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CONCEPTS IN PROTOTYPE TESTING FOR IN SITU GEOMECHANICAL INVESTIGATIONS AT YUCCA MOUNTAIN

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ABSTRACT

Geomechanical investigations comprise a significant portion of the site characterization program to be conducted at Yucca Mountain, the site of a proposed repository for nuclear waste. The investigations will include a number of large-scale experiments that will be conducted in an exploratory shaft facility at the site. A program of prototype testing has been initiated to ensure the success of these expensive and complex experiments. At present, the prototype testing program addresses three problems in rock mechanics: measurement of rock-mass strength, measurement of joint properties in situ, and measurement of rock-mass response to thermally-induced loading. Active areas of development in support of these tests include cutting deep, narrow slots in rock and fabricating high-pressure flatjacks.

I. BACKGROUND

Volcanic tuffs beneath Yucca Mountain in Nevada are being considered as a site for permanent disposal of high-level nuclear waste. Answers to several key questions regarding the acceptability of the site require an understanding of the mechanics of the host rock, a densely welded, highly jointed volcanic tuff, and of the rock-mass response to the thermal and mechanical loads that are expected in a repository. These questions include (1) whether the rock can accommodate stable openings during the period required for waste emplacement and for retrieval, if necessary; (2) whether the facility can be constructed and maintained using readily-available technology; and (3) whether the underground openings will affect waste containment and fluid flow significantly over the long term.[1]

In response to these questions, a program of analytical modeling coupled with geomechanical investigations has been developed.[2] The investigations will include laboratory testing of samples from the site, bench-scale testing of synthetic blocks, and field testing in an exploratory shaft facility (ESF) to be constructed at Yucca Mountain. In general, the purposes of geomechanical field testing are to provide data needed to perform analytical predictions and validate numerical models and to demonstrate the performance of openings under conditions approximating those expected in a repository. A suite of experiments has been planned to address these needs. These experiments are designed to measure the mechanical properties of the rock mass and of the joints, to assess the rock-mass response to loads caused by excavation and by thermal expansion, to evaluate the effects of elevated

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temperature on rock-mass behavior, and to collect data during construction of the experimental facility that will be used to plan construction of a repository in tuff.

Experiments in the ESF will be conducted with an unprecedented degree of quality control, and most will be tightly scheduled, with severe consequences for slippage. Because most of the experiments call for new equipment and techniques or new applications of existing technology, prototype testing is vital to the success of the site characterization program. Prototype testing is valuable for the following purposes: (1) testing concepts and equipment; (2) identifying unforeseen problems; (3) refining test layouts; (4) estimating costs, schedules, and manpower; (5) providing hands-on experience; (6) developing expertise in data collection and reduction; and (7) developing formal procedures to improve the chances for a successful test. Prototype testing also provides opportunities to evaluate the analytical models that will eventually be used to predict repository performance.

II. PROTOTYPE TESTING FOR IN SITU GEOMECHANICAL INVESTIGATIONS

In situ geomechanical testing in tuff has been ongoing for about 10 years.[3] Completed activities include a heated block test, three small-scale heater tests, and a room-scale excavation-effects test. Today, the geomechanics prototype testing program comprises three major thrusts: measurement of rock-mass strength, in situ measurement of joint properties, and evaluation of rock-mass response to high, heat-induced loads. To prepare for these tests, various activities categorized as equipment and instrument development and demonstration are underway.

A. Equipment and Instrument Development and Demonstration

Current emphasis in equipment development is on developing the ability to apply loads to a rock mass using flatjacks in narrow slots. Personnel at Sandia National Laboratories have devised a hydraulically driven chain saw with diamond-impregnated teeth that can cut smooth slots 16 mm wide and 1 m deep, using a 15-cm-diameter starter hole. Although several slots have been cut in welded and nonwelded tuff, the process is still far from routine. Planned design modifications will enhance the saw's durability, improve setup flexibility, and enable cutting of slots 2 m deep. Slot-cutting in tuff by water jet is also being investigated.

