Production of eco-composites as thermal insulation materials using mineral waste as modifiers

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IINTRODUCTION:

Currently, often used thermal insulating materials in buildings or attics are materials based on mineral wool or glass wool. Despite their wide use, there is no rational way to reuse them. At the time of the demolition or renovation of buildings, they become a problematic waste, difficult to manage. This project presents the use of these wastes as a filler in the production of rigid polyurethane foams. Before the waste can be used in the process, it ispre-prepared by subjecting it to thermal treatment and then grinding in a ball mill. The eco-composite production technology corresponds with the principles of the circular economy (as waste materials are used in the production of new materials).

The main objective of the project is to reduce the consumption of petrochemical raw materials for the production of insulation materials by replacing some of the ingredients with a waste-derived filler, which will result in a reduction in the price of the finished product and , at the same time, of its carbon footprint. reducing its carbon footprint. It is expected that the use of the filler will improve selected properties of the produced eco-composites in relation to rigid polyurethane foam without the addition of filler (PUR).

MATERIALS AND METHODS:

1. Characteristics of the filler

The filler was mineral wool waste used to insulate buildings. Before adding the waste to the components of the new composite, the waste was subjected to appropriate processes.

First, mineral wool waste was subjected to a temperature of 700°C for 7 minutes in a specially designed electric furnace (Phase I). Exposing the waste to high temperatures causes a significant reduction in volume and hardening of the waste. In the second stage, the burnt waste was ground in a ball mill to diameters of several tens of micrometres (Phase II). The powder prepared in this way could be used as a filler in the production of polyurethane composites. The filler preparation process is shown in Figure 1.

The pre-treated waste was observed using a Scanning Electron Microscope with an EDS detector, which is part of the equipment of the Faculty of Metals Engineering and Industrial Computer Science of the AGH University. The morphological structure and chemical composition of the filler were analysed.

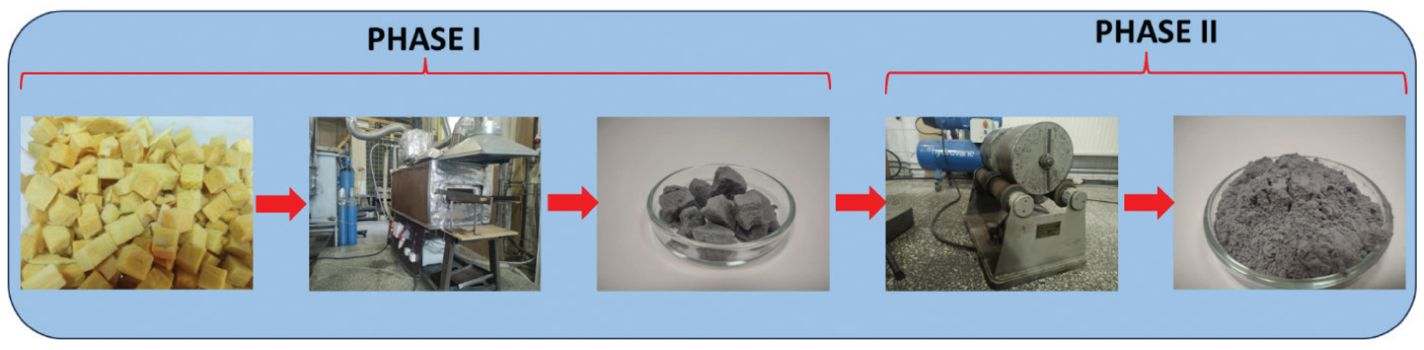

Figure 1. Scheme of the filler preparation process.

2. Production of polyurethane eco-composites

As part of the project, rigid polyurethane foams with the addition of 10% (PUR10) and 20% (PUR20) of filler obtained from mineral wool waste were produced. The percentages were calculated in relation to the finished mass of the product. The stage of eco-composite production consisted in mixing the appropriate amount of filler with polyols and then mixing with isocyanates using a mechanical stirrer at 1200 rpm for 10 seconds. After this time, the ready mixture was poured into appropriate moulds. The production process of rigid polyurethane foams is shown in Figure 2. After 24 h, they were removed from the mould and cut on a band saw to the required dimensions, depending on the type of tests performed. For comparative tests, rigid polyurethane foams without the addition of filler (PUR) were also produced.

