



PRODUCING OF NON-WOVEN FABRICS, PROVIDE ELECTRICAL ENERGY TO BUILDINGS FROM WASTE FIBERS

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ABSTRACT

Buildings constitute a large part of the total energy consumption in the world. One of the most important challenges of future buildings is to reduce the energy consumptions in all their cycle life, from construction to demolition. Designing green buildings and using thermal and acoustic insulation are useful ways to reduce the amount of energy required to maintain a comfortable environment.

This research deals with thermal and acoustic insulation properties in nonwoven fabrics made of waste fibers (50% jute, 25% cotton, 25% polyester + polypropylene). In this research 7 samples were produced with nonwoven technique and bonded using needle punching method.

The results show that, there is a direct relationship between fabrics weight, thickness and its ability to thermal insulation, while it is an inverse relationship with air permeability.

Also there is an inverse relationship between weight of non-woven fabrics and its sound absorption coefficient, and increased frequency of sound leads to increase in sound absorption coefficient at all weights.

Key Words: *Nonwoven Fabrics, Technical Textiles, Thermal Protective Fabrics, Thermal Insulation Properties of Textiles, Waste Fibers, Thermal Insulation Value (TIV), Acoustic Insulation, and Sound Absorption.*

I. INTRODUCTION

Now buildings account for 40% of the world's energy and almost half of the today's Green House gas emissions. This means that buildings contribute more greenhouse gases than traffic, which represent 31%, and industry, 28% of greenhouse gases. When we breakdown and analyze buildings' energy consumption the most worrying aspect is that most of this energy used for heating, cooling is needlessly wasted and all the recent projections claims that this consumption will rise considerably on the next years, so we must reduce energy use in new buildings .It's estimated that building sector needs to reduce energy consumption in buildings 60% by 2050.[1, 2]

One of the most important challenges of future buildings is reduce of energy consumptions in all their life phases. Designing green buildings and using thermal insulation and acoustic insulation are useful ways to reduce the energy required to maintain a comfortable environment. More energy efficient buildings reduce the quantities of fossil fuels consumed and reduce the amount of carbon dioxide and sulphur dioxide emitted to the atmosphere.[2, 3, 4]

1.1. Thermal characteristics

Thermal characteristics depend on the thermal conductivity of the wall, cell and the cell matrix, also radiation and convection, with the cell matrix being the most significant factor in determining the heat transfer characteristics. [5]

1.1.1 Thermal properties of textile fabrics

Thermal properties of textile fabrics are interest for textile researchers. The purposes of Fabrics thermal insulation which used in walls and ceiling of buildings, are to prevent heat from being conducted either into or out from an enclosed environment so a desired temperatures can be maintained inside. [6, 7, 8]

Thermal insulation value which symbolized by (TIV) represents the efficiency of the textile fabric as an insulator. It is defined as the percentage of reducing in heat loss from a hot surface maintained at a given temperature. The TIV increases to 100% when a perfect insulator is obtained. It is expressed as a percentage which represents the reduction in the rate of heat loss due to the insulation, attributed to the heat loss from the surface.[9]

1.1.2 Factors Affecting Thermal Insulation Properties of Fabrics

The thermal insulation of textile fabrics depend on their thermal conductivity, density, thickness and weight, also the efficiency of thermal insulating materials depends on the amount of dead air space present within the insulated materials. Because of this, many of the commonly used insulated materials are bulky as air helps in increasing the insulation properties of the fabric. [3, 6]

1.1.3 Fibers used in thermal insulation applications

Now, a wide range of textile materials has been used as thermal insulators in many industrial applications. [3]

Cellulose fibers have successfully proven their qualities when also taking into account an ecological view of fiber materials. Different cellulose fibers can be used for textile and technical applications, e.g. flax, hemp, jute, ramie, sisal and coir which mainly used for technical purposes. [10]

Cellulose fibers have the advantage of helping stop air leaks in addition to providing insulation value. Commonly fiberglass and cellulose products are the most economical. [11]

Due to fibers properties and low cost, cotton represents the most used textile fiber Jute is strong threads and is one of the cheapest natural fibers. It is also the most versatile, eco-friendly, natural, and antistatic fiber available. [10, 12]

Synthetic fibers improved thermal stability and are being used successfully alone or in blends for insulation applications. [8]

