

# Utilization of Waste Foundry Sand and Waste Ceramic Tiles as Partial Replacement for Fine and Coarse Aggregates in Concrete

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**ABSTRACT:** Concrete is considered to be the most widely used and versatile material of construction all over the world. In recent years, concrete technology has made significant advances which have resulted in economical improvements in strength of concretes. This economical development depends upon the intelligent use of locally available materials. To overcome the use of natural resources and by attempting to use waste materials like foundry sand and ceramic tiles in concrete could result in low cost construction. Also the use of waste foundry sand and waste ceramic tiles in construction could help to avoid the problems related to environment pollution. An attempt has been made in this study to determine the compressive strength of M20 grade concrete using waste foundry sand and waste ceramic tiles as partial replacement for fine and coarse aggregates.

**KEYWORDS:** waste foundry sand, waste ceramic tiles, compressive strength, split tensile strength.

## I. INTRODUCTION

Concrete is a versatile engineering composite material made with cement, aggregates and admixtures in some cases. Due to development in construction field, the consumption of natural aggregate is very high and at the same time the production of solid wastes from the demolitions and manufacturing units is also very high. Therefore extreme use of concrete leads to scarcity of natural aggregates. Because of this reason the reuse of waste foundry sand and waste ceramic tiles came into picture.

Foundry sand is high quality silica sand with uniform physical characteristics. Foundries attempt to reuse as much of sand as possible within the foundry process itself, but eventually a fraction becomes spent and unsuitable for further foundry processes. At the moment, 90% of this waste is disposed of to landfill as non-hazardous waste while only 10% is beneficially reused. The disposing of waste foundry sand (WFS) to landfill is becoming increasingly cost prohibitive and is likely to become more difficult as legislation governing waste disposal becomes more stringent. Currently about 500,000 to 700,000 tons of foundry sand is used annually in engineering applications. In the present study, steps have been taken to partially replace the fine aggregate with WFS.

Ceramic waste can be separated in two categories in compliance with the origin of raw materials. The first one are all fired waste generated by the ceramic factories that use only red paste to manufacture their products, such as brick, blocks and roof tiles. The second one is all ignited waste manufactured in stoneware ceramic such as wall, floor tiles and sanitary ware.

In particular, Construction and Demolition (C&D) wastes contribute about 75% of wastes worldwide. Furthermore, ceramic materials contribute about 54% of wastes within the C&D wastes. The global production of ceramic tiles during 2011-12 in the world is about 11,166 million square meters. China is the largest ceramic tiles producer which is 46.6% of world production. Compared to China, India ranks third accounting for just 691 million square meters tiles production which is 6.2% of world production. This huge amount of productions has caused them to be among the most commonly-consumed materials in the world.

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## II. RELATED WORK

Waste Foundry Sand has been tried as fine aggregate in place of sand and ceramic waste has been used as partial substitute to conventional coarse aggregate by 15%, 20%, and 30% in concrete by Saravanan [1]. The results indicated effectiveness of Waste Foundry Sand as fine aggregate and partial replacement of conventional coarse aggregate by ceramic waste up to 15%, 20% without affecting the design strength.

Er. Rahul[2], carried out an experimental study on concrete containing waste foundry sand in the range of 0%, 10%, 20%, 30% and waste ceramic tiles in the range of 0%, 10%, 20% and 30% by weight for M-25 grade concrete. The experimental results showed that there is some increase in compressive strength, split tensile strength and modulus of elasticity after replacing the fine aggregates with some percentage of foundry sand so that foundry sand can be safely used in concrete for durability and strength purposes.

Rama Rao [3], tested the concrete replaced partially with waste foundry sand and ceramic tiles and compared with conventional concrete in plastic state as well as in harden state for workability, compressive strength & split tensile strength. These tests were carried out on standard cube, cylinder for 7 and 28 days to determine the properties of concrete.

Md. Daniyal [4], used crushed waste ceramic tiles in concrete as a replacement for natural coarse aggregates with 10%, 20%, 30%, 40% and 50% of substitution. After analyzing results, the optimum value of waste ceramic tile to be used within the concrete mix with a water/cement ratio of 0.5 was determined as about 30%. The findings revealed that using waste ceramic tile leads to enhancing the properties of concrete.

