**Crack formation in Ultra High Performance Concrete investigated by electron microscopy**

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Ultra High Performance Concrete (UHPC) is a specialized concrete widely used in structures such as bridges, high-rise buildings and wind turbines. It is distinguished from ordinary concrete by its high robustness of over 150 N/mm$^2$ and a low w/c ratio of less than 0,25. Instead of sand or gravel, it contains fine-grained aggregate components such as quartz and silica fume as well as fine-grained cement components like fly ash or blast-furnace slag in addition to ordinary Portland cement.

Components used in UHPC have a broad size distribution, ranging from several tens of microns down to the nanometer scale. Thus, we use transmission electron microscopy (TEM) in addition to scanning electron microscopy (SEM) and focused ion beam (FIB) techniques to characterize the material. TEM images and EDS elemental distribution maps were acquired with an FEI Talos F200X, while SEM imaging, FIB sample preparation and "Slice & View" tomography were performed using an FEI Helios NanoLab G3.

While a large number of articles have been published on the structure and properties of UHPC,[1-3] little is known about its behavior in the case of fatigue-induced failure. Whereas, in ordinary concrete, cracking preferentially occurs at the interface of aggregate and cement paste matrix, cracks are known to sometimes penetrate the aggregate itself in UHPC. However, the preferential site of crack origination remains unknown.

In fig. 1, a single secondary electron (SE) image from a stack acquired by "Slice & View" tomography is shown. Numerous small cracks have formed in the vicinity of a cluster of silica fume particles. They originate in the cement paste matrix and terminate at the interface of silica fume and matrix. Aggregate grains and unhydratized cement particles as well as most of the matrix in the bulk of the sample appear to be free of cracks otherwise.

In fig. 2, a high-angle annular dark field (HAADF) STEM image and EDS elemental distribution maps acquired on a TEM lamella are compiled. Blast-furnace slag and unhydratized silica fume can be distinguished by their high concentration of Ca and Si, respectively, and no cracks can be observed close to the single silica fume particle. The matrix surrounding the silica fume particle contains a single accumulation of sulphur that cannot be assigned to any discrete material. Most likely, it stems from a cluster of superplasticizer molecules. These clusters have sizes of several tens of nanometers and might act as a "weak point" of the cement paste matrix and a preferential site for the origination of fatigue-induced cracking. Further investigatios are currently being undertaken.

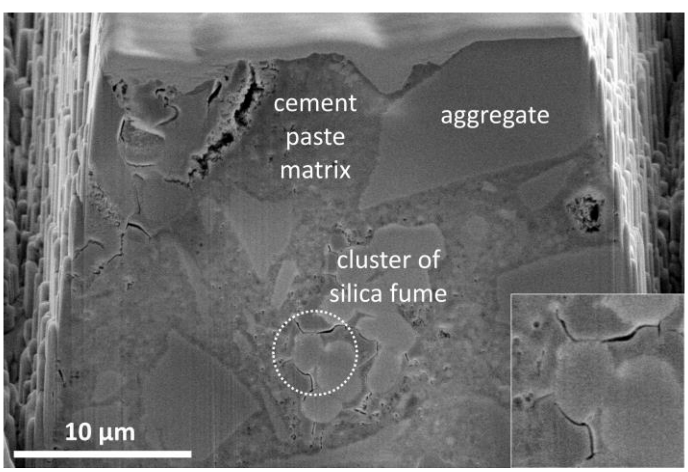


**Fig. 1:** SEM SE image from "Slice & View" tomography showing minute cracks close to a cluster of silica fume particles.

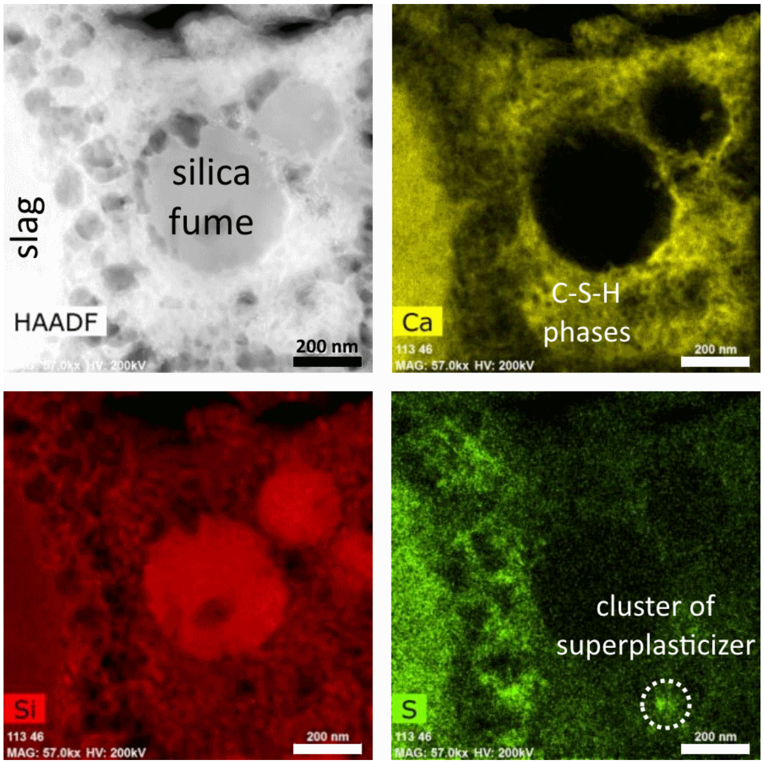


**Fig. 2:** HAADF-STEM image and EDS elemental distribution maps revealing a cluster of superplasticizer molecules in the cement paste matrix.

**References:**

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