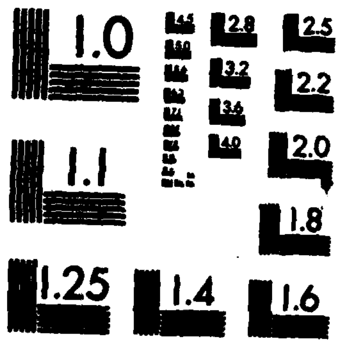
AD-A181 381 FLOW AND FAILURE OF ROCKS CONCRETE AND OTHER GEOMATERIALS(U) NORTHWESTERN UNIV EVANSTON IL S NEMAT-NASSER 27 OCT 86 AFOSR-TR-87-0596 AFOSR-84-0004 1/1

UNCLASSIFIED F/G 20/11 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

UNCLASSIFIED

DTIC FILE COPY

(2)

SECURITY C

AD-A181 381

DTIC ELECTE MAY 2 7 1987 S D D

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLAS	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) AFOSR-TR- 87-0596
6a. NAME OF PERFORMING ORGANIZATION NORTHWESTERN UNVICERSITY; 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION AFOSR/NA
6c. ADDRESS (City, State and ZIP Code) NORTHWESTERN UNIVERSITY EVANSTON, ILL 60201	7b. ADDRESS (City, State and ZIP Code) Bld 410 BOLLING AFB DC 20332-6448
8a. NAME OF FUNDING/SPONSORING ORGANIZATION AF OFFICE OF SCIENTIFIC RESEARCH; 8b. OFFICE SYMBOL (If applicable) AFOSR/NA	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER AFOSR-84-0004
8c. ADDRESS (City, State and ZIP Code) Bld 410 BOLLING AFB DC 20332-6448	10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
61102F	2302	C1	

11. TITLE (Include Security Classification) FLOW & FAILURE OF ROCKS, CONCRETE & OTHER GEOMATERIALS

12. PERSONAL AUTHOR(S) NEMAT-NASSER, S

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
FINAL	FROM 1 Oct 83 TO 31 Oct 85	Oct 27, 1986	3

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	MICROMECHANICAL MODELING, EXPERIMENTS, BRITTLE-DUCTILE TRANSFORMATION

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

THIS RESEARCH WAS TO INVESTIGATE THE MICROMECHANICS OF FLOW AND FAILURE OF ROCKS AND CONCRETE AT MODERATE TO VERY HIGH PRESSURES. THE TEHORETICAL WORK WAS TO EVALUATE MICRO-CRACK 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.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER (Include Area Code)	22c. OFFICE SYMBOL
DR SPENCER T WU	202-767-4935	AFOSR/NA

DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE. UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

UNIVERSITY OF CALIFORNIA, SAN DIEGO

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO   SANTA BARBARA • SANTA CRUZ

DEPARTMENT OF APPLIED MECHANICS AND ENGINEERING SCIENCES, MAIL CODE B-010   LA JOLLA, CALIFORNIA 92093

Rec'd OCT 28 '86

October 27, 1986

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

AFOSR-TR- 87-0596

From: S. Nemat-Nasser S Nemat-N

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.

87 5 21 328

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.)

END
7-87
DTIC