

## Abstract

Major highway concrete pavements in Iowa have exhibited premature deterioration attributed to effects of ettringite formation, alkali-silica expansive reactions, and to frost attack, or some combination of them. These pavements were constructed in the mid-1980s as non-reinforced, dual-lane, roads ranging in thickness between 200 mm and 300 mm, with skewed joints reinforced with dowels. Deterioration was initially recognized with a darkening of joint regions, which occurred for some pavements as soon as four years after construction. Pavement condition ranges from severe damage to none, and there appeared to be no unequivocal materials or processing variables correlated with failure.

Based upon visual examinations, petrographic evaluation, and application of materials models, the deterioration of concrete highway pavements in Iowa appear related to a freeze-thaw failure of the coarse aggregate and the mortar. Crack patterns sub-parallel to the concrete surface transecting the mortar fraction and the coarse aggregate are indicative of freeze-thaw damage of both the mortar and aggregate. The entrained air void system was marginal to substandard, and filling of some of the finer-sized voids by ettringite appears to have further degraded the air void system. The formation of secondary ettringite within the entrained air voids probably reflects a relatively high degree of concrete saturation causing the smaller voids to be filled with pore solution when the concrete freezes. Alkali-silica reaction (ASR) affects some quartz and shale in the fine aggregate, but is not considered to be a significant cause of the deterioration. Delayed ettringite formation was not deemed likely as no evidence of a uniform paste expansion was observed. The lack of field-observed expansion is also evidence against the ASR and DEF modes of deterioration. The utilization of fly ash does not appear to have affected the deterioration as all pavements with or without fly ash exhibiting substantial damage also exhibit significant filling of the entrained air void system, and specimens containing fly ash from sound pavements do not have significant filling.

The influence of the mixture design, mixing, and placing must be evaluated with respect to development of an adequate entrained air void system, concrete homogeneity, long-term drying shrinkage, and microcracking. A high-sand mix may have contributed to the difficult mixture characteristics noted upon placement and exacerbate concrete heterogeneity problems, difficulty in developing an adequate entrained air void system, poor consolidation potential, and increased drying shrinkage and cracking. Finally, the availability of moisture must also be considered, as the secondary precipitation of ettringite in entrained air voids indicates they were at least partially filled with pore solution at times. Water availability at the base of the slabs, in joints, and cracks may have provided a means for absorbing water to a point of critical saturation.