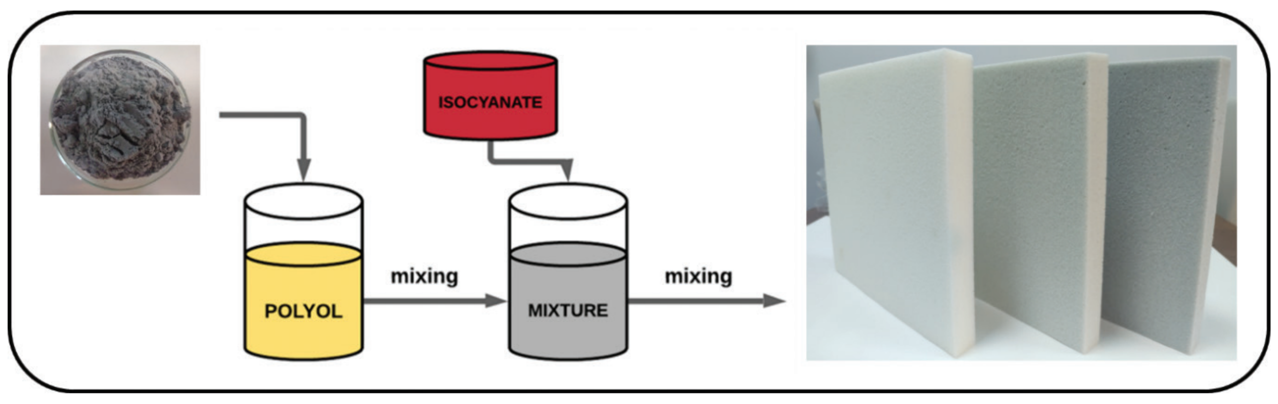

Figure 2. Scheme of the production process of rigid polyurethane composites.

3. Analysis of manufactured eco-composites

- Morphological analysis using the Scanning Electron Microscope (SEM) and analysis of the chemical composition (using the EDS detector).
- Compressive strength. Mechanical properties of the foams were assessed in accordance with EN 826:2013 using the universal testing machine, Zwick 1435, at 10% relative deformation.
- Friability. The friability was evaluated during the test carried out according to the ASTM C421–08 standard. The previously weighed samples were placed in a box with oak cubes and rotated in accordance with the parameters specified in the standard.

RESULTS AND DISCUSSION:

1. Filler

Figure 3 presents a SEM image of prepared filler. It can be noticed the presence of sharp edges of the mineral wool waste that was previously subjected to a pre-treatment process can be observed.. Table 1 shows the chemical composition of the filler. The presence of large amounts of oxygen (~38%), silicon (~30%) and sodium (~10%) may indicate the presence of silicon oxides and sodium silicates in the obtained filler.

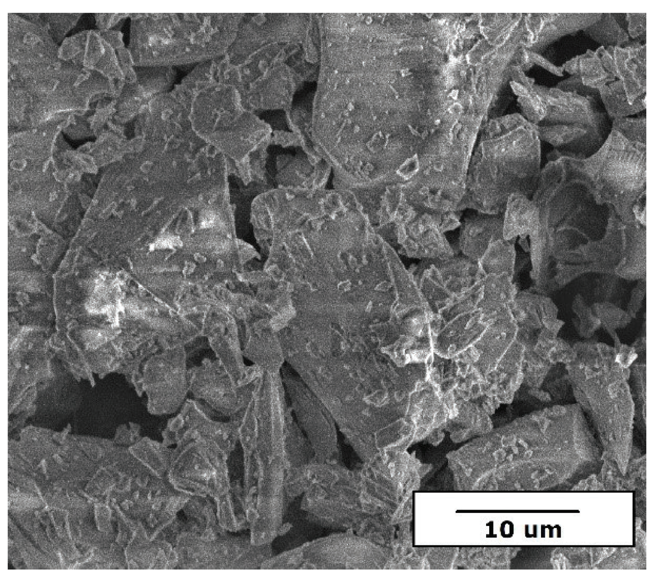

Figure 3. SEM image of the prepared filler.

