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Improving the Thermostone Properties by Treating with Some Additives

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Abstract

Thermostone industry is constantly evolving After its emergence as a distinctive building material, especially in terms of thermal and sound insulation, lightness and the preference for its use in construction, due to the speed of implementation and low costs, its use as reinforced panels was developed and was not limited to block walls only, this material began to appear in some buildings as a material to fill concrete structures and a material for creating partitions, and then it was adopted as a basic building material and it will have an effective role when integrating the industry of open system building systems that can be developed. This research examines ways to enhance specifications and create a thermostone building system that, in terms of function, performance, and construction techniques, both meets the needs of regional architecture and the technical development process as a whole. The research's goal is to increase the requirements of thermostone by introducing additives like polypropylene at a rate ranging from 1 to 5%. The addition of sodium sulfate (Na_2SO_4) or organic fumigants (phosphine and sulfur) as well as three percentages, where 20% produced the best results. The substitution of a portion of one of its constituent materials with another component, as in the replacement of 2% of sand with fly ash powder after re-grinding it to a fineness of 75-85 micrometers to suit the mixing process and the use of white sand with a purity of up to 95%. The best results were obtained when replacing a powdered glass (the best replacement percentage is 10%). the best formation percentage is 0.12%, and the research regulated the ratios of the original thermostone ingredients, such as aluminum, with decrease and increase to achieve the best outcome.

1. Introduction

The light concrete industry (thermostone) is considered one of the industries that can be developed in composition and in ways and means of use because it is a material with high specifications in terms of insulation, lightweight, speed of implementation and low costs (in building walls).

Thermostone was invented in 1924 in Sweden in order to preserve buildings, where John Alison based his initial experiments on making light concrete, where he decided to produce porous concrete and this year it became a commercial product given the name (ytong). In 1945, Joseph Heil, owner of a German company, was able to develop the Swedish world product, adding iron reinforcement to the product and the concrete became armed [1].

Given that it is used in between 50 and 80 percent of the buildings constructed in Europe and between 25 and 40 percent in Asia and Australia, thermostone has become a crucial and ideal building material since the years following the Second World War. The ASTM Institute has established the thermostone's specifications [1].

Currently there are many thermostone laboratories in the world (Australia, China, Russia, India, Germany, France, Israel, Japan, Kuwait, Malaysia, Mexico, Poland, Arab countries, Turkey, (after the use of light concrete on a large scale in Western European countries and the group of socialist countries, especially in residential and administrative buildings, it met with unparalleled success in developing countries, including Iraq [2]. Thermostone industry has developed in Iraq, where this most effective construction material has advanced to compete with other construction materials and makes an effective contribution to the implementation of construction projects of the development plan and helps support the economy [2].

The thermostone industry in the country illustrates its development and its global role in construction. Factories have been established geographically distributed over many governorates and this material is beginning to appear in some buildings, especially as a dictation material in concrete structures and as a material for creating partitions, and then it has been adopted as a basic building material and will have an effective role in the integration of systems industry Open building (OPEN SYSTEM BUILDING) that can be developed. The emergence of these systems and their presentation in the market will have the greatest role in accelerating the process of building many buildings, especially those of a recurring nature [3, 4].

The research's objective is to enhance thermostone specifications with the addition of additive materials.

2. Thermostone Industry

Light concrete made from a mixture of sand, lime and cement. The sand is in different proportions according to the type of thermostone required, with the addition of Aluminium powder and other chemicals. The mentioned materials interact chemically, resulting in the formation of spherical cells as a result of the liberation of hydrogen gas. The reaction takes place after the mixture is poured into large melds and then cut in different dimensions as customized by special cutting machines and then subjected to a final hardening process inside steam ovens.

The light concrete produced is cut into small structural pieces by means of special wires that move in three dimensions and within a specific program during the cutting process. The outer surface is smooth and the dimensions of the pieces are accurate. The differences in measurements accepted in this industry are (TOLERANCE) [5] few and as follows:

In thickness	+2mm
In width	+3mm
In length	+5mm

These few differences give thermostone superiority over concrete and as it is considered a very good material for the purposes of preparing open building systems that do not have major problems in society and do not require highly developed labor.

2.1. Thermostone Characteristics

2.1.1. Lightweight

Thermostone is characterized by its lightweight, with a density of 400-900 kg/m^3, and therefore the cost of construction is economical and this is reflected in many things such as the size of the foundation and for the purpose of comparison in the matter of density with some materials used in construction, below are the weights of some of these materials as shown in Table (1).

Table (1). Weights of basic building materials [5].

Material	Weight kg/m^3
Ordinary concrete	2300
Limestone	1700
Clay bricks	1400
Thermostone	700
Lumber	600

2.1.2. Heat and Sound Insulation

Thermostone is characterized by a good ability to sound and thermal insulation due to the presence of air bubbles in its mass. The degree of its thermal insulation depends on the coefficient of thermal conductivity, which is a function of the number of calories passing through one square meter of a wall thickness of 1 m within one hour to increase its temperature by one degree Celsius and the presence of air bubbles in concrete in light, the coefficient of thermal conductivity of air is 25%. Therefore, the thermal insulation properties of light concrete depend on its volumetric weight, and it increases with increasing density and from (6%-20). The value of the modulus changes within the same density and degree of the thermostone depending on the size of the spaces, the way they are arranged and the moisture of the material [6, 7].

