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Use of Industrial Waste – (Red Mud) in the Production of Self Compacting Concrete

Mr. Sunil Donga
Undergraduate Student, Civil Engineering Department, Kalinga University Naya Raipur, Chhatisgarh, India

Abstract: Red mud is industrial waste and causing threat to environment so to reduce the cost of the construction also to make structure more durable. Aluminium is now consumed during manufacture red mud, which is used and while remaining red mud has been undertaken sothat it can be used for construction fashion of the concrete by blending or by replacing the cement by red mud.
Keywords: Red mud, self-compacting concrete, Compressive Strength, Tensile Strength, Flexural Strength

I. INTRODUCTION

Development of self-compacting concrete (SCC) is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. Self-compacting concrete is cast so that no additional inner or outer vibration is necessary for the compaction. It flows like “honey” and has a very smooth surface level after placing.

Red mud is the insoluble product after bauxite digestion with sodium hydroxide at elevated temperature and pressure. It is a mixture of compounds originally present in the parent mineral, bauxite, and of compounds forms or introduced during bayer cycle. 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. The disposal of red mud is not easy.

In most countries where red mud is produced, it is pumped into holding ponds. when it is dry. The HINDALCO plant at Belgaum, India has adopted dry disposal mode. 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. Used foundry sands (UFS) are generated by metal casting industries.

Foundries purchase new, virgin sand to make casting moulds, and the sand is reused many times within the foundry. However heat and mechanical abrasion eventually render the sand unsuitable for use in casting moulds, and a portion of the sand is continuously removed and replaced with virgin sand. The used foundry sand, that is, the sand that is removed, is either recycled in a non-foundry application or landfilled. Estimates are that less than 15% of the 6-10 million tons of UFS generated are recycled.

As per Mineral Commodity Summaries (2015), the worldwide Bauxite production is around 234 million metric tons (MMT), red mud (RM) $9x10^7$ MT in which India accounts for 19.3 MMT and RM of $2x10^6$ MT in 2014. The greatest producers of red mud in the world are Australia, Brazil, China, Greece, Guynea, Guyana, India and many other countries. The worldwide famous companies like ALOCA, ALCAN, RUSAL, BHP, CHALCO and many others contribute. Global production of red mud is amounting more than 120MMT out of which China shares about 60 MMT tons.

Huge quantity of red mud is received from Indian aluminium sector which was obtained in 2009 from Indian major industries NALCO (2.033 MMT), HINDALCO (1.654 MMT), VEDANTA (0.366 MMT), BALCO+MALCO (0.412 MMT), totalling to 4.465 MMT Chhada 2010 which is the undisposed waste of the industry. Red mud contains large number of compounds Fe2O3 (30-60%), Al2O3 (10-20%), SiO2 (3- 50%), Na2O (2-10%), CaO (2-8%), and traces of TiO2.

This high alkaline slurry is practically a discarded waste due to it’s high value of pH (10.5 to12.5), none uniform composition, polluting surface and underground water, requirement of vast disposing area, leaching properties, formation of sodium alumino-silicate, and deteriorating the adjoining vegetation.

The world has not forgotten the adversity of 0.6 to 0.7 million cumec red mud sludge (2010) of the Ajkai Timfoldgyar plant of Hungary that affected the Bulgaria, Serbia, Ukraine and Romania and collapse of RM pond in Henan Province, China during Aug, 2016. The red mud is difficult to use with cement, as building materials, steel industries due to its rich soda content. In contrary, few of above mentioned oxides in RM are present in cement. Red mud can be used as a cementing material (Orient Cement which uses 2-4% RM of MALCO).

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II. MATERIALS USED

A. Cement

Ordinary Portland cement (43 grade) was used in this study. The cement was tested according to IS: 8112-1989 [5]. The specific gravity was found to be 3.1.

B. Fine Aggregate

Natural river sand with maximum size of 4.75mm was used in this study. The specific gravity was found to be 2.64.

