9-7-2004

Influence of Lithophysae Geometry and Distribution on Mechanical Properties of Topopah Spring Tuff

Mohammad Shahidul Islam
University of Nevada, Las Vegas, islamm3@unlv.nevada.edu

Justin Fenton

Moses Karakouzian
University of Nevada, Las Vegas, mkar@nevada.edu

Jaime Gonzalez

Amy J. Smiecinski
University of Nevada, Las Vegas, smiecins@unlv.nevada.edu

See next page for additional authors

Authors
Mohammad Shahidul Islam, Justin Fenton, Moses Karakouzian, Jaime Gonzalez, Amy J. Smiecinski, and Raymond E. Keeler

University and Community College System of Nevada

DOCUMENT CHANGE NOTICE (DCN)

DCN No. 1 **to Document No.** SIP-UNLV-033, **Revision** 0, **Effective Date:** 9/7/04.

Document Title: Influence of Lithophysae Geometry and Distribution on Mechanical Properties of Topopah Spring Tuff

Identify applicable affected page, section, paragraph, attachment, exhibit, table, figure, or other:

Delete the following: Subtask 4, "Numerical Analyses Using 2D UDEC"

This DCN may be cancelled to restore original scope to the SIP.

Approved by:

PI: [redacted] Date: 3/3/05
(Signature)
Print name: Moses Karakouzian

QA Manager: [redacted] Date: 3-24-05
(Signature)
Print name: Amy J. Smiecinski

QA Manager evaluated acceptability, that it does not violate quality requirements, and for impacts to other procedures; signature above documents this evaluation as successfully completed.

Send electronic version of this DCN to Webmaster.
Attach this DCN as first page of hard copies of document, if any.

University and Community College System of Nevada (UCCSN)
Scientific Investigation Plan (SIP)

Task Title:	**Influence of Lithophysae Geometry and Distribution on Mechanical Properties of Topopah Spring Tuff**
Task Number:	**ORD-FY04-013**
Document Number:	**SIP-UNLV-033**
Revision:	**0**
Effective Date:	**September 7, 2004**

Author:

[redacted]
Mohammad Islam — 8/19/04 **Date**

[redacted]
Justin Fenton — 8/19/04 **Date**

Approvals:

[redacted]
Moses Karakouzian, Principal Investigator — 8/26/04 Approval Date

[redacted]
Jaime Gonzalez, Technical Task Representative — 8/31/04 Approval Date

[redacted]
Amy Smiecinski, QA Manager — 9-2-04 Approval Date

[redacted]
Raymond Keeler, Project Director — 09/07/2004 Approval Date

REVISION HISTORY

Revision Number	Effective Date	Description and Reason for Change
0	09/07/2004	Initial Issue

1.0 INTRODUCTION

The current Site Recommendation study for the proposed high level nuclear waste repository at Yucca Mountain locates the repository emplacement drifts approximately 81% within the lower lithophysal unit of the Topopah Springs Formation (Tptpll), 4% within the upper lithophysal unit of the Topopah Springs Formation (Tptpul), and roughly 15% within the middle, non-lithophysal unit (Tptpmn) of the same formation. A major geomechanical issue facing the Yucca Mountain Project is to understand the thermomechanical behavior of lithophysal tuff, which comprises roughly 85% of the repository host rock.

The mechanical response is complex due to the presence of voids of varying shape, size, and distribution within a hard, brittle rock matrix. During past years, significant testing and numerical modeling investigation has been performed to assist in understanding the mechanical behavior of lithophysal rock. A series of large-scale laboratory and in-situ scale field tests have been performed to provide data on both lithophysal porosity and size effects on rock mass strength and deformability. Even with this testing program, the database of mechanical properties for this rather complex material is small. Since it is very difficult to core the lithophysal rock and since it is impossible to perform a large number of in-situ compression experiments, an alternative approach to understanding variability and uncertainty of rock mass properties needs to be developed.

Recently, numerical modeling using PFC (Particle Flow Code) and UDEC has been used to estimate the potential bonding strength and deformability of the lithophysal rock mass as a function of lithophysal porosity. The PFC is a "micromechanical" discontinuum model in which the rock matrix is represented by a large number of spheres that are bonded at their contact points with simple strength and stiffness bonds. As a rock is stressed, these bonds will deform, giving rise to elasticity; also, the bonds may fail, giving rise to complex material response. Nonetheless, numerical models need to be calibrated to represent the actual material behavior.

