INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 2)
Available online at: www.ijariit.com

Experimental investigation on geopolymer brick by using fly ash and quarry dust

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ABSTRACT

Bricks are widely used in the construction of buildings around the world. Conventional bricks are produced from clay with high-temperature kiln firing or from ordinary Portland cement (OPC) concrete, and thus contain high embodied energy and large carbon foot prints. In many areas of the world, there is already a shortage of natural resources material for the production of the conventional brick for environmental production research has been conducted. A wide variety of waste materials have been studied to produce bricks in different methods. The research can be divided into three categories based on the method for the producing bricks from the waste material: firing, cementing & geo polymerization. A mixture of sodium silicate and sodium hydroxide were cured at ambient temperature. The study of geopolymer bricks fly ash, quarry dust, and alkaline solution. For eco-friendly reaction its vital that the material used for such construction should be environment-friendly. In geopolymer bricks, main ingredients of clay burnt or cement based brick is totally replaced by the waste of burnt coal known as fly ash or pulverized fuel ash. Materials rich in silica and alumina is the necessity for the geopolymer synthesis .the activated solutions for polymerization is sodium hydroxide (NaOH) mix with sodium silicate (Na2SiO3) solution in appropriate proportion Percentage of binder and ratio of alkaline liquid to alumina silicates solids ratio had a significant impact on strength of bricks. Bricks were cast in the industrial site from the best mix compressive strength and water absorption was noted. Geo polymer Eco brick and its durability the size of the were adopted was 100mm*100mm*10m m the brick were cast with flay ash to river sand and eco sand (silica sand) with the different ratios of 1:2 1.5, by weight. The optimum water/binder ratio of 0.416 was selected as per available literature. The binder/water ratio solution (NaOH and water) to fly ash. The exposed surface turned slightly softer through an optical microscope, the corroded surface could be seen which increased with time of exposure. After the exposure to the acid solution for 18weeks. The geopolymer samples almost lost it's alkalinity and showed very low weight less in the range from 0.54%to 0.28%of initial weight. Loss of weight was found higher for a specimen with a higher percent of Na2 SiO3.

Keywords: *Compressive strength, water absorption, density, porosity.*

1. INTRODUCTION

An increasing awareness towards ecological issues has focused industries to develop materials & products that will be additional environment responsive and results in structure development. The products from a country's natural and waste by-products are important as so much because the industrialization of a nation is bothered. Brick has space with wide family of construction materials since it's primarily utilized for the advancement of external and inward dividers in structures. For creating eco-friendly building it's vital, the structure exploitation in such construction method should be environment friendly. For sample manufacturing and use of bricks from waste materials, additional analysis and development is required, not only on the technical, economic and environmental aspects however conjointly on standardization, government policy and public education associated with waste use and property development. In India, mud bricks have been broadly utilized from long time and are the overwhelming development material even today. Current interest is more than 1000 billion bricks a year. The ordinary routine of terminating dirt bricks in conventional ovens (kilns) consumes extensive amounts of coal, kindling, and different Biomass fuels. The Indian brick industry, which is the second biggest maker on the planet, beside China, devours more than 150 million tons of coal yearly without including the power utilized in brick generation, the diesel for transporting the bricks alone create exactly 180 million tons of CO_2, approximately 33% of the aggregate CO_2 emission of the worldwide industry (550 million tons of CO_2).

1.1 GEOPOLYMER

Geopolymers are inorganic, typical ceramic materials form long chain covalent bond amorphous network. The composition of the geo-polymer material is comparable to zeolitic materials however microstructure is of amorphous state rather than crystalline. In polymerization practice, quick reaction of the alkaline activated solution with Silica-Alumina minerals takes place and formation of a three-dimensional polymeric chain and ring structure made of -Si-O-Al-O bonds takes place.