Element	Wt%
C	08.23
O	38.29
Na	10.16
Mg	00.86
Al	01.18
Si	30.51
S	00.35
K	00.85
Ca	06.54
Fe	03.03

Table 1. Chemical composition of the filler (mineral wool waste).

2. Eco-composites

SEM. Observations made using the SEM microscope indicate the presence of closed polyurethane cells. Figure 4 shows a SEM images of the PUR10 material and it can be seen that the addition of the filler does not cause cell cracking and structure destruction. The filler "embeds" in the walls of polyurethane cells.

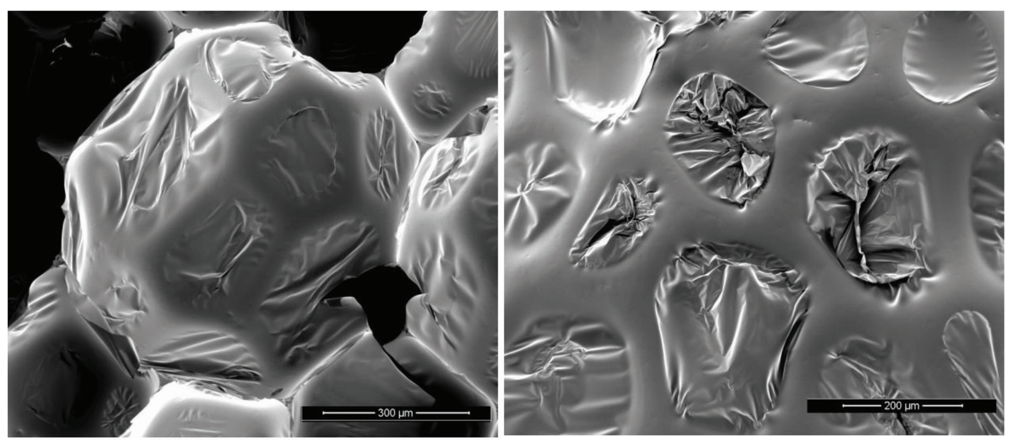

Figure 4. SEM images of the PUR10.

Compressive strength. Figure 5 shows samples prepared for compressive strength testing with the direction of foam growth marked with arrows. In order to carry out the tests, discs with a diameter of 30 mm and a height of 10 mm were punched out of the analysed materials. As a result of the analysis of mechanical compressive strength, no significant changes were observed. In all analysed cases, the compressive strength was 0.2 MPa (Table 2).

Figure 5. Prepared samples for compressive strength analysis.

Sample	Compressive strength, MPa
PUR	0.2
PUR10	0.2
PUR20	0.2

Table 2. Compressive strength values of analysed materials.

Friability. As a result of the friability tests, a significant increase in brittleness was observed for the PUR20 material. The friability of the PUR10 material is very similar to PUR, what can be seen in the photo of the cubes after the brittleness tests (Figure 6).

Figure 6. View of the samples after the friability test.

CONCLUSIONS:

Based on the conducted analysis, the polyurethane material with the addition of 10% of the filler (PUR10) seems to be the most promising. If a larger amount of filler is added, the friability of eco-composites deteriorates significantly. As part of the project, further research is planned, e.g. examining the size diameter of the filler, thermal conductivity of the produced materials and the impact of weather conditions on the parameters of polyurethane materials. In order to recreate changing weather conditions, UV lamps and freezing devices will be used in the laboratory. The test will be carried out in accordance with applicable standards. In the next stages, tests on the flammability of the produced eco-composites are planned, as it is expected that the addition of a mineral filler may significantly reduce the flammability of materials.