An understanding of the variations and uncertainties in tuff mass properties due to lithophysae is very important to better understand the mechanical behavior of the host rock. The purpose of this task is to provide greater confidence in the range of data variability and to enable the use of the numerical model for future prediction of lithophysal porosity effects.

2.0 SCOPE OF WORK

Due to the difficulty of coring rock specimens containing various sizes of cavities, analog materials can be used to simulate repository rock. The work in this current task is a continuation and refinement of the work performed in Task 27 of Co-operative Agreement DE-FC28-98NV12081. The current task will address the issues that were identified in Task 27. Specifically, these issues relate to the influence of the geometry and the distribution of lithophysae on the deformation and strength properties of Topopah Spring Tuff. The scope of the current task consists of conducting an experimental study utilizing an analog material as well as performing numerical analysis using UDEC software.

Mechanical testing on an analog material in which the lithophysal porosity, void shape, void size, and void distribution are accurately controlled will be conducted and will thus enhance our knowledge on the engineering properties of lithophysae-rich tuff. The information gathered as part of this study will include elastic (Young's) modulus and uniaxial compressive strength.

Collected data will be used to verify the numerical models generated by UDEC. These numerical models will be generated via the simulation of the analog material tests. Test data will also provide the confirmatory or corroborative data necessary to support the lithophysal material numerical model constitution that is presently being conducted by Bechtel-SAIC for the Department of Energy.

2.1 SUBTASKS

This study includes five (5) Subtasks to be completed during its 24 month duration. The Quality Assurance (QA) programs will apply to all Subtasks as referenced in section 2.2. The Subtasks are described below:

Subtask 1. *Test Planning*: As appropriate, develop a laboratory testing plan, including the analog material(s) to be tested, type of test(s), test configuration(s), testing methodology(s), procedure(s) and necessary apparatus(es), to measure the effects of lithophysal geometry and distribution on the deformation and strength properties of Topopah Spring Tuff, and to determine appropriate test parameters, including loading ranges. The result of this work element will be a test matrix identifying the number of specimens, size of the specimens, cavity configurations, and cavity distributions. The test matrix will be achieved by extracting information from DOE technical reports, panel mappings, core specimen pictures, and through consultations with DOE/Bechtel-SAIC technical staff.

Subtask 2. *Material Scoping*: Analog materials will be reviewed and evaluated to determine an ideal material for this task. The purpose of material scoping is to ensure the use of an analog material that has properties as similar to lithophysal rock as possible while maintaining viability for this Task.

Subtask 3. *Specimen Preparation*: Specimens will be prepared using the analog material determined in Subtask 1. Preparation will be accomplished through the use of a mold that will create specimens with holes completely extended throughout the specimens. The number and size of the specimens and the sizes, shapes, and distribution of the cavities will be according to the test matrix developed in Subtask 1.

Subtask 4. *Testing*: The analog specimens will be tested uniaxially for elastic modulus and compressive strength. The testing equipment will allow for the application of axial loads to the specimen as well as measure axial deformations during testing. The axial force will be measured by a load cell and the axial deformations will be monitored by LVDTs. From axial stress and strain, elastic modulus and uniaxial compressive strength will be computed. Test results will then be analyzed to assess the influence of the geometry and distribution of cavities on the elastic modulus and strength.

Subtask 5. *Numerical Analysis*: Numerical analyses using UDEC developed by ITASCA will be conducted. These analyses will simulate the tests to be conducted as described in Subtask 3. The results of the analyses will then be compared to the results found from analog material testing.

2.2 COMPLIANCE WITH THE QUALITY ASSURANCE PROGRAM

The results of this study will be utilized by DOE as a guideline for the possible modification and/or confirmation of DOE's philosophy regarding the effects of lithophysal porosity on rock mass stress-strain properties. The stress-strain data are needed to verify input values currently being used for analysis. Accordingly, this proposed study under the cooperative agreement will be quality affecting. Due to the task's quality affecting nature, this work is subject to University and Community College System of Nevada (UCCSN) Quality Assurance (QA) requirements.

