



Review

Use of recycled construction and demolition materials in geotechnical applications: A review



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ABSTRACT

The proper use of natural resources is one of the fundamental pillars of sustainable development imposed on modern societies. A more effective and efficient use of natural resources, as well as the mitigation of environmental impacts induced by their extraction could be achieved if proper management and recycling policies of Construction and Demolition (C&D) wastes were implemented. The valorisation of wastes in the construction industry is needed and is a way toward sustainability. This paper provides a literature review on studies related to the valorisation of Construction and Demolition (C&D) materials in geotechnical engineering applications, with an emphasis on their use as recycled aggregates in base layers of roadway infrastructures and as filling material for geosynthetic reinforced structures. Specifications that should be followed when these materials are used in such projects are also summarised. With this review it is intended to promote the use of recycled C&D materials, showing that research carried out all over the world has demonstrated their good performance in general.

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Contents

1. Introduction	192
2. Production and recycling of C&D wastes	193
3. Materials requirements	194
3.1. Standards related to aggregates for base layers of roadways	194
3.2. Standards and specifications for fills used in geosynthetic reinforced structures	194
3.2.1. British Standard—BS 8006	194
3.2.2. German guidelines	195
3.2.3. North American specifications	196
4. Recycled C&D materials in geotechnical applications	196
4.1. Roadway infrastructures	196
4.2. Geosynthetic reinforced structures	201
4.3. Other applications	202
5. Conclusions	203
Acknowledgments	203
References	203

1. Introduction

The reduction of non-renewable natural resource extraction is a constant concern relating to the preservation of the environment, and encourages the use of recycled materials. In recent

years environmental sustainability has demanded a decrease in the exploitation of non-renewable resources and a progressive increase in waste valorisation in diverse areas. The valorization of wastes in the construction industry is, therefore, a need and one way forward for sustainability.

After the Industrial Revolution, rapid population growth, economic development, mismanagement of the use of natural resources and a lack of environmental consciousness served to make waste management an important issue for society.

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Nowadays, problems arising from the concentration of wastes from industrial activities and urban expansion have gained great social and environmental importance.

Waste management is discussed at the International level, in particular by the United Nations (UN), who hold conferences and summits and created the “World Commission on Environment and Development (WCED-UN)” driven by an official report in 1987 entitled “Our Common Future” (WCED, 2014). This report traces the panorama of waste and its impact on the environment, proposing strategies to approach the problem, which are still perfectly valid for the management of waste. *Our Common Future*, also known as the Brundtland Report, defined the concept of sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 2014).

Meetings involving many countries, such as occurred in Stockholm in 1972 and in Rio de Janeiro 20 years later, allowed the institutionalization of issues relating to the environmental theme. The Rio +10 meeting, held in Johannesburg in 2002, and the Rio +20, held once more in Rio de Janeiro in 2012, continued this movement which seeks to regulate human action on an international scale by forming international environmental policies.

The construction industry is responsible for 50% of the consumption of natural resources (European Commission, 2001). Construction and demolition (C&D) materials have been identified by the European Commission as a priority stream because of the large amounts of wastes that are generated and their high potential for re-use and recycling. An effective and efficient usage of natural resources, as well as a mitigation of the environmental impacts induced by their extraction, could be achieved if proper management and recycling policies of C&D materials were implemented.

The importance of recycling C&D material has been raised due to the scarcity of natural aggregates, the large volumes of landfills, as well as other environmental concerns. The increased growth of construction worldwide has resulted in the consumption of vast amounts of virgin (natural) aggregates. With the increasing demands of global population more and more land has been acquired for residential, commercial, agricultural and infrastructure purposes, and this leads to difficulties in finding suitable landfill areas. Moreover, environmental considerations play a major role because recycling waste materials saves energy, reduces greenhouse emissions and delivers a more sustainable future. Although there are some measures taken by governments at national and/or regional levels to recover the C&D materials to a certain extent, plenty of room still exists to extend the recovery of C&D wastes. Without proposing sustainable alternatives for recycled C&D materials, it will be difficult to encourage or enforce the recovery of C&D materials (Arulrajah et al., 2011).