Geo polymers are new materials for fire- and heat-resistant coatings and adhesives, medicinal applications, high-temperature ceramics, new binders for fire-resistant fiber composites, toxic and radioactive waste encapsulation and new cements for brick. The properties and uses of geopolymers are being explored in many scientific and industrial disciplines: modern inorganic chemistry, physical chemistry, colloid chemistry, mineralogy, geology, and in other types of engineering process technologies. Geopolymers are part of polymer science, chemistry, and technology that forms one of the major areas of materials science. Polymers are either organic material, i.e. carbon-based, or inorganic polymer, for example silicon-based. The organic polymers comprise the classes of natural polymers (rubber, cellulose), synthetic organic polymers (textile fibers, plastics, films, elastomers, etc.) and natural biopolymers (biology, medicine, pharmacy). Raw materials used in the synthesis of silicon-based polymers are mainly rock-forming minerals of geological origin, hence the name: geopolymer.

Fig no: 1 Geopolymer of brick sample

1.1.1 Advantages

- **High Strength** – it has a high compressive strength that showed higher compressive strength than that of ordinary brick. It also has rapid strength gain and cures very quickly, making it an excellent option for quick builds. Geopolymer concrete has high tensile strength. It is not completely earthquake proof but does withstand the earth moving better than traditional concrete.
- **Resistant to Heat and Cold** – It has the ability to stay stable even at temperatures of more than 2200 degrees Fahrenheit. Excessive heat can reduce the stability of concrete causing it to spall or have layers break off. Geopolymer brick does not experience spalling unless it reaches over 2200 degrees Fahrenheit. for cold temperatures, it is resistant to freezing. The pores are very small but water can still enter cured brick. When temperatures dip to below freezing that water freezes and then expands this will cause cracks to form. Geopolymer brick will not freeze.
- **Chemical Resistance** – it has a very strong chemical resistance. Acids, toxic waste, and salt water will not have an effect on geopolymer brick. Corrosion is not likely to occur with this brick as it is with traditional Portland cement.

1.1.2 Disadvantages

- **Pre-Mix Only** – Geopolymer concrete is sold only as a pre-cast or pre-mix material due to the dangers associated with creating it.
- **Geo polymerization Process is Difficult to Create** – Geopolymer concrete requires special handling needs and is extremely difficult to create. It requires the use of chemicals, such as sodium hydroxide, that can be harmful to humans.
- **Sensitive** – This field of study has been proven inconclusive and extremely volatile. Uniformity is lacking.

1.2 GEOPOLYMER BRICK DEVELOPMENTS

In Geopolymer brick the (class F) fly ash having rich silica and alumina content reacts with alkali activated solution pre-mix of sodium silicate and sodium hydroxide results in the formation of gel known as a binder in geopolymer products. There is no use of cement in this brick production. Instead, the binder is formed by the reaction of an activated solution with a source material. Fly ash above 50%, foundry sand above 40% and (2 to 4) % of mineral.

1.3 The inference from literature study:

The inference from Literature Study Review of literature indicates a big importance for geopolymer in the near future, in the construction sector. The use of fly ash in geo-polymer concrete is particularly important, as the disposal of this waste is a worldwide problem and based on the literature the following ranges were selected for the constituents of the mixture used in further studies described in chapter 4. Low calcium (ASTM Class F) fly ash was used with a ratio of sodium silicate solution-to-sodium hydroxide solution by mass of 2.5. Molarity of sodium hydroxide (NaOH) solution was chosen in the range of 8M to14M. The ratio of activator solution-to-fly ash by mass was fixed to be 0.40. Curing at elevated temperatures was done in two different ways, i.e. curing at room temperature and in the laboratory oven at 60ºC

1.4 The scope of the Research

Accumulation of unmanaged waste especially in the developing countries has resulted in increased environmental concern. Recycling of such wastes as building material appears to be a viable solution not only for problems like pollution but also to the problem of economical design of buildings. This research has utilized low-calcium (ASTM Class F) fly ash as the base material for making geopolymer concrete which was obtained from Ennore thermal power plant, Tamil Nadu, India. The property studied includes 28 days physical, and mechanical performance of geopolymer blocks. Consequently, the scope of this research is to conduct a study on the properties of geopolymer hollow block. A parallel study was also conducted to study the behavior of geopolymer brick prism of varying height. The potential for improving the performance of new concrete mixture has to be ascertained through experimental investigation. Hence a total investigation was comprehensively planned and conducted in a systematic procedure.

