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STUDY AND DESIGN OF HYDROGEL BRICKS FOR ENHANCED INDOOR COOLING EFFICIENCY

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ABSTRACT

The bricks that are used for conventional construction are basically burnt clay bricks, cement bricks, flyash bricks. Among this flyash bricks is taken in this project to enhance the thermal resistance and thus make the rooms cool as much as possible. In this regard flyash bricks in market are collected and tested. The material composition of the flyash bricks are provided by the manufacturer was altered later by adding hydrogel in aim to make it thermal resistant brick. About 5% of poly-acrylamide is added to the flyash bricks materials to get this cooling brick. Addition of 5% poly-acrylamide hydrogel by weight of flyash to the mix increased the overall performance of the normal flyash bricks and thus provided in this report.

Keywords : *hydrogel bricks, bricks, construction material, strength.*

1 INTRODUCTION

The temperature of the world is rising daily. Around the world, the use of air conditioning systems to cool buildings has drastically increased. Growing energy use has resulted in contamination of the environment, which has caused ozone layer depletion and global warming.

The idea of using cooling bricks, also known as hydro bricks, which can serve as a remedy by bringing the interior temperature down to 7 °C is proposed. It is a creative idea for building in the future. It is suitable for usage in any climate and condition. A product called hydrogel is made up of a collection of polymeric components with a structure that tends to hold a lot of water in a 3D network. It has been used for manufacturing products which is used for many industrial and environmental purpose. Because of its water holding capacity, it can reduce the indoor room temperature.

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Hydrogel bricks are a type of construction material that incorporates thermo responsive hydrogels. These hydrogels are polymeric materials capable of absorbing and retaining large amounts of water. They are known for their self-healing and ultra-porous properties [1], [2]. Hydrogel bricks, specifically double-network (DN) hydrogels, have shown excellent cooling performance. Hydrogel bricks have been compared to wooden and brick houses in terms of their passive cooling effectiveness. While brick houses have shown superior performance in outdoor environments, wooden houses have exhibited better passive cooling in lab conditions [3]. The difference in performance can be attributed to factors such as heat conductivity, light reflection, and infrared light absorption. Hydrogel bricks have the potential to contribute to the industry of smart buildings and passive cooling. They offer a greener alternative to synthetic cooling methods and can help reduce carbon emissions and electricity consumption. By harnessing the cooling properties of hydrogels, these bricks can aid in creating more energy-efficient and sustainable structures. Hydrogel bricks, incorporating thermoresponsive hydrogels, have shown promising cooling performance and mechanical strength. Their unique properties make them a potential solution for passive cooling in construction, offering energy conservation and environmental benefits. Further research and testing are needed to explore their effectiveness in different environmental conditions and construction materials.

Hydrogel is a polymeric material with the unique property of keeping large volumes of water in its three-dimensional network cubic structure. The ability of hydrogels to absorb considerable quantities of water, retention capacity and provision for long-term use makes them highly useful in several industries and diverse environmental applications. Hydrogels are either natural or synthetic, and now a days synthetic variants are replacing natural reached properties and performance. Hydrogels are characterized by the confinement of hydrophilic polymer chains linked with cross-linking. These materials are known to have extreme workability and can be described as water swollen—making them highly versatile with a wide array of potential use cases. They possess properties very similar to that of natural tissues, making them attractive for multiple areas of research and practical use[4], [5].

2 MATERIALS AND METHODS

Fly ash, quarry dust, lime, gypsum, cement, and hydrogel are the raw materials required to make fly ash and hydro gel brick. Fly ash, also referred to as pulverized fuel ash, must meet IS 3812 Grades 1 or 2 [6]–[10]. Depending on the quality of the raw materials, the fly ash percentage is typically between 60 and 80 percent. In sand, harmful substances like silt and clay should ideally make up less than 5%. Ten to twenty percent may be used. The composition may contain hydrated lime, quick lime, or both. Lime should contain at least 40% CaO. Gypsum is the term for hydrated calcium sulphates. ($CaSO_4.2H_2O$), which ought to be at least 35% pure [11]–[13]. OPC 53 grade cement purchased from local shop which is a product from cement plant, a substitute of lime is utilized. Poly acrylamide hydrogel made by using 2g of Na-Alginate/100ml of water solution and stir it with mechanic stirrer under 60^o C heating, and then add 15g of Acrylamide (AAM) monomer and 0.01g/10ml water solution of Methylenebis accrylamide (MBBAm) crosslinker is added and the initiator 0.1g of Ammonium Peroxidisulfate is added and then the accelerator Tetramethyl Ethylenediamine is addad to initiate the polymerization reaction [5].

A pan mixer is used to manually feed fly ash, lime, sand, and gypsum. Water is then added in the proper amount to allow for intimate mixing. Depending on the quality of the raw materials, the percentage of fly ash is typically between 60 and 80 percent, with 10–20% lime, 10% gypsum, and 10% sand.

