RESEARCH ARTICLE OPEN ACCESS

An Experimental Study on Strength and Durability Properties of Concrete Incorporating Waste Foundry Sand and Waste Ceramic Tiles

S.Brahma Naidu [1], P.Sai Krishna [2], B.Damodhar Reddy [3]
K.Veerendra Sai [4], D.Mahendra [5]
Assistant Professor & Hod [1], Students [2], [3], [4], [5]
Civil Enggineering
Department of Narayana Engineering College, Gudur
India

ABSTRACT

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 biproduct 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 coarse aggregate in concrete. Ingredients for concrete are cement, coarse 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 M20 grade concrete. Concrete was produced, tested and compared with conventional concrete in plastic state as well as in harden state for workability, compressive strength and 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 behaviour 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.

1. INTRODUCTION

1.1 CONCRETE:-

Concrete is a composite material consist of mainly water, aggregate, and cement. The physical properties desired for the finished material can be attained by adding additives and reinforcements to the concrete mixture. A solid mass that can be easily moulded into desired shape can be formed by mixing these ingredients in certain proportions. Over the time, a hard matrix formed by cement binds the rest of the ingredients together into a single hard (rigid) durable material with many uses such as buildings, pavements etc., The technology of using concrete was adopted earlier on large-scale by the ancient Romans, and the major part of concrete technology was highly used in the Roman Empire. The colosseum in Rome was built largely of concrete and the dome of the pantheon is the World's largest unreinforced concrete structure. After the collapse of Roman Empire in the mid-18th century, the technology was re-pioneered as the usage of concrete has become rare. Today, the widely used man made material is concrete in terms of tonnage.

1.2 TYPES OF WASTE IN INDIA:

1.2.1 INDUSTRIAL WASTE:

1.2.1.1 WASTE FOUNDRY SAND (WFS):

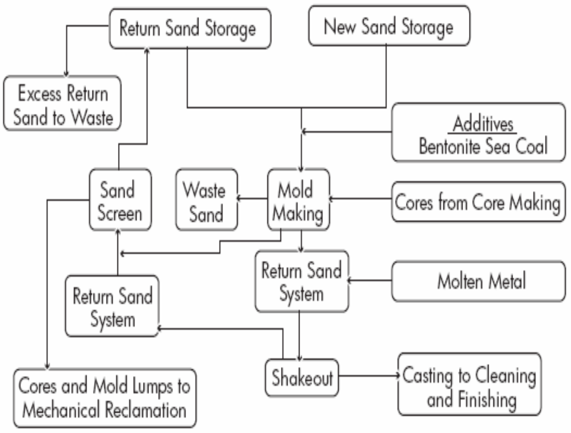
Foundry sand is high quality silica sand with uniform physical characteristics. It is produced from ferrous and nonferrous metal casting industries, where sand has been used for centuries as a moulding material because of its thermal conductivity. Indian foundries produce approximately 1.71 million tons of waste foundry sand each year (Metal World, 2006). 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.

Fig 1.1: How sand is reused and becomes foundry sand

1.2.2 CONSTRUCTIONAL WASTE:

1.2.2.1 WASTE CEAMIC TILES (WCT)

In the present construction world, the solid waste is increasing day by day from the demolitions of constructions.



There is a huge usage of ceramic tiles in the present constructions is going on and it is increasing in day by day construction field.

However, despite the ornamental benefits of ceramics, its wastes among others cause a lot of nuisance to the environment. And also in other side waste tile is also producing from demolished wastes from construction. Indian tiles production is 100 million ton per year in the ceramic industry, about 15%- 30% waste material generated from the total production. This waste is not recycled in any form at present, however the ceramic waste is durable, hard and highly resistant to biological, chemical and physical degradation forces so, we selected these waste tiles as a replacement material to the basic natural aggregate to reuse them and to decrease the solid waste produced from demolitions of construction.

1.3 TILE AND FOUNDRY SAND AGGREGATE CONCRETE:

Waste Crushed tiles are replaced in place of coarse aggregate and waste foundry sand in place of fine aggregate by the percentage of 0%, 10%, 20%, 30% and 40%. The fine and coarse aggregates were replaced individually by these waste crushed tiles and waste foundry sand and also in combinations that is replacement of coarse and fine aggregates at a time in single mix.

