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Feasibility Analysis of Utilization of Bauxite Residue in Brick Manufacturing

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ABSTRACT

Bauxite residue (red mud) is mineral slurry left behind after extracting alumina from bauxite ores using the Bayer process. It is estimated that over 248 million tons of this waste is impounded annually in the world. This paper describes the effective utilization of red mud in brick manufacturing. Red mud consists of high pH value in the range of 10.5 -13. Seawater neutralization is preferred to reduce the pH value to an optimum range of 8.5-8.9. After the neutralization process, red mud is used in brick manufacturing by replacing the clay and red soil in various percentages and it is tested. The compressive strength of all the samples were more than 3.5N/mm^2. The water absorption value for most of the samples was below 20%. The result of the tests showed that the red mud did not negatively affect the quality of the produced bricks. It is thus concluded that the red mud can be utilized as a raw material in brick manufacturing, thus maintaining sustainability in the construction sector.

Introduction

The construction industry grows rapidly and there is a great demand for raw materials. One of the basic raw materials used in brick manufacturing is clay and red soil. There is an acute shortage for clay and red soil. Hence we have made an attempt to utilize the discarded materials from the industries [3]. Thus we have effectively used red mud which is abundantly available as waste from MALCO industry, India. The long term storage of red mud possesses several problems such as vast area is required to dump, instability of storage and alkaline seepage into underground. Red mud can be used in the manufacture of building materials such as ceramics, glass products, fired & non fired bricks and concretes [6]. Hence we have used this red mud as an alternate material in brick manufacturing [1].

Red mud is available as a residue in the alumina production [4]. The high concentration of iron compounds in the bauxite gives the by-product its characteristic red colour, and hence it is commonly called “Red Mud”. The general process employed in alumina refining is the Bayer process which is adopted in MALCO. 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. It generally exits the process stream as highly alkaline slurry with pH in the range of 10–12.5 with 15–30% solids and it is pumped away for appropriate disposal.

It has been disposed of traditionally by dumping in natural depressions, and more recently by dry stacking on gentle slopes [1]. It is a complex material whose chemical and mineralogical composition varies widely, depending upon the source of bauxite and the technological process parameters. Chemical analysis shows that red mud contains aluminium, silicium, iron, calcium, titanium, sodium as well as an array of minor elements namely K, Cr, V, Ba, Cu, Mn, Pb, Zn, P, F, S, As etc.

Effects of Red Mud Dumping

For most alumina refineries, disposal of red mud is problematic. It is disposed in dry or semi dry form in holding pond. In some cases it is abandoned in bauxite mines as slurry having 30- 60% of solids concentration [5]. Red mud poses a problem as it takes up large land area and can neither be built on nor farmed, even when the mud is dry [4]. One challenge is that drying the mud requires much energy. Discharge of red mud is hazardous because of its alkalinity, airborne dust emissions shall exist. Hazardous chemical which includes caustic soda and traces of radio nuclides that are contained in red mud have been seeping into water aquifers and are possibly contaminating ground water [8]. Also plant growth is inhibited because of high pH value. Moreover making of conventional bricks spoils thousands of acres of fertile land and top soil [3].

Characteristics of red mud

Red mud is chemically stable and non-toxic. Its particle size is less than 44 microns, with a density of 2.7g/cm^3 [9]. Its brick red color is due to the iron oxides, which make upto 60% of the mass of the red mud. Other dominant particles include silica, unleached residual aluminium and Titanium oxide [8].

At all the world’s alumina plants, 1.0–1.6 tons of red mud is generated per ton of alumina and it is estimated that over 248 million tons of this waste is impounded annually in the world. The disposal of such a large quantity of this alkaline waste sludge is expensive (up to 1–2% of the alumina price), as it requires a lot of land (approximately 1 km^2 per 5 years for a 1 Mtpy alumina plant) and causes a number of environmental problems.

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Materials and Methodology

General

Uncausticised red mud and bauxite (in form of lumps) were procured from MALCO Industries Ltd., SALEM, and locally available clay and red soil were used in this project.

Chemical Constituents

Red mud collected from MALCO contains high pH of 12.5. The chemical constituents of clay and red mud are tabled as below [8].

Table 1. Chemical constituent

S.NO	CONSTITUENTS	RED MUD	CLAY
1	Fe_2O_3	40-45%	7.59%
2	Al_2O_3	20-22%	13.29%
3	SiO_2	12-15%	65.32%
4	TiO_2	1.8-2%	1.46%
5	Na_2O	4-5%	2.61%
6	CaO	1-2%	1.09%

The major chemical compositions of the red mud were silicon, aluminum and iron oxides, which are extremely similar to the major chemical compositions of the brick clay.

