Thermal Insulation of Building

Niraj Prajapati
B.E. Student
Department of Civil Engineering
Vishwakarma Government Engineering College, Ahmedabad

Jayesh Makawana
B.E. Student
Department of Civil Engineering
Vishwakarma Government Engineering College, Ahmedabad

Premal Prajapati
B.E. Student
Department of Civil Engineering
Vishwakarma Government Engineering College, Ahmedabad

Nikul Chauhan
B.E. Student
Department of Civil Engineering
Vishwakarma Government Engineering College, Ahmedabad

Yamini J. Patel
Associate Professor
Department of Civil Engineering
Vishwakarma Government Engineering College, Ahmedabad

Abstract

The walls of the buildings in general and the external walls in particular perform a major role in building, both in financial impact and in the role they play in habitability. External walls must provide acoustical and hydrothermal comfort, protection and security against intrusion, water tightness, must be long-lasting and meet the requirements associated to their use and performance. Masonry has been the elected material for the execution of external walls as it has paid an important role in buildings since first civilizations. However, since the beginning of the 20th century, masonry became confined to simple stuffing roles, as concrete and steel started to perform structural functions. Nowadays, most external walls are built with double wall layers with an inner thermal insulation and ventilation space. Certainly, the complexity that involves a building of this kind of walls increases the possibility of several anomalies. As a matter of fact, the normal evolution of the buildings outside should involve the use of simple layers. It means a lower complexity in execution and less time waste which leads to economical savings as far as workmanship is concerned. As far as the building materials are concerned one should consider the greatest possible number of criteria available and avoid cheap solutions, a trend which corresponds to the most affordable price per unit.

Keywords: Thermal Insulation, Polyurethane Foam, Expanded polystyrene

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I. Introduction

The term thermal insulation can refer either to materials used to reduce the rate of heat transfer, or the methods and processes used to reduce heat transfer. Heat energy can be transferred by conduction, convection, radiation. Thermal insulation prevents heat from escaping a container or from entering a container. In other words, thermal insulation can keep an enclosed area such as a building warm, or it can keep the inside of a container cold. Insulators are used to minimize that transfer of heat energy. In home insulation, the R-value is an indication of how well a material insulates. The flow of heat can be reduced by addressing one or more of the three mechanisms of heat transfer and is dependent on the physical properties of the material employed to do this.

In general, people living in hot regions wants to make their inside atmosphere very cool similarly people living in cold regions, wants warmer atmosphere inside. But, we know that the heat transfer takes place from hotter to colder areas. As a result, heat loss happens. To overcome this loss in buildings thermal insulation is provided to maintain required temperature inside the building. The aim of thermal insulation is to minimize the heat transfer between outside and inside of building.

A. Insulation

Insulation is defined as a material or combination of materials, which retard the flow of heat. The materials can be adapted to any size, shape or surface. A variety of finishes are used to protect the insulation from mechanical and environmental damage, and to enhance appearance.

B. Thermal behaviour

Each material transmits a certain amount of heat, this transmission being quantified by the "thermal conductivity coefficient". This coefficient is extremely important in thermal behaviour, considering that the higher the value, the worse the development of a certain material.

C. R – Value

"The R-value is the reciprocal of the amount of heat energy per area of material per degree difference between the outside and inside. The R-value is proportional to the thickness of the material. For example, if you doubled the thickness, the R-value doubles." It is also referred to as the thermal resistance or thermal rating of an insulating material. This is the parameter which is used to rate the thermal ability of an insulation. It determines the amount of resistance offered by the material to heat flow or transfer of heat energy. A higher R- value is usually preferred for better insulation.

$$\text{R-value} = k.m^2/\text{watt or } ft^2\ °F.$$

D. Objective

A thermal insulator is a poor conductor of heat and has a low thermal conductivity. Insulation is used in buildings and in manufacturing processes to prevent heat loss or heat gain. Although its primary purpose is an economic one, it also provides more accurate control of process temperatures and protection of personnel. It prevents condensation on cold surfaces and the resulting corrosion. Such materials are porous, containing large number of dormant air cells. Thermal insulation delivers the following benefits:

- Reduces over-all energy consumption.
- Offers better process control by maintaining process temperature.
- Prevents corrosion by keeping the exposed surface of a refrigerated system above dew point.
- Provides fire protection to equipment Absorbs vibration.

II. MATERIALS

Various materials used in this study are cement sheet, fibreglass, cellulose, glass wool, rock wool, gypsum board and sheet of wooden ware and pulp. Cement sheet used as wall material and remaining as insulation material.

A. Cement sheet

A cement board is a combination of cement and reinforcing fibres formed into 4 feet by 8 feet sheets (or 3 feet by 5 feet sheets), 1/4 to 1/2 inch thick that are typically used as a tile backing board. Cement board adds impact resistance and strength to the wall surface as compared to water resistant gypsum boards. Cement board is also fabricated in thin sheets with polymer modified cements to allow bending for curved surfaces.

