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THE GEOTECHNICAL BOARD
National Research Council

Activities Report
March 1, 1991 - June 30, 1992

This report covers the activities of the Geotechnical Board and its two national committees, the U.S. National Committee for Rock Mechanics (USNC/RM) and the U.S. National Committee on Tunneling Technology (USNC/TT), for the period from March 1, 1991 to June 30, 1992. *The report covers a 16-month period, through June of this year, to bring the reporting period in line with the National Research Council's (NRC) fiscal year. Subsequent reports will cover the 12-month period July 1-June 30, unless individual contracts require otherwise.*

A description of the Geotechnical Board and its committees within the context of the National Academy of Sciences/National Research Council, as well as lists of current members of the board and national committees can be found in **Attachment A**.

A list of attachments follows:

- (A) Description and membership rosters for the Geotechnical Board and its committees
- (B) Summaries of the April and July 1991 Geotechnical Board meetings; a copy of the Geotechnical News article discussing the December 1991 Geotechnical Board meeting
- (C) Sponsors of the Geotechnical Board
- (D) 1992 Program of the Geotechnical Board
- (E) Description and membership roster for the Committee on Reliability Methods for Risk Mitigation in Geotechnical Engineering
- (F) Description and membership roster for the Committee on Physical Infrastructure Technology Research Needs for the 21st Century
- (G) Description and membership roster for the Committee on Fracture Characterization and Fluid Flow in Rock
- (H) Status report of the report of the Committee on Fracture Characterization and Fluid Flow
- (I) Summaries of the July 1991 and January 1992 meetings and the agenda for the June 1992 meeting of the U.S. National Committee for Rock Mechanics
- (J) Information about the 32nd and 33rd U.S. Rock Mechanics Symposia
- (K) Recipients of the 1991 and 1992 Rock Mechanics Awards
- (L) U.S. National Committee for Rock Mechanics annual report and chairman's newsletter
- (M) Summary of the June 1991 meeting and Task Items from the February 1992 meeting of the U.S. National Committee on Tunneling Technology
- (N) U.S. National Committee on Tunneling Technology and the International Tunnelling Association
- (O) U.S. National Committee on Tunneling Technology chairman's newsletter

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ACTIVITIES OF THE GEOTECHNICAL BOARD

During the reporting period the Geotechnical Board met three times--in April, July, and December 1991. Summaries of the April and July meetings can be found in **Attachment B**; included in this attachment is a copy of an article by Peter Smeallie and Robert Schuster that appeared in the July 1992 issue of Geotechnical News about the December meeting. This meeting consisted of the board's sponsors making presentations about the geotechnical activities in their own agencies with the purpose of informing and interacting with board members and other agency personnel.

The board welcomed one new core sponsor during the period, the Federal Highway Administration. A complete list of sponsors and sponsoring agencies is located in **Attachment C**.

The overall focus of the board during the period was to begin to undertake committee studies under the auspices of the board and the national committees. **Attachment D** describes the 1992 program plan for the board and its committees. "Reliability Methods for Risk Mitigation in Geotechnical Engineering" is a study that features a workshop on reliability assessment methods in geotechnical engineering. The purpose of the workshop and the focus of the subsequent report are to examine the role of probabilistic models in characterizing geotechnical uncertainties. A description of the study and the committee list can be found in **Attachment E**.

At the request of the National Science Foundation and in conjunction with the NRC's Building Research Board, the Geotechnical Board began an extensive study to assist NSF with identifying areas of emphasis and research priorities for civil infrastructure systems (public works) that can be integrated into NSF research programs. A description of the study and the committee list can be found in **Attachment F**.

ACTIVITIES OF THE U.S. NATIONAL COMMITTEE FOR ROCK MECHANICS (USNC/RM)

During the reporting period, the USNC/RM began and is continuing a major study on "Fracture Characterization and Fluid Flow in Rocks." The purpose of this study is to review the status of current research in fracture characterization and fluid flow in rocks, identify efforts and problem areas in the field, and explore mechanisms to advance the field and better inform the geotechnical community about progress. The study is meant to address three key questions: (1) Where are the important fractures?, (2) How do flow and transport occur in a fracture system?, and (3) How can we predict and effect changes in a fracture system? A description of the study and the committee list can be found in **Attachment G**. In addition, **Attachment H** is a status report on the study given by the chairman, Jane C.S. Long, at the June 1992 U.S. Rock Mechanics Symposium.

During the reporting period, the committee met three times--in July 1991, January 1992, and June 1992. Summaries from the meetings are found in **Attachment I**. The USNC/RM sponsored two of its annual rock mechanics symposia during the reporting period. The 32nd U.S. Rock Mechanics Symposium was held in July 1991 at the

University of Oklahoma in Norman. The 33rd U.S. Rock Mechanics Symposium was held this June in Santa Fe, New Mexico, and, for the first time, was hosted by four national laboratories. Materials on both symposia can be found in **Attachment J**. The USNC/RM awarded its 1991 and 1992 rock mechanics paper awards at the symposia; winners are listed in **Attachment K**.

Finally, other activities of the USNC/RM, including the U.S. affiliation with the International Society for Rock Mechanics, can be found in a copy the annual report of the committee and the chairman's newsletter, **Attachment L**.

ACTIVITIES OF THE U.S. NATIONAL COMMITTEE ON TUNNELING TECHNOLOGY (USNC/TT)

The USNC/TT met twice during the reporting period—in June 1991 and in February 1992. Materials from these meetings can be found in **Attachment M**. The committee's representation of the United States in the International Tunnelling Association (ITA) grew much stronger during the reporting period as delegations attended ITA meetings in England and Mexico. At the 1992 ITA meeting USNC/TT member Richard Robbins was elected vice president of the association. The U.S. now has official representation on the ten ITA working groups. **Attachment N** contains materials about the USNC/TT's work with the ITA.

As part of its efforts to improve underground construction's safety and cost performance, the USNC/TT has planned a "Symposium on Underground Construction Safety Management for the Superconducting Super Collider (SSC)" to be held in July 1992 near the site of the proposed SSC in Texas. This two-day symposium will feature presentations on other large, successful projects by experts in all aspects of underground safety management, including insurance.

Finally, other activities of the USNC/TT can be found in a copy of the chairman's newsletter, **Attachment O**.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

AN INTRODUCTION TO THE GEOTECHNICAL BOARD

"Every work of man is built on, in, or with the earth, except those things that fly, float, or fall down, and these last three must start or end with some earth contact." With this somewhat comprehensive statement concerning the built environment, the Geotechnical Board began its identifying report in 1989. The board had been established two years earlier to provide advice to the U.S. government on matters of geotechnical engineering and science. The report, Geotechnology—Its Impact on Economic Growth, the Environment, and National Security, is aimed at federal agencies and other organizations to define national issues in terms of geotechnical considerations.

The Geotechnical Board Within the Academy Complex

In order to understand the services the Geotechnical Board offers the government and others, it is necessary to understand the origins, organization, and operation of the National Academy of Sciences and its operating agency, the National Research Council.

In 1863, at the height of the U.S. Civil War, Congress chartered the National Academy of Sciences as a private, nonprofit association dedicated to the furtherance of science and engineering for the public welfare. The Academy's charter, signed by President Abraham Lincoln, states that the Academy shall "whenever called upon by any department of the Government, investigate, examine, experiment, and report upon any subject of science or art" with "actual expense" but "no compensation whatever" to be paid (meaning that the advice is given by persons who volunteer their services). It is interesting to note that "art" in 1863 was taken to mean "technology" in relation to science.

At first, the Academy rendered its advice to the country through committees appointed from among its own honorary membership. By the time of World War I, however, the country's need for scientific and technical advice outstripped the ability of the Academy's then 150 members to respond.

To enable it to draw upon the broad resources of the entire U.S. scientific and technical community, the Academy established the National Research Council in 1916. In 1918 President Woodrow Wilson perpetuated the Research Council by executive order.

Today, the National Research Council stands as the principal operating arm of the National Academy of Sciences and the National Academy of Engineering, a sister organization established by the Academy of Sciences in 1964. An Institute of Medicine was established in 1970, under the charter of the National Academy of Sciences, to conduct studies of health policy issues.

The majority of the National Research Council's work is done in response to specific questions from federal agencies or from the Congress. The Research Council also is supported in part by philanthropic foundations, industry, and other organizations.

Each study, prior to initiation, must be approved by the National Research Council's Governing Board. After project approval, a committee is assembled with special care for appropriate expertise and balance of points of view. Most committee projects result in formal reports. Draft reports are subjected to rigorous peer review by independent reviewers to warrant the scientific validity of the committee's work. All National Research Council reports (except those few that are classified) are made public. Each year about 300 reports are issued; many of these are published for sale by the National Academy Press, the publishing arm of the Research Council.

The National Research Council's Areas of Major Concern

The National Research Council is unique among U.S. institutions, carrying out independent studies that provide advice to the nation on its most critical scientific and technical questions. Its advice takes many forms: early warnings of potential concerns, proposals to solve problems and set priorities, guidance in planning and policy formation, evaluation of programs, assessment of risks and benefits, encouragement of the health and progress of the scientific disciplines.

The work of the National Research Council is performed by voluntary committees. Each year some 8,000 scientists, engineers, and other professionals contribute their advice and expertise to the solution of national problems through service on approximately 800 Research Council committees. These men and women are drawn from every part of the country and from every sector—academia, government, industry, nonprofit, and public interest groups. This ability to tap the resources of the nation's entire scientific and technical community is one of the National Research Council's greatest assets.

Like science and engineering, the work of the Research Council is spread over many areas of concern. The Commission on Physical Sciences, Mathematics, and Applications is broadly concerned with ensuring the health and progress of the physical and chemical sciences, the mathematical sciences, the space and planetary sciences, computer science and technology, measurement science and technology, and the management of scientific and technical information. The work of the Commission on Behavioral and Social Sciences and Education is focused on bringing the knowledge, analytical tools, and methods of the behavioral and social sciences to bear upon the major challenges facing the nation. The Commission on Life Sciences seeks to contribute to the advancement of the life sciences in fields such as biology, biotechnology, toxicology, and environmental health issues. The Commission on Geosciences, Environment, and Resources includes atmospheric and climate sciences, earth sciences, global change research, geology, seismology, and other fields of interest related to geotechnology. Other major units of the National Research Council are the Coordinating Council for Education, the Office of International Affairs, the Office of Scientific and Engineering Personnel, the Board on Agriculture, the Transportation Research Board and the Strategic Highway Research Program, the Mathematical Sciences Education Board, and the Board on Sciences, Technology and Economic Policy.

The commission under which the Geotechnical Board operates, called the Commission on Engineering and Technical Systems, is, in addition to issues of geotechnology, involved with building and construction science, manufacturing

technologies including productivity and the U.S. competitive position, engineering education, technology for national defense, materials processing and application, natural disaster mitigation, marine engineering, aeronautics, practical uses of space technology, and energy engineering.

The Geotechnical Board was established in 1987 when the Governing Board of the National Research Council approved the formation of the board to provide the Research Council with a unified capability to address issues of geotechnology. The board addresses these issues by providing technical input and advice to government agencies for policy-making and by serving as a stimulus to the geotechnical community for research and technology transfer. From its organizing charter, the Geotechnical Board's objectives are given:

- Investigate geotechnical issues; recommend actions to government and the public,
- Advance geotechnical science and engineering through improvements in education, research, and practice,
- Enhance cooperation among public and private organizations, and
- Enhance international cooperation among scientific, technical, and professional societies concerned with geotechnical issues.

The Geotechnical Board addresses issues that have risen to the forefront of public concern, the resolution of which requires geotechnical input. Current issues identified by the board include:

- the role of geotechnology in waste management and environmental protection,
- infrastructure development and rehabilitation,
- national security,
- frontier exploration and development, such as polar regions, deep oceans, and the lunar surface,
- resource discovery and recovery,
- mitigation of natural hazards, and
- construction efficiency, safety and innovation.

As one of its current activities, the board plans to convene a workshop on safety and reliability assessment methods in geotechnical engineering. The purpose of the workshop will be to examine the role of probabilistic models in characterizing geotechnical uncertainties. It is generally acknowledged that uses of reliability theory—methods of quantifying risks that would otherwise be dealt with qualitatively through the use of

engineering judgment—have been more limited than was first expected in the early 1970s when reliability theory was promised to revolutionize geotechnical practice. The workshop will consist of invited "probabilists" (those who advocate the use of reliability methodology) and "traditionalists" who will present papers that will examine the reasons for the current state of affairs, and discuss the possibilities for deriving greater benefit from reliability methodology. The workshop, to be held in the spring, 1992, will result in a report to be issued in the fall, 1992, that will summarize the results of the workshop, addressing the needs of both practitioners and researchers. The report will propose ways to enhance greater communication and cooperation between probabilists and traditionalists.

The Geotechnical Board is also responsible for oversight of two long-standing committees—the U.S. National Committee on Tunneling Technology and the U.S. National Committee for Rock Mechanics—the interests and activities of which fall within the scope of geotechnology.

U.S. National Committee for Rock Mechanics

As a result of a recommendation from a National Research Council committee, the U.S. National Committee for Rock Mechanics was established in 1967. In 1971 the rock mechanics committee was merged with the Intersociety Committee for Rock Mechanics to provide a focal group to represent the national and international interests of the United States.

The committee provides advice on national needs in rock mechanics such as recovery of energy resources, protection of the environment, mitigation of natural disasters, and national defense. The committee synthesizes ongoing rock mechanics research and development activities through its sponsorship of the annual U.S. rock mechanics symposium.

The latest symposium, the 33rd U.S. Rock Mechanics Symposium, was held June 8-10, 1992, in Santa Fe, New Mexico. The symposium was hosted by Lawrence Berkeley Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Sandia National Laboratories. The symposium combined technical sessions with special lectures, topical workshops, and introductory short courses. Short courses were offered on fractals and on statistical methods of rock mass characterization.

The U.S. National Committee for Rock Mechanics has launched a major new study to review characteristics of fracture networks and fluid flow in rock fractures. The review will provide a statement of current research and guidance for field applications. It will cover research in fracture origin, morphology, geophysical imaging, and flow and transport analysis and modeling. A committee has been appointed under the auspices of the National Research Council; it is chaired by Dr. Jane C.S. Long and consists of 12 other members representing diverse fields including fracture hydrogeology, fracture geology, borehole and radar geophysics, rock mechanics, geochemistry, and statistics. Partial support for the study titled, "Annual Review of U.S. Progress in Rock Mechanics: Fracture Characterization and Fluid Flow," is provided by the Nuclear Regulatory Commission, the

Department of Energy, the Bureau of Mines, the Environmental Protection Agency, the Gas Research Institute, Dowell Schlumberger, and Exxon Production Research.

The U.S. National Committee for Rock Mechanics disseminates rock mechanics information through annual awards for distinguished papers, and it participates in the activities of the International Society for Rock Mechanics (ISRM) on behalf of U.S. scientists, engineers, and technologists interested in rock mechanics.

U.S. National Committee on Tunneling Technology

The U.S. National Committee on Tunneling Technology was organized in 1971 as a result of a recommendation by the Organization for Economic Cooperation and Development (OECD). The committee addresses issues concerning tunneling engineering in terms of advancing tunneling technologies, improving engineering education, and examining potential impacts on and implications for government policies, regulations, and programs. It identifies technical needs for which research is appropriate and recommends ways for the federal government to best take advantage of new tunneling technologies and practices. It participates in activities of the International Tunnelling Association (ITA) on behalf of U.S. scientists, engineers, and technologists interested in tunneling technology.

The U.S. National Committee on Tunneling Technology is undertaking a number of interesting initiatives on diverse subjects such as tunnel construction safety, impacts of global trends and foreign influences on the U.S. underground industry, prioritization of national needs of the tunneling industry, pros and cons of the use of ribs and lagging, assistance to the high-level nuclear waste industry, infrastructure needs and lunar tunneling.

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**Geotechnical Board Meeting
National Academy of Sciences' Georgetown Facility
Washington, D.C.
April 2-3, 1991**

SUMMARY OF MEETING

Purpose of the Meeting. Peter Smeallie explained the purpose of this board meeting in the context of three larger goals that coincide with the three latest meetings of the board:

1. Internal: To bring the board and the two national committees to greater familiarity and standing within the academy complex through liaisons with other boards, greater involvement with the Commission on Engineering and Technical Systems (CETS) and its strategic plan, and more use of National Research Council (NRC) resources such as Program Initiation Funds (PIF) and other NRC funds.

2. External: To make known, and in some cases, to introduce, to the board's federal sponsors the capabilities of the board in context of the NRC through activities such as the dinner and meeting in November 1990, regular transmittals to sponsors, individual meetings between sponsors and staff and board members, and other outreach and dissemination programs.

3. External: To expand the base of sponsorship and the range of activities of the board by bringing in new core support, by beginning to formalize the federal geotechnical council idea, and by initiating studies that are independently supported from core funds.

Discussion of Bias. The committee held the required bias discussion, the results of which are contained in a separate, confidential memorandum.

Reports. Arch Wood, executive director of CETS, reported that CETS is in the process of reviewing itself primarily through the development of its "Strategic Plan." Three initiatives were highlighted for potential work with the CETS boards: 1) brokering environmental solutions, 2) handling risk in engineered solutions, and 3) infrastructure. Jim Mitchell commented that the Geotechnical Board (GeoBoard) is relevant to each of these initiatives.

Andrew Lemer, director of the Building Research Board (BRB), described the BRB's infrastructure colloquium series which currently is receiving support from the National Science Foundation (NSF) and the Army Corps of Engineers. A further infrastructure study on research opportunities, to be sponsored by NSF, will be conducted jointly by the BRB and the GeoBoard. The GeoBoard endorsed the prospectus for this study.

Harvey Parker, chairman of the U.S. National Committee on Tunneling Technology (USNC/TT), described ongoing initiatives of the committee. Efforts to interest the Occupational Health and Safety Administration to fund a tunnel safety project have been unsuccessful, but the Department of Energy (DOE) has expressed an interest. The committee is exploring possibilities for providing technical assistance to the high-level nuclear waste program of DOE, in conjunction with the Nuclear Waste Technical Review Board. There is also interest from DOE on tunneling contracting practices for the nuclear

waste disposal program. Internal initiatives include the impact of foreign influence in tunneling and prioritization of underground research needs. Dr. Parker reported that the U.S. is in a strong position in the international tunneling community, especially with committee member Richard Robbins nominated for the Executive Council of the International Tunnelling Association (ITA). The GeoBoard endorsed this nomination. (Mr. Robbins was subsequently elected to the council at the April, 1991, meeting of ITA.)

Wolfgang Wawersik, chairman of the U.S. National Committee for Rock Mechanics (USNC/RM), reported on activities of the committee in light of his stated goal of maximizing the impact of the USNC/RM. A report on borehole stability, chaired by Jean-Claude Roegiers, is in NRC review. The study on fracture characteristics and fluid flow has been approved by the NRC and the committee, chaired by committee member Jane Long, is planning its first meeting to be held in Washington in early May. The GeoBoard endorsed the slate of nominees for the fracture characterization committee. The 32nd U.S. Symposium on Rock Mechanics is to be held in July at the University of Oklahoma; Dr. Roegiers is the host and he reported that 195 papers have been received; 130 have been accepted. Seventeen papers have been nominated for the annual rock mechanics awards.

The GeoBoard invited other board directors to present information about their respective activities. The following presentations were made: Steven Parker, Water Sciences and Technology Board; Kerstin Pollack, Board on Engineering Education; Kevin Burke, Board on Earth Sciences and Resources; Andrew Lemer, Building Research Board; Riley Chung, Division of Natural Hazards Mitigation; and G.P. Jayaprakash, Transportation Research Board. GeoBoard liaison representative Ron Smith described the upcoming ASFE conference in San Francisco emphasizing its focus on construction safety.

Future Lunar Geotechnical Research Needs. The board welcomed David Carrier, president of the Lunar Geotechnical Institute; Barney Roberts, manager of the NASA Planet Surface Systems Office; Connie Buoni, SAIC; and Tamara Dickinson from NASA. In a discussion concerning a potential workshop on the subject the following points were made:

- The Lunar Geotechnical Institute would be involved in the planning aspects of the effort.
- A lunar sourcebook has been published by Cambridge University Press.
- There is a need for simulant research, but it is not clear to NASA what to simulate for different circumstances.
- There is also a need for a list of design parameters for lunar soils as well as a description of generic (hypothetical) sites.
- A workshop should avoid shopping lists of needs and develop directed topical discussions.
- There is interest in NASA for support of a workshop; other possibilities include Bureau of Mines, the Army Corps of Engineers, and DOE.
- There is also a possibility of NRC support through the PIF mechanism; staff will explore.

The board endorsed continued development of a workshop on future lunar geotechnical research needs with the Lunar Geotechnical Institute. Expertise from the USNC/TT and the USNC/RM should be brought in.

Safety and Reliability Assessment Workshop. Wilson Tang and Michael Duncan distributed materials on plans for a workshop that would have as its purpose an examination of the less-than-universal acceptance of probability methods in geotechnical engineering. Committee comments included the following:

- The workshop should make a conscious effort to develop curricula in geostatistical methods.
- The workshop should seek to produce an "archival" report and delineate future research directions, although others emphasized that the effort should not be research oriented, but propose questions on where should the probabilistic approach should be used.
- Probability is already built into codes and other standards; there is no need to pose a conflict, rather to explore where it is being used, where it could be used with small improvements, and where it will probably not be used.
- A 20 person workshop would be appropriate; the GeoBoard would be used as the planning committee

The board endorsed continuation of plans for a workshop on safety and reliability assessment in geotechnical engineering. The focus should be on approaches as opposed to disciplines. Attendees should answer a series of questions that will be developed. A committee of the board should be formed to interpret workshop results and issue conclusions and recommendations.

Geotechnology and the Federal Government. Dr. Mitchell explained that he is interested in using core support to return back something of substance to the agencies that provide such support. A workshop could be planned that would be sponsored by the board, perhaps in connection with a board meeting in 1992, and that would involve invited presentations from sponsoring agencies. The board endorsed plans for a seminar, to be held in conjunction with spring 1992 board meeting, on geotechnology and the federal government to feature presentations by federal agency sponsors to an audience of other federal personnel, practitioners, and academics.

Outreach and Dissemination. Mr. Smeallie explained his reasons behind urging the board to table consideration of immediate development of a GeoBoard newsletter: it is expensive, the board is "short on news," and there are more effective ways to communicate items of interest from the board such as existing journals and magazines. Board members expressed strong interest in some type of recapping report, perhaps an annual report.

In-Situ Determination of Soil Properties. Ken Stokoe led a discussion on future directions for geophysical engineering in geotechnology. He agreed to prepare a prospectus, with Bill Gardner, for consideration prior to the next GeoBoard meeting. Dr. Roegiers suggested private sources of support as a possibility.

