Polyurethane coated non-woven: A Promising Solution for Building Insulation

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Abstract. The aim of this work is to evaluate the potential application of textile and polyurethane aqueous dispersion in insulation application in the form of a nonwoven polyurethane composite. Based on their properties, nonwoven are promising insulation solution for buildings. However, the major disadvantage is their flammability and their low mechanical property. The main purpose of this research is to improve physical, thermal and acoustical properties of these materials, by using a thin layer of polyurethane. According to the experimental results, it can be concluded that the PU layer enhanced the barrier properties of textile nonwoven. Moreover, it has a great effect on the sound absorption coefficient and thermal conductivity. The results of this study provide an effective solution for insulation application. Indeed, these alternative materials will contribute to the cost advantage as well as the green building initiative.

Keywords: Energy efficient, insulation material, nonwoven, sound absorption, thermo-physical characterizations.

1. Introduction

In Morocco as in Europe, the regulations around the energy performance of building are in strong evolution. The new regulations set ambitious targets for energy efficiency, which include minimizing energy consumption, controlling energy consumption and implementing good practices to reduce energy costs and to achieve a reduction in energy costs [1]. Thermal insulation in buildings is an important factor for the thermal comfort of its occupants. It reduces unwanted heat loss or gain and the energy demand of heating and cooling systems by conduction, convection and radiation. Several thermal insulation materials are used commercially for the insulation of buildings, but few are completely satisfactory for this purpose. The main problems are the lack of mechanical resistance, flammability and...
moisture absorption. Therefore, it is important to choose easily recyclable, renewable, locally available and environmentally friendly insulation materials.

During last few years, textile materials have found a range of applications in the field of thermal insulation. In the literature, researchers have studied the potential application of nonwovens based on acrylic fibers and they found that the developed sample exhibited excellent insulation performance with a conductivity value of 0.035 to 0.0355 W/(m.K) [2, 3]. Other studies [4, 5] have evaluated the use of textile fibers such as recycled polyester, wool as insulation materials, these materials have been tested in terms of thermal insulation, sound absorption and moisture absorption, and they found that applying these wastes as a possible thermal insulation material seems to be an adequate solution due to their ecological benefits.

Non-woven materials, because of space and weight savings, are one of the most important products in textiles that are being used as thermal insulation materials, due to these the technical advantages, they replaced traditional materials such as foam and panels. There is an increasing number of products made of nonwovens for roofing and construction, such as insulation and membranes. However, the major disadvantage is their flammability and their low mechanical property [5].

The main goal of this paper is to develop cost effective coated insulation materials for building and automotives industries, also to improve physical, thermal and fire behavioural properties of nonwoven made form reclaimed fibers, by using an aqueous dispersion polyurethane foam coatings.

2. Materials and methods

2.1. Material

The needling technique was used for the manufacture of the mechanically entangled polyester nonwoven fabric to obtain a consolidated shape with an average porosity of 99% (Table 1).

| Sample                  | Thickness [mm] | Mass per unit area [g/m²] | Bulk density [Kg/m³] | Porosity (%) |
|-------------------------|----------------|---------------------------|----------------------|--------------|
| Polyester nonwoven [PN] | 13             | 142                       | 10.93                | 99.2         |

The PU used in this study were produced by the HUNSMAN Company. A mixture of commercial aqueous dispersion of PU and thickening drop was used, the mixture was subjected for 30 min at a speed of 900 rpm to achieve a viscosity of 3510 cP.

2.2. Methods

After the PU’s preparation step, they are applied to the polyester nonwovens through a MATHIS type SV coating machine and dried for 3min at T=160 °C.

The thickness ($e$) of samples was determined based on the procedure cited in ISO 9073-2. The coating thickness C percentage was determined according to equation (1).

$$C(\%) = \frac{e - e_0}{e_0} \times 100$$  \hspace{1cm} (1)

With $e$: thickness of coated nonwoven, $e_0$: thickness of uncoated nonwoven.

Experimental observation of coated non-woven materials were carried out using optical microscope (the Leica DME). The objective lens used was a 506226 Hi plan 4x/0.1.

