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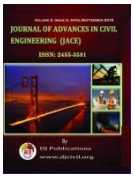

RESEARCH ARTICLE

Construction of Reusable Terrace Roof using Blended Paper Pulp and Silica Aerogel

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ABSTRACT

The main objective of this paper is to provide an eco-friendly and reusable terrace roof that reduces the effect of heat during the summer seasons. The goal is achieved with the help of paperboard and silica aerogel that aids in effective protection against heat. Silica aerogel is prepared from rice husks and paper pulp is manufactured from waste paper materials contributing to reduced utilization of crisp raw materials. The supporting structure of the terrace roof is constructed using steel frames that are welded together by gas metal arc welding. The outer skin of the roof is riveted with the supporting structure. The roof can be detached and anchored easily depending upon the climatic requirements.

Keywords: Terrace roof, Paper pulp, Silica aerogel, Gas metal arc welding, Rivet.

1. INTRODUCTION

Reusable paper can be used in the construction of temporary structures since it is cost effective and environmental friendly which can be recycled. In countries like India, summer heat is rising due to the effect of global warming. This paper concentrates on reduction of the terrace roof heating that penetrates to the interior during the summer season by the use of paper tubes and silica aerogel.

[1] A detailed note on the fabrication mechanics of the paper tubes used in the construction purpose have been discussed and factors affecting the paperboard tubes such as temperature, moisture, humidity etc. had been examined completely to promote the growth of paperboard tubes in structural engineering. [2] explored the adoption of small arc length and hemicycle sectors of paperboards as molds for cross over decks. Experimental verifications were conducted and it has been suggested that paperboard tubes are more commercial in the manufacturing process of molds for bridge decks. [3] analysed the penetration of oils into the paperboards in food packaging industries to promote the safety by using a bio-composite hindrance between the edible material and paperboard. [4] clarified the entire fabrication technique, its past and features of the paper and paperboards that are used for packaging process.

[5] evaluated the apt terrace roof construction for hot seasons in North Cyrus. From the evaluation it has been concluded that the roofs with heat resistant will perform well in the entire year for both hot and cold seasons when provided with better ventilation. [6] elucidated a research work on the construction of terrace roof using greenery intermediate. Although this is environmental friendly and energy potent, it provides no guarantee for practical applications. [7] illustrated several approaches to reduce the effect of heat inside the buildings. Still, all these methods demands less energy and several design features have to be considered for real time implementations. [8] revealed the apathetic design of terrace buildings to supress the side effect of heat for a comfortable life of the people in Malaysia. Granting a heat comfort zone, this method does not take into account, the economic benefits of this type of construction.

[9] demonstrated the arithmetic simulation of heat transferred in the form of vapour in terrace buildings with flat openings

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through TRNSYS-COMIS application. The face of flat openings provided a good comfort level. However safety of the house and belongings become a huge barrier for this approach. [10, 11] brought out various approaches and application of lofty execution of concrete in manufacturing industries besides specifying its features and parameters. Even though this material is very firm, it has less impact on the life span of the building.

[12] discussed the establishment and evaluation of blended silica aerogel and nano atoms of gold along with its properties. Eventhough the nanomaterial has promising characteristics, pragmatic applications are only suggested but not proved. [13] determined and analysed the performance of Phase Change Materials (PCMs) combined with gypsum plank as roof panels for providing good cooling effect inside the dwelling. Even if this scheme consumes less energy, there is a need for experimental confirmation. [14, 15] interpreted a summary on the effect of reveals on heat removal coefficient in the insulated residence. The analysis had been carried out for a fixed heat transmittance and immovable spot, henceforth not considering the sensible climatic changes which is a drawback.

[16] spelled out the screening of climatic conditions in similar low energy approved dwellings. This work recommended few changes in the dwellings based on average domestic temperature and on the other hand impact of inhabitant, opening and closing of windows were not taken into account. [17] reported the distinguishing characteristics of synthesized natural rubber to serve in the field of construction. But the process of manufacturing synthesized rubber is a tedious process.

This paper focuses on the construction of terrace roof using paperboard and silica aerogel to prevent the transmission of heat during summer days. Both the construction materials have numerous advantages than other existing methods.

