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Related content

Study of the behaviour of thermal insulation materials made with recycled textile fibers

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Abstract. The requirements placed on the thermal protection of buildings are becoming stricter worldwide, which causes an increased demand after thermal insulation materials. One of the ways of achieving sustainable development in this area is the use of secondary and renewable raw materials. This paper describes the results of research aimed at developing and studying the behaviour of thermal insulation materials made with recycled textile fibers.

1. Introduction

Thermal and acoustic insulation materials have become a standard part of basically all buildings. The worldwide usage of insulation materials has been rising every year (source EEB) [1]. For reasons of sustainable development and meeting contemporary requirements for the energy efficiency of buildings it is necessary to seek ways of further increase the production of thermal and acoustic insulations without putting excessive strain on material resources and increasing primary energy intensity (PEI) together with CO_2 emissions (GWP) as a consequence.

One of the possible ways of addressing this is the utilization of secondary raw materials, which can be used as a full substitute for primary materials [2, 3, 4, 5, 6, 7]. One potentially interesting option is the use of recycled textile fibers produced by various branches of industry. These fibers are currently available in good enough quality practically anywhere in the world, are affordable, and insulations made with them can have very good utility properties.

2. Recycled textile fibers

The research involved a study of various secondary fibers produced by different industrial branches. These were PES-based polymer fibers, cotton, and bast fibers. The fibers were microscopically examined and tested for thermal conductivity using specimens prepared from free layers of fibers with the bulk density of 35 kg/m^3. The measurements were made with a total 14 types of recycled fibers (including fiber mixtures). It was found that the thermal conductivity of the samples ranged within 0.038 – 0.049 W/(m.K). Thermal conductivity was proved to be markedly lower in samples that contained badly defibered clusters (e.g. recycled carpets, etc.). The thermal conductivity of samples made from pure fibers ranged within 0.038 – 0.042 W/(m.K). The subsequent research presented herein was performed with PES fibers with the thermal conductivity of 0.039 W/(m.K), average thickness of 20 μm and length of 61.2 mm, which appear to be useful thanks to their good properties and broad availability.

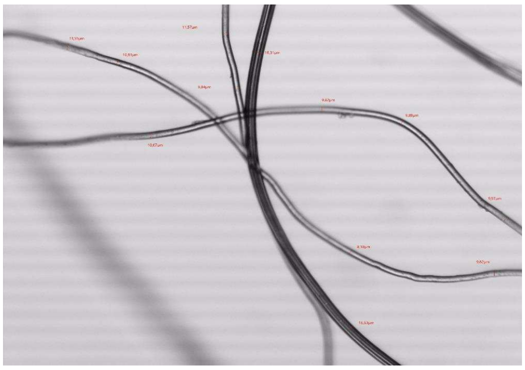

Figure 1. Microscopic image of the PES fibers.

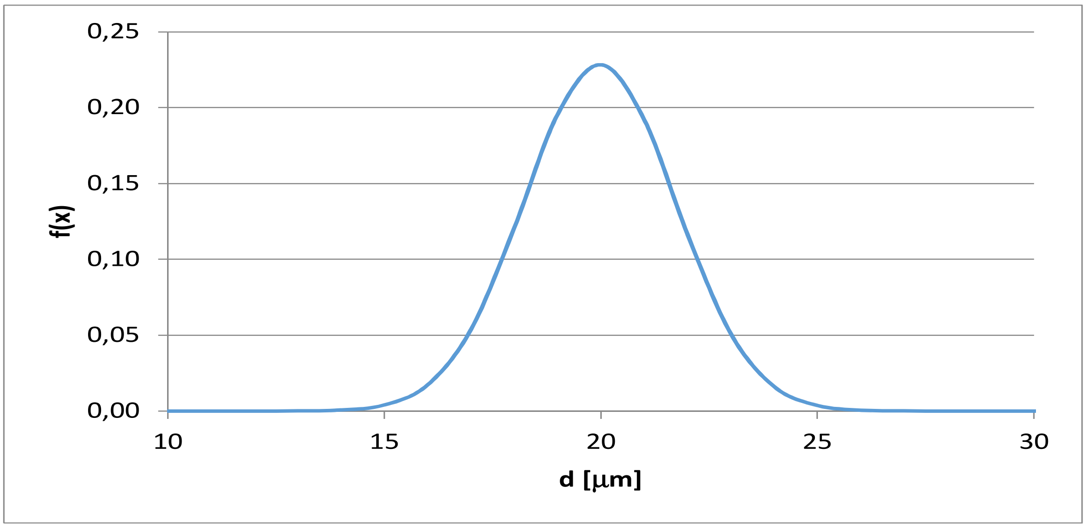

Figure 2. Diagram of the normal distribution of the fiber thickness in the PES sample (probability density).

3. Test samples

The test samples were made from a sample of recycled PES fibers (see above) and an addition of 15 % bicomponent PES fibers combined by thermal bonding. Two series of samples were made:

- Samples with the bulk density of 50 kg/m^3 with a variable thickness of 20, 40, 60, 80 and 100 mm,
- Samples with a thickness of 35 mm and varying bulk density 25, 50, 75, 100 and 125 kg/m^3.

It was not always possible to maintain the desired parameters during production. The actual thickness and bulk density values are listed below.

The samples of insulation were then made into mat specimens with the dimensions of 200 x 200 mm or 300 x 300 mm. Prior to further testing the specimens were stored at a temperature of +23°C and relative humidity 50%.

Figure 3. Photograph of a specimen with density of 100 kg/m^3.

4. Methodology

The fiber samples or mat specimens were measured for basic physical and thermal insulation properties. This involved the determination of:

- thickness according to EN 823 [8],
- length and width according to EN 822 [9],
- bulk density according to EN 1602 [10],
- thermal conductivity according to EN 12667 [11] and ISO 8301 [12].

