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Manufacturing of Soundproof and Heat Insulator from Waste Materials

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Abstract. One of the factors affecting the environment is noise. For this reason, there was a need to find ways to isolate high sounds and reduce their impact on the environment. On the other side, wastes of industrial also harm the environment. Therefore, we start studying to recycle waste into benefit use as soundproof and heat insulator.

In this research, we investigated several materials to produce a composite isolation material. This material can isolate sound and heat, using waste materials for manufacturing it. Also, illustrate the efficiency of this new composite material in isolation and cost.

In this study, we use three types of waste materials cork, cardboard and fiberglass. These waste materials produced our new composite isolation material. Our samples were manufactured with dimensions of 10*10 cm and 2 cm thickness. Different amount of these materials was investigated to produce better isolation.

Our study for the composite materials demonstrated that sample 3 was the better sound insulation than other samples that we used in our experiment, with isolation efficiency near to (84%). Moreover, sample 3 was the better one between our samples in heat isolation. In addition, sample 3 was the cheapest sample in cost of manufacturing, because we used white glue in producing of the sample.

Keywords: Soundproof, heat isolation, manufacture, waste materials.

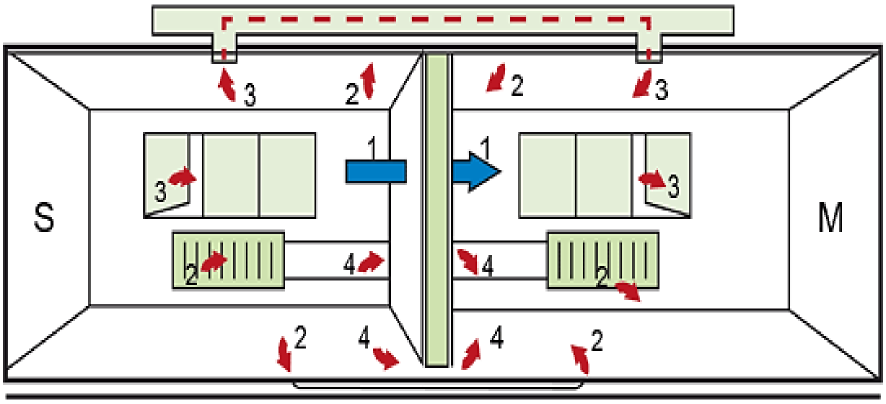
1. Introduction

1.1 Sound Insulator

Sound is transmitted through most walls and floors by setting the entire structure into vibration. This vibration generates new sound waves of reduced intensity on the other side. The passage of sound into one room of a building from a source located in another room or outside the building is termed "sound transmission".

Transmission loss or Sound Reduction Index, R dB, is a measure of the effectiveness of a wall, floor, door or other barrier in restricting the passage of sound. The transmission loss varies with frequency and the loss is usually greater at higher frequencies. The unit of measure of sound transmission loss is the decibel (dB). The higher the transmission loss of a wall, the better it functions as a barrier to the passage of unwanted noise [1].

There are two types of sound insulation in buildings: airborne and impact. Airborne sound insulation is used when sound produced directly into the air is insulated and it is determined by using the sound reduction index. Impact sound insulation is used for floating floors and it is determined by the sound pressure level in the adjacent room as shown in fig. 1 below.



1. **Direct sound transmission**
2. **Flanking transmission**
3. **Overhearing**
4. **Leakage**

Fig. 1: sound transmission in room

A) Airborne sound insulation

When a sound wave is incidental upon a partition between two spaces, part of it is reflected and part of it is transmitted through the partition. In case of lightweight structures consisting of multiple layers, such as a gypsum wall, the spring-mass law is applicable. If highly absorbent material such as stone wool is used as the spring in a double leaf wall, the sound insulation improves. The wider the cavity, the greater the benefit from stone wool will be. Typically, a 5 – 10 dB increase in R can be achieved with a filled cavity compared to an empty one [2].

