INTERNATIONAL GEOSYNTHETICS SOCIETY

Proceedings of the

Technical Workshop on Reinforcement and Drainage in Soil Structures

Barcelona, 25-27 June 2024

Technical Committees on:

Soil Reinforcement (TC-R, *International Geosynthetics Society*),
Hydraulic Applications (TC-H, *International Geosynthetics Society*), and
Reinforced Fill Structures (TC-218, *International Society for Soil Mechanics and Geotechnical Engineering*)

SIMSG ISSMGE igs Reinforcement igs Hydraulics

INTERNATIONAL GEOSYNTHETICS SOCIETY

SIMSG ISSMGE

Technical Workshop on Reinforcement and Drainage in Soil Structures

Barcelona, 25-27 June 2024

Venue:

Universitat Politècnica de Catalunya·BarcelonaTech (UPC)
Department of Civil and Environmental Engineering (DECA), School of Civil Engineering,
UPC Campus Nord, c/ Jordi Girona 1-3, 08034, Barcelona, Spain

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Edited by Ivan P. Damians Pietro Rimoldi, Yoshihisa Miyata, and Aníbal Moncada,
Internacional Geosynthetics Society (IGS) - 2024.

INTERNATIONAL GEOSYNTHETICS SOCIETY

SIMSG ISSMGE

Table of Contents

Preface: Notes from the Editors

The present volume contains the contributions to the "Technical Workshop on Reinforcements and Drainage in Soil Structures" which took place in Barcelona (Spain), from June 25th to 27th, 2024.

The event was organized by the joint collaboration of the Soil Reinforcement (TC-R) and Hydraulic Applications (TC-H) technical committees of the International Geosynthetic Society (IGS), and the Reinforced Fill Structures (TC-218) of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE).

The workshop attracted professionals from all over the world, proving to be an attractive and productive endeavor in which ideas, concepts, and products were shared, discussed, and improved upon. Participants traveled from all over Asia (Australia, China, India, Japan, Malaysia, New Zealand, United Arab Emirates), Americas (Canada, USA, Chile), and Europe (Austria, Belgium, France, Germany, Greece, Hungary, Italy, Netherlands, Portugal, Slovenia, Spain, Turkey, and UK).

Attendees and collaborators include 41 industry related participants (i.e., consultants, manufactures, and/or engineers) and 22 academy related participants, from which 3 were post-graduate students. From this, 30 collaborations were received, with a total of 48 authors and 27 different speakers. Collaborations were categorized in five distinct sections according to the following topics:

- Geosynthetic materials and soil interaction
- Numerical modelling approaches
- Design guidelines and methods
- Case histories
- Climate impact and sustainability aspects

The following table details the scientific impact of the event by analyzing the average H_i-value (H-index: numerical scale that neutrally represents how effective a researcher has been) from the authors and presenting authors (speakers):

Category	#	H-index (total)	H-index (last 5 years)	Description
Speakers	27	**16.67**	**10.33**	Average H-index by speaker *
Authors	48	**9.38**	**5.81**	Average H-index by author *

* H_i-values obtained from Google Scholar (https://scholar.google.com/); search conducted in July 2024.

Finally, the organizing committees TC-R, TC-H and TC-218, Editors, and the International Geosynthetic Society would like to thank also the collaboration of the following Sponsors:

https://www.pavitex.com/

https://www.huesker.com/

Technical Workshop on Reinforcement and Drainage in Soil Structures. June 2024, Barcelona.
Technical Committees on Soil Reinforcement (TC-R, IGS) & Hydraulic Applications (TC-H, IGS), and
Reinforced Fill Structures (TC-218, ISSMGE)
Session: ***Climate impact and Sustainability aspects***

RECYCLED CONSTRUCTION AND DEMOLITION AGGREGATES AS ALTERNATIVE FILL MATERIALS FOR GEOSYNTHETIC-REINFORCED SYSTEMS

Fernanda B. Ferreira[1], Pedro V. Pereira[2], Pedro B. Ribeiro[3], Castorina S. Vieira[1], Patrícia C. Lopes[1,3] and Maria L. Lopes[1]

[1] CONSTRUCT, Faculty of Engineering, University of Porto,
R. Dr. Roberto Frias, 4200-465 Porto, Portugal
E-mail: fbf@fe.up.pt (F.B.F), cvieira@fe.up.pt (C.S.V.), lcosta@fe.up.pt (M.L.L.),
web page: https://www.fe.up.pt/construct/

