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# USE OF MARGINAL AND RECYCLED FILLS FOR GRS STRUCTURES

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**Abstract.** *Marginal and recycled fills are increasingly being utilized in geosynthetic reinforced soil (GRS) structures like retaining walls and bridge abutments due to their cost-effectiveness and sustainability. Marginal fills, including locally available soils with less desirable engineering properties, can be used when properly engineered with geosynthetics to enhance strength and stability. Recycled fills, such as recycled concrete, asphalt, various ashes have been proved already as an eco-friendly alternative to conventional aggregates. However, these practices involve thorough characterization and testing of marginal and recycled fills to ensure their suitability for specific applications. Advanced geotechnical analyses, including laboratory tests and numerical modeling, help determine the optimal blend of materials and reinforcement for achieving desired performance criteria. Experiences with the use of residues from deinking paper industry and river debris as backfill material are presented. Time effect on the compaction and deformation characteristics as well as the impact of high basicity of backfill material have been considered.*

## 1 INTRODUCTION

According to information published by the European Aggregate Association (UEPG, 2018), the demand for European aggregates is 3 billion tonnes annually, with about half of this natural (virgin) material being consumed by the construction industry. Virgin material used in various building sector applications, particularly for earthworks, can be partially substituted by other materials, such as recycled industrial material, including those made from paper industry waste and other types of secondary low-quality soil materials. However, these secondary materials must meet the mechanical and environmental criteria set by national legislation. Although this type of fill material might have lower strength characteristics compared to high-quality aggregate from quarries, this drawback can be effectively addressed by using it in a composite with reinforcing geosynthetics. Nonetheless, the impact of backfill material, such as its chemical effect on the durability of geosynthetics, must also be considered.

The recently completed Horizon 2020 project PAPERCHAIN has validated the use of paper industry wastes as backfill material for GRS retaining structures. Additionally, the ongoing Horizon project CIRCUIT aims to use river debris from recent floods as backfill material for GRS bridge abutments.

## 2 ALTERNATIVE BACKFILL MATERIALS

### 2.1 Paper industry waste

Deinking sludge ash (DSA) and deinking sludge (DS) represent the main waste from recycled deinking paper pulp production at a paper industry company Vipap (Vipap, 2024). The DSA is a combustion residue formed in a steam boiler during the incineration of DS. Annually, 25,000 tonnes of DSA and 67,000 tonnes of DS are produced. DSA is a dry material, while the water content of DS ranges between 45% and 50%. Mixture composite of these two materials, consisting in dry mass of 70% of DSA and 30% of DS, has been developed in the scope of PAPERCHAIN project. It has been used as a backfill material for GRS retaining structure. A polymer PET geogrid was used as a geosynthetic for reinforcing the backfill.

### 2.2 Flood debris from rivers

The Horizon Project CIRCUIT (Circuit, 2024) aims to construct a new bridge on a local road in the municipality of Črna na Koroškem, Slovenia, replacing the existing bridge over a torrential creek. The project plans to use geosynthetic-reinforced soil (GRS) with cast-in-place concrete full-height rigid facing for the construction of the bridge abutments, providing an effective scour protection measure (Tatsuoka, 1993; Lenart et al., 2017). To further enhance sustainability, recycled materials have been proposed as backfill for the GRS abutments.

In August 2023, severe heavy rains caused extensive flooding and landslides across Slovenia. Over 170 major landslides were triggered, and more than 400 buildings were destroyed or rendered uninhabitable. In the Mežiška valley, where the new bridge is planned, approximately 25,000 tons of sludge were deposited by rivers and streams. Of this, 1,700 tons were exported abroad for remediation, while more than 20,000 tons need to be treated domestically. It has been estimated that a significant quantity of river debris (sand and gravel), designated as non-hazardous inert waste, can be used in construction projects. Consequently, it has been decided to use flood debris for the construction of the new GRS bridge abutments as part of the CIRCUIT project.

| Property | Paper industry waste | Flood debris |
|---|---|---|
| Optimum Water Content, $w_{opt}$) | 51% | 6,1% |
| Maximum Dry density, $\gamma_{d,max}$ | 0,95 Mg/m$^3$ | 2,26 Mg/m$^3$ |
| Particle Size Distribution | | |
| Particle (2.5-63mm) | 0 | 57% |
| Particle (0.063–2.5 mm) | 13,3% | 35,2% |
| Particle (<0.063 mm) | 86,7% | 7,8% |
| Coefficient of uniformity, $C_u$=-$d_{60}/d_{10}$ | 40 | 51,2 |
| Coefficient of curvature, $C_c$=-$d_{30}^2/(d_{60}\cdot d_{10})$ | 1,4 | 1,7 |

Table 1: Basic physical properties of two alternative backfill materials.

Table 1 presents the basic physical properties of two secondary materials - paper industry waste and flood debris - proposed for use in the GRS structures discussed here. Notably, there are significant differences between these materials, each presenting a unique challenge for their application. Three of these are discussed below.

