EXPERIMENTAL INVESTIGATION ON MARBLE DUST, RICE HUSK ASH, AND FLY ASH BASED GEOPOLYMER BRICK

Sumit Kumar[1*], Avani Chopra[2], Md. Zia Ui Haq[3]

Abstract
The goal of this research is to determine whether geopolymer bricks can be made using Fly ash (FA), Rice husk ash (RHA), and Marble dust powder (MDP). It has been researched that the process of Geo-polymerization, which uses materials that have been alkali-activated to build solid structures, offers potential as a sustainable substitute for conventional brick-making techniques. In this work, to investigate the qualities of geopolymer bricks manufactured with Fine aggregate, geopolymer brick samples were made using various combinations of fly ash, RHA, and marble dust. The researchers next tested the bricks for compressive strength, water absorption, and efflorescence to establish their quality and durability. When making geopolymer bricks with fly ash, Rice husk, marble dust, and alkaline soda-based chemical activator solution are used, along with sodium silicate, water, and a variety of Na2O/ (Al2O3 + SiO2) ratios. For this investigation, a typical brick size of 230mm x 110mm x 75mm was employed. Fly ash (50%-70%), fine aggregate (15%), Rice husk ash (15% - 30%), and Marble dust powder (5%- 30%) were used in different amounts to make the bricks. The goal of this study was to look at the impact of these various proportions on the characteristics of bricks. For all the mixture, a sodium hydroxide molarity of 12M was maintained, and the sodium silicate ratio was held fixed at 1:2.5. Fly ash building bricks of the dimensions 230 mm x110 mm x75 mm are produced during this procedure under atmospheric curing. Additionally, the compressive strength of the geopolymer bricks was compared to that of conventional bricks commonly found in the area. Different combinations of materials were used to cast and cure the geopolymer bricks under atmospheric conditions. The results showed that the geopolymer bricks made with M-sand had better compressive strength compared to those made with natural sand. The findings suggest that M-sand can be a practical alternative to natural sand for geopolymer brick production. The use of recycled material as a substitute for fired bricks in construction can supply both construction brick and economic benefits. The outcomes suggest examining the environmental and economic impact, as well as the geopolymer brick's durability properties, which would be compelling research. To measure the strength of the geopolymer bricks, compressive strength tests were done after 7, 14, and 28 days. The brick will then be examined for soundness, Efflorescence, compressive strength, and water absorption.

Keyword: - Geopolymer bricks, Fly ash (FA), Marble dust powder (MDP), Rice husk ash (RHA), and sodium silicate, sodium hydroxide activator solution, compressive strength

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[1*,] ME Student Department of Civil Engineering, Chandigarh University, Mohali, Punjab, India.
[2,3] Assistant professor Department of Civil Engineering, Chandigarh University, Mohali, India.

***Corresponding author: -** Sumit Kumar
*ME Student Department of Civil Engineering, Chandigarh University, Mohali, Punjab, India.

DOI: 10.48047/ecb/2023.12.si5a.0324

INTRODUCTION

The world's population is expanding quickly, which has raised housing demand and, in turn, increased the need for ecofriendly building materials. Bricks are a commonly used building material in many parts of the world, but their manufacturing can have an adverse effect on the environment, because so many non-renewable resources are used in them, and a lot of greenhouse gas emissions are produced. Researchers have been looking for ways to transform waste items into bricks to increase their sustainability to solve these challenges. As prospective building materials, fly ash, limestone dust, Rice husk ash, welding flux slag, marble dust powder and other industrial by-products have all been researched [1]**.** Due to its potential to produce sustainable and ecologically friendly binders using industrial waste products, geopolymer binder research has drawn a lot of attention from academics. In addition to helping in the reduction of waste produced by various industries, The industrial waste materials are used in the manufacturing of geopolymer binder help in the creation of durable and strong binders suited for a variety of designs. As a result, both academics and business experts find the study of geo-polymer binders to be intriguing and especially important [2]. Using 360 million tonnes of topsoil and 24 million tonnes of coal, India makes more than 1400 billion bricks annually, producing 42 million tonnes of CO_2 in the process. In India, fired clay bricks have traditionally been the most used building material. Fly ash bricks have recently developed appeal due to their inexpensive production costs and lightweight qualities.