[2] Domingos da Silva Teixeira S.A., 4711-911 Braga, Portugal
E-mail: pedromiguel.pereira@dstsgps.com, web page: https://dstsa.pt/

[3] Polytechnic Institute of Porto, School of Engineering, 4249-015 Porto, Portugal
E-mail: 1161567@isep.ipp.pt (P.B.R.), cpl@isep.ipp.pt (P.C.L.), web page: https://isep.ipp.pt/

Key words: Recycled C&D materials, Geosynthetics, Interface shear behaviour, Mechanical damage, Cyclic loading, Sustainability

Abstract. *The reuse and recycling of construction and demolition (C&D) waste materials have become essential as the construction sector strives to reduce its carbon footprint and contribute towards environmental preservation. In addition, the benefits of incorporating geosynthetics in geo-infrastructure design have driven significant research efforts to evaluate their behaviour when combined with unconventional fill materials. In this context, a comprehensive research study has been conducted at the University of Porto to explore the potential use of recycled C&D aggregates as alternative fill materials in the construction of geosynthetic-reinforced transport infrastructure systems. Extensive laboratory tests were initially performed to evaluate the geotechnical and geoenvironmental properties of various recycled C&D materials and to assess the feasibility of their use in transport infrastructure applications, such as embankments and capping layers. Large-scale direct shear tests were then conducted to analyse the interface shear response between recycled C&D aggregates and geosynthetics under both static and cyclic normal loading. The geosynthetic mechanical damage induced by a standard aggregate and recycled C&D materials under repeated loading was also investigated. This paper outlines the aforementioned research and some relevant outcomes, with the overall aim of promoting the adoption of ecological practices in infrastructure design and construction, in line with the 2030 Agenda for Sustainable Development.*

1 INTRODUCTION

The 2030 Agenda for Sustainable Development emphasises the need for collaborative efforts to create a sustainable and resilient future for both people and the planet. Given that the civil/geotechnical engineering practice often involves the extensive use of natural and manufactured raw materials, there has been a substantial focus on introducing new, environmentally friendly materials and recycling waste products with the purpose of mitigating the environmental impacts generated. In particular, the adoption of eco-efficient strategies in the design and construction of transport infrastructures, such as the incorporation

of recycled fill materials and geosynthetics can make a decisive contribution towards reducing the carbon footprint of such infrastructure projects and achieving more sustainable development (Yoo, 2023; Ferreira et al., 2023).

This paper discusses the suitability of recycled C&D wastes as a replacement for conventional fill materials in geosynthetic-reinforced systems. The properties of various recycled C&D aggregates are compared with the criteria defined in Portuguese specifications. The direct shear response of the interfaces between recycled C&D aggregates and two geosynthetics subjected to static and cyclic normal loading is assessed based on the results of large-scale direct shear tests. Additionally, the geosynthetic mechanical damage caused by different aggregates under repeated loading is evaluated by comparing the in-isolation tensile load-strain behaviour of intact and damaged geosynthetic specimens.

2 CHARACTERISATION OF RECYCLED C&D AGGREGATES

A series of laboratory tests was carried out following the applicable European standards to assess the geotechnical and geoenvironmental properties of four recycled materials, including two recycled concrete aggregates (C&DW_C1 and C&DW_C2) resulting from the demolition of concrete poles, and two recycled mixed aggregates (C&DW_M1 and C&DW_M2) from the demolition of buildings and other civil infrastructures (Fig. 1). The feasibility of using C&DW_C2 as an alternative aggregate in the construction of rural and forest roads was discussed elsewhere (Pereira et al., 2020). The laboratory study involved the evaluation of constituents, gradation, compaction parameters, flakiness and shape indexes, assessment of fines through the methylene blue and sand equivalent tests, Los Angeles coefficient, as well as laboratory leaching tests to determine the potential release of contaminants. The results were then compared with the technical requirements established in the Portuguese specification LNEC E474 (2009), which provides guidelines for the inclusion of recycled C&D materials in embankment and capping layer of transport infrastructures. It was found that the C&DW_M1 and C&DW_C2 can be considered as suitable alternative fill materials for embankment body and capping layer of transport infrastructures. Conversely, the C&DW_M2 and C&DW_C1 did not comply with the requirements for capping layer. In fact, the associated Los Angeles coefficients exceeded the threshold value, thus reflecting their relatively high susceptibility to breakage. However, these aggregates fulfilled the criteria to be used as embankment fills. The laboratory leaching tests revealed that the studied aggregates can be classified as inert materials, thereby not representing any concerns in terms of groundwater contamination.

