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Guest Editorial

Special issue on scanning electron microscopy of cements and concretes

Scanning electron microscopy (SEM) has been a primary tool in the investigation of the complex internal structure of concretes and hydrated cement pastes for many years. While the 'internal architecture' of concrete can be studied by various techniques such as transmission electron microscopy (for nanoscale details) or petrographic microscopy (for practical examination of field concretes), no other technique can provide the depth and breadth of information available with SEM.

In particular this is true of backscatter-mode SEM, and more specifically, of split-quadrant backscatter-mode SEM coupled with energy-dispersive X-ray spectroscopy (the latter variously abbreviated as EDX, EDS, EDXA, etc.). Most modern SEM instruments provide for the simultaneous utilization of both techniques: i.e. image examination and study of microstructural details using the SEM, and at the same time qualitative or quantitative analysis of the chemical composition of any desired feature in the image by use of the EDX system.

Backscatter-mode SEM is different from the earlier secondary electron-mode SEM methods in that the imaging is done using flat polished specimens rather than fracture surfaces, and the basis of image formation is not topographic relief but rather the existence of varying electron densities in different areas.

Concretes are peculiar engineering materials. Their properties depend on their internal structures, and vary tremendously. The microstructure changes with age, of course, but also varies with the cement used, the water:cement ratio, heat treatment or other special processing, curing or lack of it, incorporation of chemical admixtures, incorporation of fly ash, slag, silica fume, or other mineral components, and many other variables. Furthermore many concretes in service are subject to deterioration by various chemical and physical processes, all of which can modify their internal structures as well as their end-use properties. Thus, at least a nodding acquaintance with the internal architecture of cement pastes and other features within concretes would seem to be an essential tool in the armament of all who deal with concrete properties and with concrete behavior in service. This is particularly true for the expanding community of those engaged in developing mathematical models of concrete and of concrete durability.

The present special issue contains 10 papers dealing in some way with the electron microscopic characterization of cement systems. The emphasis is primarily, but not exclusively, on backscatter-mode SEM based studies. Although a wide range of cement systems are covered, including cement itself, hydrated cement pastes, conventional concretes, and blended cement hydration products of several different kinds, the coverage is far from comprehensive. Many areas of current interest, such as high-performance and self-compacting concretes are not included, and only a single paper illustrates the potentials of SEM instrumentation applied to the vast range of concrete durability problems.

This special issue begins with a paper by the present writer conceived as a 'primer'—a sort of visual tutorial illustrating the basic building blocks of 'normal' cement paste and of ordinary concretes. This is followed by a somewhat wider-ranging general contribution by Scrivener, who called attention among other things, to the limitations inherent in any two-dimensional based study of a three-dimensional structure, and to the desirability of quantitative as well as qualitative investigations.

It may be noticed that the microstructural interpretations of these two authors, while generally similar, are not always in entire agreement.

One of the limitations of backscatter-mode SEM alluded to by both general papers is that resolution (and therefore useful magnification) is somewhat limited with conventional SEM instruments. However, in their paper Kjellsen and Justnes showed that vast improvements in resolution and much higher magnifications can be obtained with field-emission based backscatter SEMs, and used that capability to illustrate the differences between the microstructures of C_3S (and alite) pastes and similar pastes made with Portland cement.

Portland cement itself is far from a simple material, and as illustrated by Stutzman, backscatter SEM and X-ray imaging can be usefully applied to both qualitative and quantitative characterization of cement clinkers.

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The detailed microstructural and chemical characteristics of ordinary hydrated cement pastes and of various blended cement pastes hydrated under a variety of conditions were investigated by Escalante-Garcia and Sharp, again using backscatter-mode SEM and quantitative EDX analyses. The hydration of cement in pastes and mortars was also investigated by Igarishi et al. who used backscatter SEM to measure the contents of residual unhydrated cement and of pores in samples of varying water:cement ratio, age, and added mineral components.

Returning to concrete investigations, one of the important parameters of any concrete is its water: cement ratio. Sahu et al. provided a novel backscatter SEM-based technique for determination of water: cement ratio in mature concrete, and showed how the results parallel those obtained on the same concrete specimens by other techniques.

Illustrating the important potential role of backscatter SEM combined with EDX in concrete durability investigations, Brown et al. reported on the changes induced in various concretes exposed to concentrated sodium sulfate solutions, and on the differences between effects induced by sodium sulfate and magnesium sulfate exposures.

Finally, two papers are provided that emphasize electron microscopic techniques other than backscatter SEM. Fernandez-Jimenez et al. illustrated the power of secondary electron mode SEM examination (of fracture surfaces) and also of transmission electron microscopy in their investigations of alkali-activated fly ash pastes being developed for waste immobilization. Corr et al. studied more conventional hydrating cement pastes, but with a uniquely-fitted low temperature secondary electron mode SEM, which maintains the specimen at −190 °C during imaging.

It is hoped that the range of papers included in this special issue provides at least a ''nodding acquaintance'' with the internal structures of concrete, and some indication of the wide range of applications that can be pursued using SEM techniques.

I am grateful to Professor Swamy for the opportunity to serve as guest editor for this special issue, and to the many invited authors, co-authors, and reviewers for their significant contributions to this issue.

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