Measurement of Heat Transfer Rates of Polypropylene and Cotton Nonwoven Fabrics via Thermal Conduction

S. M. El Arabi , Zeinab Mohamed and Fatima M.

Faculty of Textiles, University of Gezira, Wad Medani, Sudan

ABSTRACT

Industrial textiles are widely being used for different simple and complex applications. Two samples of nonwoven fabrics were used in this study to assess their ability to transfer heat. They were made of polypropylene and carded cotton web. A simple model consisting of three 1×1 m^2 brick rooms was used having two of them being coated from inside by the samples using a polymeric adhesive. The third room was left blank. The outdoors and the conjugated indoors temperature degrees, at different periods of time during the day, were measured and recorded. A mathematical correlation was carried out. The samples showed delayed heat transfer rates compared to the untreated room, which indicates better insulation properties. On the other hand the cotton carded web fabric was even better than the polypropylene fabric.

Key Words: Non-woven, technical textiles, thermal insulation, heat conductivity, thermal properties.

INTRODUCTION

The development of textile materials had passed through many stages ranging from simple domestic applications to highly complicated applications. Depending on the end-use of such materials, the suitable design can be made to attain maximum usage potentials. One of the most applications that found a ground in industrial and technical textiles is the use of textile structures in thermal insulations (Tong 1983).Thermal conductivity is defined as the mode of heat transfer in which energy exchange takes place from the higher temperature to the lower because of kinetic motion of molecules (Speak man, Chamber Lain 1930).The thermal conductivity of fabrics depends on some physical characteristics, such as thickness, aerial density, and air permeability (Mohammad *et al*., 2003). The arrangement of fibres in non-woven fabrics which are getting more reliable and suitable for the production of technical textiles for their mass productivity and extra engineered properties, play a very important role in heat transmittance that depends on the fabrication process (Pan, Gibson 2007). Non-woven fabrics are suitable for many applications when are used as a core material for technical textiles for their absorbency, elasticity, strength and other attractive properties (Wilhelm *et al*., 2003). Compared to all other fabrics and textile materials, and for the use of thermal insulation, the non-woven fabrics have the best thermal properties because of its porous structure. The heat transfer rate depends on the thermal conductivity of the medium through which the transference is occurring. The thermal conductivity is again dependent on other factors as shown in the following equation (Vignesw Aran *et al*. 2009):

$$k = (Q \times L)/((A \times \Delta T)) \qquad (1)$$

Where

k is the thermal conductivity
Q is the amount of heat
L is the thickness of the medium
A is surface area of the medium
ΔT is the temperature difference

In this paper, an attempt was done to know the rate of the heat, exposed directly from sun light, that is being transferred through brick walls and nonwoven fabrics, at one hand, and on the other hand, through only a brick wall, and getting inside a model room.

MATERIALS AND METHODS

Two different non-woven sample fabrics were used in this study. Carded cotton web layers were collected, pressed and stitched to make a non-woven fabric. The other sample is a polypropylene fibre non-woven fabric. The basic data of these samples are shown in Table 1.

Table 1: Thermally affecting properties

Property	Value	
	Polypropylene	Cotton
Grammage (gm/m^2)	500	350
Thickness (mm)	3.6	3.6
Air Permeability	Low	High
Packing density	high	low

Three model rooms each of 1×1 m^2 were built using red bricks and sand cement mixture and the walls were smoothed on all sides. The two non-woven fabrics were used to adhere, each for one room, to the walls from inside and the roof, using a simple polymeric adhesive. The third room was left without fabric treatment. Digital thermometers were used to measure the inside temperature degrees for each room having their sensors put inside the rooms using holes on top of each room, with simultaneous measurement of the outdoors temperature. The records were taken during different periods of day time and tabulated. The readings were taken five times a day for seven days continuously and the average values were calculated and used. Each room has got a wall thickness of 8.5 cm.

