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Valorization of construction and demolition wastes: RE^4 building solutions

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Abstract

This work presents the ambitious challenges of the RE^4 "*REuse and REcycling of CDW materials and structures in energy efficient pREfabricated elements for building REfurbishment and construction*" European project founded by H2020 (duration 2016-2020), dealing with the valorization of construction and demolition wastes used as raw materials for sustainable building solutions. RE^4 project aims at radically modify the construction process by promoting new technological solutions for the design and development of structural and non-structural pre-fabricated elements with high degree of recycled materials from construction and demolition waste (e.g., concretes, bricks, tiles, fine fractions or lightweight materials e.g. plastic, wood) and reused structures from the partial or total demolition of buildings available in Europe. The Project is intended for the development of innovative, cost-effective and eco-compatible building solutions and also allows the reduction of non-renewable natural raw materials consumption.

Keywords: RE^4 Project; Construction and Demolition Wastes; Eco-Sustainable Building Elements; Recycling; Reusing; Prefabrication

1. Construction and demolition wastes for the building sector: state of the art

Construction and demolition waste (CDW) is one of the most significant and voluminous waste streams in the Europe, over 800 million tons generated per year, and accounts for approximately 25%-30% of all waste generated. CDW arises from activities such as construction, partial or total demolition of buildings and civil infrastructures, roads

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construction and maintenance and consists of numerous materials, including concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, asbestos and excavated soil, many of which can be recycled. CDW has been identified a priority waste stream by the EU because of the large volume generated and the high potential for recycling and re-use. However, despite its potential, the level of recycling and material recovery of CDW varies greatly across the EU - between less than 10% and over 90% - due to the differences in building tradition or the economic activity of the country. Important developments have been included into European and International laws, which aim to promote recycling and recovering. According to the Waste Framework Directive (2008/98/EC) the challenge for Member States is to achieve by 2020 at least 70% by weight of non-hazardous CDW for reuse, recycling and recovery (*European Commission website*, Villoria Sáez et al., 2011).

Construction activities in EU has increased substantially and, in parallel, the generation of CDW. The construction sector generates a huge amount of CDW in the different phases of the construction process (extraction of raw materials, manufacture of materials, construction process itself, demolition, disposal of waste materials in landfills) (Del Rio Merino et al., 2009). On one side, the construction sector generates unacceptable levels of waste materials and, on the other side, it consumes natural resources (about 50% of all materials extracted). In addition, the construction industry is one of the major consumers of energy (more than 40% of global energy consumption) and CO_2 equivalent emissions (33%) (Lawrence, 2015). The construction sector has become increasingly aware of the importance of the environmental impacts associated with its activities. The reduction of raw materials consumption and CDW volumes, the integration of this waste in the building materials production allow the construction sector to become more sustainable. Due to its composition, there is a significant potential to reuse and/or recycle CDW; by way of example, there is a re-use market for CDW-derived aggregates in roads, drainage and other construction projects (see European Commission website) as well as studies focusing on the suitability of recycled aggregates sourced from CDW for concrete production (Silva et al., 2014; McNeil et al., 2013; Behera et al., 2014). However, recovered materials are confined to low-grade applications (unbound road base, fill, hardcore) precluding the exploitation of the high technical and economic potential value of such materials. Moreover, practical procedures are not yet widely known or practiced in the construction industry. New technologies, supported by CDW regulations, need to be implemented to allow the valorisation of CDW in the building sector thus limiting disposal in landfill while promoting reuse or recycling (Del Rio Merino et al., 2009).

2. Progress beyond the state of the art: RE^4 project

Current trends in the CDW management sector require the development of innovative technologies/strategies to increase the percentage of CDW-derived materials/structures and the valorisation of their technical and economic value. The construction sector is currently required to become more sustainable by the use of CDW, to minimize future CWD coming from the next generation of buildings and to increase the building energy efficiency. In this scenario, RE^4 project (www.re4.eu) aims to promote new technological solutions and strategies for the development of pre-fabricated elements, for both structural and non-structural applications, with high degree of CDW recycled materials (e.g., concrete, bricks, wood, plastic) and reused structures. RE^4 building solutions, suitable for both new constructions and refurbishments, will be demonstrated and validated on real scale

buildings. The ambitious challenges of RE^4 project are outlined in Figure 1, while the concept, objectives and some preliminary results are briefly presented in the following.

