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The contribution of structural design to green building rating systems: An industry perspective and comparison of life cycle energy considerations

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ABSTRACT

The construction industry provides extensive impacts to the environment with population increases further driving these pressures. In an attempt to mitigate these impacts, the industry as a whole has promoted and developed numerous green building rating systems (GBRS). These GBRS assign scores to buildings based on a variety of assessment criteria to determine a structures environmental impact. Previous research has identified shortfalls in certain areas related to these GBRS. In order to gain further insight into these systems an industry survey was conducted to establish an alternate perspective. The outcomes of this survey were consistent with that of previous research, identifying the requirement for an increase in the Embodied Energy (EE) consideration of structures in GBRS. The average estimation of the contribution of EE to a structures life cycle consumption was 28.4%. The survey findings also identified a number of other key areas through which changes in the consideration of sustainable development could be improved. The use of these findings and their comparison to previous research outcomes would assist in the development of supplementary mechanisms to improve the assessment of the environmental performance of structures.

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1. Introduction

The construction, operation and maintenance of buildings have been extensively shown to have negative environmental impacts. These are said to account for between 40 and 50% of all energy usage and anthropogenic greenhouse gas (GHG) emissions globally (Asif, Muneer, & Kelley, 2007; Baek, Park, Suzuki, & Lee, 2013; Citherlet & Defaux, 2007; Dimoudi & Tompa, 2008; Dixit, Fernández-Solís, Lavy, & Culp, 2012; Hasegawa, 2003; Langston & Langston, 2013; Smith, 2005; Stephan, Crawford, & Myttenaere, 2011; Wood, 2007). The history and origins of the consideration of sustainability in the built environment is clearly and concisely presented by Lele (1991) and Mebratu (1998). In addition to these, it has been reported that the operational contribution from buildings to total energy consumption in the United States, European Union and the United Kingdom are 40%, 37%, and 29% respectively (EPA, 2009; Pérez-Lombard, Ortiz, & Pout, 2008). In states that rely heavily on a service driven economy, for example Hong Kong, this proportion can be as high as 80% (Chau, Hui, Ng, & Powell, 2012). Waste generated by the building industry accounts for a significant proportion of landfill produced, with it being previously reported that in Australia, approximately 38% of waste generated originated from construction and demolition activities (ABS, 2010). Similarly, in the Unites States, it is estimated that the building industry is responsible for producing 25–40% of total waste (Frey, 2007).

With Australia's population predicted to increase to approximately 35.5 million by the year 2056 (ABS, 2012), and global population estimated to hit 8.9 billion by 2050 (Kates, 2000), anthropogenic pressures driving construction rates will continue (Miller & Doh, 2014). These pressures influence climate change and global warming with demand driving further environmental impacts associated with all relevant industry supply chains.

In Australia in order to keep pace with growing demand, approximately 30 million tonnes of finished building products are produced each year. Over 56% of this quantity, by mass, attributed to concrete and a further 6%, steel (Walker-Morison, Grant, & McAlister, 2007). In the US, each year, the development industry consumes over 40% of all raw stone, gravel and sand material, 25% of all raw timber, 40% of energy and 16% of water (Chong et al., 2009; Lippiatt, 1999). It is reported that globally, the production of cement alone causes between 5 and 7% of CO_2 emissions due to consumption of fossil fuels (Flower & Sanjayan, 2007; Oh, Noguchi,

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Kitagaki, & Park, 2014). These statistics highlight the potential benefits achievable by the entire construction industry, through any improved efficiency.

Notwithstanding the environmental impacts of the built environment, the construction industry provides significant contributions to the broad principles of Sustainable Development (SD) (Miller & Doh, 2014; Miller, Doh, & Guan, 2011). SD principles have been linked with the building industry, with many aspects appropriately considered. The building industry is referred to, as the lifeblood of the economy in the developed world (Miller & Doh, 2014) with its contribution to the economic dimension of SD being unquestioned. In the United States the construction industry is valued at over $1 trillion and provides critical infrastructure to support industries while creating over 6.5 million jobs (Chong et al., 2009). In Europe this industry provides the largest single contribution to employment with over 7.5%, 9.7% of the GDP and 47.6% of the gross fixed capital formation in 1999 (EU, 2001), and these trends continue globally. Buildings are also shown to provide extensive social benefits including: good quality indoor living environments, structural integrity, safety for occupants, low vibration, high degree of weather protection, high fire resistance, good thermal resistance and sound acoustic performance (CCAA, 2010; Miller & Doh, 2014).

Traditionally, economic growth has been the key driving factor in building development (Adams, 2006). The significant importance of buildings providing economic and social prosperity has consequently produced an inevitable side effect of a significant increase in energy consumption in the construction industry (Xundi, Liyin, Saixing, Jose Jorge, & Xiaoling, 2010). However, more recently, with the impacts of human activities on the environment becoming undeniable, sustainability has become an increasingly important topic across the industries stakeholders (IPCC, 2007; Miller & Doh, 2014; Turner, 2006).