C. Coarse Aggregate

SCC can be made from most normal concreting aggregates. Coarse aggregates differ in nature and shape depending on their extraction and production. SCC has been produced successfully with coarse aggregates up to 40 mm, however these trials are made keeping maximum aggregate size of 12 mm. The coarse aggregates, obtained from a local source, had a specific gravity of 2.65. The size fraction of the coarse aggregate used is extremely important for determining the optimum amount of paste content to obtain all the necessary characteristics of a flowing concrete. The fine and coarse aggregates were tested according to IS: 383-1970 [6].

D. 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. The red mud used in this study was obtained from Hindalco Industries Limited, Belgaum, and Karnataka. The red mud used in this study was sieved through 600µ sieve. The specific gravity was found to be 2.807.

TABLE-1 Chemical Composition Of Red Mud

Chemical composition	Bauxite Residue (%)	Typical Values Worldwide (%)
Fe_2o_3	51	30-60
Al_2o_3	15	10-20
CaO	13	2-8
SiO_2	10	3-50
Na_2o	0.20	2-10

E. Admixtures

Admixtures are essential in determining flow characteristics and workability retention. Ideally, they should also modify the viscosity to increase cohesion. Newly developed types of super plasticizer, known as Poly-Carboxylate Ethers (PCE), are particularly relevant to SCC. They reconcile the apparently conflicting requirements of flow and cohesion, avoiding potential problems and unwanted retardation and excessive air entrainment, particularly at higher workability if the mix design is correct. The admixture used in the current program was Algihyperplast N supplied by ALGI. ALGIHYPERPLAST-N is powerful Naphthalene based super plasticiser recommended of site mixed concrete or for concrete which requires high early strength or where concrete is placed within half an hour of mixing.

F. 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 reuseability of industrial waste (ROIW) by making it smart composite material (SCM) for green building(GB).

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Table-2 Concrete Mixture Proportion

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

III. METHODOLOGY

A. Literature Review
B. Material Procurement
C. Material Processing
D. Mixing
E. Test Samples
F. Observations

IV. EXPERIMENTAL RESULTS

A. Overall Results of Compressive Strength (SP+VMA)

The following table gives the overall results of compressive strength of self-compacting concrete containing the combination of admixtures (SP+VMA) for various percentage addition of red mud.

Table -3 Overall Results Of Compressive Strength

%addition of red mud	Compressive Strength (Mpa)	% Increase or decrease of Compressive Strength
0 (Ref)	40.59	-
1	41.18	+1.45
2	44.29	+9.11
3	42.66	+5.10
4	40.29	-0.74
5	37.62	-7.32
6	35.11	-13.50
7	34.51	-14.98
8	33.62	-17.17

The variation of compressive strength can be depicted in the form of graph as shown in figure.

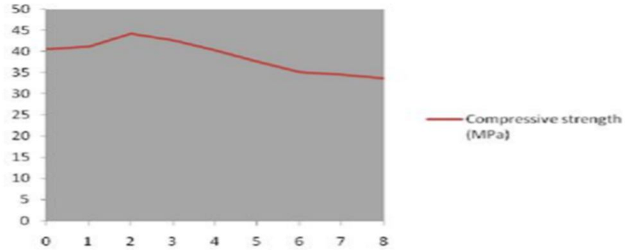

FIG-1 Compressive Strength

B. *Overall Results of Tensile Strength*

The following table gives the overall results of tensile strength of self-compacting concrete containing the combination of admixtures (SP+VMA) for various percentage addition of red mud.

Table-4 Overall Results Of Tensile Strength

% of Red Mud	Tensile Strength (Mpa)	% increase or decrease in strength
0(Ref)	3.34	-
1	4.00	+19.76
2	4.62	+38.32
3	3.34	0
4	3.25	-2.69
5	3.10	-7.19
6	2.87	-14.07
7	2.50	-25.15
8	2.16	-35.33

The variation of tensile strength can be depicted in the form of graph as shown in figure.