Thermal Insulation

Due to the good thermal insulation property of thermostone (the thermal conductivity coefficient is 0.12-0.14 °C/m) compared to the clay brick, which has a coefficient of 0.59 °C/m, we note that the thickness of 24 cm of thermostone construction is equivalent to the construction of ordinary bricks with a thickness of 36 cm in terms of ability to work thermal insulation and durability, thus saving a third of building materials and labor costs resulting from the thermal insulation ability of ordinary bricks, according to which the energy spent on heating and cooling is reduced by 60% of the electricity bill, which reduces the cost to the citizen and the stat. [8].

Acoustic Insulation

Thermostone is characterized by a distinct ability to sound insulation, i.e. isolating noise and sounds emitted from outside the building, which increases as a result of civilized and industrial progress. The thickness of 24 cm of thermostone insulates the sound by 48 decibels, which is equivalent to a thickness of 64 cm of ordinary bricks, and is equivalent to a thickness of 77 cm in the case of Cement cladding from both side. [9,10].

2.1.3. Susceptibility of the Thermostone to Water Absorption

Thermostone needs 90 days, during which the water passes through a distance of 24 cm from it. This means that a wall without a cement cladding and a thickness of 24 cm is exposed to rain for a period of three months in order for moisture to permeate through it, due to the absence of capillary channels significantly compared to the rest of the building materials, which makes the thermostone in a better location.

2.1.4. Speed of Construction Completion

The speed of completion of construction with thermstone is much higher compared to ordinary bricks due to its lightweight and large size, as the time required to build a cubic meter with ordinary bricks takes 7-9 hours, while it takes only four hours when building in thermostone.

2.1.5. Economy in the Mortar

One cubic meter of normal brick construction needs 27% cubic meter of mortar (cement, sand, plaster and lime), while building with thermostone needs 7% cubic meter of mortar for the same volume, i.e. thermstone needs 1/4 of mortar quantity for that used in brick [11, 12].

2.1.6. Economics in Basics

Due to the lightweight of the thermostone, the load placed on the foundations is less than when building with other materials such as clay bricks, lime bricks and concrete blocks, which leads to an economy in the sizes of the foundations constructed for buildings.

2.1.7. Durability

Despite the lightweight of thermostone, it has a good bearing strength, as it is possible to construct 3-4 floors with thermostone without the need for concrete structures, as its bearing strength is not less than 50 kg/cm^2 depending on the density, the tensile strength is equivalent to 20% of the compressive strength.

2.1.8. External Cement Cladding

Thermostone construction saves a good part of the cost of cement cladding because the straight and smooth walls built from thermostone consume materials and shorter time in the process of spraying and whitening them, as there is no need to polish the external surfaces, and it is sufficient to treat thermostone, for example, with a sprinkle of colored cement.

2.1.9. Salts, Expansion Coefficient, Temperature Tolerance and Moisture Resistance

Lack of salts in the installation of thermostone, the expansion coefficient of thermostone is low compared to other building materials as it is 0.34 mm/m^2, Thermostone bears high temperatures and thus is safe in fire safety in addition to its resistance to freezing and its resistant to moisture and water absorption as it has few pores.

2.1.10. Rotting

Thermostone is characterized by high resistance to rotting when exposed to mold and bacteria, and the best conditions for rotting at a temperature of 30°C and a relative humidity ranging from 95-98% [13, 14].

2.1.11. Change of Appearance and Delivery of Services

Thermostone can be punctured and water pipes, electric wires, and telephones can be passed through it. By means of screws in thermostone, this characteristic gives thermostone a good advantage compared to ready-made reinforced concrete, which is difficult to insert such services into. As for the services of sanitary establishments, they are also easy to install, especially when placed in the typical network and studying its isolation from ceilings and walls to avoid water penetration into thermostone in a quantity Large when there is a malfunction in the health system, and for this purpose, spaces must be left instead of the thermostone hole for the pipes to pass.

Raw materials are stored in warehouses to protect them from changes in extreme weather conditions. Materials such as lime, plaster, cement, carbon and aluminum are brought directly and used. The materials are weighed using an electronic scale. Water is placed with aluminum powder. After weighing the aluminum, cold or hot water is used and weighed on the scale. The raw mill is mixed and then the product is transferred to the cutting mold. The temperature rises. Heat when mixing so wait before chopping [15]. The traditional mixture consists of the following materials, with a density of 600 kg / m3 showed in Table (2) [15].

Table (2). The traditional mixture materials with a density of 600 kg/m^3.

Material	Percentage of material
Sand	68%
Nora hot	20%
Cement	10%
Plaster	2%
Aluminium of the total volume of the mixture	0.074%
Water	60-65%.

3. Experimental Procedure: The Types of Additions that Were Used in the Research

- Replacing part of the sand with coal powder (fly ash)
- Replacing part of the sand with glass powder
- Addition of polypropylene.
- Addition of toxic organic fumigants (phosphine and sulfur) known for their effectiveness against rodents.
- Controlling the amount of aluminum, by shortage or excess, to reach the best specifications.

The devices used in the research are:
- A jaw cousher or ball miller.
- High sensitivity balance
- Plastic moulds.
- Drying oven at a temperature of 190℃ and under a water vapor pressure of 8-12 atmosphere.
- Piston.
- The mixing temperature was 42-83℃.

3.1. Replacing Sand with Fly Ash
Fly ash is used after grinding it to suit the mixing process because the power plants produce a large amount of (fly ash) that can be made as a raw material for work as the material is produced daily. The charcoal is mixed and formed (completely cross-linked matrix) with thermostone raw materials. With rates starting from 10% up to 70% and under pressure of 10-20 kg/cm^2, a solar collector can be used to obtain cheap energy in production processes.

