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MECHANICAL PROPERTIES OF CONCRETE INCORPORATING WASTE CERAMIC TILES AND WASTE FOUNDRY SAND

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Abstract— From the last few years various researchers had done work in concreting and invent various techniques and methods to produce concrete which has the desired properties. Concrete is one of the most vital and common materials used in the construction field. The current area of research in the concrete was introducing waste foundry sand (WFS) and waste ceramic tiles in the ordinary concrete. Waste foundry sand is the byproduct of metal casting industries, which causes environmental problems because of its improper disposal. Construction industries requires huge amount of ceramic tiles and other ceramic for architectural appearance, the productions of which are drastically increased, due to this waste is also produce during handling and usage of ceramic tiles. Thus, its usage in building material, construction and in other fields is essential for reduction of environmental problems. This research was carried out to produce an eco-friendly concrete. This paper recommends the effective use of waste foundry sand as a partial replacement for fine aggregate and waste ceramic tiles as a partial replacement for course aggregate in concrete. Ingredients for concrete are cement, course aggregate, waste ceramic tiles, fine aggregate and waste foundry sand. An experimental investigation was carried out on concrete containing waste foundry sand (WFS) in the range of 0%, 10%, 20%, 30%, and 40% and waste ceramic tiles (WCT) in the range of 0%, 10%, 20%, 30%, and 40% by weight for M-25 grade concrete. Concrete was produced, tested 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. The aim of this research was to know the behavior and mechanical properties of concrete for its eco-friendly and economical use.

Keywords— Industrial waste, Waste Foundry sand (WFS), Waste Ceramic Tiles (WCT), OPC, Eco-friendly, Compressive strength, Split tensile strength, Workability.

I. INTRODUCTION

In the present research, experimental investigations can be carried out on concrete to investigate the effect of waste foundry sand (WFS) and waste ceramic tiles (WCT) as partial replacement of fine aggregate and coarse aggregate respectively on mechanical properties of concrete such as strength, workability, durability, etc of ordinary concrete.

A. Waste Foundry Sand (WFS)

Foundry sand is high quality silica sand with uniform physical characteristics. It is produced from ferrous and nonferrous metal casting industries, where sand has been used for centuries as a molding material because of its thermal conductivity. Indian foundries produce approximately 1.71 million tons of waste foundry sand each year (Metal World, 2006). In the casting process, heat and mechanical abrasion eventually render the sand and thus unsuitable for use in casting molds, and a portion of the sand is continuously removed and replaced with new one. This sand is treated as waste from casting industry and because of high silica content it cannot be disposed easily.

Waste foundry sand is made up of mostly natural sand material. Its properties are similar to the properties of natural or manufactured sand, the fineness modulus of waste foundry sand is 3.027. Thus it can normally be used as a replacement of sand.

The considerable disposal expense has made the current practice of WFS disposal in landfills less favorable. Besides the financial burden to the foundries, land-filling WFS also make them liable for future environmental costs, remediation problems and regulation restrictions. This issue is increasingly addressed by alternate options of reusing WFS beneficially. Beneficial reuses of WFS in variety of applications related to infrastructure engineering and rehabilitation works. Some of the researchers have reported the possible use of waste foundry sand in different civil engineering applications. These alternate applications offer cost savings for both foundries and user industries and environmental benefits at the local and national level.

