Structural Model Tests to Investigate Fracture Propagation in Discontinuous Rocks*

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The conditions of homogeneity and isotropy generally assumed in theoretical analyses of stress distribution and strength parameters are rarely realized in rocks. Most rocks are anisotropic at least, and very commonly discontinuous. The flow of stress through discontinuous material differs greatly from that in isotropic, continuous materials. The influence of anisotropies is the greatest when confining stresses are at minimum; it is no wonder, then, that they become the primary concern in relatively shallow depth operations of mining and civil engineering projects.

Research into the performance of discontinuous rocks in an engineering context is in progress in the Department of Geology, UNIVERSITY OF NEW BRUNSWICK. Plaster of Paris models of rocks with simple discontinuities have been tested in uniaxial compression, using plaster blocks of initial size 3" x 3" x6". So far, two types of discontinuity have come under investigation: planar discontinuities of the interlocking type to simulate

Figure 1. Unconfined test block in uniaxial compression (load applied vertically): tension fractures have developed sub-parallel to the direction of the discontinuity.

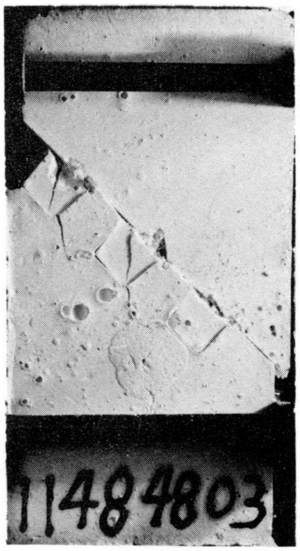

Figure 2. Unconfined test block in uniaxial compression: shear fractures have developed parallel to the discontinuity. Note the presence of vertical tension cracks.

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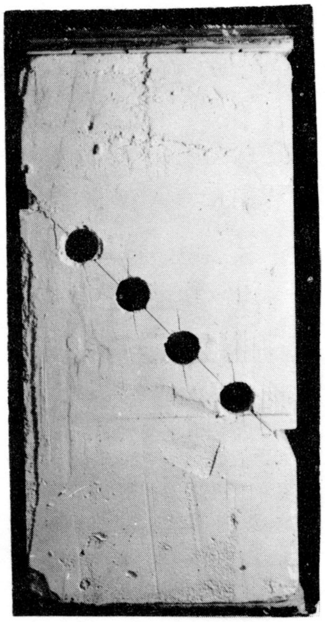

Figure 3. Unconfined test block in uniaxial compression: tension cracks have formed at the crown of the openings. Ignore pencil line joining holes

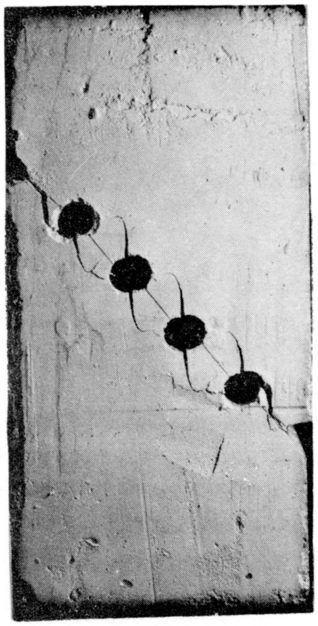

Figure 4. Same block as in Figure 3, at a later stage of deformation. Note the change in the direction of fracture propagation.

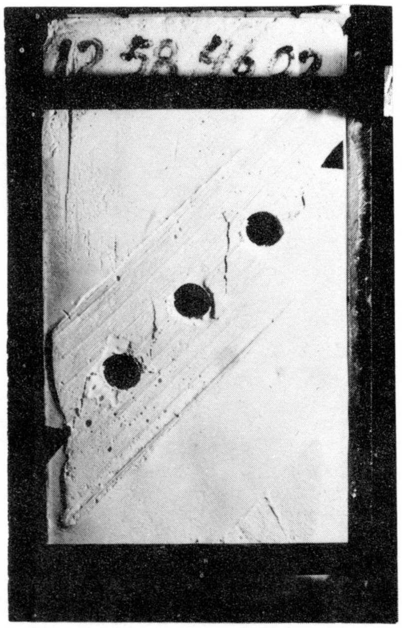

Figure 5. Confined test block in uniaxial compression. Tension cracks are oriented vertically, but localized between adjacent openings. Sloping lines on the block surface are casting marks.

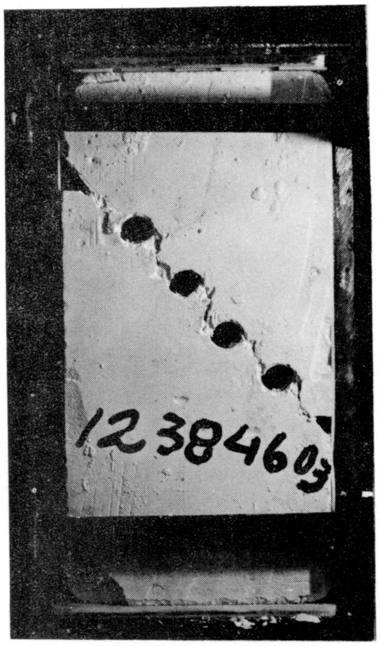

Figure 6. Confined test block in uniaxial compression: shear fractures connect adjacent openings. Note that the fracture in the middle of the figure originated as a vertical tension crack.

interlocking joints in rocks, and lines of circular discontinuities to investigate fracture propagation in porous rocks. The discontinuities were formed by the insertion of suitably-folded metal plates or straight steel rods into the plaster while still liquid; these were removed after the models had solidified. The load was applied in a uniaxial hydraulic press at a strain-rate of approximately ¼ inch per minute. The maximum compressive strength varied from 100 to 600 p.s.i. depending on the inclination and geometry of the inserted plane of weakness. A specially designed testing machine is presently under construction, which will make it possible to subject models to a biaxial stress field in future work.

Interlocking Discontinuities

Depending on the inclination of discontinuities (having identical configuration) a change from a predominantly tensile to a primarily shear mechanism of failure was observed as the inclination was increased from 30° to 50°. At low inclination the interlocking teeth separated at the base, in response to tensile stresses caused through bending of the teeth (Figure 1) by the tangential component of the applied force. The ultimate failure surface was rough and showed no signs of slickensiding. At higher angles of inclination, however, failure occurred in consequence of shear stresses (Figure 2), generally preceded by the appearance of vertical tension fractures originating at sharp corners. The ultimate failure surface was strongly slickensided. The type of failure mechanism was further influenced by the width of the interlocking teeth; in general, the shear type of failure was favoured by wide-tooth discontinuities even at relatively low angles of inclination.

Circular Discontinuities

The importance of tensile microstresses set up around small-scale discontinuities was amply demonstrated in these experiments. In one type of test, unconfined blocks having a planar arrangement of circular openings were subjected to uniaxial stress. The first fractures to appear were vertical tension cracks originating at the top of the openings (Figure 3). With further deformation the direction of fracture propagation shifted toward the horizontal to join up with adjacent openings (Figure 4). In tests where the blocks were confined on the sides by fixed metal plates, the first fractures were still caused by tension, but they shifted location to between the adjacent openings where the influence of confinement was the least effective (Figure 5). With further deformation, shear fractures generally cut across the primary tension fractures, starting from the top of one opening and ending at the bottom of the adjacent one (Figure 6). The failure mechanism, however, was dependent—in addition to confining pressures—on the inclination of the planar arrangement of openings, and the spacing between the individual holes. These influences are presently under investigation.