Utilization of Used Foundry Sand in the Development of Sustainable Concrete Mortars

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***Abstract*—Cement-based composites have been explored for several modifications by the addition of the waste materials or as the replacement of the conventional constituents. All three major ingredients namely cement, sand and aggregates have been partially or fully replaced with different natural and manmade waste materials by many researchers. The used foundry sand however, is one of the industry-based waste materials largely generated in a large quantity and remains unutilized, has not extensively explored for its possible addition in cement-based concrete mixes. This paper deals with the feasibility study and results obtained from the experimental explorations on the concrete mortars prepared by replacing the conventional river sand with used foundry sand in varying proportions from 0% to 100% replacement ratio. The study was carried out for MM1.5 grade of mortars as per the guidelines of IS: 2250-1981 consisting cement as the binder agent. The foundry sand was assessed in accordance to the IS: 2116-1980 code guidelines. The cement mortars were prepared with 0% to 100% used foundry sand fractions replacing the natural sand. All the necessary tests were performed on the mortar mixtures as per the code guidelines. The test results showed that the strength and workability properties did not changed up to 60% replacement of the conventional sand by used foundry sand. However, the mortar strength reduced gradually on the addition of the used foundry sand beyond 70% replacement scenario. The optimum replacement dosage of the used foundry sand was found to be 60%. The study provided the way for using the used foundry sand in construction applications for the mortar mixtures to develop the sustainable construction material.**

Keywords*—*Used foundry sand; Cement; Concrete mortar; flow value; Strength.

I. Introduction

Concrete is a commonly employed construction material worldwide, serving as the fundamental element for all construction and developmental activities [1]. The extensive use of concrete as a consequence of the rise in urbanization and industry has caused the riverbed to be stripped of a greater quantity of natural sand. Some of the negative effects include increased riverbed distance, decreased water table, exposed bridge substructures, influence on rivers, deltas, coasts, and marine ecologies, land loss due to river or coastal erosion, and a reduction in deposit source quantity [2].Due to limits on taking sand out of the river, which has caused sand charges to go up, the survival of the building industry has been badly affected [3].The utilization of fine aggregate, specifically sand, is a crucial element in the production of mortar and concrete, as it serves a pivotal function in the composition of the design mix [4]. Sand comprises a greater proportion of the mixture than cement. Sand's ability to occupy pores or cavities is an additional factor that contributes to its strength. Sand reduces volume changes caused by the setting and hardening processes and provides a particulate mass that can withstand the action of than cement paste alone. Consequently, sand plays a crucial function in consolidating and providing the necessary strength. Therefore, it is essential to explore substitutes for naturally occurring river sand [5-6]. Industrial wastes are growing, which is a sustainability issue. Coal bottom ash from power plants, foundry sand from metal casting, copper slag from the metal sector, crushed rock dust from stone quarries, building and demolition wastes from construction industries, etc. are generated in large quantities worldwide. There is no treatment strategy for these wastes in most poor nations, including India, thus they are dumped in landfills [7]. 39% of CO_2 emissions and more than 50% of natural resources taken from the earth are caused by the building business [8]. Taking this into consideration, In this regard, the use of alternative cementitious materials and the reuse of solid waste from the construction, steel, and foundry industries are beneficial to the environment because they reduce the exploitation of natural aggregates, as well as the emissions of CO_2 that are produced by machinery and the transport of aggregates from quarries to construction sites [9, 10]. The production of waste has risen as a result of both rising population and advances in technology. As a result, a significant number of researchers and scientists all over the globe are looking for innovative ways to get rid of these wastes or make use of them as valuable resources. For many years, a wide variety of industrial byproducts have been investigated for their potential use as replacements for fine aggregate [11]. In addition, waste tyre [12,13], marble [14,15], waste lathe fibers [16], waste lathe scraps [17], waste glass