The most important properties of thermal insulation materials are form diversity, ease of installation, thermal range, water resistance, microorganism resistance, fire resistance, and cost. [2]

1.1.4 Structure of thermal insulation fabrics

Non-woven textiles are an important part of textiles in the indoor environment. Different groups of non-woven materials can be found in buildings and means of transport. Nonwoven fabrics have advantage of containing many dead air spaces present within the material that give the fabric its insulation abilities. The selected nonwoven fabrics are suitable for usage as thermal insulators. [9, 13, 14]

I.1.5 Smart textile materials for thermal insulation for the building sector

A new inexpensive thermally insulator and “ready to use” fiber insulation phase change material (PCM) -based composite, that combines on product major skills such: thermal insulation abilities to block heat transfer into or out of the buildings, outstanding airborne sound control proficiency and also thermal storage capacities. The versatility of the concept will make it adaptable for heating and cooling purposes, enabling this product to address different climate patterns and geographical markets just by tailoring its relative composition. [1, 15]

I.2 Acoustic Insulation and Sound Absorption

Now, noise is an ever-increasing problem everywhere in the world, as noise has negative effects on physiological processes and human psychological health. Effective noise control can be achieved with a comprehensive understanding of sound phenomenon. Sound is a form of energy that is transmitted by pressure variations which the human ear can detect. To produce Sound, three components are needed: a sound source, a medium, and a detector. The sound source is a vibrating body that produces a mechanical movement or sound wave. The medium, such air, transfers the mechanical wave. The detector, such an ear, detects the sound wave. [16, 17, 18]

Sound is the quickly varying pressure wave travelling through a medium. The number of pressure variations per second is called frequency of sound, and is measured by Hertz (Hz). [18]

Sound absorption was defined as a measure of the propagation of sound energy falling on a surface and is not reflected on it. It is expressed as a coefficient or percentage of the incident energy. Absorption coefficient is the amount of the original energy less the remaining unabsorbed energy. [16]

Acoustic insulation is minimizing the transmission of sound between two areas. Another purpose of sound insulation is reducing the reflection of sound from the structures of a room and reducing any acoustic reverberation. [19]

I.2.1 How Sound Is Propagated Through Buildings

When a sound wave passing through the air meets a partition, some of the energy is reflected on it, and the rest is absorbed. Part of the absorbed energy will spread within the partition, and the rest crosses through the partition and is transmitted to the other side. [19]

The sound insulation is that property which enables it to resist the passage of noise or sound from one side to the other. This should not be confused with sound absorption which is that property of a material which permits sound waves to be absorbed, thus reducing the noise level. [18]

I.2.2 Acoustic properties of textile

The acoustic properties of textiles are connected with sound physics. Sound is vibration in a medium ex. air. Sound makes the molecules in the media vibrate and spread from the sound source in all directions as a sphere of pressure waves. Sound is often illustrated as waves, the length of these waves indicate the frequency of the sound, while the height of the wave indicates loud sound. The wavelength of a sound is the distance between the start and end of a sound wave cycle, or it is equal to the speed of sound in the material such as air divided by the frequency of the sound wave. [20, 21]

I.2.3 Sound Insulation Material

All materials have some sound absorbing properties. Incident sound energy which is not absorbed must be reflected, transmitted or dissipated. A material's sound absorbing properties can be described as a sound absorption coefficient in a particular frequency range. The coefficient can be viewed as a percentage of sound being absorbed, where 1.00 is complete absorption (100%) and 0.01 are minimum (1%). [18]

Fibrous materials have been widely used as acoustic absorbing materials in many fields, including vehicles and buildings. Natural fibers are supposed to have the same mechanism for acoustic absorption as other conventional synthetic fibrous materials, such as glass fiber and mineral wool. These fibers are often light and they are not harmful for human health and can therefore be used as sound absorbers in room acoustical products and noise barriers. Furthermore, many of these materials are currently available on the market at competitive prices. [17, 19]

I.2.4 Factors Influencing Sound Absorption of non woven materials

The efficacy of a material as a sound (noise) barrier depends on frequency of the sound Wave to which material is exposed, fabric weight per unit area, air permeability of the substrate, thickness and construction. Acoustic insulation and absorption properties of nonwoven fabrics depend on fiber geometry and fiber arrangement within the fabric structure, Summary of the factors influencing sound absorption of nonwoven materials is shown in the following Figure.[21, 22]