Table 1. Materials for fly ash and hydro gel brick (500kg mixture)

Materials name	Materials for flyash brick (kg)	Materials for hydro gel brick (kg)
Flyash	275	261.25
Lime	75	75
Gypsum	35	35
Sand dust	115	115
Cement	8	8
Hydro gel	-	13.75

The ingredients are combined in a pan. Following mixing, the mixture is sent to the hydraulic/mechanical presses via belt conveyor. The mold boxes are filled with the homogenized mortar that was removed from the roller mixer. The product is compressed under vibration, hydraulic compression, etc., depending on the machine type. Depending on the lime or cement method, the green bricks are dried in the sun for 24 to 48 hours. After that, they are piled and exposed to water spray curing once or twice daily for 7–21 days, depending on the environment [14]–[17]. The fly ash brick mix details are collected from Maniyan bricks plant at Aralvaimozhi. Table 1 shows materials for flyash and hydro gel brick (500kg mixture). These raw materials typically consist of 50–60% fly ash, 10–20% lime, 5–10% gypsum, and 15–25% sand dust.

2.1 Measurement of dimensions of brick

Brick dimensions were measured as per procedure mentioned in of IS 12894:2002 (Clause 5.2.1). And to do this test, you were going to need some equipment; an inextensible measuring device, such as a steel tape measure. Random sampling: From the brick stockpile (20 bricks or more if stack size is larger); Any blisters, small projections, or loose clay particles which might be sticking to the bricks were removed before measurement. Bricks placed adjacently touching each other in a straight row on flat ground Depending on whether the dimension they were looking at was of length, breadth or height, different arrangements will be shown. The length of the row was measured in one piece with a steel tape or similar tool, along bricks. A short ruler or measure was not allowed to be used multiple times. Where measuring all bricks in a row was impractical, the sample was divided in rows of 10 bricks. Measurements were taken in millimetres for each dimension of a row separately, and summed to determine the row measurements.

2.2 Determination of water absorption

For 24 hours, submerge the fully dry specimen in clean water at 27 ± 2 °C. Weigh the specimen after removing it and using a moist cloth to remove any remaining water. Three minutes after the specimen has been taken out of the water, finish the weighing (M2). The following formula provides the water absorption (WA), expressed as a percentage of mass, following a 24-hour immersion in cold water.

$$WA\% = \frac{M_2 - M_1}{M_1} \times 100$$

2.3 Determination of compressive strength of fly ash bricks and hydrogel brick

By grinding, you can eliminate the unevenness in the bed faces and create two parallel, smooth faces. For a full day, submerge the sample in room temperature water. Fill the frog and all of the empty spaces in the bed faces with the prepared cement mortar (1:1). For three days, keep the prepared sample in clean water in a wet jute bag. Eliminate and remove any remaining moisture. Calculate the area of two faces that are horizontal. Position the specimen between two plywood sheets, flat faces horizontal, mortar filled facing up, and carefully centre between the testing machine's plates. Note the maximum load at failure. Axial load is applied uniformly at a rate of 14 N/mm2 per minute until failure occurs.

$$Compressive\ Strength\ (N/mm^2) = \frac{Max\ load\ at\ failure\ in\ N}{Avg\ area\ of\ contact\ area\ in\ mm^2}$$

2.4 Thermal resistance test

The temperature ambiance environment was increased due to the environmental aspects. Brick specimens which were taken for the experiment is compared accordingly to their compression strength after a period of time under higher temperature. To investigate the thermal resistance test of fly ash brick and hydrogel brick, a total of 6 specimens were cast. After curing for 28 days, the specimens adopted for thermal resistance test. A material's or object's ability to withstand a heat flow is measured by its thermal resistance, which is a heat property. The opposite of thermal conductivity is thermal resistance. The temperature differential across a structure when a unit of heat energy passes through it in a unit of time is known as absolute thermal resistance, and it is the reciprocal of thermal conductance.

$$Percentage\ of\ weight\ reduction\ (\%) = \frac{W_2 - W_1}{W_1} X100$$

Where W_1, $W_2$are Weight of specimen after taking from the oven and the initial specimen in kg.

$$Percentage\ of\ strength\ reduction\ (\%) = \frac{CS_2 - CS_1}{CS_1} X100$$

3 RESULTS AND DISCUSSION

Brick dimensions were measured using the above-mentioned methodologies. The measurement's outcomes must to adhere to the restrictions described in IS 12894:2002. The findings of measuring ten fly ash bricks and ten hydro gel blocks are displayed in Table 2 and 3 respectively.

Table 2. The results obtained from the measurement of 10 fly ash bricks

Dimensions	Total Measurement for 10 Bricks (mm)	Mean Measurement for Single Brick (mm)
Length, L	1900	190
Width, W	900	90
Height, H	900	90

Ten fly ash bricks were measured, and the results showed that the overall length, width, and height were 1900 mm, 900 mm, and 900 mm and a mean measurement, were 90 mm in width, 90 mm in height, and 190 mm in length.

Table 3. The results obtained from the measurement of 10 hydro gel bricks

Dimensions	Total Measurement for 10 Bricks (mm)	Mean Measurement for Single Brick (mm)
Length, L	1900	190
Width, W	900	90
Height, H	900	90

The 10 numbers of fly ash brick and hydro gel brick are adopted for dimension tests and the result shows that the dimension brick size obtained 1st class. The fly ash brick dimension and hydro gel brick dimension are same. The dimension wise no differences in between fly ash and hydro gel brick.

