

## **Use of recycled construction and demolition waste in the landscape industry**

Salman Shooshtarian<sup>1</sup>, Mohammad Reza Hosseini<sup>2</sup>

1RMIT University, School of Property, Construction and Project Management, Melbourne Australia,

2Deakin University, School of Architecture and Built Environment, Geelong, Australia

### **Abstract**

Increased construction activities around the world have led to the generation of excessive construction and demolition (C&D) waste annually. Hence, the C&D waste stream has become a national concern in many developed and developing nations in recent years. Several studies have provided solutions to improve current C&D waste systems. Among various solutions, the establishment of a domestic market has been highlighted as an effective and sustainable solution to this issue. The development of a domestic market largely hinges on unlocking new applications for valuable C&D waste materials. This review paper investigates the potential application of these materials in the landscape industry with a focus on boosting C&D waste resource recovery activities. Some past and new applications are identified (green roof substrate, green façade, sports surface construction, soil amendment, vegetated surface mulch, vegetated permeable pavement) in this study, setting the scene for further inquiries into upcycling between the construction industry and the landscape industry. Also, the results provide a basis for policy development to encourage waste recovery and increase public and key stakeholders' awareness and further incorporate the principles of the circular economy.

**Keywords:** Circular economy; waste resource recovery; upcycling; market development; green infrastructure

### **Introduction**

In recent years, due to a worldwide increase in construction activities, the volume of construction and demolition (C&D) waste has surged. Several developed and developing nations have expressed their grave concerns over the alarming rate of C&D waste generation and accordingly have put forward various mitigation strategies. Most of these strategies follow the concept of waste hierarchy that is underpinned by avoiding and reducing, reusing, recycling, recovering, treating and disposal activities. Currently, recycling practices have significant traction as a standard and realistic best management practice. Drawing on circular economy principles, recycling delivers several environmental, social and economic benefits in comparison to landfilling. Some of these benefits include protection of the environment, reduction in greenhouse gas emissions, reduction in costs associated with raw material extraction and job creation.

It has frequently been argued that recycling activities are significantly discouraged by the lack of a sustainable domestic market [1] in which recycled products can be supplied and procured locally with a high level of confidence. Along with pecuniary imposts such as a landfill levy [2], the establishment of a domestic market is highlighted as an effective and sustainable solution to this issue [3]. The development of a domestic market, however, largely hinges on several factors [3]. In previous literature, an undeveloped C&D waste market was attributed to a range of determinants including ineffective supply chain, poor quality, cost, availability, unacceptability to end-users and lack of (information on) the market availability of the products [1, 4, 5]. It seems that the latter can be addressed through finding broader and unorthodox applications for these materials; an objective that can be achieved through the concept of upcycling, otherwise known as industrial symbiosis. Industrial symbiosis is the process by which wastes materials or by-products of an industry or industrial process become the raw materials for another.

Among various industries, the construction industry and the landscape industries have many similarities due to their focus on the creation of built environments. The historical evidence suggests the existence of industrial symbiosis between these two fields [6] such as using C&D waste as mulch or soil amendment. Green infrastructures (GI) are an integral part of today's cities, and authorities in cities are making considerable efforts to maintain and increase GI per capita. The ongoing maintenance of GI projects requires a lot of hard and natural materials that can be sourced from the C&D waste stream. Furthermore, due to evolution and innovation in the creation of various types of GI, more opportunities have arisen for industrial symbiosis between these two industries. Therefore, it is of particular importance to identify and exhibit these opportunities to stakeholders (recyclers, suppliers, architects, sub-contractors, policymakers, clients, etc.) who contribute to decisions favouring the use of recycled products in the landscape industry. This study aims to identify opportunities to upcycle C&D waste materials between the construction and landscape industry.

### **Martial mad Methods**

This study uses the document analysis technique to review upcycling activities between the construction and landscape industries. The review is based on the secondary qualitative data that is publicly available. Various search engines including Google Scholar, Scopus and Web of Science were used to collect relevant data. The search involved the application of multiple keywords such as "construction and demolition waste", "landscape", "green infrastructure", "recycling", "upcycling", "vertical greening" and "sustainable". From the selected studies, only a few are presented due to the mode of output being a conference paper. The main criteria considered for the selection of research outputs included:

1. Written in English and published between 2005 and 2020,
2. Demonstrates the application of at least one C&D waste material
3. Studies the C&D waste application in green infrastructure with vegetative elements, meaning other applications such as urban furniture, hard surfaces and decorations were excluded.

## Results

The results of the review identified six GI, wherein the applications of recycled C&D waste materials are plausible (Figure 1). These six GI are commonly constructed in cities and provide an opportunity for C&D waste market development. The following section explores these applications.



Figure 1. Applications of recycled C&D waste in the landscape industry.

Source: [pinterest.com.au](https://www.pinterest.com.au) (2020)

Note: top left: green roof, top centre: vegetated pavement, top right: sport surface, bottom left: green façade, bottom centre: mulch, and bottom right: soil amendment.

### Green roof substrate

Green roofs are vegetated surfaces on rooftops that provide a natural environment in densely urbanised areas. Green roofs are known for their environmental and psychosocial benefits [7]. Several studies have evaluated the application of recycled C&D waste materials as growth substrates in green roofs worldwide [8]. In a laboratory study, Mickovski *et al* [9] found that recycled C&D waste materials—a mixture of calcareous and siliceous aggregates—were adequate in supporting plant growth and development,

resistant to erosion and slippage, and capable of providing good drainage. In the UK, a series of field experiment results showed that crushed red and yellow brick aggregate and clay pellets are promising substrates to support the growth and development of 15 wildflower plant [10]. The authors observed that using recycled C&D waste could improve green roof resilience through increased plant cover and diversity. In Taiwan, the application of recycled glass in green roof substrate exhibited positive results [11], including similar water quality and plant growth performance to the commercially prepared substrate. In Australia, successful results were achieved from using crushed roof tiles, bottom ash and scoria in green roof substrate [12]. In recent years, there has been an increasing trend towards more green roof uptakes in populated cities, creating an untapped market for recycled C&D waste materials.

