Catalogue of Construction Products with Recycled Content from Construction and Demolition Waste

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Abstract. The main objective of the present project for the Czech government was to create a catalogue of construction products and materials which contain recycled content from construction and demolition waste. The motivation for the work was to support a higher utilization of construction products with the content of secondary raw materials in the Czech Republic. It was designed for architects, designers, civil engineers, construction contractors and public and private investors. The catalogue provides an overview of products with recycled content, a list of valid requirements on the utilization of recycled materials listed in standards and legislation. Examples of good practice are presented to break the existing psychologic barriers to the use of secondary raw materials in the Czech construction industry. This contribution summarizes the findings in the field of the recycling of construction and demolition waste and its further use as produced secondary raw materials in the construction industry.

1. Introduction

1.1. Importance of recycling in the construction sector for the transition to the circular economy

The recycling and use of construction and demolition wastes are one of the principles of sustainable construction and circular economy. The European Commission published an action plan for the Circular Economy in 2015 [1]. It describes the main principles of eco-design of products, which starts at the very beginning of the product's life. The new products should be designed as easily recyclable, with low carbon dioxide emissions and with low content of primary raw materials, which leads to the higher utilization of recycled materials.

The construction industry is one of the largest consumers of primary raw materials globally and generates almost 30% of all wastes. Majority of construction materials whose life cycle is over can be recycled and use as secondary raw material for the production of new construction product. The main prerequisite for high rates of utilization of recycled materials in the construction industry is selective demolition process. The Regulation (EU) No 305/2011 of the European Parliament and of the Council [2] is focused on the sustainable utilization of natural resources which should be achieved by construction and demolition proposal.

1.2. Recycling rates of construction and demolition waste in the European Union

Each country in the European Union (EU) has different conditions for the use of secondary raw materials. The recovery rate of construction and demolition mineral waste in EU countries is shown in Figure 1.

In the EU there are different regions in terms of available primary raw materials. The regions with plenty of natural resources are not motivated to use secondary raw materials in construction production due to wide availability and low cost of primary raw materials, the only motivation would be landfilling costs. On the other hand, the regions with a limited supply of primary raw materials are already highly motivated to prepare materials from construction and demolition waste for efficient utilization as secondary raw materials. Due to this fact, it is possible to inspire of the demolition and recycling proces in the other localities. However, it is necessary to find the appropriate approach in a given location to increase the efficiency of recycled materials utilization. The Czech Republic is a country with sufficient amount and low prices of natural resources, which mostly leads to the use of low-quality demolition and recycling process and further to the downcycling of construction and demolition wastes.

