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# A Thermal Study on Foam-Based Eco-friendly Cinder Tiles

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**Abstract:** This study focusses on usage of fly ash and metakaolin as industrial waste to aerate lightweight foam concrete (LFGC) using hydrogen peroxide. By designing and optimising the components of metakaolin, hydrogen peroxide, and fly ash, physical properties such as mechanical strength, thermal characteristics, and heat resistance are assessed. Lightweight foam concrete has a dry density between 1400 and 1800 kg/m$^3$, a bending strength between 0.7 and 1 MPa, and thermal conductivity between 0.1 and 0.7 W/mK, all of which indicate that it is more lightweight than normal concrete. By dumping solid waste on land, the environment suffers, and it leads to the release of toxic gases into the atmosphere and get polluted. As a byproduct, swapping out the cement with concrete would be a practical and cost-effective way to use the refuse. Alkaline solutions such as NaOH and $Na_2Sio_3$ are used to prepare geopolymer concrete. Samples of geopolymer concrete made with fly ash and metakaolin are cured in the oven for 24 hours. Geopolymer concrete is a form of material-based construction in which industrial raw materials supplied by businesses are incorporated into it. This lowers carbon emissions and makes the concrete more environmentally friendly. Using MATLAB, we predict which is the best value of bending strength, thermal conductivity, heat resistance, and dry density of various ash concrete. Effective input variables for geopolymer concrete include the amounts of fly ash, metakaolin, NaOH, and $Na_2SiO_3$, Fine aggregate, and the ratio of NaOH and $Na_2SiO_3$ and the output variables are bending strength, dry density, thermal conductivity, heat resistance.

**Keywords:** Lightweight Concrete Tiles, Industrial wastes, Mechanical properties, Hydrogen peroxide, Fine aggregates

## 1. Introduction

One of the key substitutions for concrete made with Portland cement is geopolymer concrete. This term was initially used in 1970s by Joseph Davidovits. Alkali-activated compounds called geopolymers have been prioritised as an alternative to normal Portland cement. They have received a lot of recent attention due to their remarkable mechanical and thermal characteristics. Moreover, geopolymers greatly reduce $CO_2$ emissions compared to OPC, with the reduction in $CO_2$ emissions being up to 86%, according to estimates. The use of FA has become essential for civil engineering, because of its economic and environmental benefits. It is a normal practise to use fly ash to diminish the greenhouse effect. Fly ash has a wide range of constituents depending on the origin and makeup of the coal being burned, but all fly ash contains significant amounts of silicon dioxide ($SiO_2$), both amorphous and crystalline, aluminium oxide ($Al_2O_3$), and calcium oxide (CaO), which are the primary mineral compounds in coal-bearing rock strata. A gas bubble is produced, and pores have been made that result in lightweight geopolymer concrete. Materials that contain a lot of silica and alumina which could react with a foaming agent. As the Earth's crust contains the most aluminosilicate compounds, the raw materials come from a variety of places. Furthermore, foamed geopolymer concrete can be made using industrial wastes including fly ash, granulated blast slag, and metakaolin. Another benefit of geopolymer is the use of industrial waste, which could lower costs as well as contribute to the achievement of the objectives of waste reduction and sustainable development. Foamed geopolymer concrete materials is a lightweight porous material and are widely used as thermal insulation components in the world. The density of foamed concrete effectively reduces the structural dead weight, building energy consumption, reduction in the number of binders used, construction time, and labour costs in handling and transportation.

The application of Lightweight foam concrete can be used in non-structural elements, building partitions, road substrates, sandwich plate cores, cushioning systems, etc. To produce an eco-friendly foam concrete composite, foam is introduced into the geopolymer matrix. From the knowledge gained it is predicted that geopolymer foam concrete not only uses solid waste as raw materials to reduce energy consumption and carbon dioxide emissions, but also has excellent early age performance, high mechanical properties, last for a long time, and good durability performance. The ash that is used in this is a better binding material. Around 60% of the total raw materials of earth are utilized by the construction industry. One ton of cement is observed to release 0.9 tons of $CO_2$ around the world. Studies on numerous by-products of industries like fly ash, metakaolin, silica fume, rice husk ash, and so on have proved to improve the mechanical and durability properties of concrete besides making concrete cost-efficient. In the steel industry, the ash form of Blast furnace slag is ground into a fine powder which is eventually named Ground Granulated Blast Furnace Slag (GGBFS). GGBFS has a chemical composition like calcium, silica, and alumina in different proportions. Here high Silica and Alumina-rich content is considered.

Geopolymer concrete has shown better compressive strength, and it can also gain early strength. It shows better properties than ordinary concrete. In the year 1923, foam concrete came into use for the first time. Cellular lightweight concrete also known as foam concrete is an aerated concrete with its density varying from 300 $kg/m^3$ to 1800 $kg/m^3$. The usage of foam leads to the creation of air voids which reduce the density and affect the strength of concrete. The curing of geopolymer concrete does not require water, it can be cured under normal room temperature conditions, and it needs oven-dry heat curing or steam curing for a period of 24 hr, it can be also cured at normal room temperature to gain strength. GGBS is a ground granulated blast furnace slag particle that is obtained from the steel manufacturing plant. The specific gravity of fly ash and metakaolin is 2.35 g/cc and 2.6g/cc.

