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NEW POSSIBILITIES FOR RECYCLING OF MINERAL WOOL SEPARATED FROM THERMAL INSULATION WASTE

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Abstract. It has become increasingly clear, that the recent consumption of mineral resources is unsustainable. The Czech Republic produces more than 217,000 tones of mineral wool annually, while its recycling stays unacceptably limited. This paper presents new possibilities how to recycle mineral wool from building insulation systems. Cladding of 30 years old building composed of FOS 125 facade was disassembled and its mineral wool boards were subjected to micro-milling in order to get filler and shortly chopped fibers to be the multifunction micro-aggregate in new design of plaster mortars. It was shown that mortars containing up to 1.2 wt. % of such waste exhibited decrease in pressure strength in the order of tens of percent than those made from reference mixture. On the other side, their bending strength was decreased slightly or oven improved. Other improvement was detected in thermal conductivity.

Keywords: Construction and demolition waste, ETICS, mineral wool, recycling.

1. Introduction

1.1. Mineral wool waste production

There is still increasing interest to save material resources and environment across all industries. Such a phenomenon is also clear in civil engineering which is strongly dependent on mineral resources. It is estimated that civil engineering consumes as many of these resources as it corresponds to the consumption of all other industrial fields together. Therefore, building stone and gravel have become critical row material. Such a situation is further complicated by depreciation of society to open new mines and quarries due to economical and aesthetic reasons. It is worth mentioning that no new quarries were opened in the Czech Republic during last 30 years [1].

Mineral insulations thus may become an endangered product. These materials occupy ca. 60 % of the market with insulations globally [2]. According to data collected by Eurostat of the European Commission, the Czech Republic produced more than 217,000 tones of wools from mineral fibers during yr. 2020. In other countries, the data are following: Germany, 615,472; France, 351,010; UK, 250,000 tones [3]. It has to be stressed out that such data do not contain glass wools since these are classified into a different group together with glass fibers for textile production. It is therefore hard to determine which part of them is made for insulations. However, some scientists estimate that glass fiber insulations create approx. 30 % of that made from basalt fibers [4].

1.2. Recycling

Although the mineral wool waste (MWW) presents only a small share of construction and demolition waste (C&DW) production in the Czech Republic, as stated in VISOH system administered by Ministry of the Environment of the Czech Republic, it is necessary to find ways how to recycle such material [5]. A number of buildings insulated by systems with ending service life are still growing. Thus, it can be expected that know-how in MWW recycling will be in demand [6]. As most of insulated building envelope are made from composite system (including building adhesives, mechanical fasteners, reinforcing meshes, base-coats, finish-coat plasters, etc.), it is hard to separate individual materials from each other. That is the reason why these materials are rather landfilled than recycled [4]. It has to be also considered that European Union requires the C&DW be recycled, while its landfilling becomes more charged which also raises interest in recycling. It is worth noting that the charge for mineral wool landfilling is 1,750 CZK per 1 tone in the Czech Republic [7].

Despite the aforementioned difficulties, some researches dealt with recycling of mineral wool from C&DW. As Wäntsi and Kärki summarized in their review paper [4], the MWW can be briquetted and thus returned into the wool manufacturing process. Adediran et al. [8] tested feasibility of incorporating the milled MWW into ceramic materials as a fluxing agent in the production of clay- and waste-based building ceramics. Gebremariam et al. [9] used the milled MWW at the form of ultrafines as cement substitution or as supplementary additives in concrete mixtures obtaining material with increased modulus of elasticity. Ramirez et al. [10] reinforced cement pastes with residues of fibers from the recycled MWW. It was shown that such modified material exhibited improved mechanical properties and lower porosity.

In this study, we present technology which is capable to produce both fiber residues and filler from the MWW. Such a technology uses a micro-mill and a separator that are together able to disintegrate individual materials in mineral wool based external thermal insulation composite system (ETICS). The MWW was applied into plaster mortar in order to improve its thermal properties and tensile strength while keeping pressure strength, if possible.

2. Materials and methods

2.1. Mineral wool waste

The MWW was provided from 34 meters high building in Kralupy nad Vltavou where the original external ETICS was replaced with new materials in 8/2020 due to tightening requirements for heat transfer through the building envelope. The ETICS was realised in yr. 1991 as the FOS 125 type which was composed from basalt mineral wool boards (density 50 kg/m^3) covered with sheet metal cladding, see Figure 1. Given that the insulation was anchored to the wall using steel frames, it was free of contamination with adhesive mortars, plaster, and other building materials.

Figure 1. Building facade under reconstruction.