Since the proposed study includes both analytical and experimental work, an extensive QA effort is incorporated into the scope of work to ensure that the UCCSN QA program is satisfied.

3.0 APPROACH

To complete this task, the proposed study is divided into (5) Subtasks. The completion of these Subtasks will allow for the influence of lithophysae geometry and distribution on the mechanical properties of Tptpll to be evaluated.

Subtask 1 will yield a completed test matrix that will be used to construct and test analog specimens as described in Section 3.2 (Test Plan). This test plan will be used to meet the objectives of Task 013.

3.1 SEQUENCE OF WORK

The five Subtasks will be completed with three funding cycles totaling 24 months. Prior to the start of any Subtasks, all QA requirements will be addressed. Subtask 1: Test Planning must be completed prior to the commencement of the remaining Subtasks. The Subtasks that will be performed during each cycle are described below.

<u>Cycle I: 02/01/04 through 09/30/04</u>
- Subtask 1: *Test Planning*
- Subtask 2: *Material Scoping*
- Subtask 3: *Specimen Preparation*

<u>Cycle II: 10/01/04 through 09/30/05</u>
- Subtask 3: *Specimen Preparation*
- Subtask 4: *Testing*
- Subtask 5: *Numerical Analysis*

<u>Cycle III: 10/01/05 through 01/31/06</u>
- Subtask 4: *Testing*
- Subtask 5: *Numerical Analysis*

3.2 EXPERIMENTAL TEST PLAN

A. Overview

To verify the results found through UDEC modeling, plane strain compression testing will be performed on a variety of analog specimens. The specimens will be nominal cubes composed of an analog material – plaster of Paris or Hydro-Stone® Gypsum Cement.

Specimens will be fashioned to contain holes that extend through the entire specimen so that they may be evaluated in two dimensions (2D). To ensure the representativeness of individual specimens, each specimen will be triplicated.

B. Analog Material

The analog material is to be determined. It will be determined by the completion of Subtask 1 and is Decision Point 1 (DP 1). Two analog materials have been identified: plaster of Paris and Hydro-Stone® Gypsum Cement.

Plaster of Paris: This material provides a compressive strength of approximately 1750 psi. It is moldable and representative. Through preliminary tests and previous experience, this material has been shown to be feasible.

Hydro-Stone®: This material provides very high compressive strength of approximately 10,000 psi. It is described as moldable; however, preliminary testing must be done to assure it meets all requirements necessary for this task.

C. General Specimen Geometry

Specimen Shape and Size: The basic geometry of all specimens will remain constant. All specimens will be cubes with nominal dimensions of 6" x 6" x 6" (Length x Width x Height).

Presence of Holes: Specimens will contain holes of various shapes and sizes; however, all holes will extend completely through the specimen. This uniformity will allow 3-dimensional specimens to be evaluated as 2-dimensional specimens.

Lithophysal Porosity: Lithophysal porosity, is the ratio of the volume of the lithophysae to the volume of the entire specimen. For this Task, a specimen's porosity will refer to the lithophysal porosity of a specimen. As the lithophysae are uniform holes extended through the length of the specimen, the lithophysal porosity may be expressed by the following equation:

$$Lithophysal\ Porosity(n) = {A_{holes}}/{A_{total}}$$

D. Internal Specimen Geometry

The internal geometry of specimens will vary with respect to the holes that are found within the specimen.

Location of Holes: The location of individual holes will be provided using x- and y-coordinates. Both the x- and y-axis pass directly through the center of the specimen; thus, the center of the specimen will be the origin.

Bridge Distance: Bridge distance is the distance (B.D.) between two adjacent holes. The bridge distance of two circular holes is shown in Figure 3.2.1. This length will vary depending on hole location, shape, and size. In general, specimens will be generated by using three different bridge distances: $B.D. \geq 0.25"$; $B.D. \geq 0.10"$; and $B.D. \geq 0.50"$.