## 2. Literature Review

Sai Krishna et.al reported a study on the fresh and hardened properties of foam concrete incorporating fly ash. The addition of 75% fly ash mixes has a density and compressive strength of 800 kg/m$^3$ to 1600 kg/m^$^3$ and 5.275 MPa is achieved. Paul et.al investigated the performance assessment of geopolymer concrete using various industrial wastes that a 20% increase in GGBFS content results in a 45% increase in compressive strength at 28 days. Zhiyuan Shao et al studied the performance of micropore-foamed geopolymers produced from industrial wastes. The mechanical properties of foamed geopolymers include compressive strengths of up to 10.7 MPa and bulk densities of up to 1.04 g/cm$^3$ at 7days. Vinith Kumar et al presented the result of their experimental Study on the Mechanical and Thermal Behavior of Foamed Concrete. The compressive strength and thermal conductivity of foam concrete vary from 2.36 N/mm$^2$ to 6.5N/mm$^2$ and 0.021 W/mk to 0.035 W/mk. It is less when compared to brick. unit weight of foam concrete is 900 kg/m$^3$ to 1100 kg/m3 almost 50% of the dead load can be reduced. When the flow of heat is reduced the air-conditioning cost can also be reduced.

Amrith raj et al analysed the physical and functional characteristics of foam concrete: A review of Entrained air of 20% increased thermal resistance by 25%. Reduced dry density and thermal conductivity by 100 kg/m$^3$ and 0.04 W/mk. Singh et al analyzed the foamed geopolymer concrete Foam concretes have thermal conductivities normally 10–50% of that of normal dense concrete Addition of foaming agents, porosity increases, density, and compressive strength decrease. Zuhua Zhang et al studied geopolymer foam concrete: An emerging material for sustainable construction Compressive strength is usually between 1 and 10 MPa in the density range of 360–1400 kg/m$^3$. The compressive strength of foam concretes decreases with a reduction in density. Singh. K et al presented the results of their experimental study on metakaolin and bagasse-based geopolymer concrete Metakaolin has shown incremental strength and at 20% attained the optimum percentage for compressive strength and after that, there is a decline in a graph when metakaolin is added is more percentage. Metakaolin at 20% replacement and Bagasse Ash at 10% replacement have shown the maximum mechanical and durability result for geopolymer concrete. Normal temperature curing for metakaolin-contained geopolymer has attained 26.93MPa strength and in the case of the oven, dry samples strength attained was 30.75MPa.

Jinyanshi, et al obtained a preparation and characterization of lightweight aggregate foamed geopolymer concrete (LFGC) aerated using hydrogen peroxide  As the expanded polystyrene content increases, the dry density of LFGC decreases from 650 to 300 $kg/m^3$, and the compressive strength decreases Too much hydrogen peroxide will cause a large expansion of the fresh pastes, which will reduce the mechanical properties and microstructure compactness of LFGC, and increase the porosity and pore diameter. In addition, excessive hydrogen peroxide will cause bubbles to collapse and merge, increasing pore connectivity. Olugbenga Ayeni et al analyzed the characterization and mechanical performance of metakaolin-based geopolymer for sustainable building applications. For various building-related applications, geopolymers based on kankara MK have shown promise as sustainable building materials. The maximum reported compressive strength value was 17.10 MPa, even though significant compressive strength values (up to 50MPa) were anticipated for the synthesized geopolymers. According to the study, the development of compressive strength was encouraged by ambient curing and an alkaline concentration of 10M. The greatest value for compressive strength obtained satisfies ASTM minimum standards for creating building materials such as building blocks, paving materials, exterior decorative items, and concrete masonry units. Hence, the construction sector can be advised to use geopolymers based on kankara MK as an environmentally beneficial and long-lasting building material.

Naghizadeh et al studied the long-term strength development and durability index quality of ambient-cured fly ash geopolymer concretes. The ambient–cured fly ash geopolymer concretes exhibited strong strength gains of 60 to 90% over the long–term duration of one year. Ambient–cured fly ash geopolymer concretes made at $Na_2O/FA$ ratio ≤ 0.09 to 0.10, gave long-term compressive strength results that were higher than 28-day strength values of the 60◦C /24hr oven–cured concrete, but the reverse was true for mixtures made at Na2O/FA > 0.09 to 0.10.Optimum compressive strength values of the fly ash geopolymer concrete were obtained at $SiO_2/FA$ ratios of 0.09 to 0.11. Increases in $H_2O/FA$ ratio from 0.32 to 0.41 while keeping $Na_2O/FA$ and $SiO_2/FA$ constant, adversely affected compressive strength, pore volume, water absorption, and durability characteristics of the geopolymer concretes. Rameshwaran et al presented the flexural behavior of fly ash-based geopolymer concrete with respectable compressive and flexural strengths, fly ash in Geopolymer can completely replace cement. Concrete with a high percentage of fly ash (100%) would develop between 40% and 50% of its 28day strength, whereas conventional concrete would reach 65% of its strength after 28 days. The strength of the aged specimen increased over time and may eventually surpass that of traditional concrete. When fly ash completely replaces the cement in geopolymer concrete composites, they are more environmentally friendly than ordinary concrete.

