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CATALOGUE OF CONSTRUCTION PRODUCTS CONTAINING SECONDARY RAW MATERIALS FROM DIFFERENT INDUSTRIES AND MUNICIPAL WASTE

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Abstract. The building industry consumes a large amount of primary raw materials and also contributes significantly to the production of waste. Applying circular principles in this field to reduce resource consumption and waste production has been investigated in several projects considering the reuse or recycling of construction and demolition waste. However, consumption of primary raw materials can also be reduced by re-targetting waste from different industries and municipal waste to produce new construction products. Thus, opportunities for the recycling of industrial and municipal waste were investigated in this project. The main output is the catalogue, which provides an overview of products with recycled content and secondary materials with the potential to be used in the construction industry such as blast furnace slag, ash, and energy by-products. Also, it contains a list of valid requirements for the use of recycled materials under specific conditions of the Czech Republic. In addition, examples of good practice are presented to break the existing behavioral barriers to the use of secondary raw materials in the Czech construction industry. This contribution summarizes the findings in the field of industrial and municipal waste recycling and its further use as secondary raw materials in the construction industry.

Keywords: Waste, circular economy, secondary raw materials, primary raw materials, recycled materials, recycled content.

1. Introduction

Sustainable buildings are based on sustainable resources, which are used for construction products. However, how sustainable are the sources of primary raw materials for the building industry?

The amount of materials consumed in the global economy is more than ten times higher than the amount of reused or recycled materials [1]. The difference between these two flows is called the circularity gap and is increasing annually. This is significantly affected due to the construction industry. On the one hand, the construction industry consumes more than 30 % of domestic material consumption in the Czech Republic [2]. On the other hand, construction and demolition waste represents almost one-third of European waste [3].

In an effort to increase circularity in the European economy, the European Commission published the Circular Economy Action Plan [4] as one of the supporting strategies for the Green Deal [5]. Both of these documents described construction and building as a key sector for reducing the impact on Climate change and exploiting resources. Meanwhile, the main regulation for high rates of recycling materials and their utilization in the construction industry is defined by Regulation (EU) No. 305/2011 of the European Parliament and the Council, which focuses on sustainable utilization of natural resources [6]. The development of this effort under the conditions of the Czech Republic is mainly defined by the Waste Management Plan, which defines the minimum recycling rate of construction waste as 70 % [7].

To support the recycling of demolition and construction waste, many activities were carried out. One of them was the publication of a Catalogue of Construction Products containing recycled materials from Construction and Demolition Waste [8].

However, the circularity of the whole economy can also be improved by re-targetting waste from different sources to industries, where it can be recycled or reused. To improve the re-targeting of resources from different industries and sectors, the second part of the previously mentioned catalog will be published at the end of 2021 [9].

The Catalogue of Construction Products Containing Secondary Raw Materials from Different Industries and Municipal Waste was prepared as a collection of information from experts, producers, and civil engineers and was discussed at round tables in cooperation with Czech authorities. In addition, the prioritization of key waste flows with a high potential for re-targetting to the construction industry was performed considering national statistics of secondary raw materials