3.2. Replacing Sand with Glass Powder in Certain Proportions
The glass was collected from the glass waste of the lamp factories and was used after washing, cleaning and grinding for obtaining the best results.

Aerated concrete blocks were mixed with different percentages of the remaining glass in order to achieve certain requirements in the industry while preserving the environment by getting rid of glass waste, where the thermostone was ground as well as the glass was ground separately, then glass powder was added as weight ratios starting from 2% up to 20%, of the total weight into thermostone powder, then mixing, pressing and drying, and then the samples are transferred to the autoclave oven.

3.3. Addition of Polypropylene
Polypropylene has been added at rates ranging from 1% to 5%, and adding toxic organic fumigants (phosphine). Polypropylene (PP) is a synthetic glue formed from the polymerization of propylene. It is one of an important family of polyolefin glues. Polypropylene is convertible into many plastic products that require stiffness, flexibility, light weight and heat resistance because it possesses its electrical and mechanical properties at elevated temperatures, in wet conditions and when immersed in water and has excellent resistance to environmental stress or cracking. It is sensitive to microbial attacks such as bacteria and putrefaction.

3.4. Addition of SO_4 Sulfate to Thermostone
Sulfate is considered one of the cheap materials and is known for its ability to withstand pressure and the possibility of increasing the porosity. Sulfur powder has been added at rates ranging from 0% to 4%.

3.5. Controlling the Proportion of Aluminum Powder in the Thermostone
Aluminum powder is added after mixing with small amounts of sand to prevent the powder from floating on the surface of the mixer, the mixing continues up to 2 min.and within 3 houres the whole test time ends. Aluminium powder was added in percentages ranging from 0.00 - 0.15%. Figure (1) shows samples of **the** Types of Additions that Were Used in the Research.

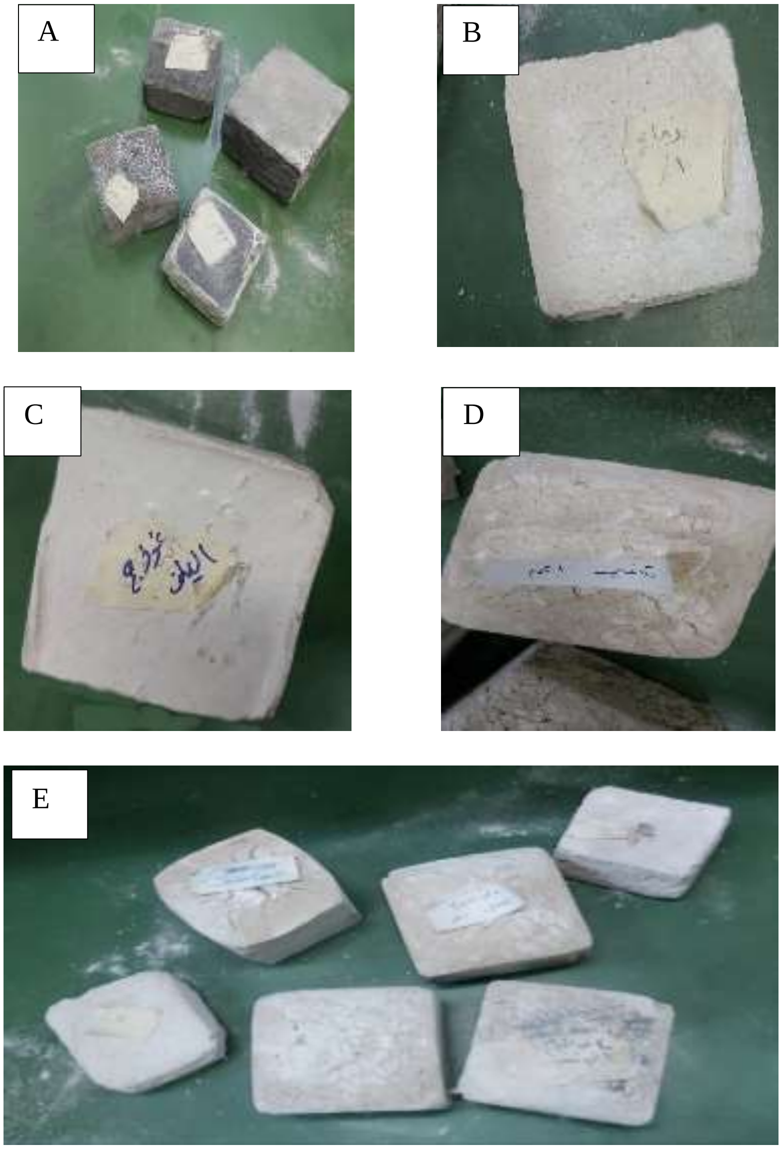

Figure (1). Samples of the Types of Additions that Were Used in the Research: (A) replacing Sand with Fly Ash, (B) replacing Sand with Glass Powder, (C) addition of Polypropylene, (D) addition of SO_4 sulphate, and (E) controlling the Proportion of Aluminum Powder.

4. Results and Discussion

4.1. Results of Replacing Part of the Sand with Coal Powder (Fly Ash)

Fly ash is added to freshly mixed cement to reduce the amount of water required for mixing as well as to function as a "lubricant" to make the cement more workable. This not only results in a smoother, flatter finish but also enhances the pump ability from the mixing truck.