A complementary effort is underway in flatjack development. Flatjack pressures up to 60 MPa are needed; in comparison, flatjacks failed at pressures below 10 MPa in the heated block experiment.[4] A prototype design, consisting of a pair of stainless steel sheets joined with split tubes, is under evaluation. Related developments include an impression bladder for pressing foil against slot walls to obtain images and a servo-controlled system for regulating flatjack pressure.

To demonstrate these technologies and to develop testing techniques, a series of flatjack-pressurization tests is in progress. Most recently, a flatjack inserted in a slot in welded tuff was pressurized to 30 MPa. The test was terminated by a rupture in the rock adjoining the slot. As a result of the sudden release in confinement, a portion of the flatjack expanded from 16 to 75 mm but did not fail. A follow-on test will be conducted with the intent of pressurizing to 60 MPa.

The single-slot tests will be followed by an "ambient block" test which, while also serving as a demonstration of cutting and pressurizing multiple slots, should provide data to evaluate analytical models. The concept and geometry will resemble that of the ambient phase of the heated block test,[4] but loading conditions will differ significantly; e.g., stress differences across the block will be on the order of 40 MPa, compared to a maximum of 12 MPa in the earlier test. During the test, rock-mass response as well as movement across individual fractures will be monitored as a function of load.

Instrument development and investigation is an ongoing activity. Recent efforts have concentrated on measuring stress changes in a heated environment. Detailed discussion of this fundamental problem, the solution to which is not yet apparent, is outside the realm of this overview.

B. Rock-Mass Strength Measurements

Numerical models that approximate the jointed rock mass as an equivalent continuum require an expression for the rock-mass "strength" that takes into account both the strength of the intact rock and the weakening effect of the joints. The compressive strength and deformational characteristics of an intact sample of rock can be measured accurately under controlled conditions in the laboratory, but an equivalent "strength" of a highly jointed rock mass is considerably more difficult to define and to quantify. Measurements are complicated by the large sample volume required to be considered representative of the rock mass and by the problems associated with isolating a fragmented sample while maintaining its integrity. Several empirical relationships for calculating rock-mass strength, based on laboratory tests and field observations, have been proposed; e.g., Hoek and Brown.[5] To assess the applicability of these predictions to the repository host rock, measurements of rock-mass strength are needed.

A block compression test has been designed to serve this purpose. A conceptual test layout is shown in Figure 1. In general, the test consists of isolating a jointed block in the floor of a drift and measuring its mechanical response to cyclic loading from the top while controlling confining stresses on the sides. Vertical loads are applied by hydraulic rams or a flatjack acting against a reaction frame braced against the roof, and confining pressure is supplied by flatjacks in slots. The plan is to load the block to failure. Based on estimates of rock-mass strength, a vertical force on the order of 11 MN (2.5×10^6 lb) will be required to fail a block 0.5 x 0.5 m with uniform confining pressure of 5 MPa.

C. In Situ Measurement of Joint Properties

The mechanical properties of joints (peak and residual shear strength, normal and shear stiffness) can readily be measured on small samples (surface area up to about 0.07 m^2) in the laboratory; however, large-scale tests (surface area at least 0.5 m^2) are required to determine the effects of scale on the parameters. An in situ shear test over approximately 0.5 m^2 of a jointed surface is planned for the ESF. This test is complicated by the fact that the jointing in the host rock is predominantly subvertical. One possible conceptual layout is shown in Figure 2.

The test design in Figure 2 is based on methods suggested by the International Society of Rock Mechanics.[6] Preparations for testing would include excavating a test pit separated by a narrow pillar from a natural vertical joint, isolating a block bounded by the pit and the natural joint by sawing around its sides (while bracing the block across the pit to hold it in place), and installing hydraulic rams beneath the block to provide shearing forces. The block would be sheared in stages at controlled rates (up to a maximum of 0.2 mm/min). The application of representative normal forces is under consideration. One approach would use very stiff reaction columns, allowing the rock mass to transfer an appropriate normal force.

