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Reutilisation of Bayer Red Mud as Moulding Material in Green Sand Casting Process-An Experimental Study

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ABSTRACT

Casting defects are usually not by accidents, they occur because some steps in manufacturing cycle does not get properly controlled and somewhere something goes wrong. Metal casting industries are continuously exposed to ever increasing demands regarding their competitiveness, sound quality products as well as in developing their specific casting process. Bayer Red mud which is a waste by product of Aluminum extraction process is dumped in large areas near the sea or nearby ponds. Bayer Red mud is dumped after the neutralization process. Neutralization is done by mechanics of seawater treatment. The mud is actively mixed with the seawater for a period of around 30 minutes to enable the reactions to take place. Clay content had significant effect on permeability, hardness or GCS while moisture content had a little effect. In this article attempt is made to carry out different experiments by making red mud a constituent in mold sand in different proportions and to manufacture castings and compare the resulting casting with regular casted components. In short, the aim is to extract economic benefits from the free and ample availability of red mud and also find a way to control the environmental pollution caused due dumping of red mud in heavy masses.

Keywords: Bayer process, Red mud, Green sand, Bentonite, Metal casting, casting defects.

I. INTRODUCTION

Recently the possibility of making sinters suitable for iron blast furnace by using iron ore fines and red mud sand in various proportions have been explored with aluminium content varying from 3-4% and basicity of the sinter was in the range of 1.9-2.4 with no alkali and TiO_2 in the sinter sample[1]. Red mud is a solid waste residue of the digestion of bauxite ores with caustic soda for alumina production [3]. Red mud is the solid waste residue of the digestion of bauxite ores with caustic soda for alumina (Al_2O_3) production. Approximately 35-40% of the processed bauxite ore goes into the waste as alkaline red mud slurry which consists of 15-40% solids and 0.8-1.5 tons of red mud is generated per ton of alumina [3]. Because of the high alkalinity, this red mud is traction. However, it is used for making tiles, building material, doors and windows, road construction, pig iron production etc [1]. Red mud disposal causes seepage of the alkaline liquid into groundwater, which might contaminate industrial, domestic, and agricultural water supplies. If Bayer red mud is completely neutralised, 15-20 times the volume of sea water is required. This requires extensive and expensive pumping and although results in a neutral product, it is completely worthless. But neutralizing is not a solution to disposal or it is not of any economic benefit. This is the reason why alumina plants dump the Bayer red mud either in the nearby ponds or it is dumped at sea. The disposal costs as per regulations may add up to 5% of the alumina production cost.

In a green sand casting process, castings are made by using sand molds formed from wet sand which contains water and organic bonding compounds, typically referred to as clay. The name Green Sand comes from the fact that the sand mold is not set, it is still in the green or uncured state even when the metal is poured in the mould. Green sand is not green in colour, but green in the sense that it is used in a wet state. Normally used

molding ingredients are silica sand (SiO_2), Chromite sand ($FeCr_2O_4$), or zircon sand ($ZrSiO_4$), 75-85%, sometimes with a proportion of olivine/ Staurolite/ graphite, Bentonite (clay) 5-11%, water 2-4%, inert sludge 3-5%.

II. METHODS AND MATERIAL

1. Parameters Affecting Quality of Castings

A. Silica Sand

Refractory sands especially silica sands are the best molding material because of excellent moldability, green and dry strength, high refractoriness, permeability, flow ability, collapsibility, chemical inertness and inexpensive.

B. Bentonite Clay

It is composed of ash made from volcanos. The main uses of bentonite are for drilling mud, binder (e.g. foundry-sand bond), purifier, absorbent, and as a groundwater barrier. In Foundries Bentonite is used as a bonding material in the preparation of molding sand for the production of iron, steel and non-ferrous casting. The unique properties of bentonite yield green sand moulds with good Flowability, Moldability and thermal stability for the production of high quality castings.