Fly-ash bricks, like conventional burnt clay bricks, may be widely employed in a variety of building construction projects. Fly ash bricks are superior in strength and lighter in weight in compared to clay bricks. The addition of fly ash as the major raw material in brick manufacturing not only allows for efficient disposal but also aids in the control of environmental pollution around thermal power stations, where fly ash accumulates as waste and generates substantial environmental pollution concerns. Due to their better quality, environmental friendliness, and government assistance, fly ash bricks are in more demand than ever before. Due to its high silica and alumina concentration, Class F fly ash is well recognized [2][3]. When fly ash (class F) is used to make bricks, the silica Si and alumina Al in the ash react with an already-mixed alkali-activated solution of sodium hydroxide and sodium silicate. This reaction results in a gel-like material that renders cement unnecessary for the creation of these bricks.

RHA is a byproduct of rice husk combustion in rice mills. RHA is the ash produce by the burning process of rice husk. When the burning process is not complete, colorized rice husk is created. Amorphous ash, which is black in color, is formed at burning temperatures between 550 and 800 C, whereas crystalline ash, which is grey in color, is formed at burning temperatures between 550 and 800 C, whereas crystalline ash, which is grey to white in color, is created at higher temperatures [4][13].

Marble is a crucial building material, especially for decorative purposes. 25% of marble is reduced to powder and dust throughout the shaping, polishing, and sawing processes. Since the turn of the millennium, the waste produced by the marble industry has significantly impacted on the environment. This problem affects a large number of nations and is not just a local one. While several nations, including Japan, Germany, Taiwan, and South Korea, import marble products [5].

In an alkaline solution, silicon (Si) and aluminum (Al) are combined to create a geopolymer. Geopolymer bricks have the strength to replace Portland cement concrete, according to several research. To give the geopolymer brick, the required compressive strength, a high molar ratio of NaOH was used. Due to its excellent strength, fireproofing, and waterproofing properties, geopolymer cement is frequently utilized in industrial and construction applications [11][15]. Additionally, it is very resistant to salts, acids, and alkalis and has non-expanding foam-like characteristics. Geopolymer b bricks are a new type of bricks that incorporate materials such as Fly ash (FA), Rice husk ash (RHA), along with an alkaline activator. Fly ash bricks have become popular in construction industries because of their ability to reduce CO2 emissions by using waste materials rather than cement. Geopolymer bricks manufactured with fly ash, on the other hand, require a higher curing temperature to obtain better compressive strength and reduced absorption [17].

In this study, the performance of a geopolymer brick manufactured from Fly ash (FA), Rice husk ash (RHA), and Marble dust powder (MDP) is assessed. It provides new techniques for creating bricks in India and increases the possibilities for recycling waste (fly ash, rice husk ash, marble dust) into useful products, notably building supplies that may be advantageous for the environment and the economy. The study's end goal is to use its findings to compare and contrast the performance of traditional bricks with geopolymer bricks in India.