[18,19], and coal bottom ash [20] have all been investigated as potential replacements for coarse and fine aggregates in the production of concrete in order to create a more environmentally friendly material. Foundry sand (FS), is the substance that is used in the production of mould boxes during the sand-casting process, which is utilized for casting both ferrous and nonferrous materials. The yearly production of 100 metric tonnes of used foundry sand has an adverse effect on the environment due to its eventual disposal in landfills [21-22]. Sand made of silica and binders, which may be derived from natural or synthetic sources, are the most important components of FS. The foundry method, as well as the metal and the binder that is utilized, may have a significant impact on the used foundry sand's physical and chemical characteristics [23]. The visual appearance of used foundry sand (UFS) may range from dark grey to black in color, depending on the amount of carbon present, and the form of the particles can be anything from sub-angular to rounded [24-25].However, it has been observed that the majority of the UFS is not considered to be dangerous [26], and its physical qualities are appropriate for use in cement-based materials such as low-strength materials [27], cement-treated bases [28], and ordinary concrete [29,30]. However, there are construction applications for used foundry sand. These include brick manufacturing, road construction, land reclamation, erosion control, green construction, landscaping, concrete production, and mortar production. The use of foundry sand in mortar manufacturing has several positive effects, including enhanced mortar qualities, reduced costs, less waste, and a more sustainable approach to building. The present study aims to use foundry sand to produce mortar without negatively impacting the environment. While different regions have different ideal conditions for used foundry sand, this investigation focused on the Cement mortar mixtures were formulated incorporating varying percentages of used foundry sand (UFS) as a replacement for natural sand, ranging from 0% to 100%. The importance of this research is found in its examination of the viability of substituting used foundry sand for conventional sand in the making of mortars. This method of using foundry sand has the potential to decrease the environmental effects of disposing of this waste while also preserving natural resources and lowering the price of raw materials. Also,the study offers insights into the consequences of this substitution on the mechanical properties of the mortar by evaluating the mortars at various concentrations of used foundry sand.

II. EXPERIMENTAL PROGRAM

A. Materials

1) Cement: For the study locally available ordinary Portland cement was used in this work as a binding material. Various tests were performed to prove the quality of the cement before its application. Physical and chemical properties are listed in Table I and III, respectively.

2) Fine Aggregate: The sand from the river was used as a fine material. Table II shows the physical features of fine aggregate.

3) Foundry Sand: Foundry sand was procured from Rajkot(India) Fig.1. For the purposes of this study, chemically bound sand was used. The physical and chemical qualities of used foundry sand depend on how the metal was cast and what binder was used.The physical and chemical properties of the used foundry sand were tested according to Indian standards and they are listed in Tables II and III, respectively.The casting sand was tested according to the IS: 2116-1980 code[31].

TABLE I. PHYSICAL PROPERTIES OF CEMENT

Properties	**Experiential values**
Residue retained on 90 µ sieve	5%
Consistency of cement	29%
Specific gravity	3.15
Initial setting time (minutes)	119
Final setting time (minutes)	232
Compressive strength –7 days	40.47 MPa
Compressive strength –28 days	57.60 Mpa

TABLE II. PHYSICAL PROPERTIES OF FINE AGGREGATE AND USED FOUNDRY SAND

Properties	**Experiential values**	
	FA	***UFS***
Specific gravity	2.66	2.48
Fineness Modules	2.94	2.57
Water Absorption (%)	1.1	0.95

Fig.1: Used Foundry Sand

TABLE III CHEMICAL PROPERTIES OF CEMENT AND USED FOUNDRY SAND

Constituent	**Experimental values**	
	Cement	***UFS***
CaO	67.2	3.6
SiO_2	18.1	91.84
Al_2O_3	3.88	2.52
Fe_2O_3	3.26	0.2
SO_3	3.72	0.12
K_2O	0.55	0.3
MgO	1.11	0.32
LOI	1.35	2.12

B. *Methodology for Sample preparation*

Mortar Sample Preparation : Mortars of the MM1.5 grade with a cement-to-sand ratio of 1:7[32], are employed here for the study. which is often used because it has low strength but a high degree of workability. These mortar mixtures can be used for basic construction activities like masonry, plastering, and pointing brick or stone walls. A higher sand concentration makes for a smoother, less labor-intensive application of mortar, but at the expense of compressive strength compared to mortars with a higher cement content.The cement mortars in this study were prepared by replacing the natural sand with varying fractions of used foundry sand, ranging from 0% to 100%. The mixture proportion for each sample are shown in Table IV.

