International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 6, June-2018

Mechanical Properties of Concrete Incorporating Waste Ceramic Tiles and Waste Foundry Sand

Yatindra Kumar

Civil Engineering Department, Punjab Engineering College Chandigarh,
Email: yatindra.iitcivil@gmail.com

Abstract—

From the previous 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 recent research area in the concrete was introducing waste foundry sand (WFS) along with waste ceramic tiles in the ordinary concrete. Waste foundry sand is the by-product of metal casting industries, which causes environmental problems if disposed improperly. Construction industries requires large amount of ceramic tiles and other ceramic materials for architectural appearance, whose productions are increased enormously. Due to the fact, 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.

Keywords— Aggregate, Mechanical properties, Sand, Waste ceramic tiles (WCT), Waste foundry sand (WFS)

I. Introduction

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 project was carried out to produce an eco-friendly concrete. This research 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 used for concrete are cement, course aggregate, waste ceramic tiles, fine aggregate and waste foundry sand. An experimental investigation was performed on concrete, which contains waste foundry sand (WFS) having ranges 0%, 10%, 20%, 30%, and 40% and waste ceramic tiles (WCT) having ranges 0%, 10%, 20%, 30%, and 40% by weight for M-25 grade concrete. Produced concrete was tested followed by comparison with conventional concrete in plastic state as well as in harden state for workability and compressive strength. These tests were performed on standard cube samples for 7 and 28 days to determine concrete properties. The aim of this research was to know the behaviour and mechanical properties of concrete for its eco-friendly and economical use. In the present research, experimental investigations was performed on concrete to examine the effect of waste foundry sand (WFS) and waste ceramic tiles (WCT) as a partial replacement of fine aggregate and coarse aggregate respectively on mechanical properties of concrete such as strength, workability etc of ordinary concrete.

II. Waste ceramic tiles (WCT)

India are included in three topmost countries in terms of tiles production in the world. This huge amount of ceramic tiles are not only 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.

Use of ceramic tile aggregate in concrete are cost effective, and also provides considerable strength to the concrete. Large amount of ceramic tiles and other ceramic materials are required for architectural appearance in constructions. Construction industries requires enormous increase of production of ceramic materials, due to the fact waste is also produced during handling and usage of ceramic tiles and is about 30 to 40% of the total production from manufacturing units in solid waste form. So, these waste tiles are selected 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 manufactured from natural materials that contains a large proportion of clay minerals. These materials acquire the characteristic properties of "fired clay" through a dehydration process followed by controlled firing at temperatures of between 700ºC and 1000ºC.Ceramic waste may come from two sources. The waste produced from ceramics industry source 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.

III. Waste foundry sand (WFS)

Foundry sand is nothing but high-quality silica sand having uniform physical characteristics. It is manufactured from ferrous and nonferrous metal casting industries, where due to thermal conductivity, sand has been used as a moulding material from centuries. Indian foundries produce about 1.71 million tons of waste foundry sand each year (metal world 2006). In the casting process, due to heat and mechanical abrasion, the sand has been rendered and thus becomes unsuitable for use in casting moulds, and a portion of the sand is continuously removed followed by replacing new one. This sand is treated as waste from casting industry and becomes hard to dispose because of high silica content. Waste foundry sand is made up of mostly natural sand material. The properties of which are like to the properties of natural or manufactured sand. Thus, it may be used normally as a replacement of sand. The considerable expense of disposal made the current practice of WFS disposal in landfills less favourable. Besides the financial burden to the foundries, land-filling WFS also make them liable for future environmental costs, remediation problems and regulation restrictions. This has been increasingly addressed by alternate beneficial options of reusing WFS. Beneficial WFS reuse in variety of applications are related to infrastructural 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.