For analysing the suitability of these waste crushed tiles and waste foundry sand in the concrete mix, workability test was conducted for different mixes having different percentages of these materials. Slump cone test is used for performing workability tests on fresh concrete. And compressive strength test is also conducted for 7 and 28 days curing periods by casting cubes to analyse the strength variation by different percentage of this waste materials. This present study is to understand the behaviour and performance of ceramic solid waste in concrete. The waste crushed tiles and waste foundry sand are used to partially replace with fine and coarse aggregate by 0%,10%, 20%, 30% and 40% .

2.1 MATERIALS USED:

In this investigation, the following materials were used:

- Ordinary Portland Cement of 53 Grade cement conforming to IS: 169-1989
- Fine aggregate and coarse aggregate conforming to IS: 2386-1963.
- Water
- Waste Ceramic Tiles
- Waste Foundry Sand

2.1.1. CEMENT:

Ordinary Portland cement is the most common type of cement in general use around the world as a basic ingredient of concrete.

The physical properties of the cement are listed in Table – 1

Table-1 Properties of cement

S.no	Properties	Test results	IS: 169-1989
1.	Normal consistency	0.32	
2.	Initial setting time	50min	Minimum of 30min
3.	Final setting time	320min	Maximum of 600min
4.	Specific gravity	3.14	
5.	Compressive strength		
	7days strength	44.6 Mpa	Minimum of 40Mpa
	28days strength	56.6 Mpa	Minimum of 53Mpa

2.1.2. FINE AGGREGATES:

River sand locally available in the market was used in the investigation. The aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity in accordance with IS: 2386-1963.The sand was surface dried before use.

Table 2: Properties of Fine Aggregate

S.no	Description Test	Result
1	Sand zone	Zone- III
2	Specific gravity	2.59
3	Free Moisture	1%
4	Bulk density of fine aggregate (poured density)	1385.16 kg/m3
	Bulk density of fine aggregate (tapped density)	1606.23 kg/m3

2.1.3. COARSE AGGREGATES:

Crushed aggregates of less than 12.5mm size produced from local crushing plants were used. The aggregate exclusively passing through 12.5mm sieve size and retained on 10mm sieve is selected. The aggregates were tested for their physical requirements are given in table.

Table 3: Properties of Coarse Aggregate

S.no	Description	Test Results
1	Nominal size used	20mm
2	Specific gravity	2.9
3	Impact value	10.5
4	Water absorption	0.15%
5	Sieve analysis	20mm
6	Aggregate crushing value	20.19%
7	Bulk density of coarse aggregate (Poured density) Bulk density of coarse aggregate (Tapped density)	1687.31kg/m3 1935.3 kg/m3

2.1.4. WATER:

Water plays a vital role in achieving the strength of concrete. It is practically proved that minimum water-cement ratio 0.35 is required for conventional concrete. Water participates in chemical reaction with cement and cement paste is formed and binds with coarse aggregate and fine aggregates. Potable water fit for drinking is required to be used in the concrete and it should have pH value ranges between 6 to 9.

2.1.5. WASTE CERAMIC TILE AGGREGATE:

The waste tiles were crushed into small pieces by manually and by using crusher. The required size of crushed tile aggregate was separated to use them as partial replacement to the natural coarse aggregate. The tile waste which is lesser than 4.75 mm size was neglected. Crushed tiles were partially replaced in place of coarse aggregate by the percentages of 10%, 20% and 30%, and 40% individually.

Fig 2.1: Ceramic Tile Aggregate Sample

Table 4: Properties of Ceramic tile aggregate

S.no	Description	Test Results
1	Origin Rock	Feldspar
2	Impact value of crushed tiles	12.5%
3	Specific gravity of crushed tiles	2.6
4	Specific gravity of tile powder (C.F.A)	2.5
5	Water absorption of crushed tiles	0.19%
6	Water absorption of Tile powder(C.F.A)	0.13%

2.1.6. WASTE FOUNDRY SAND AS FINE AGGREGATE:

Waste foundry sand is collected from the nearby metal industry and the unwanted rocks and organic matters like grass, plastic threads, plastic bags etc., are removed and sieved it by passing through 4.75mm sieve. And the sand which is passed through the 4.75mm sieve and retained on the pan is used. The sieved foundry sand is replaced in the place of fine aggregate by the percentages 10%, 20%, 30% and 40% individually.

