Characterization of Mixed Fine Construction and Demolition Wastes: Properties and Circular Economy Applications

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INTRODUCTION

Construction and demolition waste (CDW) represents 37.5% of the waste generated in Europe according to Eurostat (2020). The high volume and heterogeneity of CDW make it difficult to meet the 70% recycling and reuse target set by European and Spanish legislation on waste for non-hazardous CDW (excluding natural materials, code 17 05 04). This situation highlights the need to find practical applications for its reuse and requires the adoption of circular economy initiatives that implement strategies to minimize landfilling. This type of waste requires specific treatment plants for sorting, processing and separation of CDW to maximize the recovery and reuse of recyclable materials. This study focuses on the fine fraction of CDW (<4 mm) which is the most difficult to recycle due to its heterogeneity and variability, which varies depending on its origin. It also presents lower stability and a higher risk of leaching, both undesirable properties for use as a recycled aggregate to replace natural aggregates or coarser CDW aggregates. To identify suitable applications for this CDW, a characterization, including particle size analysis, specific surface area (SSA), cation exchange capacity (CEC) and X-ray diffraction was carried out, aiming to explore the interrelationships between these properties to better understand the behavior of the material and its potential performance in various applications.

MATERIALS AND METHODS

In a CDW treatment plant in the Community of Madrid, two types of materials were separated according to their origin and visual characteristics. The first material, referred to as Z060, originates from trenching operations and is treated with a 60 mm mesh. The second material, referred to as 02, originates from mixed CDW that was not segregated at source and is more heterogeneous. After the initial crushing phase, material 02 is separated by a star screen with a 2 mm mesh, although larger sizes pass through due to wear and tear. They were compared with a CEN standard sand, referred to as NS, according to DIN EN 196-1. Particle size analysis was performed using an electromagnetic sieve shaker (ETI-AR051) and 10 sieves with mesh sizes of 0.063, 0.125, 0.25, 0.5, 1, 2, 4, 5, 8 and 16 mm. The shaker was operated for 5 minutes, with an intensity of 60 oscillations and 2-second intermittent pauses. The CEC was determined by Cu-trien method with a 0.01 M solution of Cu(II)-triethylenetetramine in a UV-Vis GENESYS spectrophotometer, at a wavelength of 584 nm. The SSA was assessed by N_2 adsorption calculated by the BET equation in a Micromeritics® GEMINI V equipment. X-ray diffraction was measured on powder samples, in a Bruker D8 Discover diffractometer. These last three parameters were measured on the fractions between <0.063 and 2 mm.

RESULTS AND DISCUSSION

Considering the results of the particle size tests, material 02 has 65% of particles smaller than 2 mm, while material Z060 has 46% and NS has 35%. This indicates that material 02 has a higher proportion by weight of fine particles compared to material Z060 and the NS which are more similar. The CEC increases with decreasing particle size for both materials except for the NS (not significant CEC). With maximum values at particle sizes <0.063 mm: 20 ± 2 cmol(+)/kg for Z060 and 16 ± 1 cmol(+)/kg for 02. The pattern is similar in the SSA, with maximum values at particle sizes <0.063 mm: 19 ± 2 m²/g for Z060 and 14 ± 0.3 m²/g for 02, compared to the NS with a mean value of 2 ± 0.5 m²/g for all particle sizes. Analysing the X-ray diffraction results (Fig. 1), it can be observed that there is a mineralogical difference between the samples. Phyllosilicates such as vermiculite-smectite and montmorillonite are present in both materials for particle sizes <0.063 mm, and vermiculite-smectite is present for particle sizes >2 mm in Z060. Kaolinite has also been detected in both materials. Further analysis of the < 2 µm fraction will be performed in to confirm these findings. The difference between the materials is that gypsum is present in 02, whereas it is not found in Z060. These types of mineral phases are not found in NS.

