ADVANTAGES AND BARRIERS FOR USE OF EXCAVATED SEDIMENTS

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Soil excavation, including extraction from rivers, lakes, and marine sediments, can lead to a large surplus of clean or slightly contaminated excavated soil. All excavated soil is treated as waste until it is reused. Therefore, the reuse of excavated soil is an important part of sustainable construction, which also helps reduce carbon emissions and lower the cost of earthworks. The reuse of excavated soil is generally viewed positively, but there is a lack of uniform definition of construction waste and a lack of guidance and understanding of reuse. This article discusses the use of excavated soil and provides advice for good practice in the future, considering regulatory, economic, environmental, and implementation aspects. Regulatory aspects refer to the complex legislation and the lack of guidelines for reusing excavated soil. Economic aspects relate to integrated planning, including contracts for construction projects, and the interest of those involved in construction. The environmental aspect includes the impact of reused material on the soil. Logistical obstacles are discussed, which include both spatial and temporal problems due to difficulties in moving excavated soil, storing it, and coordinating supply and demand. Barriers to performing the work are related to the lack of standardization of tests to demonstrate that the geochemical and geotechnical quality of the excavated soil is suitable for reuse. Examples of the reuse of surface, river, lake, and marine soils and possible solutions to overcome the barriers to their use contributed to a proposal for increased use of excavated soils and sediments.

Keywords: Sustainable engineering, Reuse of soil, Geotechnical design, Case studies.

1 INTRODUCTION

This paper deals with soils, rocks, and sediments that are left as waste from construction works and end up unnecessarily and unused in landfills. By European Commission Council Directive (1999). All excavated soils, rocks, and sediments are treated as waste until they are reused. Therefore, the development of measures related to sustainable management will be of great importance in the future. It will be necessary to develop methods of soil reuse that do not pose a risk to public health or the environment. The (re)use of soils and sediments offers the following benefits: conservation of natural resources that would otherwise be mined, preservation of landfill capacity, reduction of costs associated with disposal, and reduction of environmental and ecological impacts (Walsh et al. 2019). This article discusses the use of excavated soils and sediments and provides advice for good practice in the future, considering various aspects of implementation. Obstacles to the reusing of excavated soils and sediments during construction are identified (Hale et al. 2021). Examples of the reuse of excavated soil, rivers, lakes and marine sediments, and possible solutions to overcome the barriers to their use are discussed. The conclusions contain suggestions on how to maximize the reuse of excavated soil and sediments.
2 ASPECTS OF USE OF EXCAVATED GROUND MATERIAL

Until the soils, rocks, and sediments are not used, they are treated as waste and, according to Hale et al. (2021), can be treated under the following aspects: 1) regulatory, 2) economical, 3) environmental, and 4) implementation. Ultimately, all aspects of waste reuse must be met for a given use.

Excavated rocks are solids that can be categorized according to various aspects: their origin (igneous, metamorphic, sedimentary), their mineralogical composition, their physical properties, their mining conditions, their usability, etc. Rock cracking is described by classes from S1 to S6 and discontinuity surface quality by classes from D1 to D4 (Marinos et al. 2007, Tsiambaos et al. 2010, CEN 2018). In practice, rocks are preferred as construction materials and are not considered here as a problem in terms of reuse.

Excavated ground soils are in common practice usually classified into 3 excavation categories (organic, for landfill, and for construction works). Geomechanical soil classification is the classification of soils into groups in which the behavior of the soils of a given group under certain physical conditions is identical. The USCS - Unified Soil Classification System (ASTM 2015, ASTM 2017) is a modified version of the AC soil classification system, developed by A. Casagrande. Both soil classification systems are used in engineering and geology to describe the structure and size of soil grains. According to the AASHTO soil classification system, soils are divided into 7 inorganic groups with a total of 12 subgroups, and there is an additional group for peat or mud. In the EU, soil classification is used according to the principles of EN ISO 14688-1.

Organic soil, like peat, as an accumulation of partially decayed vegetation, and humus, as dark organic matter produced by the decomposition of vegetable and animal matter, as well as other types of organic soils containing a significant proportion of organic matter (grass debris etc.) are not suitable as building materials. However, they are very useful for agriculture and environmental management and therefore do not end up in landfills.