2. METHODOLOGY

2.1. Terrace roof

Roof is the uppermost part of the house that acts as a barrier against changing climatic conditions. The features of the roof depend upon its purpose of usage. The substances used for constructing terrace roof may include asbestos sheet, concrete, laminated grass, straw, ceramic tiles, etc. The different types of roofing materials are depicted in figure 1.

Figure 1.Roofing materials

The architectural elements in the roof construction depend upon the materials and shape. The development of roof is based on the aiding methods available, roof pitching and the connection of roof and space below. The shape of the roof relies on the environmental conditions and available raw materials. The roof shape may be flat, dome, arch etc. There are two main parts of a roof viz the aiding method and the superficial layer. The aiding structure generally consists of beams or lintels made up of timber, iron, bamboo and steel. The superficial layer is the outermost visible layer of the roof constructed using slate, asbestos, sheet metals, hay, etc.

2.2. Paperboard

Paperboard is the thickest form of paper. Since paperboard can be easily altered, it finds application in construction, packaging and sculpture making. Paperboards can be single or multi-layered depending upon the application.

2.2.1. Manufacturing process

Paperboards are generally manufactured from raw materials such as wood, waste papers and plant products. The fabrication process usually starts with the grinding of raw materials into pulp in which the cellulose fibres are separated. There are various process that are used for converting raw materials into pulp. They are given below as follows

- Mechanical Pulping

In this process, a sharp stone combined with silicon carbide or aluminium oxide is used to crush small pieces of wood resulting in mechanical pulp which is showcased in figure 2. If the wood is subjected to vapourization

before crushing, then the resultant pulp is known as thermo-mechanical pulp. And if the raw material is handled with some chemicals before vaporization and crushing, it is considered as chemithermo-mechanical pulping.

Figure 2.Mechanical pulp

- Chemical Pulping

Chemical pulp is obtained by grinding wood along with chemicals in large vessels. Due to chemical reactions, cellulose fibres get separated from the raw material which is given in figure 3.

Figure 3.Chemical pulping process

- Recycled Pulp

Pulp obtained from old materials like magazines, newspapers etc. after the elimination of inks.

After the conversion of raw materials into pulp, it is made to proliferate into a moving belt. The pulp is dehydrated to remove water through evaporation and vacuum. Subsequently after dehydration, the entire material is pressed to remove the excess precipitation and hence subjected to high pressure steam using rollers. If necessary, resins may be added to strengthen the paperboard. Finally calendar stack is employed to smoothen the paperboard. For normal papers, succeeding pulping bleaching is done inorder to retail white colour to the paper which is highlighted in figure 4.

2.2.2. Properties of paperboards

The most important properties of paperboard includes physical properties, optical properties, strength properties, miscellaneous properties, electric properties and thermal properties.

Figure 4.Bleached pulp

2.2.2.1 Physical properties

- Grammage

The primary mass or grammage is the most important property of the paperboard. Grammage is defined as the weight of the paperboard per unit area. The grammage value of paperboard is 120-300 g/m^2 with a tolerance value of ±5%.

- Bulk

Bulk refers to the volume or thickness of paperboard with respect to weight. High bulk paperboards are used for absorbent purpose while low bulk paperboards are used for printing.

- Stability

Fibres of the paperboards are coordinated in the machine run control such that the presence of moisture alters the dimension of the paper.

- Hygroexpansivity

Hygroexpansivity cites the percentage of expansion or contraction of the paperboard due to the changes in the environmental conditions.

- Friction

Friction refers to the opposing force between the papers or the paperboard surfaces when they are brought in contact with each other. This property is expressed in coefficient of friction which is the fraction of frictional potential and perpendicular potential between two areas. Coefficient of friction can be measured with the help of two approaches using inclined plane and horizontal plane.

- Moisture

All the paperboards contain certain amount of moisture nearly in the range of 2-12% depending upon the raw materials used. The presence of moisture changes the electrical

and dielectric properties of the paperboard. Moisture weakens the bonding between the fibres. All other properties get changed due to the presence of water content. So the manufacturer has to take care during the fabrication process.

- Smoothness

This is the most important property needed for printing and writing. Smoothness indicates the flatness of the paper surface. Smoothness can be determined from three approaches especially Bekk method, Sheffield method and Print surf method.