Figure 1: Bentonite clay powder

The fundamental property of bentonite is to absorb water and expand. Binding property is mainly exploited to produce green molding sand. Under this homogenous coating made in sand Muller, even at maximum compression, water will remain in a highly rigid state, binding the sand grains and lending maximum resistance to the sand mould .Therefore, when used as an additive, it makes green sand more durable, and, in particular, more resistant to heat stress.

C. Coal Dust

Figure 2. Coal dust powder

It is a fine powdered form of coal, which is created by the crushing, grinding, or pulverizing of coal. Because of the brittle nature of coal, coal dust can be created during mining, transportation, or by mechanically handling coal.

D. Water

The amount of water varies from 1.5-8%. It is responsible for binding action of clay. Water activates the clay in sand and the clay sad mixture develops strength and plasticity. The absorbed water is responsible developing proper bond and green strength. The free water reduces strength of sand mixture.

E. Bayer Red Mud

Figure 3. Bayer red mud pond

The Bayer process, as it has become known, is used for refining bauxite to smelting grade alumina (aluminium oxide), the precursor to aluminium. In the Bayer production of alumina, red bauxite sludge is produced as a by-product, which is a fine substance of the following composition. This composition varies from different locations across various regions of country in India as listed in table I.

2. Methodology/Proposed Work

The idea is to carry out different experiments by partly replacing bentonite with red mud a constituent in green sand in different proportions, and to carry out actual molding, melting and pouring trial experiments and compare the resulting casting with casting manufactured from standard composition of green sand with foundry sand with bentonite binder, coal dust and moisture. In short, the aim is to extract economic benefits from the free and ample available red mud and also find a way to control the environmental pollution caused due to dumping of red mud in heavy masses.

3. Selection Of Process Parameters Of Study

According to research objective we want to use maximum amount of red mud in mold sand. We kept the maximum parameters constant and only changed the following ones:

- Red mud Percentage weight varied from 25-45% in steps of 5.
- Silica Sand Percentage weight varied from 50-70 % in steps of 5.

Other parameters like as Bentonite and Coal Dust percentage as constant, as we want to check the effect of Bayer red mud and silica sand on quality of casting by changing their proportion and to utilise economic benefits from the free and ample availability of red mud.

4. Experimental Procedure

The experimental steps involves,

- Sieving of neutralized red mud.
- Weighing silica sand, red mud, bentonite, coal dust proportional to weight of total mixture.
- To carry out dry mulling of the above constituents in dry muller for 2 minutes followed by wet mulling of the dry mulled sand in wet muller for 5 minutes.
- Testing of prepared sand for testing green compressive, green shear, permeability, and moisture content.
- Preparation of the mold
- Melting aluminium
- Pouring the metal in the mold cavity.
- Shake out and fettling followed by inspection for quality of casting.

TABLE I : Composition of red bauxite sludge in different locations of India [3] [6]

Company	Al_2O_3 (%)	Hematite Fe_2O_3 (%)	SiO_2 (%)	Rutile TiO_2 (%)	Na_2O (%)	CaO (%)	LOI (%)
BALCO, Korba	18.10-21.0	35.0-37.0	6.0-6.5	17.0-19.0	5.2-5.5	1.7-2.2	11.8-14.0
HINDALCO, Renukoot	17.5-19.0	35.5-36.2	7.0-8.5	16.3-14.5	5.0-6.0	3.2-4.5	10.7-12.0
HINDALCO, Muri	19.0-20.5	44.0-46.0	5.5-6.5	17.0-18.9	3.3-3.8	1.5-2.0	12.0-14.0
HINDALCO, Belgaum	17.8-20.1	44.0-47.0	7.5-8.5	8.2-10.4	3.5-4.6	1.0-3.0	10.8-14.0
MALCO, Metturdam	18.0-22.0	40.0-26.0	12.0-16.0	2.5-3.5	4.0-4.5	1.5-2.5	11.0-15.0
NALCO, Damanjodi	17.7-19.8	48.2-53.8	4.8-5.7	3.6-4.1	3.8-4.6	0.8-1.2	10.8-13.5

Table II : Details of experimental parameters and observed readings.

