Construction and Building Materials 65 (2014) 201–217

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Properties and composition of recycled aggregates from construction and demolition waste suitable for concrete production

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HIGHLIGHTS

- State of the art systematic review on the study of recycled aggregates for concrete production.
- Statistical analysis of the main properties of recycled aggregates and comparison with those of conventional aggregates.
- Proposal of a performance-based classification system for recycled aggregates meant for concrete production.

ARTICLE INFO

Article history:
Received 12 February 2014
Received in revised form 21 April 2014
Accepted 22 April 2014
Available online 20 May 2014

Keywords:
Recycled aggregates
Construction and demolition waste
Concrete
Contaminants
Density
Water absorption
Mechanical properties
Chemical composition
Size
Shape

ABSTRACT

Arising from a systematic, as opposed to narrative, literature review of 236 publications published over a period of 38 years from 1977 to 2014, the paper examines the factors affecting the physical, chemical, mechanical, permeation and compositional properties of recycled aggregates sourced from construction and demolition waste, intended for concrete production. Classifications based on their composition and contaminants have been studied. The data were collectively subjected to statistical analysis and a performance-based classification, mainly for use in concrete construction, is proposed. The results allowed producing a practical means of measuring the quality of recycled aggregates, which can be used to produce concrete with predictable performance.

1. Introduction

Development has inflicted severe damage on the environment and may endanger its sustainability. The exploitation of natural resources, in particular non-renewable resources, for construction purposes leads to millions of tonnes of construction and demolition waste (CDW) every year. Since most countries have no specific processing plan for these materials, they are sent to landfill instead of being reused and recycled in new construction.

1.1. Background

The global market for construction aggregates is expected to increase 5.2% this year, and again next year, up to 48.3 billion tonnes [1]. In the United States, the Environmental Protection Agency [2] estimated that the generation of debris, from the construction, demolition, and renovation of residential and non-residential buildings in 2003, was close to 170 million tonnes. According to Eurostat [3], the total amount of waste generated in the European Union in 2010 was over 2.5 billion tonnes, of which almost 35% (860 million tonnes) derived from construction and demolition activities and 27% (672 million tonnes) belonged to mining and quarrying operations. In 2010, these two economic sectors generated more waste than any other (Fig. 1a). Of the total waste

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http://dx.doi.org/10.1016/j.conbuildmat.2014.04.117
0950-0618/

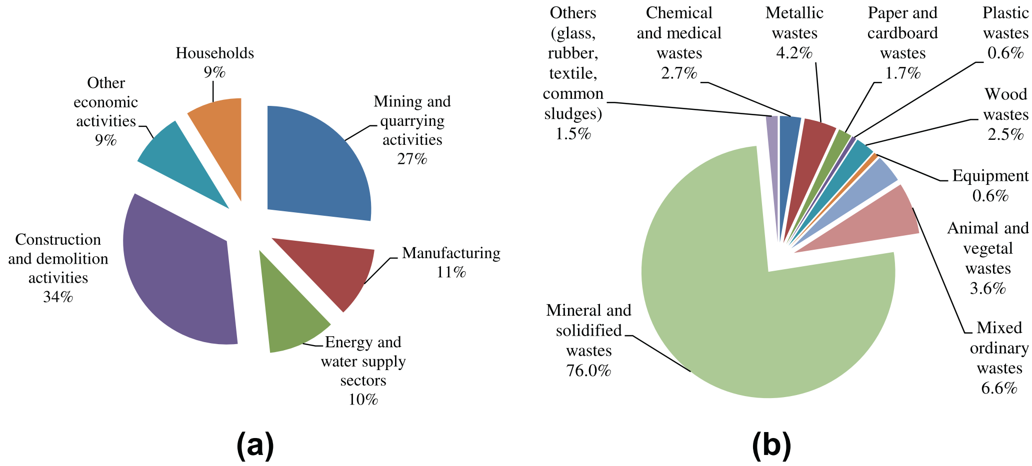

Fig. 1. Total waste generated in European Union according to: (a) economic activity; (b) waste category [3].

generated by the construction and demolition activities, and mining and quarrying operations, 97% was mineral waste or soils (excavated earth, road construction waste, demolition waste, dredging spoil, waste rocks, tailings, and others). The share of mineral and solidified wastes in relation to the total amount of waste produced was 76% (Fig. 1b).

Whilst recycling is often cited as the best way to manage CDW, there are still several obstacles to using recycled aggregates (RA) in construction:

- Lack of confidence of clients and contractors.
- Uncertainty as to its environmental benefits.
- Lack of standards and specifications that concrete producers can take into account.
- Low quality of the final product, owing to lack of knowledge and/or interest of CDW recycling plant owners.
- Distance between construction and demolition sites and recycling plants.
- Lack of a consistent supply of good quality RA that can satisfy existing demand.

Hoping to encourage and promote the use of RA, government agencies the world over have often introduced levies and legislation in an attempt to overcome barriers, with varying degrees of success. The European Union Directive No. 2008/98/CE [4] encourages the reuse and recycling of waste materials. It is expected that by 2020 new building structures will include at least 5% of recycled materials. These include paper, metal, plastic and glass, from households or other origins whose waste stream is similar to that of households, and also non-hazardous CDW. The variability of building construction methods naturally means that RA sourced from construction and demolition activities will vary in quality and composition, which will indubitably produce new construction materials of varying quality.

1.2. Importance of selective demolition

The approach to demolishing a building structure may be either conventional or selective. The construction and demolition industries still see the concept of selective demolition as being of debateable economic benefit and little practical value. A detailed economic analysis of conventional *versus* selective demolition [5] found that although the economic viability of selective demolition (with less material sent to landfill) depends largely on local conditions (i.e. labour costs, tipping fees, and market prices for recovered materials), it may ultimately be more profitable than the conventional demolition approach.

From an environmental point of view, too, there are clear benefits from using selective demolition [6,7], mainly arising from a direct reduction in the material sent to landfill. In another study [8], a life cycle assessment was performed on the environmental impacts of several conventional and selective demolition method scenarios. The results were very clear in that the selective demolition approach ensured a significant reduction of the environmental impacts specifically caused by climatic change, acidification, summer smog, nitrification and amount of heavy metals. These result from the emission of a wide array of substances, all of which are known to be important pollutants.

It was also found [8] that partial selective demolition (i.e. removal of non-structural elements for recycling, followed by traditional demolition of all other materials and their disposal in landfill) does not imply a significant environmental impact reduction. The use of this incomplete approach may even slightly aggravate the impact on the environment by increasing transportation distances and other impacts. This is largely because the means of transportation mostly used in the construction and demolition industries is road, with diesel trucks. From a complete life cycle perspective and to gain an obvious environmental impact reduction, it was estimated that the recycling rate must rise to above 90% and efforts must be made to incorporate the resulting materials into new construction.

Apart from the aforementioned advantages of the selective demolition approach, it is also the most effective way of minimizing the amount of contaminants in CDW materials. The recycling industry is well aware of this fact and realizes that if this is not done the final product is worth a great deal less, which would be very harmful to further development of the sector. Therefore, recycling plants try to promote selective demolition by imposing strict control procedures and different gate fees depending on the origin, composition and amount of contaminants present in these materials [9].

1.3. Recycled aggregate use in construction

There is a high potential for reuse and recycling of CDW since most of its components have a high resource value. There is a reuse market for RA derived from CDW in landscaping, road construction (unbound sub-base and base layers, hydraulically bound layers, bituminous surface pavements), cementitious mortars and concrete [10]. Even though the properties and types of RA studied in