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Review

The role of glass waste in the production of ceramic-based products and other applications: A review

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A B S T R A C T

This paper presents a literature review relating to the potential waste glass collection and processing as glass cullet for its use as raw material in secondary markets. Emphasis is given to the application of glass cullet in the construction industry, other than as construction aggregate, especially in ceramic-based products, including ceramic bricks, tiles and their glazing, glass-ceramics, foam glass-ceramics, and porcelain. These applications also include the use of glass cullet as a filtration medium, constituent in epoxy resins, in the production of glass fibres, elastomeric roof coatings, aesthetic finishing materials, abrasive material for surface cleaning, and paint filler. The analysis and evaluation of the vast amount of experimental research showed that glass cullet is a potentially valuable resource for the manufacture of ceramic-based products, where it can be used as substitute for expensive natural resources, improving the products' physical, mechanical and environmental performance.

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1. Introduction

The glass industry, in view of its product's high degree of recyclability, became one of the first to gather and reprocess its packaging, accomplishing very high recycling ratios. Crushed glass from post-consumer containers (i.e. bottles and jars) and flat glass rejects can be repeatedly recycled into similar products, with virtually no loss in purity or quality (GPI, 2015). It was estimated by the Glass Packaging Institute (2015) that about a tonne of natural raw matter can be saved per tonne of recycled glass used in the production of new glass products. Furthermore, using 10% of glass cullet (GC), which is the aggregate-like product of processed glass waste, in the manufacturing of new glass may mean energy savings of 2–3%. It was also established that the release of about one tonne of CO_2 can be avoided by recycling six tonnes of glass waste from post-consumer containers. Since the increasing incorporation of glass waste in batches in modern glassmaking furnaces can decrease the glass' melting time, which may also include types of glass other than those from containers (Kim et al., 2014), it is also possible to reduce the end products' cost aside from the aforementioned benefits (Beletskii et al., 2013).

1.1. Background

Recent statistics released by Eurostat (2016) showed that the total amount of generated glass waste in the European Union, in 2014, was close to 18.5 million tonnes. A comparative analysis of the total amount of treated glass waste showed that, in spite of the high quantities generated, it is almost completely recovered (i.e. the average recovery ratio in the European Union is 79%).

When considering the recycling of glass waste, one of two methods can be adopted: a closed loop or an open loop recycling approach (Enviros, 2004; Holcroft and Pudner, 2007). The first one entails treating glass waste so that it presents sufficiently high quality to be remelted into glass products (i.e. primary market). This approach is preferred, since glass can be reprocessed and used to replace more valuable raw materials, apart from yielding a product with lower CO_2 emissions and embodied energy (Vellini and Savioli, 2009; Vossberg et al., 2014). The open loop approach, on the other hand, is normally followed in circumstances in which the glass waste is unfit to be recycled back into equivalent manufactured goods and thus must be used in alternative applications. Even though the closed loop approach is ideal from a sustainability point of view, it is often impossible to follow, because glass waste can easily become mixed with a significant number of contaminants (e.g. food, labels, metallic container lids), which can adversely affect the ability of glass to retain the important required properties and aesthetics. Since the segregation of these components can prove difficult or may not be economically viable, one of the main outlets for GC has been its use as construction aggregate (Holcroft and Pudner, 2007), which does not have requirements as stringent as those of the glass making industry.

As the quantities of waste glass generated is ever increasing worldwide, it is imperative that its use is alternative markets is further developed. Apart from its use in construction, GC has been found to install some interesting properties in ceramic-based products, though it has also shown some promising results in several other applications. The scope of this paper is to highlight these alternative markets, where greater emphasis is given to construction related products, including ceramic bricks and tiles, glass-ceramics and foam glass-ceramics, glazing, and porcelain. Other less investigated applications include using GC as filtration media, in elastomeric roof coatings, glass fibres, abrasive material for surface cleaning, constituents in epoxy composites and aesthetic finishing products.

1.2. Types of waste glass

There are various types of glass with differing specific chemical composition, which can greatly influence their potential application. Table 1 presents the main types of waste glass, classified based on their original application, with a brief description of their composition. Most of these wastes are made of soda-lime-silicate (SLS) glass coming from containers and flat glass. However, despite their similar chemical composition, the collection and processing of the two types of glass are different due to the varying colour, size, shape and degree of contamination (e.g. food) of the packaging thereby making the recycling of container glass a more challenging task in comparison with flat glass.

CRT and LCD, which are normally found in electronic components (e.g. computer monitors, televisions, mobile phones), may contain notable quantities of heavy metals, such as cadmium and lead. For this reason, the disposal of these wastes and their subsequent processing are important, in order to avoid contamination

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