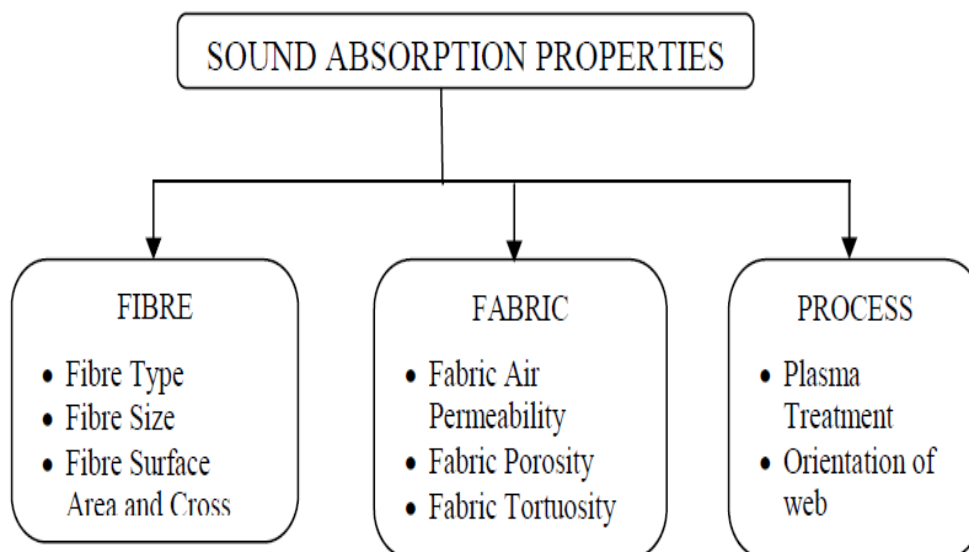


Figure 7: Factors influencing sound absorption of nonwoven materials

II. EXPERIMENTAL WORK

2.1. Specification of samples under study

In this research 7 samples were produced with nonwoven technique and bonded using *needle punching method*. It has been used seven different weights and needle penetration depth is 13mm.



Table (1) the specification of non-woven fabrics.

No.	Property	Specification
1	Fiber type	Waste (50% jute, 25% cotton, 25% polyester + polypropylene)
2	Fiber count	3, 6, 15, 25 den.
3	Fiber length	20, 30,40mm
4	Web formation	C. L. (cross – laid)
5	Fabric weight	600 – 750 –1000 - 1250 – 1360 -1500-1700gm./m ²
6	Beats/min	250
7	Needle penetration depth (two sides)	13 mm

2.2. Test applied to samples under study

The experimental tests have been achieved in the weave laboratory in the National Institute for standards and Acoustic. Activity laboratory in Housing& Building National Research Center (HBRC). In a standard environment (relative moisture: 65±2, temperature 20°C ±2).

In order to evaluate the performance properties of the produced samples, the following tests were carried out:

1-Thermal insulation of fabrics

2- Sound absorption coefficient to fabric samples.

3-Fabric air permeability using textestfx 3300 air permeability tester at a pressure of 120 pas

4-Fabric thickness

5- Fabric weight.

III. RESULTS AND DISCUSSION

Results of the experimental tests carried out on samples under study are presented in the following tables and graphs. Results were also statistically analyzed for data listed and relationships between variables were obtained.

Table (2) results of tests applied to samples under study produced with puncture depth 13 mm.

Number	Weight(g/m ²)	Thickness (mm)	Air permeability (cm ³ /cm ² /sec)	Thermal insulation (Tog)
1	600	4.51	73.82	2.4
2	750	6,08	61.09	2.49

3	1000	7,52	45,15	3.1
4	1250	8,06	39.07	3.38
5	1360	11.76	36.75	4
6	1500	13.67	34.71	4.16
7	1700	15.49	32.33	4.72