Geotechnology and Environmental Protection. Jocelyn White and Kate Blow from EIM reported on their activities on behalf of the board. Their purpose is to elevate the presence of the GeoBoard in agencies that have environmental missions through a number of initiatives including meetings with administration officials and outlining potential studies the board could become involved with in the environmental area. For example, the DOE and DOD have substantial increase in budget for clean up of federal facilities.

Are there credible mechanisms for identifying the worst sites? The GeoBoard can lend its opinion on the geotechnical aspects of this question.

The board endorsed renewal of EIM's subcontract. It also encouraged development of proposals for core support from R&D office of EPA and the environmental divisions of DOD and DOE. Concept papers should be developed to pursue advisory studies dealing with role of geotechnology in cleaning up waste sites at federal facilities. The board should also continue to work with EPA on developing studies concerned with (1) remote sensing and monitoring technologies; (2) understanding better subsurface phenomena at waste sites, and (3) application of the observational method for risk assessment at Superfund sites.

Geotechnology and Mining. The board welcomed Peter Crimes, director of technology at the American Mining Congress (AMC), and Peter Chamberlain from the U.S. Bureau of Mines. Mr. Crimes pointed out that industry has virtually eliminated R&D and that he is interested in exploring ways to reinvigorate the technical expertise of AMC's member companies. The AMC is currently organizing a geotechnical working group. Francois Hueze suggested that this initiative be delayed until the AMC's group is formed. The board agreed that Dr. Hueze (and others) should monitor prospects for board involvement in geotechnology and mining.

Invited Agency Presentations. The board expresses its appreciation to Al DiMillio from the Federal Highway Administration, Jeff Mora from the Urban Mass Transit Administration, and John Scango from the SSC office of DOE for their presentations and updates on agency activities.

Next Meeting. The next meeting is scheduled for July 20-22, 1991 in Woods Hole, Massachusetts.

Report prepared by Peter Smeallie.

Geotechnical Board Meeting
Commission on Engineering and Technical Systems
National Research Council

National Academy of Sciences' Georgetown Facility
Green Building, Room 110
2001 Wisconsin Avenue, N.W.
Washington, D.C.

April 2-3, 1991

MEETING ATTENDANCE

MEMBERS

James K. Mitchell, Chairman
J. Michael Duncan
William Gardner
James P. Gould
Francois E. Heuze
Thomas D. O'Rourke
Jean-Claude Roegiers
Reuben Samuels
Robert Schuster
Kenneth H. Stokoe
Wilson H. Tang

LIAISON

Harvey W. Parker, Chairman, USNC/TT
Ronald E. Smith, ASFE
Wolfgang R. Wawersik, Chairman, USNC/RM

GUESTS

Corinne Buoni, Science Applications International Corporation
David Carrier, Lunar Geotechnical Institute
Peter Crimes, American Mining Congress
Tamara Dickinson, NASA, Washington, D.C.
Barney Roberts, NASA Johnson Space Center

SPONSORS

Clifford Astill, National Science Foundation
Peter Chamberlain, Bureau of Mines
Albert DiMillio, Federal Highway Administration
Michael Katona, Air Force Engineering and Services Center
Francis McLean, Bureau of Reclamation (tentative)
Jeffrey G. Mora, Urban Mass Transportation Administration
Jacob Philip, Nuclear Regulatory Commission
William Roper, U.S. Army Corps of Engineers
G. John Scango, Department of Energy, Office of Energy Research
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Stephen D. Parker, Director, Water Science and Technology Board
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Jennifer Estep, Administrative Secretary

**Geotechnical Board Meeting
National Academy of Sciences Study Center
Woods Hole, Massachusetts
July 20-22, 1991**

SUMMARY OF MEETING

Purpose of Meeting Peter Smeallie reviewed the purpose of this Geotechnical Board meeting as an opportunity for the board to step back and examine itself in terms of direction, initiatives, and future goals and objectives. Board members should not attempt to strip back progress made by the board since its inception in 1988. Rather, at this meeting members should seek to unearth new ideas for board initiatives, to discuss new directions for the board, and to identify long-range goals and objectives for the board.

Mr. Smeallie went on to review the state of the Geotechnical Board. He identified a concern that the board return something of value back to the federal agencies that provide the core support. This is currently being done through active participation of federal liaison representatives. In addition, the Federal Geotechnology Workshop will attempt to foster interagency communication and cooperation in the geotechnical arena.

Procurement issues occupy an inordinate amount of staff time. Cashflow problems inhibit effective planning for the board and USNC's. Options being explored include a master agreement with one agency, multiple-year procurement arrangements, and greater use of pre-award authorizations. Jean-Claude Roegiers suggested that staff continue to pursue foundations and other private sources for core and/or special project support of the board.

U.S. National Committee on Tunneling Technology Harvey Parker reported that the USNC/TT has regained its active position in the international arena. Relations and activities with the International Tunnelling Association (ITA) are robust; USNC/TT member Richard Robbins was elected to the ITA executive council at the April 1991 annual meeting in London. The USNC/TT is cooperating actively with other related organizations such as the American Underground Space Association, the Association of Engineering Geologists, and the American Society of Civil Engineers (ASCE).

At its last meeting in Seattle in June 1991, the committee undertook a special one-day session to which outside experts (including Geotechnical Board member Jim Gould) were invited to develop a list of national needs for the tunneling industry given the rising foreign influence on the industry. Among the recommendations that emerged from the session was the suggestion to explore the possibility of USNC/TT restarting the former government Interagency Committee on Excavation Technology (ICET).

U.S. National Committee for Rock Mechanics Dr. Roegiers reported on the success of the 32nd Symposium on Rock Mechanics held in July 1991 at the University of Oklahoma in Norman. He particularly emphasized the active participation of the petroleum engineering community.

He went on to advocate a greater and more active role for the Geotechnical Board in support and participation in the standing activities of the USNC/RM, such as the Rock

Mechanics Symposium. For example, the board could help formulate policies and guidelines for the year-to-year transition of responsibility of the symposium, especially concerning the disposition of excess funds.

The board endorsed the USNC/RM's decision to recommend Barry Brady as the next USNC/RM chairman.

Outreach and Dissemination Mr. Smeallie described his meeting with John Gadsby and Lynn Pugh of the magazine Geotechnical News in June 1991 in Vancouver, Canada. They have offered to run a regular section in each issue on Geotechnical Board activities. The board endorsed the offer to have Mr. Smeallie serve as a coordinating editor for Geotechnical Board activities.

The board also agreed to continue the tabling of a newsletter, opting instead to produce an annual report that has discrete sections for the USNC/TT and the USNC/RM. These sections could be published as a separate annual report for each USNC.

Infrastructure The current Building Research Board (BRB) initiative on holding a series of infrastructure symposia is underway with "success-story" sessions planned for Phoenix, Cincinnati and Boston. The proposal submitted to the National Science Foundation on developing a research agenda for infrastructure for the 21st century has been submitted, but has yet to be awarded.

NRC Board and Other Liaison Activities Dr. Gould suggested that the Geotechnical Board consider using the BRB Technical Report series as a model for its own reports. Phil LaMoreaux lauded the newsletter of the Water Science and Technology Board as a model when and if the board decides to start a newsletter. Richard Woods reported that ASCE has decided not to pursue specialty certification for geotechnical engineers. ASFE was also negative on this. Dr. Woods mentioned that this was the last year of his liaison for ASCE; Mike Duncan will be the new liaison from ASCE. The board expressed its appreciation and commendation for Dr. Woods service. Ron Smith, liaison from ASFE, requested that the Geotechnical Board accept a request from the Institute for Professional Practice to address a future meeting of the board. The board agreed.

On a separate matter the board agreed to explore the prospect of establishing liaison arrangements with the Society of Petroleum Engineers (SPE) and the Association of Engineering Geologists (AEG).

Future Lunar Geotechnical Research Needs Mr. Smeallie reported that a proposal for internal program initiation funds to hold a planning meeting on this topic was turned down at the June meeting of the Academy's Presidents Council. However, there are still indications that the National Aeronautics and Space Administration (NASA) is interested. The board directed staff to investigate NASA's interest in supporting a workshop on the subject given the agency's budget scenario for FY 92.

Geotechnology and Mining The board agreed that Francois Heuze should serve as a liaison representative to the technical steering group of the American Mining Congress.

Safety and Reliability Workshop Jim Mitchell opened the discussion by asking members if it is appropriate for the Geotechnical Board to arrive at a position on this

subject; maybe it would be better for the board to organize a workshop that presents both sides, then delineates principal issues. Wilson Tang and Dr. Duncan led the discussion that included the following points:

- Bill Gardner emphasized that the key concept should be what are the best applications and demonstrate such.
- Dr. Tang stressed the importance to the practitioner—is there any value in using probabilistic approaches?
- Dr. Duncan observed that there are situations where probabilistic methods are appropriate and others where it is not. The workshop should be split into pros and cons.

The board decided to change title of the project to "Workshop on Reliability Methods for Risk Mitigation in Geotechnical Engineering." It also indicated a willingness, given National Research Council (NRC) committee appointment procedures, to have the board itself serve as the study committee for the workshop and the report to follow. The subcommittee to take the lead on planning the workshop would consist of Wilson Tang, Mike Duncan, Bill Gardner, and Bob Schuster. The subcommittee should meet in the fall, after the prospectus is approved by the NRC Governing Board [it was subsequently approved in October 1991] to develop specific plans for the workshop. Staff should explore additional funding opportunities such as insurance companies (Aetna Foundation, Terra, DPIC), FEMA, EPRI, API.

U.S. Agency for International Development (AID) Dr. LaMoreaux reported that the science and technology branch of AID would be interested in a Geotechnical Board presentation on its capabilities in the environmental monitoring area. Staff should contact AID's science and technology director to inquire about interest in working with the board and about setting up a possible meeting. Members of the board should also think about the potential for teams to do site visits, sponsored by host countries (such as in Eastern Europe), on environmental issues, such as methods and concepts of environmental monitoring. Dr. Gould suggested other Department of State offices should be contacted for core support such as the Office of Foreign Disaster Assistance and the Office of Foreign Building Operations.

Geophysical Engineering in Geotechnology Ken Stokoe distributed a draft prospectus for comment. The prospectus proposes a two-day workshop to begin to develop a report on future directions in this area. The workshop would allow cross fertilization of engineering geophysicists to occur. The board indicated that the subject is a very pertinent issue and thus decided to change the methodology of proposed activity from a workshop to a committee study of which a workshop would be a part. The board also debated the scope of including the down-low technologies as well as the surface technologies. Dr. Mitchell observed that the discussion makes it clear that there is value for each group and suggested that the subject deserves a broader kind of program. For example, individuals with deep (> 50m) geophysical expertise should be involved. Potential sponsors of the study include AFOSR, USGS, EPA, DNA, BuMines, as well as logging companies (GEICO, Wellex).

Federal Geotechnology Workshop The board decided that the workshop should be held in the fall, 1991, rather than the spring, 1992. The board selected December 12, 1991, as the date. A focus of the workshop should be what the Geotechnical Board can do for each agency presenting material. Dr. Mitchell observed that a lot of geotechnical work is undertaken by agencies of the federal government; the Geotechnical Board could give something back to our sponsors by holding this workshop by and for federal agency personnel.

New Business Dr. Roegiers began this section of the meeting by suggesting that board members visit federal laboratories in their area. He relayed the impressive and successful visit that he, Jane Long (chairman of the Committee on Fracture Characterization and Fluid Flow), and Peter Smeallie made in July, 1991, to the EPA Kerr Lab in Ada, Oklahoma.

Dr. Mitchell asked board members if the strategy of the board should shift from attempting to interest agencies in the core activities of the board to having the board develop prospectuses on topics it intends to undertake (such as the reliability workshop model) and then seek support for an "ongoing" study. In terms of the EPA, the board agreed to shift primary emphasis from attempting to interest EPA in core support to developing a prospectus or prospectuses on issues. Attempts should include DOD and DOE, as well.

Mr. Smith remarked that the municipal solid waste market needs advice on geotechnical design concepts. This is ten times larger than waste sites.

Dr. Mitchell pointed out that from the perspective of the geotechnical engineer in the field the problems concern the regulatory environment, site characteristics, public perceptions, and the fallacy of the public perception of risk. Mr. Gardner added that EPA's problem is overstudy and overregulation forced on the agency by the way current laws are written. Dr. Mitchell observed that the European Community has drafted guidelines for landfills and has adopted technologies from other parts of the world. Dr. Heuze commented that consideration should be given to reverse technology transfer, where, for example, foreign environmental remediation technology could be brought in to EPA and others. But, as Dr. Mitchell remarked, technology is far ahead of the ability to implement.

The board agreed to develop a prospectus for a board-initiated study on use of the observational method for the clean up of federal facilities.

Committee Membership The board agreed to circulate a proposal for reappointment of Dr. Mitchell as chairman for another term and reappointment of Dr. Heuze as board member for another term. Members were asked for suggestions for NAS/NAE or other qualified individuals to take the place of outgoing members Drs. Duncan and Stokoe.

Next Meeting The board set the next meeting for December 12-13, 1991, in Washington, D.C., in conjunction with the Federal Geotechnology Workshop.

Report prepared by Peter Smeallie

**Geotechnical Board Meeting
Commission on Engineering and Technical Systems
National Research Council**

**National Academy of Sciences
Woods Hole Study Center
314 Quissett Avenue
Woods Hole, Massachusetts**

July 20-22, 1991

ATTENDEES

Members

**James Mitchell, Chairman
J. Michael Duncan
William Gardner
James Gould
Francois Heuze
Philip LaMoreaux
Jean-Claude Roegiers
Robert Schuster
Kenneth Stokoe
Wilson Tang**

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Richard Woods, ASCE
Harvey Parker, Chairman, USNC/TT**

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**National Aeronautics and Space
 Administration**

1992 PROGRAM OF THE GEOTECHNICAL BOARD

The Geotechnical Board and its two standing committees—the U.S. National Committee on Tunneling Technology and the U.S. National Committee for Rock Mechanics—have developed a program of studies and activities to address priority geotechnical issues facing the nation. Agencies that provide support interact with the Geotechnical Board to help define the core activities program.

Geotechnical Board core activities consist of the following:

- *Workshop on Reliability Methods for Risk Mitigation in Geotechnical Engineering.* A current study that will convene a workshop on safety and reliability assessment methods in geotechnical engineering. The purpose of the workshop will be to examine the role of probabilistic models in characterizing geotechnical uncertainties. It is generally acknowledged that uses of reliability theory—methods of quantifying risks that would otherwise be dealt with qualitatively through the use of engineering judgment—have been more limited than was first expected in the early 1970s when reliability theory was promised to revolutionize geotechnical practice. The workshop will consist of invited "probabilists" (those who advocate the use of reliability methodology) and "traditionalists" who will present papers that will examine the reasons for the current state of affairs, and discuss the possibilities for deriving greater benefit from reliability methodology. The workshop, to be held in the spring, 1992, will result in a report to be issued in the fall, 1992, that will summarize the results of the workshop, addressing the needs of both practitioners and researchers. The report will propose ways to enhance greater communication and cooperation between probabilists and traditionalists.

- *Future Directions for Geophysical Engineering in Geotechnology.* A candidate study to identify research needs and future directions for geophysical engineering in geotechnology. The focus of the study will be placed on in-situ characterization of site conditions, nondestructively and noninvasively. The need to identify and prioritize research requirements results from the combination of increased demands for site characterization by remote sensing techniques, increased needs to monitor continuously the integrity and safety of geotechnical systems, the continued progress in the area of analytical modeling that exceeds the capability of the field measurements, the continued shortfall in the production of trained graduates in this area, and the continued need to optimize the limited funds that can be directed towards research either by government agencies or private industry.

Whereas progress in the areas of geophysical engineering and geotechnology has led to better understanding and capabilities in specific aspects of site characterization, the overall ability of the profession to characterize confidently a site for various functions such as hazardous waste storage or underground development has not necessarily advanced.

- *Use of the Observational Method for the Clean Up of Federal Facilities.* A candidate study to advise agencies charged with environmental clean up of federal

facilities on the application and appropriate use of the observational method—widely understood and practiced in geotechnical engineering—for waste site remediation. The observational method uses observed field performance data from carefully planned monitoring programs to plan remediation strategies. Critical issues on which the Geotechnical Board will focus attention include: (1) the identification of possible deviations from the best initial characterization of the site, (2) the determination of what quantities to observe, and (3) the development of subsequent geotechnical response actions. The board is also considering the feasibility of using a probabilistic framework to complement existing observational methods.

- *Geotechnology and Mining.* A candidate program with a view toward mining in the 21st century. Items identified for consideration include the role of automation in mining, expert systems for safety and ground support, degasification practices, underground hydraulics, and the secondary use of underground space (i.e., post-mining).

U.S. National Committee for Rock Mechanics, a standing committee of the Geotechnical Board, advises the federal government on issues of rock mechanics and rock engineering. The USNC/RM sponsors the annual U.S. Rock Mechanics Symposium, the 33rd of which will be held in Santa Fe, New Mexico, in June 1992. At the symposium, the committee announces the rock mechanics awards that seek to promote, recognize, and highlight excellence in U.S. papers and theses published on rock mechanics. The USNC/RM serves as the official U.S. national group of the International Society for Rock Mechanics (ISRM). Participation in the ISRM helps further the interests of maintaining U.S. technological leadership in rock mechanics. The USNC/RM works with interested government agencies to identify areas of concern in the rock mechanics field where the National Research Council (NRC) advisory committee capability can be brought to bear. Currently, an NRC committee is conducting a study on fracture characterization and fluid flow.

- *Fracture Characterization and Fluid Flow.* Over the past two decades, the importance of characterizing and understanding fluid flow in fracture systems has increased dramatically. Fractured petroleum reservoirs have become more important as a national resource. Most recently, fractures have been found to play a major role in containment transport at significant number of sites across the national. Tunnels and mines in hard rock consistently encounter fracture-related problems. Many of these problems have been considered intractable because fracture networks are notoriously chaotic and poorly interconnected. Consequently, recent research concerning techniques and approaches developed in separate arenas, while extensive, has not been reviewed, integrated, and communicated throughout the geotechnical community.

A committee has been appointed to review the status of current research in fracture characterization and fluid flow, to identify efforts and problem areas in the field, and to explore mechanisms to advance the field and better inform the geotechnical community about progress.

The USNC/RM will begin an additional study within the next 6 to 8 months. The topic of this study is a review of the state of R&D in rock mechanics including an

examination of the role of universities, industry, government, and the national laboratories.

U.S. National Committee on Tunneling Technology advises the federal government on issues of tunneling and underground space technology. The USNC/TT represents the United States as the official adherent to the International Tunnelling Association (ITA). Participation in the ITA helps further the interests of maintaining U.S. technological leadership in tunneling. The USNC/TT carries out activities, such as symposia and other outreach activities, that serve as forums for individuals from universities, industry, practice, and government to debate and discuss issues concerning the use of tunnels and other underground space. Candidate activities include:

- *Use of Tunneling and Underground Space for Infrastructure Improvement.* This program plans to examine two topics: (1) planning and allocation of urban underground space, and (2) anticipated impact of recent advances in tunneling technology on the underground infrastructure in the future.
- *Surface or Underground Planetary Basing.* A candidate program to conduct a workshop that would identify the advantages and disadvantages of surface or underground basing and construction. Any basing or development on extraterrestrial bodies will require excavation and the application of geotechnology.
- *Safety in Construction.* A candidate program to help agencies with tunneling projects or regulatory oversight on policy direction for its safety-related implementation and enforcement actions on construction sites. The USNC/TT believes the construction safety issue is broader than tunnel construction, per se, and advocates an initiative with other relevant boards of the NRC such as the Building Research Board.

National Research Council
Geotechnical Board

**PROSPECTUS FOR THE
WORKSHOP ON RELIABILITY METHODS FOR RISK MITIGATION IN
GEOTECHNICAL ENGINEERING**

Project Summary

The Geotechnical Board of the National Research Council will convene a workshop on reliability methods for risk mitigation in geotechnical engineering on July 14-16, 1992, in Irvine, California. The purpose of the workshop will be to examine the role of probabilistic models in characterizing geotechnical uncertainties. It is generally acknowledged that uses of reliability theory—methods of quantifying risks that would otherwise be dealt with qualitatively through the use of engineering judgment—have been more limited than was first expected in the early 1970s when reliability theory was promised to revolutionize geotechnical practice. The workshop will consist of invited "probabilists" (those who advocate the use of reliability methodology) and "traditionalists" who will examine the reasons for the current state of affairs, and discuss the possibilities for deriving greater benefit from reliability methodology. The workshop will result in a report to be issued in the fall, 1992, that will summarize the results of the workshop, addressing the needs of both practitioners and researchers. The report will propose ways to enhance greater communication and cooperation between probabilists and traditionalists.

Origin and Background

The issues of safety and reliability are clearly of great importance in geotechnical engineering. Beginning in the 1970s, a number of researchers began to examine how probabilistic and reliability methods could be used to characterize geotechnical uncertainties. Although some practical applications of probability and reliability theory have been made, after 20 years of such effort, most areas of geotechnical engineering have not been influenced to any perceptible degree, and many geotechnical engineers remain skeptical of the value of reliability theory as applied to geotechnical engineering problems.

Reasons for this lack of widespread application may include the following:

- (1) The quality of data available on a typical geotechnical project is too meager for effective use of traditional statistical methods. In addition, site variation of geotechnical conditions makes combining statistical data from site to site difficult.
- (2) In the process of applying probabilistic methods to geotechnical engineering, the problems tend to be oversimplified, thus the results achieved do not reflect the real issues at the specific site.

(3) Most engineers may not be well versed in probability language and analysis, and may be reluctant to substitute what they perceive to be unverified theory as a replacement for good engineering judgment.

(4) Early applications of probability and reliability methods may have been improper, producing vague or inconsistent results thus driving engineers away from further applications.

However, proponents of probability and reliability methods point out benefits for use in geotechnical applications including:

(1) Providing a relative measure of reliability levels between alternative designs to facilitate design decisions.

(2) Assuring consistent reliability levels between modes of performances such that resources may be optimally used through a balanced design.

(3) Comparing contributions of individual sources of uncertainty and their relative impact on the reliability of geotechnical performances, thus setting guidelines for a cost-effective site exploration, testing, and instrumentation program, and allocation of further information and future research efforts.

(4) Assisting the refinement of engineers' judgment based on site data and observed performances such that the benefits of judgmental information and observed data may be properly recognized and integrated.

Proposed Activity

A committee, under the auspices of the Geotechnical Board, will convene a workshop of approximately 30 skilled geotechnical professionals to be held on July 14-16, 1992, at the National Academy of Sciences' Beckman Center in Irvine, California. The workshop will consist of an equal number of probabilists and traditionalists, who will be invited to engage in the following activities:

(1) Deliberate on reasons for the slow acceptance of probabilistic and reliability methods. Develop position statements regarding the potential value and the current useability of such methods in geotechnical engineering practice.