The specimens had the shape of a mat, and, depending on thickness, had the dimensions of 200x200 mm or 300x300 mm. Thermal conductivity was measured on specimens with a stable laboratory moisture content ($u_{23,50}$), mean temperature + 10 °C, and temperature gradient 10 °C.

5. Results and discussion

The first step was the measurement of thickness, bulk density, and linear dimensions. It was found that the real parameters of the specimens diverted in some cases from the design, which is due to the system of prototype production and a relatively small volume of samples produced.

Table 1. Thickness and bulk density of the first series of samples with varying bulk density.

Sample No.	d [mm]	ρ_v [kg/m^3]
1 - a	21.043	48.58
1 – b	30.124	66.69
1 – c	55.438	56.53
1 – d	76.154	47.86
1 - e	90.161	52.84

Table 2. Thickness and bulk density of the second series of samples with varying thickness.

Sample No.	d [mm]	ρ_v [kg/m^3]
2 - a	35.928	26.33
2 – b	31.490	57.06
2 – c	33.247	77.22
2 – d	37.736	89.35
2 - e	38.049	104.89

Next, thermal conductivity was measured using the hot plate method. The tables below show the results.

Table 3. Thermal conductivity of the first series of samples with varying bulk density.

Sample No.	λ [W/(m.K)]
1 - a	48.58
1 – b	66.69
1 – c	56.53
1 – d	47.86
1 - e	52.84

Table 4. Thermal conductivity of the second series of samples with varying thickness.

Sample No.	λ [W/(m.K)]
2 - a	26.33
2 – b	57.06
2 – c	77.22
2 – d	89.35
2 - e	104.89

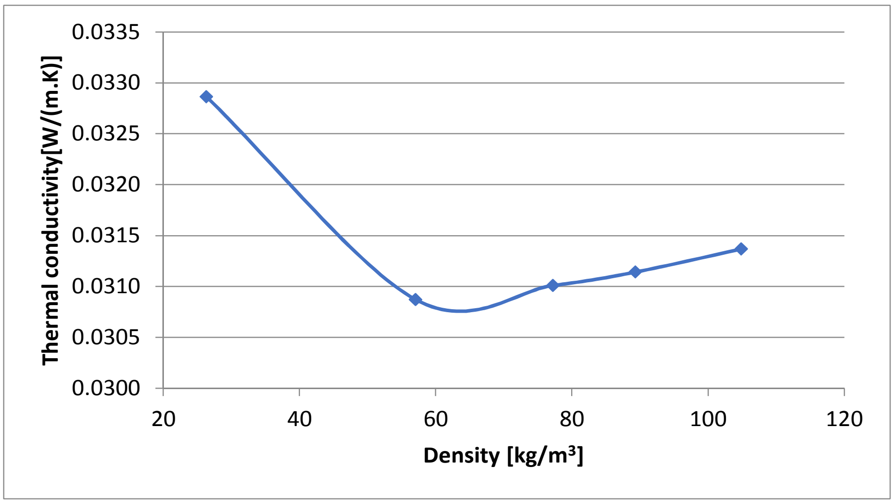

Figure 4. Diagram showing the dependence of thermal conductivity on bulk density.

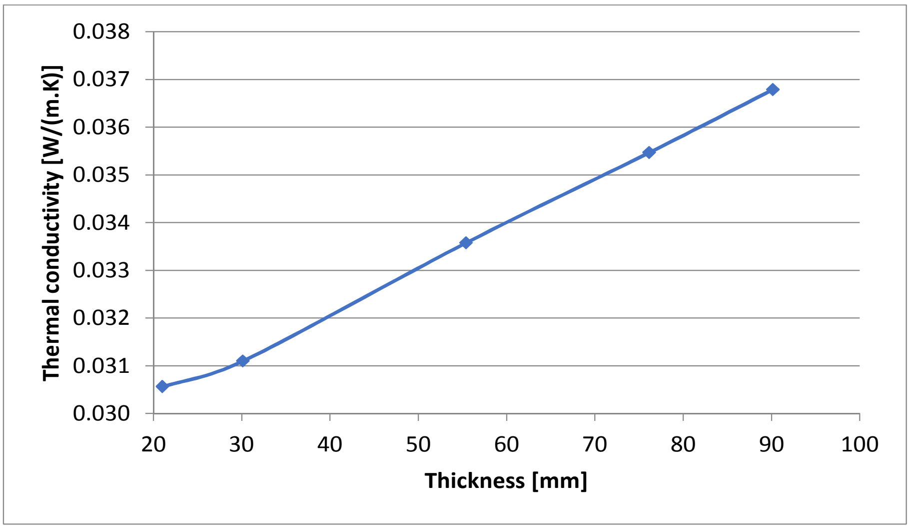

Figure 5. Diagram showing the dependence of thermal conductivity on thickness.

6. Conclusion

Thermal insulation materials made with recycled textile fibers show great promise for development and usage in civil engineering. The experiments show that the thermal insulations made with recycled PES fibers can compete with products based on mineral wool or expanded polystyrene, which currently dominate the market. When designing these materials, it is, however, important to correctly set the bulk density of the insulations and to know all the factors that influence the final properties.
The results also show the following.

- Insulations made with PES fibers have excellent thermal insulation properties; their thermal conductivity can reach values of less than 0.031 W/(m.K).
- The optimal bulk density of the samples is 50 – 80 kg/m^3.
- The key parameter of these insulations is their thickness and fiber orientation. This property is more important than bulk density (as demonstrated by diagrams in figures 3 and 4).

Acknowledgements

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