TABLE IV. GRADUAL REPLACEMENT PROPORTION OF NATURAL SAND BY USED FOUNDRY SAND (UFS).

Mix Identity	Mortar Mix (MM1.5 Grade)
Control Mix	1Cement: 7 (100% Natural Sand)
UFS 10 %	1Cement: 7 (90% Natural Sand + 10% UFS)
UFS 20 %	1Cement: 7 (80% Natural Sand + 20% UFS)
UFS 30 %	1Cement: 7 (70% Natural Sand + 30% UFS)
UFS 40 %	1Cement: 7 (60% Natural Sand + 40% UFS)
UFS 50 %	1Cement: 7 (50% Natural Sand + 50% UFS)
UFS 60 %	1Cement: 7 (40% Natural Sand + 60% UFS)
UFS 70%	1Cement: 7 (30% Natural Sand + 70% UFS)
UFS 80%	1Cement: 7 (20% Natural Sand + 80% UFS)
UFS 90%	1Cement: 7 (10% Natural Sand + 90% UFS)
UFS 100%	1Cement: 7 (100 % UFS)

C. *Test methods*

1) Flowability test: The flowability of mortar is the most important property for determining the optimal water-to-binder ratio. All mortar mixtures were put through the test according to the specifications laid down in IS 2250 (1981). The ratio of water to cement is used to calculate the amount of water needed for each mortar mix,Fig.:2. Here, we maintained a uniform range of 105–115% of the standard frustum's base diameter for each mortar's flow value.

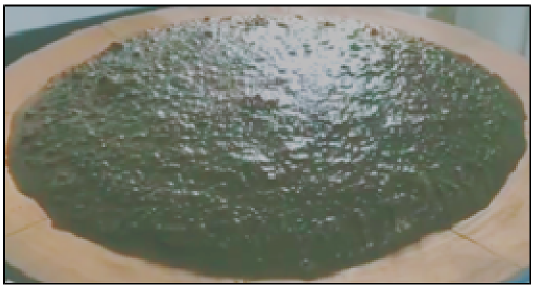

Fig.2: Flow table test of control mortar

1) Compressive strength test: The compressive strength test was performed on water-cured mortar cubes after 3, 7, and 28 days according to IS 2250 (1981) Fig.3. Four cubes of size 50 mm X 50 mm X 50 mm were tested using a compressive strength testing equipment for each specified curing time (3,7 and 28 days), and the results were noted. To determine the impact of used foundry sand in MM 1.5 grade mortar, 132 mortar cubes were cast & tested.

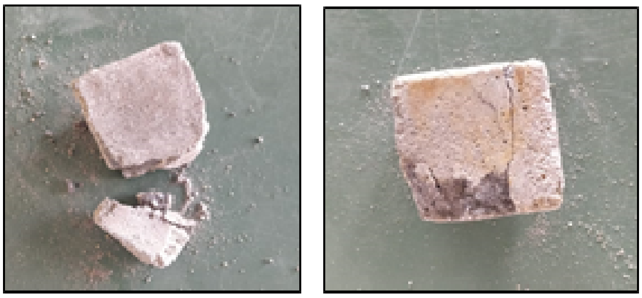

Fig.3: Compressive strength tested Specimen of Mortar

III. RESULTS AND DISCUSSION

A. *Fresh Properties*

Water requirements for needed flow according to IS 2250 (1981) can be seen in Fig.:4. At a 0.9 water-cement (w/c) ratio for the reference mortar specimen, the needed flow was attained for mix 1:7, but it took a 1.4 w/c ratio for the mix containing 100% used foundry sand. The w/c ratio of mortar containing used foundry sand was found to increase noticeably to 55%. Cement mortars' workability decreases when used foundry sand is added to the mix. The lack of workability, however, can be compensated for simply adding a superplasticizer at a modest dosage.