B) Impact sound insulation

An airborne source sets up vibrations in the surrounding air which spread out and, in turn, set up vibrations in the enclosing walls and floors. An impact source sets up vibrations directly in the element it strikes. These vibrations spread out over the whole area of the element and into elements connected to it, such as internal walls, the inner leaves of external walls and floors. The vibrations in the elements force the air beside them to vibrate and it is these new airborne vibrations that are heard.Floors should reduce airborne sound and also, if they are above a dwelling, impact sound. A heavy solid floor depends on its mass to reduce airborne sound and on the soft covering to reduce impact sound at source.A floating floor contains a layer of highly resilient material, which largely isolates the walking surface from the base, and this isolation contributes to both airborne and influence insulation [3].

- It is important to choose a suitable material and to make sure that is not bypassed with rigid bridges such as fixings and pipes.
- Air paths, including those due to shrinkage, must be avoided; porous materials and gaps at joints in the structure must be sealed.

Resonances must also be avoided; these may occur if some part of the structure (such as dry lining) vibrates strongly at a particular sound frequency (pitch) and transmits more energy at this pitch [4].

C) Flanking transmission

Flanking transmission is a more complex form of noise transmission where the resultant vibrations from a noise source are transmitted to other rooms of the building usually by elements of structure within the building. For example, in a steel framed building, once the frame itself is set into motion the effective transmission can be pronounced.

In a building, a fraction of the sound transmission between two rooms may go by a flanking building element, such as the outer wall or the ceiling. In order to avoid this, the manufacturer’s instructions must be followed carefully [5]. The figure 2 shows the principal solutions for an outer wall.

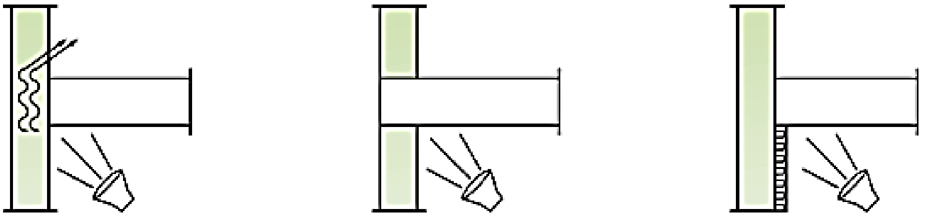


Fig. 2: Solutions for reducing the risk of flanking transmission

There are often requirements for a safety margin in the different sound data of the elements in order to avoid flanking transmission.

1.2 Thermal Insulation

Thermal insulation materials are used in many industrial process such as; glass industrial, petroleum, chemical industries, steel and aluminum, and in building structures.

Thermal insulation is most widely used in the last year and more markedly in the world. Today, the use of insulation has become more on economic necessity by using the lee's disk method conductivity of insulators because it is simple in design, cheap, has a wide operational temperature range and easy operation [6].

A) Classification of thermal insulation

There are many types of insulation available in the market, and sometimes selecting the right kind of insulation can be helpful to classify the insulation in some ways to have a better perspective of them [7].

Insulation materials can be classified widely as capacitive, reflective, and resistive materials.

- Capacitive insulation slowed down the flow of heat from one medium to another by simply absorbing the heat and releasing it slowly.
- Reflective insulation are effective against radiation but not for conduction or convection, they are mostly used in evacuated spaces, and can be used to minimize heat flow by radiation.
- Resistive insulation is made of a material of low thermal conductivity and offers effective resistance to heat flow despite its small thickness.

B) Properties of insulation

1- Density

Thermal insulation has a density which is commonly measuring for ratio of gas volume in it. The density of gases are very low comparing with density of solid and it is expressed as the weight of solid per unit volume of that insulation material.

2- Surface temperature

Insulation is designed to perform in a specified temperature that is too high or too low will limit the choices considerable. For example a surface temperature above 450 C^O will eliminate all fiber/glass insulations.

3- Corrosiveness

Mineral wool and fiberglass insulations do not cause corrosion but some insulation is corrosive, and may corrode the method surface on which they are installed.

In this research we will investigate the sound and heat isolation by manufacturing a new composite material. The produced material manufactured from waste of other materials. The new composite material consists of cork, cardboard and fiberglass. Also, we will test different amounts of these contents to find which mixture is more efficient in isolation. Moreover, we compare between these samples according to the cost.