2.2.2.2. Visual properties

- Brightness

Brightness of a paperboard refers to the percentage of blue radiation reflected back while striking the paperboard at a wavelength of 457 λ.

- Colour

Colour of a paper is in analogous to the visual recognition and is measured in terms of L a b system where L denotes the luminance of the paper, a denotes the colour from red to green and b stands for the colour from yellow to blue.

- Finish

Finish attributes to the combination of several characteristics such as silky, appearance and impressibility. There are different types of finish such as Smooth finish, Machine finish, English finish, Glazed finish etc.

2.2.2.3. Strength properties

- Bursting Strength

Bursting strength introduces the withstanding capacity of the paper ahead breach.

- Compressibility

Compressibility denotes the contraction in the consistency of the paperboard when concealed by compressive paper.

- Resiliency

Resiliency highlights the strength of the paperboard to retain its consistency after the removal of the compressive force.

- Tensile Strength

Tensile strength implies the strength of the fibres present in the paperboard and expressed in terms of kN/m.

- Wet Strength

Wet strength of the paperboard refers to the ability of the paperboard to tolerate aqueous solution.

2.3. Aerogel

Aerogel is a synthesized light weight gel material whose running component is compensated with gas resulting in a light weight and low heat conductivity. Aerogels do not have a definite chemical formula; they vary depending upon the minerals. Generally aerogels are made from oxides of silica, alumina, chromium and tin. In this paper silica aerogel has been used.

2.3.1. Preparation of silica aerogel

Silica aerogel is prepared from the outer covering of the rice grain. First the outer covering of the rice grain known as the husk is cleaned and baked at high temperature to obtain ashes. This ash is then blended with sodium hydroxide solution and subjected to boiling at 90°C. The resultant solution is denoted as Sodium Silicate Solution (SSS). SSS is filtered and again combined with kerosene. Both SSS and kerosene are whisked well. On the other hand HCL is added in drops to neutralize the solution whilst whisking so as to retrieve silica gel with a pH range of 6-7. The stirring process exceeds for more than one hour to get the quality get particles. The impurities from the gel were removed using solvent exchange process. During the solvent exchange process, dilute ethanol is used to avoid contraction of the gel. This wet silica aerogel is then dried using carbon dioxide supercritical drying as per the experimental setup shown in figure 5.

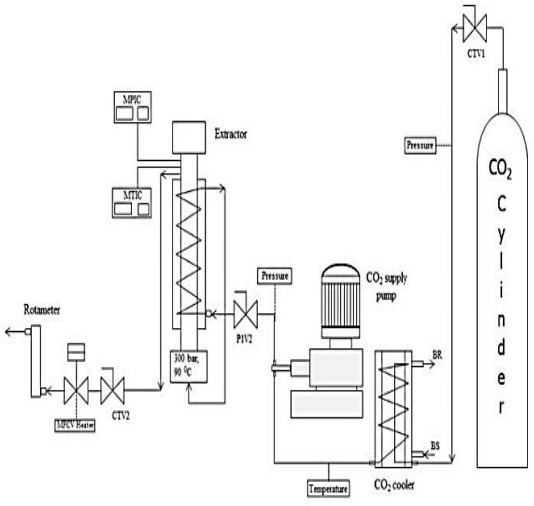

Figure 5.Supercritical drying

The setup consists of a CO_2 cylinder, rotameter, cooler and extractor. The wet gels are placed in a vessel in the extractor with a filter cloth to ensure uniform drying. Dilute ethanol is added to prevent deformation of the gel. The extractor is heated upto a specific temperature of 50°C and then exposed to high pressure CO_2 using plunger pump. Once the aerogel has reached a pressure of 150 bar, the CO_2 present in the vessel will be depressurized until it reaches the atmospheric pressure at constant temperature. The entire preparation process of silica aerogel is illustrated in figure 6.