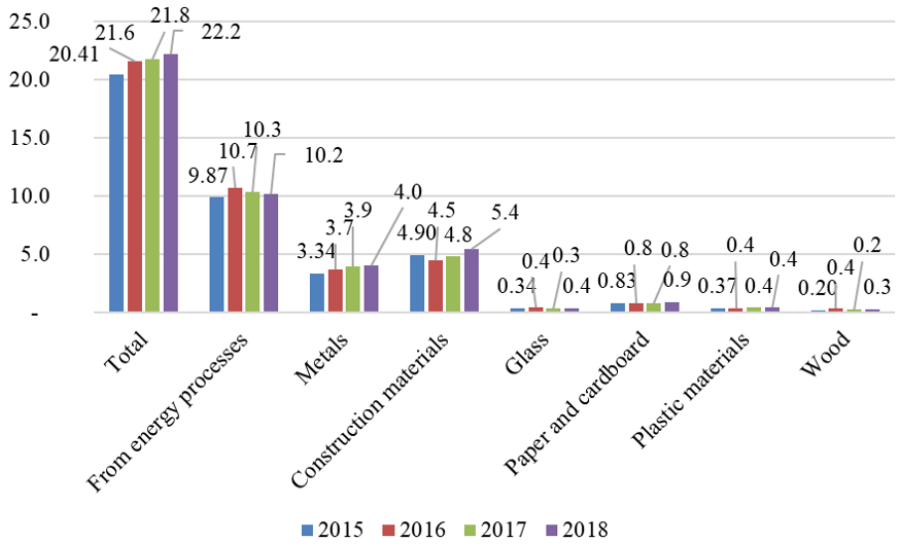

Figure 1. Production of secondary raw materials in the Czech Republic [million tons] [10].

production.

This Catalogue contributes by summarizing possible uses, risks, and barriers for recycling of waste in the building industry. It will be used by architects, designers, civil engineers, construction contractors, and public and private investors who want to improve the circularity of their projects or find new sources for their constructions and products. In the catalogue, an overview of products with recycled content is presented together with the list of valid requirements on the utilization of recycled materials listed in standards and legislation. Moreover, the Catalogue provides examples of good practices to decrease suspicions about the use of recycled materials. This contribution summarizes the findings on the possible use of secondary raw materials from different industries and municipal waste in the construction industry.

2. Methods

The preparation of this Catalogue followed after publication of the previous Catalogue of Construction Products containing recycled materials from construction and demolition waste. Similarly, the new part is based on the evaluation of national statistics describing waste production. In addition, information about the possible utilization of recycled materials in the construction industry was summarized after discussions and roundtables with experts. The group of experts included producers of industrial waste, civil engineers, and producers of construction products. The outputs of this group were consulted with state officials representing perspective focused on the protection of nature and public health. The discussions were organized in collaboration with the Ministry of Industry and Trade and the Czech Standardization Agency.

Based on evaluation of national statistics and summarization of possible utilization following key waste flows with the highest potential to be recycled were descripted in this Catalogue: slag, ashes and fly ashes, energy gypsum, plastic materials, glass, paper, composite packaging, tires and rubber, wood, and metals.

Prioritizing key waste flows was followed by a broad literature study of available standards, existing legislative documents, and regulation. The possible use of recycled materials was declared in the catalogue on the basis of communication with companies and good examples from construction practice.

The next stage of preparation of Catalogue was collecting of feedback from experts, companies, and state officials. Finally, the results of the catalog will be published as a freely available PDF document on the Web `http://www.recyklujmestavby.cz/`, which was developed for the first part of the Catalogue [9].

3. Results

The final version of the catalog will be published at the end of November 2021. However, a summary of the main outcomes is provided in the following chapters.

3.1. Production of secondary raw materials

Secondary raw material can be characterized as a product (including certified products) or recovered waste, which stopped being waste after meeting the recovery regulations. In 2018, the production of secondary raw materials was 22.2 million tuns [10]. This production increased in comparison with the production in 2017. In comparison to the extraction of primary materials in the Czech Republic, it represents approximately one third of the excavated amount of construction materials (more than 64 million tuns) [12]. Based on this, the high potential for saving of primary resources can be assumed. The largest amount of secondary materials is produced from energy processes and reached (including by-products) more than 10.2 million tun in the year 2018. The overview of the flows with the biggest amount is presented in Figure 1. The flows

Type of secondary raw material from energy processes	Production [t]	Percentage [%]
Fly ash from combustion of coal	7 322 239	60.0
Slag	1 287 574	10.5
Fly ash from fluid combustion of coal or a coal with biomass	1 452 175	11.9
Fly ash from fluid combustion of biomass	118 783	1.0
Fly ash from comb. of biomass (except fluidized bed boiler)	5 707	0.0
SDA product	70 380	0.6
Energy gypsum	1 952 843	16.0

TABLE 1. Production of by products from energy sources in 2017 [11].

