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FLOW AND FAILURE OF ROCKS CONCRETE AND OTHER
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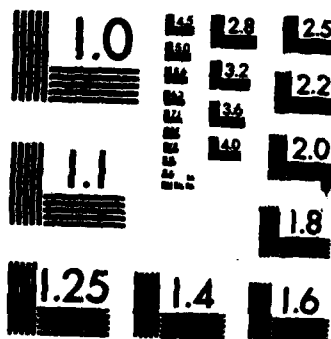
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THIS RESEARCH WAS TO INVESTIGATE THE MICROMECHANICS OF FLOW AND FAILURE OF ROCKS AND CONCRETE AT MODERATE TO VERY HIGH PRESSURES. THE THEORETICAL WORK WAS TO EVALUATE MICROCRACK INITIATION UNDER OVERALL COMPRESSION, INTERACTION BETWEEN CRACKS, AND THE FINAL FAILURE MODE OF MATERIALS. A TESTING FACILITY WAS ESTABLISHED FOR EVALUATING FAILURE MODES OF BRITTLE SOLIDS.

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October 27, 1986

To: Dr. Spencer Wu, Program Manager
Directorate of Aerospace Sciences **AFOSR-TR- 87-0596**
Department of the Air Force
Air Force Office of Scientific Research
Bolling Air Force Base, DC 20332-6448

From: S. Nemat-Nasser *S Nemat-Nasser*

Subject: Final Technical Report; Grant AFOSR-84-0004
to Northwestern University, "Flow and Failure of
Rocks, Concrete, and Other Geomaterials"

I. OBJECTIVE AND SUMMARY

The objective of this research project was the experimental and theoretical investigation of the micromechanics of flow and failure of rocks and concrete at moderate to very high pressures. It was expected that this effort would lead to macroscopic nonlinear constitutive models which reflect realistically the micromechanical events that produce observed macroscopic nonlinear and anisotropic responses of materials of this kind.

The theoretical work was based on the principal investigator's recent contributions to the micromechanical modeling of nonlinear material response. It included calculations of microcrack initiation under overall compression, interaction between cracks, and the final failure mode of materials such as rocks. In particular, attention was focused on the influence of pressure and temperature on the failure mode and on the transition from brittle to ductile response. During the research year 1983-84, the modeling of observed axial splitting and faulting at moderate pressures and low temperatures was completed. During the 1984-85 research year, we focused our efforts on understanding and modeling the brittle-ductile transition at elevated pressures and temperatures. The experimental effort was carefully coordinated with the theoretical one. It consisted of qualitative and quantitative model studies in order to identify and understand the involved micromechanics.

II. PROGRESS

During this research year, effort has been concentrated on completing the microscopic modeling; analyzing the phenomenon of faulting under moderate confining pressures; and understanding the transition from brittle to ductile failure, under suitably high confining pressures, of brittle solids containing microdefects such as pre-existing cracks. Manuscripts of the following work were completed and submitted for publication, and a number of these articles have already appeared, or will soon appear, in print.

1. H. Horii and S. Nemat-Nasser, "Elastic Fields of Inhomogeneities," *Int. J. Solids Structures*, 21 (1985) 731-745.
2. H. Horii and S. Nemat-Nasser, "Brittle Failure in Compression: Splitting, Faulting, and Brittle-Ductile Transition," *Proc. Roy. Soc. London* (1986). (Considerable effort has been devoted to completing this manuscript, which is a rather comprehensive account of our work supported by AFOSR).

In addition, the following papers have been published:

3. S. Nemat-Nasser and H. Horii, "Micromechanics of Fracture and Failure of Geomaterials in Compression," Proceedings of the ICF 6th Int. Conf. on Fracture, New Delhi, India, December 4-10, 1984; Pergamon Press, 1984, Vol. 1-R, pp. 515-524.
4. S. Nemat-Nasser and H. Horii, "Rock Failure in Compression," *Int. J. Engrg. Sci., Letters in Appl. and Engrg. Sciences*, 1984, Vol. 22, No. 8-10, pp. 999-1011.
5. H. Horii and S. Nemat-Nasser, "Compression-Induced Micro-Crack Growth in Brittle Solids: Axial Splitting and Shear Failure," *J. Geophys. Res.*, 1985, Vol. 90, No. B4, pp. 3105-3125.
6. S. Nemat-Nasser and H. Horii, "Mechanics of Brittle Failure in Compression," *Computers & Structures*, 1985, Vol. 20, No. 1-3, pp. 235-237.

In addition, the following papers were revised as required during the review process, considerably improved and expanded, and the final manuscripts were submitted for publication:

7. B. Rowshandel and S. Nemat-Nasser, "Finite Strain Rock Plasticity: Stress Triaxiality, Pressure, and Temperature Effects," *Soil Dynamics and Earthquake Engineering* (in press).
8. B. Rowshandel and S. Nemat-Nasser, "A Mechanical Model for Deformation and Earthquake on Strike-Slip Faults," *Pure and Applied Geophysics* (in press).

III. SUMMARY OF RESEARCH ACCOMPLISHMENTS

Under the AFOSR Grant No. AFOSR-84-0004, we completed a micromechanical modeling of faulting in rocks under moderate confining pressures. The essential microdefects considered in this case are pre-existing microcracks. We also made a considerable advance in the modeling the brittle to ductile transition process. The analytic formulation of this problem was completed. A number of model experiments were performed to illustrate the brittle ductile transition.

A new MTS machine, capable of biaxial loading, was obtained under other funding. It was delivered and erected in the principal investigator's laboratory at UCSD during the month of July, 1985, and we have used the

machine since September of 1985. This facility has been very important in our quantitative model experiments on the micromechanics of the failure modes of brittle solids, such as concrete, containing inclusions.

IV. REPRINTS

Sixteen copies of reprints of each paper published under Grant No. AFOSR-84-0004 are enclosed. (Reprints of the papers still in press will be provided as we receive them.)

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