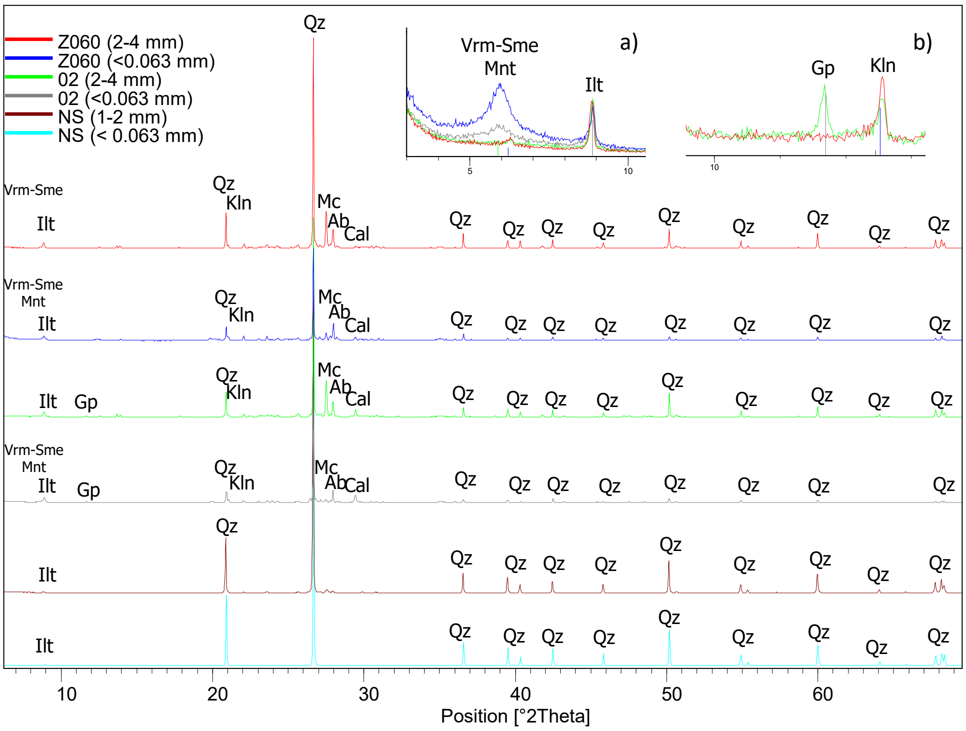

Fig 1*. Analysis of the majority mineral phases by X-ray diffraction for samples <0.063 and 2-4 of materials Z060 and 02, and for NS samples <0.063 and 1-2 mm. a) Detail of the phyllosilicate phases. b) Detail of the gypsum phase and kaolinite phase. (Ab - Albite, Cal – Calcite, Gp – Gypsum, Ilt - Illite, Kln – Kaolinite, Mc - Microcline, Mnt – Montmorillonite, Qz - Quartz, Sme – Esmectite, Vrm – Vermiculite).*

These materials could be used, for example, in green roofs due to their similarity to recycled sand, as their low thermal conductivity is known to improve the thermal efficiency of buildings (Schmidt et al, 2024). Considering CEC, SSA and mineralogical composition, both materials could be applied as pollutant filters, as the feasibility of RCDs to treat dye-contaminated water has been demonstrated, with CEC values of 0.45 - 1.40 cmol(+)/kg and SSA of 1.83 - 11.06 m^2/g (Domingues et al., 2024). These values are slightly lower than those found in our study.

CONCLUSION

To summarize, differences in the properties of the materials studied have been identified. In terms of particle size, material 02 is finer than Z060. The CEC and SSA values of Z060 are slightly higher than those of material 02. Mineralogically, the phyllosilicate fraction seems to be more present in material Z060, although this requires confirmation through analysis of the < 2 µm fraction, and gypsum has been detected only in material 02. The next steps of the study include completing the characterization and obtaining more information on material properties through leaching, density, compaction, and water absorption tests. Taking these properties into account and depending on future results, the viability of using these materials in these or other feasible applications will be tested to minimize landfilling and promote the circular economy.

REFERENCES

Domingues, N. S., Romão, É. L., Alvim, D. S., Marques, J. P., Rodrigues, V. G. S., & Kasemodel, M. C. (2024): Use of Construction and Demolition Waste for the Treatment of Dye-Contaminated Water Toward Circular economy. Water, Air, & Soil Pollution, 235(10), 663. DOI: 10.1007/s11270-024-07421-w.

Schmidt, M., de Souza, S. N. M., Secco, D., Snak, A., & Bassegio, D. (2024): Evaluation of thermal performance in green roofs using recycled construction waste sand as substrate. Urban Ecosystems, 28(1), 1–15. DOI: 10.1007/s11252-024-01614-1.