Utilization of mineral wool from construction and demolition waste: sorting, pre-treatment, and alkali activation

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Abstract. Mineral wool is one of the most difficult construction and demolition waste (CDW) fractions to recycle. Annual formation of mineral wool waste in the EU is approximately 2.5 Mt, of which a large proportion is landfilled even though the EU legislation requires 70% recycling rate for non-hazardous CDW by 2020. The present study describes first results from the WOOL2LOOP project, which aims at closing the material loop of mineral wool by introducing alkali-activation technology and value chain to CDW sorting, analysis, pre-treatment, processing, novel products development, market introduction and commercialization.

1. Introduction

Mineral wool waste from construction and demolition of buildings is one of the most difficult waste fractions to recycle. Annual formation of mineral wool waste in the EU is approximately 2.5 Mt, of which a large proportion is landfilled even though the EU legislation requires 70% recycling rate for non-hazardous CDW by 2020. [1] However, there is an increasing push from the market and the EU that mineral wool product manufacturers need to be able to receive and guarantee recycling of their used products.

Earlier attempts have been on recycling mineral wool waste into composite ceramics, indoor ceiling tiles, cement composites, wood-containing hybrid particleboards, and as artificial substrate for plants in soilless cultures. [1] However, these trials have encountered several problems related to for instance low density and high cost. In addition, post-consumer mineral wool wastes can't be recycled to the mineral wool manufacturing processes due to inconsistent quality. In fact, even the manufacturing by-products (mineral wools dusts) can be difficult to reuse within the process as the fine particles clog up cupola furnaces used for melting of raw materials.

One of the biggest challenges concerning the utilization of waste materials as a secondary raw material is the variety in waste material composition. As a part of the WOOL2LOOP project, the utilization of

novel time resolved Raman spectroscopy will be demonstrated as an important tool for mineral wool waste quality control. This will allow separation of glass and stone wools and wools of different ages as each of them has a different composition.

Concerns regarding the CO_2 emissions generated by ordinary Portland cement (OPC) manufacturing have driven the search for alternative, sustainable materials which may replace OPC in industrial settings. Increasing the use of low-CO_2 supplements as replacement for OPC is the most viable approach to reducing the CO_2 emissions associated with OPC production.

Recent studies demonstrated that alkali activation i.e. geopolymerization is a novel method to utilize mineral wool waste by converting it into ceramic or concrete-like materials. [2,3] However, geopolymerization of mixed mineral wool has been demonstrated only in lab scale but separating and assessing different wool grades is a step towards higher added value products. WOOL2LOOP aims at closing the material loop of mineral wool by introducing alkali-activation technology and value chain to CDW sorting, analysis, pre-treatment, processing, novel products development, market introduction and commercialization. The present study describes first results from the WOOL2LOOP project regarding sorting of mineral wool waste prior to demolition.

2. Materials and methods

2.1 Characterization

Stone wool, glass wool and slag wool samples were obtained from different locations in the EU and were chemically and physically characterized. The sampling instructions are based on standards EN 14899:2005 [4] and CEN/TR 15310-2:2006 [5]. The same safety and health precautions were used as regularly when working on a demolition site.

Mineral wool waste was sampled in the WOOL2LOOP project to obtain information about the physical and chemical quality variation and contamination (e.g., amount of Al and Si, organic resins etc.). Another objective was to use collected mineral wool waste samples for laboratory-scale pre-treatment and mix design development. Sampling sites are listed in Table 1.

Table 1. Mineral wool (MW) waste sampling sites of the WOOL2LOOP project.

Partner	Country	Type of material
SGE	Sweden	MW production by-product
TREE	Poland	MW from CDW
DEL	Finland	MW from CDW
TER	Slovenia	MW from CDW
REAS	Belgium, Netherlands, France	MW from pre-demolition audits (5 different sites)

2.2 Pre-demolition audits

One of the goals of the WOOL2LOOP-project was to assess the quantity and quality of fractions of mineral wool in the demolition market by performing pre-demolition audits. The more information on the mineral wool, the better recycling facilities can be implemented.