Due to the additional binding component fly ash adds to the chemical reaction equation, cement mixed with fly ash will continue to strengthen over time as it hardens. Fly ash is used after grinding it to suit the mixing process because the power plants produce a large amount of (fly ash) that can be made as a raw material for work as the material is produced daily. The charcoal is mixed and formed (completely cross-linked matrix) with thermostone raw materials. Table (3) shows the behavior of coal, as it exhibits an ideal behavior up to 20%, as it offers high strength compared to lightweight, constant low conductivity coefficient with changing temperature and humidity, flame retardant, low density, suitable for short work for the load of the building.

Table (3). The relationship of coal with the properties of thermostone.

Sample No.	(fly ash) %	Compression kg/cm²	Porosity %	Density
0	0.0	40	60	0.65
1	20%	50	55	0.63
2	40%	48	65	0.68
3	60%	26	70	0.7

By reusing or recycling the fly ash to make concrete products, the impact of fly ash on the environment can be reduced, instead of simply sending this hazardous waste to the landfill. Moreover, the concrete's permeability is decreased, enhancing long-term durability. It is resistant to freezing temperatures and non-shrinking material, making it more durable against cracking and crumbling. The pressure increases in the case of 20% at 50 kg/cm^2 as shown in Figure (2) and the porosity increases at 60% as shown in Figure (3), but the pressure decreases to 26 kg/cm^2 as shown in Figure (4), so the addition of 20% is considered the best ratio of burnt powder to improve specifications. Reducing the cost and effort, since the sand needs to be purified and washed, while we can dispense with these steps when using coal.

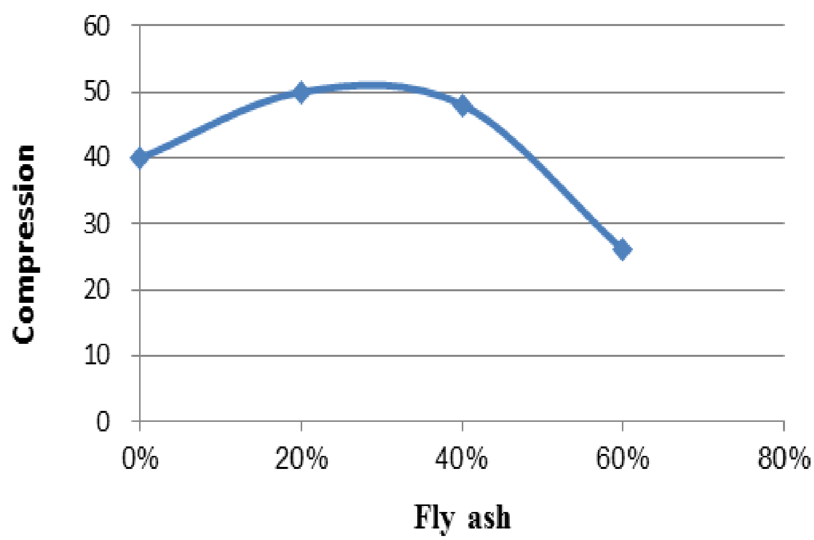

Figure (2). The relationship of pressure with the amount of coal.

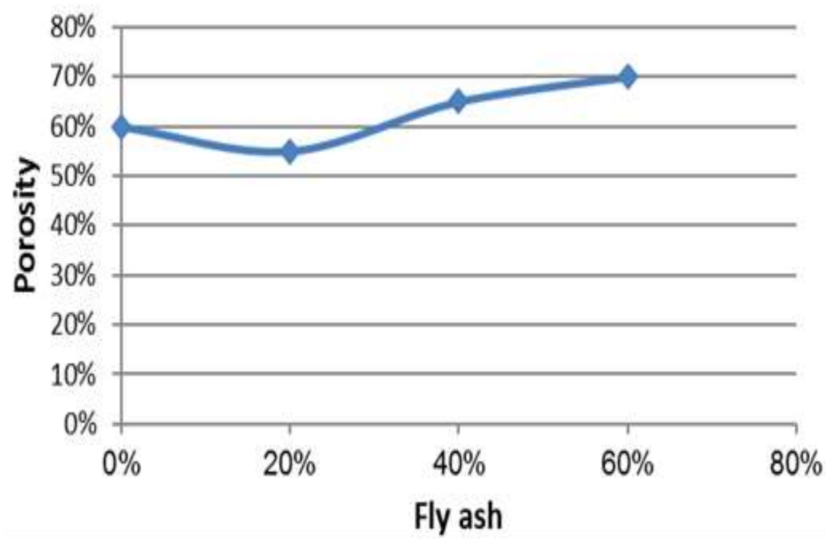

Figure (3). The relationship of porosity with the amount of coal.

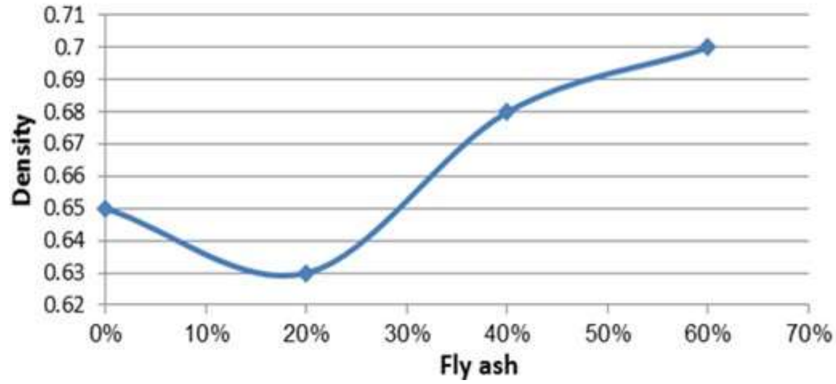

Figure (4). The relationship of density with the amount of coal.