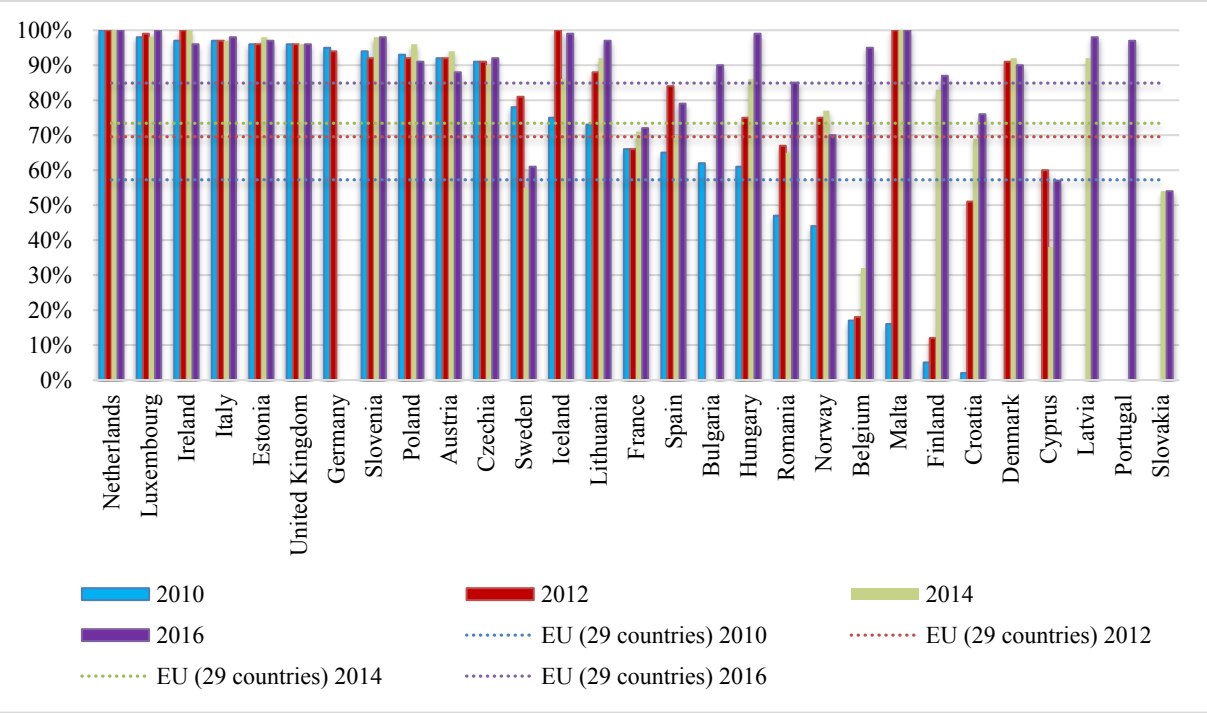

Figure 1. Recovery rate of construction and demolition mineral waste in the EU [3].

1.3. Motivation and objective

The main objective of the present project made for the Czech government was to create a catalogue of construction products and materials which contain recycled content from construction and demolition waste. The motivation for the work was to support a higher utilization of construction products with the content of secondary raw materials in the Czech Republic. It was designed for architects, designers, civil engineers, construction contractors and public and private investors. The catalogue provides an overview of products with recycled content, a list of valid requirements on the utilization of recycled materials listed in standards and legislation. Examples of good practice are presented to break the existing psychologic barriers to the use of secondary raw materials in the Czech construction industry. This contribution summarizes the findings in the field of the recycling of construction and demolition waste and its further use as produced secondary raw materials in the construction industry.

2. Methods

The creation of the Catalogue of Construction Products with Recycled Content from Construction and Demolition Waste started summarizing of the available information on the construction and demolition waste from the national statistics. It was followed by a broad literature study of available standards, existing legislative documents and regulation and communication with companies and searching for

good examples from construction practice. In collaboration with the Ministry of Industry and Trade and the Czech Standardization Agency were organized several round tables, in the early stages of the work to collect ideas and requirements of different stakeholders from the construction and recycling industry and in the final stages of the project to get feedback on form of the deliverables so that they are practical to use in the daily life.

3. Results

The final work was delivered as a PDF document [4], and also in a form of a web portal www.recyklujmestavby.cz. Summary of the main outcomes is provided in the following chapters.

3.1. Statistics of recycled materials with potential use in construction products

The amounts and recovery rates of each material type in construction and demolition waste divided according to European Waste Catalogue are reported by the Czech Statistical Office on a yearly basis [5,6] – see Figure 2. The concrete, masonry and ceramics make almost 50% share. The recycling rate of these materials is around 60% and around 30% is downcycled and used for landscaping and earth works. The second largest category are metals, which make approximately one third of the construction and demolition wastes. Metals are separated during demolition and recycling process and are collected as raw materials for the production of new metals. Almost 13% share has bituminous mixtures, coal tar and tarred products with recycling rates of more than 90%. They are mostly used as primary materials in road structures. Other material categories such as wood, glass, plastics, insulations, gypsum and other materials represent less than 2% each and their recycling rates have not been reported in detail.

