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Performance of Coconut Husk Mixed Polyurethane Foam as an Alternative Insulating Material

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Abstract*—Thermal insulation material are the major roll players in energy conservation field, so insulators should be versatile in all respects. It should have lower thermal conductivity, cheaper, non toxic, free from fire hazards, free from odor, light weight, easily available. Keeping these entire things in front it is found that there is lot of scope in finding new alternative insulation materials, which will have lower thermal conductivity and should be easily available. After going through the literature it is found that there are so many insulating material having their own feasibilities for different applications. Now a days commonly used insulating materials in various applications like refrigeration, chilling units, water coolers, ice-cream containers is polyurethane foam. It is a mixture of two chemicals namely polyether polyol and polyfunctional isocynate. Both are costly. So to reduce the cost of foam, it was a try to mix coconut husk with puff which is easily available..

I. INTRODUCTION

Now a day we have need of energy conservation to overcome the problem of energy requirements. In order to solve this problem it was an approach to work on existing insulating materials and new alternate materials. Existing materials includes Glass wool, stone wool, Cotton wool, rock wool, dry cellulose, wet spray cellulose, perlite, blown fibre with binder , polyurethane foam etc[1]. These insulators showed their excellent performance as thermal insulators. Still every insulating material has some disadvantages and limitations. So keeping this in mind it was decided to work on existing materials and new alternative materials. The waste and disposal produced by agricultural industry have shown good insulating performance like Coconut husk, bagasse, corn cob are the examples from agricultural wastes that have shown excellent insulating ability [2,3]. Individual performance of materials has been tested up till now. So it becomes essential to check the performance of blend of different existing insulating materials and new insulating materials for checking whether positive results will get or not. From this view blend and new materials are tested for checking their insulability. Polyurethane foam is mostly used in various application of cooling unit like refrigeration units, water cooling units, ice-cream container etc. Polyurethane foam is prepared from two chemicals which are very costly, so it was a try to make blend of these two chemicals with coconut husk in order to re duce the total cost of foam. As coconut husk is freely and easily available in coastal areas with abundant amount it will reduce the total cost of foam.

II. CLASSIFICATION OF INSULATION MATERIALS

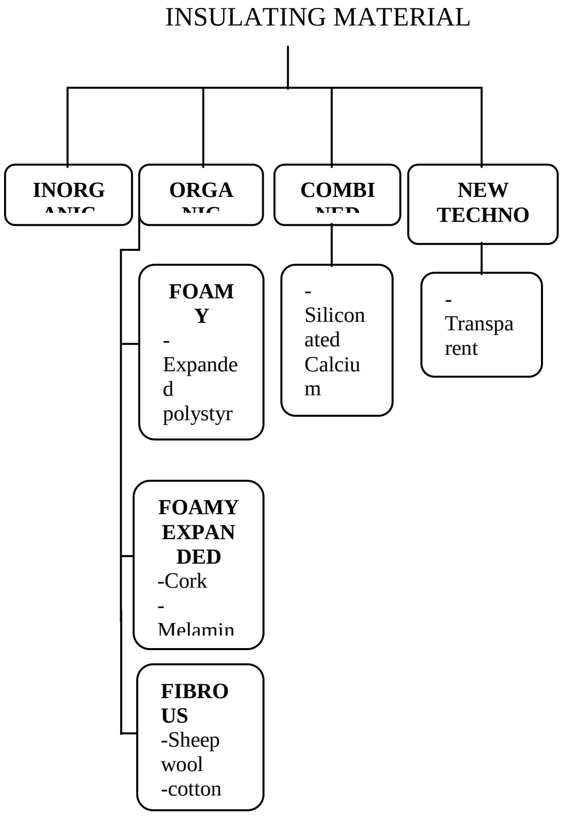

Fig 1. Classification of insulation materials [1]

A. Polyurethane foam:

For the manufacture of polyurethane polymers, two groups of at least bifunctional substances are needed as reactants; compounds with isocyanate groups, and compounds with active hydrogen atoms. The physical and chemical character, structure, and molecular size of these compounds influence the polymerization reaction, as well as ease of processing and final physical properties of the finished polyurethane. In addition, additive such as catalysts, surfactants, blowing agents, cross linkers, flame retardants, light stabilizers, and fillers are used to control and modify the reaction process and performance characteristics of the polymer[4].

B.Coconut husk and bagasse:

Coconut husk is waste material of dry coconut which is easily obtained in coastal areas of tropical countries. The coconut husk is available in large quantities as residue from coconut –fiber mattress production in many areas, which yields the coarse coir fiber. The husk consists of 30% fiber and 70% pith. Both fiber and pith are extremely high in lignin and phenolic content and it has been found that the

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coconut husk lignin can be used as intrinsic resin in board production .Bagasse is a by-product of sugar production. Bagasse is rich in celluloses.

