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MODELING OF FRACTURE PROCESS IN CONCRETE ELEMENTS INCLUDING STEEL FIBRES USING A NOVEL LATTICE MODEL

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ABSTRACT

Concrete with fibres is commonly used for industrial floors. The determination of its strength and ductility is of importance for the design of floors. This paper deals with simulations of a fracture process in concrete including steel fibres with our novel lattice model. Concrete was described at a meso-scale as a four-phase discrete material composed of aggregate, cement matrix, interfacial zones and steel fibres.

Our lattice model [1-4] differs from classical lattice beam models [5] composed of beams connected by non-flexible nodes in that it consists of rods with flexible nodes and longitudinal deformability, rotating in the form of a rigid body rotation. Thus, shearing, bending and torsion are represented by a change of the angle between rod elements connected by angular springs. This quasi-static model is of a kinematic type. The calculation of element displacements was carried out using successive geometrical changes of rods due to translation, rotation and normal and bending deformation. Thus there was no need for the global stiffness matrix and the calculation method had a purely explicit character. In spite of the need for small displacement increments (what is the inherent property of explicit numerical procedures), the computation time was significantly reduced as compared to implicit solutions. In addition, torsion in three-dimensional simulations was included. The quasi-brittle material was discretized in the form of a 3D tetrahedral grid or a 2D triangular lattice mesh made of geometrical lines (Fig. 1, the size of elements was not explicitly given). The distribution of elements was assumed to be completely random using a Delaunay's construction scheme. First, a tetrahedral grid of nodes was created in the material with the side dimensions equal to g. Then each node was randomly displaced by a 3D vector of the magnitude s. The nodes randomized in this way were connected with each other. Thus, each edge in the Delaunay mesh formed a rod. A uniform tetrahedral mesh could be obtained with parameter s=0. The model needs 2 parameters to randomly distribute elements in the lattice. The elements possessed a longitudinal stiffness described by the parameter k_l (controls the changes of the element length), a bending stiffness described by the parameter k_b (controls the changes of the angle between elements) and a torsional stiffness described by the parameter k_t (controls the changes of the torsional angle

between elements). The node displacements were calculated successively during each calculation step beginning first from elements along boundaries subject to prescribed displacements. The resultant force in a selected specimen's cross-area was determined with the aid of corresponding normal strain, shear strain, stiffness parameters, modulus of elasticity, shear modulus and specimen's cross-section area. Each element was removed from the lattice if the assumed local critical tensile strain was exceeded. All presented numerical calculations were strain controlled. The heterogeneous 3D-lattice model for concrete used in the paper requires a total of 5 material parameters for each phase and 2 grid parameters related to the distribution of elements. These material parameters were determined empirically to match experimental results at the macro-scale with numerical ones on the basis of a uniaxial tension and compression test on concrete [2]. Initial parameter values from [5] were used and afterwards were modified empirically to fit experimental stress-strain curves for uniaxial extension and compression tests on concrete.

The calculations were carried out for concrete specimens including steel fibres subject to uniaxial extension, uniaxial compression and bending. Two-and three-dimensional comparative simulations were carried out. In the calculations, the following parameters were systematically varied: a) the amount and length of fibres, b) the density, distribution and size of aggregate, c) bond and cement matrix strength and d) distribution of elements. The numerical results were compared with corresponding experiments from the scientific literature. The advantages and disadvantages of the proposed model were outlined.

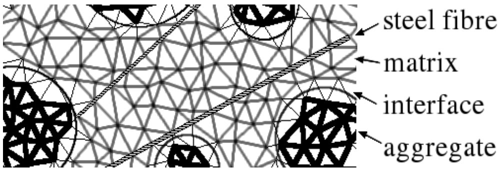

Fig. 1. Lattice composed of rods to model four phases of concrete: fibres, aggregate, cement matrix and interface

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