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CONSTRUCTION AND DEMOLITION WASTE LANDFILLS: A SOURCE OF RESOURCES

Fernando Pereira*; Filipe Marques; Ana Malheiro; Letícia Cunha; Paulo Amaral
Laboratório Regional de Engenharia Civil, Ponta Delgada, Açores, Portugal
*Corresponding author: fernando.ad.pereira@azores.gov.pt

ABSTRACT

From the seventies of the last century, with the significant increase in reinforced concrete construction, the deposition of materials and products resulting from construction, in particularly demolition, was carried out in large quantities in fields, some previously exploited as quarries or gravel pits and on the coast. These actions were intended to mask the resulting scars of exploitation processes and remodel the landscape, but also to fill in valleys or land depressions, without great productive potential. On the Azores islands, there are also several landfills resulting from the deposition of waste from the demolition of buildings damaged by earthquakes and materials resulting from landslides, such as debris flows and rockfall. These deposits mainly contain masonry materials, stone and cement blocks, bricks, clay and fiber cement tiles, pieces of wood mixed with soil, rocks, and trees, in addition to bituminous mixtures from the repavement of streets. Many of these materials could be potentially reusable in a more circular economy, as opposed to the continuous exploitation of resources, accumulation of waste, and rising production costs.

KEYWORDS: Landfills mining; Construction and demolition waste (C&DW) as a resource; C&DW deposits; Circular economy; Sustainable construction.

1. INTRODUCTION

On the Azores islands there are landfills where waste is deposited, including that from normal construction and demolition activities. Additionally, there are also deposits containing materials resulting from the removal of rubble and cleaning of streets and land following landslides, many of which are caused by floods and storms. Added to these are those resulting from the deposition of waste resulting from the demolition of damaged buildings on the islands of Faial, Pico, S. Jorge and Terceira, following the earthquakes of 1973, 1980 and 1998, respectively.

These deposits may include some metal parts, construction iron and metal scraps, but the dominant materials are stone blocks from masonry and cement blocks, bricks, clay and fiber cement tiles, and pieces of wood, rocks, and trees, all mixed with soil, from cleaning up affected areas and in addition to bituminous mixtures from repavement streets.

Considering the increase in economic and environmental costs with transport and exploration of raw materials, especially on islands, as these are remote areas, the exploration of those deposits can become economically viable, and it is therefore important to carry out their characterization and study.

2. INVESTIGATION TOOLS

2.1. Site background

From the seventies of the 20th century onwards, there was a significant increase in construction in the Azores islands. This was characterized by the widespread introduction of reinforced concrete structures and cement block masonry, not only in new constructions but also in the recovery and rehabilitation of buildings damaged by natural disasters. Consequently, previously used materials were often discarded as waste. Indeed, during this period, the Azores islands were hit by several natural disasters (Table 1), namely earthquakes and storms that caused significant damage in structures and roads. The largest were the earthquakes of 1980 in Terceira and 1998 in Faial.

Table 1 - Most destructive natural disasters since the 1970s in Azores.

Year	Island	Disaster type	Notes
1973	Pico, Faial, São Jorge	Earthquake	Severe damage to many built elements
1980	Terceira, São Jorge, Graciosa	Earthquake	Major damage in many buildings.
1986	S. Miguel	Flood, Landslides	Severe damage to many built elements
1989	S. Miguel	Earthquake	Several damaged buildings
1996	S. Miguel, Pico, Graciosa, Flores, Corvo	Strong winds, Floods, Landslides	Damage to building elements including seaports.
1997	S. Miguel	Landslides	Several buried buildings
1998	Faial, Pico, S. Jorge	Earthquake, Landslides	Major damage in many buildings.
2005	S. Miguel	Earthquake, Landslides	Damages in buildings
2009	Terceira	Floods, Landslides	Damages in buildings
2010	Flores, S. Miguel	Landslides	Damages in roads
2012	S. Miguel	Landslides	Damage to many built elements
2013	Terceira, S. Miguel	Floods, Landslides	Damage to many built elements
2015	S. Miguel	Floods, storm surge	Damages in buildings
2019	Flores, Corvo, Faial e Pico	Strong winds, storm surge	Major to building elements including seaports