Literature review

- **Dighe and Gulave,2003[6]** In their report, researchers have concluded that sustainable construction materials made from industrial waste, known as geopolymers, could be the best choice due to their affordability and environmentally friendly properties.
- **Cengizler et al.,2012[7]** investigation into non-fired FA (fly ash) brick manufacturing processes and how they react to heavy metal leaching reveals the possibility of an environmentally friendly choice. By meeting the rising demand for eco-friendly building materials both domestically and abroad, this method might help solve environmental issues while improving the economy. Additionally, the report mentions the economic advantages of this strategy.
- **Mohan et al., 2012[8]** A study investigated the viability of using RHA to make bricks in place of clay, either entirely or partially. According to the study, 30% RHA and 70% clay were the appropriate ratio for RHA and clay bricks. These bricks are lightweight, have a high density, and have a high compressive strength.
- **Bilgin et al., 2012[9]** The industrial brick has outstanding mechanical, chemical, and physical durability was found to be positively affected by the addition of marble dust powder (MP) in varying proportions, ranging from 0% to 80% by weight, to the brick mortar. The resulting simple were sintered and pressed at temperatures of 900, 1000, and 1100 degrees Celsius.
- **Al Bakri et al., 2012[10]** When testing the fly ash to alkaline activator ratio was increased from 0.3 to 0.35, The compressive strength of the fly ash-based geopolymer improved quickly, increasing from 3.695 MPa to 8.325 MPa. The ratio was changed from 0.35 to 0.4, which resulted in an increase in compressive strength from 8.315 MPa to 8.62 MPa.
- **Dara and Bhogayata, 2015[11]** The study identified adding rice husk ash to geopolymer material boosted its compressive strength by up to 25%, but then decrease by up to 40%. The percentage of rice husk ash substitution ranged from 0% to 25%, resulting in an enhancement of compressive strength from 2.24% to 1.78%. The highest increase, 5.40% was recorded at 25% substitution, as compared to normal block test results.
- **Neupane et al.,2015[12]** An experiment was carried out to look at how temperature affected compressive strength of geopolymers, the investigators built geopolymer concrete compositions with Fly ash (FA) and slag ratios of 7:3 and 4:6. Under different settings, both types of fly ash were tested for compressive strength. Aft After one day of curing and heat treatment, the compressive strengths of slag geopolymers with 7:3 and 4:6 ratios were 58 MPa and 65.5 MPa, respectively, while compressive strengths for room temperature curing were 7.2 MPa and 12.5 MPa.
- **Fapohunda et al.,2017[13]** The inclusion of rice husks in concrete increases the amount of water used. However, replacing 10% of the cement with rice husk ash results in an equal gain in strength to the control specimen. The use of rice husk ash in concrete strengthens it. the microstructure and prevent failure caused by sulphate attack, chloride penetration, and other factors. Furthermore, it produces a durable brick with excellent shrinkage properties.
- **M.V. Patil et al. 2018[14]** This research investigated the viability of using marble dust and copper slag as partial substitutes for fine aggregate in concrete. Marble dust was used as a sand substitute in blends containing copper slag in varied quantities ranging from 5% to 50%. The concrete's compressive strength was measured after 7, 28, 56, and 112 days. Then the results showed that substituting marble dust and copper slag for up to 60% of the fine aggregate increased compressive strength. The split tensile strength, flexural strength, density, and modulus of flexibility all increased in strength at a substitution rate of 60%. However, for both marble dust and sand, porosity decreased up to 60% replacement and increased beyond this limit.
- **Osman, 2019[15]** Researchers focused on several combinations of marble dust, fly ash, silica fume, and an alkali activator to examine the mechanical characteristics (compressive strength, flexural strength, and tensile strength), as well as the durability (water absorption), of geopolymer paste. The combination with a water-to-binder (w/b) ratio of 0.28 with a composition of 80% FA, 20% MDP, and displayed the maximum compressive strength, measuring 22.78 N/mm2, according to the study. Additionally, a geopolymer paste made of 90% fly ash and 10% marble dust was used, yielding a w/b ratio of 0.28 and a maximum flexural strength of 2.55 N/mm2.
- **Mohd Basri et.al., 2021[16]** The ratio of RHA to Alkaline Activator (AA), as well as the NaOH concentration, were both shown to have a significant impact on the compressive strength of geopolymer specimens (p=0.024). The RHA/AA

ratio should be between 0.7 and 0.8, and the NaOH concentration should be between 12 and 14 M to get the best compressive strength. Specifically, a RHA/AA ratio of 0.85 and a NaOH concentration of 14 M were used to produce a compressive strength of around 47 MPa. In contrast to samples with greater Si/Al ratios, which had compressive strengths of 88.95 MPa, lower Si/Al ratio samples were brittle but also showed high compressive strengths of 33.55 MPa and considerable geopolymerization.