4.2. Results of Replacing Sand with Glass Powder at Rates of 2-20%

Sand was replaced with glass powder in different proportions, starting from 2% up to 20%. Replacing sand with glass powder in certain proportions, in addition to good resistance to steam sterilization. known for their effectiveness against rodents and it turned out that the best replacement ratio was 10%, where the pressure becomes 45% kg/cm^2 and the porosity increases to 62%. The density reaches 0.72 kg/cm^3 as shown in Table (4) and Figures (5, 6, & 7).

Table (4). Relationship of glass sand with the properties of thermostone.

Sample No.	Glass powder	Compression kg/cm^2	Porosity %	Density kg/cm^3
1	2%	40	60	0.7
2	10%	45	62	0.72
3	20%	35	65	0.75

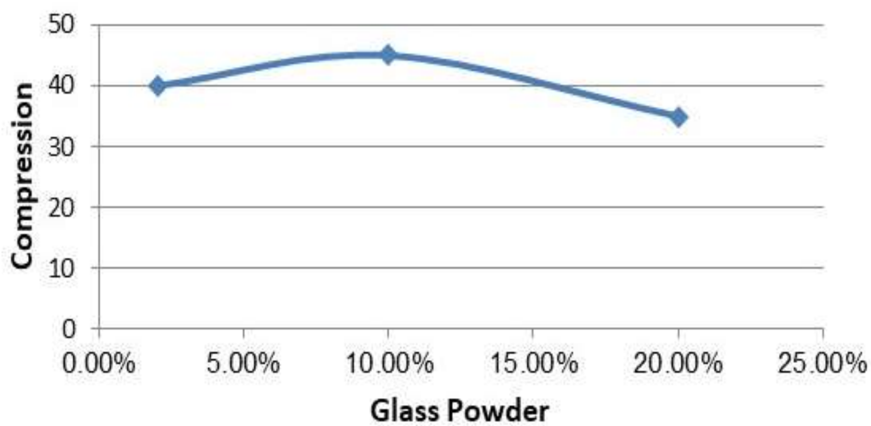

Figure (5). The relationship of pressure with the amount of glass powder.

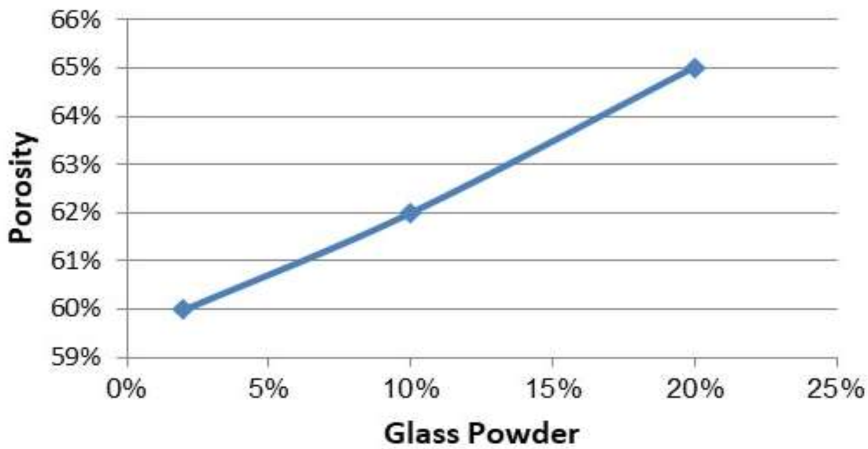

Figure (6). The relationship of porosity with the amount of glass powder.

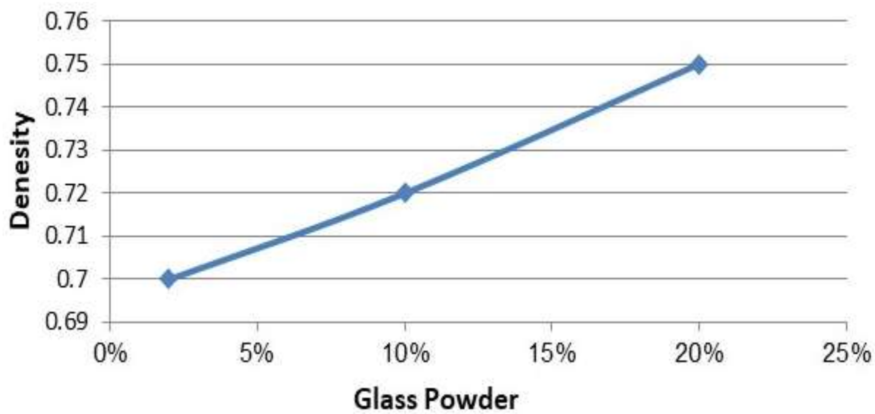

Figure (7). The relationship of density with the amount of glass powder.

4.3 Addition of Polypropylene (1%-5%)

Naturally resisting rodents by avoiding the use of toxic dusting materials as it contains iodine (I), nickel (Ni) and molybdenum (Mo), and it turns out that the best percentage of addition is 3%, and increasing the ratio reduces compressibility and reduces density by the value of the presence of polypropylene and increased porosity was also achieved, and this is evident in Table (5) and Figures (8, 9, & 10).

Table (5). The relationship of polypropylene with the properties of thermostone.