During the pre-demolition audit, we identified different mineral wool types (stone and glass wool) by their visual appearance. If there was knowledge available, we identified also different mineral wool ages. We took samples from different mineral wool products (e.g. ceiling tiles, acoustic panels, loose

mineral wool etc.) and placed each individual sample in a separate bag with a sampling record. Then we collected all the individual bags in one package for shipping.

2.3 Pre-demolition audits in Belgium between 2010 and 2019

Pre-demolition audits conducted in Belgium (predominantly Flanders) between 2010 and 2019 were examined to get a first idea of the amount and type of mineral wool waste that is released on the Belgian (Flemish) demolition market. 55 of the 119 audits mention mineral insulation material. The other audits included demolitions of older buildings and warehouses (without insulation), buildings where only synthetic insulation material was found and infrastructural works.

The following assumptions were made during the analysis of the audits:

- When the amount of mineral wool was only specified in square meters, a thickness of 5,0 cm was assumed. For ceiling panels, a thickness of 2,5 cm was assumed.
- The following specific weights were assumed when only the volume or only the weight was specified:
    - Glass wool: 20 kg/m3
    - Stone wool: 40 kg/m3
    - Mineral wool (not specified): 40kg/m3
    - Stone wool ceiling panel: 80 kg/m3
    - Mineral wool panel (soft): 80 kg/m3
    - Mineral wool panel (hard): 400 kg/m3

These numbers are based on the numbers in audits in which both weight and volume were specified and on information found on the internet.

- “Stone wool ceiling panel” was counted as “mineral wool panel (soft)” for the overview of different types of mineral wool.
- “Mineral wool panel” was counted as “mineral wool panel (soft)” or “mineral wool panel (hard) for the overview of different types of mineral wool, depending on the specific weight.

2.4 Mineral wool collection during demolition

Mineral wool was separated during demolition to a pile. If possible, the different mineral wool types (stone and glass wool) were also separated in separate piles. Once all mineral wool had been collected, the pile was homogenized by mixing (with an excavator, for example). Then the sample was taken from different parts of the mixed pile until targeted amount was reached. Different mineral wool types were not be mixed together, when possible.

3. Results from the pre-demolition audit in Belgium between 2010 and 2019

The pre-demolition audits in which mineral wool was mentioned where more closely analyzed.

- First, the amount of mineral wool waste per demolition project was examined, as well as the percentage mineral wool waste relative to the total amount of demolition waste.
- Secondly, the amounts of different types of mineral wool that were found were analyzed.
- Lastly, the location or function of mineral wool in the projects was investigated.

The reader should keep in mind that this information is based on only 55 pre-demolition audits, which is not enough to be able to extrapolate the results to the general Belgian demolition waste market. Special care should be taken when looking at the weights. These limitations aside, the presented data gives a first general insight into the types and quantity of mineral wool waste found in Belgian demolition projects.

4.1 Amount of mineral wool waste in a demolition project

The average amount of mineral wool waste in the 55 projects is 170,5 m3 (11,04 tons), but there is a large scatter: a standard deviation of 275.9 m3 (25,36 tons). The histogram in figure 1 shows the number of projects in each interval. In 21% of the observed audits, the amount of mineral wool waste is smaller than 10 m3 (one small container for demolition waste). In 40% of the cases, the volume of mineral wool is 40 m3 or less (one large container for demolition waste). In 11 of the observed projects – 20% of the cases – the amount of mineral wool waste is over 200 m3, which means that at least 5 large containers are required to transport the waste material. The lowest recorded amount is 1,4 m3 (demolition of a small shop), the highest is 1258,4 m3 (32 containers, strip-down of a large office building in Brussels).

Also, the percentage of mineral wool waste relative to the total volume of demolition waste was calculated for each project, but also a large scatter was observed there (average 9,5 vol%, standard deviation 16,4 vol%). Figure 2 shows the histogram for the data. In 58% of the cases, the amount of mineral wool waste is 5% of the total waste-volume. In 20% of the audits, this percentage is higher than 10%.

The total amount of mineral wool waste in the 55 projects is 9377 m3 (607,3 tons), which is about 5% of the total amount of demolition waste. One would need more than 230 large containers to transport this amount of waste.