- **Vijai et.al.,2021[17]** The researchers looked at how two different curing conditions, The effects of heat curing at 60°C for 24 hours and temperature variations on the density and compressive strength of geopolymer concrete were investigated. Fly ash was the principal material used, with sodium silicate and NaOH serving as chemical activators According to the results, there was no discernible difference between the various geopolymer kinds of compressive strengths after 28 days (24.4 and 34.2 MPa, respectively). This shows that the curing method does not have a long-term impact on the mechanical properties, as it does at an early stage.
- **A. Sumathi et.al.,2021[18]** investigated the use of fly ash in the construction industry and focused on identifying the best mix proportions for fly ash bricks. The specimens were 230mm x 110mm x 90mm in size, with variations in sample composition comprising fly ash (15 to 50%), gypsum (2%), lime (5 to 30%), and quarry dust (45 to 55%). The compressive strength of several mix combinations was evaluated, and it was discovered that the compressive strength varied with changes in mix proportions and curing time. The results revealed that a mix design of 15% fly ash, 53% quarry dust, 30% lime, and 2% gypsum produced the maximum compressive strength.

MATERIALS

1. FLY ASH

Fly ash is a byproduct of pulverized coal combustion in thermal power plants, the FA used in this experiment was classed as class F. It was sourced from the Rajpura thermal power plant located village near Rajpura in Patiala district in the Indian state of Punjab. Fly ash includes a high percentage of silica and alumina. Fly ash had a specific gravity of 2.15.

Fig. 1- Fly ash

Table 1. Physical properties of Fly ash (FA)::-

Parameters	Value
Specific gravity (g/cm3)	2.15
Fineness	295 m^2/kg
Moisture content	0.5%
Bulk density	1100 -1200 kg/m^3
Color	Grey

2. Rice husk ash (RHA)

Rice husk ash that is supplied from a rice mill in Kharar, Mohali, Punjab, was used as a material in this stud. India generates a significant quantity of rice husk ash, which show a high-level of reactivity and possesses pozzolanic properties. After separating it from the rice grain, the husk was burned in a burner.

Fig. 2 - Rice husk ash

Table 2. Physical properties of RHA:-

Parameters	Value
Fineness passing through 45 microns	95%
Specific gravity (g/cm3)	2.05
Specific surface (nitrogen absorption) m2/kg	27650
Particle size (µm)	6

3. Marble dust powder

Marble dust powder is used in this experiment. The collections of marble dust powder took place at Ram Krishna Marble & Tiles situated in Sector 21, Panchkula, Chandigarh


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Fig. 4 – Marble dust Powder

Table 3. Physical properties of marble dust: -

Parameters	Value
Specific gravity(g/cm^3)	2.74
Surface by blain (cm2/g)	4376

Chemical composition of Fly ash (FA), Rice husk ash (RHA), and Marble dust powder (MDP): -

Table 4. Major Chemical composition of raw material analyzed by XRF (weight percentage). waste marble dust, fly ash: -

Chemical composition%	FA %	RHA %	MDP %
Silica Oxide (SiO_2)	61.84%	87.40%	0.29%
Aluminum Oxide (Al_2O_3)	26.68%	0.46%	1.42%
Iron Oxide (Fe_2O_3)	10.75%	1.55%	0.49%
Calcium Oxide (CaO)	6.65%	1.4%	55.63%
Magnesium Oxide (MgO)	2.66%	1%	0.44%
Sulphur Oxide (SO_3)	4.24%	-	-
Potassium oxide, K_2O	2.26%	2.90%	-
Loss of ignition (Lou)	0.8%	0.15%	43.5%

4. Fine aggregate

The Fine aggregate that was simply available in Ramjee concrete pvt. Ltd., jhanjeri, S.A.S Nagar, Punjab was used as fine aggregate with a 4.75mm size Sand's sieve analysis is carried out using Zone-II the fineness modulus of aggregate is 2.4 IS 383-1970 as shown in the table.