Thermal conductivity was measured using the guarded hot plate apparatus λ-Meter EP500e as per the EN 12667. Sample size used for measurement was (200 mm × 200 mm × samples thickness). In this study, the measuring temperature was 10, 25 and 40°C. Moreover, the temperature difference between the hot plate and the cold plate is set at 15°C in all measurements.

The uniaxial tensile tests of different samples were conducted at room temperature using an MPZ3k universal testing machine, at constant crosshead speed of 5 mm.min⁻¹.
The acoustic performance was evaluated using a vertically disposed impedance tube, two microphones and a digital frequency analyzer (Figure 1). This device known by Kundt's consists of a tube of 1.2m in length and 100 mm in diameter, which was kindly provided by LEME l’EST Structure (University in Rabat-Morocco). The measurements were based on the method described in ISO 10534-2: 2001 Standard. The samples were placed in the middle of the tube, and the coated surface is located in front of loudspeaker. The frequency range used for the measurement was 50–1600 Hz. Five readings were taken randomly from each sample for evaluating acoustic properties.

3. Experimental results and discussion

According to Figure 1 and table 2, a non-linear decrease in the thermal conductivity coefficients with the increase in coating thickness. The good coefficient of thermal conductivity can be explained by the unique structure of nonwoven during the manufacturing process, it consists of dense fibers and pores [2]. The PU coated acts as an additional insulating layer with a conductivity that is constant for a given thickness (Figure 3), which explains the stabilization observed in Figure 2. By developing the thermal resistance equation (2) and measured value, it was possible to determine the thermal conductivity of the coatings. The thermal conductivity of PUF at 10°C was found 22.60 mW/(m.K).

\[ R_{th} = R_N + R_c = \frac{E}{\lambda} = \frac{E_0}{\lambda_0} + \frac{E_c}{\lambda_c} \]  

(2)

\[ \lambda_c = \frac{\lambda \times \lambda_0 \times E_c}{\lambda_0 \times E - \lambda \times E_0} \]

Where, \( R_{th} \) = thermal resistance of coated sample; \( R_N \) = thermal resistance of uncoated sample, \( R_c \) = thermal resistance of coating layer, \( E \) = thickness of coated sample, \( E_0 \) = thickness of uncoated sample, \( E_c \) = thickness of coating layer. \( \lambda \) = thermal conductivity of coated sample, \( \lambda_0 \) = thermal conductivity of uncoated sample, \( \lambda_c \) = thermal conductivity of coating layer.

| Table 2. Measured thermal conductivity |
|---------------------------------------|
| Coating thickness (%) | 10°C | 25°C | 40°C |
|------------------------|------|------|------|
| 5                      | 34.35| 36.77| 39.63|
| 15                     | 34.26| 36.498| 39.75|
| 20                     | 34.22| 36.71| 39.54|
| 25                     | 33.95| 36.49| 39.72|
| 30                     | 33.76| 36.17| 38.97|
The variation in the breaking strength of PN nonwoven coated sample is presented in Figure 4. It is clearly observed that the breaking strength increase with increase in PU coating thickness. At 5% coating thickness (CPUF), the breaking strength of the PN coated samples increases by 77.16 and 30% respectively.
Figure 4. Breaking strength in function of thickness percentage.

The Figure 5 shows the influence of the coating thickness on the sound absorption behavior of PN samples. It is clearly seen that the PUF coating has a great effect on sound absorption behavior in the high frequencies (800-1400 Hz). The sound absorption was lower at low frequencies (0-600 Hz) and increased from medium (800-1000 Hz) to high frequency range (1000-1400Hz) for all the samples, and also it is also observed that the absorption curve of all samples has been moved to the right (higher frequency), this change is due to the thickness of the sample, because by increasing the thickness of the sample, the acoustic absorption performance increases significantly, this observation is in agreement with the previous study [22, 23].

Figure 5. Sound absorption coefficient in function of coating percentage.
4. Conclusion
This article presents a study on the effect polyurethane coating on thermal and physical properties of samples made from polyester fibers for thermal insulation applications. Based on the results, it can be stated that the PU coating enhanced the physical and barriers properties of coated nonwoven. Only 5% in PUF coating thickness improves the conductivity value at 10°C. The breaking strength of PN coated samples increases by 30%. Results also have shown that coating has a great effect on sound absorption behavior in the high frequencies (800-1400 Hz) with a maximum rate of improvement of 39.3%.

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