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Stress-Based Crack Criterion for Concrete at Early Ages

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Summary

In order to enhance the quality of concrete structures, cracking in hardening concrete should be prevented as far as possible. A traditional way to assess the risk of cracking at early ages consists of minimising temperature differentials between warm and cold concrete. In this contribution the results of a recently finished study on the risk of cracking and crack criteria of hardening concrete are presented. The stress development and the tensile stress at the moment of cracking have been measured in a Temperature Stress Testing Machine. Based on the test results a criterion for cracking at early ages is formulated. A procedure for determination stresses in hardening concrete is briefly discussed. In this procedure allowance is made for the effect of the evolution of the microstructure on relaxation of stresses at early ages.

Keywords: Hydration; thermal stresses; cracking; creep; relaxation; modelling; crack criteria

1. Introduction

In the engineering practice the risk of cracking in hardening concrete has often been formulated in terms of allowable temperature differentials. From observations in the practice as well as from theo-retical considerations it has become clear that temperature criteria are very crude. The actual risk of cracking can be overestimated and underestimated considerably, resulting in too conservative or too optimistic designs. Strain or stress criteria are considered more appropirate. In this contribution both experimental and mathematical studies concerning stresses and the risk of cracking in young concrete are dealt with. The aim is to define a stress criterion for cracking of hardening concrete.

2. Outline of research strategy

For the prediction of the risk of cracking in hardening concrete the evolution of the materials properties with elapse of time must be known. In this study the development of materials properties is described as a function of the degree of hydration. The correlation between degree of hydration and strength has been demonstrated many times. More recently also attempts have been made to describe the time-dependent properties of hardening concrete has a function of the degree of hydration. This strategy has also been followed in the theoretical part of this research project. In the experimental part of the project the development of thermal stresses in hardening concrete has been investigated with a Temperature Stress Testing Machine.

3. Determination of stress development and cracking of hardening concrete

The development of stresses in hardening concrete and the risk of cracking was investigated experimentally for a number of different concretes with a Temperature-Stress Testing Machine (TSTM). With this machine stress development due to restrained deformations as well as creep and relaxation behaviour under prescribed thermal conditions were investigated. The mixtures were made with Portland cement and blast furnace slag cement and with water/cement ratios varying from 0.3 to 0.6. Curing of the concrete took place either isothermally or semi-adiabatically. Imposed deformations were restrained in whole or in part.

4. Crack criterion for young concrete and prediction of tensile stresses

For all the concrete specimens considered in the experimental program self-induced cracking occur-red at an average stress/strength ratio 0.75. Based on this data a probabilistic judgement concept is proposed in the form of a nomogram (Fig. 1). The nomogram is based on the assumption of a normal distribution of both the tensile strength and tensile stresses. With the graph an allowable stress/strength ratio η can be determined for each pre-defined probability of cracking which is considered appropriate for the concrete structure in view. This allowable stress/strength level η can be compared with the development of the stress and the strength obtained by simulation.

For prediction of the tensile stresses at early ages a calculation procedure is propsed in which allowance is made for some microstructural phenomena which occur in hardening concrete. Examples of stress predictions are presented. Preliminary results obtained with this microstructure-based calculation procedure are encouraging.

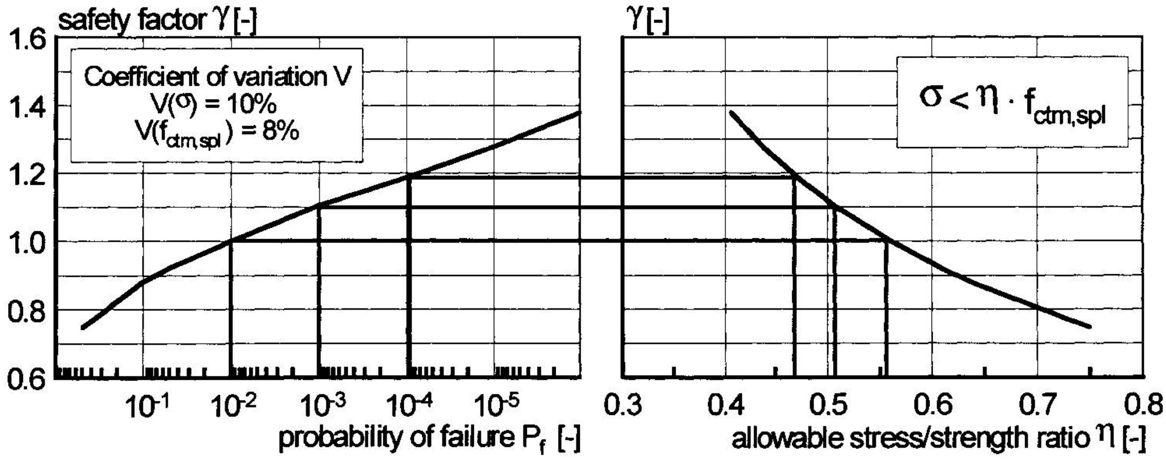

Fig. 1 Design graph for the determination of the maximum allowable stress/strength ratio in a hardening concrete structure