Fig.1. Coconut husk

It act as a binder when making board. Hence it's a binder less insulation board. Thermal conductivity of the binder less boards made from coconut husk and bagasse showed values close to those of conventional insulation materials. [3]. The properties of binder less bagasse insulation boards were superior than coconut husk boards. The binder less bagasse insulation boards at density of 350kg/m^3 satisfy the requirement of the relevant standards (except the thickness swelling) can be used as building materials for thermal insulation applications. Since the binder fewer boards are made from waste materials and without any chemical binders, it is environmental friendly and can possibly compete with conventional insulation materials. Furthermore, the manufacturing process of binder less boards is very simple; no special equipment is needed so it can easily be applied to commercial production [3].Above two materials are easily available so both can be tried for mixing with polyurethane foam. After obtaining the powder of both materials we can mix these materials with foam chemicals. In this research paper only coconut husk is used to mix with foam chemicals to check its insulating ability.

C. Procedure of making samples of polyurethane and coconut husk foam:

First step is to bring the two chemicals namely Polyether polyol & Polyfunctional isocynate required for making samples. It is available in market at cost of Rs 250/- to 275/- range per kg. Both the chemicals must be taken in equal proportion. This is because the mixture of foam needs equal amount of two chemicals for making polyurethane foam. While bringing these two chemicals we need to tightly fit the caps of bottles in such a way that it should not open to atmosphere otherwise it will solidify and will not be useful for work. After getting these chemicals, a container having shape of sample is required, where we will pour these two chemicals in equal proportion with addition of coconut husk and stirring it to become a homogeneous mixture for 30 seconds. Within two minutes from starting time of process we will get expansion of this chemical, which is puffing process and after two to three minutes we will have our testing sample.

III. PRINCIPLE EMPLOYED FOR OBTAINING THERMAL CONDUCTIVITY AND MOISTURE CONTENT

A. Thermal Conductivity:

The steady state heat flow technique was used for obtaining the thermal conductivity of materials. The basic principle of operation was to create one dimensional axial heat flow through the surface in order to use the Fourier equation of heat conduction.

$$q = -kA\left(\frac{dT}{dX}\right)$$

Where,

q is the steady state flow

k is thermal conductivity

A is cross sectional area of the sample

-dT/dX is the temperature gradient [5].

B. Physical property:

Moisture content is determined by conducting same test on forty-five samples. The moisture content of samples was determined by the following equation.

$$\text{MC (\%)} = \left(\frac{m_1 - m_2}{m_2}\right)100$$

Where m1 is mass of sample before drying (g) and m2 is a mass of sample after drying (g)[6].

IV. EXPERIMENTAL WORK

Fig.2 Experimental Set up Diagram

The apparatus used is thermal conductivity measurement of composite slabs. It consists of a central heater sandwiched between two aluminums plates. Three types of slabs are provided on both sides of heater which forms a composite structure. One slab is removed and testing sample is installed at same place. A small hand press frame is provided to ensure perfect contact between the slabs. A dimmer is provided for varying the input to the heater and measurement of input is carried out by an Ammeter and Voltmeter. Thermocouples are embedded between interfaces of slabs, to read the temperature at the surface. For different dimmer positions, readings are taken after achieving steady state condition.

Fig.3 Control Panel of Experimental Setup

Control panel shows Ammeter, voltmeter, Temperature indicator and dimmer.

I] for sample 1:

A. Thermal property:

Material: Polyurethane foam

Polyether polyol = 55ml
Polyfunctional isocynate = 55ml
Total weight of sample =130gm
Density of sample = 88.57kg/m^3
Diameter of sample board = 180mm=0.18m
Volume of sample = 0.001474m^3
Thickness of sample board = 58mm=0.058m

Observation Table 1:

SN	Time in Minute	T3°C	T4°C	Current In Amphere	Current in voltage
1	90	43	36.2	0.19	57
2	10	44.4	36.3	0.25	77.5
3	9	46.3	36.4	0.317	93
4	15	49.3	36.8	0.34	114.8
5	15	51.6	37	0.415	132.7

Note:T3 & T4 are inner & outer temperature of insulating sample.