Sample Preparation

The materials were ground and / or sieved through 4.75mm size sieve. Due to high alkalinity of red mud, seawater neutralization is preferred to reduce alkalinity.

To prepare brick samples, raw materials are taken in volume basis and are mixed thoroughly to get homogeneous mixture. Then the mixture was made into a thick paste using an appropriate quantity of water and moulded into bricks on ground of standard size, dried for 24 hours and then fired in kiln at 1000ºC-1400ºC. Specific gravity tests were done and the results were found to be for clay, red soil and red mud are 1.7, 2.35 and 1.42 respectively.

Stages Involved In Brick Manufacturing

1. Neutralization of red mud
2. Batching
3. Preparation of good earth
4. Moulding
5. Drying
6. Burning

Neutralization of Red Mud

pH of our red mud sample which is collected from MALCO is 12.5. It is highly alkaline and their disposal and potential for reuse are complicated by high concentration of Na and high alkalinity [7]. Using seawater to neutralize red mud leads to many benefits. It reduces alkalinity and sodicity in red mud. Seawater neutralization of bauxite residue causes chemical changes and improves physical properties. Reaction of bauxite residue with sea water results in neutralization of alkalinity through precipitation of $Mg^{-}Ca^{-}$ and Al-hydroxide and carbonate minerals. Neutralization by seawater was rapid in the initial stage resulting in a residue of pH 8.6.

Figure 1. Neutralization of red mud.

Batching

In this study, the red mud brick is prepared by volume batching method. We have prepared 7 numbers of samples for various ratios of red mud in bricks. The ratio of replacement of clay and red soil by red mud are given as follows

Table 2. Ratio of replecement of clay.

S.No	Sample	Replacement of clay by red mud	Volume (*l*)			Water used (*l*)
			Red mud	Clay	Red soil	
1	Sample1	20%	2.4	9.6	8	4.3
2	Sample2	40%	4.8	7.2	8	4.41
3	Sample3	60%	7.2	4.8	8	4.5
4	Sample4	80%	9.6	2.4	8	4.73
5	Sample5	100%	12	-	8	4.95

Table 3. Ratio of replecement of red soil.

S.No	Sample	Replacement of clay by red mud	Volume (*l*)			Water used (*l*)
			Red mud	Clay	Red soil	
1	Sample6	50%	4	12	4	4.3
2	Sample7	100%	8	12	-	4.6

Figure 2. Volume batching.

Figure 3. Volume batching.

Preparation of Good Brick Earth

Gravel, coarse sand, lime, kankar particles and organic matters present in the soil are removed. In this process, the top layer of the earth is removed about 20cm depth. After removing, the soil free from impurities is taken out and spread over the ground surface puddle, watered and left over for weathering. In weathering process, the material is exposed to the atmosphere for softening. Then the brick earth is mixed thoroughly and adequate water is added to obtain required consistency for moulding.

Figure 4. Hand mixing.

Moulding

The moulding can be done either by hand or by machine moulding. We preferred ground mould method. In this method ground is first made level and fine sand is sprinkled over it. Lump in the prepared brick earth is removed and dashed in the mould. And it is pressed in the mould in such a way that it fills all the corners of mould. Now the mould is lifted up and the raw brick is left on the ground. When such bricks become sufficiently dry they are carried and placed in drying sheds

Figure 5. Ground moulding.

Drying

Drying is done on specially prepared drying yards. The brick is allowed to dry till they become hard with moisture content of about 2%. It is dried for the period of 7 days.

Figure 6. Drying

Burning

Burning is done in kilns. It imparts hardness and strength to bricks. It makes dense and durable. The bricks are burnt at 1000ºC

Figure 7. Rail kiln.

Testing of samples

Determination of compressive strength

The strength of the brick is assessed by conducting compressive strength test as per IS 3495 (part1)-1992. The results are listed below

S.No	Samples	Compressive Strength (N/mm^2)
1.	Conventional Brick	5.25
2.	Sample 1	4.85
3.	Sample 2	5.379
4.	Sample 3	6.18
5.	Sample 4	5.159
6.	Sample 5	4.762
7.	Sample 6	6.12
8.	Sample 7	5.29

Determination of Water Absorption

The water absorption test on bricks is carried as per IS 3495 (part 2)-1992.

S.No	Samples	Water Absorption (%)
1.	Conventional Brick	11.3
2.	Sample 1	14.48
3.	Sample 2	17.3
4.	Sample 3	19.643
5.	Sample 4	19.72
6.	Sample 5	22.1
7.	Sample 6	18.675
8.	Sample 7	22.22

Determination of Efflorescence

Efflorescence test on bricks is carried out as per IS 3495 (part 2)-1992.