Fig 2.2: Waste foundry sand Sample

Table5: Chemical Properties of waste foundry sand

S.no	CONSTITUENTS	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

III. MIX DESIGN FOR M20 GRADE CONCRETE

Table 6: Mix design for M20 grade concrete

Cement	Fine aggregate	Coarse aggregate	Water
383 Kg/m^3	546 Kg/m^3	1188 Kg/m^3	191.6Kg/m^3
1	1.425	3.10	0.50

Table 7: Content of materials as per mix design per one cube and one cylinder:

<u>CUBE</u>	<u>CYLINDER</u>

Volume = 0.15x0.15x0.15 = $0.00338m^3$	Volume = Π/4 x0.15^2 x0.3 =$0.00530m^3$
Cement = 1.292kg	Cement = 2.029kg
F.A = 1.845kg	F.A = 2.893kg
C.A = 4.015kg 60% 20mm =2.409kg 40% 12mm=1.606kg	C.A = 6.296kg 60% 20mm =3.777kg 40% 12mm=2.518kg
Water =0.647lit	Water = 1.015lit

Table 8: Partial replacement of waste foundry sand and waste ceramic tiles:

% OF REPLACEMENT	WASTE FOUNDRY SAND	WASTE CERAMIC TILES
0%	NIL	NIL
10%	0.184kg	0.401kg
20%	0.369kg	0.803kg
30%	0.553kg	1.204kg
40%	0.738kg	1.606kg

3.1 MOULDS USED FOR CASTING:

Standard cube moulds of 150 x 150 x 150mm made of cast iron used for the cement mortar and concrete specimens for testing of compressive strength.

Cylindrical moulds of 150 mm in diameter and 300 mm height is made for concrete specimens for testing of Split tensile strength.

Fig 3.1: Samples of cube and cylindrical moulds

3.2 CASTING:

The standards moulds were fitted such that there are no gaps between the plates of the moulds. If there is any gap, they were filled with plaster of Paris. The moulds were then oiled and kept ready for casting. Concrete mixes are prepared according to required proportions for the specimens by hand mixing; it is properly placed in the moulds in 3 layers. Each layer is compacted 25 blows with 16 mm diameter bar. After the completion of the casting, the specimens were vibrated on the table vibrator for 2 minutes. At the end of vibration the top surface was made plane using trowel. After 24 hours of a casting the moulds were removed and kept for wet curing for the required number of days before testing.

Fig 3.2: Hand mixing and placing of concrete mix

3.3 CURING:

The test specimens are stored in place free from vibration; specimens are removed from moulds after 24 ± half an hour time of addition of water to dry ingredients. After this period, the specimens are marked and removed from the moulds and unless required for test within 24 hours immediately submerged in clean fresh water and kept there until taken out just prior to test. The water in which the specimens are submerged, are renewed every seven days and are maintained at temperature of 27°±2°C.The specimens are not allowed to become dry at any time until they have been testing. The specimens were put under curing for 28 days.

IV. TESTS CONDUCTED

- Workability
- Compressive strength
- Split tensile strength
- Acid attack test
- Alkaline attack test

4.1 WORKABILITY:

Workability is one of the physical parameters of concrete which affects the strength and durability as well as the cost of labor and appearance of the finished product. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e. without bleeding or Segregation.

In this study, the slump-cone test is carried out to determine the workability of concrete.

Table 9: Results of workability

S.no	% of replacement	w/c ratio	Slump(mm)
1	0%	0.50	27
2	10%	0.50	42
3	20%	0.50	76
4	30%	0.50	105
5	40%	0.50	137

4.2 COMPRESSIVE STRENGTH:

A total of 20 cubes of size 150 x 150 x 150mm were casted and tested for 7 days and 28 days testing each specimen after conducting the workability tests. The results are tabulated below:

Fig 4.1: Compression testing of Cube Specimen

Table 10: Compressive strength results of M20 grade of concrete for 7 and 28 days