### **Green façade**

Green façades are another type of vertical greening in urban environments. Previous studies have demonstrated the feasibility of the application of recycled C&D waste materials in building green façades [13]. In the EU, an international project called Green INSTRUCT (2016-2020) is underway to study the use of recycled C&D waste materials in a minimum of 70% of the green façade's net weight [14]. The project involves the prefabrication of modular wall panels made from C&D waste materials, including brick, concrete, plastic, glass and metal. The project contains six work packages (WP); in WP4, the three objectives include "identification of additional CD waste stream that can be incorporated in the recovery process", "design, implement, monitor and optimise a CD waste recovery process tailored to the project's material flow requirements" and "coordinate the material characterisation techniques employed within the project". The produced prototype involves a multi-layered integrated building block that has been designed to be faster to install than conventional envelope walls of the same size. The build provides thermal and acoustic insulation and contributes to on-site grey and stormwater management through the integration of a vertical Green Wall, providing additional functionalities [14].

### **Sports surface construction**

Another increasingly important market for recycled C&D waste is specialist sports and leisure applications. In this theme, the use of recycled glass (silica sand) as a substitute for quarried sand in turfed surfaces such as golf course has achieved significant successes [15]. Often mixed with organic matter, silica sand is used in top dressings, root zones and drainage channels in sports surface construction. A report from the US showed the successful use of silica sand in a massive golf course provided an annual cost saving between USD \$50,000 and \$100,000 [16]. As the sports fields are typically large (Figure 1), it is possible to use a large volume of recycled C&D waste materials. To put this into context, a report by the British Geological Survey (BGS) indicated that an 18-hole golf course requires 100 tonnes of sand per year for top dressing purposes [17].

**Soil amendment**

Soil amendments are added to soil to change and improve its agricultural quality. Some C&D waste materials such as timber waste, concrete and gypsum generated from drywall construction and demolition activities can be used as a soil amendment. There is historical evidence that gypsum has been ground on-site and used as a soil amendment for many decades [18]. The literature suggested that it can improve water penetration and workability of impermeable sodic “alkali” soils, soften soils with high clay content, help neutralise soil acidity, and add nutrients such as calcium and sulphur to the ground [19]. A study in the US [20] showed that the use of gypsum waste and recycled concrete could positively amend soil properties leading to enhanced growth and vegetation mediated carbon sequestration in some plant species. Further research in collaboration with the industry is needed to evaluate the application of additional C&D waste materials for these purposes.

**Vegetated surface mulch**

Mulching on vegetative surfaces has been practised for several decades in the landscape and horticulture industries. Mulching reduces weed growth, water loss and fluctuation in surface temperature values [21]. In China, gravel mulching has been part of the traditional practices to conserve water and increase crop production in its semiarid regions over the last three hundred years [3]. Landscape mulch is made of recycled timber, concrete, scoria brick and crushed rock. Timber waste generated in construction activities can be chopped and sold as landscaping mulch [22]. However, there are serious environmental concerns about the use of treated timber waste in the landscape industry due to high levels of arsenic [23]. In Kuwait, the use of recycled concrete, asphalt and crushed sandstone aggregates as mulch proved to be successful [24]. The authors observed that waste-derived mulches could conserve soil moisture, increasing the infiltration rate and thus, promoting native plant growth.

**Permeable pavement**

Construction of vegetated permeable pavement (VPP) is a method of paving vehicle and pedestrian pathways to enable infiltration of stormwater runoff, which also adds aesthetic features to built-up surfaces. Living plants in the VPP structure transpires water, actively counteracting the heat island effects. VPP is an important urban element promoted in sustainability programs such as Water Sensitive Urban Design (WSUD) and, therefore, are being considered in cities worldwide [25]. The hard surfaces of PPV can be made of recycled concrete (grasscrete), brick, plastic and tile. In the US, grasscrete is reported to be a cheaper option than previous concrete and paving blocks [26]. Several studies have investigated the use of recycled C&D in manufacturing hard surfaces of VPP and reported satisfactory results [27]. An extensive establishment of VPP systems in urban areas allows a significant usage of recycled C&D waste materials.

**Conclusion**

To appropriately respond to the increasing level of C&D waste generation, more innovative management approaches are required. Among available options, the development of a

viable and sustainable domestic market seems to be conducive. This market should be set up to maximise utilisation of the value embedded in waste materials. One way to achieve this goal is to consider industrial symbiosis, where waste in one industry becomes a resource (raw material) in another. This study aimed to determine the feasibility of industrial symbiosis between the construction and landscape industries. GIs are an integral part of cities, and their ongoing maintenance requires a large volume of materials that can be procured from the C&D waste stream. The review identified applications of recycled C&D waste materials in six GI types: green roof substrate, green façade, sports surface construction, soil amendment, vegetated surface mulch and vegetated permeable pavement. While the application of some C&D waste materials has been documented in previous research studies, further research is required to optimise the existing applications or to identify the new demands for additional waste materials. Lastly, the results of this review provide an understanding of the various possibilities for waste management among C&D waste management recovery stakeholders. Notably, the results provide a basis for policy development to encourage waste recovery following the circular economy principles.

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