Table 5: Sieve analysis of Fine aggregate

IS sieve sizes	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative Percentage Retained	Cumulative Percentage Passed
10mm	0	0	0	100
4.75mm	21.02	21.02	2.1	97.9
2.36mm	82.44	103.46	10.3	89.7
1.18mm	155.04	258.04	25.8	74.2
600 microns	232.31	490.35	49.03	50.97
300 microns	225.93	716.28	71.6	28.4
150 microns	151.83	871.11	87.11	12.89
75 microns	101.43	101.43	-	-

Fineness modulus = Cum. % wt. Retained/100

21.02+10.3+25.8+49.03+71.6+87.11/ 100 = 2.4

5. Alkaline activators

A mixture of sodium silicate and sodium hydroxide was used to ensure the consistency and uniformity of the alkaline activator solution used in the creation of geopolymer bricks. In comparison, solid capsule forms of NaOH with a purity of 98% were used, and sodium silicate contains 27% SiO_2, 8% Na2O, and 65% H_2O by mass. The sodium hydroxide molarity was held constant at 12M for all mixtures, and the sodium hydroxide to sodium silicate ratio was held at 1:2.5. To make sure that the entire solution was homogeneous, the solutions of NaOH and Na2SiO3 were mixed 24 hours before the preparation of geopolymer brick samples.

a. Sodium hydroxide

Caustic soda, also known as sodium hydroxide, is a highly corrosive metallic base that is widely employed as a powerful chemical base in a variety of sectors, including the production of textiles, soaps, detergents, and drinking water. It quickly dissolves in water, generating heat. Synthesis was used to dissolve 480 grams of sodium hydroxide in 1000 ml of distilled water to get a 12M NaOH solution.

Fig 5 Sodium Hydroxide

b. Sodium Silicate

Sodium silicate, popularly is also known as water glass or liquid glass, is a Na2SiO3-containing chemical. It is found in both solid and aqueous solution forms, and it is colourless or white in its pure form. In sectors such as detergents and textiles, sodium silicate is commonly utilised as a bonding agent.

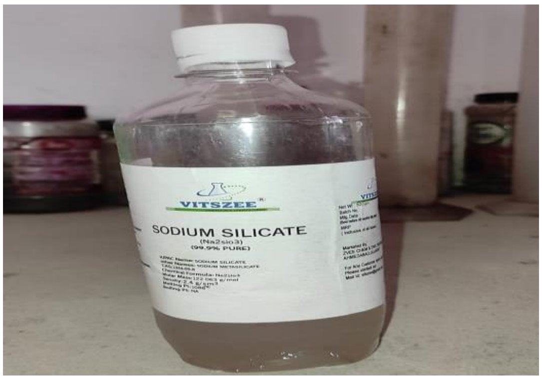

Fig 6 Sodium silicate

Mix proportion of Geopolymer brick

- **Preparation of geopolymerization activator**

Geopolymerization is a method that involves the use of an alkaline chemical activator to start a reaction that results in the creation of mineral polymer structures. The chemical activator is commonly a commercially available sodium hydroxide pellet combined with water and a sodium silicate solution. Additionally, alkaline base chemicals containing anions such as O2-, [OH]-, Cl-, and $[SO_4]_2$- are introduced at various quantities to enhance the reaction. These components work together to facilitate the geopolymerization process and the formation of the necessary mineral polymer structures. For a proper geopolymerization process, the pH of the chemical activator is kept between 11 and 12.

To reduce heat generation during polymerization, a sodium silicate and sodium hydroxide combination was made one day before being added to the dry materials [9]. To create the solution, 48grm of sodium hydroxide pellets were dissolved in water at a concentration of 12 M. The sodium silicate solution was then thoroughly mixed with the sodium hydroxide solution. The semi-solid paste that resulted was then poured into mould measuring 230mm x 110mm x 70mm for additional processing.

Fig 7 alkaline activator

- **Mixing of material**

The hand mixing method was used to combine the various elements. Fine aggregate was then carefully incorporated into the dry materials after careful mixing. The slurry was then gently re-mixed after adding fine aggregate. The chemical admixture was mixed while water is gradually added, and the mixing was halted after a usable mixture was attained. During the procedure, mixing was done often. The average strength of bricks on the market is 5 MPa, which is higher than the minimum strength criterion of 3.5 N/mm2 outlined by the IS: 1077:2007 regulation. A molarity of 12M was chosen for casting the geopolymer bricks based on the results of testing several geopolymer binder molarities. Fly ash (50%-70%), fine aggregate (15%), Rice husk ash (15% - 30%), and Marble dust powder (5%- 30%) were used in different amounts to make the bricks. source materials and binder of brick were also cast before the bricks. To enable the curing of the specimen at room temperature. The different proportions of fly ash (FA), Rice husk ash (RHA), and Marble dust powder (MDP) source material combined with fine aggregate in a 1:3 ratio to create the geopolymer mortar.