B. Waste Ceramic Tiles (WCT)

India ranks in the top 3 list of countries in terms of tiles production in the world. This huge amount of ceramic tiles are not recycled but is often used as pavement material or landfill. Ceramic tile aggregates are hard having considerable value of specific gravity, rough surface on one side and smooth on other side, having less thickness and are lighter in weight than normal stone aggregates. Using ceramic tile aggregate in concrete not only it will be cost effective, but also provide considerable strength to the concrete. Construction industries requires huge amount of ceramic tiles and other ceramic for architectural appearance, the productions of which are drastically increased, due to this waste is also produce during handling and usage of ceramic tiles. As 30 to 40% of the total production from manufacturing units is solid waste. So, we selected these waste tiles as a replacement material to the basic natural aggregate. Tiles are a mixture of clays that are pressed into shape and fired at high temperatures which gives the hardness. Ceramic products are made from natural materials which contain a high proportion of clay minerals. These, through a process of dehydration followed by controlled firing at temperatures of between 700ºC and 1000ºC, acquire the characteristic properties of “fired clay”. Ceramic waste may come from two sources. The first source is the ceramics industry, and this waste is classified as non-hazardous industrial waste (NHIW). The second source of ceramic waste is associated with construction and demolition activity, and constitutes a significant fraction of construction and demolition waste (CDW). Reuse of this kind of waste has many advantages, not least of which are the economic advantages, including job creation in companies specializing in the selection and recycling of this kind of material. It goes without saying that reuse is better than recycling.

II. MATERIAL USE AND PART ANALYSIS

A. Cement

Ordinary Portland cement 53 grade was used. It was tested as per Indian standard specification (BIS-1489 part 1:1991). Test results are given below.

“Table1. Physical Properties of ordinary Portland cement”

Physical Properties		BIS-1489:1991	Test Result
Setting time (minutes)	Initial	30 Mini	92
	Final	600 Max	284
Specific gravity		_	3.15

B. Aggregates

- **Fine aggregates**

Those fractions from 4.75 mm to 150 micron are termed as fine aggregate. The river sand as fine aggregate conforming to the requirements of IS: 383 used. Natural sand is screened, to eliminate deleterious materials and over size particles.

- **Coarse aggregate**

The fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 is being use.

"Table2. Physical Properties of Aggregate"

Sr. No.	Properties	Fine Aggregate	Coarse Aggregate
1.	Bulk Density (Loose), kg/lit	1.53	1.42
2.	Bulk Density (Compacted), kg/lit	1.74	1.49
3.	Specific Gravity	2.71	2.64
4.	Water Absorption (%)	0.4	0.3
5	Moisture content (%)	1.78	1.97

C. Waste Foundry Sand:

Waste foundry sand is made up of mostly natural sand material. Its properties are similar to the properties of natural or manufactured sand so it can be used as a replacement of sand. The fineness modulus of waste foundry sand is 3.027.

"Table3. Chemical Properties of Foundry Sand"

Sr. No	Constituent	Value (%)
1	SiO2	83.93
2	Al2O3	0.021
3	Fe2O3	0.950
4	CaO	1.03
5	MgO	1.77
6	SO3	0.057
7	LOI	2.19

Source: *R. Siddique, Waste Materials and By Products in Concrete, Spring-2008*

D. Waste ceramic tiles

Tiles are a mixture of clays that are pressed into shape and fired at high temperatures which gives the hardness. Ceramic tile aggregates are hard having considerable value of specific gravity.

"Figure1. Waste Ceramic Tiles"

"Figure2. Waste Foundry Sand"

III. METHDOLOGY ADOPTED FOR CONCRETE MIX

Mix design is a process of selecting suitable ingredients for concrete and determining their proportions which would produce, as economically as possible, a concrete that satisfies the job requirements. In pursuit of the goal of obtaining concrete with desired performance characteristics, the selection of component materials is the first step, the next step is a process called mix design by which one arrives at the right combination of the ingredients. The mix proportion was modified by replacing fine aggregate by waste foundry sand (WFS) and coarse aggregate by waste ceramic tiles (WCT) in the range of 0%, 10%, 20%, 30% and 40% both. Mix design was carried out manually conforming to IS10262:2009.