Excavated soil from embankments and other infrastructure may be considered soil, and the criteria for soils shall be applied to such material.

Soil material from demolished buildings is processed and some of the processed material acquires the property of soil, and the criteria for soils may be applied to this material.

Coarse-grained river sediments have the character of gravel and sand. Such sediments are treated as coarse-grained soils (Ficko and Žlender 2005).

Fine-grained river, lake, and sea sediments can accumulate in riverbeds, altering flow velocities, lakes, and the sea (Mladenović et al. 2014).

Floating river sediments settle and fill the bottom. It is important to determine the technology of sediment removal, cleaning, recycling, and deposition (Trauner et al. 2013, Dolinar et al. 2008).

The following sections discuss the barriers and benefits of sediments instead of excavated rocks and coarse-grained soils.

3 EXPERIENCES FROM EXISTING AND IMPLEMENTED PROJECTS

Management of excavated soils is subject to several EU directives, laws and regulations (Table 1). Legislation stipulates that the landowner is fully responsible for the disposal of construction waste on the construction site. Excavated soil can be reused on the owner's property or off-site, provided it is not contaminated. By law, excavated soil is considered waste until it is used. For the following use scenarios, the physico-chemical properties must be determined in accordance with the permissible values of the pollution parameters: land reclamation, backfilling of agricultural land, backfilling of construction land, and backfilling after excavation. The processing of excavated material is treated as waste processing, for which an environmental permit from the Environment
Agency is required. The permit is granted if the relevant documentation is submitted, and the contamination levels are within the permitted limits.

Table 1. EU directives, SI laws and regulations.

<table>
<thead>
<tr>
<th>EU directives and documents</th>
<th>SI laws</th>
<th>SI regulations</th>
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Considering the level of pollution around the world and the climate problems, the policy for sustainable development is one of the priorities. This applies especially to construction and geotechnical engineering, as the construction industry is one of the major consumers of earth materials and a major polluter. The geotechnical group at the University of Maribor (UM) is/was involved in several European Union (EU), international (INT), and Slovenian (SI) projects, related to sustainability (Table 2).

Table 2. UM projects, related to sustainability.

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<thead>
<tr>
<th>Project</th>
<th>Year</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRA-MUR-CI – Drava-Mura Cross border Initiative (Jecl et al. 2013)</td>
<td>2012-2013</td>
<td>EU project</td>
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<tr>
<td>Sediments in aquatic environments: their geochemical and mineralogical characterization, remediation, and use as secondary raw materials</td>
<td>2012-2014</td>
<td>SI project</td>
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<tr>
<td>CINDERELA – New Circular Economy Business Model for More Sustainable Urban Construction (CINDERELA 2022)</td>
<td>2020-2022</td>
<td>EU project</td>
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<td>URGE – Circular building cities (URBACT 2019)</td>
<td>2022-2023</td>
<td>EU project</td>
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<td>GEOLAB – Science for Enhancing Europe’s Critical Infrastructure (GEOLAB 2023)</td>
<td>2021-2024</td>
<td>EU project</td>
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<td>GEOTECHNOLOGY (Geotechnology 2023)</td>
<td>2023-2027</td>
<td>SI project</td>
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<tr>
<td>Bilateral research project Evaluation of Various Domestic and Industrial Waste Materials in Road Pavement Layers</td>
<td>2023-2024</td>
<td>INT project</td>
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<tr>
<td>ELGIP Working Group Reuse of Urban Soils and Sites (ELGIP 2020)</td>
<td>2018-2022</td>
<td>INT project</td>
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<td>ELGIP Working Group Sustainability (ELGIP 2023)</td>
<td>2022-2026</td>
<td>INT project</td>
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The research objective of this paper is to provide recommendations for the reuse of soils and sediments based on an analysis of the research projects listed above.

4 ADVANTAGES AND OBSTACLES TO THE USE OF EXCAVATED SEDIMENTS

Based on recent literature (Khan et al. 2022, Kataguiri et al. 2019) and data obtained within the ELGIP working group on sustainability, there are large differences between countries (also inside the EU) in terms of strategies and management of excavated soils in urban areas.