2.2. Recycling

After the metal cladding was disassembled from the building facade, insulation boards were removed from the steel frames and subjected to further processing using the stationary recycling line LAV/K - 350 Tex (Lavaris, s. r. o., Czech Republic), which is shown in Figure 2. The whole line starts with an input module (1) where the MWW is inserted. The module is equipped with the high-speed grinder LAV/K - 350 Tex. The crushed mixture is then transported into a cyclone separator (2) which divides the mixture into two parts. The first is composed primarily of the chopped fibers which can be further reused for production of recycled insulation boards or as blown insulation. Such a material is stored into the big bag (3). The second part is composed from mineral dust particles – fillers – and short fibers that are captured in a cyclone double-filter (4). The study deals with utilization of the second part and tries to find its effective application in civil engineering.

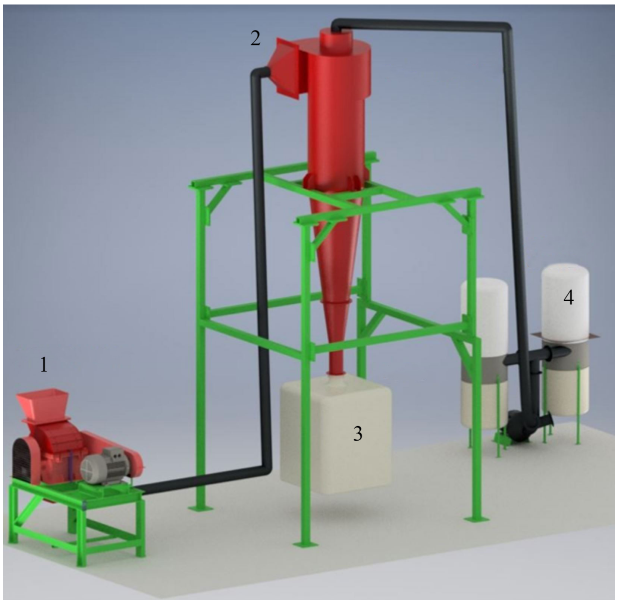

Figure 2. Scheme of recycling line LAV/K - 350 Tex.

2.3. Specimens

The filler and short fibers captured on the double-filter of the recycling line exhibit potential to be used as micro-aggregate with other beneficial properties for production of plaster mortars (defined in ČSN EN 998-1 ed. 3), as the fibers can play the role of randomly dispersed and oriented micro-reinforcement and thus increase tensile strength and ductility of the plasters. Moreover, heat insulation of such mortars can be increased due to presence of clumps of fibers that create air voids.

Composition of mixtures was designed within our previous research (see [11, 12]). It was aimed to use as much recycled material as possible while keeping mortar mechanical properties similar to reference material (conventional mixture with no additives). Six mixtures were designed differing from each other in the amount of applied recycled MWW (from 0 to 1.0 wt. % of the whole mixture). Their composition is summarised in Table 1. Water to cement ratio was increased with increasing amount of the recycled MWW in order to keep still the same mixture workability (classified using the flow test according to ČSN EN 1015-3). The last column of the Table 1 presents density of hardened mortars after 28 days of curing.

Three specimens with dimensions of 40×40×160 mm were made from each mixtures. After casting the mixtures in metal moulds, the specimens were stored in water bath for 7 days. Next, they were removed from water and left for another 21 days under standard laboratory conditions (temperature 22±1 °C, relative humidity approx. 55 %).

2.4. Testing of mechanical properties

Basic mechanical properties – compressive and bending strength – were examined following standard ČSN EN 1015-11. Destructive three-point bending strength test was carried out using loading frame MTS 40 (MTS USA). The loading rate was set to 1 mm/min. Both parts of broken specimens were subsequently subjected to pressure strength test using press EU 40 (VEB Werkstoffprüfmaschinen). In such a case, the loading was controlled with force at the rate of 0.1 MPa/sec.

2.5. Testing of thermal properties

Testing of heat properties was focused on determination of thermal conductivity coefficient λ. Heat transfer analyzer ISOMET 2104 (Applied Precision) equipped with surface probe API210412 with measuring range 0.3–2.0 W/m.K and accuracy of ±5–10 % was used. Such a device applies a dynamic method which is based on response monitoring of examined material on heat flow impulses. The measurement itself was carried out 28 days after the specimens were made. Their temperature was equal to 22±1 °C (the same as ambient air). Each specimen was measured three-times in a different position in order to obtain statistically relevant data.

3. Results and discussions

3.1. Mechanical properties

The results of compressive strength test are shown in Figure 3. It is clear that with increasing amount of the recycled MWW incorporated into the mixture, compressive strength significantly decreased. The specimens marked as "I5" (those that contained the largest amount of the recycled MWW) reached only on one third of the strength when compared to reference mixture REF. On the other side, even the I5 mixture can be considered as plaster mortar of the highest category CS IV (required compressive strength is at least 6 MPa) as defined in ČSN EN 998-1. It can be therefore said that the decrease in compressive strength as a result of the recycled MWW use is massive, however still acceptable.