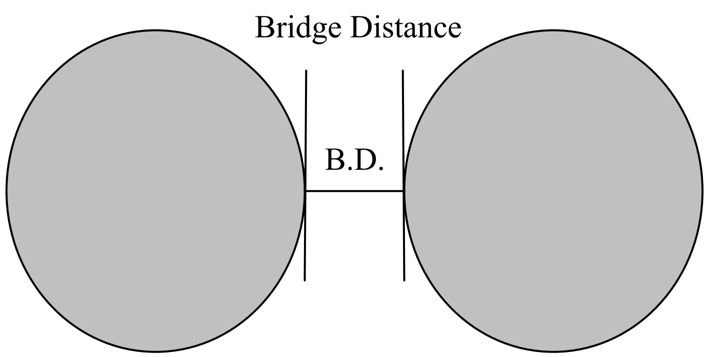


Figure 3.2.1: Bridge Distance

E. Holes Properties

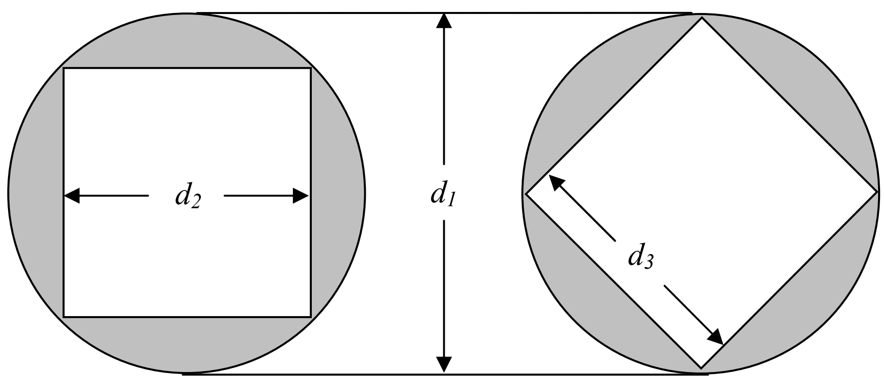
Hole Shape: This property refers to the geometry and relative rotation of the hole within the actual specimen. Three different shapes of holes will be used.

(1) Circle: These holes will be true circles - plane curves everywhere equidistant from given fixed points, centers. The rotation of this shape is not relevant as circles are symmetrical about any axis.
(2) Square: Square holes are true squares – plane areas with sides of equal distance that intersect at 90-degree angles. The sides of this shape are parallel to the adjacent specimen walls.
(3) Diamond: Diamond holes are true squares – plane areas with sides of equal distance that intersect at 90-degree angles. The sides of this shape will form 45-degree angles with the specimen walls.

Hole Size: This property reflects the relative characteristic dimensions of each shape. The characteristic dimensions of the holes are diameter for circle (d_1) and length for both square (d_2) and diamond (d_3). Sizes are found by transcribing square and diamond holes within respectively sized circular holes. This process is displayed in Figure 3.2.2 and was used to compute the sizes found in Table 3.2.1.

Table 3.2.1: Hole Sizes

Hole Size	Characteristic Dimension (inches)		
	Circle	*Square*	*Diamond*
Small	0.500	0.3536	0.3536
Medium	0.875	0.6187	0.6187
Large	1.250	0.8839	0.8839



$$\frac{\sqrt{2}}{2} d_1 = d_2 = d_3$$

Figure 3.2.2: Relationship of Circle, Square, and Diamond Characteristic Dimensions

F. Testing Constraints

The following constraints will be applied to all test specimens:

1. The ratio of the specimen's length (D) to the diameter of the circular hole (d_1) must fall between 4.8 and 12, and this relationship is shown below.

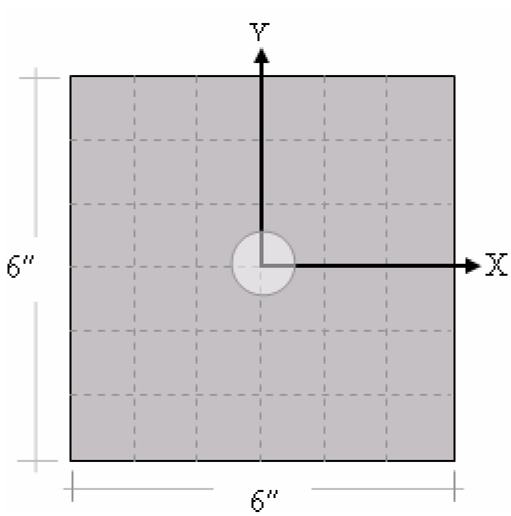
$$4.8 \leq \frac{D}{d_1} \leq 12$$

2. All specimens will maintain at least a 0.25" distance between the specimens' outer edges and the nearest hole.
3. The lithophysal porosity of the specimen must fall between 0% and 40%,