Calculations:

From Fouriers law of heat transfer,

$$q = -k1A\left(\frac{dT}{dX}\right) \quad (1)$$

q=0.86IV (2)

For first reading:

q=0.86*0.19*57
q=9.31W
Heat is flowing in two directions so heat flow in one direction is equal to. q/2
Hence,q1= =q/2=9.31/2=4.6569 W
Again heat flowing through only one third area of inner plate so, Heat flowing through plate is q2=q1/3
q2= 4.6569/3=1.5523W
From this heat only half area of plate is conducting constant heat
q3= q/2=1.5523/2=0.77615W (3)

$$A = \pi/4\left(d^2\right)$$

A=0.785(0.18^2)
A=0.025434 m^2 (4)

dT= T3-T4
dT= 43-36.2
dT=6.8°C (5)
dX=0.058m (6)
Putting values of 3,4,5,6 in eq.1
0.7761= - k1*0.025434 *(6.8/0.058)
k1=30.51/(6.8/0.058)
k1=30.51/(117.24)
k1=0.2602W/mK
The above result shown the thermal conductivity of polyurethane plate is 10 times more than standard thermal conductivity of polyurethane foam. Hence we can conclude that readings from experimental setup is 10 times more than actual ones. This is not because of setup but the reason is diameter of sample was less than heating plate.
Hence actual value will be 0.02602 (7)
Above calculations are done for all the readings as follows:

For second readings:

$$q = -k2A\left(\frac{dT}{dX}\right)$$

1.38=-k2*0.025434*(8.1/.058)
k2=0.3885
k2=0.03885W/mK. (8)

For third readings:

2.11=-k3*0.02543*(9.9/0.058)
k3= 0.4861W/mK
k3= 0.04861W/mK (9)

For fourth reading:

2.79=-k4*0.02543*(12.5/.058)
k4=0.5090
k4=0.05090W/mK. (10)

For fifth reading:

3.94 =-k5*0.02543*(14.6/0.058)
k5=0.6154W/mK
k5=0.06154W/mK (11)
Average thermal conductivity
k= (k1+k2+k3+k4+k5)/5 (12)
Put the values of 7,8,9,10,11 in eq. 12
k=(0.026+0.038+0.048+0.050+0.061)/5
k=0.044W/mK.

Average thermal conductivity k=0.044W/mK.

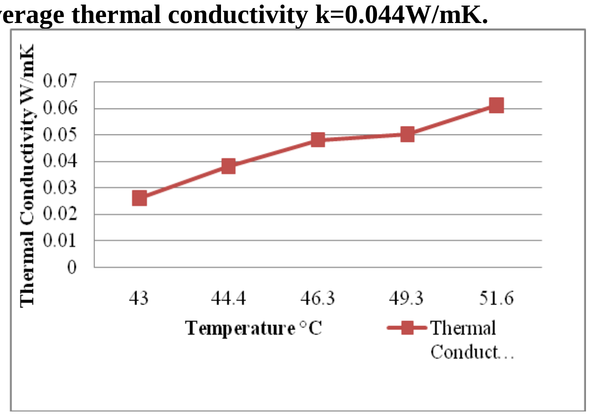

Fig.4 Thermal Conductivity of Polyurethane foam [10].

B. Physical property:

Moisture content are determined by conducting (MC) test on forty-five samples. The moisture content of samples was determined by the following equation.

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$$MC\% = \frac{m_1 - m_2}{m_2} * 100$$

Where

m1 is mass of sample before drying (g) and

m2 is a mass of sample after drying (g) .

For above sample mass of sample before drying i.e. m1=250gm = 0.250kg.

And mass of sample after drying i.e. m2 = 130gm = 0.130kg.

So, MC% = (0.250-0.130/0.130)*100=92.30%

Hence Moisture content for the sample is 92.30%

II] For sample 2:

A. Thermal property:

Material: Polyurethane foam plus coconut husk

Polyether polyol = 55ml
Polyfunctional isocynate = 55ml
Coconut husk = 60gm=0.060kg
Total weight of sample = 0.090kg
Density of sample = 61.01kg/m^3
Diameter of sample board = 18cm = 0.18m
Volume of sample = 0.001474m^3
Thickness of sample board = 5.8cm=0.058m

Observation Table 2:

S.N.	Time in min	T3°C	T4°C	Current In Amphere	Current in voltage
1	270	54.7	38.7	0.301	54
2	10	55.9	39	0.354	70
3	10	56.4	39.3	0.402	80
4	10	57.1	39.4	0.45	95
5	20	61.9	40.1	0.602	110
6	10	63.8	40.4	0.648	125

Note:T3 & T4 are inner & outer temperature of insulating sample.

Calculations:

For first reading:

From Fourier's law of heat transfer,

$$q = -k1A\left(\frac{dT}{dX}\right) \quad (1)$$

q=0.86IV (2)
q=0.86*0.301*54
q=13.97W

Heat is flowing in two directions so heat flow in one direction is equal to q/2.