Figure 1. Amount of mineral wool waste in a demolition project

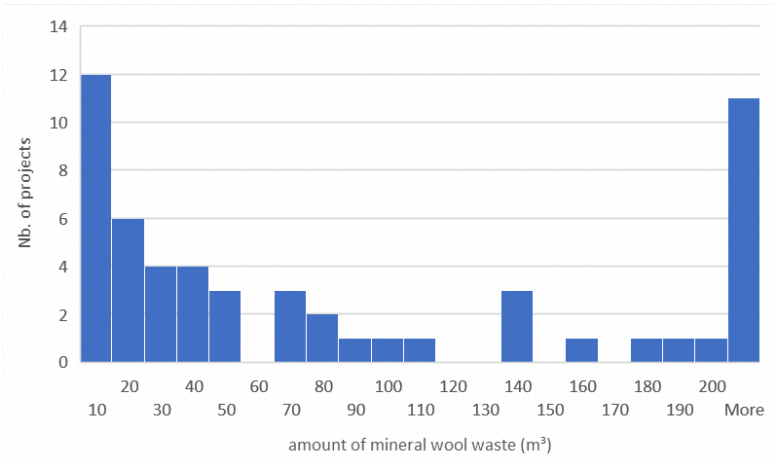
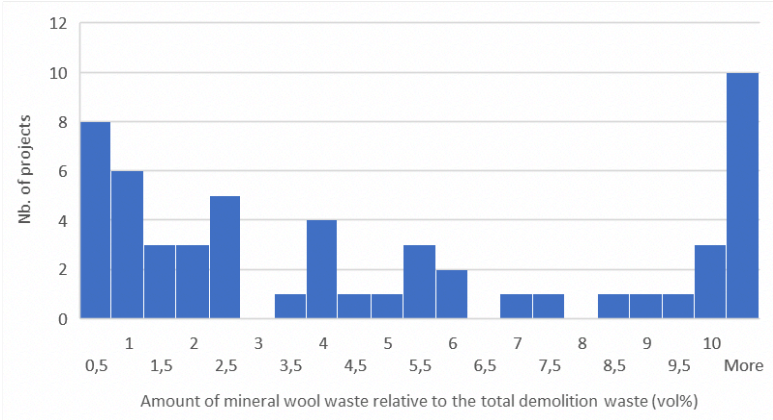


Figure 2. Percentage of mineral wool waste relative to total volume of demolition waste



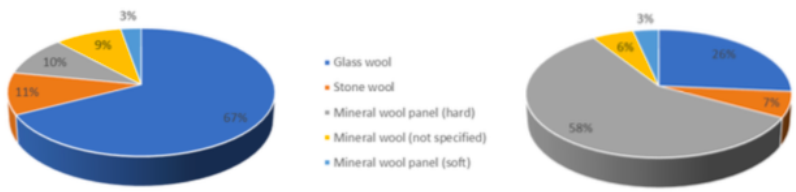
4.2 Types of mineral wool found

Table 2 shows the types of mineral wool that were mentioned in the audits, the number of projects in which they are mentioned, their corresponding total volume and weight and the volume- and weight-percentage relative to the overall amount of mineral wool waste. Terminology differed throughout the projects. 'Mineral wool panel' most probably can be assumed to be 'stone wool panel'. Figure 3 visualizes the data of table 2.

Table 2. Types of mineral wool found

Type of mineral wool	Nb. of projects	m³	vol%	tons	wt%
Glass wool	35 / 55	6301	67,4	159,4	26,4
Stone wool	4 / 55	994	10,6	39,8	6,6
Mineral wool (not specified)	5 / 55	853	9,1	34,1	5,6
Mineral wool panel (hard)	17 / 55	937	10,0	350,3	57,9
Mineral wool panel (soft)	11 / 55	261	2,8	21,2	3,5

Figure 3. Types of mineral wool found



Glass wool is clearly the most encountered type of mineral wool in the observed pre-demolition audits (67 vol% and 26 wt%). However, it should be noted that in some cases, the allocation of the term 'glass wool' to the type of mineral wool present in the building can be just an assumption of the expert. An example of this can be found in "Sampling report – Proximus | Lange Nieuwstraat 106 | 2300 Antwerp, Belgium" by REAS for WOOL2LOOP, where in the original pre-demolition audit – which dated from before WOOL2LOOP started – the insulation material was assumed to be glass wool, while later on, it turned out to be mostly stone wool. Since the start of WOOL2LOOP, more attention is paid to the type of mineral wool in the buildings.

