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Review

Mining the physical infrastructure: Opportunities, barriers and interventions in promoting structural components reuse

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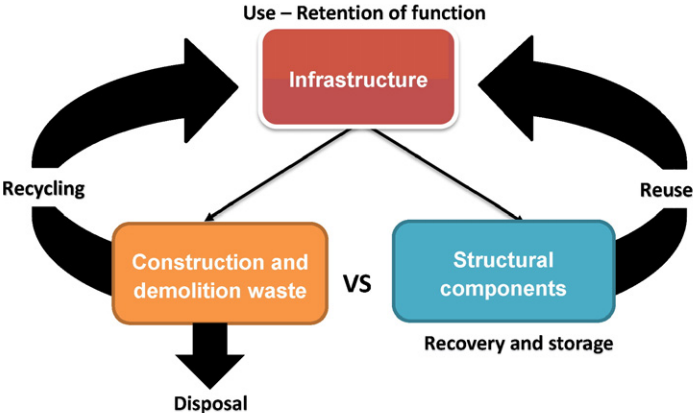
HIGHLIGHTS

- Design interventions can stimulate circularity in the construction sector.
- Interventions are not being mainstreamed due to technical/organisational constraints.
- Reuse is a win-win strategy for the construction sector.
- Typology of infrastructure components might enable the roll-out of reuse.
- Smart technologies might unlock the reuse potential of structural components.

GRAPHICAL ABSTRACT



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ABSTRACT

Construction is the most resource intensive sector in the world. It consumes more than half of the total global resources; it is responsible for more than a third of the total global energy use and associated emissions; and generates the greatest and most voluminous waste stream globally. Reuse is considered to be a material and carbon saving practice highly recommended in the construction sector as it can address both waste and carbon emission regulatory targets. This practice offers the possibility to conserve resources through the reclamation of structural components and the carbon embedded in them, as well as opportunities for the development of new business models and the creation of environmental, economic, technical and social value. This paper focuses on the identification and analysis of existing interventions that can promote the reuse of construction components, and outlines the barriers and opportunities arising from this practice as depicted from the global literature. The main conclusions that derive from this study are that the combination of incentives that promote reuse of construction components and recycling of the rest of the construction materials with the provision of specialised education, skills and training would transform the way construction sector currently operates and create opportunities for new business development. Moreover, a typology system developed based on the properties and lifetime of construction components is required in order to provide transparency and guidance in the way construction components are used and reused, in order to make them readily available to designers and contractors. Smart technologies carry the potential to aid the development and uptake of this system by enabling efficient tracking, storage and archiving, while providing information relevant to the environmental and economic savings that can be regained, enabling also better decision-making during construction and deconstruction works. However, further research is required in order to investigate the opportunities and constraints of the use of these technologies.

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Contents

1. Introduction

Our modern lifestyles are critically dependent on physical infrastructure (e.g. transport, energy, water and waste management, communications, buildings), construction and maintenance of which accounts for more than half of the total global raw resources consumed annually, and for more than one third of the total global energy use and associated emissions (Alcorn, 2003; Allwood et al., 2010, 2013; Ellis, 2011; Giesekam et al., 2014; Ness et al., 2015; Purnell, 2012). The increasing demand for housing and other services as a result of growing population requires the plan and delivery of infrastructure, at a time where resources are in decline, creating a matter of urgency in the long-term sustainability of the sector that cannot be ignored.

The production of construction materials accounts for the greatest share of carbon emitted from the construction sector, with the majority attributed to the production of steel, cement and timber. Global cement production, the main ingredient of concrete, is around 4 Gt and contributes to about 9.5% of total global carbon emissions (Olivier et al., 2014; Statista, 2015; USGS, 2015). The manufacturing of steel used for construction, contributes to about 3.3% of total global carbon emissions (Allwood et al., 2010; Cooper and Allwood, 2012; Ness et al., 2015). The global warming impact attributable to timber production is contested, but could be as high as 18% of total global carbon emissions (Purnell, 2013). In general, at least 70% of the environmental impact of an average construction material is attributed to the energy required for its production (Kay and Essex, 2009) (a notable exception being concrete, where 60% of emissions are associated with decarbonation of limestone). Concrete is the second most consumed material in the world after water (Giesekam et al., 2014) with a usage of approximately 20 Gt per annum (Behera et al., 2014). It is a composite material consisting of cement, aggregates (i.e. sand, gravel and crushed stone) and water, with aggregates occupying 65–85% of concrete's volume (Behera et al., 2014; BIO Intelligence Service, 2011, 2013; Ecorys, 2014). Aggregates and minerals such as bitumen (i.e. asphalt), clay (for bricks and tiles), limestone (for cement making), slate and gypsum, account for the largest component of construction materials used globally by mass, followed by metals (particularly steel) and wood (timber) (Ecorys, 2014; Heard et al., 2012; Horvath, 2004). In Europe, the construction sector uses by far the greatest amount of resources in the economy on a mass basis, and consumes between 5% and 10% of total energy use only for the production of construction materials (BIO Intelligence Service, 2013; EISC, 2012; European Commission, 2014; Wahlström et al., 2014).

With pressures from the Inter-governmental Panel on Climate Change (IPCC) for a 50%–85% reduction of global carbon emissions by 2050 based on the 2000 emission levels, the construction industry has become more energy efficient with regard to the processes used for the production of construction materials (Allwood et al., 2010). Yet, accelerating infrastructure development due to investment in large infrastructure in less economically developed countries, maintenance of existing stock, as well as building and retrofitting of new and existing houses results in a net increase in yearly materials and energy use and thus associated carbon emissions (Allwood et al., 2010; Couto and Couto, 2010; Durmisevic and Brouwer, 2002; Heard et al., 2012; Sassi, 2004).

A large volume of construction and demolition waste (CDW) is generated by the construction industry each year, which in industrialised countries can be up to 60% of the total amount of solid waste generated by mass (Crowther, 2014; EEA, 2012; Heard et al., 2012; Oikonomou, 2005; Sabai et al., 2013). In Europe, CDW accounts for 31% of Europe's total solid waste generated, excluding wastes from the mining and quarrying activities (BIO Intelligence Service, 2011; EEA, 2012; European Commission, 2014; Villoria Saez et al., 2013). The low cost of virgin materials, in combination with the low cost of conventional demolition and the possibility of disposing wastes to landfill, has enabled landfilling to become a popular CDW management practice in most developing counties, as well as in some European member states (BIO Intelligence Service, 2011). Pressures on limited landfill resource, and on natural resource depletion and ecological degradation caused by the increasing extraction of raw materials (Horvath, 2004; Ness et al., 2015; Sabai et al., 2013) are forcing conventional practices to be revisited, encouraging a halt to linear material flows. In Europe, the revised Waste Framework Directive (rWFD) (2008/98/EC) has mandated EU member states to implement measures in such a way as to reuse, recycle or recover of a minimum of 70% of non-hazardous CDW by the year 2020 (ETC/SCP, 2011; Office Journal of the European Union, 2008). This has led to calls for changes in both ends of the materials chain (i.e. upstream and downstream); a reduction of virgin resource demand through materials efficiency (upstream) and the proper management of the wastes generated from the construction, renovation and partial or total demolition of buildings and/or civil infrastructure (downstream) (Crowther, 2014; del Rio Merino et al., 2010; EEA, 2012; Fatta et al., 2003; Horvath, 2004; Kourmpanis et al., 2008; Pongiglione and Calderini, 2014; Symonds Group Ltd. et al., 1999; Tam and Tam, 2006b).