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Discussion

A discussion of the paper "The occurrence of two-tone structures in room-temperature cured cement pastes" by S. Diamond, J. Olek, and Y. Wang☆

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1. Introduction

The authors examined an earlier hypothesis that two-tone structures around cement grains are characteristic of cement pastes hydrated at elevated temperatures [1]. The two-tone structures were being used as internal evidence of the curing history. The authors compared backscattered electron images of cement pastes cured at room temperature (23°C) with those of cement pastes cured at 80°C. They found that similar two-tone structures could be observed in cement pastes cured at both temperatures. They also examined cement paste that had been cured at ambient temperatures for 24 years and observed similar structures. Based on this evidence, they concluded, "the presence of such structures in pastes or concretes is not in itself proof that the paste or concrete in which they are found has been exposed to high temperature curing." On the face of it, this conclusion is valid. However, there are additional microstructural features that could help determine the curing history.

2. Hydration temperature and microstructure

Verbeck and Helmuth [2] deduced from indirect evidence that when cement hydrates at low temperatures there is sufficient time for the hydration products to diffuse and precipitate relatively uniformly throughout the space between the cement grains. Accelerated hydration brought about by elevated curing temperatures does not allow time for such diffusion. The resulting microstructure is characterized by high concentrations of hydration products immediately surrounding the cement grains and large pores between the grains.

Using backscattered electron imaging, Kjellsen et al. [3] obtained direct evidence confirming Verbeck and Helmuth's hypothesis. Kjellsen et al. [4] later published a more detailed study of the microstructure of cement pastes hydrated at 5, 20, and 50°C. They examined specimens hydrated isothermally at each of the three temperatures to 30% and 70% hydration. They also examined specimens cured to 30% hydration at one temperature and then transferred to a curing bath at another temperature until they reached a degree of hydration of 70%. They identified the effects of curing temperature on three separate features of the microstructure:

1. The morphology of the CH crystals is generally lamellar and elongated when the hydration temperature is low, but more compact when the temperature is higher. Since the CH forms relatively early in the hydration process and is well developed at 30% hydration, the morphology largely reflects the temperature at the early stages of hydration.
2. The pores are finely distributed when the hydration temperature is low except for some large, isolated pores (Hadley grains). The pore structure of the specimens hydrated at various temperatures appears to be somewhere in between those of specimens isothermally cured at the two temperatures.
3. The hydration shells are more apparent in the specimens hydrated at 50°C and not at all apparent in the 5°C specimens. The specimens hydrated at various temperatures have hydration shells most closely resembling those of specimens hydrated isothermally at the final curing temperature.

Thus there are three separate microstructural features that can be used to reconstruct the curing history of cement paste and concrete. Examination of all three features together may provide more definitive information than the two-tone structures alone.

3. Silica fume-Portland cement paste

The authors followed a similar procedure with a silica fume-Portland cement paste. In this case, 10% of the cement was replaced by an equal mass of silica fume. No su-

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perplasticizer was used and the paste was mixed using a Hobart mixer. Not surprisingly, the authors observed “undispersed silica fume agglomerations” in the micrographs of these specimens. It is generally known that the extremely fine silica fume particles are difficult to disperse in cement paste and concrete. The degree of shearing action obtained in a mixer is minimal unless the mixture contains aggregate particles. Even in a mortar, the shearing action is unlikely to be sufficient to disperse 10% silica fume without the use of superplasticizer. If the authors considered it essential to avoid the use of a superplasticizer, they could have obtained better dispersion using a high-speed blender rather than a mixer.

4. Examination of 24-year-old cement paste

The authors also examined a cement paste specimen that had been hydrated continuously at ambient laboratory temperatures for 24 years. They observed two-tone structures in a number of relict cement grains. Hearn et al. [5] examined 26-year-old concrete that had been continuously cured in water at ambient laboratory temperatures. Two-tone structures can also be seen in a few of the relict cement grains in their photomicrographs.

References

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