

DETECTION OF MICROCRACKS IN CONCRETE CURED AT ELEVATED TEMPERATURE

PROBLEM STATEMENT

Temperature differentials from core to surface of the mass concrete elements during curing lead to the generation of thermal and shrinkage cracks. The Florida Department of Transportation (FDOT) requires thermal control plans to maintain temperature differentials of 35°F (20°C) or less between the core and the surface of the mass concrete elements during curing to avoid such cracks. However, FDOT has not set a maximum curing temperature requirement for the mass concrete. It has not been determined if high temperature conditions at curing alone can cause the development of microcracks. These cracks, like any other crack propagation, may eventually cause loss of structural integrity and shortening of service life. This presents the following problem: Does concrete cured at high temperatures, for example, between 180°F to 200°F, experience microcrack formation? If it does, then maximum temperature requirements would need to be specified in order to control cracking.

OBJECTIVES

The objective of this research project was to determine whether high temperatures during curing of concrete cause microcracks in the concrete matrix.

FINDINGS AND CONCLUSIONS

The literature review showed that there are no standard techniques for preparing concrete samples for microcrack analysis for which there is complete assurance that the procedure itself does not induce secondary cracking. The *in-situ* study of concrete microstructure is an area of great debate because of physical constraints in the cutting and grinding preparation process. However, the preparation procedures used in this study represented the most suitable process given constraints in time and budget, and the availability of equipment.

The specimens selected for the study were chosen from the batch of concrete mixes that produced the highest levels of heat of hydration as well as the highest total temperatures during curing. Two sets of samples were paired for comparison of temperature conditions during curing. For each sample cured at high temperature, a sample was cured at normal temperature as a control specimen. The samples for each mix were then compared for microcrack concentration.

The images generated from each sample were analyzed using a commercial microscopy imaging computer program that output the quantity of cracks found in the image field area. The criterion used for the differentiation of cracks from voids and other concrete matrix features was established to control the effects of user bias in the quantification process. It should be noted that the image areas viewed at the 150X magnification levels represent an image field of 650 microns by 870

microns. The scanned image field represented only 1% of the prepared concrete sample surface. Time resource constraints occur because of the limited image areas scanned, the number of images that can be individually analyzed, and the ability to capture and quantify microcracks at a minimum Scanning Electron Microscopy magnification level, which ultimately determines the viewable image field area.

The procedure for sample preparation used in this study was tested against a set of samples with induced cracks to validate the sample preparation technique. The samples with drying shrinkage induced cracks displayed approximately 86% more cracks than the non-dried samples.

After verifying the sample preparation technique, researchers evaluated the crack concentration in samples cured at elevated temperatures against those cured at room temperature. The research revealed that no correlation exists between concrete curing temperature and the concentration of microcracks in the concrete. The data obtained demonstrated no significant difference between the average crack densities for samples cured at room temperature cured and the samples cured at high temperature: that is, temperatures reached during mass concrete curing did not influence the formation of microcracks in the concrete structure.

However, the validity of these findings must be considered in light of the following factors:

- Control of manual grinding and polishing processes
- Exposure to heat during epoxy impregnation
- Bias in crack identification
- Variation in grayscale properties between images and its influence in crack identification results
- Percentage of concrete surface area studied

BENEFITS

The presence of voids, cracks, and other defects plays an important role in determining the mechanical performance of concrete. Studies have indicated that the development of cracks and connected crack networks contribute to the increase in the permeability and diffusivity of concrete, which negatively influence the durability of concrete. Concerns that high temperatures may cause microcracking needed to be addressed. Had high temperatures been found to contribute to microcracking, additional measures would have to be made to the mass concrete temperature control plan, and the cooler concrete mixture would require longer set times (delaying additional work on the concrete until the final set). These changes would not only slow construction, but increase costs, and they would be warranted only if found to be necessary to prevent cracking.

Subject to the limits already observed, this research showed that high curing temperatures of mass concrete do not influence the formation of microcracks in the concrete structure. Thus, there is no need to specify a maximum curing temperature to control microcrack formation.

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