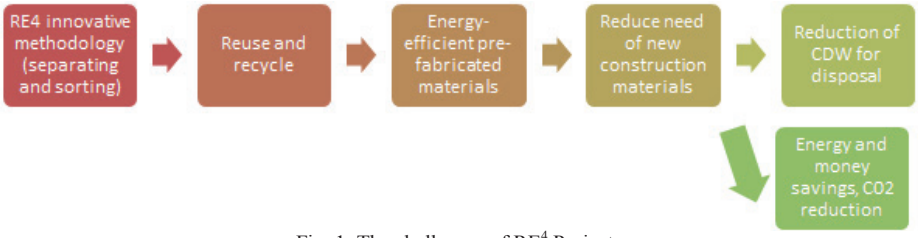

Fig. 1. The challenges of RE^4 Project

3. Overall concept of RE^4 project

The RE^4 project will develop new technologies and strategies for design and production of structural and non-structural pre-fabricated elements, with high degree of recycled materials and reused structures from partial or total demolition of different buildings typologies available in Europe. The innovation is at first focused on the development of innovative sorting technologies, which aim at the optimization and quality of materials and structures recovered from demolition activities. These CDW-derived materials and structures will be then characterized and processed by different technologies (casting, extrusion and moulding) and transformed into innovative pre-fabricated components for using in new constructions and refurbishment (Figure 2). The developed pre-fabricated components will be finally assembled into a RE^4 pre-fabricated and energy-efficient building specifically designed for an easy installation and disassembling for future reuse.

4. Objectives of RE^4 project

The overall objective of RE^4 project is to develop a fully pre-fabricated energy-efficient building made of components incorporating CDW-derived materials (up to 65% in weight) and structures (up to 80-90%). The building components to develop during the Project will be suitable for both new constructions and buildings refurbishment. The Project objective will be achieved through specific scientific, technological, demonstration and business objectives (Figure 3):

- *advanced sorting technologies for CDW (e.g,. concrete, mortar, bricks, lightweight fractions)*, based on innovative wet processing and classification systems and automated robotics equipped with advanced sensors and artificial intelligence software;
- *evaluation of the quality of CDW-derived materials resulting from the sorting*, in terms of chemical and physical properties to assess the compliance of each sorted fraction against relevant National and European specifications;
- *development of innovative building elements (e.g., concrete components, panels, facades, roof and ceiling elements, tiles) integrating high level of CDW-derived materials,* produced by mixing, casting, extrusion or moulding for both structural and non-structural applications and usable for both new constructions and refurbishment;