## 3. Materials and Their Properties

### 3.1 Fly Ash

Fly ash is a heterogeneous by-product material produced in the combustion process of coal used in power stations which is shown in Fig 1 and its SEM image is depicted in Figure 2. It is a fine grey powder with spherical glassy particles that rise with the flue gases. Fly ash offers a valuable opportunity to recycle one of the largest waste streams. In addition, fly ash can offer many benefits, both economically and environmentally when utilized as an LWA. As fly ash contains pozzolanic materials components that reach with lime to form cementitious materials. Class F FA consists of a lower amount of calcium <10% compared with class C FA. ASTM Class F FA taken from Neyveli has been used for the present work due to its easy availability. Fly ash considered for the study had a specific gravity of 2.9 and had a chemical composition of $SiO_2$, $Al_2O_3$, and $Fe_2O_3$, MgO, $SO_3$, Alkalis.

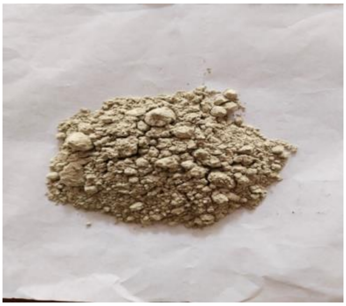


**Figure1.** Fly ash

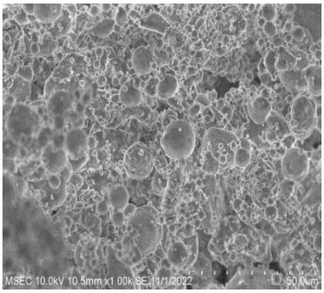



**Figure 2.** SEM image of fly ash

### 3.2 Metakaolin

Metakaolin is having high reactivity, silica-based pozzolana. It is manufactured by processing specially selected pozzolanic ingredients under controlled conditions which is shown in Fig 3 and its SEM image is depicted in Figure 4. It is a form of kaolinite which is a clay mineral that has excellent cementitious properties. It is a clay mineral that is off-white in colour and has a specific gravity of 2.6 g/cc. Metakaolin is a highly reactive pozzolanic material it also helps in reducing the environmental effects caused due to the cement industry. Metakaolin is used to produce green concrete and it is rich in silica and alumina content. By using metakaolin properties such a slight weight concrete, high strength, and high performance can be achieved. Metakaolin is an alternative pozzolanic material that is used in concrete in order to improve the properties of concrete such as durability and reduce the amount of cement used in concrete production. The chemical composition of metakaolin is $SiO_2$, $Al2O_3$, $Fe_2O_3$, $TiO_2$, CaO, MgO,$Na_2O$ and $K_2O$.

Figure 3. Metakaolin

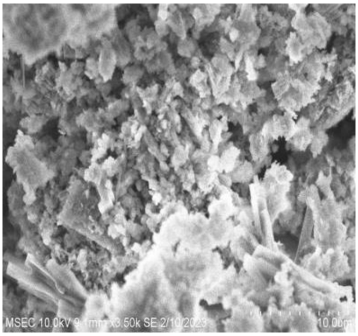


Figure 4. SEM image of Metakaolin

## 3.3 Hydrogen Peroxide

Hydrogen peroxide is a chemical compound with the formula $H_2O_2$. It is more viscous than water. Hydrogen peroxide is a hydrogen-oxygen chemical compound that decomposes into oxygen and water very easily.

Macro pores are created by adding hydrogen peroxide in different percentages. Hydrogen peroxide is taken as 0.5, 1.0, 1.5, and 2.0 % to the mix. Hydrogen peroxide has low mass density and high strength when the additional amount of hydrogen peroxide is in the 5%-6% range. Hydrogen peroxide creates macro-and micro porosity. Macro pores are created by adding hydrogen peroxide in different additional amounts. The bubble is made by adding expansion agents such as hydrogen peroxide to the mix at the time of mixing. This creates a chemical reaction that generates gas, either as hydrogen or as oxygen to form a gas-bubble structure within the concrete. The material is then formed into Molds. Each Mold is filled to one-half of its depth with the slurry. And after a certain time, the mixture expands to fill the mold above the top similar as baking a cake. After the initial setting, it is then cured for a specific amount of time to produce the final micro/macro-structure.

## 3.4 Alkaline Activator

### *3.4.1 $Na_2SiO_3$*

$Na_2SiO_3$ is in gel form and its colour of light brown .$N_aOH$ dissolves $N_aOH$ dissolves aluminosilicate, while $Na_2SiO_3$ supports NaOH as a binder, plasticizer, or dispersant. This type is used as activator has a high influence on the raw materials dissolution of Al and Si ions. It is viscous in nature, and it is purchased from commercial market Alpha chemicals, Madurai. The chemical composition is given in Table 1.

Table 1. Chemical composition of $Na_2SiO_3$

| Sl. No | Chemical Composition | Percentage |
|---|---|---|
| 1 | $Na_2O$ | 15.9 |
| 2 | $Sio_2$ | 31.4 |
| 3 | $H_2O$ | 53.3 |

### *3.4 NaOH*

When dissociates in water, it does not release many of its $OH^-$ ions. By contrast, a strong alkali like NaOH (sodium hydroxide or caustic soda) releases almost all of its $OH^-$ ions in the solution. Alkaline solutions have a large number of free $OH^-$ ions in the solution. These $OH^-$ ions like to bind to any free $H^+$ ions. So, alkali activator is used. Table 2 shows the properties of NaOH.