Specification	The main risks to reuse and recycling	Possibilities of utilization
Slag aggregates – grinding and sorting of crystal slag	Disintegration of slag in contact with water.	Backfilling, landscaping. As a layer under construction foundations. Aggregates for concrete mixtures. Prefabricated construction concrete elements.
Granulated slag – blast furnace slag produced after cooling with water	Disintegration of granulated slag is slow process.	After milling used in the cement production. Hydraulic road binder.
Boiler slag – the solid waste from combustion of solid fuels	Different composition.	Admixture for brick production to optimize properties of ceramic material.

TABLE 2. Possible use of slag in buildings.

of secondary materials are more specified in Table 1. The most important energy source for the by-products is coal combustion, in which fly ash is produced [11].

3.2. Possible use of secondary raw materials

3.2.1. Slag

Slag with potential to be used in buildings is produced as a byproduct during steel production in thermal processes and combustion. Because of these sources, slag is available in a large amount and with a low price. On the other hand, the variability of sources is connected to variability of properties. For example, slag aggregates can disintegrate when in contact with water. Based on this, use of slag in practice is limited by suspicion of practitioners. However, this main barrier can be overcome with a proper description of the original source of the slag. Other barriers are described in Table 2.

3.2.2. Ashes and fly ash

Several types of fly ashes are described in Table 3. Fly ashes are used as an admixture for cement production. Also, it is produced in high amounts and at low cost as an alternative for the cement industry. However, the main barrier is suspicion to this material, which is produced as a byproduct. However, fly ash must comply with the regulations for the declaration of ecotoxicological safety.

3.2.3. Energy gypsum

Energy gypsum is produced as a by-product in the process of wet scrubbing of flue gas using a solution with limestone. The recycling or reuse of gypsum materials and products is a highly recommended way of waste management because landfilling of gypsum materials can be allowed only under specific conditions, which will reduce the potential contact with organic matter leading to the production of hydrogen sulfide.

The possible use of energy gypsum is described in Table 4. However, the production of gypsum in the future can be reduced due to the closure of thermal power plants.

3.2.4. Plastic materials

In Table 5, the specific use of recycled plastic materials is described. The main barrier to recycling plastic waste is insufficient plastic waste classification. Municipal waste can contain tens of types of platic materials and for their use sorting capacity is needed.

Moreover, the content of toxic chemical substances in plastic materials should be tested in case this material is used on place, where, for example, there is a high probability of contact with human skin.

3.2.5. Glass

The glass is a material, which can be recycled multiple times. Moreover, using waste glass as an admixture leads to a reduction in the melting temperature in

Specification	The main risks to reuse and recycling	Possibilities of utilization
Fly ash – produced in process with high-temperature combustion	The utilization is limited by regulation describing technical properties for future use. Pozzolanic properties can be reduced during storing in space with high humidity. High difference of properties based on specific sources.	Replacement of cement. Aggregates or filler for concrete and prefabricated concrete elements. Production of aerated autoclaved concrete. Admixture for brick production. Mineral fibers. Thermal insulation products for buildings.
Fluid ash – produced in process with fluid incineration	High difference of properties based on specific sources.	Mortar production. Aggregates or filler for concrete. Hydraulic road binder. Thermal insulation products for buildings. Production of aerated autoclaved concrete. Admixture for brick production. Mineral fibers.

Table 3. Possible use of ash and fly ash in buildings.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Energy gypsum	The possible use in gypsum plasterboard is limited by technical regulations that define the gypsum parameters.	Gypsum production. Gypsum binders. Cement production. Gypsum plasterborard. Gypsum fibreboard.