## III. METHODOLOGY

In this experimental study M20 grade concrete is designed as per the code IS10262:2009. The materials used are fine aggregates, coarse aggregates, cement, waste foundry sand and waste ceramic tiles with control concrete i.e, 5%, 10%, 15%, 20%, 25%, 30% of concrete is partially replaced with the waste foundry sand and waste ceramic tiles in fine and coarse aggregates. The moulds are casted for both conventional concrete and replaced concrete with foundry and ceramic waste, casted specimens are cured in water for 7, 14, 28 days respectively. After curing, compressive strength test and split tensile strength test is conducted at 7, 14, 28 days. Two specimens are tested for each designation and average of two results will be taken.

## MATERIALS

### A. Cement

Portland cement is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar and plaster. Of the various ingredients used in concrete, cement is the most energetical and expensive. In the present investigation OPC 53 grade cement is used.

Table 3.1: Physical properties of Cement

Elements	Content
Specific Gravity	3.29
Fineness Modulus	7.9%
Standard Consistency	34%
Initial Setting time	45min
Final Setting time	300min

The table 3.1 shows the physical properties such as specific gravity, fineness modulus, standard consistency, initial and final setting time of Ordinary Portland Cement (OPC 53 grade).

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**Table 3.2: Chemical properties of Cement**

Oxides	Percentages
CaO	62.85
SiO <sub>2</sub>	20.98
Al <sub>2</sub> O <sub>3</sub>	5.42
Fe <sub>2</sub> O <sub>3</sub>	3.92
MgO	1.76
SO <sub>3</sub>	2.36
Na <sub>2</sub> O	0.28
K <sub>2</sub> O	0.53
Loss of Ignition	1.90

Table 3.2 shows the chemical composition of Ordinary Portland Cement (OPC 53 grade) that has been used for this experimental study.

## B. Water

Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely. Lower water to concrete ratio yields a stronger, more durable concrete, while more water gives a free-flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure.

## C. Fine aggregate

It is the aggregate most of which passes 4.75 mm IS sieve and contains only so much coarser as is permitted by specification. According to size the fine aggregate may be described as coarse sand, medium sand and fine sand. IS specifications classify the fine aggregate into four types according to its grading as fine aggregate of grading Zone-1 to grading Zone-4. The four grading zones become progressively finer from grading Zone-1 to grading Zone-4. 90% to 100% of the fine aggregate passes 4.75 mm IS sieve and 0 to 15% passes 150 micron IS sieve depending upon its grading zone.

**Table 3.3: Physical properties of fine aggregates**

Sl no.	Particulars	Obtained values
1	Specific Gravity	2.66
2	Fineness Modulus	4.96
3	Bulk density	1750 kg/m <sup>3</sup>
4	Water absorption	2.0%

Table 3.3 shows the physical properties such as specific gravity, fineness modulus, bulk density, water absorption of fine aggregates (sand).

## D. Waste foundry sand

Waste foundry sand is a byproduct of ferrous and non-ferrous metal casting industries where sand has been used for centuries as a molding material because of its thermal conductivity and its unique engineering properties. Foundries successfully recycle and reuse the sand many times in a foundry. When the sand can no longer be reused in the foundry, it is removed from the foundry and is termed as waste foundry sand.

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**Table 3.4: Physical properties of waste foundry sand**

Sl no.	Particulars	Obtained values
1	Specific Gravity	2.07
2	Fineness Modulus	4.49

The basic tests such as specific gravity and fineness modulus test were conducted for waste foundry sand and the results are as shown in table 3.4.

**Table 3.5: Chemical properties of waste foundry sand**

Constituent	Value (%)
SiO <sub>2</sub>	87.91
Al <sub>2</sub> O <sub>3</sub>	4.70
Fe <sub>2</sub> O <sub>3</sub>	0.94
CaO	0.14
MgO	0.30
SO <sub>3</sub>	0.09
Na <sub>2</sub> O	0.19
K <sub>2</sub> O	0.25
TiO <sub>2</sub>	0.15
P <sub>2</sub> O <sub>5</sub>	0.00

Table 3.5 shows the chemical composition of waste foundry sand. Waste foundry sand has low absorption and is nonplastic. Reported values of absorption were found to vary widely, which can also be attributed to the presence of binders and additives. The content of organic impurities can vary widely and can be quite high. This may preclude its use in applications where organic impurities could be important (e.g., Portland cement concrete aggregate). This variability has been attributed to the variability in fines and additive contents in different samples. In general, foundry sands are dry, with moisture contents less than 2 percent.