"Table4. Conventional Concrete Mix Proportion (M25)"

Water (Lit.)	Cement (kg/m3)	Fine Aggregate (kg/m3)	Coarse Aggregate (kg/m3)
170	346.93	603.64	1272.96
0.49	1	1.73	3.66

"Table5. Modified Mix Proportion for Replacement of Fine Aggregate by WFS and Coarse Aggregate by WCT"

Sr. no.	Coding	% replacement	Concrete mix design proportion					
			w/c ratio	C	FA	CA	WFS	WCT
1	NC	0% replacement	0.49	1	1.73	3.66	0	0
2	FC1	10% replacement	0.49	1	1.557	3.294	0.173	0.366
3	FC2	20% replacement	0.49	1	1.384	2.928	0.346	0.732
4	FC3	30% replacement	0.49	1	1.211	2.562	0.519	1.098
5	FC4	40% replacement	0.49	1	1.038	2.196	0.692	1.464

C=Cement, FA=Fine Aggregate, CA=Coarse Aggregate, WFS=Waste Foundry Sand, WCT=Waste Ceramic Tiles

IV. RESULT ANALYSIS AND COMPARATIVE STUDY

Keeping in mind the gap in the research area, the objective of this study was to determine the strength of concrete containing waste foundry sand (WFS) as partial replacement of fine aggregate and waste ceramic tiles (WCT) as partial replacement of coarse aggregate. For this purpose different test on harden concrete were conducted at the age of 7 and 28 days like compressive strength on 150mm X 150mm X 150 mm size cube and splitting tensile strength on 150 mm X 300 mm size cylinder. As per IS 516 Total 60 number of specimen were tested. Results are tabulated as below:

A. Compressive strength

Compressive strength tests were performed on cube samples of size 150mm X 150mm X 150mm using compression testing machine. Three samples per batch were tested with the average strength values reported in table 6

"Table6. Compressive Strength Test Results"

Sr. No	% replacement	Designation	Average Ultimate Compressive Strength	
			At 7 Days (N/mm2)	At 28 Days (N/mm2)
1	0	NC	18.75	31.42
2	10	FC1	19.30	33.78
3	20	FC2	20.10	36.23
4	30	FC3	18.45	32.06
5	40	FC4	16.20	29.89

"Figur3.Compressive Strength Test Set up"

B. Splitting Tensile strength:-

Splitting tensile strength tests were performed on flexural testing machine using cylindrical samples of size 150 mm X 300 mm. Three samples per batch were tested with the average strength values reported in table 7

"Table7. Splitting Tensile Strength Test Results"

Sr. No.	% replacement	Designation	Average Tensile Strength	
			At 7 Days (N/mm2)	At 28 Days (N/mm2)
1	0	NC	2.02	3.09
2	10	FC1	2.12	3.34
3	20	FC2	2.20	3.57
4	30	FC3	2.09	3.29
5	40	FC4	1.8	3.03

"Figure4.Spliting Tensile Strength Test set up"

C. Workability:-

Workability is the most important parameter regarding flow of concrete. As coarse aggregates are replaced by waste ceramic tiles, as coarse aggregate absorb water because of pours surface waste ceramic tiles gives a advantage here due to its one polished surface and hence absorb less water content as compare to coarse aggregates therefore provide more workable concrete

"Table6.Workability of concrete at conventional and replaced stages"

Sr. No.	% replacement	Water Added	W/C ratio	Slump	Degree of Workability
1	0	170	0.49	7	Low
2	10	170	0.49	42	Low
3	20	170	0.49	76	Medium
4	30	170	0.49	105	High
5	40	170	0.49	137	High

V. CONCLUSION

Depending upon above results and methodology adopted following conclusion were made regarding properties of concrete incorporating waste foundry sand and waste ceramic tile.

- It is found that compressive strength of concrete mix is increases with increase in percentage of waste foundry sand and waste ceramic tiles as compare to regular concrete. It was maximum for 20 % replacement after that it reduces.
- It is also found that split tensile strength increases with increase in percentage of waste foundry sand and waste ceramic tiles up to 20 % replacement after that it reduces.
- Workability of concrete mix increases with increase in percentage of waste foundry sand and waste ceramic tiles as compare to regular concrete.
- As waste foundry sand is waste from metal industries and waste ceramic tiles is waste from construction industries therefore both waste can be effectively use in concrete mix hence an eco-friendly construction material.
- By using this waste in concrete, problems regarding to safely disposal is reduced.

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