



Review

Practical recycling applications of crushed waste glass in construction materials: A review



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HIGHLIGHTS

- Detailed review of Crushed Waste Glass (CWG) as a Construction Material (CM).
- Physical, mechanical and chemical characteristics of CWG are discussed.
- Use of foamed waste glass in concrete as a lightweight aggregate is reviewed.
- Introducing expanded waste glass in ultra-lightweight fibre reinforced concrete.
- Assessing the environmental impacts of CWG and foamed recycled glass in CM.

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ABSTRACT

The disposal of waste glass in landfills is an important environmental challenge that many countries face around the world. The repurposing of waste glass into a construction material reduces the consumption of natural resources, minimizes greenhouse emissions and alleviates landfill scarcity. Over the last sixty-five years, numerous investigators have studied reusing crushed waste glass (CWG) as a construction material. However, CWG has not been widely used in concrete or asphalt construction applications across the globe. Additionally, barriers still exist that prevent CWG from being used as a fine aggregate in concrete, such as the severity of Alkali-silica reaction (ASR) expansions within concrete consisting of CWG, and the lack of understanding of these reactions. This paper presents an overview of previous studies carried out by researchers to reuse CWG as an aggregate in concrete and asphalt mixtures, an aggregate in unbound base and subbase applications, lightweight engineering material and a cementitious material. From the literature review conducted, it can be concluded that CWG has potential use as an aggregate in construction materials. More research is required to clarify contradictions regarding the properties of concrete containing CWG as fine aggregate, as well as further investigation of the properties of foamed waste glass concrete and ultra-lightweight fibre reinforced concrete containing expanded waste glass, and the use of glass powder as a filler in asphalt.

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1. Introduction

The disposal of waste glass has become a major environmental concern due to the increasing demand for landfill space and natural resources, and a greater emphasis on reducing the carbon footprint of the construction industry. The production of glass dates back to 3500 BCE in Mesopotamia, northern Syria and Ancient Egypt. By the late 1400s, early 1500s glass had already become an important commodity in European countries [52]. Ever since then, the rate of generation of waste glass (WG) has increased significantly. Even though glass is an inert material, all glass products have a limited lifespan [144,145], which leads many researchers to look for ways to redirect the amount of WG (Fig. 1) disposed of in landfills.

Initially, the uses of glass were limited to jars, beads and bowls [53], but, due to advances in technology, the number of applications of glass has skyrocketed to include windows, shelves, lighting, appliances, fibre optic cables and solar panels, etc. The surge in the number of applications of glass is largely due to the discovery of different types of glass with varying properties.

The first steps in the glass manufacturing process are the mining, transporting and processing of materials that become glass inputs [130,131]. After the inputs are transported to a glass manufacturing facility, the main processes in glass manufacturing are batch preparation, melting and refining, forming and post forming [128]. For every tonne of glass recycled, approximately 560 kg of sand, 190 kg of soda ash, 176 kg of limestone and 64 kg of feldspar are conserved Glass Packaging [47]. The most common types of glass include soda-lime glass (Fig. 2), lead crystal and crystal glass, borosilicate glass, and electric glass, which is also called E-glass. The varying chemical composition of glass is the main reason why most WG cannot be remanufactured into glass products. Due to the inert nature of glass it is a non-biodegradable material. WG that is not reused stays in landfills for an extremely long time with glass bottles taking around 1 million years to decompose (U.S. National Parks Service), which takes up valuable space that can be used for biodegradable materials.

According to the U.S. Environmental Protection Agency [130], in 2013, Americans generated 10.37 million tonnes of glass in the municipal solid waste stream, the majority of which were food and drink containers. Out of the glass disposed of, 2.78 million

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