UTILIZATION OF NON-FERROUS RECYCLED FOUNDRY SAND AS A PARTIAL REPLACEMENT OF FINE AGGREGATE IN CONCRETE

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ABSTRACT: *Non-ferrous recycled foundry sand (RFS) is the daily waste of metal casting foundries and it is dumped outside the foundries. Due to large amount of non-ferrous RFS which is used for landfills, however, it is expected that this sand is "beneficially reusable". The use of non-ferrous RFS in construction industry can be advantageous and is coincident with the concept of green concrete. The present study covers the use of non-ferrous RFS as a partial replacement of regular sand to produce low cost, environment friendly concrete. Detailed chemical analysis of non-ferrous RFS is made and the suitability of use of non-ferrous RFS as a partial replacement of fine aggregate is discussed. To investigate the effect on fresh and hardened properties of such concrete a detailed experimental study is conducted. The fine aggregate has been replaced as 0%, 10%, 30% and 45% with non-ferrous RFS. Concrete mixtures were prepared, cured, tested and compared with ordinary concrete in terms of compressive strength and workability. The compressive strength was investigated at 7, 14 and 28 days. Test results indicate a drop in workability and an increase in the compressive strength up to 30% replacement. Thus, results of chemical analysis, comparison of fresh and hardened properties of concrete with standard mix affirms that non-ferrous RFS can be used in making good quality and environment friendly concrete.*

Key words: Non-Ferrous Recycled Foundry Sand, Foundries, Green Concrete, Compressive Strength, Flexural Strength, Split Tensile Strength, Chemical Analysis of non-ferrous RFS, Environment friendly

1. INTRODUCTION

Concrete is a commonly used construction material. It is economical because the ingredients of concrete are easily available. Quality research work has been presented in the last few decades on the use of waste materials, such as; rubber tires [1], glass powder [1], marble powder [1] in concrete as a replacement of fine and coarse aggregate to produce low cost and environment friendly concrete. These wastes require special treatment to be used as replacement of fine aggregate in concrete. E.g. waste glass is to be ground before using in concrete, while, on the other hand non-ferrous RFS is such a material, which can be directly used as replacement of fine aggregate in concrete. The foundries which are making different parts of ferrous material are known as ferrous foundries and those who are making different parts of non-ferrous material are known as non-ferrous foundries. Fine sand with a binder is used for the preparation of molds and cores in ferrous and non-ferrous metal casting foundries. This sand (with binder) used for preparation of moulds and cores is termed as foundry sand [2]. Foundries use this foundry sand many times and when this sand is no longer can be used; it is dumped out. This waste sand which is going to produce pollution in the environment is termed as Recycled Foundry Sand (RFS) [3-4]. The suitability of non-ferrous RFS obtained from local foundry need to be explored.

Non-ferrous metal casting foundries annually use an estimated 10 million tons of foundry sand for casting of molds and cores. During this process, sand is typically recycled and reused many times, when this sand is not suitable for molds; it is wasted and dumped outside the foundries. Subsequently, a rough estimate by the authors reveals that 1 to 1.5 million tons of sand are discarded each year from the industrial cities of Punjab and Karachi. Therefore, it is required to explore the suitability of this waste material in the production of concrete.

Non-ferrous RFS consists of silica sand (85-90%), calcium oxide (5-6%), bentonite clay (2-3%) and water (2-5%). Non-ferrous RFS has good physical and chemical properties. Its color is black due to carbon contents. Unit weight and fineness modulus is low; due to clay particles it has more cohesion when compared to ordinary lawrenspur sand. The chemical properties of non-ferrous RFS are given in Table-1. In this waste material about 89% is pure sand which will be used in concrete as a replacement of fine aggregate, about 5% cap, which will increase the strength of concrete because it will improve the bond between the ingredients of concrete. Due to 4% aluminum and iron oxide, it will act as pozollanic material that also enhances the strength of concrete up till some percentage of replacement. Availability of Loss on ignition (LOI) is about 5-6% which is clay and carbon particles. The excess of these particles may reduce the strength.

Due to the large amount of non-ferrous RFS and better physical and chemical properties, it is required to use non-ferrous RFS in construction industry and to conclude optimum value of replacement. In this research, non-ferrous RFS is used as a partial replacement of fine aggregate in concrete to produce low cost and environment friendly concrete. Use of non-ferrous RFS in concrete can solve the disposal problem and help in green environment.