(2) Define important research and technology transfer needs for application of probability and reliability methods in geotechnical engineering practice. Identify areas where these methods are most likely to contribute to geotechnical practice.

(3) Discuss successful and unsuccessful examples of the use of probability and reliability methods in geotechnical engineering practice. Foreign applications, especially in France and Japan, will be examined.

A set of questions will be developed beforehand to focus on a variety of issues regarding the use of reliability methods in geotechnical engineering. Each participant will come to the workshop prepared with answers to those questions and ready for further discussions.

Product and Dissemination

The committee will prepare a report summarizing the results of the workshop that will be useful to practitioners who want to explore potential applications of such methods in their design practice and to researchers who are interested in undertaking studies that will advance the state of the art. The report will propose ways to enhance future communication and cooperation between the probabilists and traditionalists. The report will be available for general public dissemination

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**National Research Council
Commission on Engineering and Technical Systems
Geotechnical Board**

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PROSPECTUS

A Study of Physical Infrastructure¹ Technology Research for the 21st Century

Building Research Board/Geotechnical Board

(As approved by the Executive Committee of the
Governing Board of the National Research Council, May 14, 1991)

PROJECT SUMMARY: The Building Research Board (BRB), in cooperation with the Geotechnical Board, has been asked by the NSF's Division of Mechanical and Structural Systems, Directorate of Engineering, to undertake a study to define the state-of-the-art, basic research needs and priorities related to the technology of physical infrastructure. The study, to be conducted over an 18-month period under the general direction of the National Research Council's (NRC) Committee on Infrastructure (and under the auspices of a strategic program on infrastructure being developed by the Commission on Engineering and Technical Systems (CETS) and spearheaded by the BRB), is an outgrowth of a current project² sponsored in part by the NSF; and the NSF is expected to provide funding of \$240,000 for this study. The study is planned to incorporate an active outreach program to expand participation beyond the community of the NSF's interests and thereby enhance the study's impact. Partial support of \$40,000 for this outreach program will be sought through NRC funds. It is understood that approval of the NSF-supported study does not imply approval of NRC funds for the outreach program. A separate prospectus has been prepared for the outreach program for consideration by the Presidents' Committee at its May 23, 1991, meeting.

ORIGIN AND BACKGROUND: A primary purpose of the NSF's Division of Mechanical and Structural Systems is to expand fundamental engineering knowledge in the broad areas of solid and geomechanics, structures, construction, geomaterials³, and building systems engineering, to promote progress in engineering and technology and thereby contribute to national prosperity and security. To this end, the Division has requested that the NRC undertake a study to define the state-of-the-art, basic research needs and priorities in the technology of physical infrastructure. Focused on the fundamental underpinnings of physical infrastructure technology, the

¹ Attached is a description of "infrastructure" to delimit its scope, which has become both broad and indistinct.

² Colloquia on Infrastructure for Tomorrow's Metropolis, approved by the Executive Committee of the Governing Board on December 14, 1989.

³ Geomaterials include man-made textiles, cementitious materials, and metallic components fabricated explicitly for geotechnical applications, as well as soils and rock modified by chemical or physical means to improve their engineering characteristics.

study will nevertheless be shaped by the broad national policy debate reflected in a myriad of reports issued in the past decade⁴.

Within this context, this study will undertake to identify key research needs and opportunities for developing and applying new technical knowledge to improve efficiency, effectiveness, and quality of infrastructure facilities and services. It will build upon other research agenda-setting efforts, including work of the BRB and GeoBoard and the recent Civil Engineering Research Foundation's "National Civil Engineering Research Needs Forum."

A diverse collection of constructed facilities and associated services comprise the physical infrastructure. Despite dependence on many common principles and procedures, each of the major infrastructure "modes"--e.g., bridges or geostructures--is represented by an extensive and specialized body of technical knowledge, professional and managerial people, agencies, institutional relationships, and researchers. This modal diversity inhibits discussion of the cross-cutting issues of infrastructure. Further, serious gaps exist between principal infrastructure technology researchers and state and local government officials and other potential users of this technology.

However, a decade of thinking about infrastructure has suggested to some policy analysts that key problems and opportunities in infrastructure may be better understood by considering the common underlying intellectual body of knowledge, science, and technology of infrastructure. This intellectual body is not well defined, but a number of common features of infrastructure have received study, such as the following examples:

- Organic systems of discrete facilities, structures, and users linked together over large areas (e.g., highway or power systems)
- Long-lived facilities expected to provide very reliable service under adverse environmental conditions, often critical to basic life safety, public health, and welfare (e.g., water treatment or power generation plants)
- A common set of materials, such as steel, concrete, wood, masonry, and geomaterials used in design and construction
- Extensive use of land, underground space, and aerial, surface, and subsurface connections
- Complex and sometimes unanticipated environmental and social impacts that might be predictable and avoided or mitigated

⁴ E. g., 1984, Joint Economic Committee of the U. S. Congress; 1984, 1987, and 1988, committees of the NRC and National Academy of Engineering; 1988, National Council on Public Works Improvement; and 1990, 1991 (forthcoming), Office of Technology Assessment.

- Complex sets of factors that influence what physical service characteristics determine acceptable performance

Basic research is needed to develop better operational understanding of this common intellectual body of knowledge and to enhance its applications in practice. Such research—in areas such as behavior of soil-cements and network mathematics—will ultimately provide lessons of cross-cutting value for effective infrastructure development and management, leading in turn to enhanced productivity and efficiency in many sectors of the Nation's economy. The purpose of the study will be to develop an agenda for this research. This research agenda will present high-priority opportunities the NSF and the research community may use to guide basic infrastructure core research.

PROPOSED ACTIVITY: The study will be conducted under the general direction of the NRC's Committee on Infrastructure and under the auspices of the CETS strategic program on infrastructure being spearheaded by that commission's BRB. Initial activities under the program were approved by the Executive Committee of the NRC's Governing Board in December, 1989. The NSF and the U. S. Army Corps of Engineers are among the program's current sponsors.

The BRB and Geotechnical Board will provide staff support and, with other relevant NRC units, consultative assistance for this study. The study will be conducted in three principal stages, with most active work occurring within the middle 8 to 12 months of the anticipated 18-month period:

Stage One A series of position papers will be prepared to describe the broad meaning and scope of the intellectual body of knowledge of infrastructure and to discuss the national and global significance of this information. Surveys of relatively recent major advances in infrastructure technology, research agenda reports, and new scientific and engineering discoveries--e.g., in construction, geomaterials, building systems and other fields--that could become the cutting edge of infrastructure technology will establish a baseline for committee deliberations and detailed plans for Stage Two.

Stage Two Three to four subcommittees will address specific sets of issues in detail. The committee may invite selected experts to participate in this stage of the study, augmenting each subcommittee with two to three such experts. One subcommittee of committee members and staff will integrate all subcommittee materials into a coherent document, and will develop draft committee conclusions and recommendations for committee discussion.

Stage Three The committee will hold two colloquia (in Washington and Irvine) to review and discuss principal issues identified by the committee. Invited participants in these colloquia will include selected federal, state, and local government representatives and others having interest in and responsibility for infrastructure research and technology policy. Based on discussions at these two colloquia, the committee will finalize its recommendations. The report will be subject to NRC report review procedures.

PRODUCT AND OUTREACH PLAN: Subject to the committee's deliberations and confirmation, the committee's report is anticipated to address (1) the definition of physical infrastructure as a unified concept, the cross-cutting technologies that make the concept meaningful, and the distribution of responsibility for infrastructure technology, performance, and management; (2) the significance of physical infrastructure technology to security and quality of life in the domestic and global economy; (3) the status of modern infrastructure technology, in historic perspective, problems of current technology, and progress on new technology; and (4) a critical review of laboratories, manpower, education programs, and other resources for basic infrastructure technology research.

The committee's report, to be reviewed by members of the BRB and Geotechnical Board, will be subject to the NRC's report review procedures.

This study's significance extends well beyond the NSF's usual constituency, encompassing professional engineering communities and state and local government officials. The support and commitment of this broader community will help assure that the study has effective impact. Hence, subject to securing adequate funding, an active outreach program is planned to (1) alert key members of the infrastructure R&D community about the study, (2) engage potential users of infrastructure R&D (e.g., state and local government officials), (3) engage responsible national policy makers, and (4) enhance thereby the likelihood that the committee's work will have real positive impact. Because this program—to be integrated into the study from its outset—exceeds NSF's interests and resources, financial support is being requested from NRC funds.

EXPECTED COSTS AND SOURCES OF FUNDING: The NSF is expected to provide \$240,000 for conduct of the proposed infrastructure research agenda study. Additional support of \$40,000, to be sought from NRC funds, will enable implementation of the outreach program. It is understood that approval of the NSF-supported study does not imply approval of NRC funds for the outreach program. A separate prospectus has been prepared for the outreach program for consideration by the Presidents' Committee at its May 23, 1991, meeting. The study budget is based on the full estimated cost of this activity for an 18-month period, a total of \$280,000.

RESPONSIBLE STAFF OFFICER: Andrew C. Lemer, Director, Building Research Board, HA-274, 202/334-3376.

ATTACHMENT: Defining Infrastructure and Physical Infrastructure Technology

Note: The outreach plan has not been funded and will therefore be deleted from the study.

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DEFINING INFRASTRUCTURE AND
PHYSICAL INFRASTRUCTURE TECHNOLOGY

The word "infrastructure" was coined, according to dictionaries, in the first half of the 20th century to refer to military installations, and some researchers trace its origin to Winston Churchill. Now defined (by Webster's dictionary) as an "underlying foundation or basic framework," infrastructure has in recent decades come to connote a diverse collection of constructed facilities and associated services, ranging from airports to energy supply to landfills to wastewater treatment. Many of the facilities are built and operated by governments, and thus fall easily into the category of public works, but others are built or operated, in whole or in part, by private enterprise or in joint public-private partnership.

A committee of the NRC, reporting on Infrastructure for the 21st Century (NRC, 1987), adopted the term "public works infrastructure" including

"...both specific functional modes--highways, streets, roads, and bridges; mass transit; airports and airways; water supply and water resources; wastewater management; solid-waste treatment and disposal; electric power generation and transmission; telecommunications; and hazardous waste management--and the combined system these modal elements comprise. A comprehension of infrastructure spans not only these public works facilities, but also the operating procedures, management practices, and development policies that interact together with societal demand and the physical world to facilitate the transport of people and goods, provision of water for drinking and a variety of other uses, safe disposal of society's waste products, provision of energy where it is needed, and transmission of information within and between communities."

To the specific modes cited in that description should be added systems of public buildings—schools, health care facilities, government offices, and the like. These facilities, not as individual buildings, but tied together by the functional and administrative systems they house, provide important services to the public at large, in much the same fashion as highways and water supply facilities.

New modes may also enter the definition, particularly as we increase our efforts to avoid or mitigate an expanding list of environmental problems. Parkland, open space, and wilderness may qualify as infrastructure, not only for their aesthetic and recreational value, but because their vegetation and ecologies could become essential facilities for enhancing supplies of clean air and water.

These various facilities—infrastructures, as some term them—comprise the hard core of the concept, but to discuss infrastructure only in terms of facilities neglects the important services, provided by both private enterprise and public agencies, that are enabled by these facilities. The creation and distribution of these infrastructure services occur through distinct economic and social action that are influenced by many factors beyond

the facilities themselves. Airlines and departments of education may be encouraged or constrained by their systems of airports and schoolhouses, but have broad latitude to adjust their operations and costs in response to demands. The success of such corporations as Federal Express and DHL in air parcel delivery, for example, reflects the development of new infrastructure services based on existing infrastructures.

Physical infrastructure technology is the set of ideas, theories, analysis procedures, and production methods that yield the facilities, products, and services of infrastructure. This technology spans a broad range of science and engineering, but is characterized generally by constructed facilities linked in organic networks, and common materials (e.g., concrete, steel, glass, and other). Frequent environmental impact and societal expectations derived from the economic and social activities these facilities serve are the context within which physical infrastructure technology must function.

July 17, 1992

Building Research Board
Committee for An Infrastructure
Technology Research Agenda

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NATIONAL RESEARCH COUNCIL
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS

Annual Review of U.S. Progress in Rock Mechanics: Fracture Characterization and Fluid Flow

U.S. National Committee for Rock Mechanics/Geotechnical Board

SUMMARY INFORMATION

<u>Origin:</u>	USNC/Rock Mechanics
<u>Type of Activity:</u>	Committee Study
<u>Duration:</u>	15 months
<u>Sponsor:</u>	Geotechnical Board Sponsors
<u>Product:</u>	Report
<u>Intended Audience:</u>	Rock Mechanics Community and Government Agencies

PROJECT SUMMARY

As part of its ongoing activities to serve the rock mechanics community, the U.S. National Committee for Rock Mechanics (USNC/RM), a standing committee under the Geotechnical Board, proposes to review characterization of fracture networks and fluid flow in rock fractures. The review will provide a statement of current research and guidance for field applications. It will cover research in fracture origin, morphology, geophysical imaging, and flow and transport analysis and modeling. The activity will be accomplished by a committee of approximately twelve experts who will meet three to four times and prepare a draft report. This study will be completed within 15 months.

ORIGIN AND BACKGROUND

The U.S. National Committee for Rock Mechanics (USNC/RM) advises the government and the related industrial and scientific communities on the state of the art in rock mechanics and its relevance to problems of national importance. Since 1982, the USNC/RM has prepared reports assessing U.S. progress in rock mechanics.¹ The topic for the review is suggested by the members of the USNC/RM after consultation with

¹Reports published by the NRC are: Annual Review of U.S. Progress in Rock Mechanics—Stability, Failure, and Measurements of Circular Openings, (in NRC review); Annual Review of U.S. Progress in Rock Mechanics—Rock Mass Modification, 1990; Annual Review of U.S. Progress in Rock Mechanics—Coupled Processes, 1987; Annual Review of U.S. Progress in Rock Mechanics—Rock Dynamics, 1986; Annual Review of U.S. Progress in Rock Mechanics—Engineering Rock Mechanics, 1984; Annual Review of U.S. Progress in Rock Mechanics—Rock Mass Characterization, 1983.

sponsoring government agencies, industry representatives, and appropriate scientific personnel. At its meeting in June 1990, the USNC/RM determined that there is a need to assess current research in fluid flow in fractures and to report this to government agencies and industry involved in resource recovery, environmental restoration, hazardous waste storage and construction in fractured rock.

Over the past two decades, the importance of characterizing and understanding fluid flow in fracture systems has increased dramatically. Fractured petroleum reservoirs have become more important as a national resource. Most recently, fractures have been found to play a major role in containment transport at significant number of sites across the nation. For example, contaminants at the Stringfellow site in California are transported in a fractured granite. The U.S. Department of Energy is considering nuclear waste storage in a fractured tuff at the Nevada Test Site and in the WIPP facility, which underlies a fractured dolomite. Tunnels and mines in hard rock consistently encounter fracture-related problems. Many of these problems have been considered intractable because fracture networks are notoriously chaotic and poorly interconnected. Consequently, recent research concerning techniques and approaches developed in separate arenas, while extensive, has not been reviewed, integrated, and communicated throughout the geotechnical community.

The importance of these foregoing problems to the quality of the nation's environment and economy makes it desirable to evaluate recent work and relate recent progress and new approaches. The committee appointed to this study will consist of individuals from diverse fields and is therefore expected to produce a broadly-based report useful to researchers and engineers in a variety of fields. It will also aid government agencies responsible for sponsoring research, regulation and environmental restoration.

PROPOSED ACTIVITY

The NRC committee will consist of approximately twelve experts in single fractures and fracture networks from the fields of geology, geomechanics, geophysics, hydrology, and geochemistry. Experience with mining and tunneling, nuclear waste, toxic waste, and petroleum applications will be sought. In addition, the committee should contain expertise in policy interpretation of the subject for government sponsors.

The committee will hold three to four meetings to review the status of current research in fracture characterization and fluid flow, to identify federal efforts and problem areas in the field, and to explore mechanisms to advance the field and better inform the geotechnical community about progress.

PRODUCT AND DISSEMINATION

The committee will prepare a report that will review progress in the field of fracture characterization and fluid flow in rock fractures, and offer guidance to federal agencies and others on recent developments in the field. The report, as part of the USNC/RM "Annual Review of U.S. Progress in Rock Mechanics" series, will be distributed or made

available to the nine federal agencies that currently support the Geotechnical Board and the USNC/RM, to other appropriate federal agencies, to the rock mechanics community affiliated with the U.S. National Committee, and to the geotechnical community in general. In addition, notice of the report's publication will be made through appropriate mechanisms of the International Society for Rock Mechanics. The report will be subject to NRC review procedures.

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NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
GEOTECHNICAL BOARD
U.S. NATIONAL COMMITTEE FOR ROCK MECHANICS

STUDY OF FRACTURE CHARACTERIZATION AND FLUID FLOW

PROJECT DESCRIPTION

SUMMARY OF EXPANSION

The Geotechnical Board, through its U.S. National Committee for Rock Mechanics, has expanded the project scope and budget for its ongoing study on fracture characterization and fluid flow in rocks. The expansion is in response to fracture-related problems described by the study sponsors at the initial committee meetings, and in response to the committee's belief that the breadth of information relevant to the topic has never before been assembled in one place.

The study on fracture characterization and fluid flow has been ongoing since May 1991. The original statement of work asked the committee to review characterization of fracture networks and fluid flow in rock fractures, provide a statement of current research, and develop guidance for field applications. The proposed scope now includes more than a review. The committee is attempting to identify the tools and methods, describe the essential fundamentals behind the use and interpretation of the tools and methods, assess these methods and provide illustrative examples of their use. In addition, the committee is trying to identify areas of cross fertilization between various disciplines and between applications.

The study will be completed 24 months from its May 1991 start at an estimated total cost of \$200,000. The expansion will allow the committee the time and resources to complete a more thorough report.

ACTIVITY

The Committee on Fracture Characterization and Fluid Flow consists of 13 experts in rock mechanics, hydrogeology, hydrofractures, geophysics, geology, statistics, and seismology. The committee has met four times and has developed an initial committee draft. However, in developing this first draft, the committee concluded that the important issues concerning fracture characterization and fluid flow go beyond the original statement of task, which called for a review of current research activities and the development of guidance for field applications.

The committee believes that a more useful and more thorough investigation is warranted. In the additional 9 months added to the duration of the study, the committee will attempt to identify the tools and methods associated with identifying fractures, describe the essential fundamentals behind the use and interpretation of the tools and methods, assess these methods and provide illustrative examples of their use. In addition, the committee

is trying to identify areas of cross fertilization between various disciplines and between applications.

The committee, in its initial draft and in its proposed subsequent work, will address three common issues that have been articulated by the sponsoring agencies and others that have made presentations to the committee. These issues are:

- (1) Where are the important fractures?
- (2) How does flow and transport occur in fractures?
- (3) How can we predict and effect changes in fracture systems?

The committee will hold three additional meetings to further develop the report.

PRODUCT AND DISSEMINATION

The committee's report will be developed for Track A publication by the National Academy Press. As part of the USNC/RM series of annual reviews, it will be made available to the rock mechanics community, the environmental and waste management community, the resource recovery community, and to government, universities and industry. It will be made available to the nine federal agencies that currently support the Geotechnical Board and the USNC/RM, to other appropriate federal agencies, and to the geotechnical community in general. In addition, notice of the report's publication will be made through appropriate mechanisms of the International Society for Rock Mechanics. The report will be subject to the NRC review procedures.

National Academy of Sciences/National Research Council
Commission on Engineering and Technical Systems
Geotechnical Board
U.S. National Committee for Rock Mechanics

07/21/92

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Committee on Fracture Characterization and Fluid Flow

- U.S. National Committee for Rock Mechanics
 - Geotechnical Board
 - Commission on Engineering & Technical Systems
 - National Research Council
-

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Nuclear Regulatory Commission

Environmental Protection Agency (Kerr Laboratory,
Environmental Monitoring Systems Laboratory)

Gas Research Institute

Dowell Schlumberger

Chapter 1

Introduction

Chapter 2

Physical Characteristics of Fractures
and Fracture Patterns

Chapter 3

Physical Properties and Fundamental
Processes

Chapter 4

Fracture Detection

Chapter 5

Hydraulic and Tracer Testing

Chapter 6

Flow and Transport Models

Chapter 7

Engineering Applications

Chapter 8

Natural Processes

Chapter 9

Examples of Site Investigations

Chapter 10

Conclusions and Recommendations

Motivation

- Summarize state-of-the-art
- Describe and assess tools
- Provide communication and cross fertilization
between applications and disciplines

Chapter 1

Introduction

- Reservoirs
 - oil and gas
 - geothermal
 - water supply
- Groundwater Contamination
 - toxic and hazardous substances
 - nuclear waste
- Mining
 - in situ leaching
 - dewatering
 - mine waste disposal
 - structural stability
- Structures
 - dams and surface storage reservoirs
 - foundations
 - tunnels and caverns
 - underground fluid storage

Key Issues

- 1 Where are the important fractures?
- 2 How do flow and transport occur in a fracture system?
- 3 How can we predict and effect changes in a fracture system?

Chapter 2

Physical Characteristics of Fractures and Fracture Patterns

1

- Fracture genesis determines fracture system geometry
- Geometry controls flow

Chapter 2

Fracture Genesis

- Mechanisms for fracture formation
 - joints/extension
 - faults/shears
- Fracture initiation
 - flaws
 - stress heterogeneity on every scale
- Fracture propagation
 - extension, tension, fluid pressure
 - shear by coalescing of joints
 - shear with gouge

Chapter 2

Joint Geometry

- Joint geometry
 - strata bound in layered media
 - elliptical in massive media
- Surface features
 - conductance
- Fracture sets
 - spacing ➡ thickness, propagation rate, elastic properties, joint interaction
 - length ➡ preferential growth of long fractures
 - linkage ➡ small differential stress

connectivity

Chapter 2

Fault Geometry

- Highly diverse
- Poorly understood
- Hierarchical
- May concentrate flow parallel to σ_2
- Sealing *is* where flow *was*

Chapter 3

Physical Properties and Fundamental Processes

1

3

- Building blocks for predicting large scale behavior
- Heterogeneous “laboratory” for studying relationships
- Geometry controls the properties
- Stress sensitive 2D porous media

Chapter 3 Geometry

- Surface Geometry
 - profilometer
 - optical methods
 - fractal dimensions
- Void Geometry
 - subtract surfaces
 - woods/metal
 - epoxy

Chapter 3 **Flow**

[2]

- Lake and stream model
 - flow dominated by critical necks
- Effects of stress on geometry and flow
 - normal
 - shear
- Effect of genesis on geometry
 - more work needed
- Effect of chemical infilling

Chapter 3 Transport

- Flow dominated by necks
- Residence time influenced by large voids
- Dispersivity affected by tortuosity and connectivity

Chapter 3 Two-Phase Flow

- 2D porous media
- Stronger effect of geometry
- $k_{rw} + k_{ra} < 1$
- 2 phase mobility depends on correlation length of large pores
- Oscillatory flow?

