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Analytic Study on Electro-mechanical Properties of Reusable Industrial Waste Material (RIWM) in Self Compacting Concrete (SCC)

Gurjit Singh[1], Salman Rabbani[2], Harpal Singh[3] and Neha Kapila[4]

[1]*Dr.B.R. Ambedkar N.I.T Dept. of Electrical Engg. Jalandhar*
[2]*GNEC Dept. of Civil Engineering Ludhiana*
[3]*Guru Nanak Dev Engineering College Ludhiana*
[4]*Department of Electrical Engineering GNIEM, Naushera*
E-mail: [1]rattan4gurjit@gmail.com, [2]smilesrg786@gmail.com,
[3]hps_bhoday@yahoo.com, [4]nehabhagat23@gmail.com

Abstract—*Reusability Of Industrial Waste (ROIW) such as red mud and used foundry sand as Smart Composite Materials(SCM) for Self Compacting Concrete(SCC) which paves way to partial replacement of fine aggregate and cement in New Energy Materials(NEM) of Concrete Technology in Green Building(GB). SCC is a superlative and groundbreaking concrete that does not require vibration for placing and compaction. It has the ability to flow under its own weight by completely filling the formwork and achieves full compaction, even in the presence of crammed reinforcement. Keeping this in mind, fine aggregate was replaced with used foundry sand at 0%, 10%, 15% and 20% respectively. For each increase in foundry sand the red mud is optimized at 2% as a replacement of cement.*

Reusable Industrial Waste Materials (RIWM) measurement are carried out for compressive, split-tensile and flexural strength and also its corrosion effect for determining its mechanical properties. The performance parameters for optimization of RIWM have also cemented its way for electrical properties. Electrical resistivity of concrete (EROC) in NEM plays a vital role for setting characteristics (temporal and spatial), damage evaluation, self helped monitoring, moisture indexing and cracking. RIWM proves a partial replacement to fine aggregate and cement.

Index Terms— Reusability Of Industrial Waste (ROIW), Smart Composite Materials (SCM), Self Compacting Concrete (SCC), New Energy Materials (NEM), Green Building (GB), Reusable Industrial Waste Materials (RIWM), Electrical resistivity of concrete (EROC).

1. INTRODUCTION

The search for newer material and newer technology, particularly in the construction industry is on in scrutiny of increasing consciousness on fortification of environment and maintenance of natural resources paving way for Smart Composite Materials (SCM) of Green Building (GB). Concrete Technology has under gone from macro to micro level study in the enhancement of strength and durability properties. Self compacting Concrete (SCC) is extremely engineered concrete with much superior fluidity devoid of segregation and is competent of filling every lump of form work under its self weight only. SCC eliminates the requirements of vibration either external or internal for the compaction of the concrete without compromising its engineering properties.

The immense enhance in the extent of waste from industries, the shortage of dumping sites, prickly boost in the transportation, disposal cost and the rigorous antipollution and environmental parameter is alarming. That is why the idea of recycling the waste material and then finally using it in one form or the other has gathered momentum giving rise to Reusable Industrial Waste Materials (RIWM)[1][2][4].

Foundry sand and red mud has pozzolanic properties so it increases the binding properties and also provides better strength at the same time it reduces the cost problems. Typical red mud contains Cao, Sio2, and Fe2O3. It is disposed as slurry having a solid concentration in the range of 10 – 30%, pH in the range of 13 and high iconic strength. Dry disposal modehas been adopted by HINDALCO Plant. Here the mud after clarification passes through six stage counter current washing and after filtration (65% solids), it is disposed off by dumpers at the pond site. Foundry sand consists primarily of clean, uniformly sized, high quality silica sand or lake sand that is bonded to form moulds for ferrous (iron and steel) and nonferrous (copper, aluminium, brass) metal castings. Although these sands are clean prior to use, after casting they may contain Ferrous (iron and steel) industries account for approximately 95 percent of foundry sand used for castings. The automotive industry and its parts suppliers are the major generators of foundry sand. Used foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual binder (bentonite, sea coal, resins) and dust. Depending on the binder and type of metal cast, the pH of spent foundry sand can vary from approximately 4 to 8. . It has been reported that some used foundry sands can be corrosive to metals.

