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Application of inert wastes in the construction, operation and closure of landfills: Calculation tool

Francisco J. Colomer Mendoza *, Joan Esteban Altabella, Antonio Gallardo Izquierdo

INGRES, Ingeniería de Residuos, Dept. Mechanical Engineering and Construction, Universidad Jaume I, Avda Vicent Sos Baynat, s/n, 12071 Castellón, Spain

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ABSTRACT

Waste from construction and demolition activities represents one of the highest volumes of waste in Europe. 500 million tonnes are produced throughout the whole EU every year. In some EU members like Spain, approximately 83 per cent of such waste is disposed in landfills. The remaining part is classified and processed in treatment facilities so that it can later be used as recycled aggregates in the construction sector (sand, gravel, aggregates, etc.) but without much commercial success. The aim of this study is to use recycled aggregates from inert wastes (IW) in the different phases of a landfill (construction, operation and closure) with the aid of a new computer tool called LABWASTE.14. This tool incorporates the mathematical relationship among the activities of the landfill and provides as a result the economic viability of using recycled aggregates compared to aggregates from quarries. Therefore, knowing the needs of aggregates in landfills (dams, drainage layers, covering layers, collection wells, etc.) may determine the amount of IW that could be recovered. These calculations can be obtained from some of the data that is introduced (population, land physiography, etc.). Furthermore, the use of LABWASTE.14 makes it possible to reduce the demand for aggregates from quarries.

1. Introduction

Construction and demolition wastes (CDW) are a growing problem in many countries. They account for large part of the waste generated in cities and they are usually placed in landfills (Ekanayake and Ofori, 2004). CDW represents around 31% of all waste produced in the European Union (EU) (Fisher and Werge, 2009). It is nowadays acknowledged that the consumption of raw materials in the construction industry is a non-sustainable activity. It is thus necessary to reduce this consumption, and the volume of CDW dumped, by using this waste as a source of raw materials for the production of recycled aggregates (Rodrigues et al., 2013). In fact, in many EU countries a very limited amount of CDW is recycled, the greatest portion being deposited or used as fill material (Masood et al., 2002). However, recycling concrete waste will lead to a reduction in valuable landfill space and savings in natural resources (Tabsh and Abdeltatah, 2009). Because of this, in the EU, the strategic plans about waste include CDW. The European Action Plan on the Circular Economy includes a number of actions that will target market barriers in specific sectors or material streams, such as construction and demolition wastes as well as horizontal measures in areas such as innovation and investment (EU, 2015). All these regulations establish the minimum requirements for their production and management, in order to promote prevention, reuse, recycling and recovery. The EU Waste Framework Directive (Directive 2008/98/EC) introduces recycling and recovery targets to be achieved by 2020 for household waste (50%) and construction and demolition waste (70%). Furthermore, recycling CDW makes it possible to achieve considerable savings on energy and scarce or non-renewable natural resources. The potential to increase energy saving is about 20–40% depending on the form of recycling (Thornmark, 2001). The results obtained by Vieira and Horvath (2008) show that the recycling of concrete can have a significant impact on the reduction of the overall environmental burden of buildings. Policies that promote the recycling of concrete from buildings, e.g., increasing the recycling rate from the current 27–50% could yield a 2–3% reduction in the greenhouse gas emissions of buildings. Some works collected from the literature indicate that the performance of most recycled aggregates is comparable to that of natural aggregates and can be used in unbound pavement layers or in other applications requiring compaction (Cardoso et al., 2016).

However, many of the aggregates from recycling CDW have no commercial outlet and are landfilled without any alternative utility. On the other hand, the variability of the composition of recycled aggregates is much higher than that of natural aggregates

* Corresponding author.
E-mail address: fcolomer@uji.es (F.J. Colomer Mendoza).

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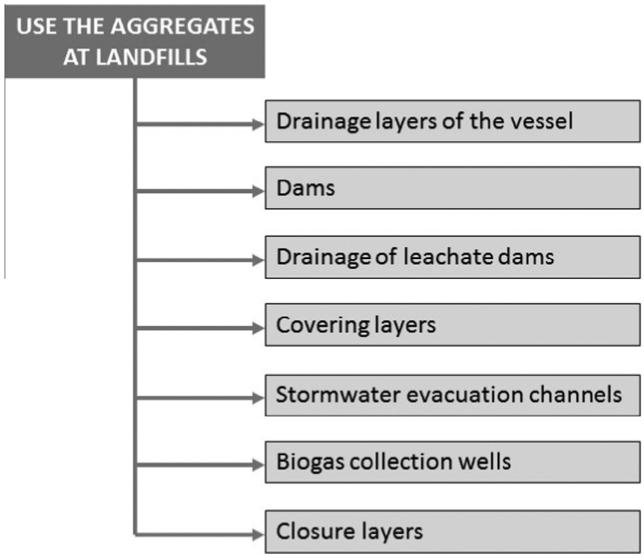

Fig. 1. Need for of aggregates in the construction, operation and closure of a landfill.

due to the different sources from which recycled aggregates are obtained and furthermore, they can also contain hazardous materials.