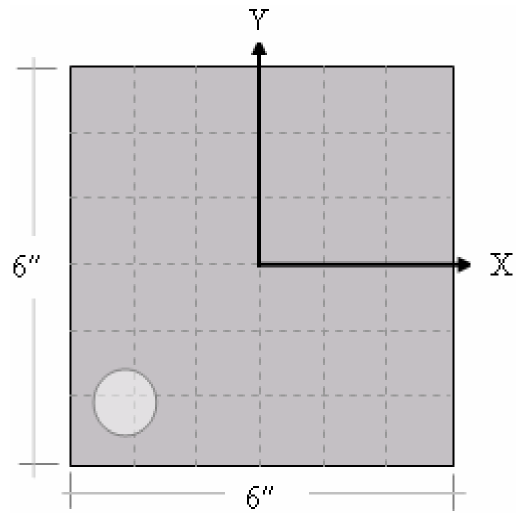
G. Specimen Design

Specimens will be designed based on the physical properties described above. Specimens will be generated based on the placement of the first hole. This will be done for all hole sizes and shapes.

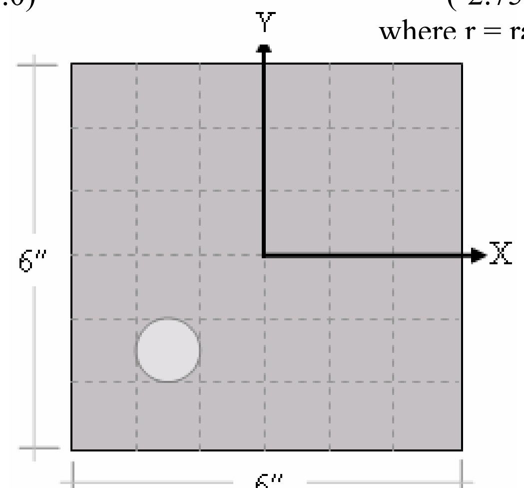
Hole Placement: An algorithm will be used that randomly places holes within the specimen so that a specified bridge distance is met or exceeded; however, the first hole's starting location will be specified. There are three starting locations that will be used; they are shown in Figure 3.2.3. Holes will be added to the starting locations until no more may be added. These locations are to be determined.



I. *Center of specimen*
(0.0 , 0.0)



II. *Corner of Specimen*
(-2.75 + r , -2.75 + r);
where r = radius of circular hole



III. *Midpoint of center and corner of specimen*
(-1.5 , -1.5)

Figure 3.2.3: Starting Hole Locations

<u>H. Specimen Selection</u>

Lithophysal porosity will be the criterion by which specimens will be selected. Figure 3.2.4 displays the porosities of specimens with respect to hole size and number of holes.