Electrical resistivity is an important physical property of Portland cement concrete, that affects a variety of applications. Electrical resistivity of Concrete (EROC) (or its inverse, conductivity) is important as a measure of the ability of concrete to resist the passage of electrical current. This has direct relevance to such applications as cathodic protection systems and hospital operating room floors, where low resistivities are required and electrically powered rapid transit lines, where high resistivities are needed. Resistivity is also used to find the moisture content. Electrical Resistivity Measurement (ERM) can be used for the performance-based evaluation of concrete. Resistivity test procedures, including sample preparation, are much easier and faster than that of the RCP test. Several techniques have been developed and studied for measuring the electrical resistivity of concrete, including the bulk electrical resistivity and surface electrical resistivity. In this article, different approaches in the measurement of concrete electrical resistivity are discussed. The correlations between the resistivity measurements and certain durability characteristics of concrete are reviewed. [9]

Kushwaha et al. (2013), have reported that the use of red mud as an admixture up to 2% will improve the compressive strength and if over 2% of red mud is added then the strength stars decreasing . Siddique et al. (2008) have reported that compressive strength, split tensile strength, flexural strength and modulus of elasticity of concrete mixtures increased with the increase in addition of used foundry sand (UFS) and also with age. Increase in compressive strength varied between 8% and 19% depending upon UFS percentage and testing age, whereas it was between 6.5% and 14.5% for splitting-tensile strength, 7% and 12% for flexural strength, and 5% and 12% for modulus of elasticity. Singh et al (2011) reported that partial replacement of UFS i.e. up to 15% will increase the strength properties of concrete . Singh et al. (2011), have reported that waste foundry sand can be suitably used in making structural grade concrete . Basar et al. (2012), have reported that waste foundry sand can be used as replacement of 20% of regular sand without compromising the mechanical and physical properties.[3][5][7][8].

In this paper we prepared self compacting concrete (SCC) by partially replacing cement material by red mud (RM) and in the same mix we have also partially replaced sand by used foundry sand for making it smart composite material (SCM). Fine aggregate material in the mixture was replaced with used foundry sand (UFS) at 0%,10%,15%,20%and25%. For each used foundry sand replacement level, 2% of cement was replaced with red mud (RM).

2. REUSABLE INDUSTRIAL WASTE MATERIAL:

These are nonuse able by-product waste material of Industries which can be reused as smart composite material (SCM) like in our case we are using them as a replacement of sand and cement.

2.1 Red Mud:

Red mud is a waste material generated by the Bayer process widely used to produce alumina from bauxite. In the Bayer process, the insoluble product generated after bauxite digestion with sodium hydroxide at elevated temperature and pressure to produce alumina is known as red mud or bauxite residue. The waste product derives its colour and name from its iron oxide content. Red mud is the iron rich residue from the digestion of bauxite.

It is one of the major solid wastes coming from Bayer process of alumina production. In general, about 2-4 tones of bauxite is required for production of each tone of alumina (Al_2O_3) & about one tone red mud is generated. After rinsing & compacting, the red mud is transported to the impoundment usually with a content of 3.5 to 5% even upto 7% Naoxide The red mud used in this study was obtained from Hindalco Industries Limited, Belgaum, Karnataka. The red mud used in this study was sieved through 600µ sieve. The specific gravity was found to be 2.82.

