A SYSTEM OF RANDOMLY ORIENTED CRACKS IN A FIELD OF COMPRESSIVE FORCES

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Most studies of the stressed-strained state of beds with systems of disruptions (cracks) assume that the cracks are oriented in an organized and uniform pattern relative to the acting forces. Although this type of ordering of crack systems is often observed, such systems were formed earlier by various natural factors. At the initial stage of formation of such disruption systems, the primary cracks that preexisted at the micro level (intercrystalline cracks) can have a random orientation with respect to the direction of acting forces.

In noncrystalline materials, the direction of primary initial cracks formed by random factors is also arbitrary. When force fields are applied, some directions are selected, and cracks grow and merge along these selected directions. It is desirable in this context to study the distribution of stresses in beds with sets of randomly oriented cracks and establish the formation patterns of ordered systems.

Problems which involve a large number of cracks are difficult to solve analytically. Physical modeling is incapable of reproducing stress fields of this kind. We use the method of boundary elements to study a stressed state. We elucidate the processes and regularities of crack growth and merger by using models of a gypsum/cement material.* We consider a system of 36 open cracks of unit length $L$ with centers at the nodes of a square grid and with internodal spacing $L$. We took 36 as a number that is sufficiently large but still amenable to computation within a limited amount of time. Equal spacing between crack centers is assumed for definitiveness and to simplify analysis of results, because if this parameter is arbitrary the problem becomes much more complex.

The maximum crack opening in this analysis was set at 0.02$L$; in the model it was 0.1$L$. We also assumed that crack orientation angles relative to the $OX$ axis of the $XOY$ coordinate system in intervals $0-165^\circ$ are equiprobable with step $15^\circ$, i.e., each of directions 0, 15, 30, ..., 165° occurs three times.

With this assumption, we took a sample of 10 random combinations and selected one randomly.

We first analyzed the stressed state in case of uniaxial compression along the $OX$ axis. According to calculations, one of the principal stresses ($\sigma_2$) in the entire region studied is compressive, while the second stress ($\sigma_1$) varies in a broad range and can be either compressive or tensile.

Since tensile stresses present the greatest hazard for rocks, we examine them closely.

We can see from Fig. 1a, which shows the distribution of $\sigma_1$ for this loading, that tensile stresses in the disruption zone are predominant. They occupy up to 80% of the area, and their concentration near the tip of individual cracks exceeds $2|\sigma_1|$ (on a contour it can attain $(7-8)|\sigma_1|$).

The direction of tensile stresses acting near crack tips in their highest concentration zones is parallel to crack contours.

The strongest tensile stresses $\sigma_1$ arise near cracks oriented subnormally (60-120°) relative to the direction of compressive forces at infinity. We distinguish in the region of analysis three zones (I, II, and III) where stresses $\sigma_1 \geq 0.5|\sigma_1|$ encompass several cracks or are adjacent to them, constituting continuous portions.

Judging by stress distribution pattern, one should expect breakdown primarily in such zones. Breakdown should occur by separation at a normal to crack boundaries. Cracks should merge and form continuous ruptures oriented along the elongation of areas with the highest stress concentration.

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Fig. 1. Distribution of stresses $\sigma_1/|T_x|$ in uniaxial compression along the OX (a) and OY (b) axes.

Figure 2a illustrates the pattern and sequence (numbers 1-5) of destruction in the course of loading. Experiments on gypsum/cement models confirm this expectation, but not entirely of loading. Indeed, destruction occurs as a result of separation, as clearly seen by the opening of newly formed cracks. Breakdown is seen primarily in places with the highest concentration of tensile stresses forming continuous ruptures oriented parallel to the direction of forces acting at infinity.