Chapter 3 Seismic Properties

- Effective Media
 - anisotropic media
- Discrete Fracture
 - displacement discontinuity
 - fracture stiffness determines velocity and attenuation
 - stiffness is related to flow

Chapter 3 Electrical Properties

- Bulk Properties $\Rightarrow$ Archie's Law
 - equivalent channel model
 - stress sensitive conductors
- Discrete Fracture

$$\left[\begin{array}{l} \text{Flow} \propto b^3 \\ \text{Current} \propto b^2 \end{array} \right] \Rightarrow \begin{array}{l} \text{different paths} \\ \text{for flow and} \\ \text{current} \end{array}$$

Chapter 4 Fracture Detection

1

-
- Surface Methods
 - low resolution ($>100\text{m}$)
 - deep penetration ($>1000\text{m}$)
 - Cross-Borehole & Surface/Borehole Methods
 - medium resolution ($10\text{--}100\text{m}$)
 - medium penetration ($>100\text{m}$)
 - Single-Hole Geophysical Methods
 - high resolution ($.01\text{--}10\text{m}$)
 - low penetration ($.01\text{--}1\text{m}$)

Chapter 4

Surface Seismic Reflection

Methods

1

- P-waves
 - vertical traveling waves do not see vertical fractures
- S-waves
 - markedly influenced by aligned fractures

Chapter 4

Electric & Electromagnetic Surface Methods

- DC (Laplace Eqn)
 - soundings can see semi-horizontal fracture zones
 - profiling can see vertical fracture
 - resolution decreases rapidly with depth
- Electromagnetic (Diffusion Eqn)
 - soundings are good for resolving conductive layers (fracture zones) but less good for resistive layers
 - in profiling, overburden masks underlying bedrock
- Ground Penetrating Radar (GPR)
 - like seismic reflection
 - resolution is a function of wave length
 - range proportional to resistivity

Chapter 4 Cross-Borehole & Surface/Borehole Methods

- VSP
- Tomograms
- Radar
- Seismic
- Attenuation
- Velocity

Chapter 4

Single-Hole Geophysical Methods

- Core inspection
 - hard rocks
 - RQD
 - fracture density
 - fracture description

- Conventional logs

advantages [

- consistent 1D profile of rock properties
- in situ measurement
- multiple independent measures of rock properties

disadvantages [

- indirect measure of properties of interest
- rocks disturbed by drilling
- measures an average of rock & well bore fluid
- biased by sampling direction

Chapter 4

Single-Hole Geophysical Methods (*cont'd*)

- Borehole imaging logs
 - optical (TV)
 - acoustic (borehole televiewer)
 - electrical (FMS)
- Acoustic wave form logging
 - refraction/reflection
 - tube waves
- Borehole radar
 - reflection
 - directional antennae
- High resolution flow meter
 - heat pulse
- Acoustic emission

Chapter 4 Monitoring Fluid Flow with Geophysical Methods

- Electrical methods
 - conductive fluid
 - saline tracers
- Seismic
 - desaturation

Chapter 5

Hydraulic and Tracer Testing

1

2

- Diagnostic
- Parameterization

Chapter 5 Hydraulic and Tracer Testing in Fractured Rock

1

2

- Hydraulic Tests
 - single borehole
 - multiple boreholes
 - interpretations in fractured rock
- Tracer Testing
 - single borehole
 - converging
 - recirculation

Chapter 5

Hydraulic Tests

- Single borehole
 - open borehole packer test
 - methodology
 - const q
 - const h
 - slug
 - pulse
 - DST
 - prototypes for analyses
 - geometry
 - steady state
 - transient
 - well bore storage
 - skin
 - double porosity

Chapter 5

Hydraulic Tests (*cont'd*)

- Multiple boreholes
 - anisotropy
 - leakage
 - “multiaquifier” analogy
- Test interpretation
 - inverse methods
 - fractal model

Chapter 5

Tracer Testing

-
- Single boreholes (injection/pump back)
 - Radially converging
 - Two well recirculation
 - Test interpretation
 - channeling
 - matrix diffusion

Chapter 6

Flow and Transport Models

2

- Conceptual Models
- Flow and Transport Models
- Higher Order Phenomena

Chapter 6

Conceptual Model Building

-
- Geology $\Rightarrow$ Fracture style and pattern
 - Inference about behavior
 - open vs. closed fractures
 - stress
 - infilling
 - Geophysics $\Rightarrow$ Find fractures
 - Well Testing $\Rightarrow$ Diagnosis
 - Model Choice $\Rightarrow$ How to represent heterogeneity?
 - scale
 - problem of interest

Chapter 6

Equivalent Continuum Models

- Volume Averaged Parameters
- Works Best for:
 - large scale
 - well interconnected fractures
 - volumetric flow vs. transport

Chapter 6

Discrete Fracture Models

- Used to find K_{ij} for continuum models
- Used as an end model
- Based on actual fracture geometry inferred from in situ sampling
- May work better for jointed rock
- Not all observable fractures are conductors

Chapter 6

Models with Multiple Scales

- Big and little fractures
- Clustered fractures
- Generators based on fracture genesis
- Equivalent discontinuum models
- Fractal networks
- Research approaches with limited application to date

Chapter 6

Higher Order Phenomena

- chemical transport
- unsaturated flow
- multiphase flow
- heat/flow
- deformation/flow

Chapter 7 Engineering Applications

3

-
- Pressures vs. Flow
 - production wells $\implies$ decrease permeability
 - hydrofracture $\implies$ increase permeability
 - flooding
 - Chemical alteration
 - reinjection of fluids
 - in situ leaching
 - Structural
 - grouting
 - drainage

Chapter 8 Natural Processes in the Earth's Crust

3

- heat
- pressure
- sealing
- fracturing

Chapter 9

Examples of Site Investigations

- Granitic Sites
 - Mirror Lake
 - Stripa
- The Multiwell Site
- The Geysers

What has been learned?

Chapter 10

Conclusions and Recommendations

- Integration
- Cross-fertilization
- Research Directions

**Meeting of the
U.S. National Committee for Rock Mechanics
July 13-14, 1991**

Residence Inn by Marriott
2681 Jefferson, Norman, Oklahoma

SUMMARY

After introductions and a brief explanation of the Geotechnical Board by Peter Smeallie, Chairman Wolfgang Wawersik described important activities of the USNC/RM including industrial and professional society coordination and the conduct of special studies. The committee is interested in taking on studies that are of vital interest to the rock mechanics community. In this light, the committee maintains contact with the U.S. membership of International Society for Rock Mechanics (ISRM); two major mailings were distributed thus far in 1991. The committee actively works to improve the U.S. Rock Mechanics Symposium and the rock mechanics awards. The committee has endorsed the candidacy of Charles Fairhurst as ISRM President, and has asked for support from the 54 member countries.

Underground Research Facility Presentation

Paul A. Witherspoon, Professor Emeritus of Geological Engineering and Faculty Senior Scientist, University of California, Lawrence Berkeley Laboratory, conducted a special session of the USNC/RM on the feasibility of establishing an underground research facility. He described two purposes of an underground research facility: (1) to identify rock mass behavior, and (2) develop instrumentation and methods for rock mass quality. Dr. Witherspoon asked the committee and guests why an underground research facility should not be undertaken. This is consistent with the request from the Department of Energy, Office of Energy Sciences, to gain a consensus from a variety of knowledgeable groups.

The fundamental problem is how to predict rock mass behavior when it is disturbed; the use of an underground research facility provides the means to investigate rock mass behavior in a way that is not currently possible today. It would provide the setting to investigate how to characterize geological, physical and chemical heterogeneities. The underground research facility would require a wide array of talent from the earth sciences: Geology, geochemistry, geophysics, geohydraulics, geomechanics, and geothermal, for example.

Benefits of the underground research facility would be many. For example, knowledge of how dissolved chemicals migrate has immediate applicability for environmental operations. The energy-related benefits include: knowledge of subsurface

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energy storage, enhanced energy recovery, radioactive waste repository design, toxic and hazardous waste isolation, foundations for large water reservoirs and dams, and recovery of methane from coal.

Comments from the committee and guests included:

- The Bureau of Mines has 4 or 5 research facilities. The use of the facilities is more for configurational than characterization, for example, fire extinguishment, ventilation, explosives. There is not much rock mechanics except for calibration of instruments. There are a variety of sites used for research but these test sites are specific rather than generic. The chasm between generic measures and site specific is wide.
- A travelling laboratory may mitigate the problems of a site specific laboratory.
- Mine openings that exist should be explored.
- The near surface test facility at Hanford is not viewed as an exemplary facility.
- An underground research facility could be devoted in part to generic research which can be applicable to problems; developing the methodology is key.
- The STRIPA project and the Canadian facility should not be overlooked.
- Too much rock mechanics research is focused on small-scale problems. Large-scale site characterization is very empirical and crude at this point.
- Fluid flow and scale effects are seen as strong candidates for study in an underground research facility.

The committee decided to provide comments on Dr. Witherspoon's presentation to Dr. Wawersik who will synthesize and respond directly to Dr. Witherspoon.

ISRM Presentation by Charles Fairhurst

Charles Fairhurst from the University of Minnesota and a candidate for the presidency of ISRM addressed the committee on the ISRM. He described the U.S. interest in the society as consistent with global economic goals. Much R&D in universities is dependent on foreign students; companies that use rock mechanics to a great extent are already international or they most likely are having a hard time surviving. The rock mechanics community has a very good track record with international collaboration. The Eastern European countries and the former republics of the Soviet Union offer the opportunity for further collaboration.

In terms of ISRM operations, Dr. Fairhurst made the following points:

- The annual directory and the **ISRM News** are compiled by volunteers.
- Eighty pages of advertising at \$1,500 a page would pay for a permanent secretariat.
- The USNC/RM should support the secretariat to the extent it can.

The committee agreed to provide ideas on the ISRM to Dr. Fairhurst and expressed its support for his candidacy for the president. [Dr. Fairhurst was subsequently elected president of ISRM at its meeting in September 1991.]

Borehole Stability Report

Jean-Claude Roegiers reported that the report has been reviewed according to the National Research Council (NRC) procedures and he is currently preparing responses to reviewers' comments. He noted that a problem exists with having committee members in different countries, but he expects to submit to NRC within a few weeks. The committee advocated undertaking effort to inform the rock mechanics community of the report's availability. It also urged staff that future annual reviews should employ technical editors at the draft stage.

Review of 32nd Rock Mechanics Symposium

Dr. Roegiers reported on the 32nd Rock Mechanics Symposium at the University of Oklahoma, which just concluded prior to the USNC/RM meeting. He indicated a significant problem with speakers not attending and said he would prepare letters to symposium speakers who did not show expressing concern. Other points made in the discussion:

- Symposium organizers should reduce the time given to reciting a speakers vita in the introduction to talks.
- Organizers should state up front that keynote speakers should submit their paper at the time of their presentation.
- While some have advocated including discussions that follow presentations in the proceedings, cost is an issue as well as the timing of issuing the proceedings.
- Those who bring papers for distribution at the symposium should be required to bring at least 400 copies.

- Corporate sponsors should be contacted for support of the symposium on a continual basis.
- Registration lists and procedures should be adopted to transferable computer-based format.
- The USNC/RM should consider establishing a subcommittee to address the interface of nominations of papers for U.S. Rock Mechanics awards and Rocha awards.
- Surplus revenues from the symposium should be remitted to the USNC/RM account for use as contingency for future symposia. Policies and procedures should be developed.
- A detailed financial accounting should be transmitted from the current symposium host to the next host and the USNC/RM as soon as possible to allow for adequate financial planning.
- Non-ISRMs-member symposium attendees will, upon registration, receive interim affiliate ISRM membership for the remainder of the calendar year. Their names will be forwarded to USNC/RM for consideration of further membership through the USNC/RM.

ISRMs

Dr. Wawersik indicated he has written a letter of support for Peter Kaiser, the nominee from Canada to be ISRM vice president for North America. He also reiterated the position of the USNC/RM that names of individuals who join ISRM directly, bypassing the national group, i.e., the USNC/RM, will be forwarded to the USNC/RM with the recommendation that the individual join the society through the national group structure. In effect, ISRM corresponding membership becomes an interim membership.

The committee reaffirmed its opposition to the graded dues proposal currently in front of the ISRM executive council. It also expressed concern over the establishment of a new ISRM "division" on blasting, although Dr. Wawersik indicated that he did not have all the facts on this issue.

The suggestion was made to contact individuals in the Society for Explosive Engineers at ISRM concerning USNC/RM.

The committee appointed Miklos Salamon as the new ISRM correspondent.

Committee on Fracture Characterization and Fluid Flow

Jane Long reported on the progress of this committee's work. She believes that the cross-fertilization issue is the key breakthrough to emerge from the committee's deliberations. The committee is attempting to go beyond a state-of-the-art report, although key issues will be identified (such as fluid flow at Yucca Mountain) in terms of state-of-the-art applications.

Liaison Activities

Dr. Wawersik asked the committee what contacts have been made with professional societies. Dr. Salamon reported that the contact person at AEG is no longer employed. Art McGarr indicated no substantial response from AGU. Dr. Long reported that the GSA has three interested groups—groundwater, tectonics, and engineering geology—but the GSA has not made any commitment to liaise with the USNC/RM. Barry Brady attended the SEG conference and made contact with the society's executives but there has been no follow-up.

The suggestion was made to have a publication booth (USNC/RM or GeoBoard) at exhibitions connected with professional society meetings.

1992 U.S. Rock Mechanics Symposium

Dr. Wawersik reported on activities connected with the 33rd U.S. Rock Mechanics Symposium to be held in Santa Fe, New Mexico, in June 1992. He announced that October 1-2, 1991 have been set as dates for the review of paper abstracts. The committee discussed the possibility of securing an NSF grant for part of the symposium cost.

The discussion turned to the frequency of holding the symposia—annually or biannually. The committee decided that an annual conference will be held at least through 1994 and that an option paper on the frequency of holding the symposium will be drafted and distributed to committee and to the ISRM membership. [It was subsequently decided not to distribute to ISRM members at this point.]

The University of Wisconsin was selected to host 1993 symposium; the University of Texas selected to host 1994 symposium.

Bias Discussion

The committee met in executive session to discuss balance and bias in accordance with NRC procedures. A separate record and memorandum have been prepared.

Next Meeting/Meeting Format

The committee set tentative dates of January 7-8, 1992, for its next meeting at the Beckman Center in Irvine, California. [The dates were later changed to January 21-22, 1992.] The committee endorsed the format of opening future meetings with a "special session" devoted to a topical concern, such as the Witherspoon presentation.

Annual Summary

Dr. Wawersik asked that committee members send him materials relevant to his preparation of the annual summary.

Composition of the USNC/RM

The committee nominated Dr. Brady for chairman to succeed Dr. Wawersik and authorized staff to explore the option of extending terms of members due to expire at the end of 1991. The committee also postponed a decision on establishing a vice chairmanship position.

U.S. National Committee for Rock Mechanics (USNC/RM) Meeting
National Academy of Sciences' Beckman Center
Irvine, California
January 21-22, 1992

DRAFT SUMMARY

Chairman Barry Brady opened the meeting—the first he has chaired—by thanking outgoing chairman Wolfgang Wawersik for his efforts during the years of his committee service and chairmanship. It was through Mr. Wawersik's efforts that the committee has adjusted and stabilized within the National Research Council. Mr. Brady commented that the U.S. is in a good position internationally with the election of Charles Fairhurst as President of ISRM. He went on to reassert that the main business of the USNC/RM involves the annual rock mechanics symposium, the special projects undertaken roughly yearly, and the awards for rock mechanics papers. The current committee must continue to review and improve these activities.

Particular issues of concern to Mr. Brady include: (1) the role of the USNC/RM in the activities of the ISRM and the level of contribution of U.S. members, (2) the relationship of the USNC/RM to professional societies, (3) initiatives with counterpart rock mechanics organizations in Canada and Mexico, and (4) improved communication with the ISRM, federal government agencies and other interested parties.

Mr. Wawersik detailed highlights from his term of office including: (1) the establishment of the committee in its current size and composition, (2) increased visibility of the USNC/RM within the academy complex, the fracture study being a good example, (3) the election of Mr. Fairhurst, and (4) the continued strengthening of the rock mechanics symposium.

Nuclear Regulatory Commission Presentation

Mr. Jacob Philip from the Nuclear Regulatory Commission with Simon Hsiung and Dan Kana delivered a briefing on the Nuclear Regulatory Commission's Seismic Rock Mechanics Research Project. The project is in support of licensing the Department of Energy for the high-level nuclear waste repository. It is two programs, a laboratory program and a field program. Each committee member was asked to provide three items for input to what the Nuclear Regulatory Commission should do in the future based on the presentation.

Borehole Stability Report

Mr. Brady commented that the subject report has experienced difficulties in the National Research Council's review process. He went on to state that there is much value in the report and that a majority of the problems are technical inconsistencies. The committee acknowledged the technical inconsistencies in the report cited by the reviewers, but reaffirmed the value of a report on the subject. The committee recommended publication once the panel and staff work through the review objections.

Fracture Characterization and Fluid Flow

Jane Long, the chairman of the Committee on Fracture Characterization and Fluid Flow, described progress with the study. She reported that it has taken a long while to define the product. In May 1991, the problems were identified, in July an outline produced, by October a draft report was generated, but with significant gaps. The project needs an expansion of scope of work and an extension of time to account for the augmented tasks the committee is undertaking. It is expected to produce a report by April 1993. The committee concurred and agreed that staff should seek approval for an expansion of the scope of work for the study and an extension of time. The USNC/RM strongly encouraged the committee and staff to work with sponsoring agencies to assure their agreement with this decision.

Professional Society Liaison Activities

Individual USNC/RM members reported on liaison activities with professional societies including GSA, RETC, AGU, SEE, AIME, ASCE, ASME, SEG, and SPE. It was decided that each professional society liaison representative should send a copy of the "1990-91 USNC/RM Annual Summary" to the appropriate person in the society.

U.S. Rock Mechanics Symposium

Mr. Wawersik reported on the plans for the 33rd Rock Mechanics Symposium to be held in June in Santa Fe, New Mexico. This symposium has no dominant theme, but will feature a number of short courses on fractals, geostatistics, and others. Two hundred seventy-five abstracts were received, and 117 were accepted. The review committee had defined criteria for evaluating the abstracts; each abstract was reviewed by at least three people. In addition, the papers have been reviewed. Interest in the symposium appears high and attendance is expected to be at projected levels.

Mr. Wawersik agreed to deliver a "diary" of the 1992 symposium material to the next symposium organizer.

The USNC/RM decided that a subcommittee should redraft symposium policies, procedures, and guidelines, including financial policies. The subcommittee should examine policies governing the symposium in terms of accessibility to the rock mechanics community, educational merit, the degree of interaction among participants, and a balanced view of the state of the art. The USNC/RM should maintain an active role in setting the policies and procedures for the symposium and should retain the right to intervene where warranted. Lew Wade will lead this subcommittee with Art McGarr, Ron Nordgren, and Mr. Brady participating.

In terms of future symposia, the committee will contact recent and potential proposers for the 36th (and possibly the 37th) symposium to test interest.

The committee tabled consideration of a joint U.S./Canadian symposium. The committee will reconsider at its next meeting. In the meantime, staff should contact Peter Kaiser to invite him to make a presentation at the next USNC/RM meeting.

Rock Mechanics Awards

At the time of the meeting only seven papers have been received. Therefore each committee member should nominate a paper for the 1992 rock mechanics awards. The committee discussed the composition of the awards subcommittee and decided that the chairman should be a current member of the USNC/RM. It was agreed, however, that J.C. Roegiers does an exemplary job with the awards and should continue through this year's efforts. He should be offered a membership position for next year's subcommittee.

New Topics for 1992-93 Special Study

The USNC/RM decided to put forward research and development in rock mechanics as the topic for the next USNC/RM special study. This will incorporate consideration of candidate topics on large scale test facility and anisotropic rock. Mr. Wade will lead the planning effort for the special study.

New Business

The committee was urged to propose new members for the USNC/RM and also to send Mr. Brady electronic mail addresses.

The next meeting was scheduled for June 5th (evening) and 6th, 1992, prior to the 33rd U.S. Rock Mechanics Symposium in Santa Fe, New Mexico.

Report prepared by Peter Smeallie.