Fig. 1: RED MUD

Table 1: Chemical Constituents and Hazardous Trace Elements of Red Mud

Chemical constituents (%)	Bayers process	Hazardous trace element (ppm)	Bayers process
Fe_2O_3	26.41	**As**	267.3
Al_2O_3	18.94	**Pb**	56.6
SiO_2	8.52	**Hg**	67.3
CaO	21.84	**Cd**	27.1
Na_2O	4.75	**Cr**	537.8
TiO_2	7.40	**Ba**	212.0
K_2O	0.068	**Zn**	103.2
Sc_2O_3	0.76	**Cu**	78.2
V_2O_5	0.34	**Mn**	187.5
Nb_2O_5	0.020	**Ni**	984.9

2.1.1 Mechanical property of red mud

Red mud has a great effect on concrete, it enhances the compressive strength of concrete when added upto 2% addition as a replacement of cement. The experimental densities of the composites were achieved by the Archimedian method of weighing small pieces cut from the composite rods first in air and then in water, while the theoretical density was calculated using the rule of mixtures, according to the weight fraction of the combined reinforcement particles. The evaluation for the porosities of the produced composites is done from the difference between the expected and the observed density of each sample.

2.2. Used Foundry Sand

Foundry sand is a byproduct of ferrous and non-ferrous metal casting industries. Foundry sand is high quality silica sand which has unvarying physical characteristics. It is a by-product of ferrous and nonferrous metal casting industries, where sand has been used for long period as a moulding material as it has the property of thermal conductivity.Foundries successfully recycle and reuse the sand many times in the foundry. When the sand can no longer be reused in the foundry, it is removed from the foundry and is termed as used foundry sand. It can then be used as reusable industrial waste material(RIWM) for smart composite buildings(SCM).Classification of foundry sands depends upon the type of binder systems used in metal casting. Basically there are two types of binder systems which are being used, and based on that foundry sands are classified as clay bonded systems (green sand) and chemically bonded systems. In this study we have used Green foundry sand as a New Energy Material (NEM) for Green Building (GB). Its specific gravity was found to be 2.42.

Table 2: Chemical composition of used-foundry sand

Constituents	Value%
SiO_2	87.91
Al_2O_3	4.70
Fe_2O_3	0.94
CaO	0.14
MgO	0.30
SO_3	0.09
Na_2O	0.19
K_2O	0.25
TiO_2	0.15
P_2O_5	0.00
Mn_2O_3	0.02
SrO	0.03
LOI	5.15

2.3 Recycling of Foundry Sand

In typical foundry processes, sand from collapsed molds or cores can be reclaimed and reused. A simplified diagram depicting the flow of sand in a typical green sand molding system is presented in Figure. Some new sand and binder is typically added to maintain the quality of the casting and to make up for sand lost during normal operations. Little information is available regarding the amount of foundry sand that is used for purposes other than in-plant reclamation, but spent foundry sand has been used as a fine aggregate substitute in construction applications and as kiln feed in the manufacture of Portland cement.

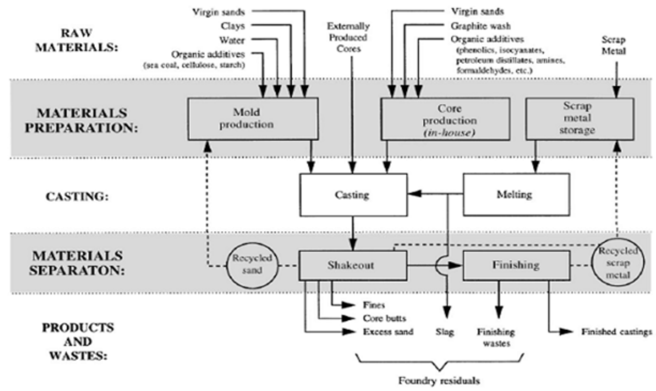

Fig. 2: Formation of Foundry Sand

2.4 Electrical Properties of Concrete

Electrical Concrete Resistance (ERC) can be calculated by applying a current using two electrodes attached to the split ends of a uniform cross-section specimen. Electrical resistivity is obtained from the equation:

$$R = \rho\frac{\ell}{A}$$

(1) ρ = R A ℓ , {\displaystyle \rho =R{\frac {A}{\ell }},\,\!} RRRrrghvjgvgj

R is the electrical resistance of the specimen, the ratio of voltage to current (measured in ohms, Ω)

ℓ is the length of the piece of material (measured in metres, m)

A is the cross-sectional area of the specimen (measured in square metres, m^2).