**Table 2.** Properties of NaOH

| Sl. No | Properties | Description |
|---|---|---|
| 1 | Colour | White |
| 2 | Density | 2.70g/ml |
| 3 | Odour | Odourless |
| 4 | Appearance | Crystalline |
| 5 | Form | Flakes |
| 6 | Purity | 98% |

### 3.5 Fine Aggregate

#### *3.5.1 M sand*

Manufactured sand is produced from hard granite stone by crushing which is shown in Fig 4. The crushed sand is of cubical shape with grounded edges, washed and graded to as a construction material. The size of manufactured sand (M-Sand) is less than 4.75mm.It has a good grade in the necessary percentage. The necessary strength of concrete may be maintained because it doesn't contain any soluble or organic compounds that would impact cement's characteristics and setting time. As opposed to river sand, it does not include any contaminants that might weaken the binding between cement paste and aggregate, such as clay, dust, or silt coatings enhanced concrete durability and quality. M-Sand is created using cutting-edge international technology from a specific hard rock, resulting in the achievement of the desired sand characteristic.

**Figure 4.** M sand

### *3.5.2 River sand*

River Sand is a natural sand that is made from weathering or erosion processes, unlike other sands that are made from crushing rock and is shown in Figure 5 and its properties are given in Table 3. River Sand can vary in gradation but is typically coarse sand. It can be used in all types of landscaping and construction projects including concrete sand, drainage areas, arena footing and soil amendments. It is made from the same material of the local rock it eroded from, so usually it is mainly silica sand from quartz. Our River Sand is sub-angular in shape, but other sources can be rounded. The most popular option for fine aggregates is natural river sand. The natural weathering of rocks over millions of years produces river sand. Compared to other types of sand used in building, river sand is significantly superior and is extracted from riverbeds. Sand is a naturally occurring granular substance made up of tiny pieces of rock and mineral. The natural beauty of river sand is formed of rounded granules and particles. Sand is frequently categorised into three grades: coarse, medium, and fine, depending on the composition of its textural properties.

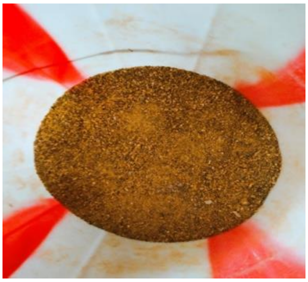


**Figure 5.** River sand

**Table 3.** Properties of fine aggregate

| Sl. No | Property | River Sand | M Sand |
|---|---|---|---|
| 1 | Specific gravity | 2.7 | 2.8 |
| 2 | Relative density | 48% | 38.7% |
| 3 | Fineness modulus | 4.5 | 3.7 |
| 4 | Zone | III | III |
| 5 | Size | <2.36 | <2.36 |
| 6 | Colour | GREY | LIGHT BROWN |

# 4. Experimental Testing

## *4.1 Flexural Strength*

Flexural strength, also known as modulus of rupture, bending strength, or transverse rupture strength is a material property, defined as the stress in a material just before it yields in a flexure test. The flexural strength represents the highest stress experienced within the material at its moment of yield. For a rectangular tile sample under a load, the bending strength is of:

$$\sigma=3FL/2Bd^2$$

*F* is the load (force), *L* is the length of the support span, *b* is width, *d* is thickness

The test should be conducted on the specimen immediately after being taken out of the curing condition to prevent surface drying which declines flexural strength. Place the specimen on the loading points. The hand-finished surface of the specimen should not be in contact with loading points. This will ensure acceptable contact between the specimen and loading points. Center the loading system in relation to the applied force. Bring the block applying force in contact with the specimen surface at the loading points. Applying loads by allowing the steel all to flow. By applying load at certain point, the tile gets broken and take the weight of the steel ball with the pan and take the weight of the empty pan and by using the formula you can calculate the flexural strength of the specimen.

## 4.2 Dry Density

Dry density refers to the density of the sand, when it is taken in the dry state.Prepare the mold for casting the tile and paint the mold with grease for easy removal. Mixing the materials according to the amount we already found. Then cast the tile and leave it for some day and keep in an oven for 24 hrs. and demold it and measure the weight of the tile which is demolded.

Prepare the mold for casting the tile and coat the mold with grease for easy removal. Mixing the materials according to the amount. Then cast the tile and leave it for some day and keep in an oven for 24 hrs. and demold it and measure the weight of the tile which is demolded in a dry state.

## 4.3 Thermal Conductivity

Foam concretes have thermal conductivity normally 10–50% of that of normal dense concrete. The tiles are tested for thermal conductivity by placing it in the oven so that two sides of the tiles are exposed to heat. The tiles are kept under the oven for 6 hours because in Tamil Nadu the temperature during the summer season reaches the maximum of 44°C and this high temperature will be around 10am to 4pm, so the tiles are tested under 45°C for 6 hours. FM1,

FM2, FM3, FM4, FR1, FR2, FR3, FR4, FMM1, FMM2, FMM3, FMM4, FMR1, FMR2. FMR3, FMR4 for eighteen mixes for which thermal conductivity is conducted.

### 4.4 Heat Resistance:

Thermal resistance is a measurement of the difference in temperature at which a substance or item resists the flow of heat. Testing for heat resistance is done to determine how long the tiles will last. This test has been performed on Foam based tiles and regular mix tiles. The tiles are cured, and they are to be maintained in an electrical furnace at 100 and 200 degrees Celsius for 3 hours the weight of the tiles should be noted before and after keeping the tiles inside and outside the electric furnace.