National Research Council
Geotechnical Board

Meeting of the
U.S. NATIONAL COMMITTEE FOR ROCK MECHANICS

LaFonda on the Plaza Hotel
100 East San Francisco
Coronado Room
Santa Fe, New Mexico
(505) 982-5511

June 6, 1992

AGENDA

Saturday, June 6th

10:00 a.m. **EXECUTIVE SESSION**

Update on Committee Appointments and Bias Discussion
Completion (*Peter Smeallie, Herbert Einstein*)

Review of Agenda

10:15 **SESSION OPEN BY INVITATION**

Welcome, Introductions, Review of Agenda (*Barry Brady*)

10:30 **ISRM** (Attachment A)

- President's Remarks, (*Charles Fairhurst, Peter Kaiser*)
- ISRM Council Meeting, September 1992, England (*Barry Brady*)
- Role of USNC/RM on ISRM Commissions (*Herbert Einstein*)
- U.S. Correspondent (*Miklos Salamon*)
- ISRM U.S. Membership (*Peter Smeallie*)

11:30 **Other International Initiatives** (Attachment B)

- Idea for a North American Rock Mechanics Symposium
 (*Peter Kaiser*)
- Proposed U.S./Mexico Meeting in March 1993 (*Barry Brady*)

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12:00 noon Working Lunch at the Meeting Table

12:30 p.m. Special Studies (Attachment C)

- Borehole Stability (*Jean-Claude Roegiers*)
- Fracture Characterization and Fluid Flow (*Jane Long*)
- R&D in Rock Mechanics (*Lewis Wade*)
- Others/Discussion of Next Study

2:00 Rock Mechanics Awards (Attachment D)

- 1992 Awards (*Jean-Claude Roegiers*)
- Composition of Awards Panel (*Barry Brady*)

2:30 U.S. Rock Mechanics Symposium (Attachment E)

- Report on 1992 33rd Symposium, Santa Fe (*Wolfgang Wawersik*)
- Report on 1993 34th Symposium, Madison
- Report on 1994 35th Symposium, Austin (*Priscilla Nelson*)
- Potential Sites for the 1995 36th and 1996 37th Symposia (*Scott Huang, Jaak Daemen*)
- Policies and Organization of the U.S. Rock Mechanics Symposium (*Lewis Wade, Arthur McGarr, Ronald Nordgren*)
- Corporate Financial Contributions/Exxon Production Research (*Peter Smeallie, Ron Steiger*)
- Other Issues Regarding the Symposium

5:00 Related Reports and Activities (Attachment F)

- Geotechnical Board/USNC/TT (*Peter Smeallie, Jean-Claude Roegiers, Priscilla Nelson*)
- Drilling Initiative (*Peter Smeallie*)
- Update on the SSC (*James Monsees*)
- Update on the Yucca Mountain Project (*Barry Brady, Wolfgang Wawersik*)
- Report on the Fractured & Jointed Rock Masses Conference (*Bernard Amadei*)

5:50 Next Meeting

6:00 Adjourn

8:30 Committee Dinner at Pink Adobe Restaurant, 406 Old Santa Fe Trail
(2-1/2 blocks from La Fonda hotel)

*32nd U.S. Symposium on
Rock Mechanics*

**ROCK MECHANICS
AS A
MULTIDISCIPLINARY
SCIENCE**

July 10 - 12, 1991

*Co-Sponsored by the
U.S. National Committee for Rock Mechanics
and the
Society of Petroleum Engineers*

**CONTINUING EDUCATION AND PUBLIC SERVICE
THE UNIVERSITY OF OKLAHOMA**

MONDAY, JULY 8	TUESDAY, JULY 9	WEDNESDAY, JULY 10	THURSDAY, JULY 11	FRIDAY, JULY 12
8:00-18:00 Pre-Conference Tour to Tulsa	Pre-Conference Tour to Tulsa	8:00 - 9:00 Keynote Addresses		
		9:00 - 12:00 Technical Sessions	9:00 - 12:00 Technical Sessions	9:00 - 12:00 Technical Sessions
	14:00 - 17:00 Lunar Rock Mechanics Specialty Session	12:00 - 13:00 Luncheon	12:00 - 13:00 Awards Luncheon	12:00 - 13:00 Luncheon
		13:00 - 17:00 Technical Sessions	13:30 - 18:30 Geology Field Trip	13:00 - 17:00 Technical Sessions
	18:30 Registration and Ice Breaker	18:30 Cocktails and Banquet	18:30 Halliburton Research Center Tour and BBQ	Closing 17:00

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PAPERS

IN-SITU STRESSES

- *Hydraulic Fracture Stress Measurement in Rocks with Stress-Dependent Young's Moduli* by M.B. Dusseault & Y. Wang
- *Stress Profiling Techniques in Heterogeneous Over-Pressured Formations* by M. Thiercelin
- *Poroelastic Effects Related to Stress Determination by Micro-Frac Tests in Permeable Rock* by T.J. Boone, P.R. Kry, S. Bharatha & J.M. Gronseth
- *Extended Leakoff Tests to Measure In-Situ Stress During Drilling* by K.R. Kunze & R. P. Steiger
- *In-Situ Stress After Underground Nuclear Events* by M.J. Baldwin, D.R. Townsend, S.P. Hopkins, T.J. Coffey & J.W. LaComb
- *Anelastic Strain Recovery of Rock Core from the English Midlands* by S.R. Butterworth, P.N. Chroston, C.A. Davenport, C.J. Evans & N.R. Breerton
- *Effect of Reservoir Depletion and Pore Pressure Drawdown on In Situ Stress and Deformation in the Ekofisk Field, North Sea* by L.W. Teufel, D.W. Rhett & H.E. Farrell
- *Stress Distribution in South-Central Oklahoma and its Relationship to Crustal Structure and Contemporary Seismicity* by W.L. Ellis
- *Stress Trajectories in Southwestern Ontario Using Wellbore Breakout Orientations* by N.A. Yassir & M.B. Dusseault

INSTRUMENTATION/MEASUREMENT TECHNIQUES

- *PC-Aided Triaxial Tests With Windows Graphical User Interface* by G.G. Ramos & S.R. Scale
- *A New Method for Measuring Rock Complete Stress-Strain Curve* by Y. Zheng, H. Dai, C. Xu & J. Yu

- *Core Quality Control in Petroleum Engineering* by F.J. Santarelli & M.B. Dusseault
- *A Hybrid Borehole Device for Site Investigation in Rocks* by C.K. Ip, R.A. Irvin & I.W. Farmer
- *A Comparison of the USBM Gage and the CSIRO Cell in Various Rock Conditions* by M. Cai & L.J. Thomas
- *In Situ Dilatometer Creep and Relaxation Test: Application to Time-Dependent Behavior of Deep Clays* by G. Rousset & M. Bouilleau
- *Prediction of Rock Hardness and Drillability Using Acoustic Emission* by S.J. Jung, K. Prisbrey & G. Wu
- *The Use of Acoustic Emission Technique for Identification of Failures of Tensioned Grouted Rock Anchors* by A. Bouja, G. Ballivy, B. Benmokrane, Z. Piasta & N. Feknous
- *SALTDATA: A Graphical Database for the Physical Properties of Rocks Associated with Mining of Potash and Salt* by M.J. Reeves & D. Stead

FRACTURING

- *A Mechanism of Deformation and Fracture of Brittle Rocks* by A.V. Dyskin, L.N. Germanovich & R.L. Salgenik
- *Effect of Borehole Size and Pressurization Rate on Hydraulic Fracturing Breakdown Pressure* by B.C. Haimson & Z. Zhao
- *Examination of Near-Wellbore Effects on Hydraulic Fracturing of Coal* by M. Khodaverdian, J.D. McLennan, A.H. Jones & R.A. Schraufnagel
- *Rock Fracture Toughness and Fracture Energy in Aqueous Chemical Environments* by M. Akram & M.G. Karfakis
- *Rock Fracture Tests in Simulated Downhole Conditions* by X.L. Zhao & J.-C. Roegiers
- *Hydraulic Fracture Initiation from Horizontal Wellbores: Laboratory Experiments* by C.M. Kim & H.H. Abass
- *Water Injection-Induced Shear Fracturing in the Ekofisk Field* by D.W. Rhett & L.W. Teufel

- *An Examination of the Conditions Causing Subhorizontal Hydraulic Fractures in a Highly Stressed Granite Batholith* by N.A. Chandler & C.D. Martin
- *Experimental Simulation of Hydraulic Fracturing in Shallow Coal Seams* by H.H. Abass, C.M. Kim & S. Hedayati
- *Simulation of Multiple Hydraulic Fractures in a Discrete Element System* by S. Thallak, L. Rothenburg & M. Dusseault

ROCK PROPERTIES

- *A Physical Assessment of Test Specimens in the Post-Peak Regime* by C.W. Felice, D. Norman & P.E. Senseny
- *Critical State Shale Mechanics* by R.P. Steiger & P.K. Leung
- *Determination of the Elastic Properties of Anisotropic Rock Masses from In-Situ Expansion Tests* by B. Amadei & W.Z. Savage
- *The Effects of Temperature and Pressure on the Mechanical Properties of Lac du Bonnet Grey Granite* by J.S.O. Lau, R. Jackson & B. Gorski.
- *The Effects of Zeolitized Tuff on Grain Density Determinations* by J.W. Martin, C.W. Felice, R.T. DeVan & B. Ristvet
- *Effect of Electro-Osmosis on the Indentation of Clays* by S. Roy & G.A. Cooper
- *The Effect of Percolating Structures on the Petrophysical Properties of Berea Sandstone* by D.L. Agrawal, N.G.W. Cook & L.R. Myer
- *Predicting Permeability and Electrical Conductivity of Sedimentary Rocks from Microgeometry* by E.M. Schluter, N.C.W. Cook, R.W. Zimmerman & P.A. Witherspoon
- *Estimates of Permeability and Relative Permeability for Sandstone Using Image Analysis of Cross Sections* by S.C. Blair & J.G. Berryman

- *Anisotropic Stress Influence on the Permeability of Weakly-Cemented Sandstones* by M.S. Bruno, C.A. Bovberg & F.M. Nakagawa
- *Correlation Between Mechanical Behaviour and Petrological Properties of Rock Salt* by A. Pouya
- *Effects of Temperature and Pore Water on Creep of Rock* by M.H.H. Hettema, C.J. de Pater & K-H.A.A. Wolf

DYNAMICS/SEISMICITY

- *Modeling Elastic Waves in Fractured Rock with the Kirchhoff Method* by K.T. Nihei, N.G.W. Cook & L.R. Johnson
- *Penetration Behaviour of Rock Formations during Exploration Drilling Operations in Turkey* by M.E. Akun & C. Karpuz
- *Drilling Induced Formation Damage - Stress and Temperature Effects* by P. Horsrud, R.M. Holt & L. Renlie
- *The Research on the Correlation of the Dynamic-Elastic Mechanical Parameters of Rocks with Classification of Rock Drillability* by R. Wang
- *Fracture Mechanics in the Context of Rock Crushing: Preliminary Experimental Results Concerning the Impact of Limestone Spheres* by R. Santurbano & C. Fairhurst
- *Faults as Sources of Induced Mining Seismicity* by A. Zorychta & Z. Kleczek
- *The Results of Prediction of Seismic Events in Czechoslovakia* by J. Buben & V. Rudakov
- *Microseismic Mapping of a Hydraulic Fracture* by S. Talebi, L.M. Vandamme, W.J. McGaughey & R.P. Young
- *Time-Dependent Acoustic Emission Studies on Potash* by D. Stead & Z. Szczepanik
- *An Examination of Energy Calculations Applied to Coal Bump Prediction* by K.A. Heasley
- *New Approaches to Studying Rockburst-Associated Seismicity in Mines* by J. Coughlin & R. Kranz

- *Fully Grouted Anchors Under Shock Loading* by H. Hagydorn
- *Influence of Rock Properties on Methods for the Verification of Underground Nuclear Explosions* by T.N. Dey

MODELLING

- *Use of Physical Models in Geomechanics* by J. Skorpova
- *A Finite Element Approach for Poorly-Consolidated Reservoirs* by J. Du, M.B. Dusseault & L. Rothenburg
- *A Constitutive Model for Characterizing Dilatancy in Rock* by J.-C. Roegiers, M. Azemuddin, M.M. Zaman & A. Abdulrahem
- *Influence of Pore Pressure on the Drilling Response of PDC Bits* by E. Detournay & C. Atkinson
- *Stress and Behavior of Material Under Direct Shear* by A.T. Iannacchione & L.E. Vallejo
- *A Mathematical Model to Simulate the Stick-Slip Mechanism of Faulted Rocks* by Z.-Y. Tao & L.-M. Zhang
- *On a Coupling of Physical and Mathematical Modelling in Contact Problems of Geotechnics* by V. Dolezel & P. Prochazka
- *An Integrated Model of Fracture Flow and Solid Deformation* by M. Bai & D. Elsworth
- *A Method for the Evaluation of the Long Term Convergence of Underground Excavations in Rocksalt* by D. Nguyen-Minh
- *An Elasto-Viscoplastic Model for Stress Analysis of Mining Excavations* by M. Rizkalla & H.S. Mitri
- *Adaptive Optimal Mesh Generator for Hydraulic Fracturing Modeling* by R.J. Chilton & J.-J. Wang
- *Mining Applications of an Elastodynamic Boundary Element Method* by M.G. Mack & S.L. Crouch

LABORATORY TESTING

- *The Tensile Failure of Chalk* by N. Loc, M.H. DeFreitas & M.E. Jones
- *Residual Strength Envelopes Using the Confined Shear Test Method* by M. Gyenge, R. Jackson & B. Gorski
- *Consolidated Undrained Triaxial Test Procedure for Shales* by R.P. Steiger & P.K. Leung
- *The Use of a Simple Index Test in Petroleum Rock Mechanics* by F.J. Santarelli, J.L. Detienne & J.P. Zundel
- *Hollow Cylinder Collapse: Measurement of Deformation and Failure in an X-ray CT Scanner, Observation of Size Effect* by A.P. Kooijman, M.G.A. van den Elzen & C.A.M. Veeken
- *Preliminary Results of Plane-Strain Testing of Soft Rock* by J.F. Labuz & E. Papamichos
- *Micro-Experimental Study on Damage Behaviour and Investigation of Damage Variable in Rock* by Q. Xiao, X. Ye & W. Lou
- *The Role of Wetting Fluids During the Indentation of Porous Rocks* by F.R. Suarez-Rivera, P.J. Cook, L.R. Myer & N.G.W. Cook
- *Compaction and Permeability of Simulated Waste* by R.S. Luker, T.W. Thompson & B.M. Butcher
- *The Effect of Brine on the Creep of WIPP Salt in Laboratory Tests* by N.S. Brodsky & D.E. Munson
- *On The Nature of the Scaly Texture Developed in Melange Deposits* by M.D.P. Enriquez-Reyes & M.E. Jones
- *Cement Borehole Plug Performance in Welded Tuff* by K. Fuenkajorn & J.J.K. Daemen
- *Interaction of Surrounding Rock and Pressure Tunnel Lining in the Full Strength Model Test* by S. Yang, C. Tian & M. Xie

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ANALYSIS

- *Similarity in Geotechnics and Calibration of Models from Equivalent Materials* by J. Vacek
- *Nonlinear Analysis of Stress and Strain in the Composite Rock* by J. Xu, X.-F. Xian, H. Li & G. Yin
- *Perforation Stability - Physical and Numerical Modelling* by J.M. Somerville & A.Bin Samsuri
- *Geomechanical Analysis in Mine Design: An Integrated Approach Using Microseismicity, Numerical Modelling and Structural Geology* by W.F. Bawden & R.P. Young
- *Simplified Three-Dimensional Roof-Pillar-Floor Interaction Analysis Including Time Effect* by W.M. Pytel & Y.P. Chugh
- *Study on the Behavior of Bolted Underground Opening by Using Trap-Door Technique* by B.-L. Chu, C.G. Go & Z.-Y. Yang
- *An Empirical Method for Calculation of Maximum Subsidence* by P.P. Bahuguna, B. Singh, A.M.C. Shrivastava & N.C. Saxena
- *Stability Evaluation of High Mountainous Slopes by a Method of Percolation Theory* by B. Kostak & Z. Kudrna
- *The Monolithic Stability Limit Analysis of Etan Arch Dam in Complex Rock Formations with Three-Dimensional Nonlinear Finite Element Method and Geomechanical Rupture Model* Tests by W. Zhou, R. Yang & J. Yang
- *Access to Geotechnical Information* by E. Ashworth

FIELD OBSERVATIONS

- *Floor Characteristics and Its Bearing Capacity* by D.-W. Park & Y.-M. Jiang
- *Study on the Stability of Soft Interbed in Bedded Rock* by C. Hou & N. Ma
- *Regional Coal Fracture Patterns and Coalbed Methane Development* by S.E. Laubach & C.M. Tremain

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- *Relation Between Hydrocarbon Extraction, Local Induced Deformations and Major Tectonic Events: Example of the Pyrenean Area* by J.-R. Grasso, D. Fourmaintraux, Ph. Volant & V. Maury
- *Partial Extraction to Control Surface Subsidence Due to Coal Mining* by M.D.G. Salamon
- *Subsidence Over An Abandoned Dissolving Salt Mine* by G. Barla, M. Civita & P. Jarre
- *Analysis of Early Creep Closures in Geomechanically Connected Underground Rooms in Salt* by D.E. Munson, R.L. Jones & K.L. DeVries
- *Fracturing Around Excavations in Salt at the WIPP* by R.F. Cook & W.M. Roggenthen
- *Changes in Rock Salt Permeability Due to Nearby Excavation* by J.C. Stormont, C.L. Howard & J.J.K. Daemen
- *WIPP Intermediate Scale Borehole Test - A Pretest Analysis* by J.C. Arguello
- *The Closure of WIPP Disposal Rooms Filled with Various Waste and Backfill Combinations* by J.R. Weatherby, W.T. Brown & B.M. Butcher
- *The Structural Response of a WIPP Disposal Room with Internal Gas Generation* by J.R. Weatherby, J.C. Arguello, B.M. Butcher & C.M. Stone

WELLBORE STABILITY

- *Practical Wellbore Stability Assessment Requires A Multi-Disciplinary Input* by K.A. Kwakwa & A.S. Batchelor
- *Stress-Induced Anisotropy in Rock and Its Influence on Wellbore Stability* by B. Wu & J.A. Hudson
- *3D Stress Effects in Elastoplastic Wellbore Failure Models* by R.T. Ewy
- *The Prediction of Yield Zone Development Around a Borehole and Its Effect on Drilling and Production* by B.G.D. Smart, J.M. Somerville & K.J. MacGregor

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- *The Rock Mechanical and Hydraulic Analysis of the Water Bearing Strata Around a Circular Shaft and Tunnel* by G. Ni
- *Time-Dependent Borehole Stability under Mechanical and Thermal Stresses: Application to Underground Nuclear Waste Storage* by J.M. Kemeny & N.G.W. Cook
- *Input Uncertainties and Calculated Borehole Closure* by A.F. Fossum, P.E. Senseny & B.H. Thacker
- *Comparison Between Field Observations and Theory for Stress-Induced Borehole Ellipticity* by K.S. Hansen
- *Evaluation of Optimal Mudweight in Soft Shale Levels* by Ph. Charlez & O. Heugas
- *Wellbore Instability of Shales Using A Downhole Simulation Test Cell* by D.P. Salisbury, G.G. Ramos & B.S. Wilton

DESIGN

- *In Search of a Design Methodology for Rock Mechanics* by Z.T. Bieniawski
- *Rockbolt Support Design Using a Probabilistic Method of Key Block Analysis* by D.B. Tyler, R. Trueman & R.J. Pine
- *Application of Telescopic Rockbolt and Flexible Shotcrete in the Tunnel Surrounded by Rock Subject to Large Deformation* by Y. Zheng, L. Song & D. Wang
- *Stress-Induced Stability Problems - A Coal Mine Case Study* by H. N. Maleki, A. Weaver & R. Acre
- *Adaptable Support in Large Deformable Soft Rock Tunnels* by J. Lu & H. Lu
- *Stability Assessment and Design Model Development for Petroleum Storage Cavern Network in a Rock Salt Dome* by M.R. Salami
- *The Use of Field Data in the Design of Rock Slopes* by G.D. Matheson

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DISCONTINUITIES/FLUID FLOW

- *A Comparison of Procedures for Defining Orientation Domains in Jointed Rock* by M. Cravero, G. Iabichino & A. Mahtab
- *Generation of Artificial Extension Joints and their Mechanical Properties* by T.-H. Huang & Z.-Y. Yang
- *Effect of Normal Rigidity on the Shearing Behavior of Rock Discontinuities* by B. Benmokrane & M. Bouraoui
- *Comparison of Direct Shear and Hollow Cylinder Tests on Rock Joints* by T.B. Reardon, E.C. Drumm & D. Lange-Kombak
- *Fractal Characterization and Modeling of Natural Rock Joint Surfaces* by S.L. Huang, R.C. Speck & S.M. Oelfka
- *Inversion of Hydraulic and Electrical Data for the Determination of Fracture Aperture* by A.R. Piggott, J. Xiang & D. Elsworth
- *The Activity of Tectonic Fault and the Research for its Mechanism Related to Rock Mechanics* by Z.-Y. Tao, L.-M. Zhang & T.-M. Chen
- *Topological Structure of Fracture Systems in Rock* by D. Lin & C. Fairhurst
- *A Hydromechanical Representation of Rock Fractures* by A.R. Piggott & D. Elsworth
- *Fracture Spacing, Density, and Distribution in Layered Rock Masses: Results from a New Experimental Technique* by H. Wu & D.D. Pollard
- *Expert System of Discontinuity Properties Evaluation* by Y.-M. Lin & X.-T. Feng

33rd U.S. Symposium on Rock Mechanics

**June 8-10, 1992
Santa Fe, New Mexico**

THIRD ANNOUNCEMENT AND TECHNICAL PROGRAM

***A Regional Conference of the
International Society for Rock Mechanics***

ISRM

Sponsored by:

U.S. National Committee for Rock Mechanics
International Society for Rock Mechanics
U.S. Department of Energy - Office of Basic Energy Sciences

Hosted by:

Lawrence Berkeley Laboratory
Lawrence Livermore National Laboratory
Los Alamos National Laboratory
Sandia National Laboratories

The U.S. Rock Mechanics Symposium is an annual meeting to promote the synthesis of rock mechanics activities in professional societies, academia, industry, and government.

Session Schedule

Monday, June 8				
	Room 1	Room 2	Room 3	Room 4
8:00 a.m.-8:30 a.m.	Opening Session			
8:30 a.m.-9:30 a.m.	Keynote (Auditorium): "Evolution of Fractures and Fracture Systems." D. D. Pollard Stanford University			
9:30 a.m.-10:00 a.m.	Break			
10:00 a.m.-12:00 p.m.	Fault Mechanics Topic 2 (6 papers)	Subsidence & Ground Motions Topic 4 (5 papers)	Underground Storage & Sealing Topic 7 (5 papers)	
12:00 p.m.-1:30 p.m.	Lunch, Hotel La Fonda			
1:30 p.m.-3:15 p.m.	Experimental Methods Topic 16 (5 papers)	Reservoir Completion & Stimulation Topic 6 (4 papers)	Design & Supports Topic 8 (5 papers)	
3:15 p.m.-4:00 p.m.	Break			
4:00 p.m.-5:00 p.m.	Experimental Methods Topic 16 (3 papers)	Reservoir Completion & Stimulation Topic 6 (3 papers)	Design & Supports Topic 8 (3 papers)	

Tuesday, June 9				
	Room 1	Room 2	Room 3	Room 4
8:00 a.m.-9:00 a.m.	Plenary Session (Auditorium): Special Studies of the U.S. National Committee for Rock Mechanics			
9:15 a.m.-10:15 a.m.	Origin of Stress in the Lithosphere Topic 1 (3 papers)	Rock Mass Monitoring Topic 3 (3 papers)	Fracture Mechanics Topic 14 (3 papers)	
10:15 a.m.-10:45 a.m.	Break			
10:45 a.m.-12:05 p.m.	Origin of Stresses in the Lithosphere Topic 1 (4 papers)	Rock Mass Monitoring Topic 3 (4 papers)	Fracture Mechanics Topic 14 (4 papers)	
12:05 p.m.-1:30 p.m.	Lunch and Awards, Sweeney Center			
1:30 p.m.-2:30 p.m.	Physical Rock Properties Topic 15 (6 papers)	Geostatistics & Reliability Topic 13 (3 papers)	Workshop Geotechnical Design Methodology	Workshop Modeling Fractured Reservoirs
2:30 p.m.-3:30 p.m.		Nonlinear Dynamic Systems Topic 12 (3 papers)		
3:30 p.m.-4:00 p.m.	Break			
4:00 p.m.-5:00 p.m.	Physical Rock Properties Topic 15 (3 papers)	Blasting Topic 5 (4 papers)	Workshop Geotechnical Design Methodology	Workshop Modeling Fractured Reservoirs

Wednesday, June 10				
	Room 1	Room 2	Room 3	Room 4
8:00 a.m.-9:00 a.m.	Keynote (Auditorium): "Rock Mechanics Contributions from Defense Programs," F. E. Heuzé, Lawrence Livermore National Laboratory			
9:15 a.m.-10:15 a.m.	Constitutive Modeling & Strain Localization Topic 11 (3 papers)	Numerical Methods Topic 10 (3 papers)	Fluid & Contaminant Transport Topic 9 (3 papers)	Workshop Induced Seismicity
10:15 a.m.-10:45 a.m.	Break			
10:45 a.m.-12:05 p.m.	Constitutive Modeling & Strain Localization Topic 11 (4 papers)	Numerical Methods Topic 10 (3 papers)	Fluid & Contaminant Transport Topic 9 (4 papers)	Workshop Induced Seismicity
12:05 p.m.-1:30 p.m.	Lunch, Box Lunch			
1:30 p.m.				Workshop Induced Seismicity

List of Papers

1: Origin of Stresses in the Lithosphere

Session Chairs: B. C. Haimson, *University of Wisconsin*; H. Swolfs, *United States Geological Survey*

[Tuesday a.m.]