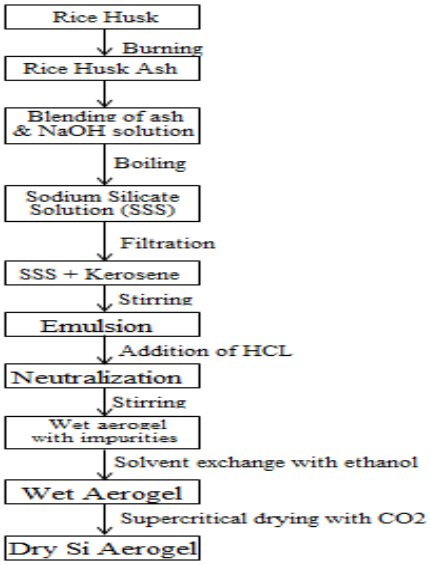

Figure 6.Flowchart for preparation of silica aerogel

2.3.2. Properties of silica aerogel

The various properties that distinguish silica aerogel are as follows:

- Silica aerogel exhibits extremely very low heat conductivity.
- They are the lightest solid material.
- Average stretch travelled by the gel particles during dispersal is low.
- Passage speed of sound is very less in silica aerogel material.
- Amount of thickness of silica aerogel can be altered.
- They are translucent in nature.
- Refractive index is very low.
- Small dielectric constant.
- They resemble fragile material but in nature they are rigid.

2.3.3. Applications of aerogel

Aerogels finds applications in diverse areas such as

- As an absorbent for cleaning spill over.
- As a condensing assistant in paints.
- As a catalytic agent.
- In optics and imaging.
- In purification of drinking water.
- In medicine delivery scheme.

3. RESULTS & DISCUSSIONS

First rice husks are collected to prepare the silica aerogel. The collected husks were cleaned, burned and then boiled with sodium hydroxide solution to obtain sodium silicate solution. A part of this sodium silicate solution is taken and kept aside for further usage in the preparation of pulp for the paperboard.

The remaining sodium silicate solution is stirred along with kerosene and after solvent exchange process with ethanol, wet silica aerogel is thus obtained.

For the manufacture of paperboard, three types of pulping namely mechanical, chemical and recycled pulp were produced and compared. For mechanical pulping, timber wood has been taken as the raw material and cut into small pieces and subsequently crushed using silicon carbide stone. In chemical pulping the timber wood is steamed, made to saturate with sodium hydroxide solution and processed further to obtain the pulp.

For recycled pulping, old newspapers, wrapping papers, magazines and waste papers have been collected and mixed with virgin fibres to gain more mechanical strength. Since recycled paperboards are used for construction purposes, there is no need for removing the printed inks from the papers. The raw materials (waste paper and virgin fibres) are mixed with chemicals to break down into cellulose fibres. Paperboards are manufactured in all the three methods for a length of 10 cm and thickness of 2 cm and comparisons were made in terms of materials as shown in table 1 and expenditure as in figure 7.

From the above table and figure we can interpret that overall cost and production efficiency is comparatively less for chemical pulping whereas it is higher for recycled pulping.

So finally pulp that has been fabricated from the old papers and magazines is used. No bleaching is performed after all the paperboard is used for terrace roofing. The pulp thus formed is blended together with wet silica aerogel to form a new compound material.

Subsequently this compound material is used to produce a paperboard with high thermal resistivity as highlighted in figure 8.

Table 1.Comparison based on materials and effects

Methods	Raw Materials	Processing Effects
Chemical Pulping	Wood along with chemicals	Gases are released during chemical reactions.
Mechanical Pulping	Wood	Production of saw dust
Recycled Pulping	Waste Papers and virgin fibres	Environmental friendly

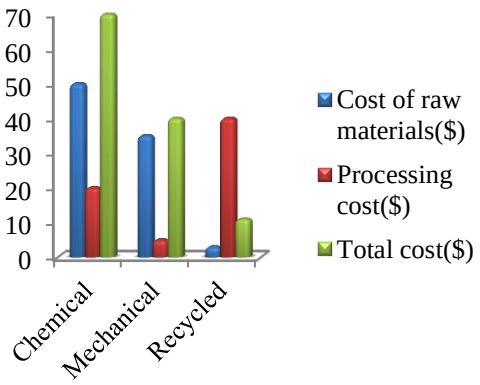

Figure 7.Correlation of three methods depending upon cost

Figure 8.Fabricated paperboard

The properties of ordinary paperboard and paperboard blended with silica aerogel have been compared in figure 9. It shows that paperboard that is blended with silica aerogel have better properties and qualities than ordinary paperboard.