3.1 The effect of the different properties of non-woven fabrics on thermal insulation property

3.1.1. Effect of the fabric weight on the thermal insulation property

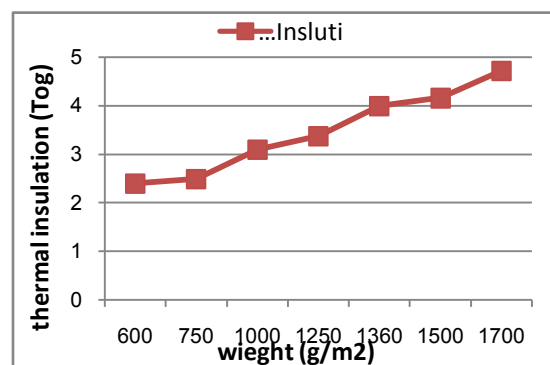


Fig. (1) Effect of weight on thermal insulation of fabric

Table (3) regression equation and correlation coefficient for the effect of weight g/m² on thermal insulation of fabric at needle penetration depth 13 mm

Regression equation	Correlation coefficient
$Y = 0.96 + 0.0021X$	$R^2 = 0.972$

It is obvious from table (2, 3) and fig. (1) that, there is a direct relationship between fabrics weight and its ability to thermal insulation.

As samples of 1700 g/m² weight have scored the highest values of thermal insulation, this may be because the increase in weight means increase in number of fibers per unit area, so increase the compact of fabrics, this reduce the aerobic blanks between these fibers, leading to reduce the heat lost during those blanks, so thermal insulation of the fabrics increased.

3.1.2. Effect of the fabric thickness on the thermal insulation property

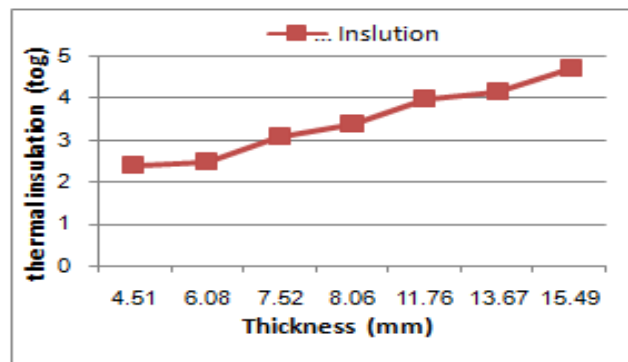


Fig. (2) Effect of thickness on thermal insulation of fabric

Table (4) regression equation and correlation coefficient for the effect of thickness on thermal insulation of fabric at needle penetration depth 13 mm

Regression equation	Correlation coefficient
$Y = 1.459 + 0.2092 X$	$R^2 = 0.967$

It can be seen from the table (2, 4) and fig. (2) that, there is a direct relationship between fabrics thickness and its ability to thermal insulation. This is mainly due to Increasing the thickness of the fabric means increasing the number of fibers in the unit area, thus increasing the compact of fabrics, which reducing the amount of heat lost during aerobic blanks so thermal insulation increased.

3.1.3. Effect of the fabric air permeability on the thermal insulation property:

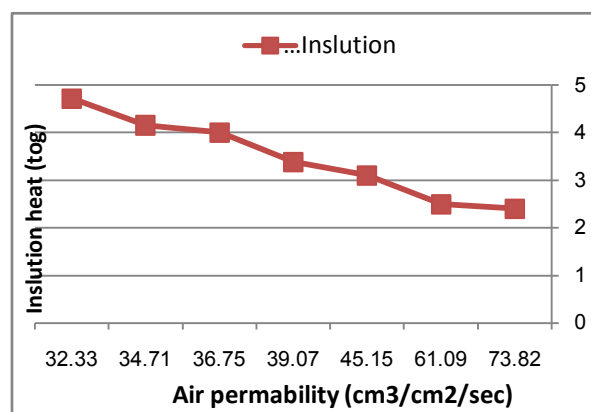


Fig. (3) Effect of air permeability on insulation heat

Table (5) regression equation and correlation coefficient for the effect of air permeability on thermal insulation of fabric at needle penetration depth 13 mm

Regression equation	Correlation coefficient
$Y = 5.799 - 0.051X$	$R^2 = 0.813$

Table (2, 5) and Fig. (3) Show that, there is an inverse relationship between the air permeability of non-woven fabrics, and its ability to thermal insulation. This can be attributed to the increased of air permeability of

fabrics, results in reduced integration of these fabrics, thus increasing the spacing ,so more heat lost through them, reduces its ability to thermal insulation .