"In Situ Stress Heterogeneity Identification with the HTPF Tool,"
F. H. Cornet & J. Mosnier

"A Field Comparison of Techniques for Determining the Direction of Hydraulic Fractures," D. P. Yale, M. K. Strubhar & A. W. El Rabaa

"Hydraulic Fracturing Measurements in New York City Reaffirm the Uniformity of the Stress Regime in Northeastern United States," B. C. Haimson

"Development of a Piezomagnetic Method to Determine Fault-Related Stress Variations," S. Narbutovskih, R. J. Martin & R. J. Greenfield

"Dynamic Stress Measurements Using Piezomagnetism," R. J. Martin, III & J. S. Noel

"Tectonic Structures and Wellbore Breakout Orientation," P. Aleksandrowski, O. H. Inderhaug & B. Knapstad

"Core Relaxation Measurements on Compacted Sedimentary Formations (well Ba1)," J. Dellandre & J. Sarda

2: Fault Mechanics

Session Chairs: J. Logan, *Texas A&M University*; T.-F. Wong, *State University of New York at Stony Brook*

[Monday a.m.]

"The Influence of Fluid Flow on the Mechanical Behavior of Faults,"
J. M. Logan

"Strength Recovery along Simulated Faults by Solution Transfer Processes," J. T. Fredrich & B. Evans

"Fluid Injection for Rockburst Control in Deep Mining," M. Board, I. Rorke, G. Williams & N. Gay

"The Transition from Stable Sliding to Cyclic Stick-Slip: Effect of Cumulative Slip and Load Point Velocity on the Nonlinear Dynamical Behavior in Three Rock-Gouge Systems," Y. Gu, T. Wong

"An Analytical Model for Stress Concentration and Failure along Fault Planes," D. Hopkins

"Mechanics of Fault Zone Development in Brittle Dilatant Analog Geomaterial" G. Archambault, R. Flamand, A. Rouleau & R. Daigneault

3: Rock Mass Monitoring

Session Chairs: M. Langer, *Federal Institute for Geosciences and Natural Resources, Germany*; D. E. Munson, *Sandia National Laboratories*

[Tuesday a.m.]

"Long Term Behavior of a Large Cavern in Sedimentary Rock," A. Pahl & W. Glogler

"The ASPO Hard Rock Laboratory - Overview of Pre-Investigations and Monitoring," L. O. Ericsson & K-E. Almen

"Monitoring the Geomechanical and Hydrogeological Response in Granite for AECL Research's Buffer/Container Experiment," N. A. Chandler, B. H. Kjartanson, E. T. Kozak, C. D. Martin & P. M. Thompson

"Monitoring the Excavation-Induced Response of Granite," R. S. Read & C. D. Martin

"HAW Test at Asse: Measured and Calculated Rock Response," T. Rothfuchs, H-K. Feddersen, V. Graefe, B. Hente & K. Wieczorek

"Implementing and Monitoring Thermomechanical Tests in a Salt Formation of a French Potash Mine," M. Ghoreychi, M. Raynal & J. Roman

"Application of Rock Mass Monitoring for Stability Assessment of Pit Slope Failure," T. M. Ryan & R. D. Call

4: Subsidence and Ground Motions

Session Chairs: R. Boade, *Phillips Petroleum Co.*; M. E. Jones, *University College, London*

[Monday a.m.]

"Mechanics of Pore Collapse and Reservoir Compaction in Weak Porous Rocks," A. Abdulraheem, J.-C. Roegiers & M. M. Zaman

"Development of Dynamic Subsidence over Longwall Panels in the Northern Appalachian Coal Region," V. Adamek, P. W. Jeran & M. A. Trevits

"The Rate-Type Compaction of a Weak North Sea Chalk," M. Andersen, N. Foged, H. F. Pedersen

"Reservoir Compaction and Surface Subsidence above the Lost Hills Field, California," M. S. Bruno & C. A. Bovberg

"Subsidence-Induced Shear Failures above Oil and Gas Reservoirs," J. M. Hamilton, A. V. Maller & M. D. Prins

5: Blasting

Session Chairs: C. Aimone, P.-A. Persson, New Mexico Institute of Mining & Technology; D. Preece, Sandia National Laboratories

[Tuesday p.m.]

"Effects of Blasting Practices on Fragmentation," M. S. Stagg, R. E. Otterness & D. E. Siskind

"Computer Modeling of Gas Flow and Gas Loading of Rock in a Bench-Blasting Environment," D. S. Preece & S. D. Knudsen

"Improved Modeling of the Dynamic Fracturing of Rock with Propellants," J. F. Schatz

"A Numerical Study of the Effectiveness of Mechanical Rock Bolts in an Underground Opening Excavated by Blasting," K. M. Chua, C. Aimone & N. Majtabai

6: Reservoir Completion and Stimulation

Session Chairs: R. Nordgren, Rice University; C. Yew, University of Texas at Austin

[Monday p.m.]

"Rock Mechanics Issues in Completion and Stimulation Operations," N. R. Warpinski

"Influence of Pressurization Rate on the Magnitude of the Breakdown Pressure," E. Detournay & A. Cheng

"Stress Path Dependence of Matrix Permeability of North Sea Sandstone Reservoir Rock," D. W. Rhett & L. W. Teufel

"Studies on Stability of a Simulated Borehole in Compacted Clay," S. Roy & G. A. Cooper

"Numerical Representation of Multilayer Hydraulic Fracturing," M. G. Mack, A. R. Piggott & J. L. Elbel

"Experimental Investigation of Cavity Stability," J. Tronvall

"Thermal Stresses Near a Circular Opening in an Unconsolidated Reservoir," Y. Wang, J. D. Scott & M. B. Dusseault

7: Underground Storage and Sealing

Session Chairs: R. S. Harig, Parsons Brinckerhoff; J. Ratigan, RE/SPEC, Inc.

[Monday a.m.]

"Observed Cavern Performance of a Large Underground Storage Facility in Weak Jointed Chalk," G. Barla & U. Rabagliati

"Effect of Internal Gas Generation on the Extension of Pre-existing Fractures around WIPP Disposal Rooms," J. G. Argulo, J. R. Weatherby, C. M. Stone & F. T. Mendenhall

"Effects of the Moon on Underground Caverns," P. Berest, P. A. Blume & G. Durup

"Mechanical Effects of Pressure and Temperature Variations on Annular Cement in Oil Wells," I. Charara & D. Nguyen Minh

"Measured and Calculated Closures of Open and Brine-Filled Shafts and Deep Vertical Boreholes in Salt," D. E. Munson, K. L. DeVries, D. M. Schiermeister, W. F. DeYonge, & R. L. Jones

8: Design and Supports

Session Chairs: M. G. Salamon, Colorado School of Mines; L. V. Wade, U. S. Bureau of Mines

[Monday p.m.]

"Integration of Stress Analysis into the Mine Excavation Design," M. A. Coulthard, N. C. Journef & C. F. Swindells

"Trial Underhand Longwall Stope at the Lucky Friday Mine, Mullan, Idaho, U.S.A," J. K. Whyatt, T. J. Williams & W. G. Pariseau

"A Neural Network - Expert System Hybrid Approach for Tunnel Design," R. Sterling & C. Lee

"Failure Modes and Pillar Behavior in the Zinkgruvan Mine," J. Sjöberg

"An Approach for Thermal Load Considerations in a Repository Design Methodology," M. Nataraja, T. Brandshaug, A. Chowdhury & N. Tanious

"Reinforcement Design for Jointed Rock Masses," C. R. Windsor & A. G. Thompson

"Full Scale Field Tests of High Capacity Rock Anchors," G. A. Scott & D. A. Bruce

"Rehabilitation Roof Bolting in a Deep Salt Mine," J. C. Shook

9: Fluid and Contaminant Transport

Session Chairs: P. R. La Pointe, Golder Associates, Inc.; J. L. Yow, Jr., Lawrence Livermore National Laboratory
[Wednesday a.m.]

"Immiscible Fluid Flow in a Fracture," L. J. Pyrak-Nolte, D. Helgeson, G. M. Haley & J. W. Morris

"Analytical and Experimental Studies of Heat Convection by Water Flow in Rock Fractures," J. Zhao

"Scale Effects in Estimating Fractured Rock Block Conductivity from Packer Tests," J. F. Geier & L. Hassler

"Predicting Fracture Permeability from Bed Curvature," D. D. Schultz-Ela & J. Yeh

"3D Stochastic Simulation of Fracture Network and Flow at Stripa Conditioned on Observed Fractures and Calibrated or Measured Flow Rates," J-P. Chiles, F. Guerin & D. Billaux

"Discrete Feature Dual Porosity Analysis of Fractured Rock Masses: Applications to Fractured Reservoirs and Hazardous Waste," W. S. Dershowitz, T. W. Doe & P. C. Wallmann

"The Application of a Three-Dimensional Fracture Network Model to a Hot-Dry-Rock Reservoir," G. W. Lanyon, R. D. Kingdon & A. W. Herbert

10: Numerical Methods

Session Chairs: J. Ghaboussi, University of Illinois; H. S. Morgan, Sandia National Laboratories
[Wednesday a.m.]

"Some Theoretical and Computational Aspects of Large Scale Discrete Element Analysis," J. Ghaboussi

"A Direct Boundary Integral Method for Multilayered Rock with Fractures," S. Selcuk & S. L. Crouch

"Modeling Rock Joints and Blocks by Manifold Method," G-H. Shi

"An Implicitly Coupled Model of Fluid Flow in Jointed Rock," D. Swenson & M. Beikmann

"Modeling Flow in Non-Homogeneous Rock Joint Using the Integral Transform Method," B. Amadei & T. Illangasek

"A Micromechanical Investigation of the Influence of Couple Stresses on Failure in Granular Materials," J. P. Bardet, Q. Huang & J. Proubet

11: Constitutive Modeling and Strain Localization

Session Chairs: J. W. Rudnicki, Northwestern University; H. L. Schreyer, University of New Mexico
[Wednesday a.m.]

"Localization Studies under Triaxial Conditions," D. J. Holcomb

"The Formation of a Yield-Surface Vertex in Rock," W. A. Olsson

"Constitutive Model for Rocks Accounting for Viscoplastic Deformation and Damage," P. Nawrocki & Z. Mroz

"Mesh-Sensitivity Analysis of an Impact Test on a Double-Notched Specimen," L. J. Sluys & R. de Borst

"Evolution of Fractal Geometries in Deforming Material," H. B. Muehlhaus, B. E. Hobbs & A. Ord

"A Microphysical Constitutive Model for Fractured Granular Materials," L. G. Margolin & B. C. Trent

"A Theory on Water Activity between Drill-Fluid and Shale," C. H. Yew, M. E. Chenevert & C. L. Wong

12: Nonlinear Dynamic Systems

Session Chairs: J. Dienes, Los Alamos National Laboratory; J. B. Rundle, Lawrence Livermore National Laboratory
[Tuesday p.m.]

"Statistical Model for Rock Fracture," S. Blair & N.G.W. Cook

"Nonlinear Dynamical Models for Earthquakes and Frictional Sliding: An Overview," J. B. Rundle

"Studies on Mechanism of Rock Bursts-Associated Seismicity Mines by Using Fractals and Damage Mechanics," H. Xie & W. G. Pariseau

13: Geostatistics and Reliability

Session Chairs: R. Barnes, University of Minnesota; H. H. Einstein, Massachusetts Institute of Technology
[Tuesday p.m.]

"Interpretation of Fracture Spacing and Intensity," W. S. Dershowitz & H. H. Herda

"Relative Probabilities of Joint Intersections," M. Mauldon

"Fragment Size Distributions and Rock Joints," D. S. Young & W. Zhang

14: Fracture Mechanics

Session Chairs: A. K. Maji, University of New Mexico; P. L. Swanson, U.S. Bureau of Mines
[Tuesday a.m.]

"Application of Fracture Mechanics in Geological Materials," E. P. Chen

"Specimen Size Effect of Fracture Toughness of Kollax Gabbro," X. Yi, Z. Sun, F. Ouchterlony & O. Stephansson

"On the Pore-Based Mechanism of Dilatancy and Fracture of Rocks under Compression," A. V. Dyskin, L. Germanovich & K. B. Ustinov

"Energy Dissipation Processes Affecting Crack Growth in Quasi Brittle Materials," E. A. Steffler, G. B. May & J. S. Epstein

"Fracture Mechanics in Hydraulic Fracturing," J. Shlyapobersky & A. Chudnovsky

"Microcrack Interaction Leading to Shear Fracture," D. Lockner, Z. Reches & D. Moore

"Nonlinear Model for Fracture at the Concrete-Rock Interface," A. K. Maji & J. Wang

15: Physical Rock Properties

Session Chairs: N.G.W. Cook, University of California at Berkeley; A. Duba, Lawrence Livermore National Laboratory
[Tuesday p.m.]

"The Variation of the Thermal Conductivity of Tuff with Moisture - Experimental Results and Proposed Model," E. Ashworth

"Modulus Dispersion and Attenuation in Tuff, Sandstone, and Granite," R. W. Haupt, R. J. Martin, III, X. Tang, W. J. Dupree & R. H. Price

"Modeling of the Elastic Properties of a Schistose Rock from Seismic Measurements," G. J. Hesler, III, L. R. Meyer & N.G.W. Cook

"Study on the Transmission of Shear Waves across Thin Liquid Films and Thin Clay Layers," R. Suarez-Rivera, L. R. Myer & N. G. W. Cook

"Shale Swelling at Elevated Temperature and Pressure," M. E. Chenevert & S. Osisanya

"Fabric Changes Induced in a Cemented Shale through Consolidation and Shear," M. J. Leddra, D. N. Pelley & M. E. Jones

"Strain States During Stress Path Testing of Chalk," N. M. Loe, M. J. Leddra & M. E. Jones

"Aspects of Transient Creep of Olivine," D. R. Hanson & H. A. Spetzler
"Problems and Promises of Index Testing of Rocks," P. Grasso, S. Zu & A. Mahtab

16: Experimental Methods

Session Chairs: B. Amadei and H. Spetzler, University of Colorado
[Monday p.m.]

"Hand-Held Velocity Probe for Rapid Outcrop and Core Characterization," M. L. Batzle & B. J. Smith
"Laboratory Simulation of Core Damage Induced by Stress Release," R. M. Holt & C. J. Kenter
"Fiber Optics—A New Method for Monitoring Stress Changes," F. Hornuth, J. Chen & E. M. Van Eeckhout
"Application of Kaiser Effect to Measure In-Situ Stresses in Underground Mines," M. Momayez & F. P. Hassani
"A Feasibility Study of Modal Analysis in Geotechnical Engineering - Field Phase," X. Sun & H. R. Hardy, Jr.
"Elastic Interface Waves along a Fracture: Theory and Experiment," L. J. Pyrak-Nolte, J. Xu & G. M. Haley
"Seismic Behavior of Fractures under Normal Compression," K. T. Nihei & N. G. W. Cook
"Verification of a Seismic Tomogram Interpretation by Finite Element Analysis," D. W. H. Su & S. A. Cotten

1991 USNC/Rock Mechanics Awards Recipients

Thomas J. Boone, Esso Resources Canada Ltd., "Simulation of Hydraulic Fracture Propagation in Poroelastic Rock with Application to Stress Measurement Techniques," Applied Research

Thomas J. Boone, Esso Resources Canada Ltd., "Simulation and Visualization of Hydraulic Fracture Propagation in Poroelastic Rock," Ph.D. Student Thesis

Neville G.W. Cook, Department of Materials Science and Mineral Engineering, University of California, Berkeley, "Transmission of Seismic Waves Across Single Natural Fractures," Basic Research

Russell T. Ewy, Exxon Production and Research Company, "Deformation and Fracture Around Cylindrical Openings in Rock," Ph.D. Student Thesis

Anthony R. Ingraffea, School of Civil and Environmental Engineering, Cornell University, "Simulation of Hydraulic Fracture Propagation in Poroelastic Rock with Application to Stress Measurement Techniques," Applied Research

Steven Jones, Cyprus Plateau Mining Corporation, "Case Study on the Use of Grouted Support in a Two-Entry Gate Road," Case Histories

Larry R. Myer, Staff Scientist, Earth Sciences Division, Lawrence Berkeley Laboratory, "Transmission of Seismic Waves Across Single Natural Fractures," Basic Research

Laura Pyrak-Nolte, Visiting Assistant Professor, Civil Engineering Building, Purdue University, "Transmission of Seismic Waves Across Single Natural Fractures," Basic Research

Jean-Claude Roegiers, School of Petroleum and Geological Engineering, University of Oklahoma, Norman, "Simulation of Hydraulic Fracture Propagation in Poroelastic Rock with Application to Stress Measurement Techniques," Applied Research

Stephen Signer, Spokane Research Center, U.S. Bureau of Mines, "Case Study on the Use of Grouted Support in a Two-Entry Gate Road," Case Histories

1992 USNC/Rock Mechanics Awards Recipients

James M. Bridell, Department of Civil and Mineral Engineering, University of Minnesota, Minneapolis, "Reducing Frictional Constraint in Compression Testing Through Lubrication," M.Sc. Student Thesis

Steven L. Crouch, Professor and Head, Department of Civil and Mineral Engineering, University of Minnesota, Minneapolis, "Mining Applications of an Elastodynamics Boundary Element Method," Applied Research

Mark G. Mack, Senior Development Engineer, Dowell Schlumberger Inc., "Mining Applications of an Elastodynamics Boundary Element Method," Applied Research

Gregg A. Scott, Civil Engineer/Principal Designer, U.S. Bureau of Reclamation, "Deformation of Rock Foundations Under Dams," Case Histories

John C. Stormont, Senior Member of Technical Staff, Sandia National Laboratories, "Gas Permeability Changes in Rock Salt During Deformation," Ph.D. Student Thesis

**U.S. National Committee for Mechanics 1990/91
— Annual Summary —**

ISRM is represented in the United States by the U.S. National Committee for Rock Mechanics (USNC/RM) in the National Research Council/National Academy of Sciences. The USNC/RM was started in 1964. It is a national committee under the Geotechnical Board and has seven major goals:

(1) Promote coordination and synthesis of rock mechanics developments among U.S. technical and professional societies and organizations involved in rock mechanics.

(2) Advise the U.S. government and the related industrial and scientific communities on the issues in rock mechanics. This includes conducting special studies and preparing reports on issues of national importance using both committee members and selected specialists.

(3) Promote a dialogue between the practitioners of rock mechanics and the rock mechanics research community.

(4) Assist the government and the private sector in identifying rock mechanics problems of national interest.

(5) Act as the U.S. national group to the International Society for Rock Mechanics.

(6) Sponsor the annual U.S. Rock Mechanics Symposium.

(7) Promote, recognize, and highlight excellence in rock mechanics by sponsoring awards for outstanding papers on rock mechanics published in the United States.

The committee currently consists of ten members chosen to provide a balanced representation from the U.S. rock mechanics community. Individual committee members continue to maintain ties with professional societies with active programs in rock mechanics.

The USNC/RM participated actively in the 7th International Congress on Rock Mechanics held in Aachen, Germany in September 1991. The U.S. delegation commends Dr. J. Coulson on completion of his term as ISRM Vice-President—North America and looks forward to working with Dr. P. Kaiser of Canada, the newly elected Vice President—North America. The delegation and the USNC/RM are pleased with the election of Prof. C. Fairhurst as President of ISRM.

The 32nd U.S. Rock Mechanics Symposium was sponsored jointly by the USNC/RM, ISRM, and the Society of Petroleum Engineers (SPE). The meeting was hosted by the University of Oklahoma in Norman. The conference scheme, "Rock Mechanics as a Multidisciplinary Science," was stressed by three keynote addresses by Prof. W.F. Bawden, Queens University, Canada (*The Evolution of Rock Engineering as a Practical Tool in Underground Hard Rock Mining and the Implementation of Future Technological Change*), Prof. J. Rice, Harvard University (*Rock Friction and Earthquake*

Mechanics), and Dr. A. Perkins, ARCO Oil and Gas Company (*Significance of Rock Mechanics in Petroleum Engineering and Some Challenges for the Future*).

The U.S. Rock Mechanics Symposium in Norman provided the forum for announcing the 1991 awards of the USNC/RM. The Basic Research Award was given to L. Pyrak-Nolte (Purdue University), L.R. Myer (Lawrence Berkeley Laboratory), and N.G.W. Cook (University of California-Berkeley) for a paper entitled *Transmission of Seismic Waves Across Single Natural Fractures*. T.J. Boone (Esso Resources Canada Ltd.), A.R. Ingraffea (Cornell University), and J.C. Roegiers (University of Oklahoma) were honored with the Applied Research Award for *Simulation of Hydraulic Fracture Propagation in Poroelastic Rock with Application to Stress Measurement Techniques*. S.R. Singer (U.S. Bureau of Mines) and S. Jones (Cyprus Plateau Mining Corp.) were the recipients of the Award for Case Histories for the paper *Case Study on the Use of Grouted Support in a Two-Entry Gate Road*. Co-winners of the award for best doctoral thesis were T.J. Boone (Cornell University) for *Simulation and Visualization of Hydraulic Fracture Propagation in Poroelastic Rock*, and R.T. Ewy, University of California-Berkeley, for *Deformation and Fracture Around Cylindrical Openings in Rock*.