2. Theory

In this section we will explain the theory that used in the calculation of sound isolation according to the sound reduction index R. Moreover, we will illustrate the theory of thermal conductivity.

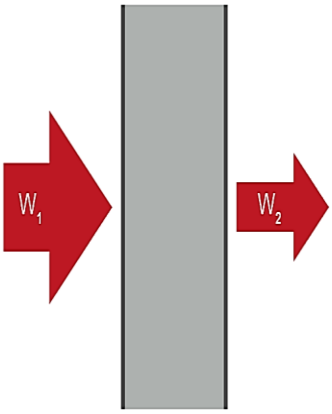
2.1 Sound Reduction Index (R)

For single leaf structures, such as a homogenous concrete wall, the transmission follows the mass law, that is, the more massive the structure, the smaller the quantity of transmitted sound.

Calculation of the sound reduction index R is based on test results obtained at different frequencies. If the measurements are performed in situ (in a real building) the values are denoted R’. The standard test procedure is defined in EN ISO 140, where standard methods are given for both laboratory and field measurements [8].

$$\mathbf{R = 10 \log_{10} W1/W2}$$

The difference between laboratory and field values can be a significant number of dB depending on the construction details and workmanship. If a partition consists of different kinds of elements – for example, a wall with windows and doors which have different sound transmission characteristics – the overall sound reduction index must be calculated. Figure 3, shows the different sound reduction index R based on the amount of sound transmission. The sound reduction index for holes and slits is nearly equal to 0 dB.



R (dB)	W1/W2
0	1
10	10
20	100
30	1 000
40	10 000
50	100 000
60	1 000 000

Fig.3: Sound Reduction Index according to sound transmission

The influence of holes and slits may therefore be important, for instance, at the connections between walls, at doors and windows without sealing strips, and at any necessary openings in partitions. If there is an acoustically absorbent material in the slits, it will give a higher sound reduction index for the slits.

2.2 Thermal conductivity

Thermal conductivity is one of the best important properties of the thermal insulation. The best insulation has the lowest conductivity.

Thermal conductivity is a property of material that expresses the heat flux $F=(w/m^2)$ that will flow through material if a certain temperature gradient $DT(k/m)$ exists over the material thermal conductivity is usually expressed in $w/m.k^0$ and called I .The usual formula is [9]:

$$I=\frac{f}{DT}$$

- **Thermal transport in insulations**

The heat always flows from wormer to cooler surfaces; this flow does not stop until the temperature in the two surfaces is equal [10].

In order to understand how insulation works, it is important to understand the concept of heat flow or heat transfer by four different ways:

Solid conduction (q_S), gas conduction (q_g), radiation (qr) and convection (q_c). The total heat flow (q_t), is a result of interaction between the four modes of heat transfer

$$q_t = f(q_s, q_g, q_r, q_c)$$

And the total thermal conductivity (k_t) can be described by a simple addition of solid conductivity (k_s), gas conductivity(kg) , radiation conductivity (K_r), and the convection conductivity (K_c)

$$K_t = K_s + K_g + K_r + K_c$$

- **Measurements of thermal conductivity**

The heat transfers from high to low temperature region. So the energy is transferred by conduction and that the heat transfer rate per unit area is proportional to the normal temperature gradient as below [11].

$$\frac{q}{\mathrm{A}}\alpha\frac{\delta T}{\delta \mathrm{X}}$$

The proportional is constant; it is called the coefficient thermal conductivity then,

$$q=-\mathrm{A}K\frac{\delta T}{\delta \mathrm{X}}$$

The proportional constant, K, is a transport properly known as the thermal conductivity and the minus sign is a consequence of the fact that heat transferred in the direction of decreasing temperature.The equation is called Fourier's Law of heat conduction. Where in the temperature distribution is linear, the equation may be expressed as below:

$$q=-KA\frac{dT}{d\mathrm{X}}$$

Or $$q = -KA\frac{T_2 - T_1}{\Delta X}$$ (by integration)

Then

$$K = -\frac{q}{A}\frac{dX}{dT}$$

Now, the coefficient of thermal conductivity (K) can be calculated after measuring the quantities in the right hand side of the equation

