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Smart steel: new paradigms for the reuse of steel enabled by digital tracking and modelling

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ABSTRACT

When reconfigured into a cohesive system, a series of existing digital technologies may facilitate disassembly, take back and reuse of structural steel components, thereby improving resource efficiency and opening up new business paradigms. The paper examines whether Radio Frequency Identification (RFID) technology coupled with Building Information Modelling (BIM) may enable components and/or assemblies to be tracked and imported into virtual models for new buildings at the design stage. The addition of stress sensors to components, which provides the capability of quantifying the stress properties of steel over its working life, may also support best practice reuse of resources. The potential to improve resource efficiency in many areas of production and consumption, emerging from a novel combination of such technologies, is highlighted using a theoretical case study scenario. In addition, a case analysis of the demolition/deconstruction of a former industrial building is conducted to illustrate potential savings in energy consumption and greenhouse gas emissions (GGE) from reuse when compared with recycling. The paper outlines the reasoning behind the combination of the discussed technologies and alludes to some possible applications and new business models. For example, a company that currently manufactures and 'sells' steel, or a third party, could find new business opportunities by becoming a 'reseller' of reused steel and providing a 'steel service'. This could be facilitated by its ownership of the database that enables it to know the whereabouts of the steel and to be able to warrant its properties and appropriateness for reuse in certain applications.

1. Introduction

The construction industry accounts for more than one third of total energy use and its associated global greenhouse gas (GHG) emissions. The corollary to this is that the construction sector has the largest potential for cutting GHG emissions (UNEP, 2012). As the steel industry is responsible for about 6.5 per cent of emissions, and 51 per cent of global steel is used for construction (Basson, 2012) hence the challenge of mitigating the effects of climate change, coupled with carbon pricing mechanisms and global financial pressures, are placing increasing pressure on the steel industry to reform its production and consumption processes (Environmental Leader, 2007). Although the amount of energy required to produce a tonne of steel has been dramatically reduced (approximately 50 per cent) since the 1980s, the industry acknowledges that 'there is now only room for marginal improvement on the basis of existing technology' and that major 'breakthrough' technological changes are required (World Steel, 2012, p. 2).

Globally, while steel recovery rates for recycling are estimated at 85 per cent for the construction sector, there is a relatively low-level of reuse of components. According to Sustainable Steel Construction (SSC), reuse of steel in construction means taking steel components from an older building and using them in a new project with minimal reprocessing; thus, 'structural components such as beams, columns or non-structural components such as cladding panels or staircases are taken from one project and reused in another' (SSC, 2012). As SSC has also noted, reuse is well-known to be more resource efficient because less energy is required to reconfigure or re-manufacture products. However, there are a number of barriers to reuse, including the lack of confidence of designers in the structural properties and performance of reused steel components. Anecdotally, the identification of materials to be re-used in the design phase is a significant factor in the uptake of re-use as there is no easily defined marketplace for salvaged materials. This situation is further exacerbated by the absence of

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procedures in the current design codes for determining the necessary properties for reclaimed steel.

Accordingly, this paper proposes the reconfigured use of a disparate collection of existing technologies and business models into a cohesive system to improve the current low level reuse. With a focus on the architecture, engineering and construction (AEC) sector, a system is envisaged that would facilitate an automated approach to the location and carbon allocation of high embodied energy components such as structural steel elements used extensively in the construction industry. Further to the concept of assigning a unique identifier and mapping the physical steel elements, a CAD based database could be employed using the same captured information to provide a virtual open market place for elements sale prior to reuse. Moreover, combined with the use of RFID enabled movement tracking technology, this process would allow an accurate accounting of indirect (transport) embodied energy costs of a given element at a given time or potentially part of that element over a different period of time.

The paper is arranged as follows. Firstly, challenges facing the steel industry are outlined in Section 2, including cost pressures and the need to reduce emissions due to clean energy requirements and carbon pricing legislation, with the industry seeking to project itself as exercising responsible stewardship of resources. This leads to the research questions, with the subsequent sections structured to address these. After putting forward (Section 3) a vision and theory towards a more resource efficient steel industry, the role that could be played by steel reuse in such a transformation is discussed. In Section 4, the paper examines how enabling 'smart' technologies such as RFID and BIM may enable the reuse of steel, and presents a theoretical case study scenario to illustrate the connections between the various technologies and demonstrate that the approach is workable. Section 5 indicates how these technologies may create a platform for new paradigms and profit centres such as a life cycle data service, reselling service and product-service system (PSS). A case analysis is presented in Section 6, illustrating the potential energy savings that could accompany reuse in comparison to recycling. After further discussing potential benefits in terms of emissions reductions and cost savings, Section 7 examines circumstances required for successful application and factors that may motivate change, including legislative imperatives such as the green building rating system. As this is an embryonic field of endeavour and empirical research is yet to be conducted, the paper is concluded in Section 8 by discussing limitations of the research approach and putting forward a pathway towards more extensive research on reuse of steel in the AEC sector.