Terrace roofing is erected for an area of 100 sq ft with four steel frames by drilling holes in the four corners of the parapet. The steel frames have a width of 190 mm and a height of 454 mm as shown in figure 10. The total weight of the beam is 67.1 mm.

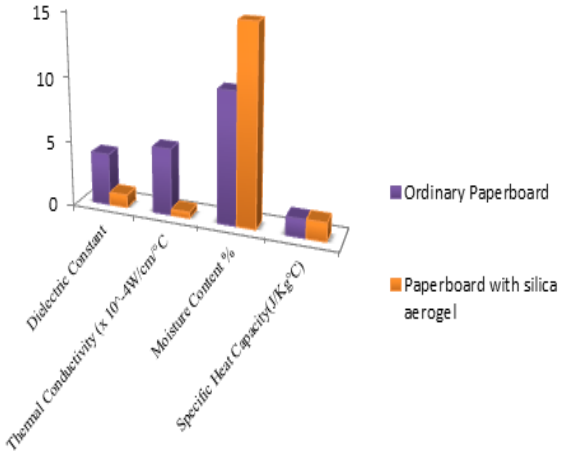

Figure 9.Difference between ordinary paperboard and paperboard with silica aerogel

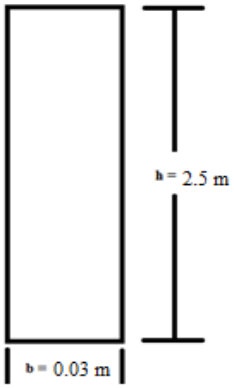

Figure 10.Dimension of single frame

Both the column frames are joined together as in figure 11 with another horizontal frame by the process of gas metal arc welding. Gas metal arc welding is chosen because of its advantages such as low cost, high reliability etc.

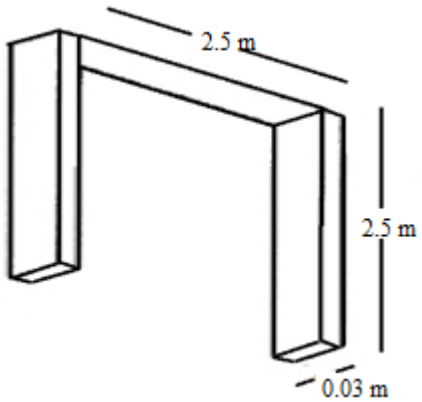

Figure 11.Welded steel frames

These frames that are welded together act as the aiding support of the roof. The

outermost layer of the roof will be the manufactured paperboard. The paperboard is fitted along with the steel frames by riveting. The finished roof will appear as sown in figure 12.

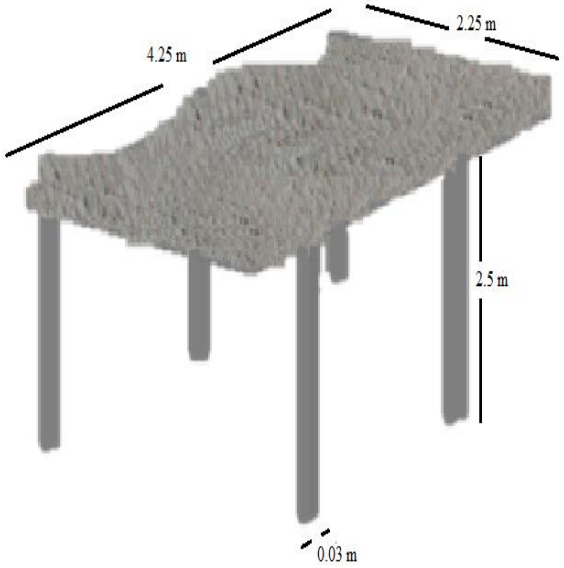

Figure 12.Finished roof

The paperboard is coated with wax to tolerate moisture to a little extent.

4. CONCLUSION

Thus a eco-friendly and reusable terrace roof has been constructed to use in the hot summer seasons. Since silica aerogel is combined paper pulp, it offers excellent heat resistivity. Further work can be carried out to provide better waterproofing to the roof.

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