Experiment no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Red Mud %	45	35	30	45	45	40	35	30	25	25
Silica Sand %	50	60	70	50	50	55	60	65	70	70
Bentonite%(Constant)	3	3	3	3	3	3	3	3	3	3

Coal Dust%(Constant)	2	2	2	2	2	2	2	2	2	2
Moisture Content%	6.2	5.6	5.2	5.1	4.8	4.4	4.0	3.8	3.4	4.2
Type of Pouring	Open	Open	Open	Closed	Closed	Closed	Closed	Closed	Closed	Closed
Sprue, Runner and riser uses	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pouring Temperature in ^{0}c	740^{o}C	740^{o}C	740^{o}C	1250 ^{o}C	740^{o}C	740^{o}C	740^{o}C	740^{o}C	740^{o}C	740^{o}C
Green shear strength in gm/cm^3	150	140	135	135	155	135	145	145	125	140
Green compressive strength in gm/cm^3	1050	1020	1020	1020	1040	1010	1030	1030	990	1035
Permeability with large orifice	151	155	170	135	145	160	168	168	175	170
Permeability with small orifice	12.5	12.7	14.2	11.5	11.9	13.1	13.7	13.7	14.6	14.2
Moisture Content %	6.2	5.6	5.2	5.1	4.8	4.4	4.0	3.8	3.4	4.2

III. RESULTS AND DISCUSSION

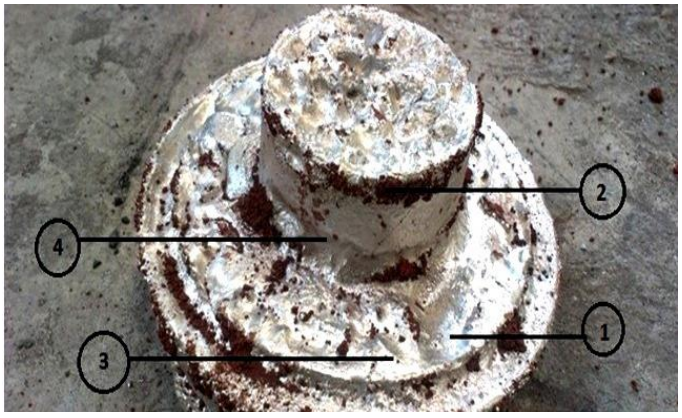

Figure 4. Defective Casting from Experimental Trial 1 showing shrinkage and porosity defects.

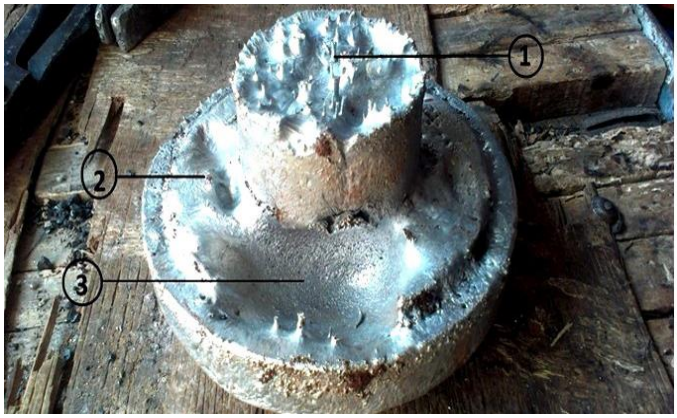

Figure 5. Defective Casting from Experimental Trial 2 showing shrinkage porosity and metal sinking defect.