Moreover, in recent years, this problem has been exacerbated by the economic situation in Europe. The decline in construction output has resulted in a drop in the amount of this product on the market. A possible application would be its use in the construction and operation of landfills where recycled aggregates could replace aggregates from quarries.

The objective of this study is to determine the technical and economic feasibility of using recycled aggregates from CDW recycling plants, in the construction, operation and closure of landfills. Hence, firstly, the properties of CDW must be analyzed. Secondly, a technical and economic analysis is performed. This analysis determines the characteristics that allow a benefit to be obtained from the recycled aggregates, with respect to the use of aggregates from quarries or natural aggregates. The economic feasibility depends on many factors, which include the cost and transport of the aggregates. This study proposes the creation of a software tool that takes into account those factors. Nevertheless, while the economy is not currently a major factor in recycling concrete in all regions around the world, it may become more important in the future due to the lower transportation costs and energy consumption that are commonly associated with recycled materials (Tabsh and Abdeltatah, 2009).

Therefore, tool presented here, called LABWASTE.14, raises the use of CDW in the construction, operation and closure of landfills to a draft level. Thus, the user (construction company, operator, etc.) could know roughly the amount of material (aggregates) that will be needed for the construction, operation and closure. It also offers the possibility of carrying out a preliminary study of the cost (Fig. 1).

2. Methodology

LABWASTE.14. has been developed by means of Excel® software application. By using the mathematical relationships between the variables in a landfill, it can provide the results required to present a preliminary design and quotation for a draft of a landfill. These variables are defined as follows.

2.1. General data

In this section, the tool requests information regarding the supply of aggregates, both from quarries and recycled, since each activity requires a sort of materials. This information is related to:

- Distance from the landfill to the quarry or to the recycling plant.
- Types of aggregates available with their size and density (sand, graded aggregates, gravel, mixed) and the price of each type of aggregate according to its grain size.
- Cost of transport.

2.2. Construction of the landfill body

In order to dimension the landfill body, it is necessary to introduce information about the main characteristics which define the structure of the different layers. The information required is:

- Type of landfill according to its topography (in an area, in a valley or on a hillside) or according to the type of waste (inert, non-hazardous industrial, municipal or refuse) and the average density of the waste deposited there (D_M) in kg m^{-3}.
- Geometrical data: estimate perimeter in meters, estimated available area (E_{AV}) and estimated average depth (E_D) in meters. With these data, the tool calculates the approximate capacity of the landfill body (C_V) in m^3 and area to be waterproofed (A_W) in m^2.
- Population to be served (P_{AB}) in inhabitants, and waste generation rate (D_{WD}) in kg $inhabitant^{-1}$ day^{-1}. With these data, the tool calculates the annual waste generation rate deposited in the landfill (A_{GR}) in t $year^{-1}$.
- Climatic data: average monthly temperature (°C), maximum monthly average rainfall, average maximum rainfall in 24 h (L m^{-2}), monthly evapotranspiration (L m^{-2}) and data collection period (years).
- Need (yes or no) of an artificial barrier to waterproof the bottom of the landfill body (if the original layer does not meet the requirements of permeability).

Therefore, by means of Eq. (1), from the above data the tool calculates the estimated useful life (UL) of the landfill in years. Above the impermeable layer of the landfill body, it is advisable to apply a layer of drainage gravel in order to evacuate leachates. By means of Eq. (2), the tool calculates the amount of gravel (C_{RL}) in tonnes needed for the drainage of the bottom, according to the thickness of the drainage layer (T_{DL}) in m and the density of the gravel (D_{GR}) in t m^{-3}.

$$UL = \frac{C_V \cdot D_M}{A_{GR} \cdot 1000} \quad (1)$$

$$C_{RL} = A_W \cdot T_{DL} \cdot D_{GR} \quad (2)$$

2.3. Construction of dams

The tool shows the geometry of the section of the toe dam. Generally, the structure of the dam is always similar to a scalene trapezium, with different upstream and downstream inclination angle. The construction material must have good mechanical properties in order to construct a safe dam. Thus, very useful materials for these sorts of constructions (earth dams) are graded aggregates, which can be well compacted. Nevertheless, the properties of graded-aggregates must be known and accepted by the regulations of the country (Gonzalez, 2002; US Department of Transportation, 2009).

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