IV. ROLE OF AGGREGATES IN CONCRETE

Concrete comprises a mixture of aggregates, cementitious material, and water. Aggregate is commonly considered as inert filler, which weighs 60 to 80 percent by volume and 70 to 85 percent by weight of concrete. Although aggregate is considered inert filler, it is a necessary component that defines the concrete's thermal and elastic properties and dimensional stability. Aggregate is classified in terms coarse and fine aggregate. Coarse aggregate is usually having size greater than 4.75 mm, while size of fine aggregate is less than 4.75 mm. The compressive aggregate strength is a key factor in selecting type of aggregate. While estimating the strength of normal concrete, most of concrete aggregates are several times stronger than the other concrete components and therefore not a factor in the strength of normal strength concrete. Before mixing concrete to obtain a desirable mixture, one must know other physical and mineralogical properties of aggregate.

These properties include shape and texture, size gradation, moisture content, specific gravity, reactivity, soundness and bulk unit weight. Strength, workability, and durability of concrete are determined by physical and mineralogical properties of aggregate with ration water and cementitious material. Aggregate shape and texture affects the properties of fresh concrete more than hardened concrete. Workability of concrete is more for using smooth and rounded aggregates in comparison to rough angular or elongated aggregate. Most of the natural sands and gravel obtained from riverbeds or seashores are smooth and rounded having excellent aggregates properties. Crushed stone produces higher percentages of angular and elongated aggregates, that's have a higher surface-to-volume ratio, better bond characteristics but require more cement paste to produce a workable mixture. The surface texture of aggregate may be either smooth or rough. A smooth surface can increase workability, but a rough surface generates a stronger bond between the paste and the aggregate creating a higher strength.

V. MATERIALS SOURCES AND PROPERTIES

The source of Natural Coarse Aggregates and Sand is Mubarakpur and Cement is from Solan, Himachal Pradesh. Waste ceramic tiles are obtained from the junk at Punjab Engineering college, Chandigarh and Waste Foundry sand from Contour Automotive product limited, Mubarakpur, Derabassi. The waste ceramic tiles were crushed to 10mm and 20mm Nominal Single Sized. The 20mm and 10mm Nominal Single Size Coarse Aggregates (As per IS 383: 1970) were mixed in 60:40 respectively to make 20mm Nominal Graded Coarse Aggregates. And the same is to be followed for waste ceramic tiles. The natural coarse aggregates and fine aggregates are replaced by waste ceramic tiles and waste foundry sand respectively in the following proportion.

Concrete Labelling	NC	RC10	RC20	RC30	RC40
% Replacement of Waste Ceremic Tiles	0	10	20	30	40
% Replacement of Waste Foundry Tiles	0	10	20	30	40

The concrete cubes of standard size 150mm x 150mm x 150mm were casted for each ratio and were tested at 7 days and 28 days. They were kept in the water bath one day after casting.

Table 1: Properties of cement (Used Cement: Ultratech OPC-43 Grade Cement)

S.No.	Parameter	IS-Code for Testing	Result
1	Specific Gravity	IS-4031 (Part 11) 1988	3.15
2	Standard Consistency	IS-4031 (Part 4) 1988	33.15%
3	Initial Setting Time	IS-4031 (Part 5) 1988	1 hr 15 min
4	Final Setting Time	IS-4031 (Part 5) 1988	4 hr 33 min

Table 2: Properties of natural aggregates (coarse: Nominal Single Size 20mm and 10mm)

S. No.	Parameter	IS-Code for Testing	Result
1	Specific Gravity (20mm)	IS 2386 (Part 3) 1963	2.64
2	Specific Gravity (10mm)	IS 2386 (Part 3) 1963	2.62
3	Water Absorption (20mm)	IS 2386 (Part 3) 1963	1.20%
4	Water Absorption (10mm)	IS 2386 (Part 3) 1963	2.31%

Table 3: Sieve analysis of sand for zone determination (Fine aggregate sand)