Table 4. Possible use of energy gypsum in buildings.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Recycled polyvinyl chloride (PVC)	Insufficient sorting of PVC	Backfilling. Landscaping. As a layer under construction foundations. Aggregates for concrete mixtures.
Recycled plastic materials from municipal waste	Variable composition of municipal waste. High amount of types of plastic materials.	Products and accessories for garden. Covering of terrace, pavement, fences.
Recycled polyester	Insufficient sorting of PE	Geotextiles
Recycled polystyrene (EPS)	Insufficient sorting of EPS	Recycled EPS
Recycled plastic insulation for cables	Insufficient sorting of PVC	Floor covering
Recycled materials from automobile interiors	Inseparable mixture of plastic materials and textile materials.	Acoustic insulation

Table 5. Possible use of plastic materials in buildings.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Flat glass – from deconstruction or as waste from automobile industry	An insufficiently sorted batch of glass can be devalued by impurities and different types of glass.	Window fillings.
Recycled glass	Insufficient sorting	Glass fibers – thermal and acoustic insulations, foam glass. Lightweight aggregates for concrete. Glass fibers as reinforcement.

TABLE 6. Possible use of recycled glass in buildings.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Recycled paper	Insufficient sorting	Blown cellulose fibers as thermal and acoustic insulation. Fibers as reinforcement.

TABLE 7. Possible use of paper in buildings.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Recycled composite packaging	Disintegration of slag in contact with water.	Boards as construction elements, roof covering.

TABLE 8. Possible use of recycled composite packaging in buildings.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Recycled tires and recycled rubber	The health risk should be secured according to the regulations for the use of products containing recycled rubber.	Coverings of playgrounds. Floors for industry, coverings for balconies and terraces. Insulation against vibration.

TABLE 9. Possible use of tires in buildings.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Furniture wood	Possible contamination with dangerous substances (glues, paint)	Woodfibre boards and insulations
Wood from wood industry		Production of pellets for energy recovery.
Wood from municipal waste	Wood can be damaged by biological processes or infested by pests.	Composting. Energy recovery.

TABLE 10. Possible use of recycled composite packaging in buildings.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Metal packaging, metal parts of machines and tools, and metal waste from the manufacturing industry	Insufficient sorting.	Production of new metal parts and products.

Table 11. Possible use of recycled metals packaging in buildings.

batches for the production of glass from primary resources. Other risks and possible use are described in Table 6.

3.2.6. Paper

Paper material can be contaminated by impurities from municipal waste. However, in case of proper sorting, the paper material has several possibilities for utilization, which are described in Table 7.

3.2.7. Composite packaging

Material recycling of composite packaging is limited due to the number of materials used and the technology of their connection. Thus, the composite packaging is often just shredded. The possible utilization of this material is described in Table 8.

3.2.8. Tires and rubbers

In Table 9, the possible use of tires and rubbers is described. The main barrier to their recycling is the risk that the recycled material contains dangerous substances. Therefore, these materials must be tested and fulfil the regulations for their use.

3.2.9. Wood

Taking into account the effort to circularity, wood should be reused or recycled, but, in some cases, incineration with energy recovery can be a more economical way of waste management. However, possible use for recycling or reusing wood waste is described in Table 10. The main barrier to the reuse of wood is possible contamination by pests or dangerous substances.

3.2.10. Metals

The sorting of metals is supported by high value of scrap, which can be easily sold in facility for waste collection. In addition, metals have high potential to be recycled after sorting due to the high cost of the primary resource and the sufficient infrastructure for recycling. The possible use of metal is briefly described in Table 11.

4. Conclusion

The Catalogue contributes to increasing the circularity of materials in the Czech economy by identifying key material flows with high potential to be used in the building industry. Moreover, the Catalogue presents the products with recycled content and examples of good practices. Furthermore, the possible use of secondary raw materials is described according to the European and Czech legislation.

For each of the key material flows, risks and barriers in the recycling process were described. One of the main barriers is the suspicion against the use of products with recycled content. Nevertheless, the products containing recycled materials must fulfil at least the same regulations on the market as the products made from primary resources.

Further research is planned on possibilities of how to re-target waste materials and increase circularity. However, research should focus not only on re-targetting of materials but also on improving materials, as inputs to the economy, to be recyclable in the future.

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