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# EXPERIMENTAL STUDY ON RED MUD BASED GEOPOLYMER BRICKS

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***ABSTRACT***

*The metallurgical processing of Bauxite results in production of very large quantity of red mud. Studies were carried out on 230*100*70 mm size geopolymer bricks .Red mud, fly ash and micro silica are used as binder material .Alkaline solution of sodium hydroxide and sodium silicate were used in the geopolymerization process. Red Mud was used upto 50 % as replacement for clay. Micro Silica was used for strength enhancement .The bricks had a compressive strength of 9.456 MPa for 50% use of red mud. Water absorption was about 2.5% and showed very good resistance against sulphate environment. The advantages are: good compressive strength, elimination of curing, 100% replacement of clay by fly ash and red mud.*

***Keywords****: Geopolymerization, Compressive Strength, Red Mud, Precuring*

## I .INTRODUCTION

Due to over population there is a demand of basic needs which results in construction activity and production of industrial wastes. Construction activity includes the utilization of materials for housing facility. It leads to utilization of construction materials such as bricks, blocks which uses materials such as cement, clay, sand etc. These traditional materials are being utilized necessary measures should be considered to replace these traditional materials so that they are available in future. Industrial wastes such as fly ash, ggbs, gbs etc are used as alternative material for these traditional materials. For the present investigation fly ash, red mud and micro silica are being used as binder material in production of bricks.

The term Geopolymer was first termed and research related to Geopolymer was initially done by Joseph Davidoivits. It is a new innovative method. These are formed by alkaline activation of alumina silicate materials. They are formed when source material is activated with alkaline solution develops high mechanical strength initial stages only. . Liquids such as sodium or potassium hydroxide and sodium or potassium silicate solution (aqueous solution) are referred as alkaline liquids in which raw materials which contain alumina silicate undergo reaction. The wastes which possses alumina and silicate and which can readily react with alkaline solution lead us to the new green technological process named as geo polymerization. India is the second largest producer of bricks in the world .India is estimated to have more than 1,45,000 brick kilns producing more than 236 billion bricks. Hence, lot of fertile soil is used in production of bricks explicitly affecting the agricultural productivity of land. So replacing material for clay should be introduced.

## II. MATERIAL PROPERTIES

### Red mud

Red Mud is a solid waste residue which is obtained by extracting aluminium from bauxite ore. Bauxite Reserves present around the world is around 3 million tonnes out of 65 million tonnes globally [2]. Around 5.8 million tonnes of aluminium is generated annually all over the world [3]. For the present investigation red mud is procured from Hindalco, Belgaum. The chemical and geotechnical property of red mud is listed in below table

Fig 1: Red Mud at HINDALCO Ltd,Belgaum

Table no 1: Chemical properties of red mud.

| SI.No. | Chemical Properties | Values |
|---|---|---|
| 1. | Iron Oxide | 40-45% |
| 2. | Aluminate | 18-22% |
| 3. | Titanium Oxide | 12-20% |
| 4. | Silicates | 8-10% |
| 5. | Sodium Oxide | 3-5% |
| 6. | Calcium Oxide | 3% |

Table 2: Geotechnical properties of red mud

| SI.No. | Particulars of test | Values |
|---|---|---|
| | Geotechnical properties | |
| 1. | Specific Gravity | 2.85 |
| 2. | Liquid Limit | 35% |
| 3. | Plastic Limit | 25.5% |
| 4. | Shrinkage Limit | 25% |
| 5. | OMC | 19.5% |
| 6. | MDD | 14kN/cum |

**Fly ash**

Fly ash is an industrial waste which is generated during combustion of coal in power plants Around 131 million tonnes of fly ash is generated in US alone. Therefore disposal of this industrial waste is of greater importance. Fly ash used in the present study for obtaining brick was extracted from Raichur thermal power plant. Fly ash used belongs to class F. It contains less than 20% lime. The physical and chemical properties are mentioned in below table

Table 3: Physical properties of fly ash

| SI. No | Physical Properties | |
|---|---|---|
| 1. | Colour | Whitish Grey |
| 2. | Form | Powder |
| 3. | Bulk Density | 1047kg/Cum |
| 4. | Specific Gravity | 2.2 |
| 5. | Fineness | 0.4-0.04mm |
| 6. | Moisture | Less than 0.3% |

Table 4: Chemical properties of fly ash

| SI No | Constituents | Value (%) |
|---|---|---|
| 1. | Silicon dioxide | 61.54 |
| 2. | Iron oxide | 24.08 |
| 3. | Aluminium oxide | 6.73 |
| 4. | Calcium oxide | 3.12 |
| 5. | Magnesium Oxide | Less than 1(0.73) |
| 6. | Manganese | Less than 1 |
| 7. | Phosphorus | Less than 1 |
| 8. | Sulphates | 0.10 |
| 9. | Potassium | 0.09 |
| 10 | Un burnt carbon | 1.2 |
| 11. | Titanium | Traceable |

**Micro silica**

Micro silica also known as silica fume is a by product of ferrosilicon and silicon alloy production. It helps to enhance strength as well as durability properties. It also reduces thermal cracking. It is spherical in shape and its individual size is very small. It leads to improved engineering properties. Provides increased resistance to abrasion as well as corrosion.