Following disasters, namely floods, storms, and earthquakes, waste is transported in a completely uncontrolled manner to landfills. Since this is an emergency situation, the important thing is, as quickly as possible, to clean up the rubble and try to return some normality to people's lives. While a construction and demolition waste landfill includes many products of industrial origin, the urban solid waste landfills present a much greater heterogeneity in the waste deposited. These deposits usually have a greater concentration of stone materials and soils.

2.2. Landfill characterization parameters

Conceptually, the procedure for assessing the mining potential of a landfill includes spatial analysis, age and materials analysis, as well as a projection of future flows of materials and construction and demolition waste (Bogoviku and Waldmann, 2021).

The first step to begin evaluating the mining potential of a landfill is the spatial analysis, consisting of its location (Figure 1) and a georeferenced mapping that allows determining parameters such as the area and volume of the landfill and the surrounding built and natural environment.

The majority of waste landfills of urban solids appeared, essentially, in the second half of the 20th century. Construction and demolition waste landfills began to appear on Azores islands later, in the beginning of the 21st century, after new materials associated with new construction techniques and requirements, imposed the devaluation of ancestral materials and techniques. On the other hand, landfills associated mainly with the deposition of waste from natural disasters are relatively well dated, since, in general, they were new deposits created to respond to emergencies. However, in some of them, there may have been some subsequent deposition at the site.

Figure 1 – Recent Landfills on Faial Island

In demolition (waste from damaged or ruined buildings) coarse mineral fractions predominate, especially stone masonry materials, to which materials such as tiles and ceramic bricks with a finer matrix are added. Another characteristic material of traditional Azorean construction sent to waste landfills is the wood used in paving, ceilings and partitions, which has been rejected due to rot, contamination by xylophages, apparent structural fragility and vulnerability to fire.

The materials are closely linked to the era of the building's construction. Therefore, the age of the buildings is an important piece of data to estimate the types or fractions of waste that could result from their demolition or rehabilitation. Associating the construction period with geographic areas will allow the generation of maps of potential waste (Bogoviku and Waldmann, 2021) and, consequently, estimate the needs for waste management and treatment and recovery potential. In regions such as the Azores, affected by numerous catastrophic events, especially natural disasters (e.g., earthquakes, landslides), there are construction periods in clearly well-delimited geographic areas linked to the events.

By studying maps prior to a disaster and the number of damaged buildings, it will be possible to estimate the volumes and types of materials existing in landfills. Furthermore, through mapping the risk areas, it will also be possible to obtain an estimate of the buildings that could be affected in the future.

The extent and depth of the site, which allow the determination of the volume of waste, with its composition (Nguyen *et al.*, 2021), define the essential parameters for the characterization and evaluation of the economic potential of the landfill exploitation (Table 2).

Table 2- Parameters of interest for landfill mining operation.

Steps	Parameters	Prospection tools
Spatial analysis	Location Size Depth Volume Built environment Natural environment features Topographic features Access roads	Historical cartography Aerial and satellite images Recognition in the field by pits, geotechnical drilling
Age analysis	Opening of landfill Duration of deposition Closure of the landfill	Administrative files and reports
Materials analysis	Type Mineral fractions Mixtures Contamination	Probes Laboratory analysis
Projection of future flows of materials and construction and demolition waste	Age of construction Materials inventory	Final construction drawings Construction technical dossier Risk Management Plan Deconstruction and demolition plans Public investment plans Territorial planning plans

3. RESULTS AND DISCUSSION

3.1. Economic, environmental and social impacts

The need for new constructions and rehabilitation of the existing ones leads to a greater demand for construction materials (Yang *et al.*, 2022), worsening the impacts of the exploitation of raw materials and natural mineral resources that are not renewable. Therefore, its continuous and increasing exploitation can lead to their depletion and considerable environmental risks (Bogoviku and Waldmann, 2021). So, mining from landfills should be considered as a means of closing the life cycle of materials, contributing to reducing the demand for virgin raw materials (Winterstetter *et al.*, 2021).