Figure 6. Defective Casting from Experimental Trial 3 showing shrinkage porosity and metal sinking

Figure 7. Defective Casting from Experimental Trial 4 showing incomplete casting

Figure 8. Defective Casting from Experimental Trial 5 showing rough surface finish and sand inclusion

Figure 9. Defective Casting from Experimental Trial 6 showing rough surface finish and sand inclusion

Figure 10. Defective Casting from Experimental Trial 7 showing rough surface finish and sand inclusion

Figure 11. Defective Casting from Experimental Trial 8 showing rough surface finish and sand inclusion and pin holes

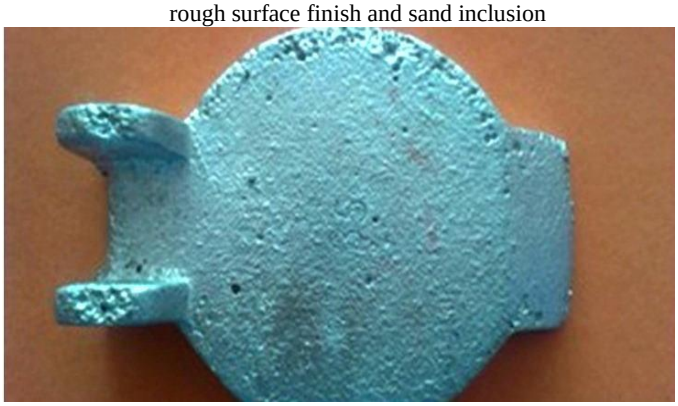

Figure 12. Defective Casting from Experimental Trial 9 showing rough surface finish, gas holes and sand inclusion

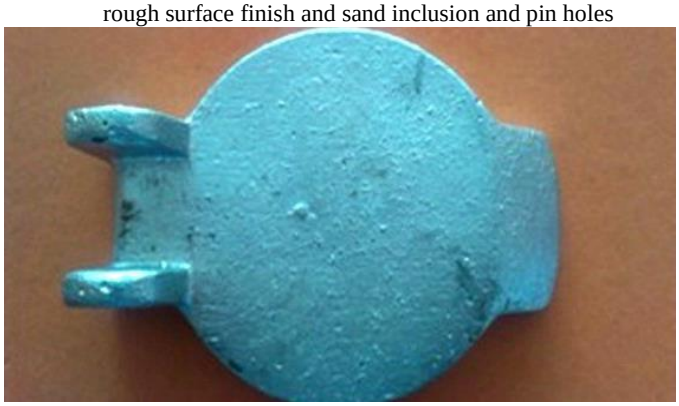

Figure 13. Sound Casting from Experimental Trial 10 showing a better surface finish

Figure 14. Sound Casting from Experimental Trial 10 with 25% red mud showing a better acceptable surface finish

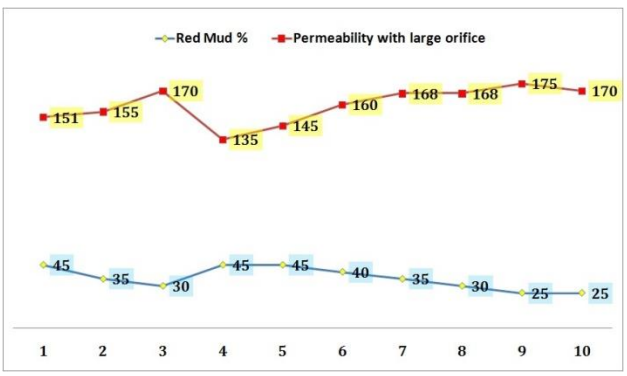

Figure 15. Effect of percentage of red mud on permeability of molding sand using 1.5mm diameter orifice over permeability meter during experimental trial 1-10

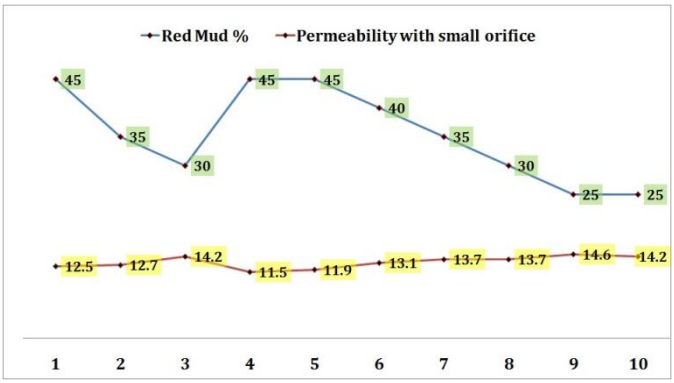

Figure 16. Effect of percentage of red mud on permeability of molding sand using 0.5 mm diameter orifice over permeability meter during experimental trial 1-10