Preparations are under way for the 33rd U.S. Rock Mechanics Symposium from June 8-10, 1992, in Santa Fe, New Mexico. The schedule of the meeting was coordinated with the schedule of the Topical Conference on Fractured and Jointed Rock Masses of the ISRM Commission on Rock Joints, June 3-5, 1992, Lake Tahoe, California. Both conferences are regional conferences of ISRM. The Santa Fe meeting is cosponsored by the Office of Basic Energy Sciences, U.S. Department of Energy. The Santa Fe symposium will be preceded by a tutorial shortcourse on fractals in the geosciences with demonstrated and potential applications. A second shortcourse is planned on the use of geostatistics in rock mass characterization. Four workshops will be held on Induced Seismicity, Geotechnical Design Methodology, Modeling of Fractured Reservoirs with Emphasis on Scaling, and Coal Pillar Mechanics. The shortcourses will be offered at minimal cost. All workshops will combine topical foci with ample opportunities for discussions. The workshop Geotechnical Design Methodology is motivated by the need for a systematic, cost-effective implementation of rock mechanics principles. The importance of applications are also reflected, for example, in the sub-themes of the induced-seismicity workshop; deep mining, oil and gas exploitation, reservoir loading, and liquid injection at depth. Further workshop details will be distributed with the second announcement of the 33rd U.S. Rock Mechanics by January, 1992.

The existence and schedules of an ever increasing number of rock mechanics meetings sponsored by ISRM and by professional societies mandate that the U.S. Rock Mechanics Symposia be coordinated more closely with other national and international conferences. To accomplish this, the USNC/RM has extended the planning of the rock mechanics symposia to three years. The 1993 U.S. Rock Mechanics Symposium will be held June 28-30 at the University of Wisconsin with organizing faculty in the Departments of Materials Science and Engineering/Geological Engineering, Geology and Geophysics, and Engineering Mechanics. Special workshops in the area of in situ stress, borehole breakouts, and proelasticity are being contemplated. The 35th U.S. Rock Mechanics Symposium in 1994 will be hosted by the University of Texas at Austin with participation from the Texas Bureau of Economic Geology and industry. The Texas site was selected because of the opportunity to visit the Super Conductor Super Collider site

near Dallas during the main construction phase. The exact date of 1994 Rock Mechanics Symposia will be announced early in 1992.

The USNC/RM believes that the proliferation of geotechnical/rock mechanics meetings tends to reduce the attendance of each individual meeting and creates difficulties in the collection of high-quality original papers. Some criticism has also been raised concerning the lack of rigorous paper reviews which cannot be conducted completely in an annual cycle between the submission of abstracts and paper publication. For these and several other reasons, the USNC/RM has initiated a careful evaluation of the frequency, formats, and publication policy of its conferences. Workshops are being reviewed as a means to enhance discussions of work in progress, and publication of selected papers in special issues of journals or monographs are being considered. Topical conferences might highlight the needs of industry or broaden the scope of the Special Studies of the Committee. The USNC/RM is also considering the possibility of having a joint American/Canadian Rock Mechanics Symposium.

The USNC/RM has entered a major new study entitled, "Fracture Characterization and Fluid Flow." The study is chaired by Dr. Jane C.S. Long and twelve members representing such diverse fields as fracture hydrogeology, fracture geology, borehole and radar geophysics, rock mechanics, geochemistry, and statistics. The introduction to the prospectus of this study states: "Over the past two decades, the importance of characterizing and understanding fluid flow in fracture systems has increased dramatically. Fractured petroleum reservoirs have become more important as a national resource. Most recently, fractures have been found to play a major role in containment transport at a significant number of sites across the United States. For example, contaminants at the Stringfellow site in California are transported in fractured granite. The U.S. Department of Energy is considering nuclear waste storage in a fractured tuff. Tunnels and mines in hard rock consistently encounter fracture-related problems. Many of these problems have been considered intractable because fracture networks are notoriously chaotic and poorly interconnected. Consequently, recent research concerning techniques and approaches developed in separate arenas, while extensive, has not been reviewed, integrated, and communicated to others throughout the geotechnical community. The importance of these problems to the quality of the nation's environment and economy makes it desirable to evaluate recent work and relate recent progress and new approaches." Plans are to have the results of this study presented and discussed at the 1992 U.S. Rock Mechanics Symposium in Santa Fe.

Members of the USNC/RM, together with members of the Geotechnical Board/National Research Council, also participated in evaluations of large-scale in situ methods to study the effects of heterogeneities and scale on rock mass behavior. During the last meeting of the USNR/RM, Prof. Paul Witherspoon, Lawrence Berkeley Laboratory and University of California-Berkeley, discussed both the need for and potential approaches to such an investigation and how it would complement ongoing underground-storage and mining programs.

Strong interactions between the USNC/RM, industry, and professional societies are reflected in the co-sponsorship of technical sessions and joint membership in the USNC/RM and the rock mechanics working groups of the American Society of Civil Engineers (ASCE), Society of Mining Engineers (SME), Society of Petroleum Engineers (SPE), and American Society of Mechanical Engineers (ASME). Halliburton Services

Company hosted a tour of the Halliburton Research Laboratory. Marathon Oil Co., ARCO Oil and Gas Co., Phillips Petroleum Co., Dowell Schlumberger, U.S. Geological Survey, and the U.S. Bureau of Mines are participating in special studies and in the organization of workshops for the next U.S. Rock Mechanics Symposium. During the 31st U.S. Rock Mechanics Symposium, ASCE conducted a field-course on engineering systems of rock mass classification. With proper refinements this course is but one example of how joint initiatives of the USNC/RM and professional societies can bring together researchers and practitioners to test new ideas.

The past year was the second since the reorganization of the U.S. National Committee of Rock Mechanics. The committee has been pleased about the endorsement by the National Research Council and sponsorship of its technical functions by many government organizations and private industry. The committee intends to use its technical accomplishments, enhanced communications, and its neutral role within the National Academy of Sciences/National Academy of Engineering to serve the U.S. rock mechanics community and ISRM. Special efforts will be continued to increase the number of affiliates of the USNC/RM and, therefore, increase the U.S. membership in the International Society for Rock Mechanics.

NATIONAL RESEARCH COUNCIL
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
GEOTECHNICAL BOARD
U.S. NATIONAL COMMITTEE FOR ROCK MECHANICS

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Washington, DC 20418
FAX: (202) 334-3315 3370

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Harris Building, Room 274
2001 Wisconsin Avenue, N.W.
(202) 334-3136

May 15, 1992

USNC/RM CHAIRMAN'S NEWSLETTER

Dear Committee Members and Colleagues:

This letter is intended to inform members of the U.S. National Committee for Rock Mechanics (USNC/RM), International Society for Rock Mechanics (ISRM) members, members of the rock mechanics community, sponsoring agencies, and others about current activities of the USNC/RM. I plan to circulate several newsletters during the year, in the Spring (this issue), Fall and Winter. The Rock Mechanics Symposium in mid-Summer supplants a summer newsletter as it provides ample opportunity for direct communication between members. In distributing this letter, an invitation is extended to members and colleagues seeking submission of comments and items you suggest for circulation to members, and any proposals you may have to promote the interests of our geomechanics scientific and engineering communities.

The primary business of the USNC/RM revolves around its sponsorship of the annual U.S. Rock Mechanics Symposium, the (roughly annual) special study and the awards process that recognizes distinguished contributions to the discipline of rock mechanics. Other business includes our participation in the affairs of the ISRM and specific efforts associated with national rock mechanics matters raised by members or sponsors. I will briefly summarize points of interest arising from our business, in the full knowledge that some of the items discussed may be well known to many colleagues.

ROCK MECHANICS SYMPOSIA

The committee's preoccupation with the annual symposium arises from its central role in the scientific and professional vitality of our national community. It is a vehicle for presentation of work of topical interest and presents the opportunity for effective peer review of current work. It also attracts international attention as a snapshot of the status of U.S. rock mechanics and, increasingly, as a venue for international researchers seeking prompt review and recognition of their work. Some concerns of the committee are to assure a high technical quality for the symposium proceedings and to assist local organizing committees with some management details in conduct of the meeting.

The 33rd Symposium

Notices providing details of the 33rd Symposium, to be held June 8-10 in Santa Fe, have been widely circulated. The specialist workshops on Coal Mine Pillar Design, Geotechnical Design Methodology, Modeling of Fractured Reservoirs, and Induced Seismicity augment an impressive technical program. Following as it does the regional ISRM conference in Lake Tahoe on Fractured and Jointed Rock Masses (June 3-5), the symposium presents an attractive concentration of

USNC/RM Chairman's Letter
May 15, 1992
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technical sessions and workshops addressing many contemporary issues in geomechanics research and practice. Organization of the symposium by geomechanics staff of the national laboratories was a helpful and timely initiative on their part.

The 34th and 35th Symposia

These meetings are scheduled respectively for the University of Wisconsin, Madison in 1993 and the University of Texas at Austin in 1994. The chairpersons of the respective local organizing committees are Bezalel Haimson and Priscilla Nelson. The programs at each center will reflect local matters of specific scientific or current interest to the national rock mechanics constituency. In the case of the University of Texas symposium, for example, the symposium schedule is linked to availability of access to excavations housing the Superconducting Super Collider at Waxahachie.

Future Symposia

To assure continuity in organizing future symposia beyond 1994, the USNC/RM is discussing tentative proposals by several universities to host the meetings. Although it is quite an onerous task for the organizers, hosting a symposium provides a local geomechanics group with opportunities for presenting the capabilities, resources, and facilities of their local program, and technical and professional recognition in the peer community. The USNC/RM is encouraged by the level of interest displayed by prospective hosts for the 1995 and 1996 meetings.

Considerable experience in hosting successful symposia is being mobilized in a small group led by Lewis Wade, which is currently drafting a set of policy and management guidelines for the conduct of symposia. The document will provide a concise statement of symposium objectives and operating arrangements, which can be used as a management template by local organizing committees.

SPECIAL STUDIES

Special studies of the USNC/RM are conducted by a team chaired by a current member of the committee, with the purpose of providing an account of the status of a topic of contemporary interest to the rock mechanics community. The report on the study may become a source of reference for several years, as was the case of the "Rock Mechanics Research Needs" report of the early '80s. The study currently in progress considers the topic "Fracture Characterization and Fluid Flow", and is being performed by a group chaired by Jane Long. A session has been scheduled at the Santa Fe symposium for Jane Long to review the scope and status of her team's efforts. A notable aspect of the study has been the interest generated in government agencies and industrial corporations, expressed partly in the financial support they have provided to conduct the study.

A small team is now considering the terms of reference and scope for a special study on funding of rock mechanics research in the United States, a matter of some interest in the prevailing economic climate. In the future, members of the rock mechanics community will be invited to propose topics they consider ready for a special study.

AWARDS

Outstanding contributions to the basic science and engineering applications of rock mechanics are recognized annually by appropriate awards of the USNC/RM. The success of the award process is dependent on identification by individual members of papers worthy of recognition. Papers may be nominated throughout the year, but the particular requirement is to ensure nominations are made to the director of the USNC/RM by the end of January. An earnest effort in nominating suitable papers is required to ensure that outstanding work in the U.S. rock mechanics community is duly recognized and that the stature of the awards is preserved.

RELATIONS WITH PROFESSIONAL SOCIETIES

The reorganization of the USNC/RM in 1989 had the unfortunate consequence of loosening the established links between the many professional societies with interests in rock mechanics and the committee. While the linkage is maintained informally by individuals' joint membership of societies and affiliation with the USNC/RM, the committee strives to maintain formal contact with the management of the formerly affiliated societies. Although reports and notices are sent to societies, we are aware that we could perhaps do a little more in maintaining contact with them. Suggestions for improvements in that regard would be welcome.

NATIONAL ROCK MECHANICS PROJECTS

Two rock mechanics projects of major technical significance are the SSC project at Waxahachie, Texas and the radioactive waste isolation project at Yucca Mountain, Nevada. Excavation and furnishing of openings for the SSC will constitute one of the largest underground construction projects ever undertaken, distinguished by the very close tolerances prescribed on permissible ground displacements under the loads applied by the immense installed hardware. We can anticipate many interesting discussions and publications and other contributions to engineering rock mechanics practice in the course of this major enterprise.

For several years, activity on the Yucca Mountain project has been constrained by concerns about the suitability of the site, expressed in a model of site behavior positing periodic raising of the water table by coupled tectonic, thermal, and hydrologic mechanisms. A recent report by a National Research Council panel considered the model and the related knowledge of the geology and hydrology of the Basin and Range province. The report, which is an interesting scientific document in its own right, did not endorse the proposed model, perhaps contributing to a return to a more deliberate approach to characterization and assessment of the site.

INTERNATIONAL ACTIVITIES

As the accredited U.S. national group of the International Society for Rock Mechanics (ISRM), the USNC/RM plays a fairly active role in the business of the ISRM. By his election as president of the ISRM last year, Charles Fairhurst was recognized for the many technical and other contributions he has made in rock mechanics. For observers of the rather imposing political process in which an ISRM president is elected, many were impressed by the way in which

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Wolfgang Wawersik and Peter Smeallie presented Charles's nomination and engaged the support of ISRM council members.

The next meeting of the ISRM council is at Chester, U.K., in September, on the occasion of the EUROCK'92 Symposium on Rock Characterization. U.S. items of business for the agenda will be considered at the next meeting of the USNC/RM, to be held at Santa Fe in June.

I hope this note provides you with a reasonable idea of the activities and plans of the USNC/RM. If you wish to contribute to a future letter or respond to items in this one, I would be pleased to hear from you.

Best wishes,

A handwritten signature in cursive script, appearing to read "Barry Brady".

Barry Brady
Chairman

National Research Council
Geotechnical Board

U.S. National Committee on Tunneling Technology

Special Session of the USNC/TT
June 20, 1991
Westin Hotel
Seattle, Washington

**National Needs of the Underground
Construction Industry from a Global Perspective**

SUMMARY OF MEETING

This one-day special session of the U.S. National Committee on Tunneling Technology (USNC/TT) involved the committee and liaison representatives joined by invited guests (see attendance list). The purposes of the session were to (1) evaluate direction of the underground construction industry—domestic and international aspects, (2) identify principal issues facing the industry and correlate with industry specialty groups, and (3) set priorities and relate to cost reduction of tunnels. Attachment A, "National Needs of the Underground Construction Industry from a Global Perspective," describes the plan for the special session.

The session opened with Harvey Parker, chairman of the USNC/TT, and Peter Smeallie, staff director of the USNC/TT, explaining the reorganization of the USNC/TT, the context of operation within the National Academy of Sciences' complex, and some recent initiatives of the USNC/TT. These include: (1) tunnel construction safety, (2) impacts of global trends and foreign influences on U.S. underground industry, (3) prioritization of national needs of the tunneling industry, (4) pros and cons of use of ribs and lagging, (5) expert panel support/overview for major projects, (6) expert panel support/overview and/or technical assistance to the high-level nuclear waste industry, (7) infrastructure study, and (8) lunar tunneling.

Dr. Parker went on to explain that he believes it is time to update the seminal underground research needs document that was produced in 1971 by the Underground Construction Research Council. He stated that the growing international tunneling activity and new transportation policies emerging from Washington, D.C. and from statehouses demand a new look at the needs of the tunneling industry.

In the discussion that followed, many points were made:

- There are at least four areas of significant change in national policy that could have implications for the tunneling industry. These are in (1) transportation policy, (2) increased environmental protection and disposal of waste, (3) a renewed interest in infrastructure improvement, and (4) increased reliance on science.

- A reluctance of local governments to tolerate surface disruptions should be beneficial to the tunneling industry.

- The USNC/TT should debate its role within the industry. For example, should it explore and advocate new technologies and practices that result in cheaper, safer tunnels for government agencies that construct tunnels? Or should it be made proactive in calling attention to the benefits of tunneling and underground construction?

- Most universities offer very little in underground construction. Perhaps USNC/TT could address the lack of educational infrastructure needed for informed decision making.

- There is no shortage of symposia, workshops and other fora. Tunnelers should work to dispel adverse myths about cost and safety of tunnels; they should provide decision-makers with reliable information.

- Cost components of tunneling should be examined to decide which are "drivers" and, of those cost drivers, which we can do something about and which we can not.

- A significant problem exists with miscalculation of tunneling cost estimates based on changing the ground rules. For example, political considerations tend to keep the cost estimates of a project low, but adding societal costs, such as minority contracting participation, will raise these estimates.

- There is considerable technical variety for tunnels based on projected longevity. For example, tunnels are being built with very short life expectancy, such as in the case of mining tunnels. Tunnels are also built that are expected to remain viable for thousands of years, as in the case of high-level nuclear disposal repositories.

- Standardization has been shown to provide few benefits. For example, the Japanese experience with standardizing pre-cast tunnel lining froze the state of their technology in place, allowing other nations to pass them by.

The participants decided to form the following discussion groups to address the principal issues that emerged from the open discussion. They were:

- (1) Needs of Underground Design, Construction, and Suppliers (M. Kelley, chair; F. Anderson, S. Nelson, R. Pond, E. Cording, R. Robbins, T. McCusker)
- (2) Direct and Indirect Advantages of Tunneling (R. Sterling, chair; P. Smeallie, R. Gray, R. Miller, G. Brierly)
- (3) Environmental and Special Underground Construction (P. Nelson, chair; J. Peshel, C. Daugherty, H. Parker)

Brief reports from the working groups were given at the close of the day. The first group on needs identified five principal needs:

- (1) Need to address rectifying disincentives in government procurement practices.
- (2) Need for flexibility and review for exceptions of NFPA fire and life safety guidelines for special needs of the underground construction industry.

- (3) Need for federal support for the identification and transfer of technology from overseas, principally Japan and Europe, to American industry.
- (4) Need for support of federally supported research for the underground construction industry on a basis comparable to other countries' support for underground development.
- (5) Need to address the disconnect between the design and the construction of the final product, including low bid requirements, liability of engineers, dispute review boards.

The group on direct and indirect advantages of tunneling considered different perspectives of the underground construction industry and concluded that a "truth package" focused on various levels of government officials would dispel myths about the cost, safety and other disincentives in undertaking underground projects. Costs have come down. Underground spaces are safer to build, and remain among the safest engineered facilities in terms of performance, environment, and human use. There is a need, however, to foster greater government activity in promoting and building underground spaces, such as:

- (1) improved procurement practices (less constraints, time delays),
- (2) ownership of underground space in urban areas,
- (3) planning for effective use of underground space,
- (4) federal role in the maintenance of records of underground systems (using GIS technologies) such as the geological data, and
- (5) recognition of underground facilities as long-term investments.

The group on environmental and special underground construction looked at five considerations:

- (1) Cost—the problem of uneven cost comparisons and the tendency for uneven multiplier effects in cost estimates because of the one-of-a-kind nature of these tunnels.
- (2) Environment—the benefit of increased and controllable security in underground space; the use of corridors for multiple purposes.
- (3) Construction—the construction schedule usually allows for minimization of weather risk and the capability for one-pass construction. There is minimal risk to the schedule if the geologic hazards (up-ahead knowledge) can be known and mitigated and if the inflow and exflow of groundwater can be understood before going in.
- (4) The special projects usually are "flag raisers" and draw attention to the benefits of underground space.
- (5) The group also identified the following tasks:

- Offer underground construction as part of the solution; work with environmental concerns.
- One-pass lining systems are needed for environmental application. Permeability of lining materials and reactivity of lining materials are issues, especially in the presence of hazardous or nuclear waste.
- Special attention must be paid to design criteria and specifications.
- Federal procurement practices need revision.
- Follow-up on the SSC study report as a unique structure.

**Meeting of the U.S. National Committee on Tunneling Technology
June 21-22, 1991**

Dr. Parker opened the meeting by posing the question: Is there a causal connection between government support of research and the reduction in tunneling costs as well as the improvement in tunneling safety records?

The special session yesterday began to provide a look into the factors that may provide an answer to that question. But the committee should focus on an end product—a strategic plan for the tunneling community. He mentioned the 1971 report that described the tunneling industry and outlined what needs the industry had.

One method of organizing the committee's ideas is through a matrix such as that depicted below:

The intercepts of the matrix would describe the need and, if applicable, who is currently addressing the need or who should address the need. For example, under transit, there is a need for greater understanding in the area of tunnel rehabilitation. UTRC is currently working on this.

Committee members discussed the possibility of a USNC/TT survey of the U.S. tunneling industry to determine industry needs, to learn what industry is doing to address those needs and to set some priorities on these needs. The USNC/TT could then select high priority, but discrete, projects such as how dispute resolution boards are affecting the industry. The matrix that would emerge from the survey would probably be 3-D in terms of needs, activities, and priorities. Dr. Parker, Ray Sterling, and staff agreed to begin to develop a first cut at a matrix.

Susan Nelson suggested that the USNC/TT should follow up on the contracting study done for the SSC to evaluate what was implemented from the report. Mrs. Nelson, Dr. Sterling, and Priscilla Nelson agreed to take on this task.

Discussion turned to government disincentives to cost-effective tunnel or underground projects. Many code requirements are simply not applicable to underground construction. For example, access and egress requirements may be based on above-ground requirements; underground transit station sizes may be unrealistic; fire and safety codes need reexamination for applicability to the underground situation.

But the principal theme that emerged from the committee dealt with procurement in all forms and at all levels of industry and government. Government regulations on contracting do not recognize the unique specialties required in underground construction. Contracts limit the ability or incentive for a firm to select options or try anything innovative. Union requirements can contribute to this non-flexibility. Often proposal

evaluation panels lack the necessary detailed tunneling expertise. Improved RFPs and improved bid packages are needed. Emphasis on low front-end costs can contribute to cataclysmic failure, such as the expensive breakdown of a TBM during construction.

The committee agreed that a role of the government as owner of a tunnel or underground space should be to push innovation and development of new technologies. For example, the SSC project is a good example of a project that should encourage innovation in technology and in procurement practices.

The issue of tunneling cost was debated. Are costs of tunneling going down because of improved technology? Or are the new and varied uses of a tunnel keeping bottom line tunneling costs at record highs? Are the contractors making more money? Data are skimpy; Houston maintains good records. Comparable data may be found for projects in San Francisco, Chicago, and the Washington Metro.

But the central issue for the committee to wrestle with is: Is the industry healthy, and, if not, what should be done? The USNC/TT should focus on the question in its future deliberations.

Outreach and Dissemination

The committee agreed that an annual summary of activities will be prepared with the incorporation, perhaps, of a centerpiece article. News items about and by the committee can be incorporated into the AUA newsletter. Former Tunneling Technology Newsletter subscribers should be alerted to this.

ITA

Richard Robbins reported on the April 1991 annual meeting of the International Tunnelling Association held in London at which he was elected to the Executive Council of the ITA. Thirty-one of 38 member nations attended. Mr. Robbins made the following observations:

- Affiliate membership in the ITA is lagging as a solid source of funding, but it may be temporary.
- The ITA has endorsed a continued relationship with Pergamon Press for publication of the journal, Tunneling and Underground Space Technology.

Attachment B is a press release issued after the annual meeting that summarizes the key points.