Table-1 Chemical composition of Non-Ferrous RFS

Constituents	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_4	Cr_2O_3	LOI
Values (%)	88.6	3.62	0.36	5.32	1.40	0.7409	0.02	5.42

2. LITERATURE REVIEW

The use of RFS in different fields of civil engineering has been discussed by different workers in [5-10]. Javed and Lovell, [5], Abichou, [6], Rafat Siddique [7-9], Gurpreet Singh [8] and Yogesh Aggarwal, [10]. Abichou *et al*, Javed and Lovell and Guney *et al*, [15] have published their work in the field of highway. Tikalsky *et a*l, Siddique *et al* and Nail *et al* did work in the field of controlled low strength (CLS) material. Deng and Tikalsky [21], Braham and Dungan *et al*, [20], Engroff *et al* and Quaranta et al has reported in the field of geotechnical, ceramic tiles and hot mix concrete.

Limited work has been done on the use of RFS as fine aggregate in concrete. Only a few researchers Rafat Siddique *et al*, Guney *et al*, Yogesh Aggarwal et al, Gurpret Singh *et al* [11-12], Dushyant *et al* [13-14], and Yogesh Aggarwal et al, has worked on the mechanical properties of concrete incorporating RFS.

Rafat Siddique *et al.*, [7], investigated the strength properties of concrete with used foundry sand at 7, 28, 90 and 365 days of curing period. Guney *et al*, [15], investigate the properties of concrete with waste foundry sand at 28 and 56 days of curing period for high strength concrete. Paratibah Aggarwal *et. Al.*, [9] investigate the strength of concrete with used foundry sand at 28, 90 and 365 days of curing period. Gurpreet Singh *et. al*, [11-12], investigate the mechanical properties of concrete with waste foundry sand at 7, 28 and 91 days of curing period. Dushyant *et.al*., [13-14] investigate the properties of concrete with used foundry sand as partial replacement of fine aggregate and 10% Pozzocrete as a replacement of cement at 7, 14 and 28 days of curing period. Yogesh Aggarwal *et. al.*, [10] investigate properties of concrete with waste foundry sand and bottom ash as a replacement of fine aggregate at 28, 90 and 365 days of curing period. Among all above mentioned researchers, no one discussed that foundry sand used for research is taken from ferrous or non-ferrous foundries.

From above mentioned study, it is clear that the behavior of RFS in concrete is explored, but no one explores the behavior of concrete with ferrous and non-ferrous RFS. Moreover, the composition of the RFS in Pakistan is different due to the presence of a local binder whereas in literature, bentonite, clay and resins are used as a binder. It is required to explore the behavior of ferrous and non-ferrous RFS individually on mechanical properties of concrete by considering local binder.

In this research work, a detailed experimental program is designed to explore fresh and hardened properties of concrete produced with non-ferrous RFS as replacement of sand. Detail of the experimental program is in following

3. EXPERIMENTAL METHODOLOGY

Research was undertaken for 20 MPa concrete mixes with different percentage replacement of non-ferrous RFS. Four batches of concrete incorporating non-ferrous RFS were prepared for 0%, 10%, 30% and 45% replacement and represented as M_0, M_{10}, M_{30} and M_{45} respectively. First let us discuss material properties.

3.1 MATERIALS

The cement used was Ordinary Portland Cement (OPC) of 43 grades and satisfying the ASTM C1157 requirements. Tests of normal consistency, initial and final setting time were conducted on cement sample and results are listed in Table-2.

Table-2 Properties of OPC 43 grade cement

Sr.#	**Test Name**	**ASTM Standard**	**Results Obtained**
1	Normal Consistency (%) [16]	C 187	28
2	Initial Setting Time (min)[17]	C 191	135
3	Final Setting Time (min)[17]	C 191	215

Results show that the cement used for research work was good and satisfying the limiting values of initial and final setting time.

Locally available Margala crush was used as a coarse aggregate having 19 mm of maximum size. Locally available Lawrenspur sand was used as fine aggregate with nominal size of 4.75mm. Non-ferrous RFS is taken from Khan Moulding Foundry. Coarse aggregate, fine aggregate and non-ferrous RFS were tested as per ASTM standards and results are listed in Table-3.

Table-3 Properties of fine aggregate, coarse aggregate and non-ferrous RFS

Sr.#	**Test Name**	**Coarse Aggregate**	**Fine Aggregate**	**Non-Ferrous RFS**
1	Bulk Density (kg/m^3)	1568.2	2086	1407.7
2	Specific Gravity	3.02	2.7	2.56
3	Water Absorption (%)	0.99	2.15	3.2
4	Moisture Content (%)	0.33	0.67	1
5	Fineness Modulus[16]	6.659	2.33	1.40

Comparing the properties of non-ferrous RFS and fresh sand it is observed that water absorption of non-ferrous RFS is more and fineness modulus is less as compared to fresh sand.

In Figure-1, grain size [18] is shown on horizontal axis and cumulative weight retained on each sieve is shown on vertical axis. Gradation curve shows that particles of non-ferrous RFS lie in the range of 150-300 microns. Therefore, surface area of non-ferrous RFS will be more in concrete as compared to ordinary lawrenspur sand; this may result in the low workability. As the percentage of non-ferrous RFS will increase, surface area of fine aggregate will also increase which will increases the demand of cement to achieve the required bond strength that may result in reduction in strength of concrete due to reduction in water cement gel.