S.No	Samples	Efflorescence
1.	Conventional Brick	Slight
2.	Sample 1	Slight
3.	Sample 2	Slight
4.	Sample 3	Slight
5.	Sample 4	Moderate
6.	Sample 5	Moderate
7.	Sample 6	Slight
8.	Sample 7	Moderate

Cost analysis

1. **Cost of conventional brick**

Cost of one brick = Rs 3.6

2. **Cost of Red Mud Brick**

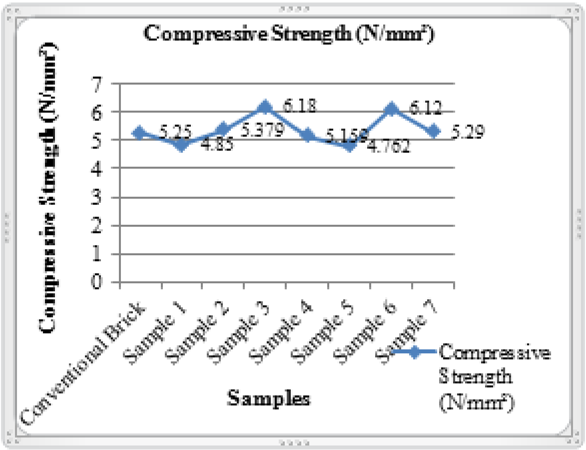
Cost of red soil for 0.5 m^3 = Rs 238.5

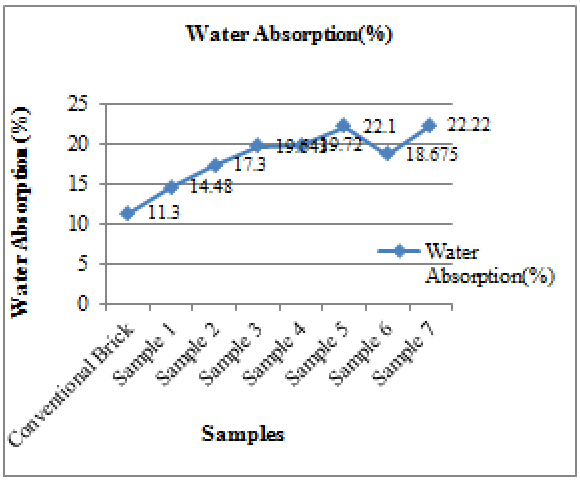
Cost of red mud for 0.5 m^3	=	Rs 170
Total cost for transportation	=	Rs 48.875
Labour cost for 1m^3	=	Rs 262.35
Water cost for 1m^3 brick	=	Rs 85.86
Total cost	=	Rs 1691.88
(including wastage and cost of wood)		
Cost for one brick	=	Rs 3.54

Result and Discussion

To check the feasibility of the utilization of red mud in the bricks, the tests viz, Compressive strength, water absorption and efflorescence were conducted. The results of the tests were listed below

S.No	Samples	Compressive Strength (N/mm^2)	Water Absorption (%)	Efflorescence
1.	Conventional Brick	5.25	11.3	Slight
2.	Sample 1	4.85	14.48	Slight
3.	Sample 2	5.379	17.3	Slight
4.	Sample 3	6.18	19.643	Slight
5.	Sample 4	5.159	19.72	Moderate
6.	Sample 5	4.762	22.1	Moderate
7.	Sample 6	6.12	18.675	Slight
8.	Sample 7	5.29	22.22	Moderate





The compressive strength of various brick samples were investigated by performing tests. When comparing these samples the compressive strength of samples 3&6 were higher about 6.18N/mm^2& 6.12N/mm^2respectively.

The compressive strength of sample 5 is 4.762 N/mm^2 which is lower than other samples. The compressive strength of all the samples are more than 3.5N/mm^2. So, It can be used for construction purpose like conventional bricks.

All the samples have minimum water absorption values, which lies below 20% except samples 5& 7.

Cost analysis was also done including material procurement, manufacturing, transportation and wastage charges for these samples. And it works out to be INR 3.54 for a single sample where the conventional brick is available for INR 3.60.

Conclusion

The compressive strength of our samples is more or less same when compared to conventional bricks. This can be suggested for the present brick manufacturing. In addition to that, the production cost of red mud brick, which is Rs3.54 also favors this aspect. Thus we can suggest red mud as an alternative material for brick manufacturing. This reduces the environmental pollution and also leads to sustainability in the construction sector.

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