4.1 Benefits of Reusing Soils and Sediments

Reuse of excavated soil and sediment offers several benefits, which can be summarized as follows.
1) Reuse of excavated soil and sediment reduces the need for new excavated soil and conserves natural resources.
2) It reduces the need for landfills and preserves the capacity of existing landfills.
3) Environmental impacts, such as carbon footprint and pollution, are significantly reduced.
4) Costs associated with disposal are reduced.

For a detailed discussion of the benefits of reusing soils and sediments, see Hale et al. (2021).

4.2 Obstacles to the Use of Excavated Sediments

The obstacles can be divided into the following: 1) legal, 2) organizational (management and design), 3) logistical and 4) material quality.

The biggest barrier in the European Union is the inconsistency of sediment reuse procedures and their implementation at the regional and local levels.

4.2.1 Regulatory barriers and authorities

Legal barriers and administrative procedures often result from the absence of existing regulations. Several laws and regulations must be followed for the reuse of soils and sediments (initially treated as waste) (Table 2). There are no uniform guidelines for the reuse of excavated sediments, which is a fundamental obstacle. In general, the reuse of excavated soil requires an environmental permit issued by the authorities and sometimes a health risk assessment is also required. However, there are no guidelines that define the entire process, which leads to great uncertainty. The administrative procedures are also time-consuming, which is a problem for projects with tight deadlines. Another problem is determining the owners of the material to be used. The investor is responsible for the environmental impact of using the sediment. However, if he disposes of the soil in a landfill, he has no liability problems afterwards. For these reasons, reuse is not attractive enough. To ensure that the sediment is suitable for use, certain standard tests and parameters must be carried out and included in the planned use strategy (Tsiambaos and Saroglou 2010).

4.2.2 Implementation barriers

In current practice, there is not (yet) a holistic approach to the use of dredged sediments, which is the main obstacle to this approach becoming established. In construction and demolition projects, the normal reuse of soil is not the responsibility of all parties involved in the project. As a result, the reuse of excavated soil is largely neglected during planning. Currently, there are no project synergies for the timing and movement of excavated soil from one location to another to meet supply and demand. To achieve the goal of making the reuse of excavated soil a common practice, new strategic approaches are likely to be required.

4.2.3 Economic barriers

During construction work, space on the construction site is often very limited and the excavated soil must be stored. Another obstacle is the limited storage time of excavated soil for a certain period of time before the next use. According to the European Landfill Directive, waste can only be stored for 1 year. In the case of recycling, the storage period is limited to 3 years before recycling. A special permit is required for longer storage. The reuse of soils requires additional costs for transportation to and from the interim storage or remediation site. This leads to additional costs and increased greenhouse gas emissions. Both together can lead to a negative environmental and financial situation. This economic barrier is exacerbated when the cost of new land and landfill tax is low and there are no special incentives for reuse.
4.2.4 Material quality barriers

Any excavated sediment must be tested for use as it may be contaminated. The qualities can vary greatly, so it must be checked whether the material in question can be reused for the intended purpose. There are no specific guidelines on how to prove whether excavated sediment meets the conditions for use from a geotechnical and geoenvironmental point of view. For these reasons, it is easiest and simplest for the investor and for the contractor to use raw material with known properties instead of reusing excavated material of possibly inferior quality.

5 PROPOSALS

A comparison in European countries has shown that the use of excavated sediments is currently extremely limited and excavated material often ends up in landfills.

Experience with existing projects and the consideration of aspects of the reuse of excavated sediments leave no doubt that this needs to be increased in the future.

In order to better implement the reuse of excavated soil and sediments, a harmonization of management systems is required. A uniform approach promotes cooperation and ultimately improves expertise.

Regulatory and planning approaches should be improved to enable investors, designers, and developers to reuse excavated soils and sediments.

Simple and clear guidelines are needed to inform those considering reuse how this can be achieved in practice.

Incentives for investors to reuse excavated soil and sediment are important.

In order to increase the reuse of excavated soil, proper documentation plays an essential role. It must be clear from the documentation that the material is of sufficient quality and suitable for the intended use.

Traceability and quality control of the excavated material as well as clearly defined responsibilities are of key importance. Simple logistical systems are needed to document the quantities and properties of the excavated material as well as the location and type of use of the material.

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