Table 6: - Mix proportion for geopolymer brick

Fly ash %	Rice husk ash%	Marble dust powder %	Fine Aggregate%	Sodium hydroxide	Sodium silicate
70%	25%	5%	15%	1	2.5
70%	20%	10%	15%	1	2.5
70%	15%	15%	15%	1	2.5
60%	30%	10%	15%	1	2.5
60%	25%	15%	15%	1	2.5
60%	20%	20%	15%	1	2.5
50%	30%	20%	15%	1	2.5
50%	25%	25%	15%	1	2.5
50%	20%	30%	15%	1	2.5

- **Batching, Mixing and curing**

The basic components for geopolymer mortar were combined in the laboratory using a pan mixer. The mixture was progressively combined with a pre-mixed alkaline activated solution for 4 to 6 minutes, depending on the consistency. The geopolymer bricks were made using a 1:3 combination of fly ash, rice husk ash, marble dust powder, and sand, and a standard-size mould of 230 x 110 x 75 mm was employed. 12M NaOH was used to make an alkaline solution. The geopolymer bricks were cast in the Mould and allowed to cure for 24 hours on the roof under ambient conditions. Figure 8 shows a diagram of the geopolymer bricks. After the bricks had been de-mould, they were either heated to a higher temperature, left at room temperature, or placed in water to cure. The bricks were made to cure at ambient temperature for 7 period of 7 days, 14 days, and 28 days using the room temperature curing procedure. The bricks were submerged in water for the same ageing times when using the water-curing process. The dried bricks' compressive strength and water absorption were then assessed. d.

Fig 8 Curing

Result and discussion

Test on bricks: -

- Compressive strength
- Water absorption
- Efflorescence test

COMPRESSIVE STRENGTH TEST

A compression testing device with a max capacity of 2000 kilonewtons and a continuous loading rate of 200 kilograms per square centimeter per minute is used to gauge the Compressive strength of the geopolymer bricks. For assessing the compressive strength of clay bricks and fly ash bricks, the testing process complies with the specifications defined by Indian Standards IS: 1077-1992 and IS: 3495 (Part 1) After 7 day and 14 days curing of the specimens, the specimens are tested for compressive strength using various material ratios and molar ratios of the alkaline solution. Below are presented the test's findings.

Fig 9 Compressive strength on CTM

The compressive strength of geopolymer bricks that are water-cured may be lower than that of bricks that are cured under other conditions. This can be because of the high-water content and low temperature present during the curing process. In addition, the low temperature may impede the polycondensation reaction, which may be a factor in the geopolymer bricks reduced compressive strength after being cured under water. It may be necessary to optimise the curing conditions, such as water content and temperature, to increase the compressive strength of geopolymer bricks dried in water.

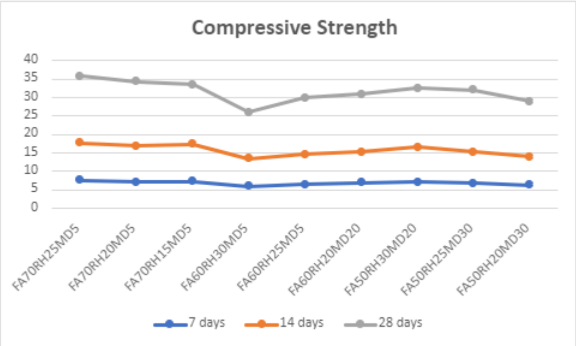

Fig 10 Compressive Strength

• WATER ABSORPTION

Water absorption is a major factor effect on brick durability. The less water that penetrates a brick, the greater its durability and resistance to the environment. The results show that increasing the Rice husk ash to water ratio and the curing temperature increase water absorption. As indicated in Figure 11, the water absorption rate of geopolymer bricks was shown to be greater after 7 days of room temperature curing compare to 14 days and 28 days. This shows that prolonged curing durations could produce bricks that are denser, less porous, and absorb water less slowly. However, it is crucial to remember that the ideal curing time might change according on the particular mix of design and curing circumstances employed. The appropriate curing time for geopolymer bricks in various applications may require more study. As previously, as the volume of Rice husk increases, more linked pores allow water flow to appear. pear. In any case, increased water absorption may reduce compressive strength.