The ERC can be premeditated from the electrical current (I) passing through the specimens. The method, consists of two cylindrical probes, each with two electrodes prepared from stainless steel and spaced at different layer depths. The two probes should be placed apart. The resistivity of concrete at each depth can be determined by the paired-electrode technique. An alternating current is applied between the electrodes and the resistivity is obtained by measuring the resistance (dE/dI, Ohm's law) and by a parameter that depends on the geometry of the electrodes and on the distance between them (A/L). Thus, the resistivity (R) is premeditated according to equation

$$\rho = \frac{V.A}{I.\ell} \quad (2)$$

For circular,

$$\rho = \frac{2\pi.V.\ell}{I} \quad (3)$$

Where ρ is the electrical resistivity of concrete (Ω. cm); V is the applied voltage; I is the current intensity; A is the area of the side of the specimen in contact with the electrode (cm^2); and L is the distance between the electrodes (cm). [9]

3. MATERIALS USED OTHER THAN RIWM

Below enlisted are materials used for smart materials.

3.1 Cement

Ordinary Portland cement (43 grade) was used in this study. The cement was tested according to IS: 8112-1989. The specific gravity was found to be 3.2.

3.2 Fine Aggregate

Natural river sand with maximum size of 4.75mm was used in this study. The specific gravity was found to be 2.66.

3.3. Admixture

Admixtures are essential in determining flow characteristics and workability retention. Ideally, they should also modify the viscosity to increase cohesion. The admixture used here for the experiment is MasterGlenium SKY 8632. It is an admixture of a new generation based on modified polycarboxylic ether. The product has been primarily developed for applications in high performance concrete where the highest durability and performance is required.It is free of chloride & low alkali. It is compatible with all types of cements.

4. EXPERIMENT AND RESULT OF RIWM

The experimental results are discussed below :

4.1 Preparation and Casting of Specimens

Cubes of 150 × 150 × 150 mm were casted for compressive strength. For split tensile strength 150 × 300 mm cylinders were cast and For the flexural strength beams of 100 × 100 × 500 mm were cast. All the specimen are kept at room temperature for 24 hours after casting and then demoulded. After demoulding the cubes are kept in water tank for curing.

4.2. Properties of Fresh Concrete

The properties of fresh concrete such as slump, passing ability, filling ability and segregation resistance were determined according to EFNARC specifications. The tests carried out to determine these properties were slump flow test, L – box test, V – funnel test and U – box test. [10].

4.3. Properties of Hardened Concrete

The compressive strength tests on the cubes were performed at ages 7 and 28 days. The split tensile tests on cylinders and the flexural strength tests on beams were performed at 28 days. All tests were performed in accordance with the provisions of IS: 516-1959.

4.4 Concrete mixture proportion

In this study five concrete mix proportions were made. The first mix was a conventional type (without RIWM) and the remaining four mixtures contained red mud and UFS i.e RIWM. The conventional or controlled SCC mix was designed for M25 grade. EFNARC guidelines were followed to design the SCC mix. Cement material in the mixture was replaced with red mud at 2%,For each 2% red mud replacement level, 10%,15%,20%,25% of fine aggregate (regular sand) was replaced with used foundry sand (UFS) in order to persive the reuseablity of industrial waste (ROIW) by making it smart composite material (SCM) for green building(GB).