This paper presents a state-of-the-art review on the research and usage of different types of recycled C&D materials in geotechnical engineering projects, with an emphasis mainly on their application as filling material for embankment construction and as base layers for transportation infrastructures. Their geotechnical and geo-environmental properties have been analysed by researchers all over the world, and are described and discussed here. The review also summarizes some standards and specifications that should be followed when selecting the backfill material for the construction of embankments stabilized by reinforcement elements and for usage as base layers of roadways.

2. Production and recycling of C&D wastes

The act of recycling is almost as old as humanity itself. Schulz and Hendricks (1992) cite records of use of crushed masonry by the Romans, in the production of a mixture of lime, water and sand

for the construction of their buildings. More recently, demolition debris has been significantly recycled since the end of the Second World War with the use of crushed brick as aggregates in concrete for the reconstruction of buildings.

Construction and Demolition (C&D) wastes are usually defined as the residues from the operations of construction, reconstruction, extension, alteration, maintenance and demolition of buildings and other infrastructures. These wastes consist of distinct types of materials, and are a heterogeneous residue that can contain any material that is part of a building or infrastructure as well as any other materials used during construction work. According to the European Waste Catalogue (Commission Decision, 2000/532/EC), C&D wastes can be composed of:

- Concrete, bricks, tiles and ceramics;
- Wood, glass and plastic;
- Bituminous mixtures, coal tar and tarred products;
- Metals;
- Soil (including soil excavated from contaminated sites), stones and dredging spoil;
- Insulation materials and asbestos-containing construction materials;
- Gypsum-based construction material; and
- Other construction and demolition materials.

In Europe, particularly in Portugal, the construction industry presents unique aspects involving traditional methods, which lead to the production of high amounts of waste. As mentioned previously, the construction industry is responsible for the consumption of 50% of natural resources and the production of around 50% of the waste (European Commission, 2001).

The C&D wastes are therefore likely to range between a total of 310 and 700 million tonnes per year in the European Union, representing 0.63 to 1.42 t per capita per year. The systematic inclusion of wastes coming from excavations could significantly increase these amounts, ranging from a total of 1,350 to 2,900 million tonnes of waste per year (2.74 to 5.9 t per capita per year) (EC DG ENV, 2011).

Table 1 shows the amounts of C&D wastes produced in different countries of the EU and their rates of reuse and recycling.

The reuse or valorisation of C&D materials on the one hand reduces the use of natural resources (non-renewable), and on the other hand avoids the landfill of inert materials coming from the construction industry. Despite these main advantages of C&D wastes recycling, some member states of the European Union have low recycling rates, including Portugal, which has a recycling rate of about 5%. This rate is below the EU average (46%) (EC DG ENV, 2011) and far below the minimum of 70% stipulated by the Waste Framework Directive of the European Parliament, to be achieved in 2020 (UE Directive, 2008/98/EC).

In fact, in the European Union there are major differences in terms of management of C&D wastes in different countries. There are countries where the recycling of C&D materials has become a common practice, and elsewhere, where this practice is now at the beginning or practically non-existent (EC DG ENV, 2011). Table 1 shows that there are 6 countries in the European Union (Denmark, Estonia, Germany, Ireland, United Kingdom and The Netherlands), which have already achieved the objectives proposed by the European Directive. The truth is that in these countries there are three main factors that have accelerated waste recycling: shortage of raw materials; difficulty in finding places for landfills and legal and economic measures that promote recycling. However, there are some countries with a less than 40% rate of C&D waste recycling (Czech Republic, Poland, Finland, Greece, Hungary, Cyprus, Spain and Portugal). The low recycling rates in Portugal are mainly due to the abundance of natural aggregates of very good quality and the lack of technical regulations for the use of recycled aggregates.

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