## 5. Results and Discussion

### 5.1 Dry Density

*Fly ash + M sand + Hydrogen peroxide:*

From Table 4 to 9, the dry density results are given, and it is pictured in Fig 6. A combination of Fly ash, M sand and different percentage of Hydrogen peroxide. At 0.5% we get a low density of about 1894 and at 2% we get the least weight of tiles.

**Table 4.** Fly ash + M sand + Hydrogen peroxide

| Percentage | Dry Density (Kg/M$^3$) |
|---|---|
| 0.5 | 1984 |
| 1.0 | 1962.6 |
| 1.5 | 1877 |
| 2.0 | 1749.3 |

*Fly ash + River sand + Hydrogen peroxide*

Casting of combination of Fly ash, river sand and hydrogen peroxide of various percentage. We achieve a high foam with light weight at 2% of $H_2O_2$.At the 2% we get a weight of about 1301Kg/m$^3$.

**Table 5.** Fly ash + River sand + Hydrogen peroxide

| Percentage | Dry Density (Kg/M$^3$) |
|---|---|
| 0.5 | 1706 |
| 1.0 | 1536 |
| 1.5 | 1493 |
| 2.0 | 1301 |

### *Metakaolin + M sand + Hydrogen peroxide*

Casting of Metakaolin tile by using M sand and adding hydrogen peroxide at various percentage. By the addition of different percentages, we can reduce the weight of tiles by 2% we can get a very light tiles at the dry density of 1002.2Kg/m^3.

**Table 6.** Metakaolin + M sand + Hydrogen peroxide

| Percentage | Dry Density (Kg/M$^3$) |
|---|---|
| 0.5 | 1301.3 |
| 1.0 | 1297.8 |
| 1.5 | 1106.1 |
| 2.0 | 1002.2 |

### *Metakaolin + River sand + Hydrogen peroxide:*

By adding metakaolin, river sand with different percentages of hydrogen peroxide. At 0.5% we get a high weight when compared to adding 2% of hydrogen peroxide foam. At 2% the dry density is about 1096Kg/m$^3$ and at 0.5% the dry density is 1285.7 Kg/m$^3$.

**Table 7.** Metakaolin + River sand + Hydrogen peroxide

| Percentage | Dry Density (Kg/M$^3$) |
|---|---|
| 0.5 | 1285.7 |
| 1.0 | 1239.3 |
| 1.5 | 1167.5 |
| 2.0 | 1096.0 |

### *Fly ash + Metakaolin + M sand + Hydrogen peroxide:*

By taking partial fly ash and metakaolin and mixing it with river sand, and various hydrogen peroxide concentrations. When compared to adding 2% of hydrogen peroxide foam, we get a high weight at 0.5%. Dry density ranges from 1706.6kg/m3 at 0.5% to around 1280 kg/m3 at 2%.

**Table 8.** Fly ash + Metakaolin + M sand + Hydrogen peroxide

| Percentage | Dry Density (Kg/M$^3$) |
|---|---|
| 0.5 | 1706.6 |
| 1.0 | 1664.0 |
| 1.5 | 1499.7 |
| 2.0 | 1280.0 |

### *Fly ash + Metakaolin +River sand + Hydrogen peroxide:*

By taking partial fly ash and metakaolin and mixing it with river sand, and various hydrogen peroxide concentrations. When compared to adding 2% of hydrogen peroxide foam, we get a high weight at 0.5%. Dry density ranges from 1728.2kg/m3 at 0.5% to around 1386.6kg/m3 at 2%.

Table 9. Fly ash + Metakaolin +River sand + Hydrogen peroxide

| Percentage | Dry Density (Kg/M$^3$) |
|---|---|
| 0.5 | 1728.2 |
| 1.0 | 1664.4 |
| 1.5 | 1578.7 |
| 2.0 | 1386.6 |

From the above results by analyzing, we get lightweight, when we add Metakaolin and M sand by the addition of 2% of hydrogen peroxide.

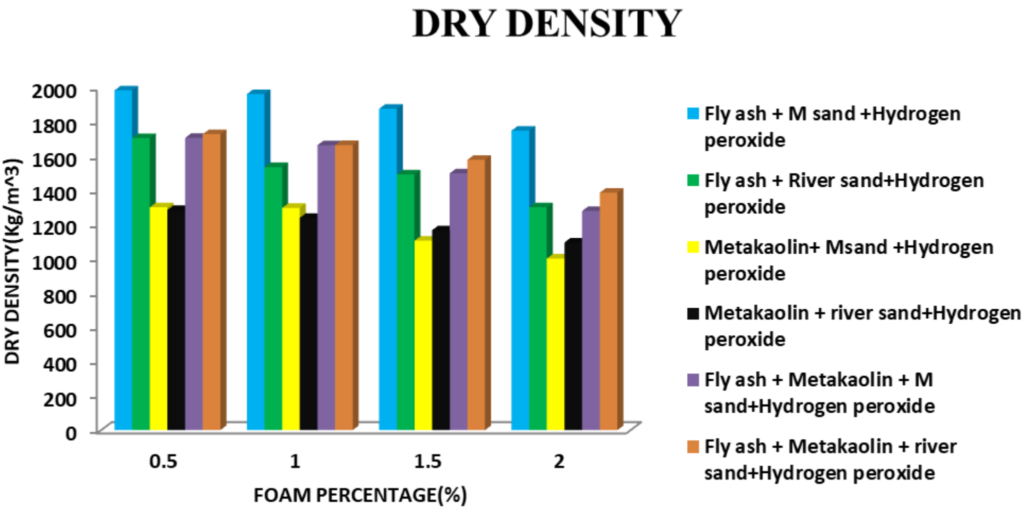



Figure 6. Dry Density

## 5.2 Flexural Strength

### *Fly ash + M sand + Hydrogen peroxide:*

From Table 10 to 15, the flexural strength results are given, and it is pictured in Figure 7. With the combination of fly ash and M sand by adding hydrogen peroxide at different percentages we get a high strength at 0.5%. The strength is about 0.656N/mm$^2$.