D. Thermal response measurements

A product of the decay of nuclear waste is heat, which has been predicted to elevate temperatures at the walls of waste-emplacement drifts to 100 °C, to reverse principal stress directions, and to drive compressive stresses in the crown up to 50 MPa [7] (based on two-dimensional finite-element analyses with the rock mass modeled as a homogeneous, linearly elastic material). Several in situ thermomechanical experiments have been developed to investigate the effects of heat and of the high heat-induced stresses on the rock mass and on the stability of the openings. Preparations are underway to conduct a prototype of one of these: the thermal stress test.

The main objective of this experiment is to measure the response of the rock mass to high compressive stresses (locally greater than 50 MPa) in a large volume of rock (approximately 50 m^3) within a limited period. The experiment consists of heating the rock directly above the roof of a repository-scale drift for a period not exceeding 6 months while monitoring temperatures, displacements, stress changes, and microseismic events in and around the heated area. The duration was selected to ensure that the test could be completed in the time frame allotted for site characterization; and the roof was selected for heating so that destabilization of the rock mass, if it occurred, would be readily apparent. The prototype test will demonstrate the feasibility of this experiment; provide preliminary data to evaluate thermal-mechanical numerical models of rock-mass behavior and opening stability; and provide an opportunity to evaluate equipment, instruments, and experimental techniques in an elevated-temperature environment.

A preliminary layout of the test is shown in Figure 3. Instruments will be placed as close to the heated area as possible. Emphasis is placed on measurement of displacements, both within the rock mass using borehole extensometers, and between reference points on the drift surface.

Before this prototype test can be conducted, considerable materials-acceptance testing and checking of instruments are required. Some materials still under investigation or development are a fine-grained pumpable cement-based grout that matches the rock properties at ambient and elevated temperatures (up to 200°C), a very-high-temperature (>500°C) ceramic grout needed for heater installation, and a ceramic fiber insulation that can be sprayed in place.

III. SUMMARY

Characterization of the Yucca Mountain site requires field investigations in geomechanics to provide answers to key questions regarding preclosure and post-closure repository performance. Experiments conducted in the ESF at Yucca Mountain will have extremely high visibility, stringent quality assurance requirements, high costs, and tight schedules. To ensure success in the ESF, prototype testing in advance is a necessity. Prototype testing in geomechanics is currently directed toward finding solutions to the problems of measuring the strength of a jointed rock mass, measuring mechanical joint parameters in situ, and evaluating the response of a jointed rock mass to high thermal loads.

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REFERENCES

1. T. E. BLEJWAS, "Planning a Program in Experimental Rock Mechanics for the Nevada Nuclear Waste Storage Investigations Project," 28th U.S. Symposium on Rock Mechanics, Balkema (1987).

2. T. E. BLEJWAS, "Experiments in Rock Mechanics for the Site Characterization of Yucca Mountain," 30th U.S. Symposium on Rock Mechanics, Balkema (1989).

3. R. M. ZIMMERMAN and R. E. FINLEY, "Summary of Geomechanical Measurements Taken in and Around the G-Tunnel Underground Facility, NTS," SAND86-1015, Sandia National Laboratories (1987).

4. R. M. ZIMMERMAN, R. L. SCHUCH, D. S. MASON, M. L. WILSON, M. E. HALL, M. P. BOARD, R. P. BELLMAN, and M. L. BLANFORD, "Final Report: G-Tunnel Heated Block Experiment," SAND84-2620, Sandia National Laboratories (1986).

5. E. HOEK and E. T. BROWN, Underground Excavations in Rock, Institution of Mining and Metallurgy, London (1980).

6. E. T. BROWN, Ed., Rock Characterization Testing and Monitoring: ISRM Suggested Methods, Pergamon Press, Oxford (1981).

7. C. M. ST. JOHN, "Reference Thermal and Thermal/Mechanical Analyses of Drifts for Vertical and Horizontal Emplacement of Nuclear Waste in a Repository in Tuff," SAND86-7005, Sandia National Laboratories (1987).

