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The Acoustic Emission Parameters Obtained during Three-point Bending Test on Thermal-stressed Concrete Specimens

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Abstract

Fire response of concrete structural members depends on thermal, mechanical, and deformation properties of concrete. These properties vary significantly with temperature and also depend on the composition and characteristics of the concrete batch mix as well as heating rate and other environmental conditions. Concrete structures could be exposed to extreme temperature conditions. Examples of such conditions are concrete foundations for launching rockets carrying spaceships, concrete structures in nuclear power stations or those accidentally exposed to fire, for instance in the case of tunnel fires. This paper analyses acoustic emission signals captured during three-point bending test on thermal-stressed concrete specimens. The method of acoustic emission is an experimental tool suitable for monitoring the failure processes in materials. The typical parameters of acoustic emission signal were identified during the acoustic emission records for different concrete specimens to further describe the under-the-stress behaviour and failure development. The amount of crack growth was continuously monitored using four acoustic emission sensors mounted on the specimens.

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1. Introduction

After the terrorist attacks, the worldwide interest in the design of structures for fire greatly increased. Currently, the structural fire safety is one of the key considerations in building applications. When subjected to heat, concrete responds not just to instantaneous physical changes, such as expansion, but by undergoing various chemical changes.

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This response is especially complex due to the non-uniformity of the material. Concrete contains both cement and aggregate elements, and these may react to heating in a variety of ways. First of all, there are a number of physical and chemical changes which occur in the cement subjected to heat [1,2].

Some of these are reversible upon cooling, but others are non-reversible and may significantly weaken the concrete structure after a fire. Most porous concretes contain a certain amount of liquid water in them. This will obviously vaporize if the temperature significantly exceeds the moisture level range of 100 - 140 °C or so, normally causing a build-up of pressure within the concrete. If the temperature reaches about 400 °C, the calcium hydroxide in the cement will begin to dehydrate, generating further water vapor and also bringing about a significant reduction in the physical strength of the material. Other changes may occur in the aggregate at higher temperatures, for example, quartz-based aggregates increase in volume, due to a mineral transformation, at about 575 °C and limestone aggregates will decompose at about 800 °C. In isolation, the thermal response of the aggregate itself is more straightforward but the overall response of the concrete due to changes in the aggregate may be much greater. For example, differential expansion between the aggregate and the cement matrix may cause cracking and spalling. These physical and chemical changes in concrete will have the effect of reducing the compressive strength of the material. Generally, concrete will maintain its compressive strength until a critical temperature is reached, at which point it will rapidly drop off. This generally occurs at around 600 °C. This is only a little higher than critical temperatures for steel, but because of the much lower conductivity of concrete the heat tends not to penetrate very far into the depth of the material, meaning that the structure as a whole normally retains much of its strength (timber is similar in being able to retain strength in its depth once surface layers have been attacked by fire) [3,4].

The dynamic modulus of elasticity was determined by means of two non-destructive methods. The first was the ultrasonic (US) pulse velocity test, which determined the dynamic elastic modulus E_{cu}. The static modulus of elasticity was determined by means of the compressive test, which is ended by measuring the specimens' compressive strength (i.e. specimen failure).

The principle of the ultrasonic pulse velocity test is the repeated releasing of ultrasonic impulses into the specimen and measuring the time T required for them to travel through, which is then used in the determination of the velocity of ultrasonic wave propagation v_L through the concrete. In the end, the dynamic modulus of elasticity is calculated using the equation:

$$E_{cu} = \rho \cdot v_L^2 \cdot \frac{1}{k^2} \cdot 10^{-6}, \tag{1}$$

where E_{cu} is the dynamic modulus of elasticity in MPa, ρ is the material's bulk density in kg/m^3, v_L is the ultrasonic pulse velocity in m/s and k is the dimensionality coefficient.

The dimensionality coefficient k equals 1 for a one-dimensional environment, and in the cases of two- and three-dimensional environments it depends on the value of Poisson's ratio μ, which can be determined by means of the resonance method (as was done in the experiment described here).

The time for which the ultrasonic pulse travelled through each specimen was measured longitudinally in three positions. The ultrasonic wave velocity was calculated for each position and the average of the results was used as the velocity v_L in the calculation of the elastic modulus according to (1). The procedure of E_{cu} determination was in accordance with the standard [5].

The static modulus of elasticity of each specimen was determined in accordance with the standard [6] using 200 mm resistance strain gauges and a testing press FORM+TEST ALPHA 3-3000. The resulting values of the elastic modulus E_c were calculated according to the equation:

$$E_c = \frac{\Delta\sigma}{\Delta\varepsilon} = \frac{\sigma_a - \sigma_b}{\varepsilon_a - \varepsilon_b}, \tag{2}$$

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