Hence, q1= q/2=13.97/2=6.98 W

Again heat flowing through only one third area of inner plate so, Heat flowing through plate is q2=q1/3

q2=6.98/3=2.32W

From this heat only half area of plate is conducting heat in axial direction.

q3=q2/2=2.32/2=1.16W (3)
A=π/4(d^2)
A=0.785(0.18^2)
A=0.025434 m^2 (4)
dT= T3-T4
dT= 54.7-38.7
dT=16°C (5)
dX=0.058m (6)
putting values of 3,4,5,6 in eq. 1
1.16= - k1*0.025434 *(16/0.058)
k1=45.60/(16/0.058)
k1=45.60/(275.86)
k 1=0.1653W/mK
Actual value will be 0.01653W/mK (7)

For second reading:

1.7759=k2*0.025434 m^2(16.9/0.058)
k2=0.2396 W/mK
k2=0.02396 W/mK (8)

For third reading:

2.304=k3*0.025434 m^2(17.1/0.058)
k3=0.3073 W/mK
k3=0.03073 W/mK (9)

For fourth reading:

3.063=k4*0.025434 m^2(17.7/.058)
k4=0.3946 W/mK
k4=0.03946 W/mK (10)

For fifth reading:

4.74=k5*0.025434 m^2(21.8/.05/8)
k5=0.4959 W/mK
k5=0.04959 W/mK (11)

For sixth reading:

5.805=k6*0.025434 m^2(23.4/.058)
k6=0 .5658 W/mK
k6=0.05658 W/mK (12)

Average thermal conductivity =(k1+k2+k3+k4+k5+k6)/6 (13)

Putting the values of 7,8,9,10,11,12 in eq. 13

Hence, Average thermal conductivity for polyurethane foam and coconut husk is **(k) =** **(**0.01653+0.02396+0.03073+0.03946+0.04959+0.05658)/6

k= 0.03614W/mK.

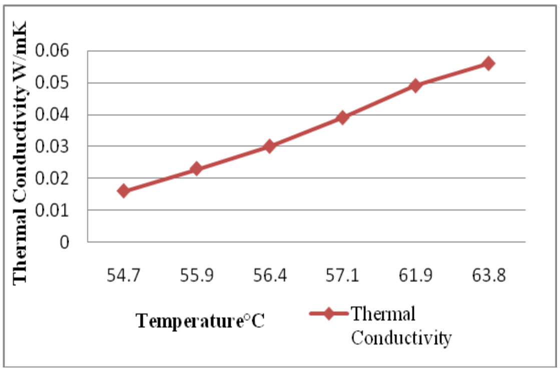

Fig. 5 Thermal Conductivity of Polyurethane foam plus coconut husk [10].

B. Physical property:

Moisture content test:

$$MC\% = \frac{m_1 - m_2}{m_2} * 100$$

For above sample, mass of sample before drying i.e. m1= 258gm = 0.258kg.

and mass of sample after drying i.e. m2 = 90 gm =0.90 kg.

So, MC% = 186.66%

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Hence Moisture content for the sample is 186.66%

V. DENSITY AND THERMAL CONDUCTIVITY OF SOME MATERIALS

Material	Density Kg/m^3	Thermal Conductivity factor λ (W/mK)	Reference
Glass wool			
Minimum	13	0.030	
Maximum	100	0.045	[1]
Stone wool			
Minimum	30	0.033	
Maximum	180	0.045	[1]
Extruded Polystyrene			
Minimum	20	0.025	
Maximum	80	0.035	[1]
Expanded Polystyrene			
Minimum	18	0.029	
Maximum	50	0.041	[1]
Polyurethane Foam			
Minimum	30	0.020	
Maximum	80	0.027	[1]
Binder less Coconut Husk insulation			
Minimum	250	0.046	
Maximum	350	0.068	[3]
Binder less Bagasse Insulation			
Minimum	250	0.049	
Maximum	350	0.055	[3]
Sheep wool			
Minimum	20	0.050	
Maximum	40	0.034	[7]
Flax			
Minimum	20	0.035	
Maximum	100	0.045	[8]
Flax and Hemp	39	0.033	[8]
Cellulose			
Minimum	30	0.041	
Maximum	45	0.050	[8]
Cellulose (recycled paper)	30	0.041	
Cellulose (wood fibre)	30	0.050	[8]
Narrow-leaved Cattail fibre			
Minimum	200	0.0438	
Maximum	400	0.0606	[9]

From above chart, it can be said that readings of new material are within range of existing materials.

VI. CONCLUSION

From above work it is concluded that coconut husk plus polyurethane foam have shown positive results as a thermal insulator. Thermal conductivity of polyurethane foam was 0.044W/mK and of coconut husk mixed polyurethane foam it was 0.03614W/mK. So future work can be done on this material.

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