A slightly different trend can be observed in the case of bending strength test. As Figure 4 shows, specimens I1 overcome by ca. 13 % those made from reference mixture. After addition more amount of the recycled MWW (all specimens I2–I5), bending strength decreased but significantly slower than in case of compressive strength. The highest detected decrease was equal to ca. 37 %. Such a phenomenon can be attributed to the function of short fibers that are randomly distributed and oriented through the matrix, as assumed in Chapter 2.3. These fibers are able to reduce creation of drying and shrinking cracks and thus contribute to the achievement of higher bending (tensile) strength. These findings are in accordance with our previous research, see [13, 14]. Based on the cited researches, it can be assumed that matrices containing the milled MWW are able to exhibit ductile behaviour because of short fibers bridging the cracks after the matrix fails in tension. It will be the subject of our further research.

3.2. Thermal properties

Figure 5 shows that thermal conductivity of tested specimens decreases with increasing amount of the recycled MWW. While the reference mixture reached on 1.82 W/m.K, those mixtures that contain the MWW exhibited improvement from ca. 10 to 40 %. Their thermal insulation properties are thus improved. Such a finding corresponds to changes in density of hardened mortars (see Table 1). As the amount of the MWW is increased, the density decreases by up to 17 % as a consequence of increasing porosity.

4. Conclusions

The presented study deals with recycling of the mineral wool waste (MWW) and thus tries to contribute in issues connected with a global deficit of mineral resources and their unsustainable consumption. Recycling line LAV/K-350 Tex developed by Lavaris, s.r.o., Czech Republic, showed to be very effective in processing of the MWW from external thermal insulation composite systems. A building in Kralupy nad Vltavou older than 30 years was insulated with the new insulating system since the old one (FOS 125) does not meet current requirements. Old insulation boards from basalt fibers were removed from the sub-construction (steel frames) and subjected to the recycled line in order to remove all impurities. The original fibers were chopped with a high-speed mill to achieve (i) fibers for recycled blown insulation and (ii) short fibers with dust particles – filler. The study focuses on the second mentioned materials that are considered to be hardly usable in technical practise. It was shown that they can play the role of multifunction micro-aggregate in plaster mortars.

Mortar mixtures containing besides standard materials also recycled aggregate at the amount of 0–1.2 wt. % of the whole mixture were designed for production of laboratory specimens with dimension of 40×40×160 mm. These were after 28 days of curing and hardening tested in order to find out their pressure and bending strength and thermal conductivity. The finding are as follows:

- Pressure strength massively decreased (over 60 %) with increasing amount of the recycled MWW. However, even those specimens that contained the highest amount of the MWW exhibited still acceptable

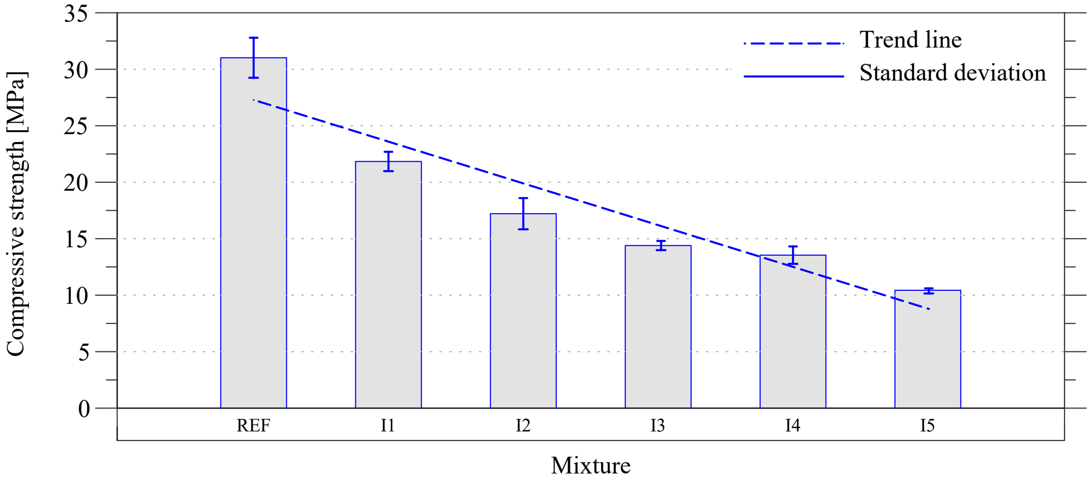

Figure 3. Compressive strength of tested specimens.

