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Review

Recycling of seashell waste in concrete: A review

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HIGHLIGHTS

- Seashell waste such as oyster, mussel, scallop and cockle shells usage in concrete.
- The characteristics of seashell waste in aggregate and powder forms are summarized.
- Effects on the fresh and hardened properties of concrete are discussed.

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ABSTRACT

In order to reduce the dependency on virgin materials for construction, efforts have been made to incorporate by-products and wastes from different industries as alternatives in concrete. Originating from the fishery industry, seashell waste, such as oyster shells, mussel shells, and scallop shells, among others, is available in huge quantities in certain regions, and is usually dumped or landfilled without any re-use value. This paper summarizes previous research concerning the use of seashell waste as a partial replacement for conventional materials in concrete and other related cement-based products. The characteristics of different types of seashell waste, as well as the effects of incorporating the seashells on the fresh and hardened properties of concrete, are discussed. The material characteristics suggest that, similar to limestone, seashell waste could be an inert material due to the high calcium oxide content. However, proper treatment such as heating at high temperature and crushing to achieve appropriate fineness are desirable for a better quality material. It is shown in past research that while seashell waste has been used as a replacement for both cement and aggregate, there is still a lack of investigation concerning its durability, as well as the actual influence of seashell powder as a cement replacement material. Despite the reduction in the workability and strength, based on the review, it is suggested that seashell waste could still be utilized as a partial aggregate at a replacement level of up to 20% for adequate workability and strength of concrete for non-structural purposes.

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1. Introduction

The current trend in concrete engineering is shifting towards the sustainability aspect due to the depletion of natural concrete-making materials as well as the environmental impact arising from the utilization of these materials. Hence, there is a steady increase in realizing the sustainability of concrete production through the use of recycled waste materials as substitutes for conventional materials in concrete. For this purpose, a number of studies have been carried out to utilize wastes originating from different sources, such as construction and demolition waste [1,2], and from a variety of industries including steel [3], agricultural [4–6], glass [7], and rubber [8], among others. These wastes are available in huge volume in certain countries, and, hence, have the potential to be re-used in large-scale concrete production. The utilization of waste materials in concrete could moderate the problem of excessive consumption of conventional materials as well as reduce the amount of waste generated.

Another potential waste material that is available in abundance is waste seashells. There are many different types of waste seashell available, such as oyster shells, mussel shells, scallop shells, periwinkle shells and cockle shells. In China, which is the largest producer of shellfish in the world, about 10 million tonnes of waste seashells are disposed of in landfills annually. This amount of seashell waste primarily consists of oyster, clam, scallop, and mussel shells [9], most of which are landfilled with only a small fraction re-used for other purposes, such as fertilizers and handicrafts. The re-use is limited due to the restriction on the amount that can be used, the problem of soil solidification, and economic problems [10]. In addition, there are problems with illegal dumping of these waste seashells into public waters and reclaimed land. These waste seashells, if left untreated for a long period of time, can cause foul odours due to the decay of the remaining flesh in the shells (Fig. 1) or the microbial decomposition of salts into gases, such as H_2S, NH_3 and amines [11]. These problems can negatively affect the quality of living for people in close proximity and result in environmental pollution issues.

Fig. 1. Dumped seashells with remaining flesh [12].

Oyster shell waste is a common problem in many countries, including China, South Korea, and Taiwan. For every 1 kg of oyster shells, about 370–700 g of waste shells are produced [9]. Of the total amount of seashell waste in China, it is approximated that 300,000 tonnes of oyster shells are available annually [13], while, in Taiwan, an excess of 160,000 tonnes of oyster shell waste is generated every year [14]. In South Korea, in 1993, it was reported that about 320,000 tonnes of oyster shells were produced, of which only 30% were re-used [11].

The region of Galicia, located in the north of Spain, is the world's second-largest producer of mussels after China. Annually, about 25,000 tonnes of mussel shell waste is produced in this region with over 1 million tonnes available worldwide [15]. Similar environmental problems exist due to the dumping of mussel shells as the microbial decomposition of the waste could create health issues [16]. In Peru, a significant quantity of scallop shell waste is produced yearly amounting to some 25,000 tonnes, which results in environmental pollution due to the unpleasant odours when dumped in open areas [17]. In Nigeria, periwinkle shell waste is discarded after consumption of the periwinkle a source of food for the locals. The aforementioned wastes result in huge deposits of this waste as only a small portion is re-used by the locals as aggregate in concrete [18].

Previously, these wastes were researched for different purposes, such as heavy metal removal [19–23] and incorporation into polymer composites [24,25]. With a view to exploring the potential utilization of these wastes in concrete, substantial research work has been conducted in terms of re-using the discarded seashells as a replacement for conventional materials, such as cement, sand, and coarse aggregate. Hence, the following section summarizes and reviews the previous findings on the use of recycled seashells in concrete.