2. MATERIAL USED

2.1 Fly ash: Fly ash is a fine particulate material separated from the flue gas of coal-fired power stations that are rich in alumina and silica. As the production of fly ash rises continuously and creates serious environmental pollution problems, fly ash should be treated as a valuable resource or reused as a raw material in new technology with good properties. Class F fly ash has been considered as pozzolanic materials or porcelain and can be activated by high alkaline solutions to act as a binder through chemical polymerization reactions. The low-calcium (ASTM Class F) fly ash as the base material for making geopolymer concrete which was obtained from Ennore thermal power plant, Tamil Nadu, India. Fly ash was characterized using X-ray fluorescence (XRF) for determination of chemical composition in the raw material used and the results showed that SiO2 and Al2O3 account for over 60 %. Fly ash particles are mostly minute solid sphere and hallows ecosphere with some particles even being planispheres which are spheres containing smaller spheres. Some of the minerals impurities of the clay, shale, Feldspar etc… are fused in suspension and carried out of the combustion chamber in exhaust gases. The exhaust gases cool. The fused materials solidify into spherical glassy particles called fly ash.

Fig: 2 Fly ash powder collecting

2.2 Quarry dust: Quarry dust is a byproduct of the crushing process which is a concentrated material to use as aggregates for concreting purpose, especially as fine aggregates. In quarrying activities, the rock has been crushed into various sizes; during the process, the dust generated is called quarry dust and it is formed as waste. So it becomes a useless material and also results in air pollution. Therefore, quarry dust should be used in construction works, which will reduce the cost of construction and the construction material would be saved and the natural resources can be used properly. Most of the developing countries are under pressure to replace fine aggregate in concrete by an alternate material also to some extent or totally without compromising the quality of concrete. Quarry dust has been used for different activities in the construction industry, such as building materials, road development materials, aggregates, bricks, and tiles.

Fig no: 3 Quarry dust

2.3 Sodium Hydroxide:

Sodium hydroxide is also known as lye and caustic soda is an inorganic compound with the formula NaOH. It is a white solid ionic compound consisting of sodium cat ions and Na+ and hydroxide anions OH-. Sodium hydroxide is a highly caustic base and alkali that decomposes proteins at ordinary ambient temperatures and may cause serve chemical burns. it is highly soluble in water and readily absorbs moisture and carbon dioxide from the air. it forms a series of hydrates $NaOH.nH_2O$.

Fig no: 4 Sodium hydroxide (NaOH)

2.4 Sodium silicate:

Sodium silicate is the common name for compounds with the formula (Na2SiO2) no A well-known member of this series is a sodium metasilicate, Na2SiO3. Also known as water glass or liquid glass, these materials are available in aqueous solution and in solid form. The pure compositions are colorless or white, but commercial samples are often greenish or blue owing to the presence of iron-containing impurities. They are used in cement, passive fire protection, textile and lumber processing, refractories, and automobiles. Sodium carbonate and silicon dioxide react when molten to form sodium silicate and carbon dioxide. Anhydrous sodium silicate contains a chain polymeric anion composed of corner-shared {SiO4} tetrahedral and not a discrete SiO32−ion. In addition to the anhydrous form, there are hydrates with the formula Na2SiO3·nH2O (where n = 5, 6, 8, 9), which contain the discrete, approximately tetrahedral anion SiO2(OH)22− with water of hydration. For example, the commercially available sodium silicate pentahydrate Na2SiO3·5H2O is formulated as Na2SiO2(OH)2·4H2O, and the monohydrate Na2SiO3·9H2O is formulated as Na2SiO2(OH)2·8H2O. The pent hydrate and monohydrate forms have their own CAS Numbers and 13517-respectively.