**Alkaline solutions**

Geo polymer is a process in which it undergoes geo polymerization with the help of alkaline liquids. Sodium Hydroxide is available in the form of pellets and sodium silicate in the form of solution

which is denser when compared to water. These alkaline liquids play a very critical role in geo polymerization process. They react with silica and aluminium present in the source material. In the present study source material used is red mud and alkaline solution used is sodium hydroxide which is available in the form of pellets and sodium silicate in the form of solution.

**Sodium hydroxide**

Sodium hydroxide available is in the form of flakes with 97% purity. It was obtained from Amar chemicals, a local chemist shop, Bangalore. In the present study only one concentration is used in preparing solution that is 10M. For 10M concentration 10x40=400g of NaOH solids are present in one litre of solution where 40 g represents molecular weight of sodium hydroxide.

**Sodium silicate**

For the present study commercially available sodium silicate solution was used. It was obtained from Amar chemicals, local chemist. From the test results sodium silicate posses water content around 37.6% and specific gravity 1.64. The ratio of sodium silicate and sodium hydroxide used for calculating quantity is around 2.5.

**Sand**

It is a fine aggregate which is used in the manufacture of construction products. In the present study it is used as fine aggregate in production of red mud based geopolymer bricks. River sand is being used in the present study. The obtained specific gravity of sand is 2.62. From sieve analysis it was obtained in Zone III[3].

**III. Preparation of geopolymer bricks**

The following standard method of mixing was followed. The alkaline solution was prepared one day prior before it is added to the dry materials. The ratio of Sodium Silicate to Sodium Hydroxide solution (by mass) was 2.5 based on the literature survey [10, 11, 12, 13].

Red mud, Fly ash, Micro silica and sand were dry mixed for 3 minutes prior to addition of alkaline solution. The bricks were casted into 230 *110*75 mm brick moulds. After casting, the specimens were covered and were placed in HACC (Hot Air Curing Chamber) for pre-curing at 40 ˚C for 3 hours [13]. The moulds were kept in ambient temperature for 18 hours. The moulds were demoulded and were kept for curing at 60˚C in HACC for a period of 24 hours.

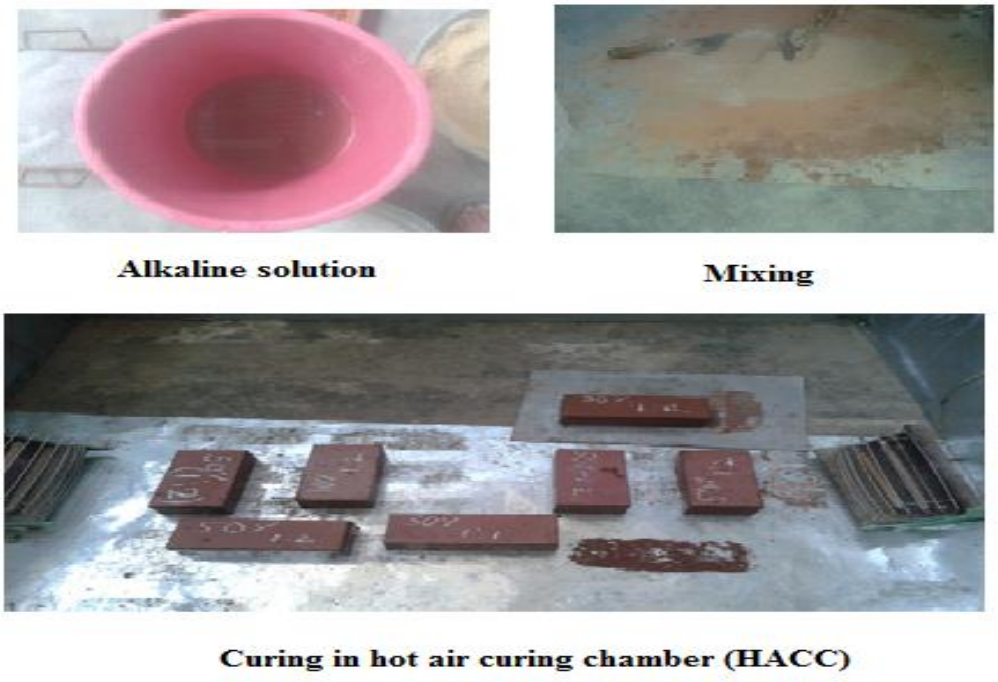


Fig 2: Preparation of Red mud geopolymer bricks.