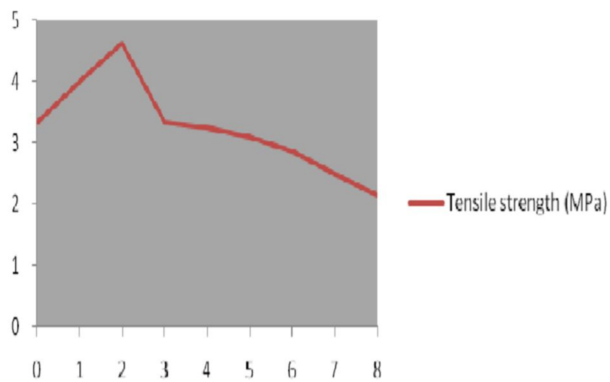

FIG-2 Tensile Strength

C. *Overall Results of Flexural Strength*

The following table gives the overall results of flexural strength of self-compacting concrete containing the combination of admixtures (SP+VMA) for various percentage addition of red mud.

Table-5 Overall Results Of Flexural Strength

% addition of Red Mud	Flexural Strength (Mpa)	% Increase or decrease of Flexural Strength
0(Ref)	5.12	-
1	5.36	+4.69
2	5.53	+8.01
3	5.50	+7.12
4	5.26	+2.73
5	5.15	+0.59
6	4.92	-3.91
7	4.83	-5.66
8	4.40	-14.06

The variation of flexural strength can be depicted in the form of graph as shown.

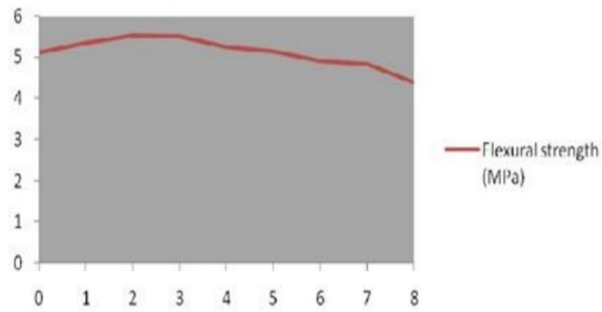

FIG-3 Flexural Strength

D. Overall Results of Flow Properties

Overall flow test results of effect of addition of red mud in various percentages on the Properties of self-compacting concrete containing an admixtures combination of (SP+VMA).

TABLE-6 Overall Test Results

% of Red Mud	Slump Flow (mm)	Slump Test (sec)	V – Funnel Flow Time(sec)	U – box Filling height H1-H2 (mm)	L – box		
					Blocking ratio H2/H1	(T20) Sec	(T40) Sec
0	680	4.9	33.10	0	0.812	9.24	15.8
1	700	4.7	24.61	0	0.88	6.30	10.2
2	720	4.3	18.70	0	0.96	3.80	6.5
3	710	4.6	32.80	5	0.85	4.60	8.8
4	680	5.3	34.60	5	0.83	5.20	9.2
5	650	5.8	36.80	10	0.78	5.50	11.2
6	630	8.6	42.00	10	0.60	6.30	13.4
7	590	12.4	52.80	15	0.39	7.20	15.6
8	560	13.2	66.54	20	0.16	9.40	25.2

V. CONCLUSION

Based on the experimentation conducted, the following observations were made and hence some conclusions.

1) It has been observed that the compressive strength of self-compacting concrete produced with the combination of admixtures such as (SP+VMA) goes on increasing up to 2% addition of red mud. After 2% addition of red mud, the compressive strength starts decreasing, i.e. the compressive strength of self-compacting concrete produced with (SP+VMA) is maximum when 2% red mud is added. The percentage increase in the compressive strength at 2% addition of red mud is +9.11MPa. Thus, it can be concluded that maximum compressive strength of self-compacting concrete with the combination of admixtures (SP+VMA) may be obtained by adding 2% red mud which is a waste material from aluminium industry.
2) It has been observed that the compressive strength of self-compacting concrete produced with the combination of admixtures such as (SP+VMA) goes on increasing upto 2% addition of foundry waste sand. After 2% addition of foundry waste sand, the compressive strength starts decreasing, i.e. the compressive strength of self-compacting concrete produced with (SP+VMA) is maximum when 2% foundry waste sand is added. The percentage increase in the compressive strength at 2% addition of foundry waste sand. Thus, it can be concluded that maximum compressive strength of self-compacting concrete with the combination of admixtures (SP+VMA) maybe obtained by adding 2% foundry waste sand which is a waste material of ferrous industry (foundry).