Table 3: Concrete mixture proportion

Mixture no.	M-0	M-1	M-2	M-3	M-4
Cement (kg/m3)	368.72	361.35	361.35	361.35	361.35
Fine aggregate (kg/m3)	632.52	569.28	537.64	506.016	474.39
Coarse Aggregate(kg/m3)	690.14	690.14	690.14	690.14	690.14
Red mud %age	0	2	2	2	2
Red Mud in (kg/m3)	0	7.374	7.374	7.374	7.374
Used Foundry sand %age	0	10	15	20	25
Used Foundry sand in (kg/m3)	0	63.252	94.878	126.504	158.13
Water (kg/m3)	223.44	223.44	223.44	223.44	223.44
Super Plasticizer 1% by weight of cement (1/m3)	3.6	3.6	3.6	3.6	3.6

5. RESULT AND DISCUSSION

5.1 Compressive Strength

The concrete mixtures were made with the controlled mix as well as with red mud and UFS in order to make the reuseablity of industrial waste (ROIW) and to check the compressive strength after 28 days of curing.

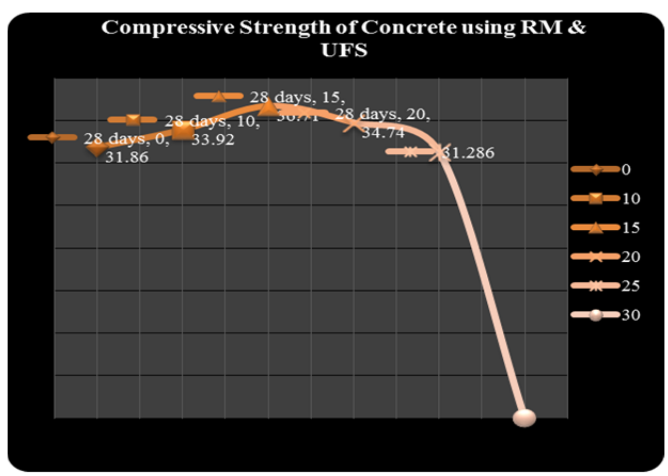

Fig. 4: Compressive Strength of Concrete using RM & UFS

At 28-day, the control mixture M-0 (0% RM, 0% UFS) achieved a compressive strength of 31.86 MPa. The mixtures M-1(2% RM, 10% UFS), M-2 (2% RM, 15% UFS), M- 3(2% RM, 20% UFS) and M-4(2% RM, 25% UFS) achieved compressive strengths of 33.92 MPa, 36.71 MPa, 34.74 MPa and 31.286 MPa respectively. The compressive strength reached an optimum value at M-2 and then decreased for M-3 and M-4.there is an increase in strength of 6.4%, 15.4% and 9.2% and was observed for M-1,M-2 and M-3 respectively with respect to conventional or controlled mix. A decrease of 0.38% was observed for M-4.

5.2 Splitting-Tensile strength

The split tensile strength is shown in fig. At 28-day, the control mixture of SCC achieved a split-tensile strength of 2.763 MPa. The mixtures M-1, M-2, M-3 and M-4 achieved splitting-tensile strengths of 3.035 MPa, 3.539 MPa, 3.295 MPa and 3.146 MPa respectively.