John Peshel expressed surprise that ITA is not actively looking into nuclear waste geologic repositories.

Dr. Parker reported on initial successful meetings with interested parties at the United Nations on behalf of ITA, and indicated he would continue representing ITA in this international forum.

Lunar Tunneling

Russell Miller reported that the influential Stafford report, America at the Threshold, recommended a permanent base on the moon. At the IDEEA One Conference, Dr. Miller is sponsoring a session on underground space technology.

Nuclear Waste

Dr. Peshel urged the committee to bring its tunneling expertise to the issue of high-level nuclear waste in deep geologic repositories. DOE needs outside expertise not just in tunneling technology (now estimated at 120 miles of tunnels needed) but also for material handling in tunnels (for example, canisters containing nuclear waste).

Peer Review

Mr. Smeallie reported that the issue of using the USNC/TT in a project peer review mechanisms is probably not within the practices of the National Research Council, but there may be exceptions, as has been the case with the SSC project.

Infrastructure

Dr. Sterling, who serves on the Building Research Board/Geotechnical Board Committee on Infrastructure, reported on the first meeting of the committee held in March 1991. Currently, the committee is planning a series of infrastructure symposia. He will keep the USNC/TT apprised on this effort.

Safety

Fred Anderson reported that OSHA has completed its underground safety report. In terms of the expression of interest from DOE's SSC office in supporting a study on safety, Mr. Anderson suggested other parts of DOE for matching support.

Liaison Reports

Mrs. S. Nelson, executive director of the American Underground-Space Association, reported that the soon-to-be-released publication, Global Review: Underground Space 91/92, will review underground projects around the world, and should help to dispel myths about safety, cost, and functionality. She mentioned the AUA-sponsored conference to be held in Boston in October 1992.

Charles Daugherty reported that the Association of Engineering Geologists is currently not very active in tunneling. The AEG itself is moving more toward environmental interests.

Next Meeting

The committee agreed that a mid-winter meeting should be held, most likely in Washington, D.C.

Action/Decision Items

Attachment C contains the action and decision items that came out of the meeting.

Report prepared by Peter Smeallie

October 21, 1991

Revised by Harvey Parker

November 25, 1991

USNCTT TASK ITEMS
02/21/92

Task
Completed = 01/01/01

BOSTON MEETING

Meeting arrangements		
Meeting schedule	Smeallie Sterling	03/31/92
Meeting arrangements - tours		
Set date and time	Smeallie Sterling Nelson(S)	03/31/92
Meeting handouts		
Distribute to committee	Smeallie	09/15/92
USNCTT-sponsored speaker		
Confirm participation	Smeallie	03/15/92

COMMITTEE DEVELOPMENT

Committee calendar		
Prepare	Sterling Smeallie	01/01/01
Developments in mechanics		
applicable to u/g works		
Oral review for committee at	Hutchinson	10/03/92
Boston meeting		
Expand FTA (UMTA) circulation		
list		
Circulate for additional	Smeallie All	05/15/92
suggestions		
Explore liasons with APWA and		
Soc. Trenchless T.		
Contact associations	Sterling Smeallie	03/31/92
Improved post-construction		
reports		
Strategy	Daugherty Mergelsberg	07/31/92
Liason with DNA		
Discuss with Don Linger	Smeallie Sterling	03/15/92
Nominations		
List of all prior members of	Smeallie	06/30/92
USNCTT		
Letter requesting nominations	Smeallie	07/31/92
Nominating committee - short	Sterling Smeallie	09/30/92
list of new members		
Committee discussion of	Sterling Smeallie All	10/03/92
nominees		

Revised committee guidelines Proposal	Sterling Smeallie	06/30/92
Review	Smeallie All	08/31/92
Adoption	Smeallie All	10/03/92
Revive Interagency Committee on Excavation Tech.		
Call key past members	Parker	03/31/92
Tunnel myths		
Article for magazine or newsletter	Nelson(P)	04/30/92

COMMITTEE OUTREACH

Annual report Draft	Smeallie Sterling Parker	04/15/92
Chairman's letter		
Letter #1	Sterling	03/31/92
Letter #2	Sterling	06/30/92
Letter #3	Sterling	10/31/92
Letter to former T. Tech. newsletter subscribers		
Distribute	Smeallie	04/15/92

GLOBAL COMPETITIVENESS

Commerce Dept. report on tunnelling		
Obtain	Smeallie	02/28/92
Global comparison of tunnelling costs		
Tunnel costs article	Mergelsberg	07/31/92
Priorization of tunnelling needs		
Develop matrix	Parker Nelson(P)	06/30/92
Review 1993 Commerce Dept. questionnaire form		
Send comments	Smeallie All	04/30/92

INFRASTRUCTURE

NRC committee on infrastructure		
Participate	Sterling	10/03/92
NRC research agenda		
Follow	Sterling	10/03/92

NRC urban infrastructure
initiative
Follow

Sterling

10/03/92

INTERNATIONAL TUNNELLING ASSOCIATION

Annual meeting in the U.S.

Select date(s)

Robbins Parker Nelson(S)

05/20/92

Executive council meeting in the
U.S.

Propose

Robbins Parker Nelson(S)

05/20/92

U.S. committees to interact with
ITA working G.s

Identify and discuss interest

Parker Nelson(S) Robbins

03/15/92

PROCUREMENT OF TUNNEL DESIGN & CONSTRUCTION

Define committee approach to
issue

Outline

Kelley Duscha Harig
Robbins Matthews

06/30/92

SSC CONTRACTING PRACTICES

Follow-up on green book

Contact DOE, PBMK

Duscha Nelson(P) Harig
Matthews

04/15/92

SSC SAFETY STUDY

Safety study

Recommend format and panelists

Smeallie Others

02/28/92

YUCCA MOUNTAIN CONTRACTING PRACTICES

Contracting practices study

Establish framework and funding
for study

Parker Peshel Smeallie

03/31/92

ASSOCIATION
INTERNATIONALE DES TRAVAUX
EN SOUTERRAIN
AITES

ITA
INTERNATIONAL
TUNNELLING
ASSOCIATION

*Towards an
improved use
of underground
space*

*In Consultative Status, Category II with the
United Nations Economic and Social Council*

EIGHTEENTH ANNUAL MEETING - ACAPULCO, 1992

PRESS RELEASE

The International Tunnelling Association held its 18th Annual Meeting in Acapulco from May 16th to 20th, 1992, in conjunction with the international congress on "Towards New Worlds in Tunnelling", organised by the Mexican Tunnelling Association AMITOS. The meeting was attended by representatives, delegates, observers and working group members from 22 of the 38 Member Nations of the Association.

MEMBER NATIONS REPRESENTED

South Africa, Germany, Austria, Belgium, Brazil, Canada, Korea, Denmark, Egypt, Spain, United States of America, Finland, France, Italy, Japan, Lesotho, Mexico, Norway, Netherlands, United Kingdom, Sweden, Czechoslovakia.

MEMBER NATIONS NOT REPRESENTED

Algeria, Australia, People's Republic of China, Colombia, Hungary, Iceland, India, Morocco, New Zealand, Poland, Portugal, Switzerland, Thailand, Russia, Venezuela, Yugoslavia.

MEMBERSHIP

The Association has registered the membership of 41 new Affiliate Members, (11 Corporate Members and 30 Individual Members) taking the total to 156 Affiliate Members, accounting for 5 resignations and 6 cancellations.

NEW EXECUTIVE COUNCIL

Z EISENSTEIN	Canada	President	Until 1995
AM MUIR WOOD	United Kingdom	Honorary President	
CJ KIRKLAND	United Kingdom	Past President	Until 1995
JF BOUCARD	France	Past Vice-President	Until 1995
R ROBBINS	United States	Vice-President	Until 1995
M SERRAND	Spain	Vice-President	Until 1995
H DUDDECK	Germany		Until 1995
W DE LATHAUWER	Belgium		Until 1995
E ABDEL SALAM	Egypt		Until 1994
S KIYOYAMA	Japan		Until 1993
A GLERUM	Netherlands		Until 1993
C BERENQUIER		Secretary General	Until 1993

"Tunnelling and Underground Space Technology" (TUST)

TUST is the official journal of ITA and many cooperating organizations from various countries.

In 1990 and 1991, 8 issues of the journal have presented nearly 70 papers from 30 countries and from several ITA working groups. Two very interesting state-of-the-art reports one on shotcrete, another on floating tunnels are planned in the next year, and also interim papers.

In the past five years, the number of cooperative organizations has nearly quadrupled, from 6 in 1987 to 23 as of today. These organizations are listed at the front of each issue, and news of their activities published in a special section.

The policy of handling new subscriptions was reviewed.

Relations with the United Nations

The General Assembly has terminated the four-year report that ITA has to prepare for the United Nations. This report recalls the aims of the Association and the evolution of its geographical representation; it also indicates that ITA has cooperated with UN Agencies by exploring possibility of co-sponsoring workshops with UNDP, and successfully responded to request from UNDTCD for tunnel experts. Lastly it listed the international congresses and workshops ITA has sponsored and attended.

The General Assembly has confirmed the preparation by Brazil for a Symposium interesting the United Nations, and the relation with ECOSOC that must be initiated for the studies on the Gibraltar Straits Crossing.

Open Session

The ITA Open Session on May 19, 1992, discussed the theme of the Congress "Towards New Worlds in Tunnelling". Past ITA President Jack Lemley, the Key Speaker, believed that real progress would only be made if our industry evolved a new philosophy of "Human Team Dynamics" to obtain the true advantages offered by rapid technological development. Panellists Dr. Fukuchi (Japan), Prof. Duddeck (Germany), Dick Robbins (USA), and J.F. Bougard (France), added their comments and views on improved technology.

Bylaws

The General Assembly has added two sections to the Bylaws, one on the use by the Member Nations of the logo and heading of ITA letters, the other on the sponsoring conditions of technical meetings organized by Member Nations.

The next ITA Meetings will take place:

- In Amsterdam (Netherlands) from April 18-21, 1993, in conjunction with an international Congress on "Options for Tunnelling".
- In Cairo (Egypt) from April 3-7, 1994, in conjunction with an International conference on "Tunnelling and Ground Conditions".
- In Stuttgart (Germany) from May 6-11, 1995, in conjunction with the conference celebrating the 35th anniversary of STUA.

WORKING GROUPS

No. 2 - Research

Animateur: J de la Menardiere (France)

This working group was integrated with representatives from 5 Member Nations. The "Subsidence in urban areas" study continues in process. The first draft has been submitted to all group members and it is expected to have the final version during 1993, as it is considered to be released in 1994.

As far as the study on "Noise and vibration during operation" is concerned, a questionnaire has been sent to the attention of all group members.

Finally it is being considered to start, whenever possible, another study on "injection grouting and compensation grouting".

No. 3 - Contractual sharing of risk

Animateur: W.O. Salter (USA)

The Group will call for suggestions for improvement in the first 25 Recommendations, but agreement was that there is no need to update any for the foreseeable future. There is need to update and distribute the survey form to all member nations to assess implementation of ITA's recommendations. The Group will continue its call for suggestions of new topics to be evolved into risk-sharing proportions. It will commence work under the new "contractual practices" mandate including reviving topics tabled in the past as not appropriate as risk matters. This latter task concerns the following subjects: types of contracts, evaluation of tenders, evaluation of claims and resolution of disputes.

No. 4 - Subsurface Planning

Animateur: M. Barker (U.S.A.)

Underground facilities, from transportation tunnels to shopping centers, must be safe and comfortable for human use. The Working Group on Subsurface Planning met in Acapulco, May 17 and 18 to embark on a major project to develop international guidelines for fire and life safety in underground facilities. Unlike buildings above ground, facilities below the surface must overcome human fears and eventually be seen as safe and pleasant to fully attain the benefits of subsurface projects.

No. 5 - Health & Safety

Animateur: N.M. Krige (South Africa)

The Group met on two occasions and 7 delegates from 7 nations attended both meetings. During the meetings the Group approved the final draft of "Guidelines for good tunnelling practice" and this document will now be referred to the Executive Council for approval and publication by the ITA.

It was decided that for the next year a survey must be made under all Member Nations of the occurrence of accidents during underground construction works. Statistics obtained will be used to motivate nations to become more safety conscious.

No. 6 - Maintenance & Repair of Underground Structures

Animateur: A.J. Howard (United Kingdom)

Ten nations were represented at the Group Meeting.

The study of non-destructive investigation methods has now advanced to the point to allow preparing a "state of the art" report for publication.

Some progress has been made on the study of leak sealing. This will be taken forward during the year, with the intention of having a draft report ready for the meeting in 1993.

No. 7 - Design of Underground Waste Repositories

Animateur: H. Duddeck (Germany)

In promoting the use of the underground also for non-nuclear waste repositories, the ITA Working Group 7 is gathering knowledge of the engineering approach to these structures, as mine galleries, caverns, abandoned mines, etc. Guidelines of the design and the safety assessments for the different layouts of the barriers against failure scenarios are in preparation.

No. 11 - Immersed and Floating Tunnels

Animateur: P.C. Van Milligen (Netherlands)

Members of this international working group joined together in smaller sub-groups to get the mutual understanding about the various points of view.

Most of these sub-groups came to their final version of their part of the report, which was discussed in detail during this ITA Congress in various Working Group meetings. By taking advantage of the presence of all tunnel experts at this congress, various new information could be considered to approve the contents of the report.

It is the intention of the Working Group to present their final report during the ITA Congress in Amsterdam in April 1993 to the ITA Members.

No. 12 - Shotcrete Use

B. Malmberg (Sweden) in absence of the J. Franzen (Sweden)

This Working Group has finalized the status report on Shotcrete since the last ITA Conference in London. The main task in Acapulco has been to discuss the draft on Compilation of Guidelines and Recommendations on Shotcrete, expected to be published the end of 1992.

One task of primary interest is the durability of shotcrete. A compilation of case histories and recommendations will be carried out during 1992-93.

Another important task is to look at the health and safety aspects related to dust, additives, etc. Recommendations on this issue will also be compiled during next coming years.

No. 13 - Direct and Indirect Advantages of Underground Structures

Animateur: J.P. Godard (France)

The Working Group met twice with 8 participants from 6 nations. The Group decided to follow two main approaches, one to focus on car parking cost benefit studies, the other to collect basic data concernign the quantification of the various advantages and disadvantages of underground facilities.

No. 14 - Mechanised Tunnelling

Animateur: S. Kuwahara (Japan)

This Working Group was established at the London General Assembly last year. The goal is to establish criteria for applicabilities, selection and performance of mechanized tunnelling equipment from the engineering and production aspects. The first operation is agreed to conduct researches to find out current TBM performances.

NATIONAL RESEARCH COUNCIL
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
GEOTECHNICAL BOARD
U.S. NATIONAL COMMITTEE ON TUNNELING TECHNOLOGY

Attachment O

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April 27, 1992

USNC/TT CHAIRMAN'S LETTER

Dear Committee and Friends:

This letter is to try to keep our committee members, sponsors, liaisons and others informed of the activities of USNC/TT throughout the year. Since the cessation of the USNC/TT newsletter and because the committee meets infrequently, I think it is important to have a regular vehicle of communication on committee activities. This letter is the informal route I have chosen. We also plan to take full advantage of the other opportunities discussed under committee outreach below. I plan to write this letter quarterly with its exact timing to reflect an ability to report on important meetings or committee activities. Because this is the first letter, I will try to provide a general view of the scope and direction of our current activities.

Committee Outreach

A number of people have mourned the passing of the USNC/TT newsletter and wondered why it was stopped. The decision was taken by the committee for several reasons:

1. When the newsletter was being published originally, the USNC/TT had a separate staff. Now, the same size of staff handles the Geotechnical Board, the U.S. National Committee for Rock Mechanics (USNC/RM) and the USNC/TT. A newsletter is a time-consuming activity and takes away from other important committee and staff activities.
2. The American Underground Space Association (AUA) newsletter now fulfills a similar communication role for the tunneling and underground construction industry with a lively and interesting newsletter. The committee felt it would rather use this vehicle for much of its news (as it has been encouraged to do by the AUA) than to maintain a duplicative role.
3. The committee felt that an annual report of USNC/TT activities would provide a better formal vehicle to let the U.S. community know what the committee has accomplished and is planning to undertake, with a lesser demand on staff time and resources.

The liaison members to the USNC/TT from allied societies and organizations also provide an important communication role. They bring issues of broad national concern

to the committee and present the viewpoints of their respective societies. They also pass information back from the committee to their constituencies. We are currently in the process of adding committee liaisons from the American Public Works Association (APWA) and the North American Society of Trenchless Technology (NASTT) as mentioned in the discussion of infrastructure issues below.

Special task committees of the USNC/TT are another means of involving a broader range of participants in USNC/TT activities. These often include many participants outside the immediate group of committee members and liaisons and outside the specific underground construction community.

International Activities

We are fortunate to have at present Dick Robbins as an Executive Committee member of the International Tunnelling Association (ITA). Dick Robbins, well known to all in the tunneling community, was our national representative to the ITA until his election to the Executive Council last year. His place as U.S. Representative has now been taken by Harvey Parker, the former Chairman of our committee. It is intended that Dr. Parker, with input from Dick Robbins and other participants and attendees at ITA activities will provide regular reports of ITA affairs to our USNC/TT sponsoring agencies and the community at large.

The committee has been concerned for some time with the erosion of the U.S. competitive technological position in underground construction over the past decades and is undertaking several activities to address this question. One approach to this problem is to encourage more U.S. participation in the activities of the ITA and following the USNC/TT committee meeting in February, a parallel U.S. committee has been linked to each of the ITA working groups (ten in total—see list) picking a chairperson to create one if necessary. The USNC/TT recognizes the existing interests or activities of other underground construction organizations in the U.S. and has used existing committee structures where available. Exactly how the new committees among these U.S. counterparts will function is not exactly determined yet. In most cases, it will depend on the directions of the ITA working groups and the energy and enthusiasm of the nominated U.S. representative to the committee. It is important to stress that the ITA working groups welcome any participants and that many people besides the official representatives play important roles in the working groups.

We expect the U.S. representatives to participate vigorously in their working groups and to provide good communication in keeping the U.S. community abreast of ITA activities. We anticipate that the U.S. representatives will rotate on a fairly regular basis to provide incentives to participate and to keep activity levels high.

Questions are sometimes raised as to why the USNC/TT is the official representative of the U.S. to the ITA. In partial answer to this question, I can offer a few observations. The National Research Council currently has 30 U.S. national

committees which fulfill this role in many different international bodies. Originally done as a way of allowing continuity in participation in international scientific and engineering activities for government, industry and academia through the National Academy of Sciences complex, it still offers important benefits as vehicle for U.S. participation:

1. The USNC/TT as a National Research Council committee is in an excellent position to advise the federal government and its agencies of important developments and activities in the international community.
2. Sending a delegation to the ITA meetings is a costly activity. The precedent of NRC's role in such international committees allows the selection of U.S. participants without regard to whether their personal circumstances would allow them financially to participate.

The USNC/TT role as an official representative to the ITA should not be seen as a bar to international activities by people outside the immediate committee. The ITA meetings are open to anyone and the USNC/TT is anxious to assist any U.S. groups in increasing their participation in the activities of the ITA.

Global Competitiveness/Procurement Issues

In reviews and discussions of the U.S. technological position in underground construction relative to Europe and Japan, the same issues continually resurface—those of the institutional impediments to private R&D and innovation that appear to exist to a greater extent in the U.S. than in Europe or Japan. Such issues include the litigious nature of our society which directly inhibits innovation and the procurement methods for our design and construction of public works which provide little or no incentive and/or reward for innovative solutions. Issues such as these are often controversial and difficult and impact on some of the cherished notions of the historical ways of doing business in the U.S. Nevertheless, they need to be examined as to whether there are some adjustments that could be made in some types of projects to encourage innovation.

Mindful of the long-term success of the USNC/TT effort in the contracting practices area carried on through most of the 1970s, we have convened a subcommittee this year to examine what changes might be possible in the area of procurement practices for underground construction to encourage innovation and private R&D efforts. As this subcommittee examines the possibilities, a decision will be made as to whether to make this a major committee effort. It is certainly a national problem of critical significance.

Infrastructure-Related Efforts

The committee is concerned about the growing importance of underground infrastructure in the future (especially in our urban areas) and the lack of a coordinated approach to dealing with the issues raised. Since the National Research

Council has a special committee on infrastructure under the joint auspices of the Building Research Board and the Geotechnical Board, the USNC/TT will coordinate its efforts through this committee to address specific infrastructure issues related to underground construction. I am privileged to also serve on this committee and provide the link to our efforts within USNC/TT. As mentioned above, we are also in the process of adding new committee liaisons to the APWA and the NASTT to strengthen communication in this area.

SSC Safety Study

The construction of the Superconducting Super Collider (SSC) will be one of the major underground construction projects ever undertaken. Following the special study of recommended contracting practices for the SSC completed in 1989, the committee this summer will be convening a special meeting which will provide a forum to discuss how safety can be enhanced during the construction of the SSC. The committee is in a unique role to facilitate this kind of dialogue and will continue to try to offer its services in such projects of special national importance and scale.

Yucca Mountain Contracting Practices

Discussions are currently being held about the possibility of the committee carrying out a contracting practices study for the High-Level Radioactive Waste Repository being considered for Yucca Mountain. This would be another massive underground project of critical national importance and involving many miles of underground tunnels in its eventual configuration. The study would recommend contracting and management practices for the underground works tailored to the special site and functional requirements of the waste repository and the special quality control requirements of a nuclear-related facility. It is hoped that a start can be made on such a study later this year.

Future Meetings of the Committee

In addition to the meeting connected with the safety issues for the SSC construction this summer, a general meeting of the committee will be held in Boston just prior to the AUA conference on North American Tunneling (Oct. 3-8, 1992). The committee generally tries to attach its meetings to a tunneling or underground construction conference where possible to avoid diluting U.S. activities. During the AUA conference there will be a USNC/TT-sponsored lecture given by an invited speaker. It is intended that such a lecture will be a regular event at U.S. underground construction meetings in the coming years with leading U.S. academics and practitioners in the field asked to prepare a special lecture to review a particular aspect of tunneling and underground construction.

I hope this letter has given you an idea of the scope of activities underway at the USNC/TT. Other activities related to the underground are also occurring in the U.S. National Committee for Rock Mechanics and the parent board for both our committees—the Geotechnical Board. Please write or call me if you have any

USNC/TT Chairman's Letter
April 27, 1992
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comments or questions about our activities or suggestions for issues we should tackle. We intend to be active, to concentrate on the issues which are of national significance or long-term importance, and to try to make a real impact in those few areas we are able to tackle.

Sincerely,

A handwritten signature in cursive script, reading "Ray L. Sterling". The signature is written in dark ink and is positioned above the printed name.

Raymond L. Sterling
Chairman

**DATE
FILMED**

9/21/93

END