Fig no: 5 Sodium silicate used for experimentation

3. MIX DESIGN PARAMETER

The ratio fly ash to quarry dust by mass is varied from 1:2 to 1:5 ratio. The compressive strength of fly ash-based geopolymeric masonry bricks was decreased as the ratio of fly ash to sand, by mass, increased. The fly ash-based geopolymeric masonry bricks were cured in the oven at 60 _C for 24 h. The compressive strengths and water absorption for the test masonry bricks were measured after aging for 7 days. The measured seventh-day compressive strengths of test bricks, while the results for water absorbed by the bricks

Table No: 1 for mix design parameters for geopolymer brick

S/no	Fly ash	Quarry dust	Sodium hydroxide	Sodium silicate
M1	3	0	420	1080
M2	1.2	0.3	0.210	0.540
M3	0.9	0.6	0.210	0.540
M4	0.6	0.9	0.210	0.540

3.1 Sample preparation:

The samples of geopolymer brick were prepared in the ratio of 1:2 ratio form for solids and we have to take the chemicals ratio of 2.5:1 for liquid. First, we have taken sodium hydroxide and weighted it and mixed the sodium hydroxide with water. We have taken the sodium silicate in other beaker and weighted it and both we have mixed in one beaker and stirred it, kept aside for 24 hours of time. And we have taken fly ash taken the lumps by using the sieve of 1.18 micron and sieved and the quarry dust we have sieved by using 1.18 microns .mix it well then after taking the chemicals of sodium hydroxide and sodium silicate. Pour the chemicals into the fly ash and quarry dust mix it by using the trowel until it becomes a paste. Take the mould and place the paste into the mold arrange in 3 layers by 25 of dumping strokes with the help dumping rod. and keep it under sunlight.

Fig no:5 Mixing process of geopolymer brick

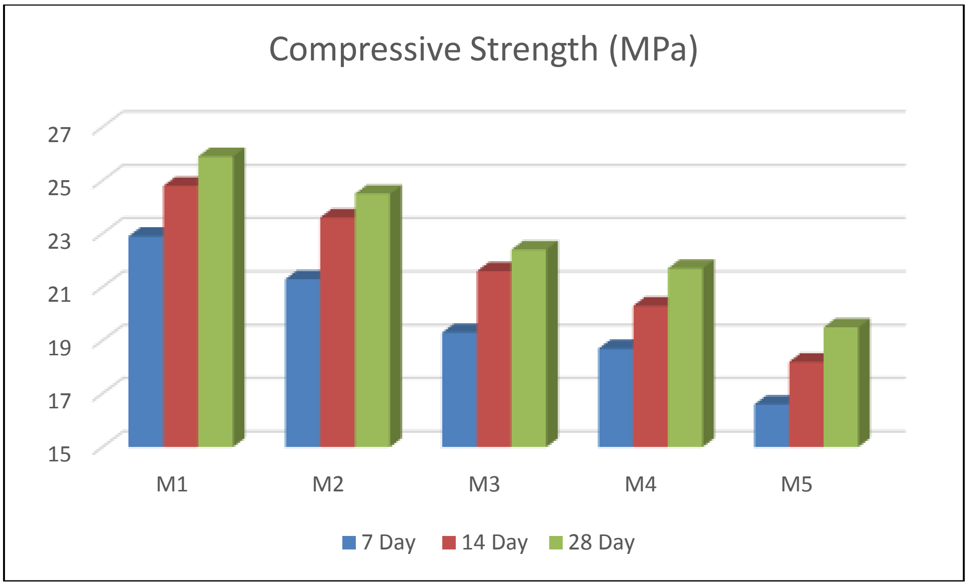
4. RESULT AND DISCUSSION

4.1 Compressive strength:

The compressive strength of geopolymer bricks was decreased as the ratio of fly ash to quarry dust, by mass increased. When the ratio of fly ash to sand increased, the mass of sand used also increased. Therefore, the geopolymeric bricks became crumbly and caused the decrease in strength of geopolymeric bricks. As seen from graph no 1, the ratio 1:2 of fly ash to sand, by mass, produced the highest compressive strength, compared to others, which is 17 MPa. However, the 1:2 ratio does not have good structure and shape when removed from the mold due to the flaccid samples and poor workability. For this reason, a 1:3 ratio of fly ash to quarry dust, by mass, was selected as the most suitable and basic mixture for further study of other parameters. This is because the 1:2 ratios of mass has obtained