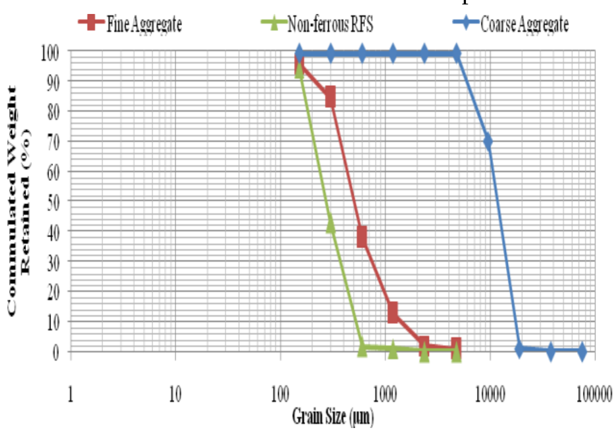

Figure-1 Grain size distribution of coarse aggregate, Fine aggregate and Non-ferrous RFS

To achieve the required results, mix is designed for 20 MPa compressive strength of concrete and methodology is adopted for sampling, casting and testing of specimen. Detail of mix design and test specimen is in the following.

3.2 Mix Design and Test Specimen

Mix design was prepared according to ACI-318 for 20 MPa of 28 days compressive cylinder strength of concrete. Using the physical properties of cement, sand and crush with constant w/c ratio mix design prepared is 1:2.2:3.8. Water to cement ratio is kept constant 0.56 (by weight) in all mixes (control and with non-ferrous RFS).

Standard cylinders of size 150mmφ x 300mm height were used for casting of test specimens for compressive strength. For each mix, six cylinders were casted. Out of these six cylinders, two were tested for compressive strength after 7 days, two cylinders after 14 days and two cylinders after 28 days of curing age.

Properties of fresh and hardened concrete are recorded by using different techniques. Details of results obtained for fresh and hardened concrete by using different techniques are discussed in the following.

4. RESULTS AND DISCUSSIONS

4.1 Slump and Compaction factor Test

Slump and compaction factor tests were performed on fresh concrete to check the workability of concrete. Slump was measured as per ASTM standards [19]. Fresh concrete after mixing is poured in the standard cone in three layers. Each layer was compacted with 25 blows of tamping rod and the drop in height is noted.

Compaction factor test provides indirect value of workability. This is measured by compaction factor test apparatus by taking the ratio of free fall weight of concrete to weight of compacted concrete. Slump and compaction factor values of control concrete and concrete mixes at different replacement level of non-ferrous RFS are listed in Table-4.

It is clear from the results that slump and compaction factor decreases with increase in non-ferrous RFS contents in concrete, which results in the low workability of concrete incorporated with non-ferrous RFS but at 45% replacement, the workability of concrete is within the permissible limit. Reduction in workability is due to more surface area of finer particles of non-ferrous RFS and large amount of loss on ignition (LOI).

Table-4 Slump and compaction test values of non-ferrous RFS concrete

Mix Designation	M_0	M_{10}	M_{30}	M_{45}
Percentage of NF RFS	0	10	30	45
Slump Value (mm)	75	70	62	60
Compaction Factor	0.92	0.88	0.86	0.85

After checking properties of fresh concrete, concrete is casted into cylinders to check compressive strength of hardened concrete at 7, 14 and 28 days of curing period. Now we discuss behavior of non-ferrous RFS concrete against the compressive strength.

4.2 Compressive Strength

Compressive strength was measured by using computer aided universal testing machine. Cylinder specimens were placed in vertical position as mentioned in ASTM C 39 and load is applied by strain control rate of 2 mm/min. Two cylinders for each mix were tested and average was reported as compressive strength. Results are compared for 20 MPa concrete mix and mixes with 10%, 30% and 45% replacement of fine aggregate with non-ferrous RFS. Results for all mixes at 7, 14 and 28 days of curing are listed in Table-5.

Table-5 Test results for compressive strength of non-ferrous RFS concrete

Mix Designation		M_0	M_{10}	M_{30}	M_{45}
Type of test	Age (days)	Percentage Replacement of Non-ferrous RFS			
		0	10	30	45
Compressive Strength by using ASTM C39 (MPa)	7	13.48	14.63	14.21	12.12
	14	15.68	17.83	16.97	14.87
	28	20.24	23.79	22.11	15.4

Results show a continuous increase in compressive strength up to 10% and 30% replacement and decrease at 45% replacement of non-ferrous RFS however 10% replacement gives optimum value. Strength is also increasing with age.