RESULTS AND DISCUSSION

Temperature degrees measurements

The temperature degrees for the different rooms are shown in Table 2. The highest rate of heat transfer was recorded in the blank room. The difference between the outdoors temperature and indoors one is very low. The room which had been lined with the fabrics showed a higher difference amongst the whole readings.

Table 2: Record of Temperature

Temperature degrees (°C)			
Outdoors	Indoors		
	Blank	Cotton	PP
32	31	30	31
33	31	31	31
34	30	27	27

35	33	32	32
36	35	33	32
38	37	33	34
39	37	34	36
40	39	38	38

There are some points where no clear difference was noticed between the three model rooms. Very low temperature degrees were noticed for the treated rooms and that was because of rain falls on that day, an indication of hygroscopic property of the textile materials compared to any other material specially the cement-sand mixtures. It is also noticeable that the fabrics showed almost similar results.

The results gave an indication that almost the whole amount of temperature is being transmitted inside the blank room**,** whereas the fabrics tended to decrease this amount. This is merely because of the possible entrapped air inside the non-woven fabrics in addition to the added thickness which delayed the heat transfer.

Calculation of thermal conductivity

Referring to equation 1, the amount of heat, Q, and the surface area of the medium, A are constant values in our model. Hence, the thermal conductivity can be expressed as follows:

$$k = (a1 \times L)/(a2 \times \Delta T) \qquad (2)$$

Where $a1$and $a2$ are constants,
Then;

$$k = A \times L/\Delta T \qquad (3)$$

Where A= $a1$/ $a2$.

The calculated results of thermal conductivity , k, are shown in Table 3. ΔT values were calculated from the average temperature degrees.

Table 3.Thermal conductivity calculations

The model	L (m)	ΔT(°C)	k ($Wm^{-1}C^{-1}$)
Blank	0.0850	1.750	0.049×A
Cotton	0.0886	3.625	0.024×A
PP	0.0886	3.250	0.027×A

The lowest value of thermal conductivity was found in the room with cotton fabric followed by that of polypropylene fabric with a very low difference between both values. These values are inversely proportional to the temperature differences which means that whenever the indoors temperature is close to the outdoors one, a higher value of thermal conductivity is resulted. The blank room has got the highest value of thermal conductivity. This shows that the treatment of walls from inside using non-woven fabrics, prohibits high rates of heat transfer and this will create a comfortable weather inside rooms.

Mathematical relations characteristics

The mathematical relations between the outdoors and the indoors temperature degrees for each of the three models were plotted in Figures 1, 2, and 3.