Table no.2 Compressive Strength for developed geopolymer bricks

Mix Design	Compressive Strength (MPa)		
	7 Day	14 Day	28 Day
M1	22.9	24.8	25.9
M2	21.3	23.6	24.5
M3	19.3	21.6	22.4
M4	18.7	20.3	21.7
M5	16.6	18.2	19.5



Graph no:1 Compressive strength at different days of curing

4.2. Water absorption:

The geo polymer was immersed in water for 24 hrs. Of time then we take out with dry cloth and weight the brick by using weighing balance and note down the value the percentage of the water absorption were as found in table 3

Table: 3 Water absorption test

s/n0	Mix design	Water absorption
1	M1	13
2	M2	14.9
3	M3	15.9
4	M4	16

The percentage of water absorption of increased with mix design. The bond strength mainly depends up on the reaction between fly ash and alkaline solution .as the percentage of the mix design increased the fly ash decreased hence the bonding strength also decreased if the bonding strength there was possibility of more voids and hence the water absorption increased . The water absorption of the mix design (M 1) is 13% has obtained as minimum water absorption as 14.9% for the geo polymer brick and quarry dust.

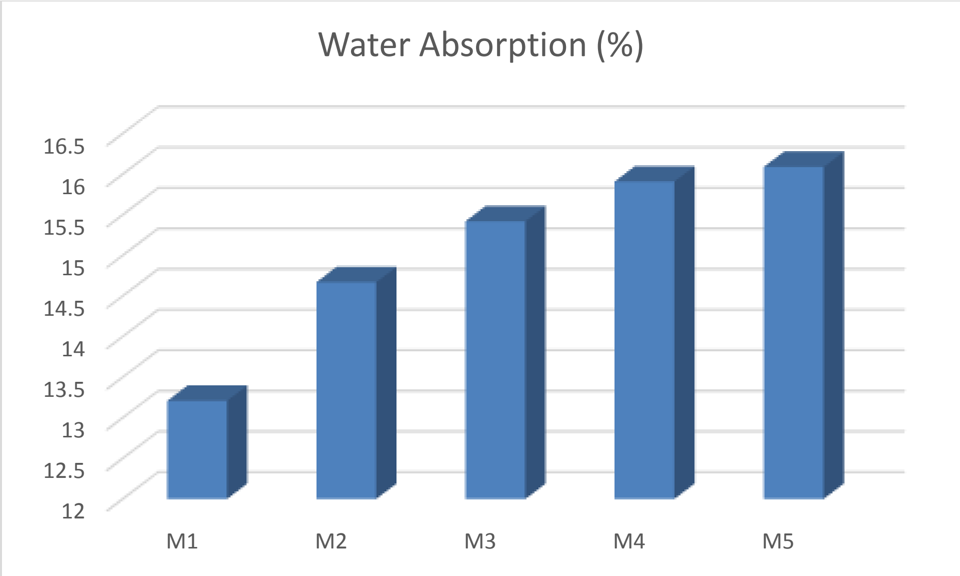


Fig no: 6 Water absorption for different curing temperature

Density analysis: The density of the samples was measured by dividing the dry mass by the volume. All reported results are an average of three different measurements. As shown in Figure 3, the density of the manufactured bricks decreased from 1860 kg/m3 to 1610 kg/m3 for the control samples when the curing temperature increased. The density of foamed geo polymer bricks decreased by 3.9% and 3.5% when 1:2 and 1:2.5 ratio of foaming agent to water was used. Low density or lightweight bricks have great advantages especially in construction field including lower structural dead load, easier handling, lower transport costs, and lower thermal conductivity.

