Abstract of Dissertation

論文の内容の要旨

Quantitative Evaluation of the Effectiveness of Expansive Concrete as a Countermeasure for Thermal Cracking and the Development of its Practical Application

(温度ひび割れ対策としての膨張コンクリート使用効果の定量的検証とその効果的活用策に関する研究)

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Cracking is a familiar phenomenon in concrete engineering. After the cracks occur, deterioration of the concrete construction will be accelerated. Both durability and appearance are affected. For long time, avoidance of cracking has been pursued by many researchers and engineers. A lot of research work has been conducted on the investigation of the causation and prevention of cracking. Autogenous shrinkage, drying shrinkage and thermal stress are thought to be the main causations that introduce cracking. Many effective methods have been developed to prevent cracking. For example, low heat cement is used to reduce the temperature rise, shrinkage reducing admixture is adopted to reduce self-desiccation, and expansive agent is applied to compensate for the shrinkages. Among these methods, expansive concrete has the most impressive performance, and cracking was prevented successfully in some cases. However, it was found that cracking still occurred sometimes, especially in the case of mass concrete in which a high temperature rise was generated.

The first objective of this study is to investigate the causation of the failure of the expansive concrete to prevent cracking. The occurrence of cracking is determined by tensile strength, self-strain and restrained stress. Since tensile strength varies in a narrow range, self-strain and restrained stress were mainly studied. Self-strain includes autogenous shrinkage, drying shrinkage, thermal deformation and artificial expansion. Restrained stress is determined by potential self-strain, restrained degree, Young's modulus and stress relaxation. A full restraint condition was adopted to distinguish the responsibility of material quality and structural design that results in cracking. Therefore self-strain, Young's modulus and stress relaxation are the main influencing factors on cracking and were chiefly investigated.

After referring to most of the unixial restraint testing methods in previous researches, a temperature-stress testing machine (TSTM) was constructed to conduct full restraint experiments and free deformation experiments to quantitatively inspect the effects of influencing factors. Free deformation was measured at the beginning and information on first day could be obtained. In addition, a special method was proposed to measure the evolution of the early age Young’s modulus. Based on past reports, early age evolution of the thermal expansion coefficient was also ascertained according to the hardening process of concrete.

By the thermal expansion coefficient, temperature history and tested free deformation, thermal deformation and non-thermal deformation were decomposed. The effect of autogenous shrinkage and artificial expansion of different concretes on cracking were compared. Furthermore, early age stress relaxation was obtained based on the Young’s modulus evolution. It was verified that autogenous shrinkage is the main causation of cracking for normal concrete, and that artificial expansion of normal aggregate expansive concrete is relaxed and stops early, and fails to counteract thermal shrinkage. Therefore, early age stress relaxation and stagnant expansion during the temperature drop are the main causations of the failure of the normal aggregate expansive concrete to prevent cracking.

On the other hand, it was found that early age stress relaxation of lightweight aggregate expansive concrete was a little smaller than that of normal aggregate expansive concrete due to lower stiffness. In addition, a noticeable phenomenon was observed where the artificial expansion of lightweight aggregate expansive concrete could continue during the temperature drop. Thus, countermeasures for early age thermal cracking were proposed based on application of lightweight aggregate and expansive agent for joint-free pavements and mass concrete. Experimental verification was conducted to confirm that thermal cracking could be avoided by the lightweight aggregate expansive concrete. Therefore, the second objective of this study was achieved.