3. Experiment

Basically, we apply a sound by using audio file from phone then measuring the amount of noise in dB. Our experiment can be illustrated in three steps. First, we manufactured an isolation room with dimension of 70*40*35 cm. This isolation room is made of multilayer of metal, cork, sponge, fiberglass, and foam. Second, we made a square hole in the top of the isolation room with a dimension of 10*10 cm, samples will be inserted in this hole, and then we will do our experiment. Third, we put a microphone inside the room and connected it with a wire to a computer outside the isolation room. On the other hand, we used a noise meter to calculate the noise outside the room. Finally, we play a recorded sound and measuring the noise outside and inside the room. We compare between the noises form outside and inside of the isolation room to measure the efficiency of our samples in isolation. This experiment can be explained in fig.4 below.

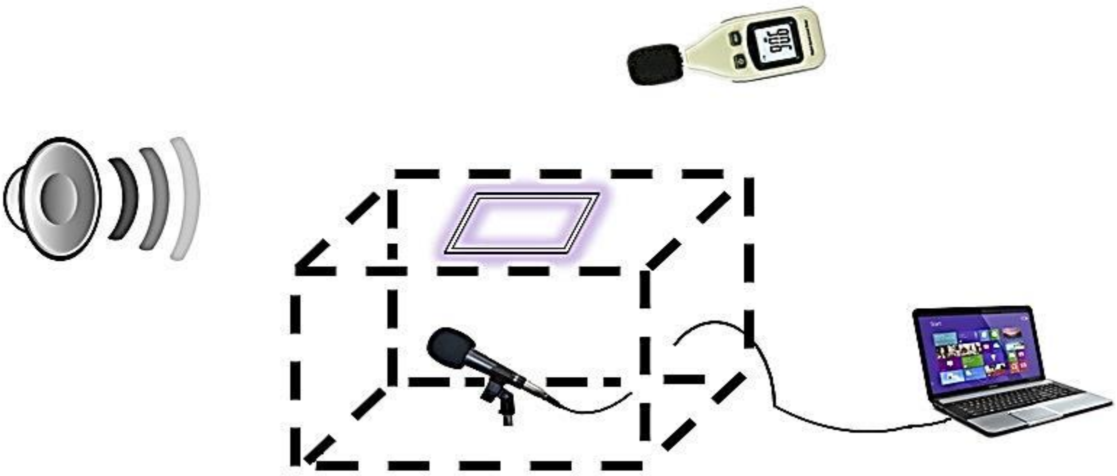


Fig. 4: A scheme explaining our experiment.

3.1 Devices that were used in mustering

A) GM1351 Digital Sound Level Meter

Professional GM1351 Digital Sound Level Meter Decibel Logger 30-130dB. It is designed according to following standards, International Electrician Committee Standard: IEC 651 TYPE 2 & ANSI 1.4 TYPE 2. It's a modern compact and portable appearance design, the accuracy up to among 1.5dB. With a maximum value holding function to lock up the maximum reading. Large LCD screen with digits reading. Auto power off design for energy saving. Auto backlight display. Portable, easy-to-use and handy instrument for sound quality control in factory, traffic, family, and audio system.

Measuring range: 30-130dBA
Accuracy: among 1.5dB
Frequency range: 31.5Hz to 8.5KHz
Frequency weighting: A
Digital display: 4digits
Resolution: 0.1dB
Sample rate: 2 times/second
Microphone: 1/2 inch electret condenser microphone
Max hold: MAX

Fig. 4: GM1351 Digital Sound Level Meter

Power supply: 9V battery
Product weight: 105g
Product size: 14.2 * 5.3 * 3.5cm

B) Computer and Microphone
In this experiment we used a computer to install a program which is used to determine the sound level inside the isolation room. On the other hand, a small microphone was located inside the isolation room, which is used to detect the sound, and transmit the signal to the program. In this experiment, we used a program called "Decibel Meter", which works on windows 10.

