Effect of Very Fine Ground Glass Pozzolan on Fresh and Mechanical Properties of Ultra-High-Performance Concrete

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Extended Abstract

Optimizing the packing density and particle-size distribution of the components of the concrete affect greatly its mixture design. This effect is more dominant in case of concrete mixtures with low water-to-binder ratio like the ultra-high-performance concrete (UHPC). Adding quartz powder — the main component in UHPC — with a close particle-size distribution to that of cement — to a binary system of quartz sand and cement in the UHPC was found to slightly affect the packing density of the system due to the physical interlocking between the quartz powder and cement particles. In addition and due to the similarity in the particle size, the quartz powder does not fill the micro gap within the cement particles. Furthermore and based on the Environment Canada Report (2015), the quartz powder causes immediate and long-term environmental harmfulness because of its biological diversity that is considered as an environmental hazard. Therefore, this paper presents the possibility of using the "*very fine glass pozzolan*" to replace up to 100% of the quartz powder in the UHPC to overcome the aforementioned issues related to the use of the quartz powder.

In the current study, the quartz powder were replaced by the *very fine glass pozzolan* of a mean particle-size diameter (D_{50}) of 3.5 µm, while keeping the quartz sand, cement, and silica fume quantities constant in all mixtures. The reference UHPC mixture was optimized based on the packing-density theory. The effects of using the *very fine glass pozzolan* on the fresh and

compressive strength properties of the UHPC were evaluated. The effect of two different curing conditions on the compressive strength of UHPC mixtures were also studied: normal curing at a temperature of 20 ± 2ºC and a relative humidity (RH) of 100%; and a standard steam curing at a temperature of 90ºC and 100% RH for 48 h.

The results showed that the *very fine glass pozzolan* with particle-size distribution having a D_{50} of 3.8 µm can be used as an optimal material to fill the gap between the quartz sand and cement particles. When replacing 100% of the quartz powder with *very fine glass pozzolan*, the compressive strength of 250 MPa can be achieved after two-day steam curing compared at 216 MPa for the reference mixture (containing 100% quartz powder). The mixture containing 100% *very fine glass pozzolan* replacement exhibited 18% higher 91-day compressive strength after normal curing than the reference mixture. It is worth noting that quartz powder is considered as a filler in the UHPC design, while, in contrast, the *very fine glass pozzolan* can exhibit pozzolanic reactivity at ambient temperature in addition to the filler effect.

The fresh and rheological properties of the UHPC were also improved due to the replacement of quartz powder by the *very fine glass pozzolan*. For example, the mini-slump flow diameter increased from 190 to 235 mm when using the *very fine glass pozzolan* to replace 100% of quartz powder in the reference UHPC. The particle-packing density of the UHPC mixtures was observed to be significantly improved when incorporating the *very fine glass pozzolan*. For example, the packing density values obtained from the compressible packing model for the reference (100% quartz powder), and 100% the *very fine glass pozzolan* were 0.79 and 0.83, respectively. This was attributed to the fact that the *very fine glass pozzolan* have finer particles than the quartz powder, which could also contribute to enhancing the concrete workability.

This strength and rheology improvements were due to increase in the maximum packing density of the UHPC mixtures made with the addition of the *very fine glass pozzolan*. As a general conclusion, by controlling the engineering packing density and particles distribution, a more sustainable UHPC can be produced as the case of using the *very fine glass pozzolan* to totally replace the quartz powder.

Keywords: *Very fine glass pozzolan*, Packing density, Quartz powder, Compressive strength, Rheology, Ultra-high-performance concrete (UHPC).