Hydration Properties of Low Heat Portland Cement

K. Mori, Y. Inamura*, O. Yamamuro*, K. Oishi**, K. Kimura**, T. Sato, K. Itoh, M. Sugiyama, M. Kawai*** and T. Fukunaga

*Research Reactor Institute, Kyoto University, *ISSP, University of Tokyo, **Shimizu Corporation, ***Institute of Materials Structure Science, KEK*

Low Heat Portland Cement (LHPC) clinkers have occupied important positions in materials of huge buildings. The compressive strength of the hardened LHPC may be strongly associated with the hydration properties of LHPC. Recently, quasi-elastic neutron scattering (QENS) technique has attracted much attention, because the QENS experiments provide us dynamical information of water molecules in materials. Even though cement clinkers have a lot of components, the hydration properties can be easily investigated from the point of view of the bound water in the hydrated cement.

In this work, the hydration properties of LHPC were studied using the high-resolution pulsed cold neutron spectrometer, AGNES. The energy resolution is 120 μ eV, using PG002 monochromator (λ = 0.422 nm). The LHPC clinkers were hydrated with light water (H2O) at 28 degree in air. The H2O to LHPC mass ratio was kept constant at 0.5.

The time evolution of the QENS spectrum of the LHPC was obtained until 5 days of hydration at Q ˜ 20 nm-1, where Q is the momentum transfer. The QENS spectrum is extremely broad in the early hydration period, while the elastic peak at around E = 0 meV is drastically grown in later hydration period. This behavior can be safely interpreted; the hydration process changes free water into -OH or water of crystallization. The signals of bound water (BW) and free water (FW) in the whole QENS spectrum were separated. In the first instance, the QENS intensities, I(Q,E), were represented as follows:

$$I(Q,E)=\{(BW0+BW1)d(Q,E) +(FW1)L(Q,E)\}R(Q,E)+BG,$$

where the first and second terms on the right-hand side indicate elastic and quasi-elastic scatterings for BW and FW, and BG is the constant background. d(Q,E) and L(Q,E) are represented as the delta function and Lorentzian, respectively. Note that the BW0 corresponds to the component of gypsum in the LHPC and was employed as the constant value. The R(Q,E), which is described by Gaussian, indicates the resolution function of the AGNES spectrometer. Finally, the excellent fits between the observed and calculated patterns could be obtained for all QENS data.

The ratio of the signal from the BW1 of bound water to the total signal of water, BW1 + FW1, was defined as BWI (= BW1 / (BW1 + FW1)), and calculated. The BWI as a function of t is shown in Fig. 1. The hydration process in three different stages could be clearly observed in our experiments using QENS. In the induction period, no hydration products are created up to ˜ 0.1 in day. The consumption of FW is ˜ 20% after 1 day of hydration, and then the hydration rate decreases gradually.

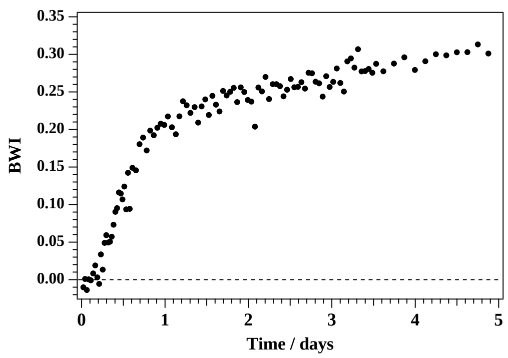

Fig. 1. Bound water index, BWI, of the hydrated LHPC as a function of hydration time.