3.2 Samples
In this research we use three types of waste materials; cork, cardboard and fiberglass. These waste materials produce our new composite isolation material. Our samples were manufactured with dimensions of 10*10 cm and 2 cm thickness. Different amounts of these materials were investigated to produce a better isolation. These amounts are illustrated in fig.5 below:

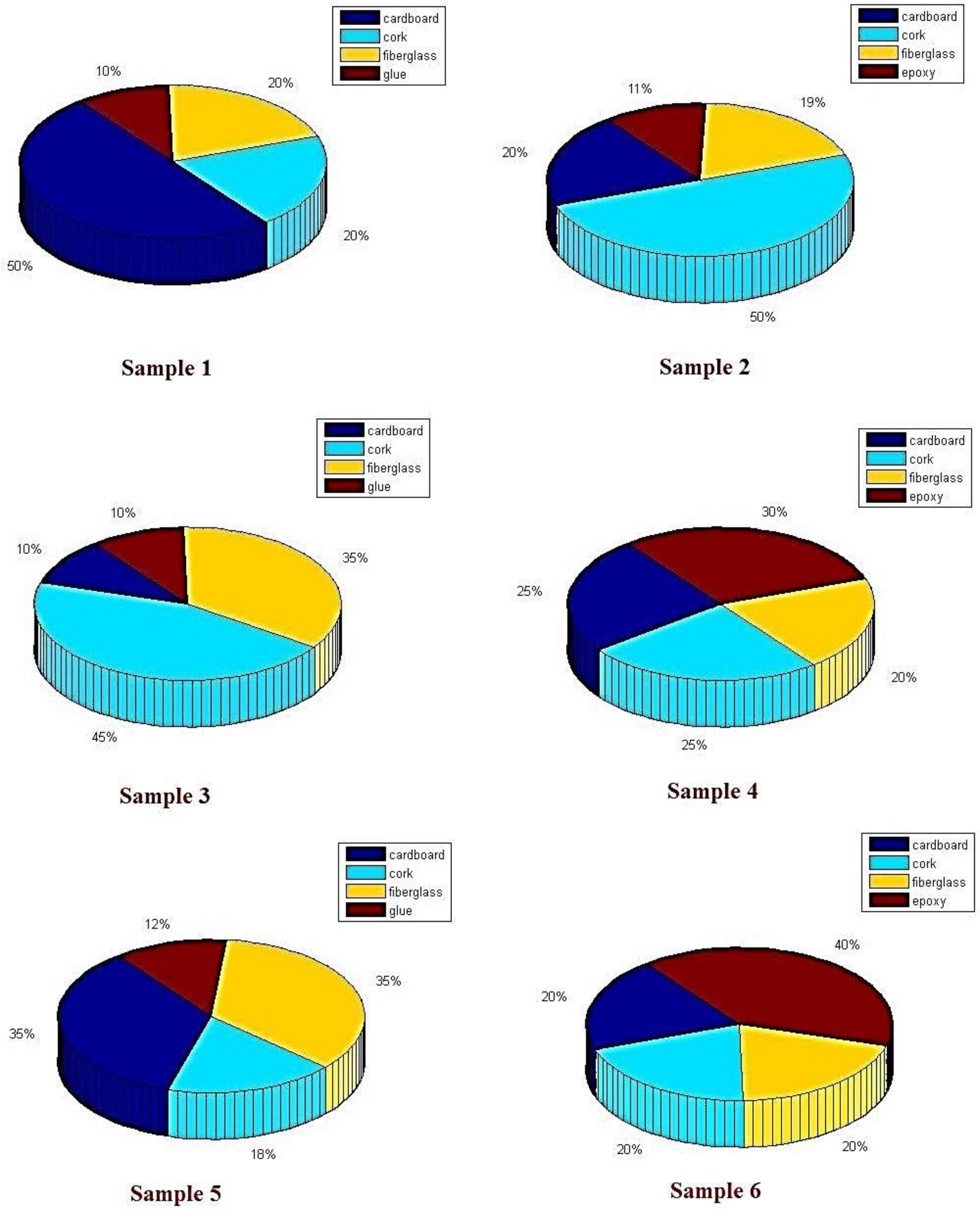


Fig. 5: our samples with different amount of the waste materials

4. Results and Discussion

In this section we will illustrate our results in two parts. First part is sound insulation, and the second part explains the heat insulation.