Sample No.	Poly propylene	Compression kg/cm²	Porosity %	Density Kg/cm³
0	1%	40	60	0.65
1	2%	42	58	0.54
2	3%	44	56	0.55
3	4%	35	35	0.4
4	5%	26	26	0.35

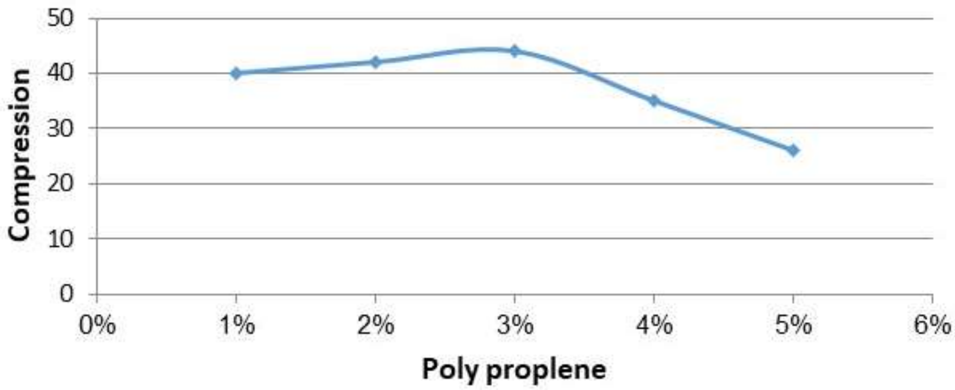

Figure (8). The relationship of pressure with the amount of polypropylene.

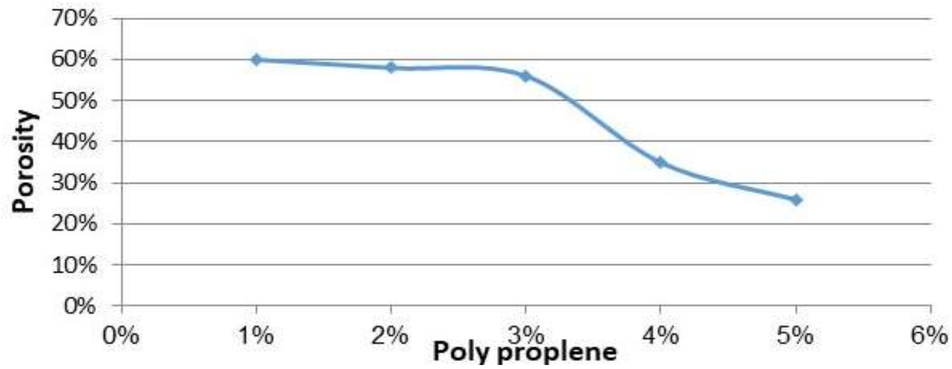

Figure (9). Relationship of porosity with the amount of polypropylene.

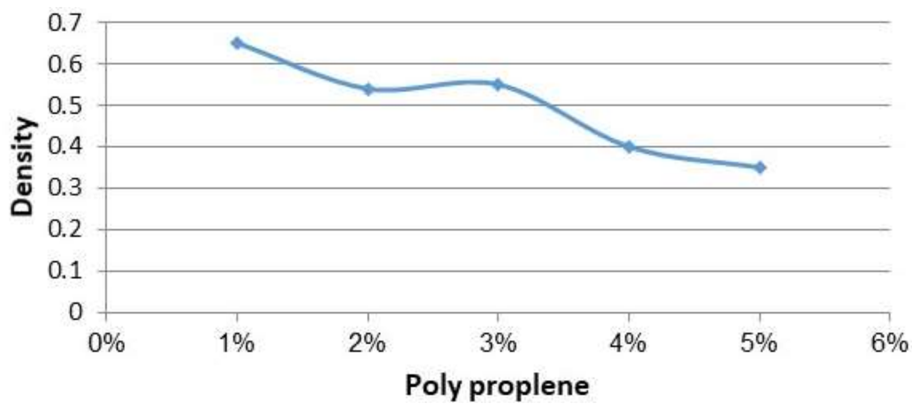

Figure (10). Relationship of density with the amount of polypropylene.

4.4. Results of Addition of SO_4 Sulfate to Thermostone

Sulfate is considered one of the cheap materials and is known for its ability to withstand pressure and the possibility of increasing the porosity. Sulfur powder has been added at rates ranging from 0% to 4%.

Exploitation of raw materials whose availability may cause a lot of pollution to the environment and make their products environmentally friendly materials. The best addition rate was 2%, as the pressure increased and the porosity stable. Table (6) and Figures (11 & 12) illustrate the relationship of pressure and porosity with sulfates. It turned out that the best addition is 2%, where the pressure becomes 44 kg/ cm² and the porosity 35% and as shown in Table (6).

Table (6). Relationship of sulfate with the properties of thermostone.

Sample No.	SO_4	Compression kg/cm²	Porosity %
0	0%	40	60
1	1%	42	73
2	2%	44	77
3	3%	35	75
4	4%	26	74

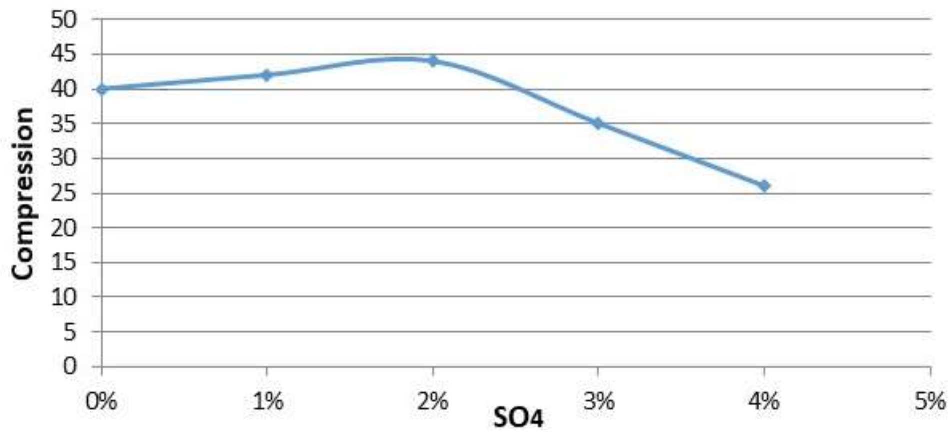

Figure (11). is the relationship of pressure with the amount of sulfate.