**Fig1. Waste foundry sand**

Figure 1 shows the waste foundry sand obtained from ferrous and non-ferrous metal casting industries that had been used as a moulding material. It has been used as a partial replacement for fine aggregates (sand) in the preparation of concrete for the following experimental study.

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## E. Coarse Aggregates

Crushed stone aggregates of 20mm size obtained from local quarry site were used for the experiment. The physical properties of coarse aggregates are shown in table below.

**Table 3.6: Physical properties of coarse aggregates**

Sl no.	Particulars	Obtained values
1	Specific Gravity	2.7
2	Fineness Modulus	4.406
3	Water absorption	0.25%

Table 3.6 shows the results for various tests such as specific gravity, fineness modulus and water absorption for coarse aggregates.

## F. Waste ceramic tiles

The amount of ceramic tile waste on earth is enough for use as a coarse and fine aggregate in concrete. Ceramic tile is produced from natural materials sintered at high temperatures. There are no harmful chemicals in tile. Waste tiles cause only the hazard of pollution. So due to such reasons waste tiles are stored in factory fields because of their economic value. Ceramic waste can be transformed into useful fine and coarse aggregates. It has been calculated that about 30% of the daily production in the ceramic industry is left as a waste. This waste is not recycled in any form at present.

**Table 3.7: Physical properties of waste ceramic tiles**

Sl no.	Particulars	Obtained values
1	Specific Gravity	2.3
2	Fineness Modulus	14.4%
3	Impact value	24%

Table 3.7 shows the various physical properties such as specific gravity, fineness modulus and impact value of waste ceramic tiles.



**Fig2. Waste ceramic tiles**

Figure 2 shows the waste ceramic tiles that has been used as a partial replacement for coarse aggregates in the preparation of concrete in the following experimental study.

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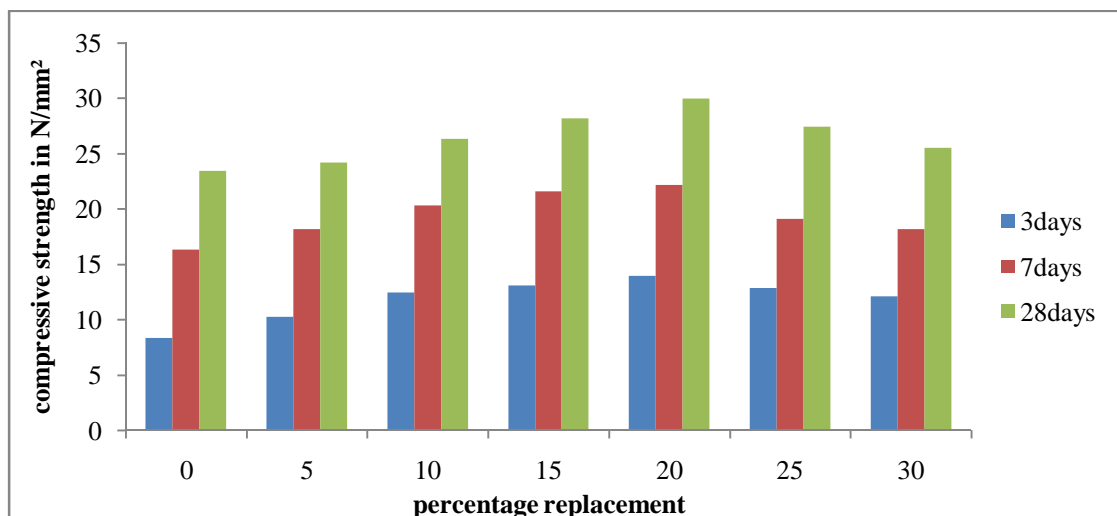
## IV. EXPERIMENTAL RESULTS

### Mix Proportion by volume = 1: 1.8: 3.02

1= cement  
1.8= fine aggregate  
3.02= coarse aggregate  
0.5= Water-cement ratio

**Table 4.1: Compressive Strength in N/mm<sup>2</sup> with different percentage of waste foundry sand replacing fine aggregate and waste ceramic tiles replacing coarse aggregate for M20 grade concrete**

