

# Reinventing Slag: Sustainable Processing of Secondary Metallurgical Resources for Alternatives to Natural Sand

## The Sand Challenge and the Slag Opportunity

Slag is produced in large quantities in high temperature metal production and is a reliable but often underutilized material stream. With targeted metallurgical processing and controlled granulation, it can be transformed into engineered aggregates for sustainable construction. At the same time, natural sand, which is essential for cement and concrete, is facing increasing environmental and regulatory constraints. This creates a clear opportunity to use slag based engineered aggregates as a sustainable alternative to natural sand.



Figure 1: Slag landfill in North Macedonia (left), and the Gambian coast affected by sand extraction (right)

## Sustainable Slag Processing and Metal Recovery

The slag processing approach starts with targeted metal recovery. In this step, residual nonferrous metals can be recovered by carbothermic reduction using bio-based carbon (biocoke) instead of fossil petroleum coke. The slag chemistry is then adjusted in a controlled manner, and the molten slag is subsequently granulated and cooled under defined conditions to tailor particle size, morphology, and phase composition for use in cementitious systems.



Figure 2: Conceptual illustration of the slag treatment process applied to 40 kg of slag, including the major output materials.

## Environmental and System-Level Impact

This approach links lower-carbon metallurgy with sustainable construction materials. Renewable carbon can reduce CO<sub>2</sub> emissions during slag treatment, while the use of slag as a sand substitute lowers the demand for natural aggregates and supports the circular use of by-products. The integrated concept combines metal recovery, emission reduction, and sustainable material use within one process chain.

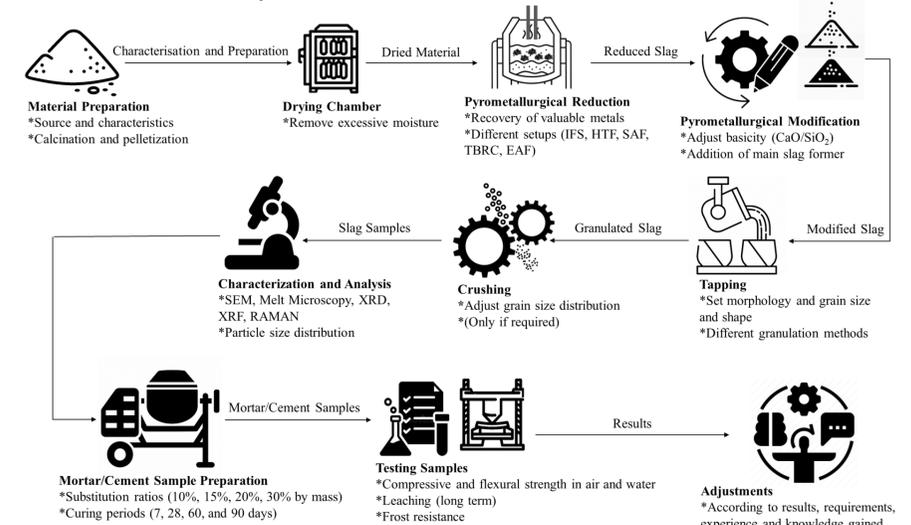


Figure 3: End-to-end approach to slag refinement and application in cementitious systems

## Towards Cement Applications

Current work focuses on mechanical performance, freeze-thaw durability, and long-term leaching behaviour. First results are highly promising, showing compressive strength comparable to or exceeding conventional natural sand systems. Leaching remains well below legal limits, confirming effective metal immobilization within the slag matrix. Slag-derived granulates show strong potential as sustainable alternatives to natural sand in cementitious materials.

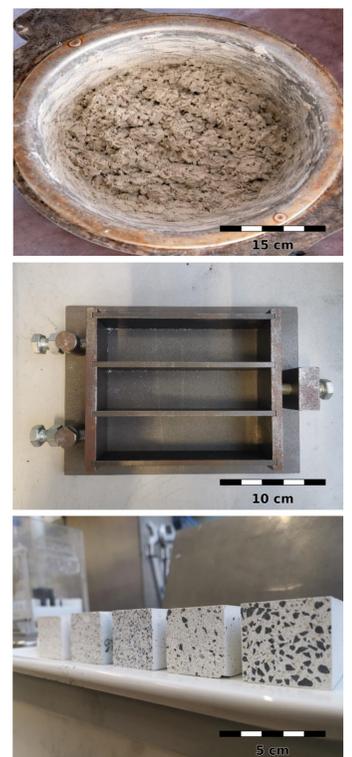


Figure 4: Preparation of mortar samples



**Dipl. Ing. Ehab Tara**  
Department Metallurgy  
Chair of Nonferrous Metallurgy  
ehab.tara@unileoben.ac.at  
+43 3842 402 5264  
www.nichteisenmetallurgie.at  
www.greenzinc.at

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