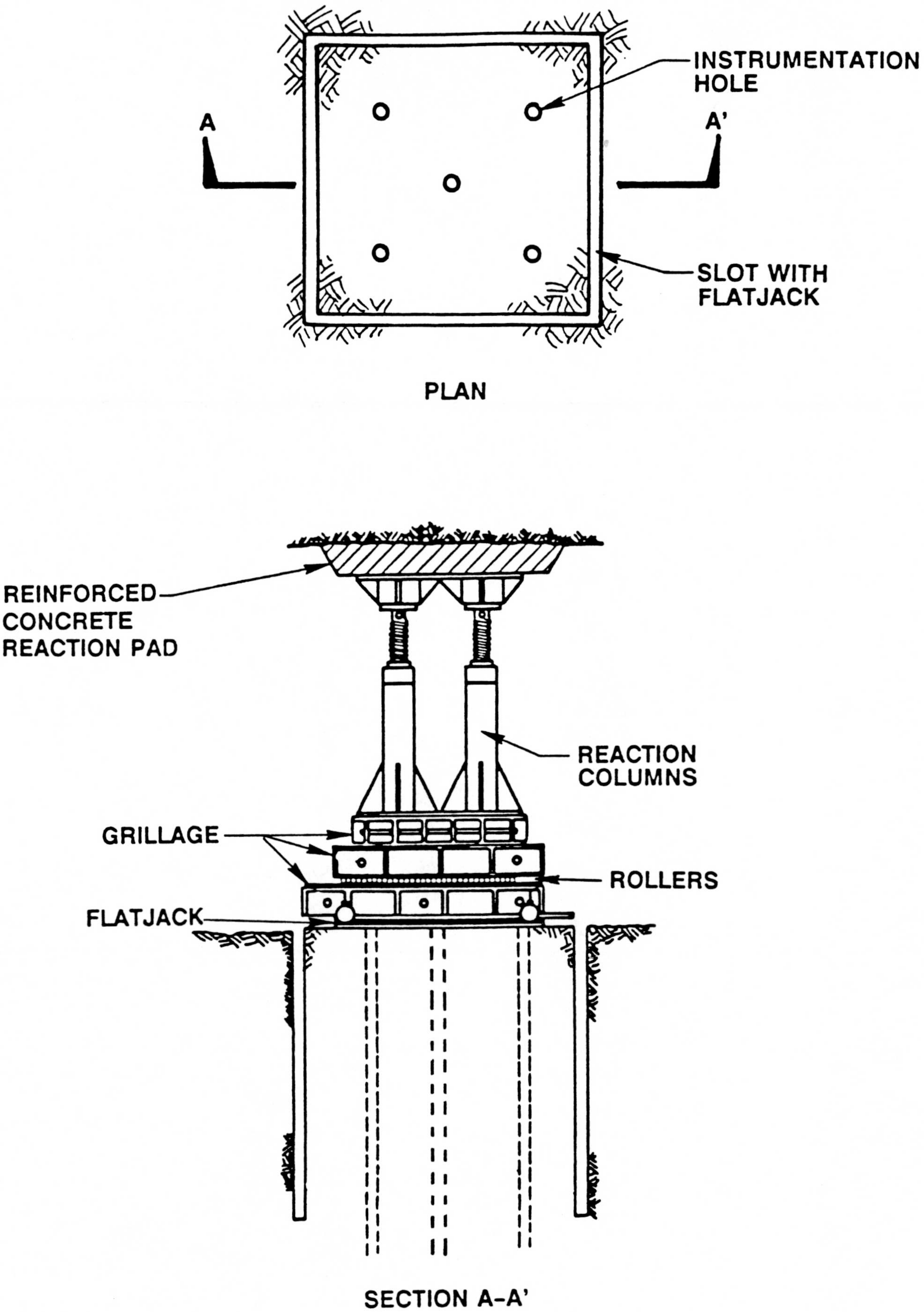

FIGURE 1 CONCEPTUAL LAYOUT OF BLOCK COMPRESSION TEST

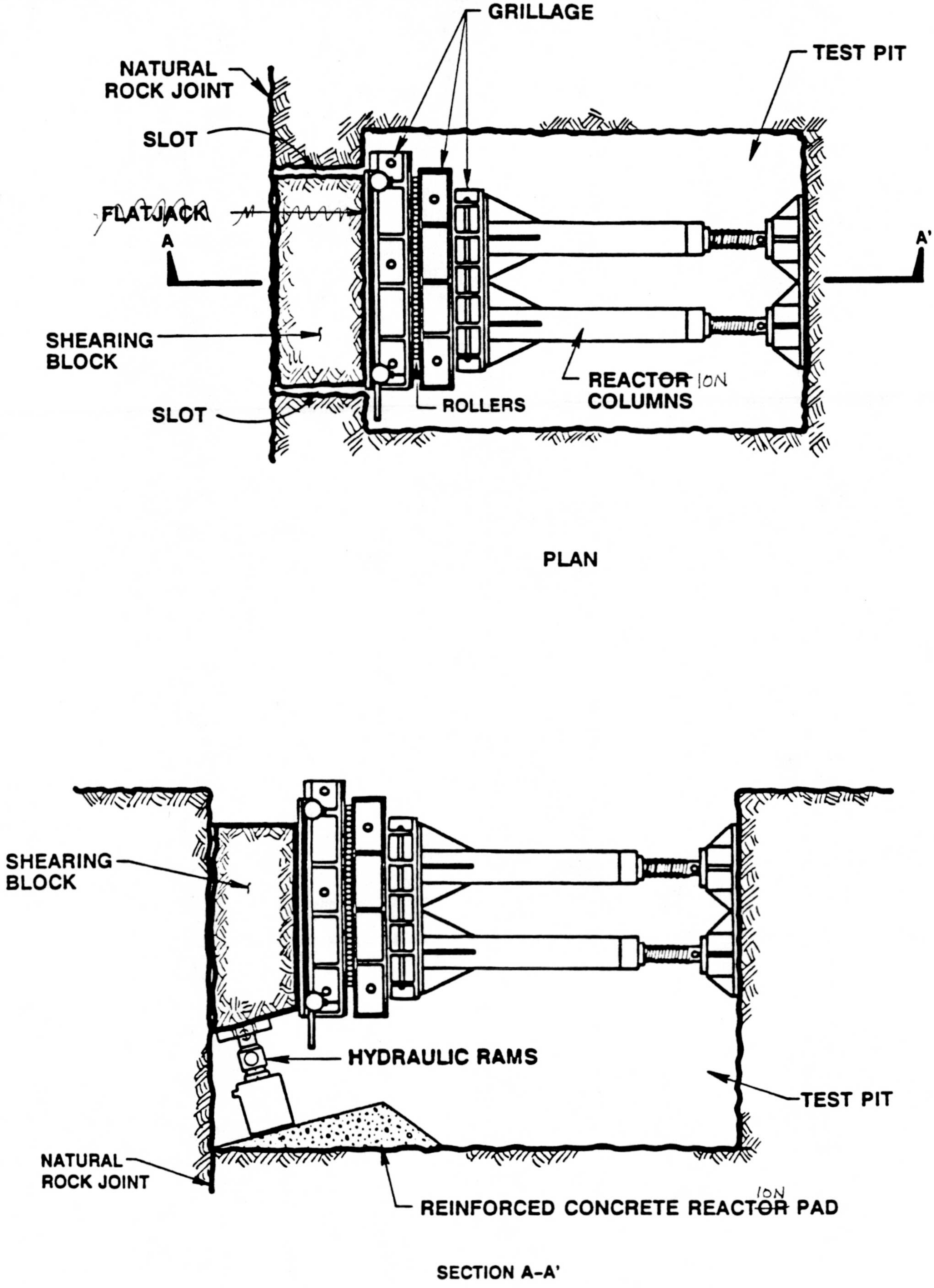

FIGURE 2. ONE CONCEPT FOR LAYOUT OF IN SITU JOINT SHEAR TEST

