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Sustainable management and utilisation of concrete slurry waste: A case study in Hong Kong

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ABSTRACT

With the promotion of environmental protection in the construction industry, the mission to achieve more sustainable use of resources during the production process of concrete is also becoming important. This study was conducted to assess the environmental sustainability of concrete slurry waste (CSW) management by life cycle assessment (LCA) techniques, with the aim of identifying a resource-efficient solution for utilisation of CSW in the production of partition wall blocks. CSW is the dewatered solid residues deposited in the sedimentation tank after washing out over-ordered/rejected fresh concrete and concrete trucks in concrete batching plants. The reuse of CSW as recycled aggregates or a cementitious binder for producing partition wall blocks, and the life cycle environmental impact of the blocks were assessed and compared with the conventional one designed with natural materials. The LCA results showed that the partition wall blocks prepared with fresh CSW and recycled concrete aggregates achieved higher sustainability as it consumed 59% lower energy, emitted 66% lower greenhouse gases, and produced lesser amount of other environmental impacts than that of the conventional one. When the mineral carbonation technology was further adopted for blocks curing using CO_2, the global warming potential of the corresponding blocks production process was negligible, and hence the carbonated blocks may be considered as carbon neutral eco-product.

1. Introduction

Nowadays, environmental protection and sustainability are becoming important issues globally. In most countries, the construction industry is a major source of environmental problems and contributes significantly to natural resource depletion. The construction industry consumes approximately 50% of the earth's natural resources and produces 50% of its waste (De Schepper et al., 2014). With the booming of construction activities, a considerable amount of construction and demolition (C&D) waste is generated every day. The conventional waste management method of C&D waste may result in significant environmental impact. According to the Hong Kong Environment Protection Department (HKEPD), over 62,000 tpd (tonnes per day) of C&D waste were generated in 2013, of which 95% were disposed as public filling materials for land reclamation and 5% were disposed of at landfills (HKEPD, 2015). The C&D waste management in Hong Kong is now becoming a serious public concern due to the running out of disposal outlets to accommodate the huge amount of solid wastes. C&D waste can be reused as a raw material in the manufacture of secondary materials/products (Rodrigues et al., 2013).

Among the C&D wastes, concrete slurry waste (CSW) generated from the production of concrete is currently disposed of at landfills in Hong Kong. CSW is sourced from the aggregate reclaiming system of ready-mixed concrete batching plants, where over-ordered/rejected fresh concrete is washed out to retrieve the aggregates and concrete mixer trucks are cleaned. The wastewater is then treated in a sedimentation tank, where the suspended solid particles in the wastewater are deposited and dewatered to form the CSW.

In the literature, a few recycling and reuse strategies of CSW have been reported and they include replacement of natural aggregates in concrete or concrete products (Kou et al., 2012a,b), using it as a cementitious material in road bases (Zhang and Fujiwara, 2007), a filler in concrete (Correia et al., 2009; Zervaki et al., 2013), a glass-ceramics component (Tian et al., 2007), and a slurry-based geo-polymer (Yang et al., 2009), although the most common destination is landfilling (Tam, 2008; Sealey et al., 2001). In addition, the concrete slurry wash water can also be reused in new concrete (Chatveera et al., 2006; Su et al., 2002), and as a sorbent of chemicals, such as CO_2 capture, phosphorus recovery and water clarification (Iizuka et al., 2012a,b). The

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authors' research team has developed a new approach to recycle and reuse fresh CSW as a cementitious paste to produce a type of partition wall blocks, namely "eco-partition wall blocks", which is produced by proportioning appropriate amounts of fine recycled concrete aggregates (FRCAs) (<5.0 mm) and fresh CSW, and subjected to an accelerated mineral carbonation process.

Life cycle assessment (LCA) is considered as an effective tool for evaluating the environmental impacts associated with a process or a product through identifying, quantifying and assessing the impacts, and it is widely applied in eco-labeling programs, strategic planning, promotion, process improvement and product design globally (Reza et al., 2011). A number of previous LCA studies focused on quantifying the environmental impact of conventional construction products and materials (Omar et al., 2014; Broun and Menzies, 2011; Sanchez et al., 2009; Broun et al., 2014; Liu et al., 2014; Hong et al., 2012; Bovea and Powell, 2016; Ding et al., 2016). However, no LCA study has been reported concerning the assessment of environmental sustainability of various CSW management strategies, and construction products produced with CSW. Therefore, this study was conducted to assess and compare the environmental sustainability of different CSW management strategies and their utilisation for the production of partition wall blocks by the LCA technique. The results of present study are expected to promote sustainable CSW management and utilisation in construction products.