3.1 The effect of the weight of non-woven fabrics on sound absorption coefficient

The following table shows the measurements of the sound absorption coefficient for the samples under study at third octave frequencies from 250:6300 Hz.

Table (6) the measurements of the sound absorption coefficient for samples with different weight at third octave frequencies from 250:6300 Hz.

Third octave Frequencies (Hz)	Sound absorption coefficient at 600 g/m2	Sound absorption coefficient at 750 g/m2	Sound absorption coefficient at 1000 g/m2	Sound absorption coefficient at 1200 g/m2	Sound absorption coefficient at 1350 g/m2	Sound absorption coefficient at 1500 g/m2	Sound absorption coefficient at 1700 g/m2
250	0.07	0.06	0.06	0.05	0.04	0.04	0.03
315	0.08	0.07	0.06	0.05	0.05	0.04	0.03
400	0.08	0.08	0.07	0.05	0.05	0.04	0.03
500	0.12	0.1	0.1	0.9	0.07	0.06	0.06
630	0.15	0.14	0.13	0.1	0.09	0.7	0.07
800	0.19	0.18	0.17	0.13	0.1	0.1	0.08
1000	0.27	0.25	0.24	0.17	0.14	0.12	0.1
1250	0.41	0.37	0.31	0.23	0.18	0.15	0.14
1600	0.47	0.42	0.34	0.31	0.24	0.21	0.2
2000	0.71	0.69	0.67	0.49	0.36	0.34	0.32
2500	0.8	0.73	0.68	0.52	0.45	0.38	0.33
3150	0.94	0.92	0.89	0.75	0.64	0.6	0.52
4000	0.98	0.97	0.92	0.89	0.76	0.73	0.7
5000	0.99	0.98	0.97	0.94	0.93	0.91	0.85
6300	0.99	0.98	0.97	0.97	0.97	0.95	0.94

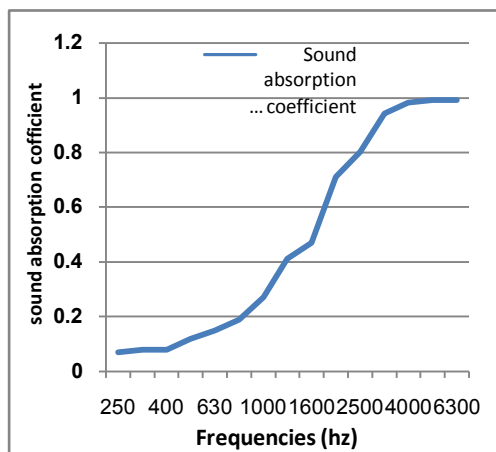


Fig. (4) The sound absorption coefficient of non-woven

fabrics at varying frequencies at 600 gm. / m²fabrics at different frequencies at 750 gm./m²

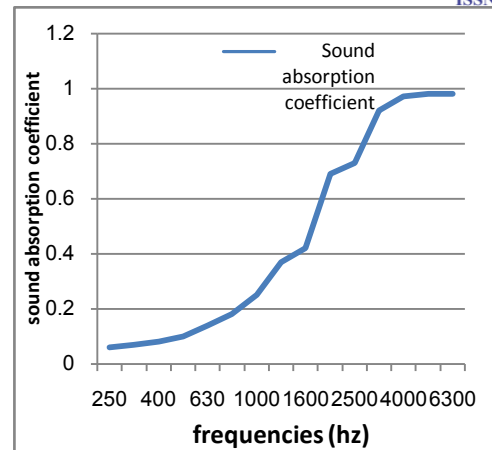


Fig (5) the sound absorption coefficient of non-woven

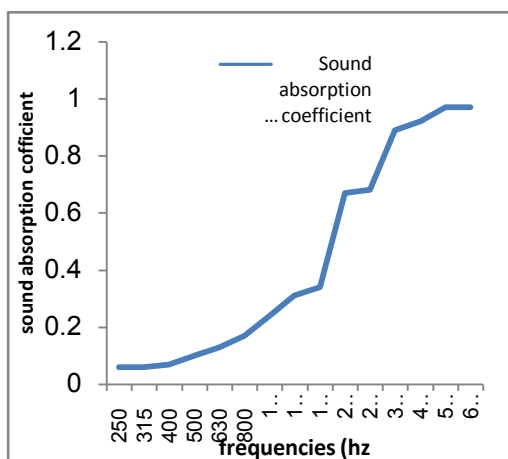


Fig. (6) The sound absorption coefficient of non-woven

fabrics at varying frequencies at 1000 gm. / m²fabrics at different frequencies at 1200 gm./m²