% of replacement	For 7 days	For 28 days
0%	22.71 Mpa	33.40 Mpa
10%	20.33 Mpa	29.91 Mpa
20%	18.53 Mpa	27.26 Mpa
30%	11.01 Mpa	16.20 Mpa
40%	5.70 Mpa	8.39 Mpa

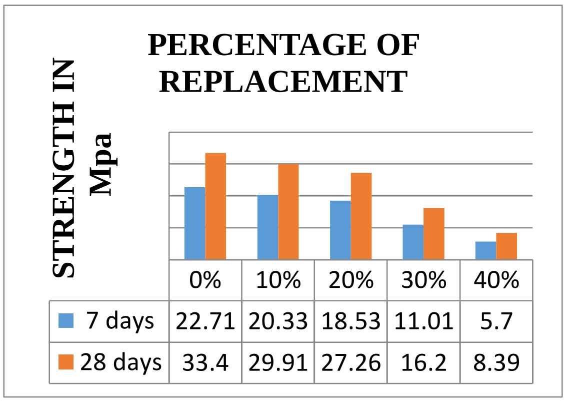


Fig 4.2. Comparison of Compressive strength of M20 at 7 and 28 days

4.3 SPLIT TENSILE STRENGTH:

The split tensile strength obtained by testing the cylindrical specimen for M20 grade of concrete to all the mixes designed for various replacements are given below:

Fig 4.3: Split Tensile Testing and Specimen (Cylinders)

Table 11: Split tensile strength results for M20 grade of concrete

% of replacement	For 7 days	For 28 days
0%	9.94 Mpa	11.98 Mpa
10%	8.40 Mpa	9.08 Mpa
20%	8.50 Mpa	14.17 Mpa
30%	6.82 Mpa	7.57 Mpa
40%	2.35Mpa	2.60 Mpa

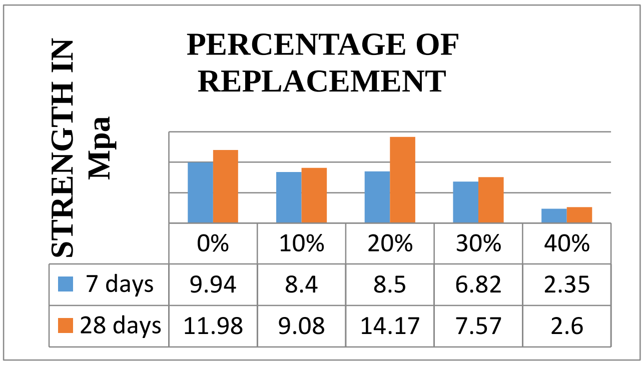


Fig 4.4: Split tensile strength for M20 at 7 and 28 days

4.4 ACID ATTACK TEST:

The concrete cube specimens of various concrete mixtures of size 150 mm were cast and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for

28 days after 28 days of curing. Sulphuric Acid with pH of about 2 at 5% weight of water was added to water in which the concrete cubes were stored. The pH was maintained throughout the period of 28 days. After 28 days of immersion, the concrete cubes were taken out of acid water. Then, the specimens were tested for compressive strength.

The compressive strength obtained by testing the cube specimens in acid for 28 days of M20 grade of concrete to all the mixes designed for various replacements are given below:

Table 12. % loss of compressive strength reduction of cubes in acid curing after 28 days.

% of replacement	compressive strength with water curing	compressive strength after acid curing	% loss in compressive strength
0%	33.40	31.82	4.73
10%	29.91	28.62	4.31
20%	27.26	26.30	3.52
30%	16.20	15.74	2.84
40%	8.39	8.24	1.79

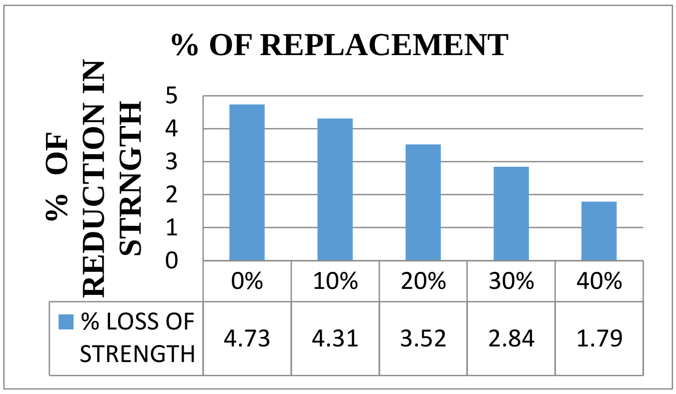


Fig 4.5: % loss of compressive strength reduction of cubes in acid curing after 28 days