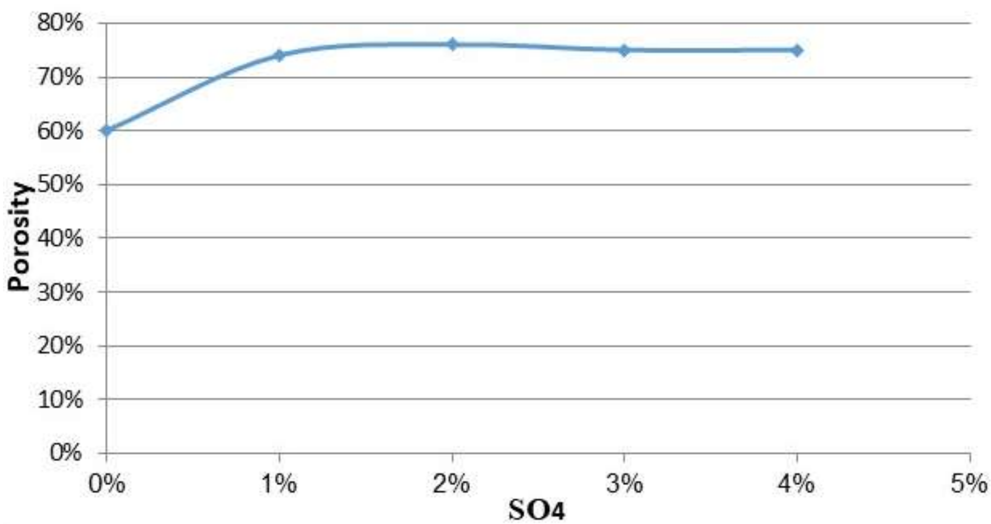

Figure (12). Relationship of porosity with the amount of sulfate.

4.5. Results of Controlling the Proportion of Aluminum Powder in the Thermostone

The strength increases when adding 0.12% of aluminum with an increase in porosity to 75% and aluminum can be produced to reduce the cost of producing thermostone from aluminum exhaust. Table (7) and Figure (13) shows the relationship of pressure and aluminum powder and shows Figure (14) The relationship of porosity of aluminum powder as Figure (15) shows the relationship of density to aluminum powder.

Table (7). The relationship of aluminum powder with the properties of thermostone.

Sample No.	Al powder	Compression kg/cm²	Porosity %	Density
0	0%	40	70	0.6
1	0.08%	36	74	0.63
2	0.12%	42	75	0.62
3	0.15%	39	74	0.62

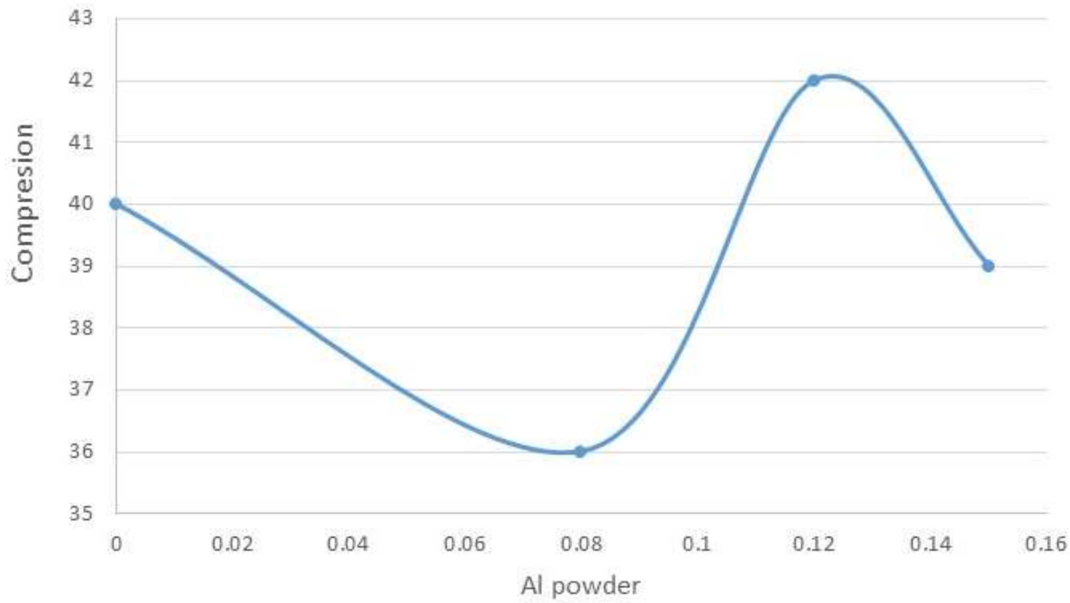

Figure (13). The relationship of pressure with the amount of aluminum powder.