Fig. 1: Cement Sheet

B. Polystyrene Material

1) Polyurethane Foam

While not the most abundant of insulations, polyurethane foams are an excellent form of insulation. Nowadays, polyurethane foams use non-chlorofluorocarbon (CFC) gas for use as a blowing agent. This helps to decrease the amount of damage to the ozone layer. They are relatively light, weighing approximately two pounds per cubic foot (2 lb/ft^3). They have an R-value of approximately R-6.3 per inch of thickness. There are also low density foams that can be sprayed into areas that have no insulation. These types of polyurethane insulation tend to have approximately R-3.6 rating per inch of thickness. Another advantage of this type of insulation is that it is fire resistant.

Fig. 2: Polyurethane Foam

2) Expanded Polystyrene (EPS)

Polystyrene is a synthetic aromatic polymer made from the monomer styrene. Polystyrene can be solid or foamed. Expanded polystyrene (EPS) is a rigid and tough, closed-cell foam. It is usually white and made of pre-expanded polystyrene beads. Polystyrene is one of the most widely used plastics, the scale of its production being several billion kilograms per year.

Polystyrene foams are produced using blowing agents that form bubbles and expand the foam. In expanded polystyrene, these are usually hydrocarbons such as pentane although it is a closed-cell foam, both expanded and extruded polystyrene are not entirely waterproof or vapour proof. Discarded polystyrene does not biodegrade for hundreds of years and is resistant to photolysis.

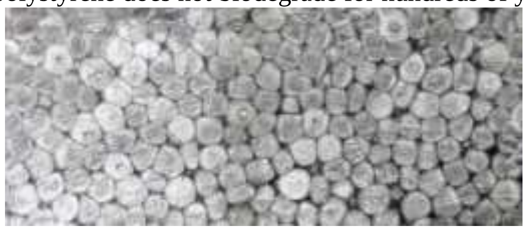

Fig. 3: Expanded polystyrene

a) Property of EPS

Thermal conductivity/ λ (lambda) W/ m.K = 0.034–0.038 (18)
Thermal resistance at 100mm K·m2/W = 3.52
Specific Heat Capacity J/(kg.K) = 1300
Density kg / m3 = 15 – 30
Thermal diffusivity m2/s = N/A
Embodied energy MJ/kg = 88.60 (16)
Vapour permeable: No

3) Extruded Polystyrene

Extruded polystyrene foam (XPS) consists of closed cells, offers improved surface roughness and higher stiffness and reduced thermal conductivity. (19) It is slightly denser and therefore slightly stronger than EPS. Water vapour diffusion resistance (μ) of XPS is very low - making it suitable for application in wetter environments.

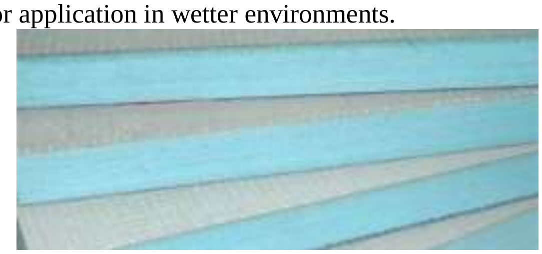

Fig. 4: Extruded polystyrene

a) Property of XPS

Thermal conductivity/ λ (lambda) W/ m.K = 0.033–0.035 (18)
Thermal resistance at 100mm K·m2/W = 3
Specific Heat Capacity J/(kg.K) = N/A
Density kg / m3 = 20 - 40
Thermal diffusivity m2/s = N/A
Embodied energy MJ/kg = 88.6 (16)
Vapour permeable: No

C. Aerogel

Aerogel is a synthetic porous ultra-light material derived from a gel, in which the liquid component of the gel has been replaced with a gas. The result is a solid with extremely low density and low thermal conductivity. Nicknames include frozen smoke and solid air, or blue smoke owing to its translucent nature and the way light scatters in the material. It feels like fragile expanded polystyrene to the touch. Aerogels can be made from a variety of chemical compounds. Aerogels are good thermal insulators because they almost nullify two of the three methods of heat transfer (convection, conduction, and radiation). They are good conductive insulators because they are composed almost entirely of gas and gases are very poor heat conductors. They are good convective inhibitors because air cannot circulate through the lattice. Aerogels are poor radioactive insulators because infrared radiation (which transfers heat) passes through them.

Silica aerogel is the most common type of aerogel. The silica solidifies into three-dimensional, intertwined clusters that comprise only 3% of the volume. Conduction through the solid is therefore very low. The remaining 97% of the volume is composed of air in extremely small nanopores. The air has little room to move, inhibiting both convection and gas-phase conduction.