% LOSS OF WEIGHT REDUCTION OF CUBES AFTER 28DAYS ACID CURING:

Table 13. % loss of weight reduction of cubes in acid curing after 28 days

% of replacement	Initial weight	Final weight	%loss in weight
0%	8.16	7.80	4.41
10%	7.96	7.62	4.27
20%	7.89	7.57	4.05
30%	7.82	7.58	3.07
40%	7.39	7.24	2.03

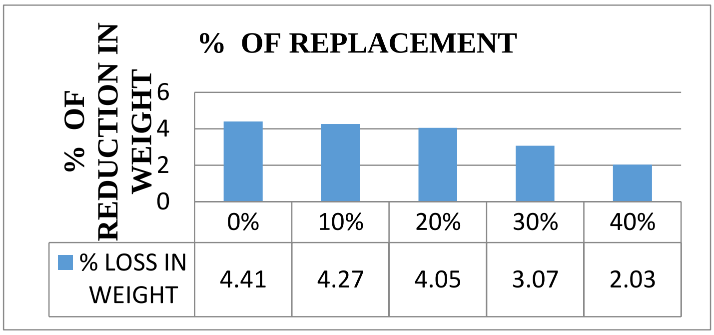


Fig 4.6. % loss of weight reduction of cubes in acid curing after 28 days.

4.5 ALKALINE ATTACK TEST PROCEDURE:

To determine the resistance of various concrete mixtures to alkaline attack, the residual compressive strength of concrete mixtures of cubes immersed in alkaline water having 5% of sodium hydroxide (NaOH) by weight of water was found. The concrete cubes which were cured in water for 28 days were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. Then the cubes were immersed in alkaline water continuously for 28 days. The alkalinity of water was maintained same throughout the test period. After 28 days of immersion, the concrete cubes were taken out of alkaline water. Then, the specimens were tested for compressive strength. The resistance of concrete to alkaline attack was found by the % loss of weight of specimen and the % loss of compressive strength on immersion of concrete cubes in alkaline water.

The compressive strength obtained by testing the cube specimens in alkali for 28 days of M20 grade of concrete to all the mixes designed for various replacements are given below:

Table 14. % loss of compressive strength reduction of cubes in alkaline curing after 28 days.

% of replacement	compressive strength with water curing	compressive strength after alkali curing	% loss in compressive strength
0%	33.40	31.88	4.55
10%	29.91	28.70	4.05

20%	27.26	26.48	2.86
30%	16.20	15.90	1.85
40%	8.39	8.26	1.54

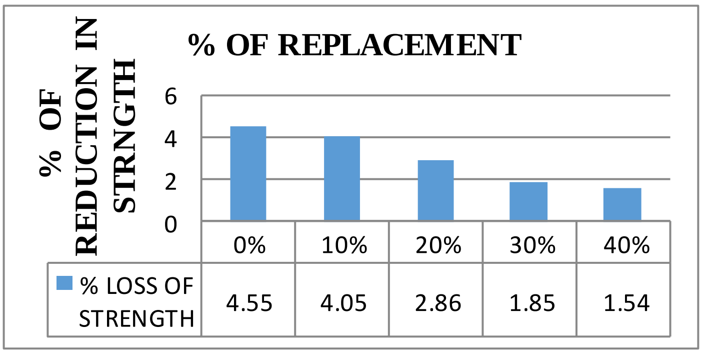


Fig 4.7. % loss of compressive strength reduction of cubes in alkaline curing after 28 days

%LOSS OF WEIGHT REDUCTION OF CUBES AFTER 28DAYS ALKALINE CURING:

Table 15. % loss of weight reduction of cubes in alkaline curing after 28 days.