In partial response to the identification of the issues above, and related specifically to environmental impacts in the building industry, a number of mechanisms have been developed to assess the environmental performance of structures. Green Building Rating Systems (GBRS) assign scores to buildings based on a variety of assessment criteria including for example: potential savings in energy and water consumption, indoor environmental quality and the use of innovative materials. GBRS are becoming more prevalent globally with extensive variations existing (Fowler & Ranch, 2006). The UK based Building Research Establishment's Environmental Assessment Method (BREEAM) has been previously identified as one of the world's pioneering rating systems (Fowler & Ranch, 2006). Leadership in Environmental and Energy Design (LEED) and Greenstar, the most popular rating systems in the USA and Australia respectively, have adopted rating methodologies based partially on the mechanism introduced by BREEAM (Fowler & Ranch, 2006). In each of the abovementioned rating systems, scores are assigned in a number of categories by meeting or exceeding benchmark criteria. The exact rating criteria as well as the scores available are dependent on building type, location and GBRS utilised. A final score is usually provided in terms of either a percentage or an ordinal qualitative descriptor (e.g. a number of 'stars'). The potential for these GBRS to effectively assess, and promote, sustainable development is well documented with numerous studies identifying their importance (Bilec, Ries, & Matthews, 2007; Clark, 2003; Deane, 2008; DEWR, 2007; Ding, 2008). Conversely, issues with these assessment tools have been previously identified (Ding, 2008; Dixit et al., 2012). Ding (2008) noted that while there is no doubt that these assessment methods contribute to the goal of SD, the current assessment systems have limitations in their effectiveness and usefulness. Ding (2008) concluded that there is a requirement for greater collaborations across the building industry to promote and improve these existing assessment systems. It is anticipated that supplementary material is required to more suitably assess a buildings environmental performance.

When considering environmental performance across any Building Life Cycle (BLC), there are two important phases to define: Embodied Energy (EE) and Operational Energy (OE). The total life cycle energy consumption of a building includes both of these phases (Dixit, Fernández-Solís, Lavy, & Culp, 2010; Dixit et al., 2012; Goggins, Keane, & Kelly, 2010). It has been reported that the existing GBRS, tend to underestimate the role of EE in a typical BLC (Frey, 2007; Miller, Doh, Lima, & Oers, 2014). A recent study by Miller and Doh (2014) presents the variability estimated in published literature of the proportions of EE and OE in the BLC of typical concrete and steel framed structures. Despite this variability, it is widely accepted that EE and OE of approximately 20% and 80% respectively, when considering a typical BLC is common (Miller et al., 2014). The average of the proportions of these phases, in the study conducted by Miller and Doh (2014), was 18.6% EE in comparison to 81.4% OE. Notwithstanding these findings, investigations into the proportion of points being allocated to EE considerations in three main existing green building assessment systems are approximately 11%, 8% and 7% by BREEAM, LEED and Greenstar respectively (Miller et al., 2014). It was apparent from these assessments, that current GBRS underestimate the weighting of EE contributions.

The potential role of structural engineers in achieving reductions in environmental footprint of a building is commonly neglected due to the industry focus on OE (Ramesh, Prakash, & Shukla, 2010). A previous study suggested an initial over investment in EE was supported where the outcomes dictated BLC improvements in OE efficiencies (Ramesh et al., 2010). It is accepted that there are justifiable motivations for this, however technologies are advancing. Zero Energy Buildings (ZEB) provides a new philosophy to enable stakeholders to contribute to the sustainable performance of structures. Zuo, Read, Pullen, and Shi (2012) noted that technologies would not have to drastically improve to produce carbon-neutral buildings. ZEB have become increasingly common, with Zahedi (2010), Marszal and Heiselberg (2011) and Zuo et al. (2012) all observing buildings with zero net OE requirements (ZEBs). These studies also indicated that the incidence of ZEBs would increase (Marszal & Heiselberg, 2011; Zahedi, 2010; Zuo et al., 2012). Subsequently, continuation would result in the EE contribution of buildings being the sole influence of a BLC environmental energy performance. It has therefore been said that assessing the performance of ZEBs should appropriately incorporate the quantification of EE (Butera, 2013).

Whilst the significant contribution of OE in the BLC energy is noted, the literature suggests that increased involvement of structural engineers in decisions regarding sustainability would be desirable. It would not be implausible with the advent of ZEB for EE considerations to become the principal environmental performance consideration. In the short term, sustainability decisions would ideally be made by an interdisciplinary teams of professionals with structural engineers being a vital contributor (Miller & Doh, 2014). To progress the enhancement of sustainability considerations in the building industry, a universal standard and mechanism are required. To date, no such instrument exists that appropriately considers all industry stakeholders (Ding, 2008; Dixit et al., 2012; Miller & Doh, 2014).

The factors presented categorically reinforce the requirement for the improvement of the consideration of EE in the current building design and construction process as well as existing GBRS. It was anticipated that further developing an understanding of the existing GBRS and their contribution to the improvements in environmental performance of structures will contribute to the development of the supplementary tools required to improve buildings environmental performance. To successfully implement EE reducing initiatives in existing standards, acceptance by the

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