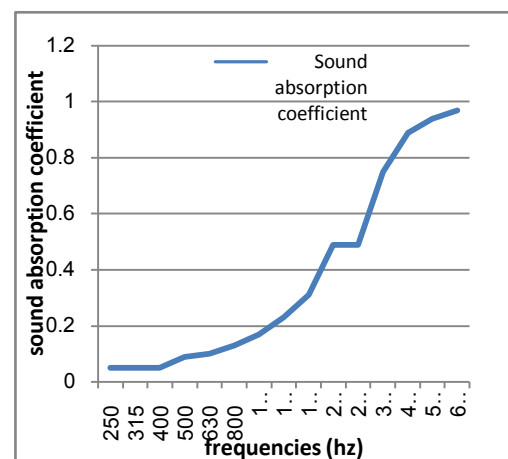


Fig (7) the sound absorption coefficient of non-

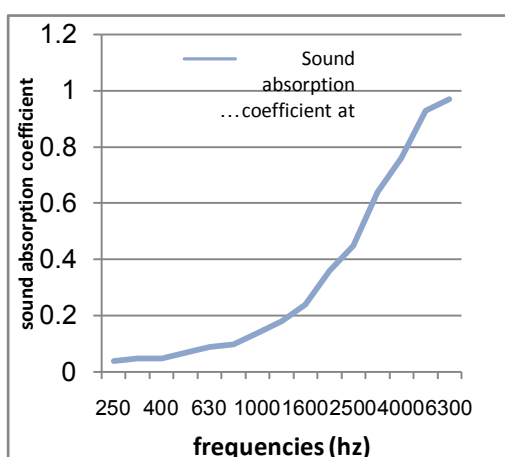


Fig. (8) The sound absorption coefficient of non-woven

fabrics at varying frequencies at 1360 gm. / m²fabrics at different frequencies at 1500 gm./m²

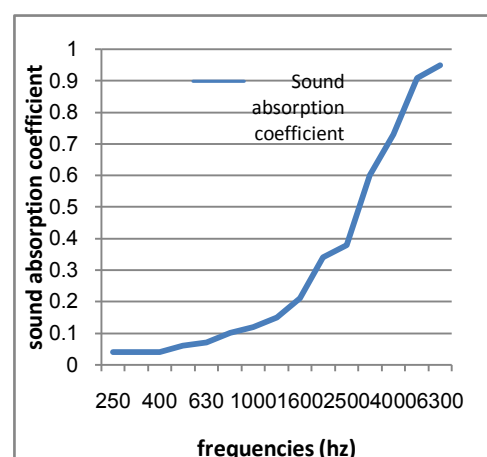


Fig (9) the sound absorption coefficient of non-woven

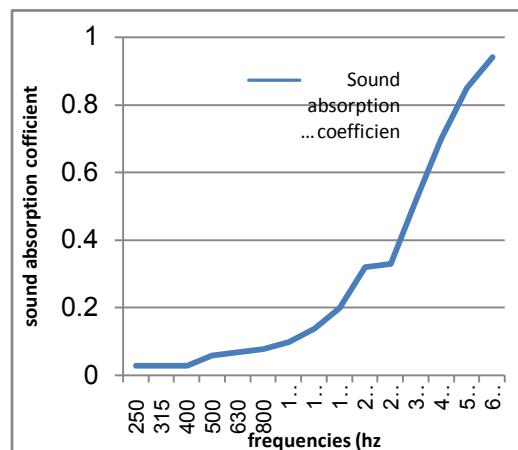


Fig (10) the sound absorption coefficient of non-woven fabrics at different frequencies at 1700 gm. /m²

