Understanding of the reactivity of granulated blast furnace slags by a multi-scale structural characterization

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Abstract

Granulated blast furnace slag is a by-product of the iron making process. It has been used for many years as a cement constituent (type CEM II and CEM III) or as a concrete addition, replacing Portland cement clinker up to 80% in some niche applications. Above a certain addition level, GGBS-containing binders have superior long term properties but early strengths development is below the ordinary Portland cement (OPC) or cements with lower additions levels. Moreover, as a by-product, slags with different origins show various short and long term effects on the mechanical strength of the concrete. Two reasons for that are different chemistry and glass contents. But in order to understand really the behavior difference of slags with different origins, it is important to consider a complete multi-scale description of the slags, such as the structure of the vitreous matrix (the main phase) as well as the identification of inhomogeneities such as inclusions or nanocrystals. Blast furnace slags are Ca-Si-Mg-Al oxide glasses (in most cases 95 to 100% glass content) containing numerous secondary elements such as Na, K, Fe, Ti, Mn... The homogeneity of the glass matrix was investigated at different scales using both SEM and TEM coupled with EDS analyses evidencing a heterogeneous local dispersion of minor elements in the matrix. Multi-nuclear high resolution solid state NMR was used to describe the vitreous network. 27Al MAS and 3Q-MAS NMR experiments evidenced the presence of both tetra- and penta-coordinated aluminum species in slightly different amounts according to the composition of the slag. 29Si MAS NMR experiments outlined the difference in polymerization of the samples. Finally, the crystalline phases of the slags were appreciated using XRD, SEM and TEM. The different structural organizations are related to the development of the short term strength of the slags.

Keywords: blast furnace slag, structure, NMR, TEM

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