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Carpet recycling: A review of recycled carpets for structural composites

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HIGHLIGHTS

- 400,000 tonnes of carpet waste are sent for disposal to UK landfill sites annually.
- Different end-of-use options for carpet waste in the UK are discussed.
- A tonne of recycled carpet waste saves 4.2 tonnes of CO_2 emissions.
- Carpet based composites are potentially suitable for structural applications.

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ABSTRACT

Carpets are multilayer mixtures of different polymers and inorganic fillers that are difficult and costly to reprocess upon disposal. About 400 000 tonnes of carpets are sent to landfill in the UK annually, however, the landfill option is becoming increasingly impractical due to increasing landfill costs and the physical limitations on the number of landfill sites available in the UK. In addition, carpets are non-biodegradable and reduce the availability of landfill for other uses. Hence, this leads to a major drive to increase carpet recycling, which could potentially have a significant positive impact on the environment. This paper gives an overview of the composition of carpets, and the different classifications of carpet waste. In addition, the paper discusses the different end of use options for carpets in the UK. The paper also reviews the different manufacturing processes that utilise carpet waste as raw material in the fabrication of structural composites. The tensile and flexural properties of these composites are presented and discussed. These mechanical properties appear to support the use of carpet waste as potential composite materials for structural load-bearing applications.

1. Introduction

Waste is a component that plays a key role in the issue of climate change, particularly as its disposal produces several greenhouse gas emissions that contribute to global climate change (United Nations Environment Programme, 2002). According to the Department for Environment, Food and Rural Affairs (DEFRA), England generates about 177 million tonnes of waste annually (Department for Environment Food and Rural Affairs, 2014b). The most common route for disposal of waste has been to landfill. However, disposal of waste to landfill results in the release of methane (CH_4) and carbon dioxide (CO_2) to the atmosphere, and methane emissions are more harmful (by a factor of 20) than CO_2 emissions (United Nations Environment Programme, 2002). Hence, the issue of reducing harmful gas emissions is a major environmental concern. DEFRA (Department for Environment Food and Rural Affairs, 2011) estimates that one tonne of general waste reused or recycled saves over 3 tonnes of CO_2 equivalent. Hence, the European Union's seventh framework programme aims at finding innovative ways of utilising waste as a resource (European Union, 2010).

Carpets, which are typically used as floor coverings, are composite materials that are difficult and costly to separate and reprocess at the end of their useful lives (Miraftab and Mirzababaei, 2009; Realff et al., 2005). This is because they are multilayer mixtures of different polymers and inorganic fillers (Realff et al., 2005). In waste streams, carpets are classified as textiles, and textiles account for about 2%–5% of all waste going to landfill in the UK (Miraftab and Mirzababaei, 2009). Although, this appears to be a small quantity, it is

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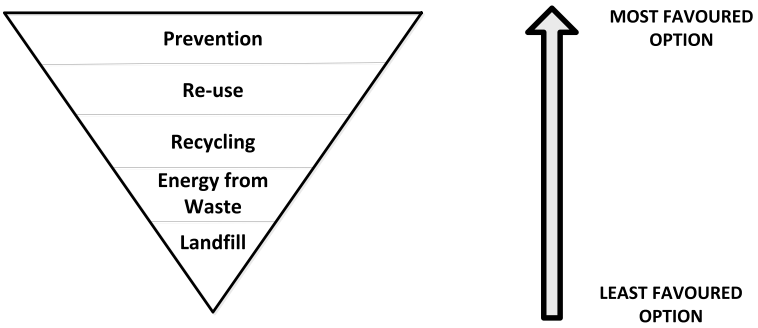

Fig. 1. Carpet waste management hierarchy (Bird, 2014).