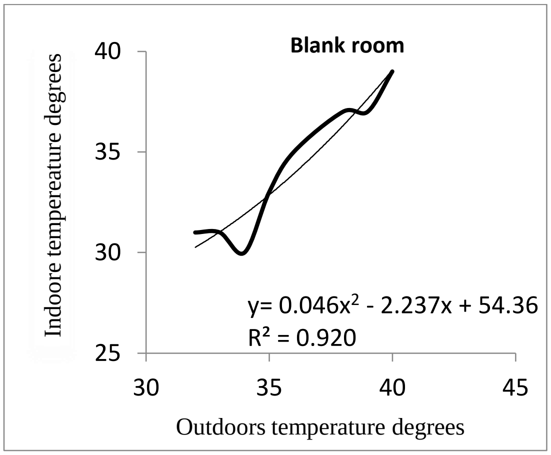

Fig. 1: Temperature degrees relationships for blank room

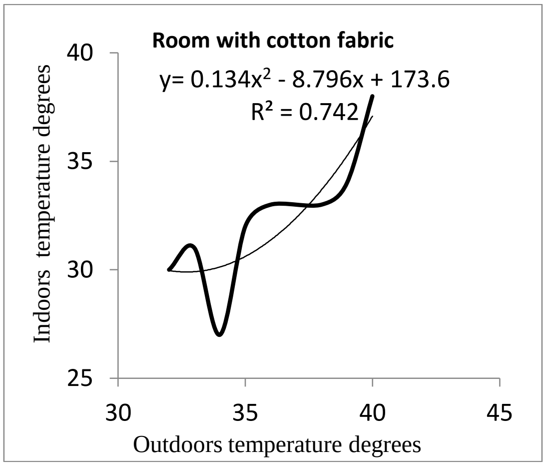

Fig. 2: Temperature degrees relationships for cotton

fabric treated room

The polynomial equations were shown for each plot together with the regression values. The blank room showed the highest value of regression, which means close temperature degrees and so a high rate of heat transfer. The room treated with cotton nonwoven fabric has the lowest value, an indication of low rates of heat transfer.

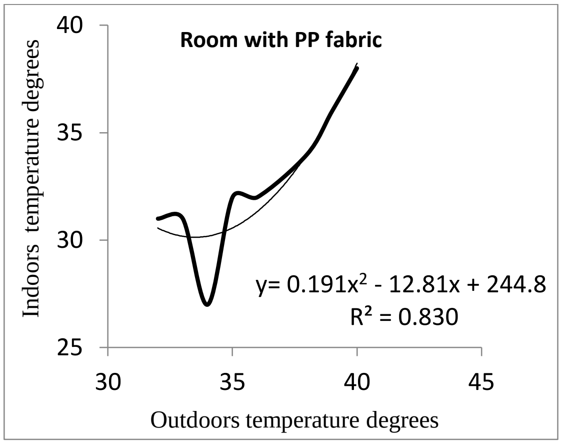

Fig. 3: Temperature degrees relationships for PP fabric

treated room

The room treated with polypropylene nonwoven fabric showed a value which is near to that of cotton. Thus, the blank room has the highest rate of heat transfer, whereas the treated rooms have low rates of heat transfer. This shows clearly that nonwoven fabrics are suitable for heat insulation because of their characteristics of structure, fibre lay-out, and orientation.

CONCLUSION

The nonwoven fabrics can be used to decrease the rates of heat transfer from outside of buildings and so can create a comfortable non-damp weather inside these buildings. The use of cotton non-woven fabrics is more suitable than that made of polypropylene non-woven fabrics. This paper establishes for the use of nonwoven fabrics in the field of construction as a medium of delaying heat transfer.

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مجلة الجزيرة للهندسة والعلوم التطبيقية المجلد الحادي عشر، العدد الثاني،1438ه/2016م

قياس معدلات إنتقال الحرارة للأقمشة غير المنسوجة من البولي بروبابلين والقطن عبر التوصيل الحراري

د. صلاح الدين محمد العربي، زينب محمد، فاطمة محمد
جامعة الجزيرة – كلية النسيج

الخلاصة

يتم إستخدام الأقمشة الصناعية على نطاق واسع في التطبيقات البسيطة والمعقدة. في هذه الدراسة تم إستخدام عينتين من الأقمشة غير المنسوجة من البولي بروبابلين والقطن وذلك لمعرفة قابلية كل منهما لنقل الحرارة . تم عمل نموذج مبسط من ثلاث غرف مبنية من الطوب الأحمر بأبعاد 1×1×1 م^3 وتم تبطين غرفتين من الداخل واحدة بقماش البولي بروبابلين والأخرى بقماش القطن، وتم ترك الثالثة دون تبطين. تم قياس درجات الحرارة داخل وخارج الغرف الثلاث في نفس الأزمان وتم حساب العلاقات الرياضية التى تربط بينها.

أوضحت الدراسة تباطؤ معدل إنتقال الحرارة من الخارج إلى داخل الغرف المبطنة مقارنة بالغرفة غير المبطنة مما يدل على أن الأقمشة تمتلك خواص للعزل الحراري وأن قماش القطن أفضل من قماش البولى بروبابلين في هذه الخاصية .

كلمات مفتاحية : غير منسوج، منسوجات صناعية، عزل حراري، توصيل حرارى، خواص حرارية.