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Websites:

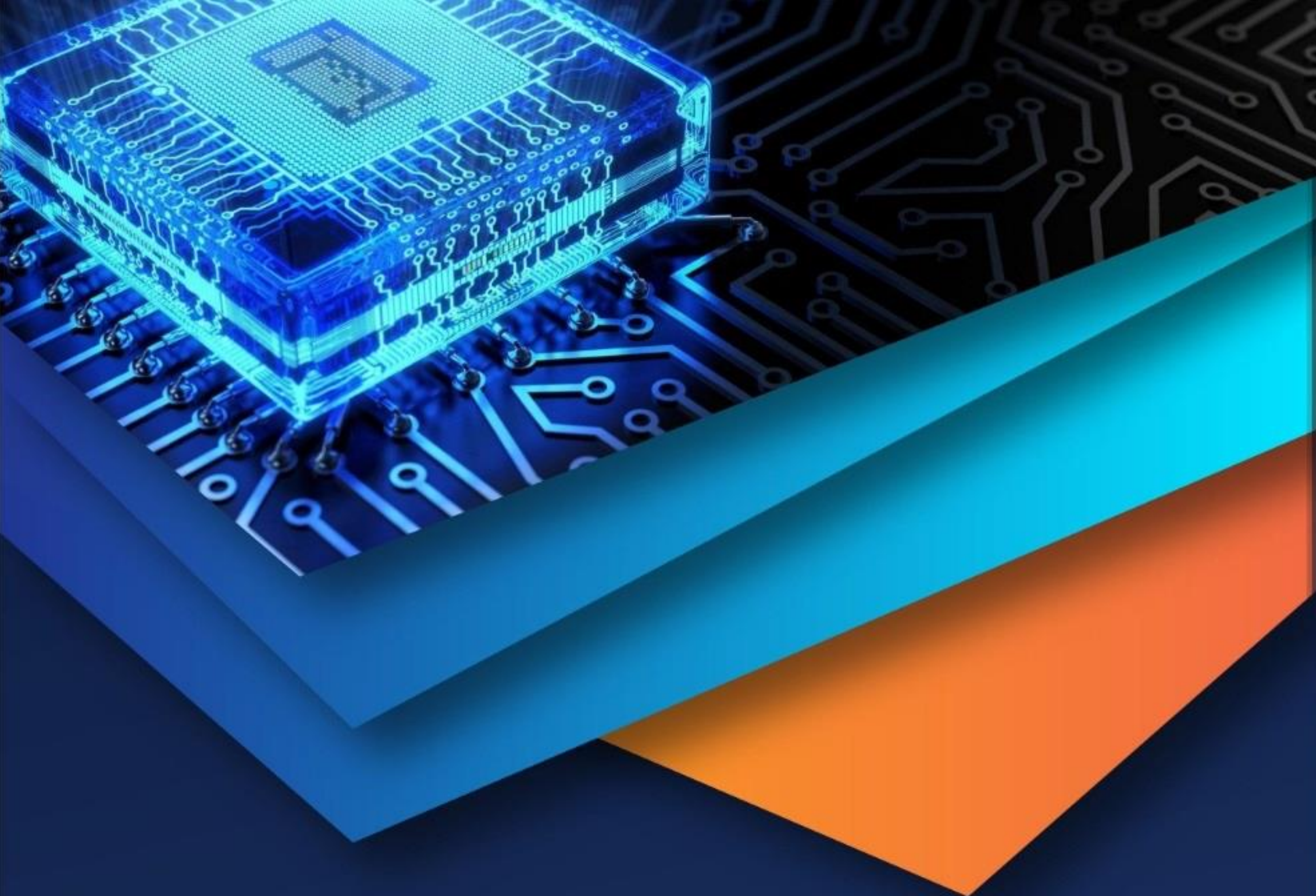
www.redmudproject.com

Author's Details:

Mr. Sunil S. Donga

Undergraduate student
Civil Engineering Department
Kalinga University,
Naya Raipur, Chhatisgarh

Email – sunildonga7698@gmail.com



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