% replacement of waste foundry sand and waste ceramic tiles	Load after No. of days of curing in (MPa)		
	3 days	7days	28 days
0% (NC)	8.4	16.32	23.45
5%	10.3	18.2	24.22
10%	12.5	20.32	26.31
15%	13.1	21.6	28.2
20%	13.98	22.16	29.96
25%	12.90	19.12	27.42
30%	12.11	18.20	25.52



**Fig 4.1: Shows the variation of Compressive Strength at 3, 7 and 28 days for M20 grade concrete with different percentages of waste foundry sand replacing fine aggregate and waste ceramic tiles replacing coarse aggregates**

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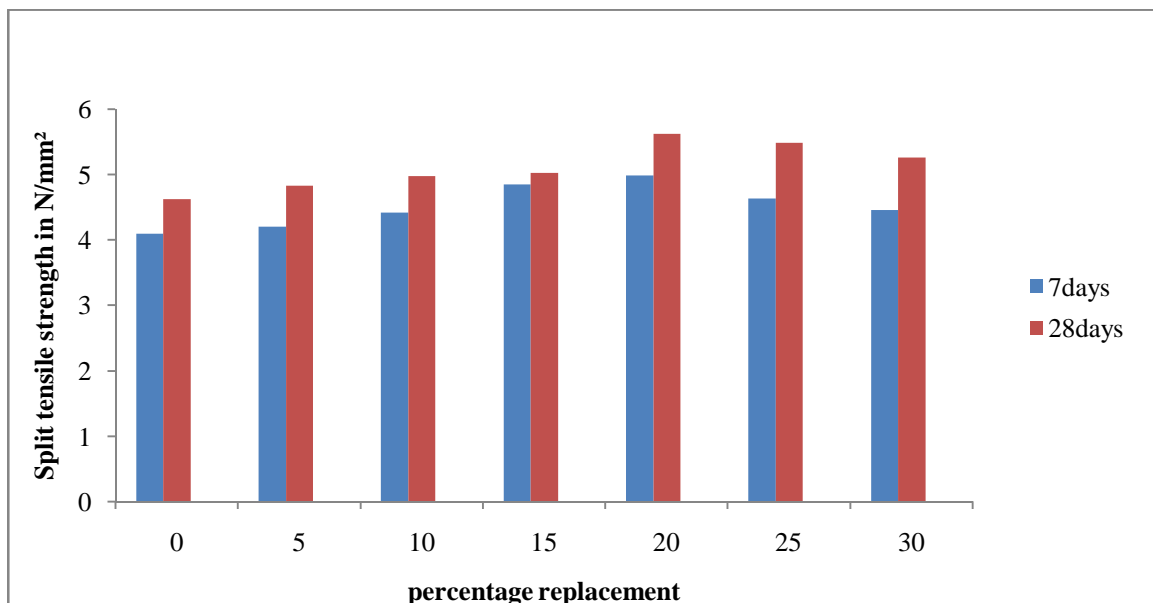
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The above graph indicates the variation of Compressive Strength of concrete at 3, 7 and 28days of curing for M20 grade concrete with different percentages of waste foundry sand replacing fine aggregate and waste ceramic tiles replacing coarse aggregates. It was observed that, strength of concrete increases gradually with increases in percentage of replacement upto 20% after which it decreases.

**Table 4.2: Split Tensile Strength in N/mm<sup>2</sup> with different percentage of waste foundry sand and waste ceramic tiles for M20 grade concrete**

% replacement of waste foundry sand and waste ceramic tiles	Split tensile strength in N/mm <sup>2</sup>	
	7days	28days
0%	4.098	4.627
5%	4.21	4.83
10%	4.42	4.98
15%	4.85	5.025
20%	4.99	5.625
25%	4.64	5.49
30%	4.46	5.26



**Fig 4.2: Shows the variation of Split Tensile Strength at 7 and 28 days for M20 grade concrete with different percentages waste foundry sand replacing fine aggregate and waste ceramic tiles replacing coarse aggregates.**



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## V. CONCLUSION

The maximum compressive strength and split tensile strength of the concrete are obtained when 20% of fine and coarse aggregates were replaced with waste foundry sand and waste ceramic tiles respectively. The compressive strength and split tensile strength has decreased for 25% and 30% replacement with waste foundry sand and ceramic tiles, however there is little variation in strength compared to conventional concrete. Utilization of waste foundry sand and waste ceramic tiles in concrete mix have the advantage of reduction in cost of construction materials. By using waste foundry sand and ceramic wastes in concrete, problems regarding safe disposal is reduced.

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