4.1 Sound Insulation

After we made our preparation and placed the sample in the room hole, we read and record the sound reduction index R value for our samples.Our samples were manufactured with dimensions of 10*10 cm and 2 cm thickness. Basically, we applied a recorded sound for measuring the amount of noise flowing through our samples, then calculating the sound reduction index R. The sound reduction index measurement is in dB. We used theindex R value to evaluate insulation integrity as shown in fig.6 below.

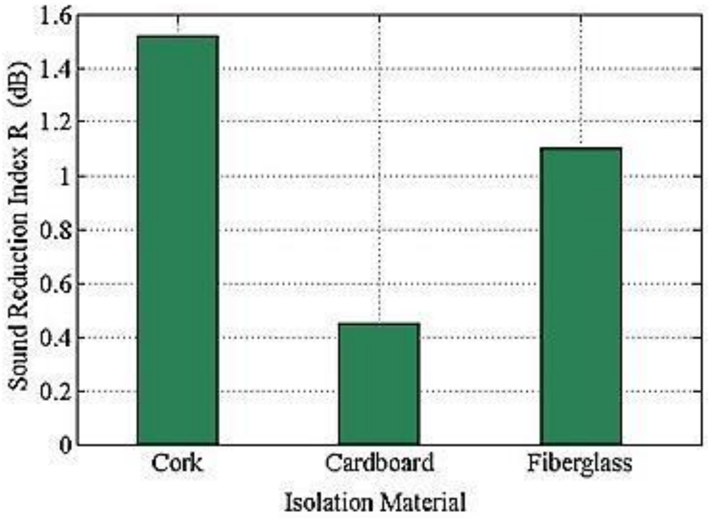


Fig.6: Sound insulation for our waste materials

Figure 6 shows that the insulation for our waste materials; cork, cardboard and fiberglass, which were used to produce our new composite isolation material. From this figure, we can illustrate that the cork showed more isolation than the other materials. On the other hand, cardboard revealed the lowest isolation efficiency in this group of materials.

After we investigated the sound insulation for each component of the materials that used to produce our composite isolation material, we start to measure the sound reduction index R for our new composite material as shown in fig. 7 below.

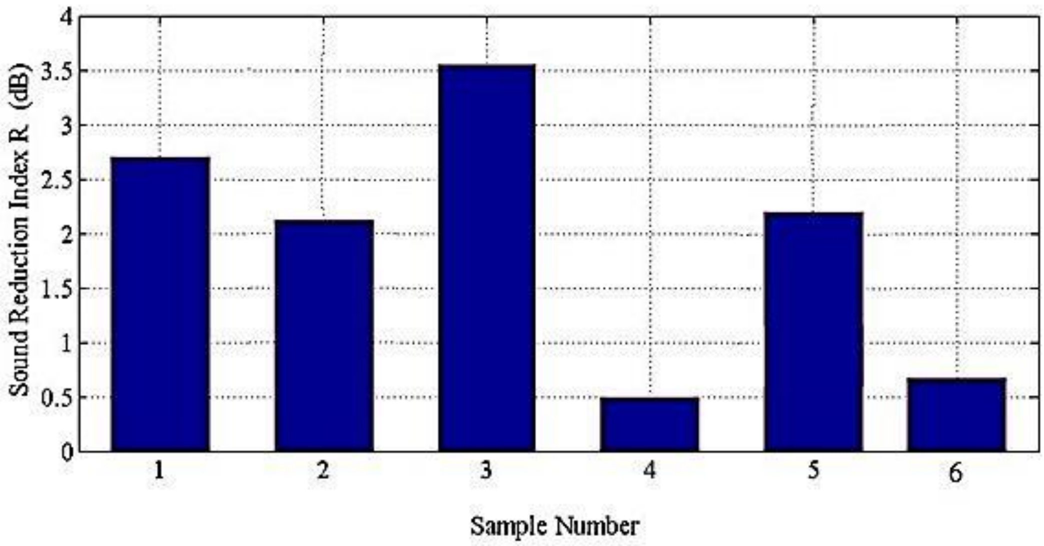


Fig.7: Sound insulation for our samples of the new composite material

Figure 7 explained that sample 3 was the better insulator than other samples that we used in our experiment. Moreover, sample 1 ranked as the second in isolation power after sample 3. On the other hand, sample 4 showed the lowest isolation efficiency among our samples' group.