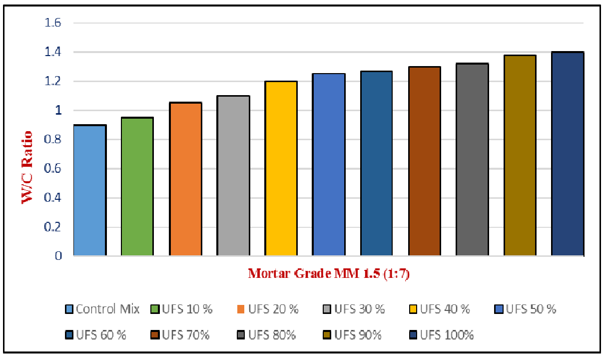

Fig. 4: W/C Ratio value of Various Replacement level of UFS

B. *Water Absorption*

The variations for water absorption in cement mortars with substitution of used foundry sand are graphically represented in Fig.:5. It is clear that as the proportion of used foundry sand in mortar has grown, water absorption for mortars manufactured with used foundry sand has increased as well. The water absorption is 5.42% for the 1:7 reference mix, however, it is 10.48% for mortar with 100% used foundry sand.

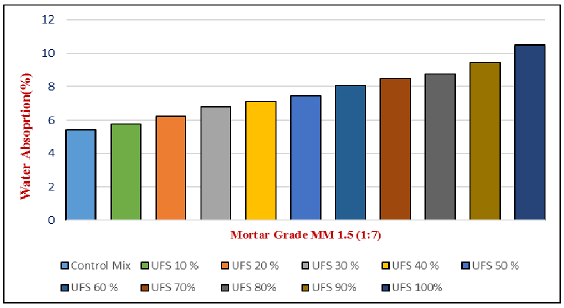

Fig. 5: Water Absorption value of Various Replacement levels of UFS

C. Compressive Strength of Mortar

The 3,7 and 28-day compressive strength of mortar control mix with a conventional sand-cement combination under MM1.5 grade (1:7) were compared with Used foundry sand mixtures (Control mix to UFS 100%) in Fig.: 6,7, and 8.