% of replacement	Initial weight	Final weight	%loss in weight
0%	8.16	7.86	3.68
10%	7.96	7.62	3.14
20%	7.89	7.67	2.79
30%	7.82	7.70	1.53
40%	7.39	7.31	1.08

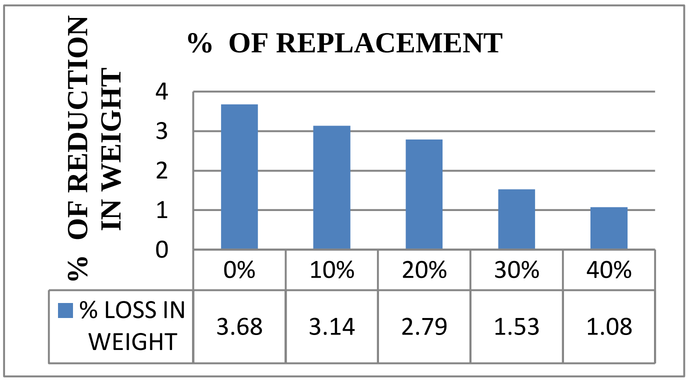


Fig 4.8. % loss of weight reduction of cubes in alkaline curing after 28 days.

V. CONCLUSIONS

The following conclusions are made based on the experimental investigations on compressive strength and split tensile strength considering the environmental aspects also:

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 conventional 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 safety to disposal is reduced.

REFERENCES

[1] Daniela Sani and Francesca Tittarelli, “Used Foundry Sand in Cement Mortars and Concrete Production” Open Waste Management Journal, 2010, 3, 18-25

[2] 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 (2011) 1916–1925

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

[4] Rafat Siddiquea, Gurpreet Singh, "Utilization of waste foundry sand (WFS) in concrete manufacturing", Resources Conservation and Recycling 55 (2011) 885–892

[5] Gurpreet Singh, Rafat Siddiquea, "Effect of waste foundry sand (WFS) as partial replacement of sand on the strength, ultrasonic pulse velocity and permeability of concrete", Construction and Building Materials 26 (2012) 416–422

[6] H. Merve Basar, Nuran Deveci Aksoy, "The effect of waste foundry sand (WFS) as partial replacement of sand on the mechanical, leaching and micro-structural characteristics of ready-mixed concrete", Construction and Building Materials 35 (2012) 508–515

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

[8] Gurdeep Kaur, Rafat Siddique, Anita Rajor, "Properties of concrete containing fungal treated waste foundry sand", Construction and Building Materials 29 (2012) 82–87

[9] Pathariya Saraswati C, Rana Jaykrushna K, Shah Palas A, Mehta Jay G, Patel Ankit N, "Application of Waste Foundry Sand for Evolution of Low-Cost Concrete", International Journal of Engineering Trends and Technology (IJETT) – Volume 4 Issue 10 - Oct 2013

[10] Yogesh Aggarwal a,⇑, Rafat Siddique, "Microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates", Construction and Building Materials 54 (2014) 210–223.

[11] Smit m.Kacha, abhay v. Nakum, ankur Bhogayata, "Use of used foundry sand in concrete", International journal of research in engineering and technology eissn: 2319-1163 | eissn: 2321-7308Saveria Monosi,

[12] Mr. I .M. Attar1 Prof. A.K. Gupta2 IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN: 2278-1684, PP: 38-42

[13] Dushyant Rameshbhai Bhimani, Jayesh kumar pitroda, Jaydevbhai j. Bhavsar, "Used foundry sand: opportunities For development of eco-friendly low cost Concrete" International journal of advanced engineering technology eisen 0976-3945

[14] Hemanth Kumar Ch1,Ananda Ramakrishna K2, Sateesh Babu K3, Guravaiah T4, Naveen N5, Jani Sk6, "Effect of Waste Ceramic Tiles in Partial Replacement of Coarse and Fine Aggregate of Concrete, International Advanced Research Journal in Science, Engineering and Technology

[15] Punit Malik, 2Jatin Malhotra, 3Arjun Verma, 4Piyush bhardwaj , 5Akhil Dhoundiyal and 6Nitin Yadav Mix Design for Concrete with Crushed Ceramic Tiles as Coarse Aggregate

[16] IS: 1918–1966 Methods Of Physical Tests For Foundry Sands

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

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

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

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

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

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

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

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

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

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