Table 4. Experimental test results

Sample	% of water absorption		Compressive strength		Strength loss (%) due to thermal attack	
	fly ash brick	hydrogel brick	fly ash brick	hydrogel brick	fly ash brick	hydrogel brick
A	8.57	7.46	12.38	12.80	12.11	9.84
B	9.46	6.81	12.22	12.92	11.92	8.09
C	9.14	7.19	11.91	12.75	11.43	8.36
D	8.51	7.12	11.04	12.86	11.38	8.62
E	7.66	6.15	12.60	12.92	10.69	9.84
Average	8.67	6.94	12.03	12.85	11.50	8.95

The experimental test results are shown in Table 4. The water absorption value of flyash brick is obtained higher value compare to hydro gel brick. Optimum strength brick is achieved specimens is hydro gel brick and also hydro gel brick thermal resistance also higher compare to the fly ash brick. The water absorption, compressive strength and strength loss due to thermal attack values are graphical represented in Figure 1, 2 and 3.

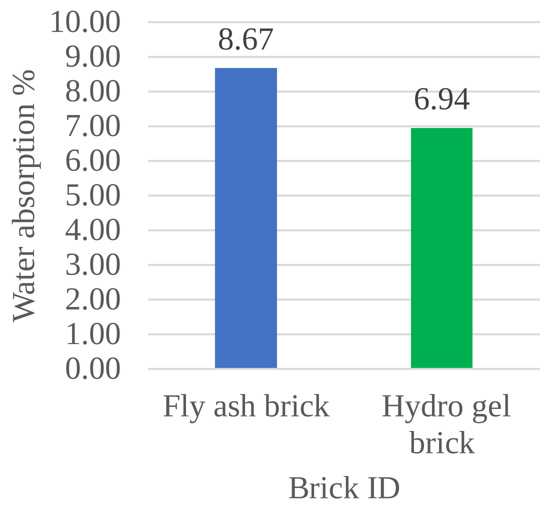

Figure 1. Average Water absorption result for hydro gel brick and fly ash brick

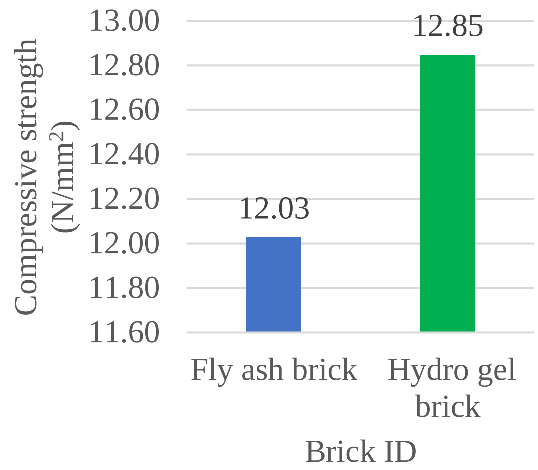

Figure 2. Average Compressive strength result for hydro gel brick and fly ash brick

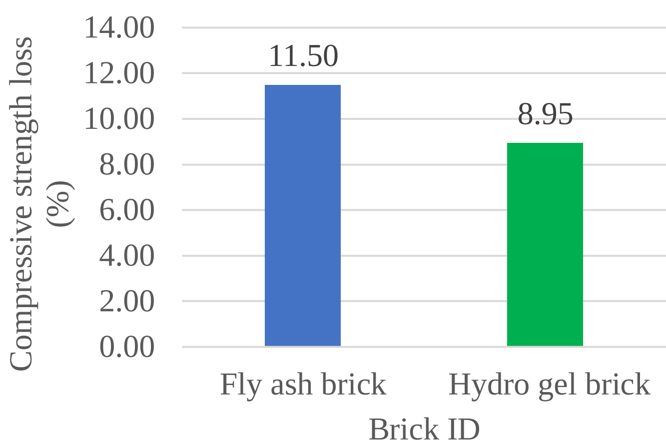

Figure 3. Average Compressive strength loss result for hydro gel brick and fly ash brick (Thermal resistance)

4 CONCLUSION

The flyash brick and hydro gel bricks are adopted for dimension test, water absorption, compressive strength and thermal resistance tests and the results are analyzed. Fly ash brick dimension and hydro gel brick dimension are same. No dimension variation. Water absorption percentage hydro gel bricks are obtained low compare to the fly ash brick. Fly ash brick water absorption percentage is 8.67% and hydro gel brick water absorption is 6.94%. it will be 1.73% lower compare to the fly ash brick. Compressive strength of hydro gel bricks are obtained optimum strength compare to the fly ash brick. Fly ash brick Compressive strength is 12.03N/mm^2 and hydro gel brick Compressive strength is 12.85N/mm^2. it will be 6% higher compare to the fly ash brick compressive strength. The strength loss due thermal attack for fly ash brick is 11.50% and the strength loss due to thermal attack for hydrogel brick is 8.95%. The fly ash brick strength loss loss is higher compare to hydro gel brick strength.

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