Sieve Size	Amount Retained (g)	Cumulative Sum	% Retained	% Passed
4.75mm	21.2	21.2	4.24	95.76
2.36mm	26.2	47.4	9.49	90.51
1.18mm	55.1	102.5	20.52	79.48
600µ	42.2	144.7	28.97	71.03
300µ	161.7	306.4	61.34	38.66
150µ	161.4	467.8	93.65	6.35
Pan	31.7	499.5	100.00	0.00

The Sand as per IS 383: 1970 is of **ZONE III.**

Table 4: Properties of sand

S. No.	Parameter	IS-Code for Testing	Result
1	Specific Gravity	IS 2386 (Part 3) 1963	2.71
2	Water Absorption	IS 2386 (Part 3) 1963	1.97%

VI. Mix Design (IS-10262:2009)

Characteristic Strength f_{ck} – The characteristic strength is defined as the strength of the concrete below which not more than 5% of the test results are expected to fall.

Target Mean Strength f_{ck}' – In order that not more than the specified proportion of test results are likely to fall below the characteristic strength, the concrete mix is proportioned for a higher target mean strength called f_{ck}'.

Sand Zones – Higher the Zone finer the sand. There are total of 4 zones.

Concrete Grade = M25

Cement = OPC 43 grade

Maximum nominal size of aggregates = 20mm (Graded as per IS - 383)

Sand Zone = ZONE III

Target Mean Strength

Characteristic strength f_{ck} = 25 N/mm^2

Target Mean Strength (To be achieved during testing)

$f_{ck}' = f_{ck} + 1.65*s$

For M25 grade of concrete the value of **s** as per IS - 10262 Table 1 is 4.0

So, f_{ck}' = 25 + 1.65*4 = **31.6 N/mm^2**

Free Water Cement Ratio

As per IS - 456 Table 5 for reinforced concrete, the limiting value of w/c ratio is 0.50 for moderate exposure condition.

Taking the value of **w/c ratio as 0.49**

Minimum cement content is **300 kg/m^3** of concrete

Water Content

For 20mm nominal maximum size of aggregates the **Maximum water content per cubic metre of concrete** is given by Table 2 of IS – 10262: 2009 which comes out as 186kg for saturated surface dry aggregates.

Taking water content = **180 kg**

Cementitious Material Content

The amount of cementitious material is calculated from free w/c ratio and the quantity of water per unit volume of concrete.

Cement content = (w/c ratio) / (Water content) = 177.6/0.48

= **367.345 kg/m^3 > 300 kg/m^3** (Here m^3 represents 1 cum of concrete)

Volume of Coarse Aggregates per unit volume of Total Aggregate

Considering the zone of sand as **Zone III**

Taking Maximum Nominal Size of coarse aggregates as **20mm**

From Table 3 of IS 10262: 2009 the volume of coarse aggregates per unit volume of total aggregate is obtained as 0.64 for w/c ratio of 0.5

Still using value of 0.64.

For w/c ratio of 0.49 the volume of coarse aggregates should be increased.

Increasing the volume of coarse aggregates by 0.002.

Volume of coarse aggregate per unit volume of total aggregates is taken as **0.642**

Volume of Cement, Water and All-in-aggregates

The Specific Gravity of cement = 3.15

Volume of cement = 367.345/3150 = **0.117 m^3 per 1 m^3 of concrete**

Specific Gravity of water = 1

Volume of water = 180/1000 = **0.18 m^3 per 1 m^3 of concrete**

Volume of All-in-aggregates = 1 – 0.117 – 0.18 = **0.703 m^3 per 1 m^3 of concrete**

Quantity of Coarse and Fine aggregates

Mass of Coarse Aggregates = 0.703*0.642*2.64*1000 = **1191.50 kg/m^3 of concrete**

Mass of Fine aggregates = 0.703*0.358*2.71*1000 = **682.04 kg/m^3 of concrete**

Mix proportions

Cement = 367.345 kg

Fine Aggregates = 682.04 kg

Coarse Aggregate = 1191.50 kg

Ratio = 367.345: 682.04: 1191.50

= **1 : 1.858 : 3.245**

VII. TRIAL MIXES AND FINAL MIX PROPORTIONS

Three trial mixes were prepared for different w/c ratio to find compressive strength adjust the workability of the mixes. Apart from these three other trials were also conducted just to check the workability.