**Table 10.** Fly ash + M sand + Hydrogen peroxide

| Percentage | Flexural Strength (N/Mm^2) |
|---|---|
| 0.5 | 0.656 |
| 1.0 | 0.577 |
| 1.5 | 0.505 |
| 2.0 | 0.461 |

### *Fly ash + River sand + Hydrogen peroxide:*

Casting of tile using fly ash, river sand and for foam add the hydrogen peroxide at various percentages. At 0.5% we get a high strength.

**Table 11.** Fly ash + River sand + Hydrogen peroxide

| Percentage | Flexural Strength (N/Mm^2) |
|---|---|
| 0.5 | 0.402 |
| 1.0 | 0.374 |
| 1.5 | 0.127 |
| 2.0 | 0.113 |

### *Metakaolin + River sand + hydrogen peroxide*

At 0.5% of adding hydrogen peroxide there leads to a smaller number of pores, so we get a high strength when we compared to adding of 2% of hydrogen peroxide.

**Table 12.** Metakaolin + River sand + hydrogen peroxide

| Percentage | Flexural Strength (N/Mm^2) |
|---|---|
| 0.5 | 0.225 |
| 1.0 | 0.202 |
| 1.5 | 0.168 |
| 2.0 | 0.153 |

### *Metakaolin + M sand + hydrogen peroxide*

When compared to adding 2% of hydrogen peroxide, adding 0.5% of hydrogen peroxide results in fewer pores and a higher strength. In this combo we get a high strength of 0.231N/mm$^2$ at 0.5% of $H_2O_2$.

Table 13. Metakaolin + M sand + hydrogen peroxide

| Percentage | Flexural Strength (N/Mm^2) |
|---|---|
| 0.5 | 0.231 |
| 1.0 | 0.201 |
| 1.5 | 0.156 |
| 2.0 | 0.103 |

### *Fly ash + Metakaolin + M sand + hydrogen peroxide*

With the combination of fly ash and metakaolin tiles are cast by adding $H_2O_2$. At 2% we get less weight at about 0.211N/mm$^2$.At 0.5% we get a high strength of about 0.437N/mm$^2$.

Table 14. Fly ash + Metakaolin + M sand + hydrogen peroxide

| Percentage | Flexural Strength (N/Mm^2) |
|---|---|
| 0.5 | 0.437 |
| 1.0 | 0.418 |
| 1.5 | 0.371 |
| 2.0 | 0.211 |

### *Fly ash + Metakaolin + River sand + hydrogen peroxide:*

$H_2O_2$ is added to fly ash and metakaolin before the mixture is used to cast tiles. At 2%, the weight is reduced to around 0.362N/mm$^2$. We achieve a high strength of around 0.446N/mm$^2$ at 0.5%.

Table 15. Fly ash + Metakaolin + River sand + hydrogen peroxide

| Percentage | Flexural Strength (N/Mm^2) |
|---|---|
| 0.5 | 0.446 |
| 1.0 | 0.421 |
| 1.5 | 0.408 |
| 2.0 | 0.362 |

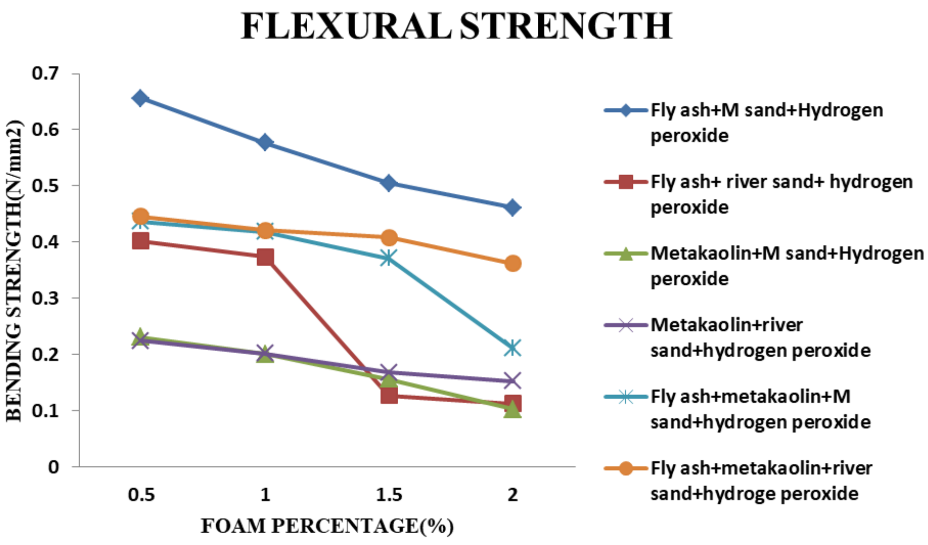



Figure 7. Graph of Flexural strength

### 5.3 Heat Resistance

*Fly ash + M sand + Hydrogen peroxide:*

From Table 16 to 21, the heat resistance results are given, and it is pictured in Figure 8. By the addition of different percentages of $H_2O_2$ we get a lightweight tile, and it is kept in a furnace for 200 degrees Celsius. The tiles should be at good heat resistance. At the 0.5% we get a residual bending strength of about 0.48N/mm$^2$.

