Looking deeper into slag-based cementitious materials

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The built environment requires vast amounts of resources and accounts for about 50% of all extracted material [1]. The extensive use of concrete at global scale is no longer sustainable in terms of both CO_2 emission and exploitation of primary resources. In this scenario, the European Commission adopted a new Circular Economy Action Plan which directly addresses the building sector as an intervention area and legal obligations are foreseen for the introduction of recycled content requirements in concrete. One strategy is reducing the cement content in concrete, being cement the concrete component with the highest carbon footprint. Blast furnace slags, by-products of iron and steel making, are already extensively used as replacement of cement, and the current EU regulation allows the use of hydraulic binders composed up to 80 wt% of slag (CEM-III/B). However, the challenge for the future is realizing high-performance hydraulic binders completely replacing the cement content and implementing different types of metallurgical slags e.g. basic oxygen furnace slag and electric arc furnace slag. This strategy aims at the production of sustainable building materials at low carbon footprint. Indeed, within a circular economy perspective, the conversion of industrial by-products with a costly management into raw materials for the construction sector is an attractive solution both in terms of economic and environmental savings. Establishing a waste-to-resource supply chain is addressed to the protection of natural resources, to the safe and profitable reuse of landfilled wastes and to the mitigation of climate changes

The comprehension of the basic mechanisms involved in the hydration or alkali activation process of a slag-based cement is fundamental in optimizing the performances of the binder. Specifically, setting and hardening time, workability of fresh pastes and durability of hardened products are all important features to be considered from the point of view of industrial applications. These features are strongly related to structure of the phases forming during hydration or alkali activation at the atomic and nanometre scale. In slag-based cement, the reaction products mainly consist in calcium aluminium silicate hydrates (C-A-S-H gel) with variable stoichiometry and an ordered atomic arrangement at the nanoscale. These poorly crystalline phases are difficult to characterize implementing traditional Bragg diffraction techniques. An innovative approach based on Wide Angle X-ray Total Scattering (WAXTS) measurements coupled to modelling techniques based on the Debye Scattering Equation (WAXTS-DSE method) is a promising approach to get a deeper insight into the atomic arrangement of these poorly crystalline materials [2,3].

The proposed research project aims to accomplish the following goals:

- development of experimental and modelling tools based on WAXT-DSE method aiming at describing nanometer-scale features of C-A-S-H;

- achieving a detailed comprehension of slag chemical parameters controlling its reactivity in cement or alkali activated systems;

- achieving detailed knowledge on the slag phase equilibria, thermodynamic and physicochemical properties by applying high-temperature thermodynamic modelling (e.g. using FactSage package).

The ultimate objective is to clarify the main chemical- and phase-composition parameters controlling the reactivity of slag in cement systems, and to optimize the formulations leading to the manufacture of concrete with the desired performances.

The research project is part of the current research activity on hydraulic binders at the Circe Center-Geoscience Department, University of Padua. Collaborations with the OPIGEO s.r.l, IGG-CNR of Padua and the Total Scattering Laboratory (To.Sca.Lab) at University of Insubria are foreseen.

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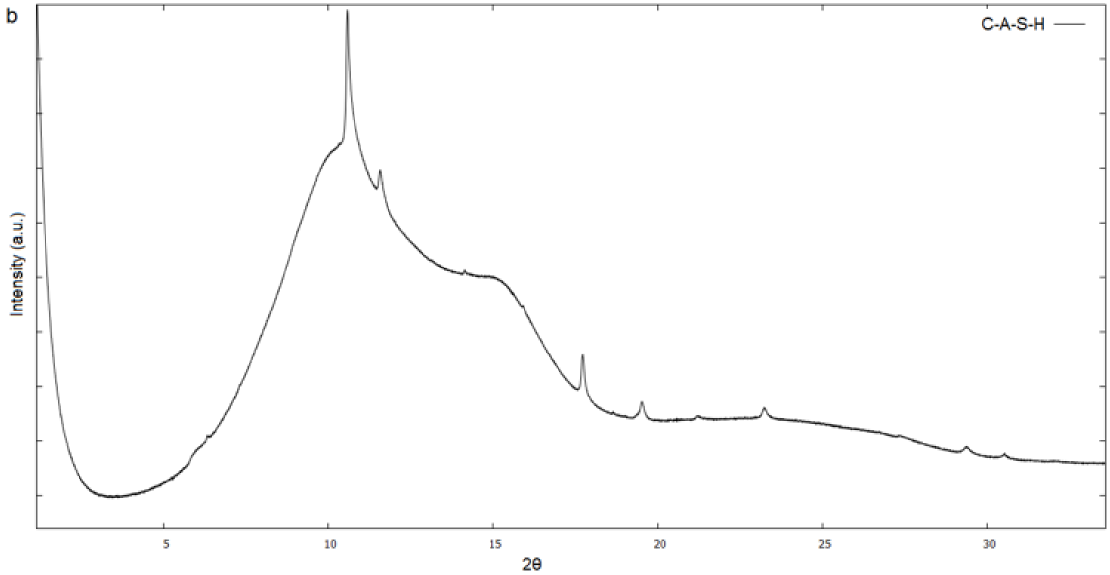

Figure 1. Wide Angle X-ray total scattering signal of C-A-S-H (λ=0.56456 Å).

References

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