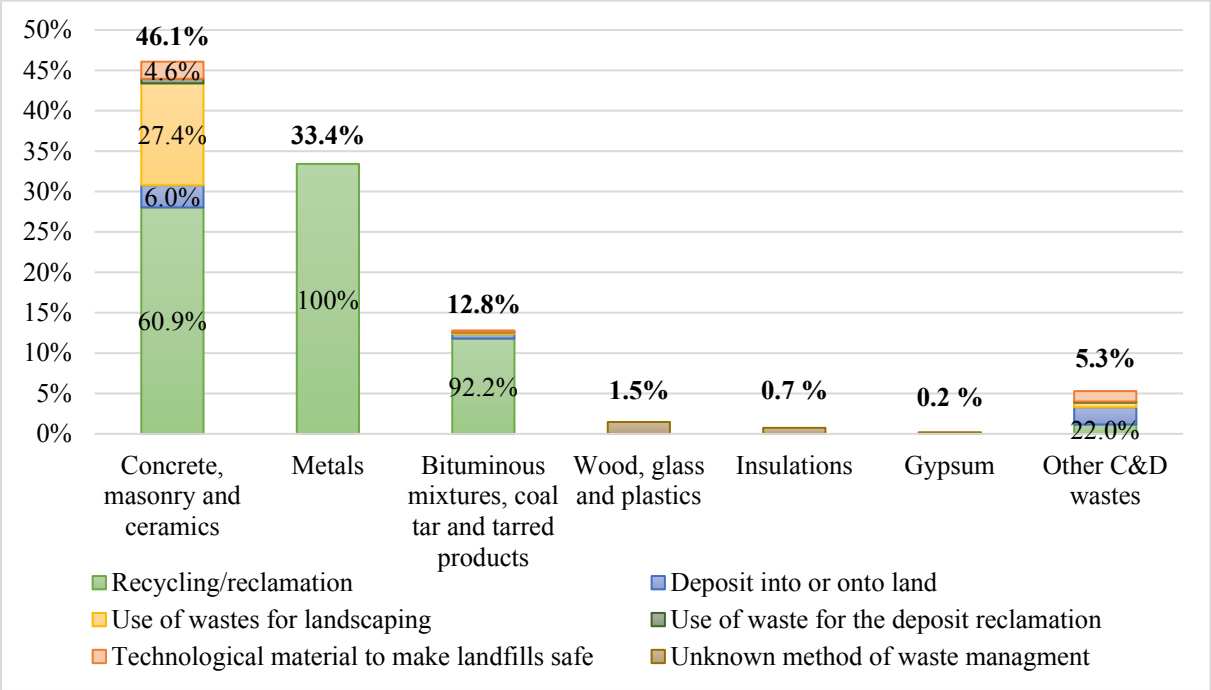

Figure 2. The weight percentage of material categories in construction and demolition waste and their further use [5,6].

3.2. Potential use for recycles materials

3.2.1. Concrete, masonry and ceramics. The potential use of recycled concrete, masonry and ceramics is related to their original use in structures and the quality of demolition and recycling process. There are possibilities to reuse or recycle these materials for new construction products, but there are some limitations and barriers in the utilization.

The original use of waste concrete originating from buildings or transportation structures influences the possible quality of utilization (see Table 1). The main barriers are high availability and low cost of natural resources, uncertainty of the quality of the recycled material and its influence on the properties of new products.

Table 1. The waste concrete – main risks to reuse or recycling and its possible utilization.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Concrete from foundation structures and floors	Unwanted impurities, soil content	Backfilling Landscaping
Reinforced concrete from structural elements from buildings or transportation structures	The quality and properties of recycled aggregate Limitations of the utilization are defined by standards The possibility of unwanted impurities	Gravel replacement (foundation structures, interior structures) [7–9] Sand replacement [10,11] Cement replacement [12,13] Mineral admixture
Concrete sludge	Separation of materials (aggregate, water, cement slurry)	Aggregate replacement

Waste masonry originating from buildings shall contain only red bricks, ceramic blocks and mortars. However, it is usually contaminated by other materials such as ceramic, glass, plastic, wood etc. which limits possibilities of further use (Table 2). The main barriers to their reuse and recycling are high availability and low cost of natural resources, uncertainty of the quality of recycled material and its influence on the properties of new products.