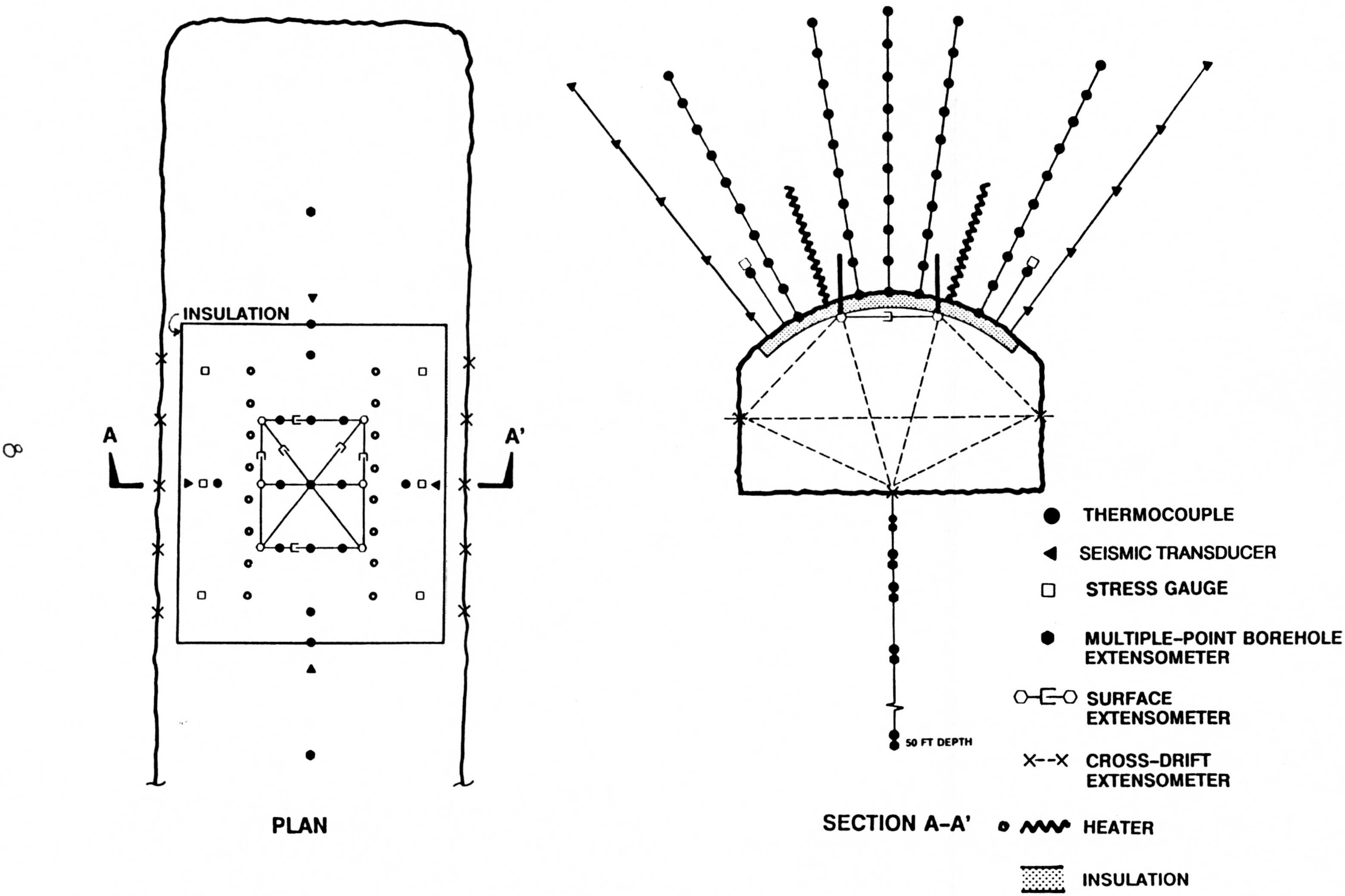

FIGURE 3. CONCEPTUAL LAYOUT OF THERMAL-STRESS TEST

Appendix

Information from the Reference Information Base
Used in this Report

This report contains no information from the Reference Information Base.

Candidate Information
for the
Reference Information Base

This report contains no candidate information for the Reference Information Base.

Candidate Information
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