Mathematical Model of Failure Process of Concrete as Three-Component Structure

Vladimir G. Tsuprik,
Far Eastern Federal University, School of Engineering,
Vladivostok, Russia

ABSTRACT

The paper presents the description of an experimental method for strength criteria of concrete. The concrete is considered as a three-component structure that allows one to use the integrated characteristics of fracture toughness for concrete in terms of specific energy. This energy is sufficient to form the new surfaces resulting from fracture through an outlay of energy for mechanical rupture of the internal ties in concrete. Concrete samples with two cracks were studied in two directions.

KEY WORDS: Structural strength; concrete; fracture strength; fracture surface; critical stress intensity factor.

INTRODUCTION

Despite the introduction of the modern practice of construction using new structural composites, one of the most popular materials for construction is still concrete. Strength is one of the important parameters of concrete for engineering practice. The standard methods of concrete strength determination do not take into account high levels of development of building mechanics, fracture mechanics and theories of concrete. The compressive strength of concrete from tests with cubic samples is known to vary. There are many reasons to consider that this characteristic is influenced by certain conditions. One reason is the difference in the general mathematical expression for compressive strength of concrete and the stress-strain state inside the concrete sample. It is obvious that the sample failure or fracture occurs from the development of deformation associated with tension and shear.

On the other hand, the concrete in reinforced concrete structures practically never fails solely due to tensile and shear strains. Thus the fracture of concrete is more than just the elementary event that defines the transition state of some element of the structure from before failure to after failure. The most essential feature of fracture of solid bodies is the process of elastic energy dissipation in the loaded volume of the material and the accumulation of microcracks that define the further development of the destruction process. The destruction thus is a complex process developing in the most loaded part of the structure. This process describes the emergence of microcracks, their junction and development into macroracks resulting in fracture of the structure.

PHENOMENOLOGICAL PARAMETERS OF CONCRETE

The structure of concrete is heterogeneous; consisting of small and large aggregates, hydrate formations of cement, micro- and macro pores, and microcracks. The appearance of all kinds of cracks and pores occurs due to thermal hardening processes of cement hydration and technological conditions of preparation of concrete mixtures. These phenomenological features of concrete structure and stochastic character of their allocation inside each sample explains a wide scatter of concrete strength determination by standard methods.

In terms of the criteria which satisfactorily describe the growth of a single crack in a material under tensile stress using fracture mechanics, two parameters are considered: tensile stress intensity factor at the crack tip $K_{t}$ and specific (effective) fracture energy $G_{1c}$ (which refers to the square of the newly formed surface of the crack as a result of the destruction or fracture).

The data about the above-mentioned parameters of crack resistance are insufficient with regard to such a complex material as concrete. Data are available for the stress intensity factor $K_{t}$ at the crack tip for the cohesion interface of the cement-sand matrix with course aggregates (Ziegeldorf, 1983). For adhesion of the cement-sand matrix with limestone $K_{t}=0.16$ MPa m$^{1/2}$; and with quartzite $K_{t}=0.21$ (Wittmann et al., 1981) obtained results for concrete compression $K_{c}=0.12$ and the values of specific energy of destruction in the tests with beams with a notch gave $G_{1c}=1.7$ N/m.

The existing techniques for the experimental determination of the fracture characteristics for concrete are limited in their application in engineering practice. Research that takes into account the dependence of the fracture characteristics of concrete from parameters based on the heterogeneity of the structure is complicated, because there is no technique for defining such parameters taking into account the tensile nature of destruction when testing concrete in tension or compression. The determination of the laws that influence the heterogeneity of concrete structure and this relationship to crack resistance has the importance for improvement in the determination of strength parameters of concrete and subsequently reduction of energy consumption. This is the actual scientific task.