**IV. Tests on Brick unit**

**A. Compression strength**

Bricks were casted by varying red mud content up to 50%. Totally 18 bricks was casted for determining compression strength on bricks. Tests was carried out as mentioned in the code[5]. The following results were obtained.

Table 5: Compression strength results for different variations of red mud

| SI No | Specimen Designation | Avg compression strength(Mpa) | |
|---|---|---|---|
| | | 1:1 | 1:2 |
| 1. | RM Brick 1 (10%) | 6.703 | 5.688 |
| 2. | RM Brick 2 (30%) | 7.825 | 6.340 |
| 3. | RM Brick 3 (50%) | 9.456 | 6.484 |

Fig 3: Testing of Geopolymer Brick

Fig 4: Failure of brick after testing

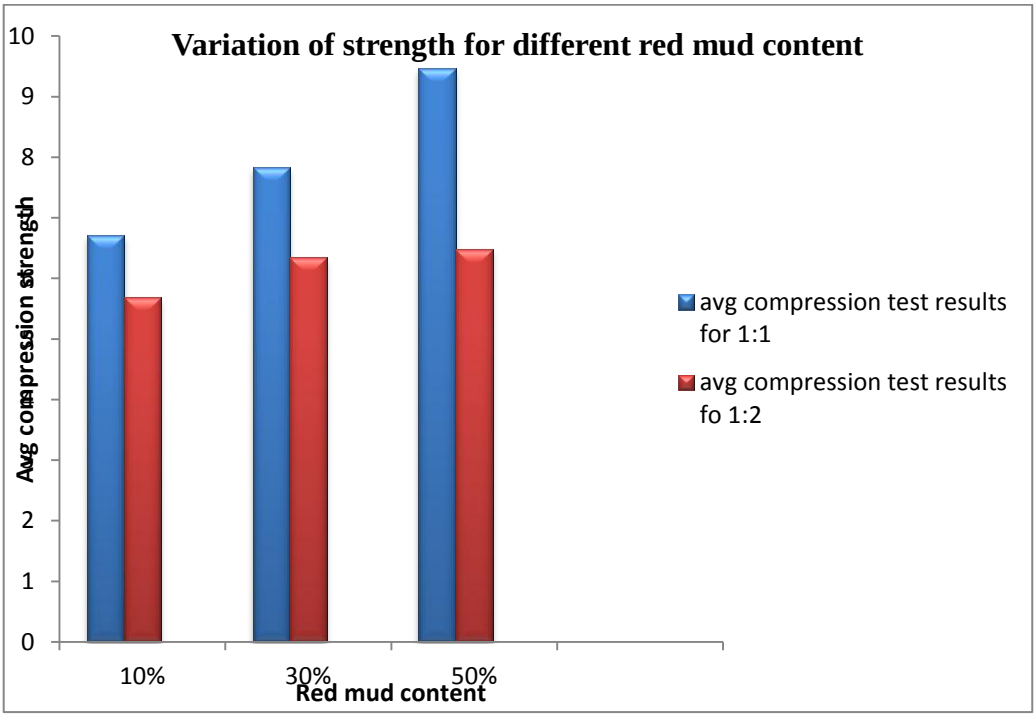


Fig 5: Graph representing variation in compression strength with respect to red mud content

The red mud geopolymer bricks hasdensity 2000 Kg/m$^3$. It was observed that Geopolymer bricks of 50 % red mud variation exhibited a higher compressive strength compared to 10 % Red Mud variation. Hence, it was adopted for further experiments. However , all the variations exhibited compressive strength more than minimum compressive strength of 3.5 MPa as specified by Indian Standard IS:1905:2002[9].

**B. Water absorption**

Water absorption for red mud GP bricks are determined by immersing in water for 24 hrs according to code [6]. The test was conducted for both 10% as well as 50% replacement of Red mud content. Totally 12 bricks was casted for the present test. Geo polymer bricks come under higher classes of about 12.5Mpa as per code its water absorption should be less than 20%. The values so obtained satisfies the IS code 3495:1992(Part 2). The following results were obtained

Table 6: Water absorption results

| SI No | Brick designation | Avg water absorption (%) | |
|---|---|---|---|
| | | 1:1 | 1:2 |
| 1. | RM Brick 1 (10%) | 1.4473 | 1.9467 |
| 2. | RM Brick 3 (50%) | 2.102 | 2.491 |

Results so obtained were less than 20% which satisfied codal provisions.

**C. Flexural strength**

This test is conducted to determine the tension failure in bricks which is basically caused at the bottom when loading is applied on the bricks which is as shown in the below figure. It was carried according to code [7]. Totally 18 bricks was casted by using 10%, 30% and 50% replacement of red mud content.