When a waste landfill is closed, it is simply left untouched, so an alternative would be to assess and regulate its mining (Winterstetter *et al.*, 2015). The creation of waste landfills depends on several aspects related to waste production and is conditioned by cultural, socio-economic, political, and legal aspects (Winterstetter, 2016). Its mining will also have to take many of these aspects into account.The recovery of deposited materials will contribute to the economy, and it will make possible to reduce the backlog of occupied and unused land, returning it to better use and diminishing the environmental impacts associated.

Landfill mining will be like conventional mining of virgin raw resources (Winterstetter, n.d.), and its characterization study will also be similar to the prospecting of natural resources, carried out through conventional methods, such as drilling or opening observation wells, complemented with laboratory analyses (Nguyen *et al.*, 2018). However, because landfills are deposits that are not controlled by the type of material or particle size, their operation requires a more careful and differentiated approach than the utilized on a deposit of natural resources.

The costs and benefits of landfill mining may vary considerably, depending on the objectives and the most significant economic benefits will, above all, be indirect (Rosendal, 2009). However, a project of this nature could generate revenue if the market for recovered materials is boosted. Landfill mining could be also a process to increase the capacity and useful life of current landfills and to reduce the closure costs and the pressure to create new waste disposal areas (Guimarães *et al.*, 2023).

The types of materials extractable from a landfill depend on the waste stream to the landfill and glass, plastic, metals or aggregates are directly recyclable. the landfills created on the Azorean islands until the end of the 20th century predate recent recycling activities. They contain fewer varieties of materials and higher concentration of construction stones and soils, with less content of wood, metals, organic waste and electrical equipment and as in the disaster waste landfills the dominant fractions will be essentially inert, these landfills could have great potential for exploitation in technical and economic terms.

Relating the construction period with the geographic location and even with historical events will allow the generation of maps of potential waste and thus provide information on future waste management and treatment needs.

Therefore, carrying out studies to characterize landfills will make it possible to evaluate potential economic, environmental, and social benefits and estimate operational costs and possible needs for specific legal regulation (Rosendal, 2009).

3.2. Challenges

The exploitation of landfills waste must be combined with a strategy of resource recovery and land remediation, thus offsetting costs, making the recovery of materials but also the appreciation of land economically viable.

In regions with territorial discontinuity, such as small islands, the need for productive land may become a factor to justify the interest in landfill mining regardless of economic and environmental aspects (Winterstetter, 2018), but the economic and environmental potential will be more significant if all the different materials in the different landfills on the island are quantified (Frändegard *et al.*, 2013).

Despite the already highlighted importance of mining in landfills, several factors must be considered when assessing exploitation feasibility such as political and governmental interest, secondary product market, technology appropriate to the size of mining, and landfills for waste resulting from mining (Guimarães *et al.*, 2023).

A challenge that should not be ignored is related to the possible poor quality of the materials to be recovered, their limited use or low economic value or, devaluation due to inadequate mining logistics (Rosendal, 2009).

4. FINAL REMARKS

Eco-construction corresponds to sustainable development. Circular economy has unavoidable principles whose adoption is essential for the construction sector. Landfill mining is a way to recover resources and remediate unproductive and untouched land. Even with some environmental impact, landfill mining will minimize impacts associated with landfills, such as leaching, subsidence and degraded landscape, reduce virgin raw materials mining and revalue the territory. The identification and prospecting of landfills to assess their economic potential and thus return resources to the economy is a potentially interesting project, especially in island territories with significant territorial discontinuity, limited raw materials and high transportation costs.

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