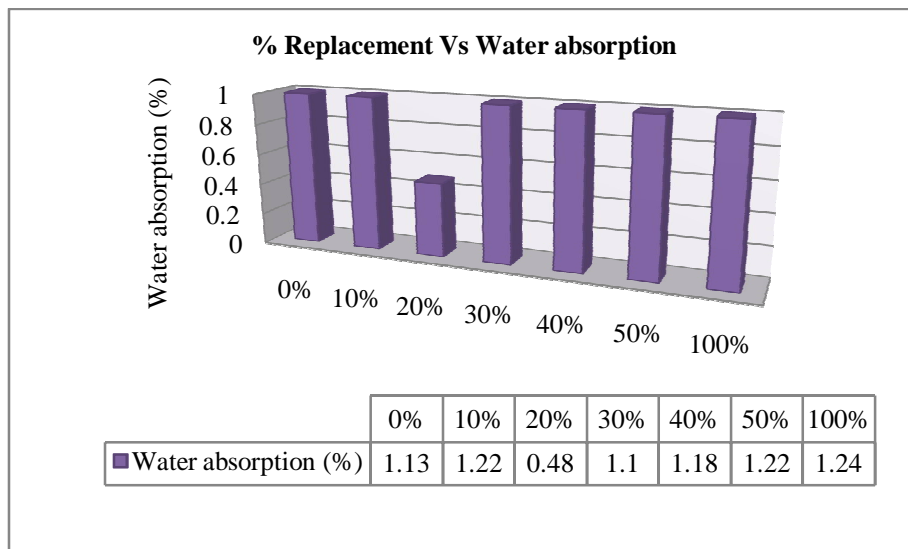


Figure 5. % Replacement of WFS Vs Water Absorption

Three blocks taken at random from the samples selected are dried to constant mass in a suitable oven heated to approximately 100°C. After cooling the blocks to room temperature they are weighed in kilograms (to the nearest 10 g) and the density of each block is plotted in Figure 6.

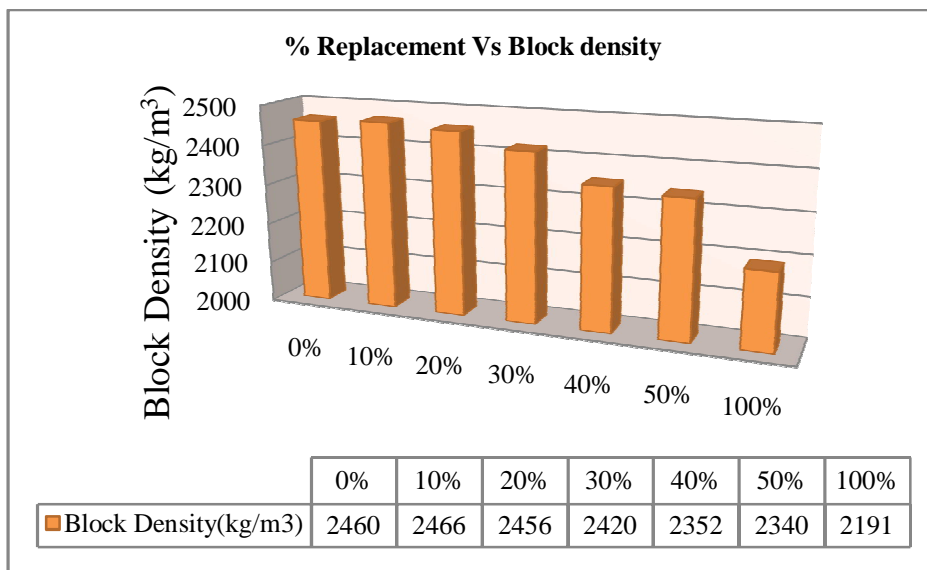


Figure 6. % Replacement of WFS Vs Block density

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Drying Shrinkage was found out using micrometer gauge by noting down wet measurement and dry measurement for three selected blocks. The difference between the 'original wet measurement' and the 'dry measurement' expressed as a percentage of the 'dry length' is calculated and plotted in Figure 7

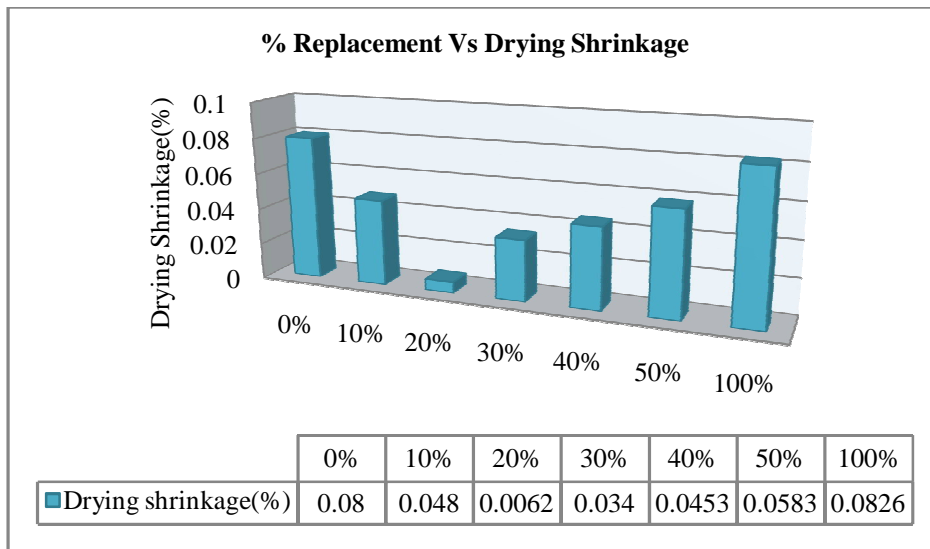


Figure 7. % Replacement of WFS Vs Drying Shrinkage

The specimens which have previously been used for the drying shrinkage test after the completion of that test, was immersed in water for 4 days, the temperature being maintained at  $27 \pm 2^\circ\text{C}$  for at least 4 hours prior to the removal of the specimens and the wet length measured. The moisture movement was determined as the difference between the dry and wet lengths and expressed as a percentage of the dry length for each specimen and shown in Figure 8.