Table 16. Fly ash + M sand + Hydrogen peroxide

| Percentage | Residual Bending Strength(N/Mm^2) |
|---|---|
| 0.5 | 0.48 |
| 1.0 | 0.46 |
| 1.5 | 0.39 |
| 2.0 | 0.32 |

*Fly ash + River sand + Hydrogen peroxide*

The residual bending strength is high at the percentage of 0.5 when compared to the percentage of 2. At 0.5% residual strength is of 0.46N/mm$^2$ and at the 2% it is about 0.26N/mm$^2$.

Table 17. Fly ash + River sand + Hydrogen peroxide

| Percentage | Residual Bending Strength(N/Mm^2) |
|---|---|
| 0.5 | 0.46 |
| 1.0 | 0.32 |
| 1.5 | 0.29 |
| 2.0 | 0.26 |

### *Metakaolin + M sand + hydrogen peroxide*

Addition of metakaolin, M sand and hydrogen peroxide at different percentage we get a good residual bending strength at the adding of 2% of $H_2O_2$.In this combo we get a very low residual strength of 0.21 when compared to fly ash.

Table 18. Metakaolin + M sand + hydrogen peroxide

| PERCENTAGE | RESIDUAL BENDING STRENGTH(N/mm^2) |
|---|---|
| 0.5 | 0.21 |
| 1.0 | 0.18 |
| 1.5 | 0.12 |
| 2.0 | 0.10 |

### *Metakaolin + River sand + hydrogen peroxide*

Similarly to the above material M sand is replaced by river sand and the heat resistance test is taken and the residual bending strength value is higher at the time of adding 0.5% of $H_2O_2$.thevalue at 0.5% is 0.23N/mm$^2$.

Table 19. Metakaolin + River sand + hydrogen peroxide

| Percentage | Residual Bending Strength(N/Mm^2) |
|---|---|
| 0.5 | 0.23 |
| 1.0 | 0.18 |
| 1.5 | 0.14 |
| 2.0 | 0.13 |

### *Fly ash + Metakaolin + M sand + Hydrogen peroxide*

This tile is cast with the combination of fly ash and metakaolin mixed with the aggregate of M sand. In this combo we get a high resistivity of heat at 0.5% and low at 0.5%.

Table 20. Fly ash+Metakaolin + M sand + hydrogen peroxide

| Percentage | Residual Bending Strength(N/Mm^2) |
|---|---|
| 0.5 | 0.42 |
| 1.0 | 0.38 |
| 1.5 | 0.34 |
| 2.0 | 0.2 |

### *Fly ash + Metakaolin + River sand + Hydrogen peroxide*

Here M sand is replaced with River sand and the same combo of fly ash and metakaolin is tested as the same at the 0.5% we get a good heat resistance value.

Table 21. Fly ash+Metakaolin + River sand + hydrogen peroxide

| Percentage | Residual Bending Strength(N/Mm^2) |
|---|---|
| 0.5 | 0.43 |
| 1.0 | 0.39 |
| 1.5 | 0.38 |
| 2.0 | 0.34 |

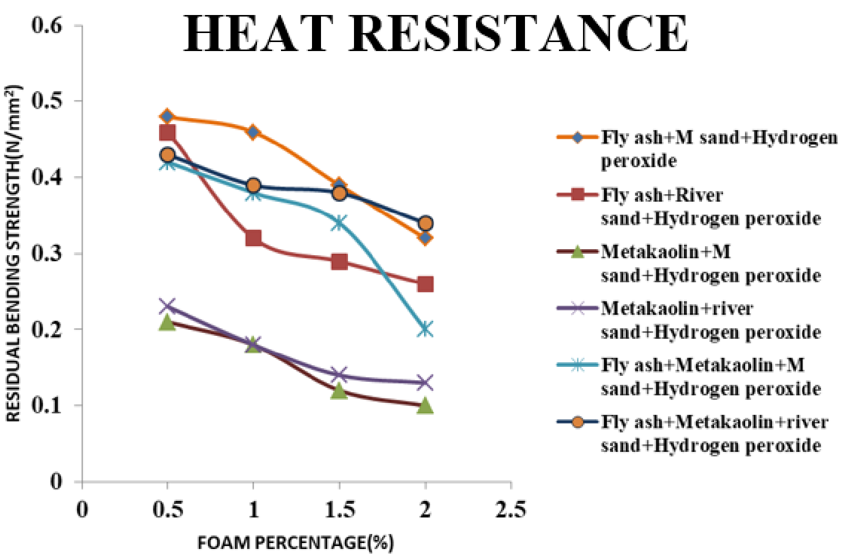



Figure 8. Heat Resistance

## 5.4 Thermal Conductivity

### *Fly ash + M sand + hydrogen peroxide:*

From Table 22 to 27, the thermal conductivity results are given, and it is pictured in Fig 9. Casting of tiles using fly ash, M sand and different percentages of $H_2O_2$.And after curing it is kept in a thermal conductivity tester and after the test results get ready. For 0.5% the thermal conductivity is about 0.3W/mK and at 2% it gets reduced.