Table 2. The waste masonry and ceramics – main risks to reuse or recycling and their possible utilization.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Red bricks	Difficult demolition process	Reuse as a brick
Crushed bricks	Worse properties than natural materials The use is not allowed by standards	Gravel replacement (precast wall block) [14,15] Sand replacement [14,16]
Milled bricks	Difficult separation during the demolition process	Clay (e.g. for courts)
Mixed masonry waste	Contamination by unwanted impurities due to low-quality demolition and recycling process (paper, plastics, wood, glass, etc.) The use is not allowed by standards Worse properties than natural materials	Backfilling Landscaping Gravel replacement (precast wall block) [17,18] Sand replacement [19]
Brick and ceramic powder	Contamination by unwanted impurities due to low-quality demolition and recycling process (paper, plastics, wood, glass, etc.)	Cement replacement [20,21] Mineral admixture

3.2.2. Metals. Metals have a high potential of recycling due to high prices of metal waste. Metals are separated from construction and demolition waste and are collected in special centers and further used as raw material for the production of new metal elements (Table 3). The recycling rate of metals is almost 100%.

Table 3. The waste metals – main risks to reuse or recycling and their possible utilization.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Structural elements	Contamination by unwanted impurities due to low-quality demolition and recycling process	Metal elements
Steel reinforcement	Insufficient separation from concrete	
Aluminum profiles	Contamination by unwanted impurities due to low-quality demolition and recycling process	Aluminum profiles

3.2.3. Bituminous mixtures, coal tar and tarred products. The possibilities of the utilization recycled asphalt are due to their original use and the quality of the recycling process. Options for recycling are in Table 4. It has to be guaranteed that the reclaimed asphalt is free of contamination for its recovery or recycling as a construction material.

Table 4. The waste bituminous mixtures, coal tar and tarred products – main risks to reuse or recycling and their possible utilization.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Aggregates for unbound and hydraulically bound materials	Contamination by fuels and oils	Civil engineering work and road construction
Bituminous mixtures	Contamination by fuels and oils	Reclaimed asphalt

3.2.4. Wood, glass and plastics. The potential use of recycled wood, glass and plastics depends on their original use in structure and the quality of dismantling process. Options for reuse and recycling together with limitations and barriers in Table 5.

The waste wood from timber structures can be contaminated by chemicals for protection of wood against biological degradation. This contamination influences future utilization. The wood panels federation define the amount of chemicals contained in wood. This wood is enabled to use as raw material for wood panels production [22].

The waste materials from windows can be separated during the demolition process and used as raw material for the production of new products. Materials coming from dismantling windows are flat glass, aluminum, plastics, wood and steel. The flat glass is clear and valuable material without impurities and with high potential of close-loop recycling without influence of the quality of new products. Plastic frames are produced from unplasticized polyvinyl chloride (PVC-U) which is after dismantling 100% recyclable. PVC from old windows can be recycled at least seven times without having any impact on the quality or weather resistance characteristics [23] or it can be added the new plastic window frames [24].

Table 5. Wood, glass and plastics – main risks to reuse or recycling and their possible utilization.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Wood (timber structures, timber frames)	Biological degradation The necessity of selective demolition process (deconstruction)	Reuse as a structural element Wood panels [22]
Flat glass (windows, envelopes)	The necessity of dismantling of windows components	Secondary raw material for the flat glass production [25]
Plastic frames (windows)	The necessity of dismantling of windows components	Secondary raw material for the plastic frames production [24]

3.3. Thermal and acoustic insulations

The potential use of recycled insulations is related to the type of insulation and its original use in structure (Table 6). It is easier to dismantle and recycle insulation on which are no additional layers such as plasters, adhesives, etc. Nowadays, the recycling of waste arising during production of insulations is efficient and is normally carried out. The recovery rate of this waste material is approximately 75% for glass insulation [26]. It is also possible and efficient to recycle waste insulation arising during the construction process of large buildings and complexes. However, it is not efficient to recycle insulations from demolition waste due to potential contamination of unwanted impurities and thus very demanding recycling.