Also, we can illustrate the insulation efficiency of our samples in fig.8 bellow. From fig. 8 we can show that sample 3 was more efficient in isolation (83.67 %) than other samples. On the other hand, sample 4 was the worst efficient in sound isolation

(19.5 %).

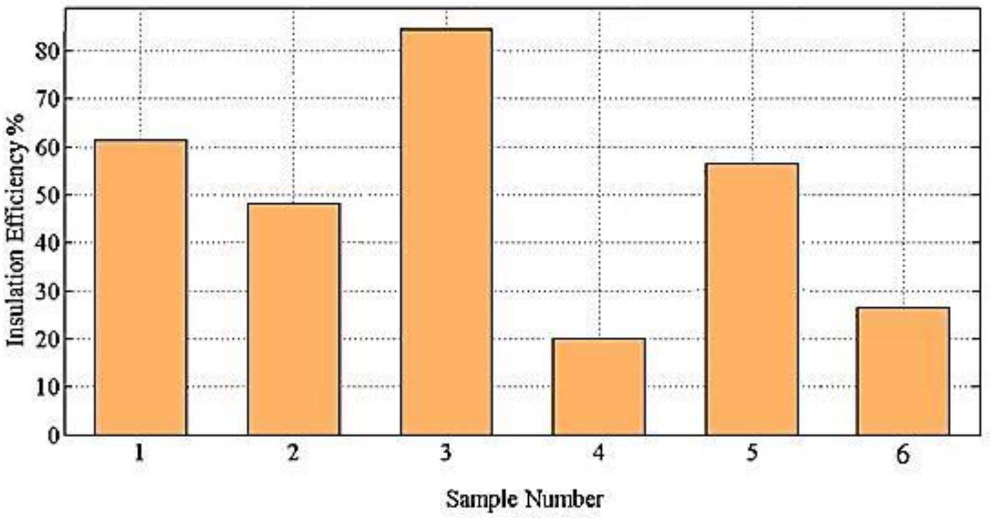


Fig.8: Insulation efficiency for our samples of the new composite material

4.2 Heat Insulation

In this part we calculated the coefficient of thermal conductivity (K) after measuring the heat that transferred in the direction of decreasing temperature. This thermal conductivity was measured for our samples and can be shown in fig. 9 below:

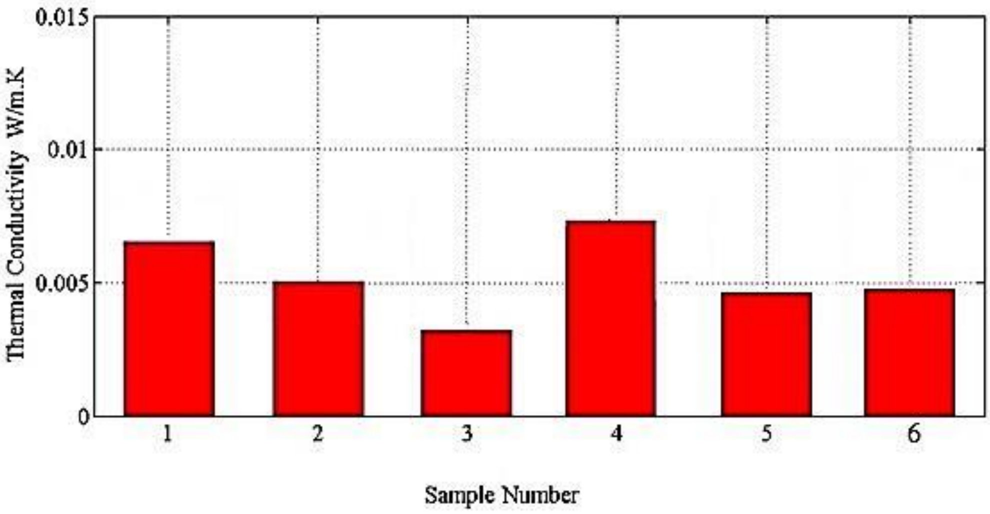


Fig.9: Heat insulation for our samples of the new composite material

This figure illustrated that sample 3 is the better one among our samples in heat isolation; also sample 5 ranked the second in heat isolation. On the other hand, sample 4 showed a lower efficiency in heat isolation among our samples, followed by sample 1 in weakness in isolation.