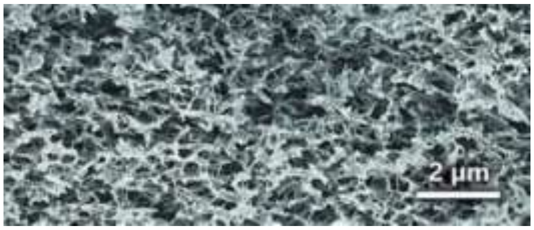

Fig. 5: Aerogel

1) Property of Aerogel

Thermal conductivity/ λ (lambda) W/ m.K = 0.014
Thermal resistance at 50mm K·m2/W = 3.8 for 50mm
Specific Heat Capacity J/(kg.K) = 1000
Density kg / m3 = 150
Embodied energy MJ/kg = 5.4kgs / CO^2 per m^2
Vapour permeable: No

D. Hemp

Hemp fibres are produced from hemp straw of the hemp plant. Most hemp is imported, but an increasing amount of home-grown crop is becoming available. Hemp grows up to a height of nearly 4 metres within a period of 100-120 days. Because the plants shade the soil, no chemical protection or toxic additives are required for hemp cultivation. The product is composed of, usually, 85% hemp fibre with the balance made up of polyester binding and 3-5% soda added for fire proofing.

Fig. 6: Hemp

1) Property of Hemp

Thermal conductivity/ λ (lambda) W/ m.K = 0.039 - 0.040
Thermal resistance at 100mm K·m2/W = 2.5
Specific Heat Capacity J/(kg.K) = 1800 - 2300
Density kg / m3 = 25 - 38
Thermal diffusivity m2/s = N/A
Embodied energy MJ/kg = 10
Vapour permeable: Yes

E. Hempcrete

Hempcrete is a mixture of hemp hurds (shives) and lime (possibly including natural hydraulic lime, sand, pozzolanas or cement) used as a material for construction and insulation. Hempcrete is easier to work with than traditional lime mixes and acts as an insulator and moisture regulator. It lacks the brittleness of concrete and consequently does not need expansion joints. Hempcrete walls must be used together with a frame of another material that supports the vertical load in building construction, as hempcrete's density is 15% that of traditional concrete.

Fig. 7: Hempcrete

F. Reflective Sheet Materials

Reflective sheet materials like aluminium sheets, gypsum boards, steel sheet Materials will have more reflectivity and low emissivity. So, these materials are having high heat resistance. The heat gets reduced when solar energy strike and gets reflected. These are fixed outside of the structure to stop the heat entrance into the building.

Fig. 8: Reflective Sheet

G. Sheet Prepared by use of Woodenware and Pulp Material.

Wood is not a fantastic insulator, but has a very advantageous blend of decent R value, high strength, light weight, and significant thermal mass. It's mainly a structural material of course, and its R value is actually much better than other structural things like concrete, steel, aluminium.

Pulp is a lingo cellulosic fibrous material prepared by chemically or mechanically separating cellulose fibres from wood, fibre crops, waste paper, or rags. Many kinds of paper are made from wood with nothing else mixed into them. This includes newspaper, magazines and even toilet paper. Pulp is one of the most abundant raw materials worldwide.

Fig. 9: Mixing of Wooden ware and pulp

III. MODEL OF BUILDING

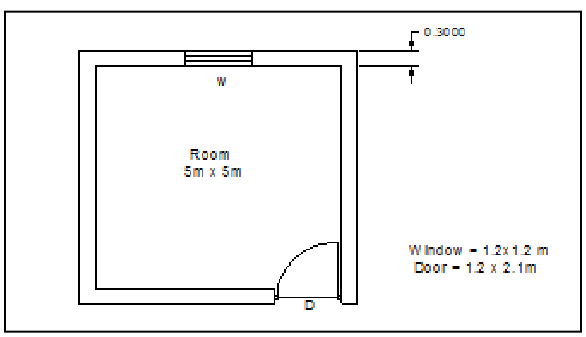

Fig. 10: Plan of Building

A. Model wise material

Table – 1
Model wise material

Building No	*Wall Material*	*Ceiling Material*	*Paint (outer face)*
Building 1	*Cement sheet*	*Cement sheet*	*Distemper*
Building 2	*Polyurethane Foam, Hemp*	*Reflective Sheet Materials*	*Distemper*
Building 3	*Aerogel, Hempcrete*	*Wooden ware and Pulp material*	*Distemper*

IV. TEMPERATURE MEASUREMENT TEST

A. *Methodology*

Method consists following flow of work such as Design of model (i.e. width, length, thickness, height, Scale),
Procurement of material, Model preparation, Installation of insulation material and paint the model. Dimension and scale of building model are shown as fig-10 and model consist 30mm wall thickness and 20mm ceiling thickness. There are number of insulation material applied to the model and its detail property given in article II. Here, total three models are made for the comparison of between them; one is made by only cement sheet, no insulation material used to it. And other remaining two models contain insulation material as given in table-2. During preparation of model cutting of cement sheet is done by steel cutting tool and material applied manually. Bond tide glue used for the adequate joint of cement board and its adhesive property is giving the good bond strength to the cement board. After the completion of model, distemper is made over its outer surface.