Fig 6: Testing of bricks for flexural strength

| SI No | Brick Designation | Avg Flexural strength | |
|---|---|---|---|
| | | 1:1 | 1:2 |
| 1. | RM Brick 1 | 3.267 | 2.960 |
| 2. | RM Brick 2 | 4.083 | 3.573 |
| 3. | RM Brick 3 | 4.721` | 3.981 |

Table 7: Flexural strength results

Flexural strength value for 10% replacement is very good when compared to fired clay bricks. The strength goes on increasing for 30% as well as 50% replacement of red mud content. As the quantity of sand decreases strength decreases. For 1:2 strength was lesser when compared to 1:1.

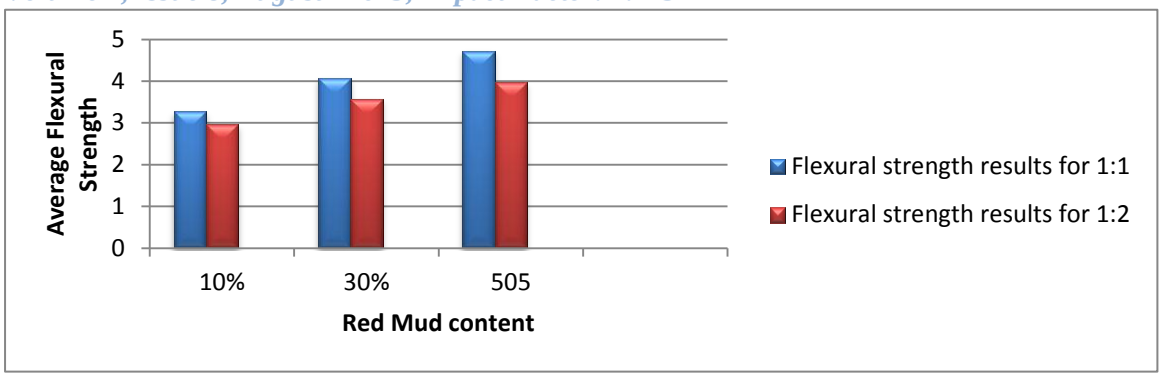


Fig 7: Variation of flexural strength with respect to red mud content

**D. Durability test- Sulphate resistance**

The test was carried out according to code [8].For the above tests 18 brick were casted using 50% red mud content as it possessed highest compression strength. The prepared specimens were dipped in sulphate solution its weight loss and compressive strength are noted.

Fig 8: Testing of bricks after immersion in sulphate solution.

Table 8: Test results for 14 days

| SI No | Brick designation | Weight (gms) | | Compression strength(Mpa) | |
|---|---|---|---|---|---|
| | | Initial | Final | Initial | Final |
| 1. | RM Brick 3 | 3.310 | 3.265 | 9.456 | 10.86 |
| 2. | RM Brick 3 | 3.300 | 3.241 | | 12.065 |
| 3 | RM Brick 3 | 3.221 | 3.120 | | 11.52 |

Table 9: Test results for 28 days

| SI No | Brick designation | Weight(gms) | | Compression strength(Mpa) | |
|---|---|---|---|---|---|
| | | Initial | Final | Initial | Final |
| 1. | RM Brick 3 | 3.354 | 3.285 | 9.456 | 12.608 |
| 2. | RM Brick 3 | 3.372 | 3.185 | | 12.956 |
| 3. | RM Brick 3 | 3.390 | 3.197 | | 13.369 |

Increase in compression strength was found for bricks with 50% replacement when immersed in sulphate solution for both 14 and 28 days.

## V. CONCLUSION

The present industrial challenge is disposal of waste materials. The construction industry , on the other hand aims at using this solid waste as an alternative material. The following conclusions were made when red mud was used and varied upto 50% .Red Mud can play a major role in replacing huge amount of fertile clay that is being used in Brick industry

1. The increase in compressive strength with the increased Red Mud content showed the participation of Red Mud in Geopolymerization.
2. Water absorption of geo polymer bricks was around 2.5% for 50% replacement which satisfies IS code 3495:1992. As quantity of red mud increases water absorption also increases.
3. Flexural values so obtained are higher when compared to convectional bricks. As quantity of red mud increases flexural strength also increases.
4. The bricks with maximum strength i.e. 50% replacement of red mud showed good resistance against sulphate. Deterioration of materials was very less. These bricks showed increased strength. It can be concluded that these bricks showed good resistance against sulphate environment in fact its strength got increased.

As a result it can be concluded that use of red mud in production of geo polymer bricks provided superior mechanical properties and can be used in construction industry for masonry construction Red Mud can play a major role in replacing huge amount of fertile clay that is being used in Brick industry

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