**Table 22.** Fly ash + M sand + hydrogen peroxide

| Percentage | Thermal Conductivity(W/Mk) |
|---|---|
| 0.5 | 0.3 |
| 1.0 | 0.23 |
| 1.5 | 0.21 |
| 2.0 | 0.1 |

### *Fly ash + River sand + hydrogen peroxide*

At the 2% we get a less thermal conductivity of 0.12% and we get a high density at 0.5 %. At the high density we get a high thermal conductivity. At 1% we get a thermal conductivity of about 0.24W/mK.

**Table 23.** Fly ash + M sand + hydrogen peroxide

| Percentage | Thermal Conductivity(W/Mk) |
|---|---|
| 0.5 | 0.32 |
| 1.0 | 0.24 |
| 1.5 | 0.22 |
| 2.0 | 0.12 |

### *Metakaolin + M sand + hydrogen peroxide*

In this the combination of metakaolin M sand and adding different percentages of hydrogen peroxide. In this, due to a light weight this has a very low thermal conductivity. At 2% the thermal conductivity is 0.10W/mK.

**Table 24.** Metakaolin + M sand + hydrogen peroxide

| Percentage | Thermal Conductivity(W/Mk) |
|---|---|
| 0.5 | 0.14 |
| 1.0 | 0.11 |

| | |
|---|---|
| 1.5 | 0.10 |
| 2.0 | 0.10 |

### *Metakaolin + River sand + hydrogen peroxide*

This tile is made of metakaolin, river sand and adding various percentage of hydrogen peroxide. This combination is of range 1W/mK.

Table 25. Metakaolin + River sand + hydrogen peroxide

| Percentage | Thermal Conductivity(W/Mk) |
|---|---|
| 0.5 | 0.12 |
| 1.0 | 0.1 |
| 1.5 | 0.1 |
| 2.0 | 0.1 |

### *Fly ash + Metakaolin + M sand + hydrogen peroxide:*

In this the fly ash and metakaolin are added at 50% of the weight taken. After casting, the curing is over. It is kept in a thermal conductivity tester and after the results are ready it is noted. At 0.5% we get a thermal conductivity of about 0.32W/mK.

Table 26. Fly ash+Metakaolin + M sand + hydrogen peroxide

| Percentage | Thermal Conductivity(W/Mk) |
|---|---|
| 0.5 | 0.32 |
| 1.0 | 0.30 |
| 1.5 | 0.25 |
| 2.0 | 0.22 |

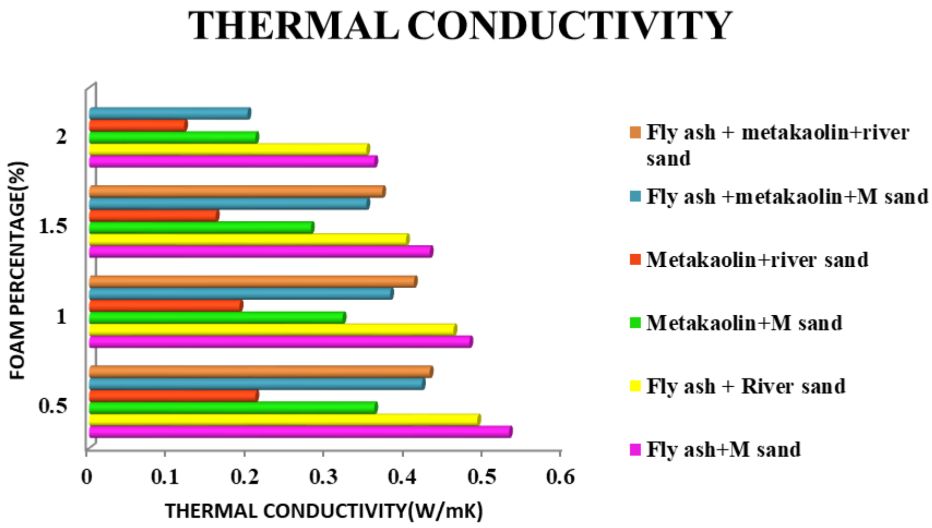
### *Fly ash + Metakaolin + River sand + hydrogen peroxide*

Fly ash and metakaolin are added to this at 50% of the weight originally collected. The tile is maintained in a thermal conductivity tester until the results are ready to be documented. Thermal conductivity at 0.5% is approximately 0.3 W/mK.

Table 27. Fly ash+Metakaolin + River sand + hydrogen peroxide

| Percentage | Thermal Conductivity(W/Mk) |
|---|---|
| 0.5 | 0.3 |
| 1.0 | 0.29 |

| | |
|---|---|
| 1.5 | 0.27 |
| 2.0 | 0.23 |




## 6. Conclusion

From the above tests we conclude that:

- With the combination of fly ash, Metakaolin with M sand by adding 1.5% of hydrogen peroxide, lightweight of 1499.73 kg/m^3 has been achieved.
- The flexural strength is high, about 0.371N/mm^2.
- Residual bending strength is about 0.34N/mm^2 with Fly ash +Metakaolin+ M sand +2%Hydrogen peroxide
- By analyzing overall, the best combination of tiles is obtained with the mixture of (Fly ash + Metakaolin +M sand + 1.5% of H2O2)

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