Due to its high specific weight (up to 400 kg/m3), hard mineral wool panel accounts for a high weight-percentage (58%), while volume-wise, it is comparable to stone wool and 'mineral wool (not specified)' (about 10%).

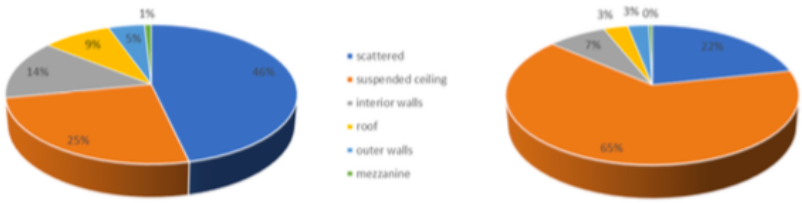
4.3 Location of mineral wool in demolition projects

Table 3 shows the locations (or functions) of mineral wool that were mentioned in the audits, the number of projects in which they are mentioned, their corresponding total volume and weight and the volume- and weight-percentage relative to the overall amount of mineral wool waste. Figure 4 visualizes the data of table 3.

Table 3. Location of mineral wool

Location of mineral wool:	Nb. of projects	m³	vol%	tons	wt%
scattered	11 / 55	4348	46,4	131,1	21,6
suspended ceiling	38 / 55	2393	25,5	393,5	64,8
interior walls	11 / 55	1299	13,9	45,4	7,5
roof	16 / 55	823	8,8	18,4	3,0
outer walls	4 / 55	433	4,6	16,2	2,7
mezzanine	3 / 55	80	0,9	2,7	0,4

Figure 4. Location of mineral wool



The most important application of mineral wool is in the ceilings. The high wt% is due to the higher specific weight wool is 'scattered', which means that a combination of some of the different applications was found in the building, or that no location or function was mentioned in the audit. Insulation between interior walls is the next important application (14 vol% and 7wt%). The application of mineral wool for the insulation of outer walls is not often encountered in these audits, mostly because the age of the building: insulating outer walls is a quite recent trend. The large share of suspended ceiling- and interior wall insulation can be explained by the large surface of suspended ceiling and interior wall in office buildings and houses.

4. Requirements for geopolymer products

Each product and application demonstration case (i.e., non-reinforced precast concrete, reinforced panels, acoustic panels, dry concrete mortar, and 3D printing) requires different geopolymer material properties.

In order to put building products on the market it is essential to follow Construction Product Regulation (CPR) which sets the rules how to prepare a Declaration of Performance (DoP) and to label products with CE mark. The basis for the CE marking is harmonized standards or European Technical Assessment (ETA). Since the WOOL2LOOP technology and products are not covered by harmonized specification, the potential route for CE marking and market uptake is either preparation of EAD (European Assessment Document) or National technical assessment procedure.

Within both procedures, the final products needed to be evaluated according to the provisions of CPR (Construction products regulations), taking into account essential requirements (as relevant). Performance indicators were established based on the standards for concrete or clay based products, like EN 206:2013 for reinforced structures, standards for clay pavers (EN 1344:2013), and paving flags (EN 1339:2003) for products developed and standard EN 998-1:2017 and BS 5838-2:1980 for dry mix mixture. In the case of WOOL2LOOP products which do not belong to the group of products in the building sector (such as, products based on 3D printing), the performance assessment will be executed based on common practice in the specific field or according the investors' requirements for the given sector.

5. Conclusions

Stone wool and glass wool waste come in various forms from the construction and demolition sector. Glass wool was most common wool type encountered in the pre-demolition audits, however it is challenging to determine the quantities as the density of the wool types have large variation. Geopolymer product and application demonstration cases (non-reinforced precast concrete, reinforced panels, acoustic panels, dry concrete mortar, and 3D printing) requires different geopolymer material properties and thus different raw material and mix design compositions. Sorting of mineral wool waste prior to demolition is desirable for the purpose of using it as geopolymer raw material.

6. Grant support

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