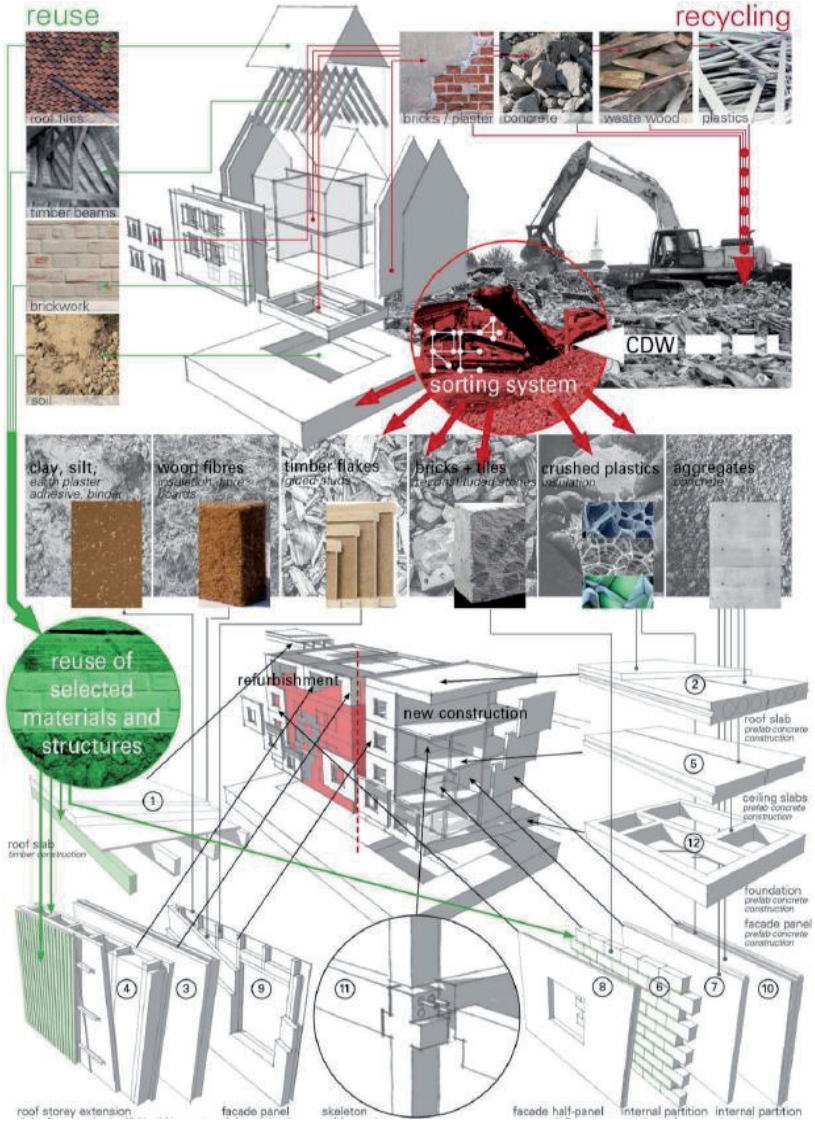

Fig. 2. Conceptual architecture of RE^4 Project
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- *innovative design concepts* for smart installation and disassembly/re-use of RE^4 pre-fabricated buildings, made of RE^4 pre-fabricated elements integrating advanced features;
- *demonstration in industrial environment of RE^4 solutions for new constructions*, representatives of building archetypes across Europe, and *demonstration of RE^4 solutions for refurbishment*; *demonstration of the strategy for disassembly and reuse materials and structures from dismantled buildings* in a suitable existing building;

- *enhancement of the sustainability* in terms of CO_2 savings (over 30%), energy savings (20%), higher resource efficiency (recycled materials in final product up to 65%), less waste generation and CDW disposal in landfill;
- *development of a BIM-compatible DSS and platform for CDW estimation and management*;
- *development of business models for industrial exploitation.*

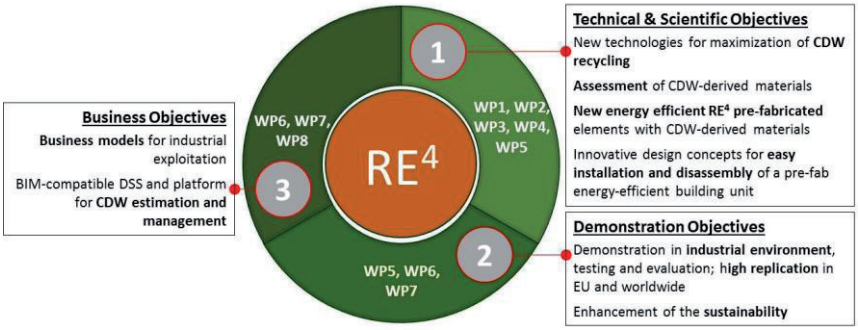

Fig. 3. Outline of RE^4 Project

5. Preliminary results

In order to achieve the main goal of RE^4 Project, that is development of a pre-fabricated building including up to 65% by weight of CDW-derived materials, an advanced sorting system able to classify CDW by material classes is under development. The goal is to achieve the complete separation of the coarse fraction of CDW materials obtaining sorted classes of aggregates, bricks, ceramics, glass, plastic and wood with a purity higher than 90%. Preliminary results show that the innovative robotic sorting system allows to achieve high-quality sorting of CDW (Zerbi et al, 2017). Sorted materials will be then further processed to obtain the size requirements for the target construction applications (e.g. aggregates with size 0/2, 2/8 and 8/16 mm will be produced for concretes development).

6. Acknowledgements

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