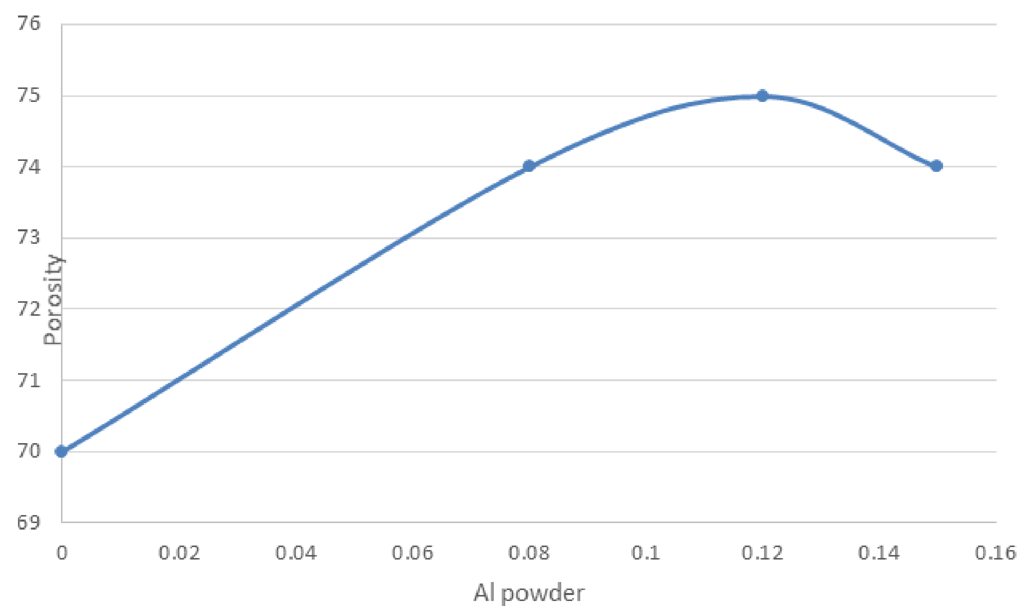

Figure (14). Relationship of porosity with the amount of aluminum powder.

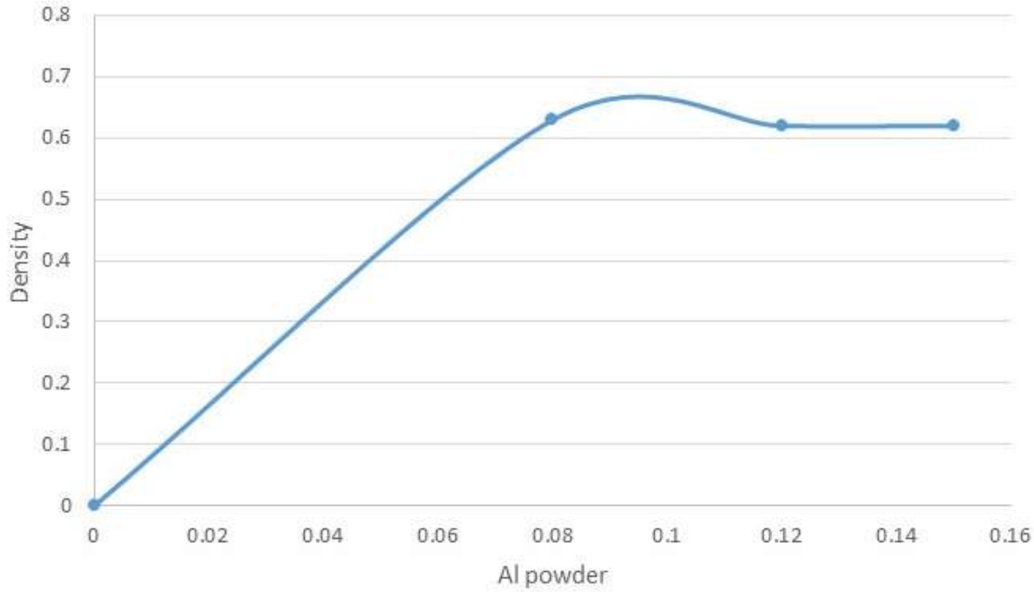

Figure (15). The relationship of density with the amount of aluminum powder.

By studying the results of this replacement, it was found that it achieves the following:
1. Cost Reduction.
2. Eliminate some environmental pollutants by using them as a component in the thermostone industry.
3. Improving the chemical properties of thermostone.
4. Increasing the permeability and preference in terms of density, absorbency and insulation strength, as shown in Table (4) White sand can be used due to the low salt content in it and its purity up to 95%

Adding polypropylene in percentages of 1-5% as shown in Table (5):
1. Increasing the strength by adding reinforcing materials to the thermostone.
2. Elimination of some environmental pollutants by using them as a component in the thermostone.
3. Cost Reduction.
4. Increased porosity.

5. Conclusions

Fly ash behaves best when applied at a 20% concentration because it has a high strength to weight ratio, a steady low conductivity coefficient with changing humidity and temperature, flawless ignition resistance, a low density, and is appropriate for quick work of increasing load. 10% is the ideal replacement percentage for sand, increasing the pressure to 45% kg/cm^2 and the porosity to 62%. There is a 0.72 kg/cm^3 density. It turns out that 3% is the optimal level of polypropylene addition; as the percentage rises, compressibility and density decrease by the polypropylene value. The pressure rises to 75 kg/cm^2 and the porosity reaches 44% with 2% sodium sulfate addition (Na_2SO_4).

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