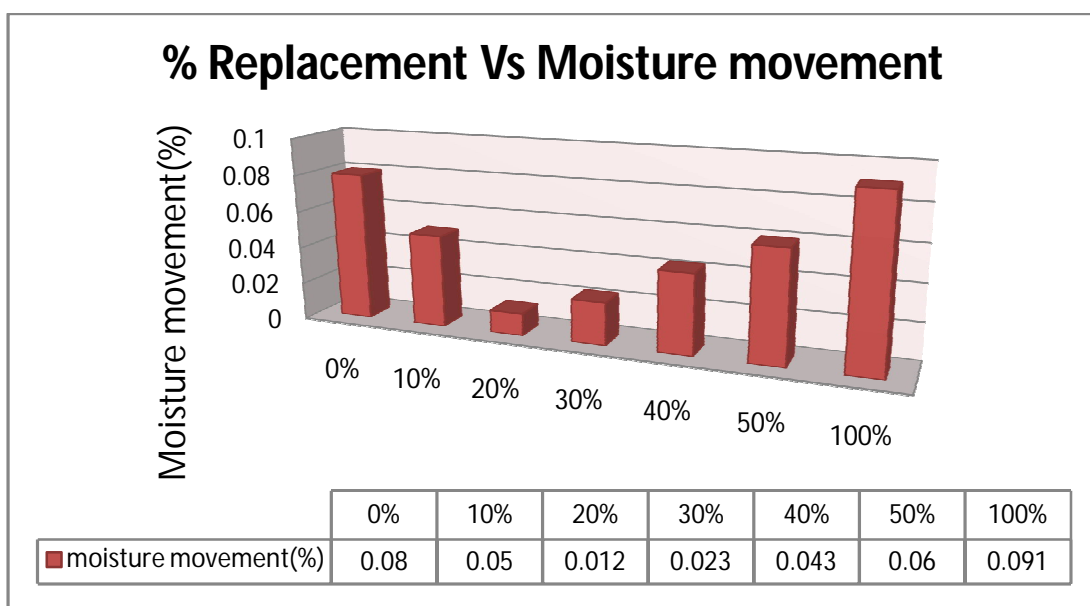


Figure 8. % Replacement of WFS Vs Moisture movement

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## VII. DISCUSSION

From the tests, the obtained value of maximum strength was 20% replacement. Further addition decreased the strength. Water absorption limit as per the codes was 10% of volume. But it was found that the addition of waste foundry sand in concrete has induced some minor variations in water absorption. However in all the cases observed values were much less than the permissible value in the order of 12.4% of the maximum allowed value. Block density value decreased by the increase of waste foundry sand which may be due to the reduced value of specific gravity for waste foundry sand. Moisture movement limit as stipulated in code was 0.1%. For this parameter also addition of waste foundry sand from 0-100% was found to be within limits. Drying shrinkage also followed the conditions of codes given as maximum limit as 0.09%, which was also satisfied for all percentages of replacement. For 20% replacement moisture movement, drying shrinkage and water absorption value decreased and in the later increase of percentages it increased which shows optimum replacement gave good results in all tests as specified in codes.

## VIII. CONCLUSIONS

- ✓ From the test results obtained it is evident that ordinary concrete blocks can be made high strength and thereby it can be used in construction of shear walls, load bearing walls, infill walls etc. It can also be used in earth quake prone areas for higher lateral resistance.
- ✓ Incorporation of waste foundry sand increases the strength of blocks and optimum percentage of replacement was found between 20 to 30 %.
- ✓ For 100% replacement efflorescence was noted which may be due to heavy salts present in waste foundry sand. Hence 100% replacement is not advisable as it may be harmful for connected R.C.C works like footings, columns, beams, slabs etc.
- ✓ The Indian Standard codes IS 2185(1979) [11] prescribes strength up to 5 N/mm<sup>2</sup> for concrete masonry blocks whereas burnt clay bricks are available in different grades starting from a strength of 3.5N/mm<sup>2</sup> to 35N/mm<sup>2</sup> as per IS 1077(1992) [12]. For special applications heavy duty burnt clay bricks are available in strengths of 40 N/mm<sup>2</sup> and 45 N/mm<sup>2</sup> as per IS 2180(1988) [13]. In the present scenario the code prescribed strengths for concrete masonry blocks are very insufficient to cater the loads especially in seismic regions. So the Indian standard code for the concrete blocks has to be revised accordingly to accommodate a wide range of strengths for different applications.
- ✓ Volumetric batching specified in the code has to be changed to weigh batching in line with the good construction practices as modern weigh batching equipments are available in affordable cost for the commercial production to ensure durability and consistent strength for the manufactured blocks.

## ACKNOWLEDGEMENTS

The authors would like to acknowledge their deep gratitude to their working organizations for the constant encouragement and support rendered to them from time to time.

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**Vol. 5, Issue 5, May 2016**

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