Table 5: Trial mix 1

	Cement	Sand	Coarse Aggregates		
Mix Proportions	1	1.79	3.258	w/c ratio	0.45
Mix in kg	10	17.9	32.58	Water (kg)	4.5
7 Day Testing			28 Day Testing		
	kN	N/mm2		kN	N/mm2
Cube 1	702.2	31.21	Cube 1	896.4	39.84
Cube 2	696.1	30.94	Cube 2	748	33.24
Cube 3	601.6	26.74	Cube 3	874.8	38.88
	Average	**29.63**		Average	**37.32**
Workability = 15mm Slump (True Slump)					

Table 6: Trial mix 2

	Cement	Sand	Coarse Aggregates		
Mix Proportions	1	1.825	3.250	w/c ratio	0.47
Mix in kg	10	18.25	32.50	Water (kg)	4.7
7 Day Testing			28 Day Testing		
	kN	N/mm^2		kN	N/mm^2
Cube 1	686.250	30.50	Cube 1	810.1	36
Cube 2	677.25	30.10	Cube 2	872.5	38.78
Cube 3	589.5	26.20	Cube 3	754.4	33.53
	Average	**28.93**		Average	**36.10**
Workability = 30mm Slump (True Slump)					

Table 7: Trial mix 3

	Cement	Sand	Coarse Aggregates		
Mix Proportions	1	1.858	3.245	w/c ratio	0.49
Mix in kg	10	18.58	32.45	Water (kg)	4.9
7 Day Testing			28 Day Testing		
	kN	N/mm2		kN	N/mm2
Cube 1	588.5	26.1	Cube 1	845.9	37.6
Cube 2	570.4	25.4	Cube 2	806.0	35.8
Cube 3	550.6	24.5	Cube 3	780.4	34.7
	Average	**25.33**		Average	**36.03**
Workability = 55mm Slump (True Slump)					

Table 8: Trial mix 4

	Cement	Sand	Coarse Aggregates		
Mix Proportions	1	1.862	3.242	w/c ratio	0.50
Mix in kg	10	18.62	32.42	Water (kg)	5.0
7 Day Testing			28 Day Testing		
	kN	N/mm2		kN	N/mm2
Cube 1	582.75	25.90	Cube 1	839.250	37.30
Cube 2	549.00	24.40	Cube 2	780.750	34.70
Cube 3	528.75	23.50	Cube 3	756.00	33.60
	Average	**24.60**		Average	**35.20**
Workability = 100mm Slump (Collapse)					

The mix proportions of **Trial 3** are decided to be **Final**.

VIII. CASTING OF SPECIMENS

Firstly all the materials required for making the concrete mix were weighed using the weighing machine which had a least count of 10g. The casting of six cubes i.e. three for 7 day testing and three for 28 day testing required about 10kg of cement and other materials in proportion to it. No admixtures of any type are used in the formation of concrete.

The weighed material was then added to the concrete mixer in the order of Coarse Aggregates, Sand and finally the cement the water was added to the mix in the very last. The contents were allowed to mix for about 5 minutes after adding the water and then poured down in the tray. The slump test was carried out before placing the concrete in the moulds.

The properly oiled mould were filled with the concrete mix and vibrated by vibratory table for 2 to 3 minutes. The moulds were removed after one day of casting and cubes were placed in the water bath until their testing date.

IX. RESULT

The workability was determined after each casting and is tabulated as below.

Table 9: Workability

The workability was determined after each casting and is tabulated as below

Workability			
Concrete Labelling	% Replacement of Waste Ceremic Tiles	% Replacement of Waste Foundry Tiles	Workability
NC	0	0	55
RC10	10	10	63
RC20	20	20	65
RC30	30	30	72
RC40	40	40	89

Compressive Strength: The cubes casted with different replacement ratios of Natural Coarse Aggregates by Recycled Concrete Aggregates were tested after 7 and 28 days of casting and the results are displayed in the tables and graphs below.