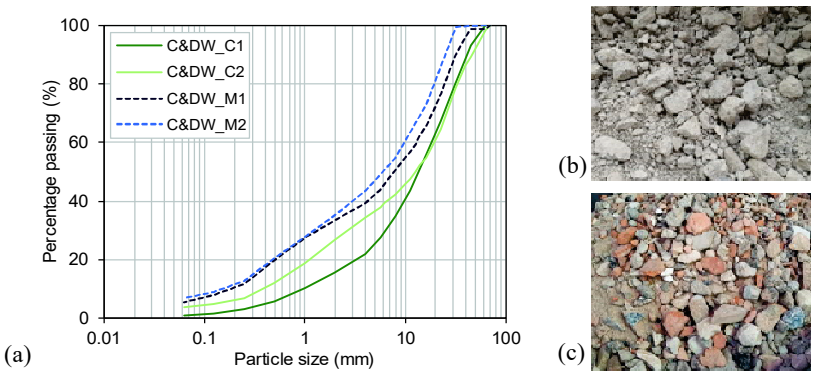

Figure 1: Recycled C&D aggregates: (a) particle size distribution; (b) C&DW_C1; (c) C&DW_M1.

3 DIRECT SHEAR BEHAVIOUR OF RECYCLED C&D AGGREGATES-GEOSYNTHETIC INTERFACES UNDER CYCLIC NORMAL LOADS

The interface shear response between the aggregate C&DW_M1 and two geosynthetics was evaluated by large-scale direct shear tests carried out under both static and cyclic normal loading (Fig. 2a). A biaxial geogrid (GGR) manufactured from polypropylene (PP) textured flat bars with welded junctions and square apertures, and a laid geocomposite reinforcement (GCR) comprising a geogrid and a mechanically bonded PP geotextile welded within the geogrid structure were employed in this study. The direct shear tests under static loading were conducted under normal stresses ranging from 25-75 kPa, whereas the cyclic tests were performed by applying sinusoidal waves with varying amplitudes ($\Delta = \pm 12.5$ and ± 25 kPa) and frequencies (f = 0.2 and 1 Hz), under initial normal stress of 50 kPa. Test results have shown that the interface shear behaviour and associated strength parameters are comparable to those generally observed for interfaces involving similar geosynthetics and conventional fill materials. The cyclic normal loads induced a reduction in the peak interface shear strength, particularly under higher amplitude or lower frequency values (Fig. 2b).

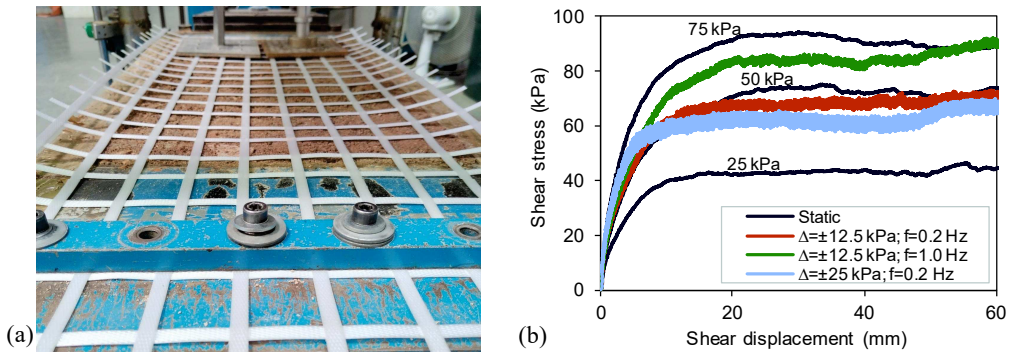

Figure 2: Large-scale direct shear tests: (a) lower shear box; (b) selected results (GGR - C&DW_M1 interface).

4 GEOSYNTHETIC MECHANICAL DAMAGE CAUSED BY RECYCLED C&D AGGREGATES

The mechanical damage to geosynthetics (GGR and GCR) caused by granular materials under repeated loading was simulated in the laboratory using two distinct aggregates: a synthetic standard aggregate, SSA (i.e. corundum) and the recycled aggregate C&DW_M1 (Fig. 3a). These tests aimed to replicate the degradation that geosynthetics may experience during field installation (ISO 10722). The potential geosynthetic damage was then quantified based on the induced changes in the short-term tensile load-strain behaviour (Fig. 3b).