# 3 CHALLENGES

## 3.1 Chemical impacts

The primary challenge in using waste as fill material in GRS structures is the potential negative impact to the environment. Soil toxicity can be assessed by producing and analyzing a leachate from the waste material to determine its chemical composition. Concentrations of potentially toxic elements in leachates from paper industry waste composites are within the limits for inert materials (Fifer Bizjak et al., 2021).

Additionally, the resilience of geosynthetic materials in contact with waste must be considered. Despite its high alkalinity (pH 12), paper industry waste does not affect the strength characteristics of the PET geogrid used in the project (Lenart et al., 2024). Tensile tests conducted on 2×15 specimens of geogrid yarns with partially removed coating showed no significant difference in tensile strength before and after long-term exposure to the hyper-alkaline environment.

## 3.2 Workability of fill materials

When planning to use waste materials with the potential for cementation, calcification or other types of chemical bonding as backfill, it is crucial to consider the effect of time on the formation of these bonds. After wetting and mixing the composite, both the time to compaction and the curing time play an important role in achieving the final properties of the GRS backfill material. Due to formation of chemical bonds in these composites, the strength of the backfill material increases over time. Unfortunately, strength might decrease with increasing delay between mixing and compaction, as it happens in case of composites from paper industry wastes (Fifer Bizjak et al., 2021) shown in Figure 1.

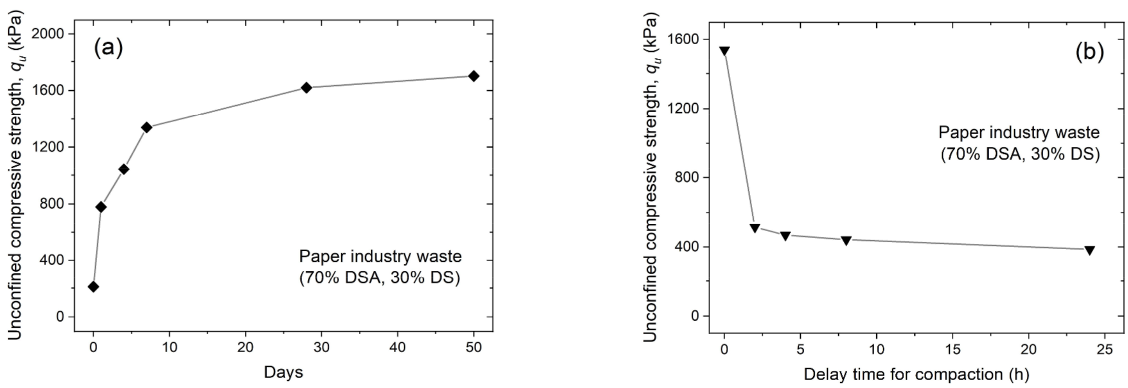


Figure 1: Uniaxial compressive strength of composite from paper industry waste in relation to curing time (a) and with delay in compaction time (b).

## 3.3 Deformation properties

Backfill selection for GRS structures primarily depends on ensuring compaction, drainage, workability, and maximizing the shear strength of the GRS composite. The shear strength can be significantly affected by using rounded flood debris aggregate. Given the unique interaction between the fill material and geosynthetic, empirical validation of the ultimate vertical capacity of a GRS abutment (Circuit, 2024) is essential. A large-scale performance test (Lenart et al., 2014) using the same geosynthetic reinforcement and backfill material planned for the site should be conducted (Figure 2) in that case.

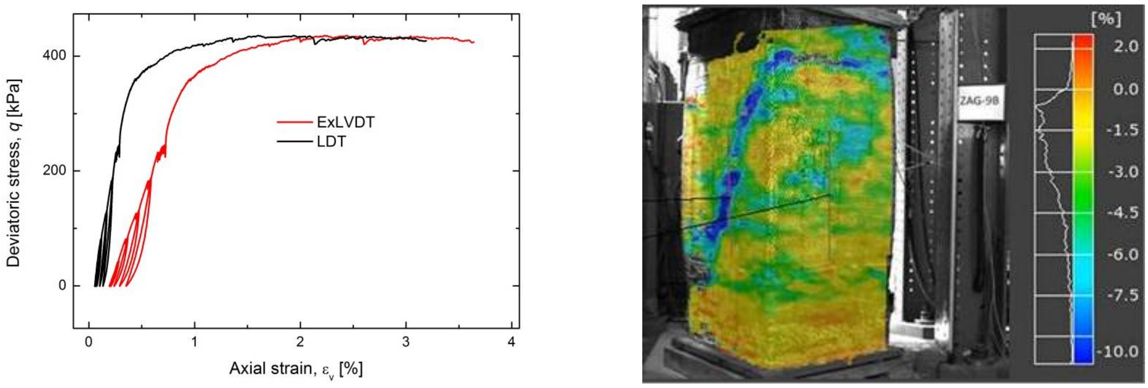


Figure 2: Typical results of performance test of GRS composite.

## 4 CONCLUSIONS

Marginal and recycled fills, such as paper industry waste or flood debris, can be effectively used in GRS structures. However, specific characteristics of these alternative fill materials—such as toxicity, chemical interaction with geosynthetics, workability, and deformation properties of the GRS composite—must be carefully considered.

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