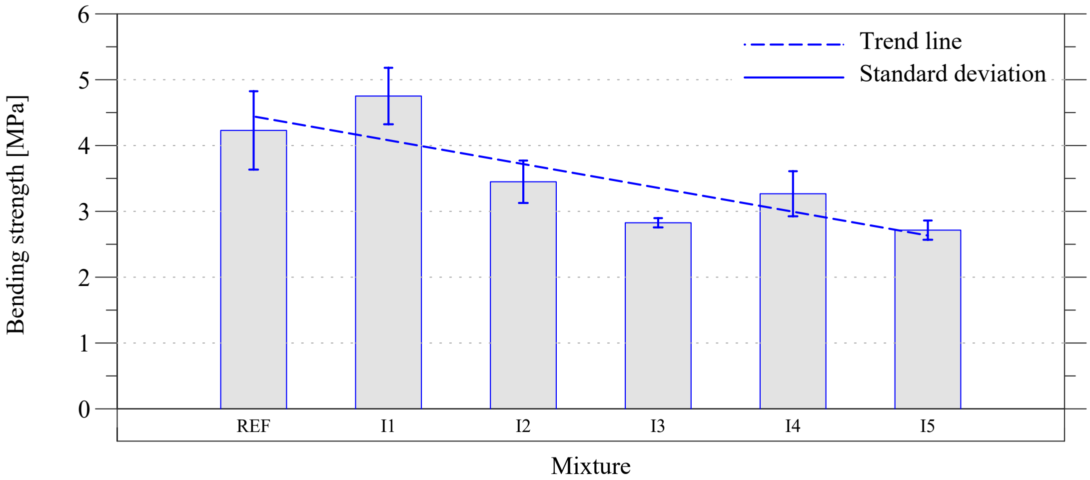

Figure 4. Bending strength of tested specimens.

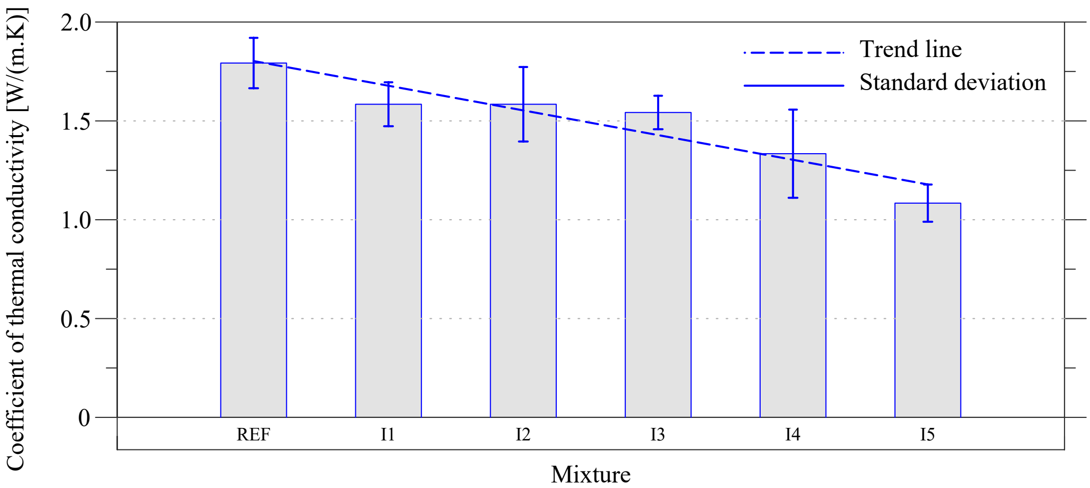

Figure 5. Thermal conductivity of tested specimens.

Mixture	Cement [g]	Sand 0-2 mm [g]	Concrete fines [g]	Water [g]	MWW [g]	Density [kg/m^3]
REF	225	900	375	270	0	2,053
I1				270	4.6	1,932
I2				300	9.2	1,909
I3				320	13.8	1,839
I4				345	18.4	1,803
I5				370	23.0	1,705

Table 1. Composition of plaster mortar mixtures.

strength (more than 10 MPa) to be considered plaster mortars according to relevant technical standards.

- Bending strength at first increased (by 12 %) with increasing amount of the MWW, however, after reaching the amount of 0.3 %, the strength decreased very slightly (from ca. 19 to 35 %).
- Coefficient of thermal conductivity decreased up to 40 % with increasing amount of the MWW. Thermal resistance of the material was thus improved.

Aforementioned findings prove that the recycled MWW can be processed into the form of micro-aggregate to be a part of plaster mortar mixtures. Based on achieved results, it can be concluded that such material acts as randomly oriented reinforcement (short fibers), insulation aggregate (clumps of fibers), and substitution for fine fraction of virgin aggregates (dust particles).

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