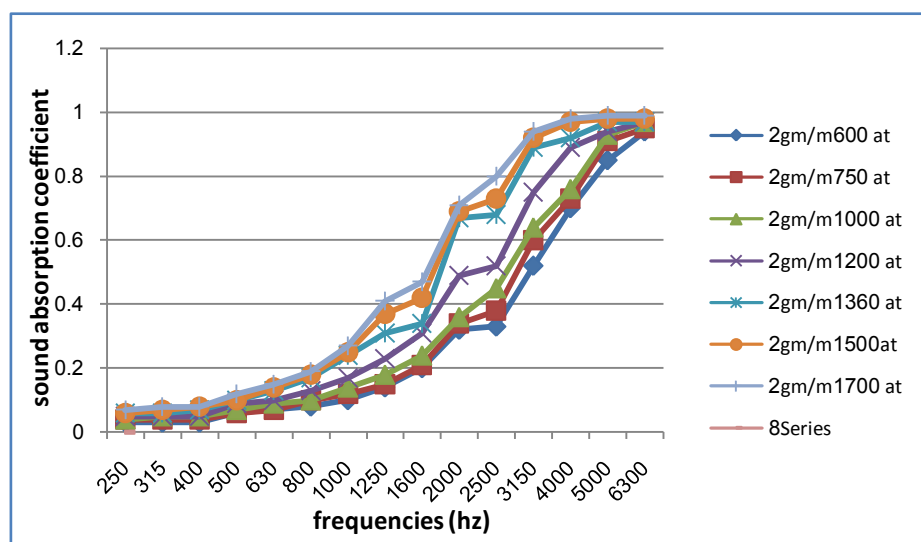


Fig (11) the sound absorption coefficient of non-woven fabrics at different frequencies and different weight

Table (7) regression equation and correlation coefficient for the effect of air permeability on thermal insulation of fabric at needle penetration depth 13 mm

Regression equation	Correlation coefficient
$Y = 0.255 - 0.00017X + 0.00017Z$	$R^2 = 0.813$

Where: Y sound absorption coefficient, X weight, Z frequencies

It is obvious from tables (7) and fig. (4-11) that:

- 1- There is an inverse relationship between weight of non-woven fabrics and its sound absorption coefficient, that is mean the increase in weight leading to decrease in its sound absorption coefficient, this is due to that, increase weight per square meter of fabric leading to increases layer of fibers; so air spaces in the fabric which sound absorption on it will decreases.



- 2- Increased frequency of sound leads to increase in sound absorption coefficient at all weights, this is consistent with all previous studies; where the improvement of sound absorption depends significantly on the wavelength of the sound, which appears clearly with a high frequency. That can be explained from the following low:

$$\text{Velocity} = \text{wavelength} \times \text{frequency}$$

$$\text{Therefore wavelength} = \text{Velocity} / \text{Frequency}$$

It can be observed from the previous law that, there is an inverse relationship between wavelength and frequency, that mean increased in the frequency, leading to decrease in wavelength, so easily absorbed into spacing of the non-woven fabric.

It is also known that, the vibrated sound produced from the reflection of wave length on a smooth surface, while it is absorption when it is passing into fabrics which compressible, so using these fabrics as insulation material in the building help us to dispense equipment control sound with high costs, which acoustical filtration.

It is worth mentioning that the sound absorption helps to purity sound inside the hall, either rebound and not absorption helps to confuse, not purity and clarity of sound.

Although the use of materials such as Rockwool and fiberglass can insulation greater than the material which used in this paper, but these material are better because they are cheaper and environmentally friendly.

IV. CONCLUSIONS

The aim of this work was to investigate the thermal insulation properties of cross-laid nonwoven fabrics of waste fibers. Based on the previously calculated and experimental results of samples under study produced as heat insulators, the researcher concluded the following points:

- 1- There is a direct relationship between fabrics weight and its ability to thermal insulation.
- 2- There is a direct relationship between fabrics thickness and its ability to thermal insulation.
- 3- There is an inverse relationship between the air permeability of non-woven fabrics, and its ability to thermal insulation.
- 4- There is an inverse relationship between weight of non-woven fabrics and its sound absorption coefficient.
- 5- Increased frequency of sound leads to increase in sound absorption coefficient at all weights.
- 6- Materials such as Rockwool and fiberglass can insulation greater than the material which used in this paper, but these materials are cheaper and environmentally friendly.

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