2. The challenges and research questions

2.1. The steel industry and its challenges

Globally, over 1.3 billion tons of steel are manufactured and used every year, with close to 50 per cent of steel produced and used in mainland China, and it is predicted there will be continuing strong growth in the volume of steel produced. While steel is one of the world's most recycled products, it is claimed that 'this continued growth prevents the demand for steel being met by means of recycling of end-of-life steel products alone, hence, making it necessary to continue converting virgin iron ore into steel' (World Steel, 2012). However, whilst this may be the case given current approaches to steel production, consumption and building configurations, are there scenarios, configurations and technologies that may enable much increased reuse and recycling in future, involving less primary production, which may enable the necessary paradigm shift?

In theory, steel is 100 per cent recyclable, which means its life cycle is potentially endless: 'steel is an almost unique material in its capacity to be infinitely recycled without loss of properties or performance' (World Steel, 2012, p. 3). In Australia, about 65 per cent of steel available for recycling goes back into the making of new steel (BlueScope Steel, 2009). This involves 'urban mining' and melting down and 'up-cycling' of old inefficient cast iron by combining this with higher quality steel to produce a more efficient product suitable for certain applications. BlueScope produces steel using a blast-furnace oxygen technique (BF-BOS), which uses virgin material – including iron ore, coke and fluxes – as well as 17-20 per cent scrap steel (BlueScope Steel, 2012).

However, steel making, recycling and associated processes use considerable amounts of energy leading to high level of greenhouse emissions; for example, in Australia, BlueScope Steel's total greenhouse gas emissions in the financial year ending 30 June 2007 were 12.53 million tonnes (BlueScope Steel, 2008). It is among 500 Australian companies impacted by the Australian Government's plan for a Clean Energy Future and especially its carbon price legislation (Australian Government, 2011a,b). To assist the steel industry make this transition and be competitive in this new market, the company has been granted AUD$100 million under the Government's 'Steel Transformation Plan' (Wilson, 2011).

Also in response to the challenges, the industry is seeking to reduce emissions, improve efficiency of resource use, and project itself as a 'responsible' industry. The World Steel Association has introduced a 'climate action recognition program', recognising steel producers who fulfil their commitment to participate in a CO_2 data collection program, and promotes a life cycle approach to measure greenhouse impacts from all stages of manufacture, product use and end-of-life (World Steel, 2012). In Australia, a 'steel stewardship forum' was initiated in 2007 to implement sustainable development over the steel life cycle (Steel Stewardship Forum, 2011).

2.2. Research questions

Rynikiewicz (2008) has highlighted the dramatic shifts required in the steel industry, noting that attention has moved from 'cleaner production' to 'regime transformation' or socio-economic paradigm shift, and that the industry may be one of the first sectors to experience 'industrial transformation'. He has proposed that changes are required not only in technologies but also 'at the levels of systems of production, distribution and in consumption patterns'. This leads to the research questions forming the basis of this paper, namely:

a) What part could reuse of steel play in such industrial transformation? (which is discussed in Section 3);
b) What are the enabling technologies and alternative business approaches? (which are explored in Sections 4 and 5);
c) What are the potential savings in energy and greenhouse emissions? (which are analysed through a case example in Section 6).

The rest of this paper is structured to address these research questions, with the relevant sections shown in brackets above. Accordingly, a 'Smart Steel' paradigm for effective reuse of steel is proposed (Section 5) while the potential for implementation of the new paradigm, and its implications, are also discussed (Section 7).

3. A vision for the steel industry

3.1. A resource circulating industry

As encapsulated by Schmidt-Bleek (2000) and others, the concept of resource efficiency (RE) involves delivering more services (S) or outputs, with less material input (MI). In simple terms, resource efficiency is the amount of resource used per unit of input