2. Materials and methods

2.1. Current CSW management strategies

Four identified strategies for CSW management in literature are shown in Fig. 1, and described below:

- ***Strategy 1:*** Landfilling: including transport and normal procedures for C&D waste landfilling.
- ***Strategy 2:*** Producing supplementary cementitious materials (SCM): including grinding and sieving processes.
- ***Strategy 3:*** Producing recycled fine/coarse aggregates: including collection and transport of hardened CSW, and then crushing and sieving processes.
- ***Strategy 4:*** Using fresh CSW as a cementitious paste: including collection and transport of fresh CSW and directly reusing (within 3 days) in construction products (e.g., partition wall blocks).

2.2. Description of different CSW management strategies

The different possible outputs of CSW are shown in Fig. 2. The most common practice for CSW management is landfill disposal (strategy 1) (Kou et al., 2012a,b). For landfill disposal, the dewatered fresh CSW is transported from the concrete batching plants to the landfill sites. However, this approach is not an environmentally sustainable option due to the energy consumption and emissions associated with transport and handling. Moreover, due to the high alkaline content in CSW, the indiscriminate disposal of CSW at landfills may cause detrimental effects to the surrounding environment and ecosystems (Sealey et al., 2001).

Alternative management options such as (i) reuse as a supplementary cementitious material (SCM) (strategy 2), (ii) use as recycled aggregates as the substitution of natural aggregates (strategy 3), and (iii) reuse fresh CSW as a cementitious paste in construction products (strategy 4) have been proposed by several studies. It is noticed that several pre-processing steps (e.g., crushing and sieving) are required to prepare CSW as aggregates or SCM.

Some technical breakthroughs are required to use CSW in new construction products. For example, recycled aggregates produced by hardened CSW can be used as an alternative aggregate in concrete to replace natural aggregates. However, the use of 100% recycled CSW aggregates is likely to have a negative influence on concrete properties, e.g., compressive strength, modulus of elasticity, shrinkage and creep (CCANZ Technical report, 2011). Kou et al. (2012a,b) showed that about 50% recycled fine CSW aggregates may be used to substitute river sand for producing non-load bearing concrete products like partition wall blocks. Correia et al. (2009) concluded that although the use of recycled fine CSW aggre-

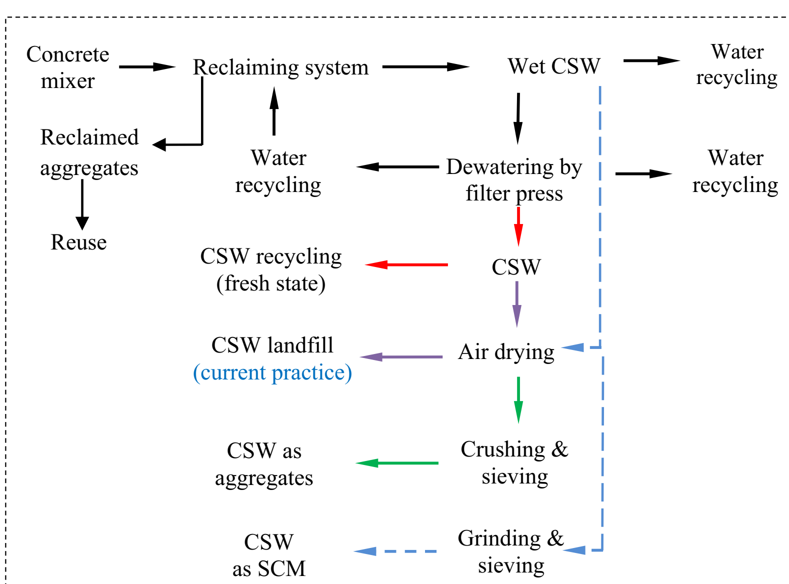

Fig. 1. Different strategies of CSW management.

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