Deterioration of Concrete due to Delayed Ettringite Formation

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Abstract

Delayed ettringite formation (DEF) is also referred to as "Heat Induced Internal Sulfate Attack" which is an internal swelling reaction of the concrete that occurs in the presence of water without any external ingress of sulphate. Often DEF is associated with other deterioration mechanisms such as aggregate silica reaction (ASR). Crack pattern due to both DEF and ASR are very similar and therefore it is difficult to identify the exact cause for cracking without carrying out petrographic and SEM studies of the affected concrete. Cracking due to DEF was originally reported in steam-cured concrete railway sleepers but it can also occur in large concrete pours where core temperature can be very high as a result of heat of hydration. Recently, severe cracking in some of the pile caps of bridge piers in the Southern Highway project was reported. After extensive investigations, it was found that the main cause for cracking in those pile caps was DEF.

It is widely accepted that concrete subjected to high temperature (>70 °C) at early age and exposed to moisture continuously or intermittently after concrete has hardened is likely to crack due to DEF. Therefore this problem can occur in thick concrete members like pile caps, deep beams, bridge piers and raft foundations.

One suggested mechanism of cracking due to DEF is known as "Uniform Paste Expansion Theory". According to this theory, expansion is taking place uniformly and isotropically in the paste phase due to conversion of monosulphate uniformly distributed in paste phase to Ettringite. The other predominant theory with respect to DEF is "Ettringite Crystal Growth Theory". According to this theory, expansion is attributed due to pressure exerted by the growing ettringite crystals in the micro cracks between cement paste and aggregate. Since there is evidence to support both theories, both mechanisms may be possible and depending on the environmental condition one may be more prevalent.

There are many factors influencing DEF and most of the time, limiting value of one factor depends on other factors. Despite extensive investigations in connection with DEF, the direct cause of damage, the chronological development of the concrete damaging mechanism, and the role of different influences such as alkali content, SO_3, MgO and C_3A were not yet clearly solved. However, with the present knowledge, there is a general agreement by all researchers that there is a very low risk of concrete deterioration due to DEF if the early age concrete temperature is kept below 70 °C. Apart from controlling maximum temperature rise in concrete and composition of cement, use of fly ash or slag blended cement is also effective in mitigating cracking due to DEF.