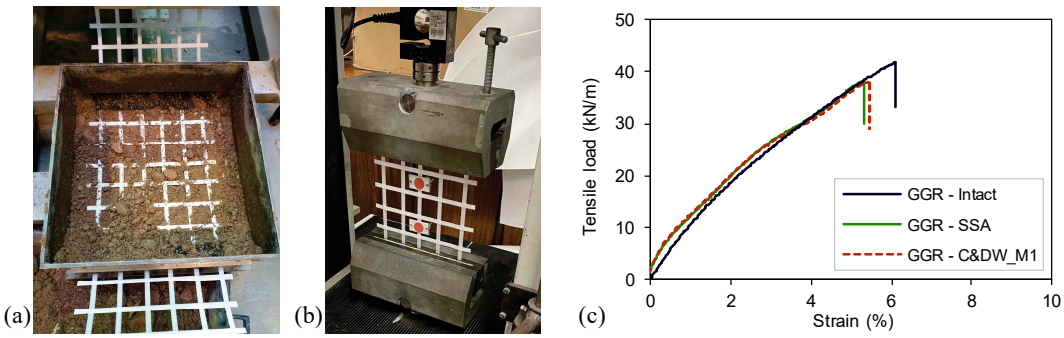

Figure 3: Mechanical damage under repeated loads: (a) damage simulation; (b) tensile tests; (c) GGR results.

The average load-strain curves presented in Fig. 3(c) indicate that the maximum tensile strength of the GGR reduced by up to 10% upon the damage simulation process. However, the secant stiffness at very low strains was found to slightly increase. No significant differences were observed between the degradation caused by the distinct aggregates.

5 CONCLUSIONS

The potential use of recycled C&D aggregates in the construction of geosynthetic-reinforced systems was investigated in this study by a series of laboratory tests. The characterisation of four recycled C&D materials revealed that these aggregates may be used as alternative fill materials in transport infrastructure applications. The interface behaviour between a mixed recycled C&D aggregate and two geosynthetics subjected to static and cyclic normal loading was evaluated through large-scale direct shear tests. It was found that the load frequency is positively correlated with the interface peak shear strength, whereas the load amplitude produces the opposite effect. The degradation of geosynthetic short-term tensile strength induced by recycled C&D waste under repeated loading did not exceed 10%. Overall, the results showed that using recycled C&D aggregates combined with geosynthetics may be considered as a promising approach to meet global sustainability requirements.

ACKNOWLEDGMENTS

The first author gratefully acknowledges Grant No 2021.03625.CEECIND/CP1679/CT0002 with DOI 10.54499/2021.03625.CEECIND/CP1679/CT0002 from the Stimulus of Scientific Employment - Individual Support provided by Fundação para a Ciência e Tecnologia (FCT). This work was financially supported by: Base Funding - UIDB/04708/2020 with DOI 10.54499/UIDB/04708/2020 (https://doi.org/10.54499/UIDB/04708/2020) of the CONSTRUCT - Instituto de I&D em Estruturas e Construções - funded by national funds through the FCT/MCTES (PIDDAC). The authors also wish to thank Naue GmbH & Co. KG (c/o Jörg Klompmaker and Amir Shahkolahi) and RCD, SA (c/o Catarina Santos) for providing the geosynthetics and recycled C&D aggregates, respectively.

REFERENCES

Ferreira, F.B., Vieira, C.S., Pereira, P.M., and Lopes, M.L.; 2023. Recycled construction and demolition waste as backfill material for geosynthetic-reinforced structures. In: Sustainable Civil Engineering: Principles and Applications (Chapter 1). 1st edn. CRC Press, Taylor & Francis Group, Boca Raton, 1-27.

LNEC E474; 2009. Guide for the use of recycled materials coming from construction and demolition waste in embankment and capping layer of transport infrastructures. Portuguese Laboratory of Civil Engineering, Lisbon, Portugal.

Pereira, P.M., Ferreira, F.B., Vieira, C.S., and Lopes, M.L.; 2020. Use of recycled C&D wastes in unpaved rural and forest roads - Feasibility analysis. Proceedings of the 5th International Conference WASTES, Lisbon, Portugal, 4-6 September 2019, pp. 161-167, Taylor & Francis Group.

Yoo, C.; 2023. Geosynthetic solutions for sustainable transportation infrastructure development. Sustainability 15(22): 15772. https://doi.org/10.3390/su152215772.