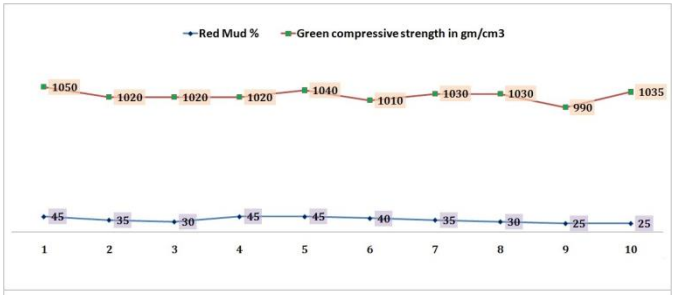

Figure 17. Effect of percentage of red mud on Green compressive strength of molding sand over Universal strength measuring machine during experimental trial 1-10

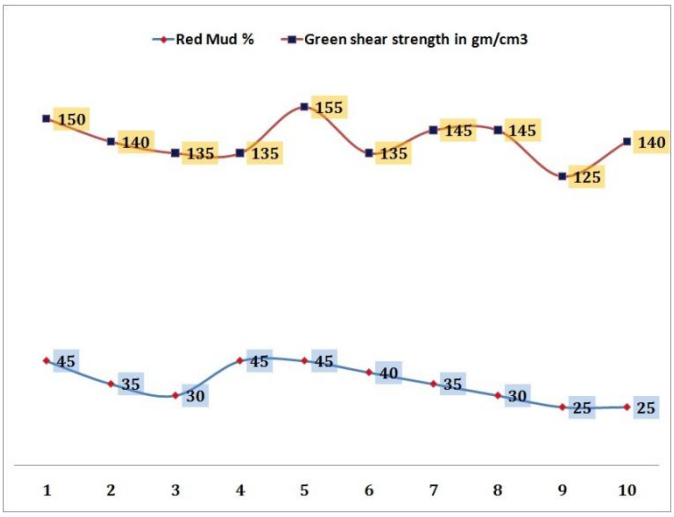

Figure 18. Effect of percentage of red mud on Green shear strength of molding sand tested over Universal strength measuring machine

IV. RESULTS AND DISCUSSIONS

Table II indicates experimental trial parameters and observed readings of mold permeability, green and shear strength of mold. The casting obtained with experimental trial 10 gives satisfactory and reliable results in quality of casting. Among experimental trial 1 to 9, most of castings are defective because of blow hole, shrinkage, gas holes, pinholes, rough surface finish. The possible causes for defects are too high Moisture content of sand, or water released too quickly, too low gas permeability of the sand or too high Bentonite percentage [7][8].With reduced red mud percentage and moisture content average green compressive strength of 1017 gm/cm^3, green shear strength of 138.33 gm/cm^3, permeability of 170 and 14 with large and small orifice respectively is obtained. The clay and moisture content had significant effect on green compressive strength while moisture content had a little effect on green compressive strength.

V. CONCLUSION

In this experimental work neutralized Red Mud is reused in molding sand of Aluminium foundry. This will help to solve the alarming disposal problem of the waste. To achieve the same, different mixtures of Red Mud and Silica Sand has been tested for defects in casting and mixture of 25% Red Mud, 70% Silica Sand, 3% Bentonite (binder) and 2% Coal Dust, is found best for producing aluminium castings. A comparison of reference casting (from molding sand without Red Mud) and the results obtained with casting obtained from molding sand with Red Mud confirmed the potential of neutralized Red Mud for using it as a constituent in molding sand.

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