Table 10: compressive strength of cubes after 7 days at various replacement percentages of WCT & WFS

Compressive Strength after 7 days				
Concrete Labelling	**Cube 1**	**Cube 2**	**Cube 3**	**Average**
NC	22.58	27.64	24.65	24.96
RC10	23.52	27.8	25.2	25.5
RC20	23.97	28.1	25.8	25.96
RC30	23.16	27.53	24.62	25.1
RC40	21.5	25.97	23.4	23.62

Table 11: compressive strength of cubes after 28 days at various replacement percentages of WCT & WFS

Compressive Strength after 28 days				
Concrete Labelling	**Cube 1**	**Cube 2**	**Cube 3**	**Average**
NC	37.58	35.96	36.21	36.58
RC10	37.92	36.58	36.5	37
RC20	39.54	36.23	37.63	37.8
RC30	37.85	36.05	36.31	36.74
RC40	35.55	36.1	34.02	35.22

X. CONCLUSIONS

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.
- 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.

REFERENCES

[1] Awoyera Paul O., Ndambuki Julis M., Akinmusuru Joseph and Omole David O., "Characterization of ceramic waste aggregate concrete", *HBRC Journal*, pp.1-6, 2016

[2] Daniela Sani and Francesca Tittarelli, "Used Foundry Sand in Cement Mortars and Concrete Production" *The Open Waste Management Journal*, 3, pp.18-25,2010

[3] El-Hadj Kadri, Rafat Siddique, "Effect of metakaolin and foundry sand on the near surface characteristics of concrete", *Construction and Building Materials* ,25, pp. 3257–3266,2011

[4] Gurpreet Singh, Rafat Siddique, "Abrasion resistance and strength properties of concrete containing waste foundry sand (WFS)", *Construction and Building Materials* ,28, pp.421–426,2012

[5] Lin Deng-Fong, Luo Huan-Lin, Lin Jyung-Dong and Zhuang Mei-Ling, "Characterizations of temperature effects on sintered ceramics manufactured with waste foundry sand and clay", *Journal of materials cycles and waste Management*, 20(1), pp.127-136, 2018

[6] Rafat Siddique, Yogesh Aggarwal, Paratibha Aggarwal, El-Hadj Kadri, Rachid Bennacer, "*Strength, durability, and micro-structural properties of concrete made with Used-foundry sand (UFS)*", Construction and Building Materials 25, pp. 1916–1925,2011

[7] Senthamarai R.M. and Manoharan P.D., "Concrete with ceramic waste aggregate", *Cem. Concr. Comp*., 27, pp. 910–913,2005

[8] Torkittikul P., Chaipanich A., "Utilization of ceramic waste as fine aggregate within Portland cement and fly ash concretes", *Cem. Concr. Comp*., 32, pp.440–449,2010

[9] IS:1918–1966 Methods of Physical Tests for Foundry Sands

[10] IS-456 - 2000-Plain and Reinforced Concrete Code of Practice

[11] IS-516-1959 -Methods of tests for Strength of concrete.

[12] IS-12269 - 1987- Specifications for 53 grade OPC.

[13] IS 2386 (Part 1, 3 & 4) - 1963, Method of testing of aggregates for concrete.

[14] IS 1199-1959 - Method of sampling and analysis of concrete.

[15] IS 7320-1974 - Specification for concrete slump test apparatus.

[16] IS 5816-1970- Method of test for split tensile strength of concrete cylinders

[17] IS 579-1959 - Method for strength of concrete.

[18] IS 10262-1982 - Recommended guidelines for mix design

[19] IS 383 – 1970: Indian Standard "Specification for coarse and fine aggregates from naturals sources for concrete"