Table no: 4 density of the geopolymer brick

S/ no	**Mix design**	**Density (kg/m^3)**
1	M1	1860
2	M2	1740
3	M3	1635
4	M4	1630
5	M5	1610

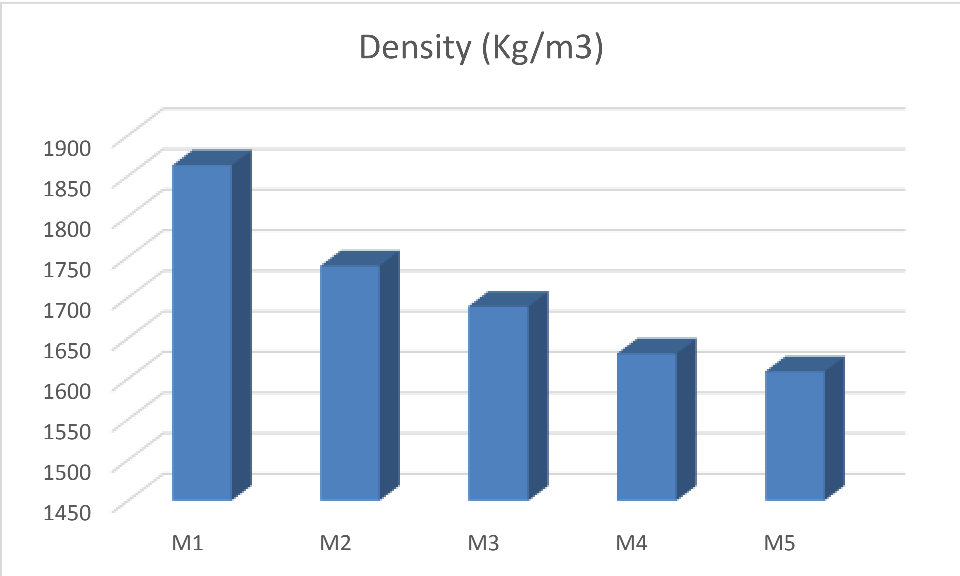


Fig no: 7 Density for different mix designs

Porosity: The porosity is defined as the ratio of total pore volume to total volume .the porosity of brick depend up on the water absorption due to the poses of voids of various sizes .According the graph no:8 say that the increased in porosity the lesser bond between a sodium silicate matry also the addition quarry dust which is having less specific surface area and the partial size because it causes the creation of voids due to the porosity increase the lesser the particle of the raw material there will be decrease in the porosity as in the case of mix design of M1&M2 as shown in graph no:8.

Table no: 5 Porosity of the samples

S /no	Mix design	Porosity of the samples
1	M1	21.7
2	M2	22.5
3	M3	22.85
4	M4	23.75
5	M5	23.85

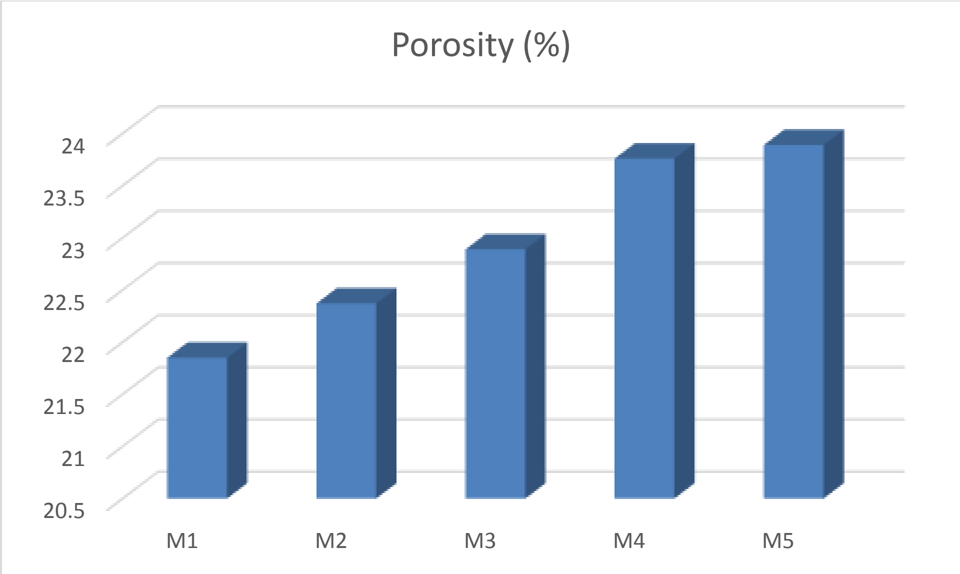


Fig no: 8 Apparent Porosity for different mix designs

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