Increase in strength is due to presence of binding material (lime) which is also used for preparation of cement. As the non-ferrous RFS is finer in size, confinement of concrete mix will be more, that will also enhance the strength. Decrease after 10% replacement is due to more surface area of fine particles which results in reduction of water cement gel.

Increase in strength at 7 days of curing period at 10 % replacement is 8.5%, at 14 days of curing age is 13.7% and at 28 days of curing period is 17.5%.

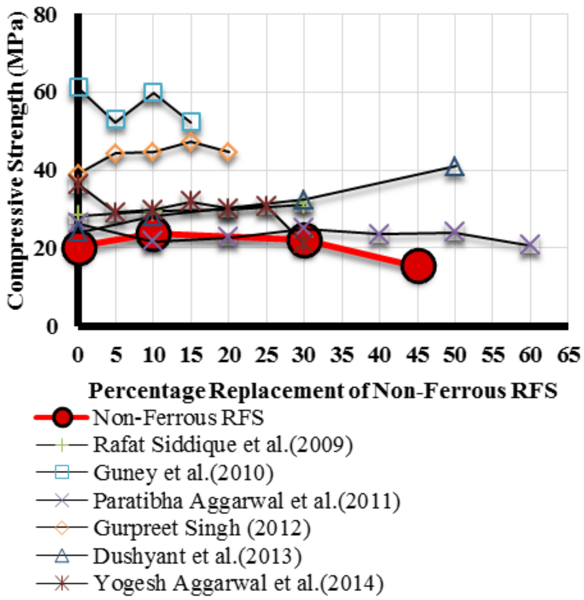

Figure-2 Comparison of compressive strength with replacement of Non-Ferrous RFS at 28 days

In Figure-2, results of different researchers are shown along with the current work at 28 days of curing. Most of the researchers work up till 30% replacement. Rafat Siddique et al, Gurpreet Singh and Dushyant et al, work shows an increase in strength with the increase in percentage replacement of used foundry sand.

Gunney et al, Paratibah Aggarwal et al and Yogesh Aggarwal et al, work explore a marginal decrease in strength with increase in contents of used foundry sand. The present study shows an increase up till 30% replacement of non-ferrous RFS then decrease. Behavior is compatible with previous work, although non-ferrous RFS used is from local foundries. Thus, non-ferrous RFS can be used as replacement of fine aggregate in concrete to find the product rich in strength and also will save the environment from pollution. At the same time, cost is an important factor for our country. If the cost of concrete with non-ferrous RFS will increase, then it will be uneconomical and may not have a good impact in the market potential. To check the impact on economy, a detailed cost analysis was done. Detail of cost analysis is as under.

4.3 Cost Analysis

As aggregate form the main part of concrete and cost of concrete depends upon the cost of aggregates. In this research fine aggregate is replaced with the RFS which is waste material of metal casting foundries, so cost is going to reduce effectively. For 1 meter cube of concrete, cost of concrete is analyzed by considering control concrete and concrete incorporating recycled foundry sand. Results are described in Table-6 and Table-7.

Table-6 Cost of materials

Sr. #	Material Description	Rate (Rs/Kg)
1	C (BESTWAY)	10.3
2	F.A (Lawrenspur)	2.4
3	C.A (Margala)	2.5
4	NF RFS	0.5

C=cement, F.A=Fine Aggregate, C.A = Coarse Aggregate, NF RFS = Non-Ferrous Recycled Foundry Sand

Results show that concrete prepared with mixing of non-ferrous RFS is economical as compared to control concrete. For 30% replacement of non-ferrous RFS, 5.3% cost is reduced for one meter cube of concrete.

5. CONCLUSIONS

Based on experimental research work regarding the compressive strength of non-ferrous RFS concrete, it is observed that compressive strength of concrete increases up to 30% replacement of non-ferrous RFS but optimum value was 10 % of non-ferrous concrete. Hence it concludes from the present study that

- For the production of good quality concrete non-ferrous RFS can be used.
- Compressive strength of concrete increases with the increase in non-ferrous RFS contents.

Use of non-ferrous RFS can save the cost of concrete up to 1.7% at 10% replacement of non-ferrous RFS, ultimately cost of structure

Table-7 Cost comparison for one meter cube of concrete using non-ferrous RFS

Mix Designation	Weight of aggregate used in mix (Kg)				Total cost (Rs)	Reduction in cost (%)
	C	F.A	C.A	RFS		
M_0	361.43	795.14	1373.43	0	9006.81	0
M_{10}	361.43	715.63	1373.43	79.51	8847.78	1.77
M_{30}	361.43	556.60	1373.43	238.54	8529.73	5.30
M_{45}	361.43	437.33	1373.43	357.81	8291.19	7.95

- Environmental effects from the foundry waste and disposal problem of foundry waste can be reduced through this research.

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