5. Conclusion

This study depends on investigation of several materials to compose a new isolation material. This material can isolate sound and heat, using waste materials for manufacturing it. Also, illustrates the efficiency of this new composite material in term of isolation and cost.

In this study, we used three types of waste materials cork, cardboard and fiberglass. These waste materials produced our new composite isolation material. Our samples were manufactured with dimensions of 10*10 cm and 2 cm thickness. Different amounts of these materials were investigated to produce better isolation.

Our study demonstrated that sample 3, which consists of (10% cardboard, 45% cork, 35% fiberglass and 10% glue) was the better sound insulation than other samples that we used in our experiment, with isolation efficiency near to (84%). Moreover, sample 3 was the better one among our samples in heat isolation. In addition, sample 3 was the cheapest one in cost of manufacturing, because we used white glue in producing the sample instead of epoxy.

Nomenclature

R	sound reduction index		
f	Heat flux w/m^2	K	Thermal conductivity $(w/m.c^{\circ})$
DT	Temperature gradient K^0/m	q	The measured heater power (w)
I	Thermal conductivity $w/m.k^0$	A	The area of specimen cross-section (m^2)
q	the heat transfer rate	Δx	The average thickness of specimen (m)
$\frac{\delta T}{\delta X}$	Is the temperature gradient	ΔT	The average temperature difference between the hot face and cold face.

References

[1]Hassan, O.A.B., Building Acoustics and Vibration: Theory and Practice, World Scientific Publishing Company, 2009,pp. 33-34.

[2]Patnaik, A., Mvubu, M., Muniyasamy, S., Botha, A., Anandjiwala, R. D., Thermal and sound insulation materials from waste wool and recycled polyester fibers and their biodegradation studies, Energy and Buildings, 2015, V. 92 .

[3]Hopkins, C.,Turner, P., Field measurement of airborne sound insulation between rooms with non-diffuse sound fields at low frequencies. Appl. Acoust. 2005, 66 pp. 1339–1382

[4]Gerretsen, E., Calculation of airborne and impact sound insulation between dwellings, journal of Applied Acoustics, 1986, V. 19,4,pp. 245 – 264.

[5]Quirt, J.D., Nightingale, T.R.T.,Airborne Sound Insulation in Multi-Family Buildings, National Research Council Canada, Construction Technology, March 2008, Update No. 66,

[6] AL-Ajaj, E. , Jafeer,H., Shawky, A., The Effect of metals as Additives on Thermal conductivity of Epoxy Resin, Iraqi Journal of Physics, 2010,V. 8, pp. 74-79.

[7] F. Robinson and P.A. Solomon, Thermal insulation materials, GEN, Courtaulds Aerospace Limited, Mar 7, 1995.

[8] Kiyota, Y., Asai, M., Sugita, H., and Akiyama, A., "Low Frequency Noise Reduction by Improving Sound Insulation Materials," SAE Technical Paper, May 1, 1995

[9] A.M. Papadopoulos, State of the art in thermal insulation materials and aims for future developments, Energy and Buildings, Volume 37, Issue 1, January 2005.

[10]BjørnPetterJelle, Traditional, state-of-the-art and future thermal building insulation materials and solutions – Properties, requirements and possibilities, Energy and Buildings, Volume 43, Issue 10, October 2011.

[11]AzraKorjenic, VítPetránek, Jiří Zach, JitkaHroudová, Development and performance evaluation of natural thermal-insulation materials composed of renewable resources, Energy and Buildings, Volume 43, Issue 9, September 2011.