Fig 11 Water absorption

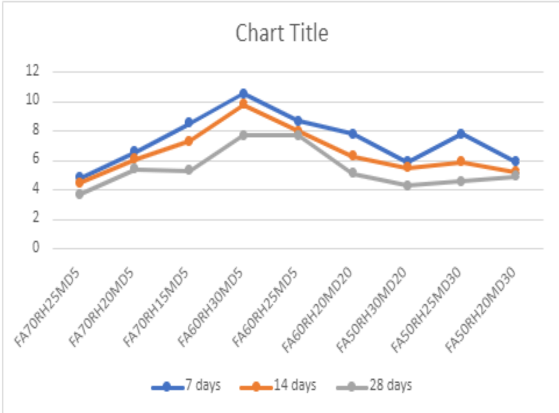

Fig 12 Water absorption

• EFFLORESCENCE TEST

Efflorescence is a white crystalline salt compound made up of magnesium sulphate, calcium sulphate, sodium and potassium carbonates. This test was done according to IS: 3495(Part 3) Typically, efflorescence is caused by wet conditions, condensation, low temperatures, among other things, and deposits on the surface of the bricks. The occurrence of efflorescence in bricks is classified as nil, faint, moderate, heavy, and serious (IS: 3495, Part-III). No white areas have been detected since the day of de-molding; hence efflorescence is recorded as nil.

Table 9 Result of Efflorescence test

S. no	Brick type	Nil	Slight	Moderate	Heavy	Serious
1	FA70RH25MD5	-	Yes	-	-	-
2	FA70RH20MD5	-	Yes	-	-	-
3	FA70RH15MD5	Yes	-	-	-	-
4.	FA60RH30MD5	-	-	Yes	-	-
5	FA60RH25MD5	Yes	-	-	-	-
6	FA60RH20MD20	Yes	-	-	-	-
7	FA50RH30MD20	-	Yes		-	-
8	FA50RH25MD30	-	-	Yes	-	-
9	FA50RH20MD30	-	-	Yes	-	-

Future implementation of geopolymer bricks and recommendations

The study's methodology and findings show that geopolymer bricks could be an acceptable replacement for burnt bricks. Future research should, however, focus on the endurance of this geopolymer material as well as the optimum means of including it in the brick production line. Research is currently being done to evaluate the adjustments required in the burnt brick production chain to incorporate geopolymer bricks.

Several guidelines should be considered when putting geopolymer bricks into practice. To begin, a comparison of the different stages of life of traditional and geopolymer bricks should be performed to assess the latter's environmental impact and sustainability. Second, to optimise production and increase brick quality, a complete analysis of the raw material preparation process, as well as the process of producing and drying geopolymer bricks on an industrial scale, should be performed. Finally, geopolymer brick research and development offer promise for sustainable construction methods. Additional efforts should be made to incorporate the new material into the building sector, with an emphasis on optimizing the manufacturing process and ensuring the final product's quality.

Conclusion

The results of this investigation could be generalized to the following:

- The geopolymer brick specimens made at a 12 M NaOH concentration have an increased compressive strength.
- It has been identified that the combination of silica-based (Fly ash and rice husk ash) and CaO-rich MDP may be used as a cement substitute since they are suitable with one another.
- The geopolymer bricks with a material ratio of 70:25:5 consistently display the highest compressive strength during both the 7-day and 14-day periods, when compared to other combinations, while using a constant alkaline solution of 1:2.5. The compressive strength increases from 12.6 MPa to 18.1 MPa
- Geopolymer bricks have a lower water absorption rate, as they show water absorption of up to 5.4%. In comparison, normal clay bricks typically have a water absorption rate of around 20%.
- Geopolymer brick has a high compressive strength when mixed with fly ash 70%, rice husk ash 25%, and marble dust 5% with an alkaline activator

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