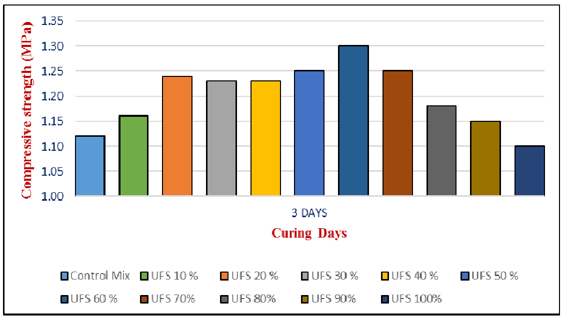

Fig.6: Comp. Strength test values for MM1.5 Grade Mortar Mixes at 3 days

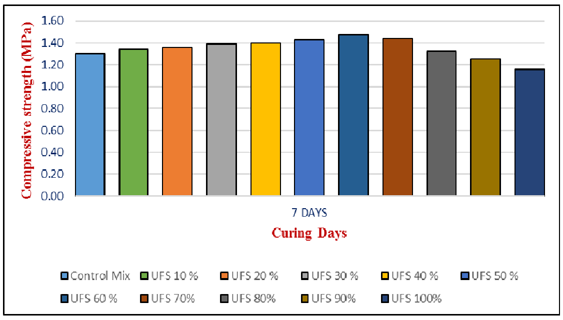

Fig.7: Comp. Strength test values for MM1.5 Grade Mortar Mixes at 7 days

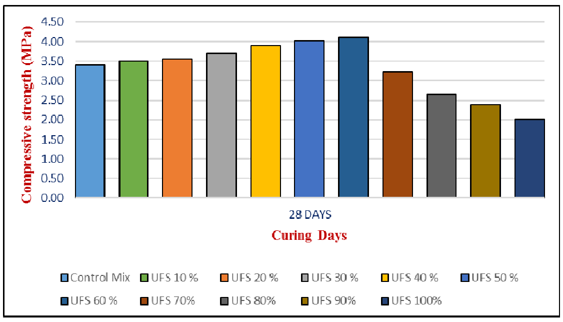

Fig.8: Comp. Strength test values for MM1.5 Grade Mortar Mixes at 28 days

From the Result, it was found that the compressive strength increased when using a 10% substitution ratio of Used Foundry sand in place of natural sand. The value of the mix was observed to increase beyond control, such as 10%, 20%, 30%, and so on. The strength of mortar in the MM 1.5 grade increases up to 60% proportion. Compressive strength created by mortar made with used foundry sand is greater than that of mortar prepared with control mix by up to 60% across all ages tested. So, the outcome satisfied with the requirements of IS 2250 (1981) for masonry mortar.

All masonry mortars are categorized based on their compressive strengths in accordance with Indian standard specifications. The method outlined in Appendix A of IS:2250-1981 was followed to determine the compressive strength. Masonry mortars should ideally be graded according to their minimum compressive strength in accordance with IS: 2250-1981 and IS:1905-1987[33,34]. The IS:2250-1981 and IS:1905-1987 significant codes have provided 38 and 26 distinct mortar mixtures, respectively. When the two tables are combined, 51 different mixture combinations are given. Based on the findings of the experiments, new mortar mixtures have been proposed for use with the masonry units. whose information is given in Table V.

Table V NEW SUGGESTED MORTAR MIXES FOR UFS VARIATION

Mix Identity	Compressive Strength at 28 days (MPa)	Substitute for mortar mix as per	
		IS 2250:1981	IS 1905:1987
Control Mix	3.40	MM3	M2
UFS 10 %	3.50	MM3	M2
UFS 20 %	3.55	MM3	M2
UFS 30 %	3.70	MM3	M2
UFS 40 %	3.90	MM3	M2
UFS 50 %	4.02	MM3	M2
UFS 60 %	4.10	MM3	M2
UFS 70%	3.22	MM3	M2
UFS 80%	2.65	MM2	M2
UFS 90%	2.38	MM2	M2
UFS 100%	2.02	MM2	M2

IV. CONCLUSIONS

The experimental work carried out on the specimens prepared with the Used Foundry Sand as a replacement at various percentage of the natural river sand in mortar mixes to reach to the following conclusions;

- Based on the results of a chemical study, we can say that Used Foundry Sand can be a very good resource for making mortar. So,the problems of waste disposal and the cost of maintaining landfills are decreased.
- The workability of fresh mortars is reduced by Used Foundry Sand appearance as being finer and more Uniformly sized than natural sand, particularly at the highest replacement rate.

- The addition of used foundry sand usually reduces its mechanical strength. A lack of workability reduces the amount of binding paste in mortar, which causes the mortar to develop pores and weaken.
- The test results revealed that the mortar formulations strength and workability were unaffected up to a 60 percent replacement ratio of conventional sand with used foundry sand. In excess of this replacement ratio, the mortar's strength progressively decreased. The optimal replacement percentage of used foundry sand was therefore established to be 60%.
- The study provided the inspiration for the suggestion that suitable mortar with natural sand substitution with used foundry sand could be used for the construction of masonry structures.
- According to these findings, incorporating used foundry sand into mortar mixtures at proportions of up to 60% percent does not compromise the mortar's capacity for either strength or workability. This hints at the possibility of employing used foundry sand in construction applications; doing so would offer an environmentally friendly replacement for traditional river sand.
- Overall, this study contributes to the growing body of research on waste material utilization in cement-based composites. The successful incorporation of used foundry sand in mortar mixtures up to a certain replacement ratio shows its potential for sustainable building practices.

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