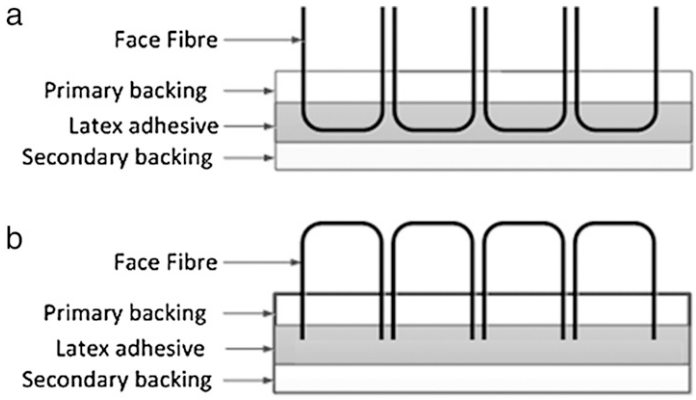

Fig. 2. Typical construction of carpet: (a) cut-pile (b) level-loop.

worth noting that carpet waste has low bulk density, and hence occupy a large volume of landfill. According to Carpet Recycling UK (Bird, 2014), 400 000 tonnes of carpets are sent to landfill in the UK annually. However, the landfill option is becoming increasingly impractical given the increasing landfill costs, and the physical limitations on the number of landfill sites available in the UK (Bird, 2013). By 2025, carpet waste will be banned from UK landfill, because they are non-biodegradable and reduce the availability of landfill for other uses (Bird, 2014).

Fig. 1 shows the carpet waste management hierarchy according to Carpet Recycling UK (Bird, 2014). The hierarchy shows that the prevention option is the 'most favoured option'. The prevention option can be achieved through the use of fewer raw materials where possible in the design and manufacturing process, which, in turn, reduces the waste generated as well as the greenhouse gas emissions associated with the fabrication of carpets (Department for Environment Food and Rural Affairs, 2014a). In addition, prevention of carpet waste can be achieved through the use of reduced carpet volume, and/or by increasing carpet longevity through adequate maintenance or repair (Department for Environment Food and Rural Affairs, 2014a; United States Environmental Protection Agency, 2003). However, the prevention option is limited. According to the carpet waste management hierarchy, prevention offers the best outcome for the environment, followed, by re-use, recycling, energy from waste (via incineration) and lastly landfill disposal (Department for Environment Food and Rural Affairs, 2011; Bird, 2014).

According to Peoples (2006), an important approach to carpet recycling is the development of non-carpet products containing carpet waste. In view of this, the materials embodied in carpet waste may be suitable as raw materials for the development of load-bearing structural composites. Furthermore, this recycling approach can be highly economical, relatively cheap and environmentally friendly depending on the manufacturing processes involved (Vaidyanathan et al., 2013; Mihut et al., 2001; Wang, 2006a). To date, only a few studies have been carried out on the development of structural composites from carpet waste. Such developments will create a stable pathway for carpet waste and provide new materials for load-bearing applications. Additionally, one tonne of recycled carpet waste saves 4.2 tonnes of CO_2 emissions (Carpet Recycling UK, 2010). Thus, carpet recycling could have an important and positive impact on the environment.

This paper gives a brief overview of the composition of carpets and the classification of carpet waste. In addition, the different carpet waste processing options in the UK are discussed, including: waste to energy via Incineration, fibre reprocessing, carpet re-use and plastics reprocessing. The paper also focuses on studies that have been carried out on the fabrication of carpet based composites using different manufacturing processes. The mechanical properties of these composites are presented and compared.

1.1. Composition and classification of carpet waste

A typical carpet consists of four layers: face fibre, primary backing, adhesive and secondary backing (see Fig. 2) (Jain et al., 2012). The top layer, which is the face fibre, can either be nylon, polypropylene, polyester, polyethylene terephthalate (PET), mixed synthetics or natural fibres such as wool (Bird, 2014; Jain et al., 2012; Miraftab et al., 1999). The primary backing is the layer into which the yarns of the face fibres are bonded. Elastomeric adhesive is applied to the underside of the primary backing to hold the face fibres together (The Carpet and Rug Institute, 2003). The elastomeric adhesive is typically made of styrene–butadiene rubber (SBR), which can be filled with