Table 6. The waste insulations, main risks to reuse or recycling and their possible utilization.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Expanded polystyrene	Hazardous substances	Light-weight concrete
Mineral wool	The necessity of selective demolition process (deconstruction)	Reuse as a secondary raw material for the mineral wool production

3.4. Gypsum plasterboards

The potential use of recycled gypsum plasterboards is related to its original use in structure (Table 7). Nowadays, the recycling of waste arising during production of plasterboards is efficient and is normally used. It is also possible and efficient to recycle waste plasterboards arising during the construction process, which is not contaminated of unwanted impurities such as plasters, synthetic paints, etc. High motivation for recycling of gypsum plasterboards is complicated landfilling due to the production of the toxic gas H_2S during landfilling in inert landfills [27].

Table 7. The waste gypsum, main risks to reuse or recycling and their possible utilization.

Specification	The main risks to reuse and recycling	Possibilities of utilization
Gypsum (Plasterboards)	The necessity of selective demolition process (dismantling of plasterboards) High availability and low cost of raw material Contamination of unwanted materials (plasters, synthetic paints, etc.) Inefficient refundability	Plasterboards [28] Gypsum for cement production [29]

4. Construction products with recycled content

There are construction products and materials with recycled materials content which are normally used in the building industry. On one hand, some of these materials are possible to use in the same way as conventional materials. On the other hand, other materials have limitations of utilization which are defined in standards or have to be determined by producers. Examples of construction products with recycled materials content are in Table 8.

5. Conclusion

The recovery rate of waste materials from construction and demolition waste depends on the quality of the demolition and recycling process. Waste materials which are dismantled during the demolition process have a high potential for utilization as secondary raw materials for production of new construction elements. Nevertheless, there are many materials which are contaminated by unwanted impurities or chemicals. This mostly leads to complicated and non-efficient recycling. For this reason, it is very important to optimize the demolition and recycling processes to obtain high quality secondary raw materials which will be technical, ecologically and economically comparable with primary raw materials.

Table 8. Examples of construction products with recycled materials content.

Construction product	Possible utilization	Maximum content of recycled materials content
Recycled mixed aggregate	Backfilling Landscaping	Up to 100%
Recycled concrete aggregate	Aggregates for bituminous mixtures Aggregates for unbound and hydraulically bound materials	The maximum content of recycled aggregate it is not defined by standards.
Recycled aggregate concrete	Concretes of defined exposure classes	Up to 50% of coarse fraction of recycled concrete aggregate
Precast concrete elements	Precast concrete elements Same ways as conventional concrete	Up to 20% of recycled concrete aggregate with defined origin
Concrete blocks for walls with recycled (concrete, masonry or mixed) aggregate	Same ways as conventional products Limitations of utilization have to be determined	The maximum content of recycled aggregate it is not defined by standards.
Metals	Same ways as conventional products	Up to 95%
Reclaimed Asphalt	Bituminous mixtures	Up to 100%
Wood panel	Same ways as conventional products	The maximum content of recycled aggregate it is not specified by standards.
Windows with PVC-U profiles	Same ways as conventional products	Up to 100% Approx. 30%
Mineral wool (stone)	Same ways as conventional products	Not specified amount of waste from production
Mineral wool (glass)	Same ways as conventional products	Up to 80% of waste glass Approx. 50% of waste glass
Expanded polystyrene	Same ways as conventional products	Not specified amount of waste from production
Gypsum plaster boards	Same ways as conventional products	Up to 10% of waste gypsum from production

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