B. *Instrument used for test*

Here, main two types of instrument are exist one namely thermocouple censor and other PID controller.

1) *K-type Thermocouple*

The type K is the most common type of thermocouple. It's inexpensive, accurate, reliable, and has a wide temperature range. The type K is commonly found in nuclear applications because of its relative radiation hardness. Maximum continuous temperature is around 1,100C.

A thermocouple is exposed when the thermocouple wires are welded together and directly inserted into the process. The response time is very quick, but exposed thermocouple wires are more prone to corrosion and degradation. Unless your application requires exposed junctions, this style is not recommended.

There are many types of thermocouples, each with its own unique characteristics in terms of temperature range, durability, vibration resistance, chemical resistance, and application compatibility. Type J, K, T, & E are "Base Metal" thermocouples, the most common types of thermocouples. Type R, S, and B thermocouples are "Noble Metal" thermocouples, which are used in high temperature applications.

Thermocouples are used in many industrial, scientific, and OEM applications. They can be found in nearly all industrial markets: Power Generation, Oil/Gas, Pharmaceutical, BioTech, Cement, Paper & Pulp, etc. Thermocouples are also used in everyday appliances like stoves, furnaces, and toasters.

Thermocouples are typically selected because of their low cost, high temperature limits, wide temperature ranges, and durable nature.

Fig. 11: Thermocouple

2) *PID Controller*

a) What is PID controller?

A PID (Proportional Integral Derivative) controller is a common instrument used in industrial control applications. A PID controller can be used for regulation of speed, temperature, flow, pressure and other process variables.

Fig. 12: PID Controller

b) How a PID Controller Works?
As discussed above that a PID controller uses the control algorithm as three modes, i.e., proportional + integration + derivative. The proportional term applies appropriate proportional changes for error (which is the difference between the set point and process variable) to the control output. In fact, many control applications work quite well with only proportional control.

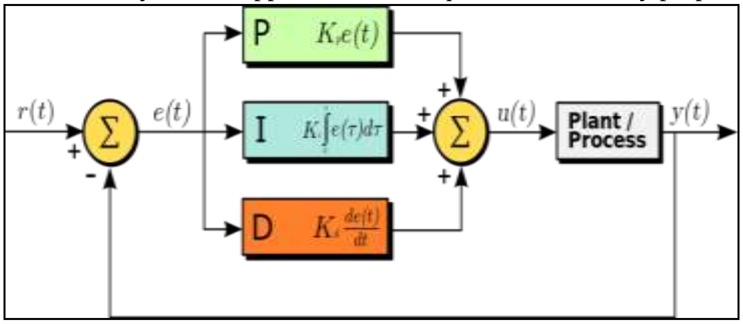

Fig. 13: Flow work of PID Controller

The integral term examines the process variable over time and offset of set point and then corrects the output if necessary. Derivative control monitors the rate of change of process variable and accordingly changes the output when there are unusual changes.

Each parameter of three control functions is adjusted by user to get the desired performance from the process. It measures the output of a process and controls the input by maintaining the output at a desired value (also called as set point). The most common example of PID controller is controlling temperature in many industrial applications.

C. *Test procedure*

For the testing of temperature measurement, models are rest in atmospheric temperature for the 45 minute. Thermocouple used for the temperature measurement. During the testing, first of all outside temperature is measured and then inside temperature is measured by the Thermocouple subsequently. Test result is given in table-2 below. Generally, the entire model giving positive reading. But it is shown that better performance given the model-III. As per the test result, Aerogel, Hempcrete and sheet of wooden ware and pulp giving the better result as compared to other material. In detailed, comparison and Temperature variation between them can be shown in Table2.

Table – 2
Test Result

Sr. No	Building No.	Duration	Outside Temp.	Inside Temp.	Difference in Temp.
1	Building 1	45 Min	44˚c	43.5˚ c	0.5˚ c
2	Building 2	45 Min	44˚c	41˚ c	3˚c
3	Building 3	45 Min	44˚c	38.5˚ c	5.5˚ c

V. CONCLUSION

As per the study, analysis and results we can conclude that natural materials based on technical hemp, Hempcrete, wooden ware obtained from agriculture can among others, be also used for the production of thermal insulation materials for wall construction and pitched roofs.

Model of aerogel, Hempcrete and sheet of wooden ware and pulp is giving the better result compare to other model and its give more difference between inside and outside temperature. By providing this natural material in building comfort living can be achieve.

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