Fig; split tensile strength

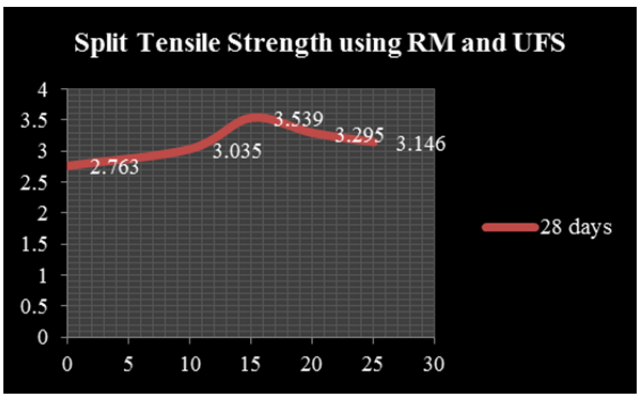

Fig. 5: Split Tensile Strength using RM and UFS

5.3 Flexural Strength

The flexural strength is shown in fig.3. At 28-day, the control mixture NSCC achieved a flexural strength of 5.298 MPa. The mixtures M-1, M-2, M-3 and M-4 achieved flexural strengths of 5.923 MPa, 5.532 MPa, 5.854 MPa and 5.975 MPa respectively. The maximum flexural strength was achieved at 2% red mud with 15% UFS. After this the flexural strengths reduced marginally and then remained almost constant. The flexural strength achieved for all the mix is more than the control mix and all these values are more than IS specified values. An increase of 9.9%, 7.6%, 7.4% and 9.6% was observed for M-1, M-2, M-3 and M -4 respectively with respect to controlled mix of SCC.

5.4 Electrical Resistivity Of Concrete

Corrosion measurement

Investigations have found correlations between concrete resistivity and both the corrosion initiation and the propagation period. The corrosion rate often has an inverse correlation to the electrical resistivity of concrete. Hornbostel et al. have compiled a comprehensive literature review on the relation of corrosion rate and electrical resistivity as well as the contributing factors. In general, higher electrical resistivity of concrete lowers the risk and the rate of corrosion.

Crack detection

The presence of cracks in the microstructure of concrete can change the transport properties of concrete. Cracks change the connectivity of pore structure, therefore the electrical properties of concrete. The electrical resistivity technique can also be used to detect and monitor the initiation and propagation of cracks in concrete. The development of microcracks in cementitious composite materials under tensile test was accurately determined by Ranade et al.

Setting time measurement.

The concept of electrical resistivity has been used to develop test methods for determining the setting time of cement mortars and concrete. As the fresh concrete sets and hardens, depercolation (discontinuity) of the capillary pore space increases the electrical resistivity. Bentz et al. studied the feasibility of using electrical resistivity technique for predicting the setting time of cement paste and concrete mixtures.

Moisture content

Another potential application of the electrical resistivity method is to determine the moisture content of concrete. Rajabpour et al.15 investigated the use of resistivity measurement in assessing the moisture content of concrete. However, the application and reliability of the method to determine the moisture content has yet to be evaluated

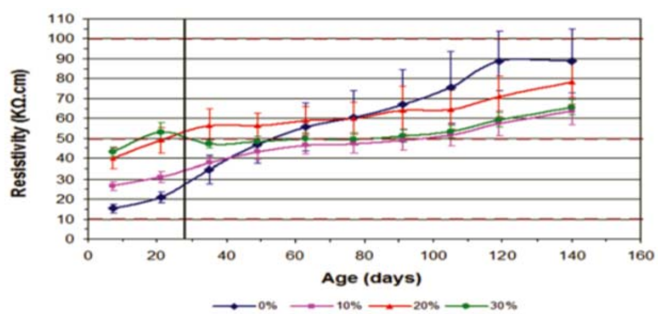

Fig. 5: Electrical Resistivity w.r.t Age []

6. CONCLUSION

Reusable Industrial Waste Materials (RIWM) measurement are carried out for compressive, split-tensile and flexural strength and also its corrosion effect for determining its mechanical properties. The performance parameters for optimization of RIWM have also cemented its way for electrical properties. Electrical resistivity of concrete (EROC) in NEM plays a vital role for corrosion measurement, setting characteristics (temporal and spatial), damage evaluation, self helped monitoring, moisture content indexing and crack detection..

It is seen that after addition of Red mud at optimized value of 2% and UFS at 15%.the compressive strength, split tensile strength and flexural strength of concrete increases and after addition of more RM and UFS the compressive strength, split-tensile strength and flexural strength, tend to decrease. RIWM proves a partial replacement to fine aggregate and cement.

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