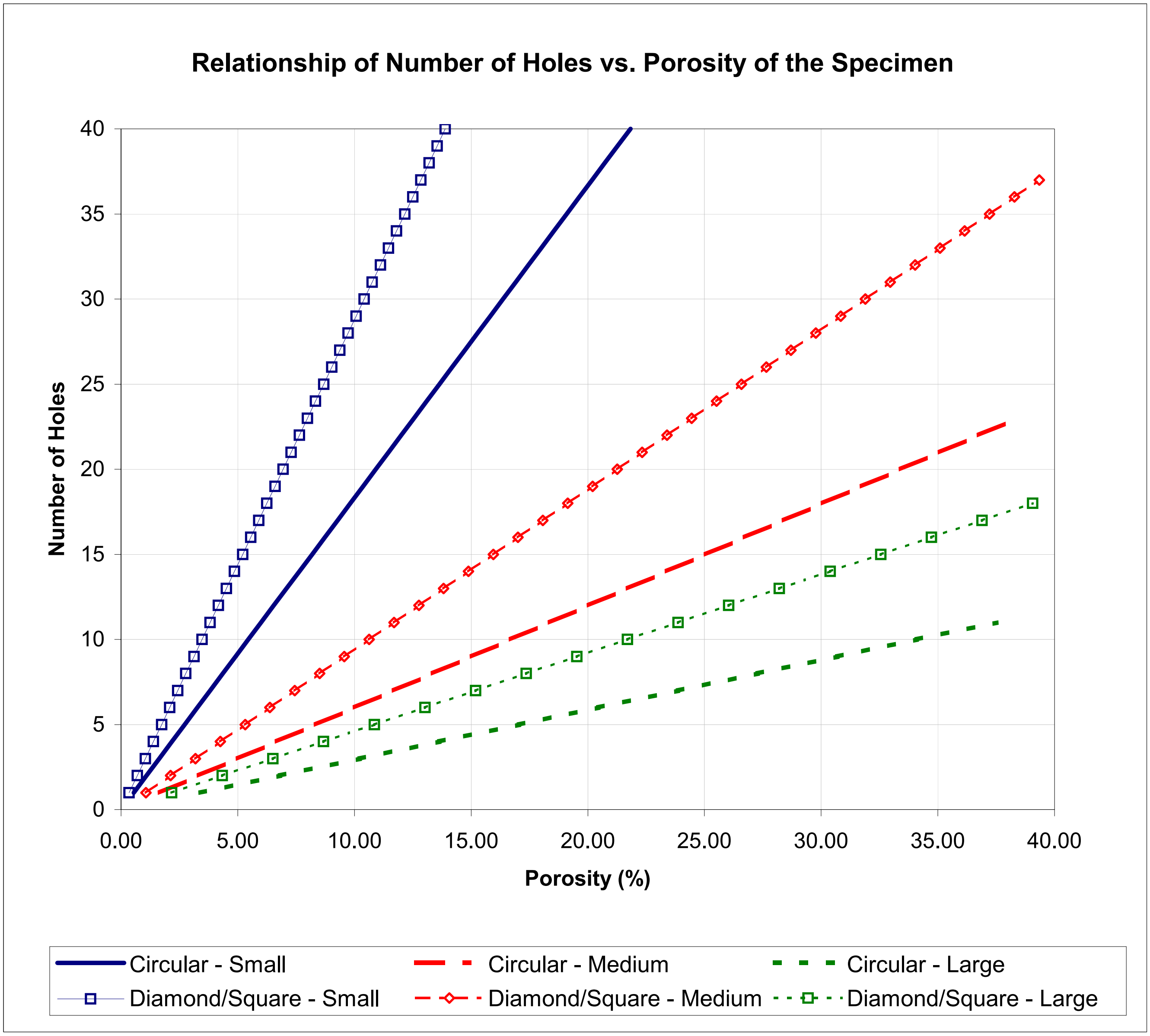


Figure 3.2.4

Specimens containing circular holes with a bridge distance $\geq 0.25"$ will be the majority that are tested. Those specimens that contain square and diamond holes will be tested to spot check the results found from circular hole testing. Similarly, specimens with bridge distances $\geq 0.10"$ and $\geq 0.50"$ will be tested only as spot checks. This is done so that the impact of shape on the specimen and the impact of bridge distance on the specimen may be discovered. Table 3.2.2 displays the preliminary porosities of the specimens that will be tested. The finalized test matrix, providing hole locations and specimen porosity will be prepared in Subtask 1. A total of 162 specimens that have a bridge distance $\geq 0.25"$ will be tested.

Table 3.2.2: Preliminary Specimens with Bridge Distance $\geq$ 0.25"

Hole Shape	Hole Size (Dimension)	# of Starting Hole Locations	Approximate Nominal Porosities	Number of Specimens*
Circular	*Small (0.5")*	*3*	*3%, 13%, max*	*3*3*3 = 27*
	Medium (0.875")	*3*	*3%, 13%, max*	*3*3*3 = 27*
	Large (1.25")	*3*	*3%, 13%, max*	*3*3*3 = 27*
	Mixed	*3*	*3%, 13%, max*	*3*3*3 = 27*
Square	*Medium (0.6187")*	*3*	*2%, 8%, max*	*3*3*3 = 27*
Diamond	*Medium (0.6187")*	*3*	*2%, 8%, max*	*3*3*3 = 27*

*** Multiplied by 3 due to triplication of specimens**

Specimen configurations for the remaining two bridge distances, $B.D. \geq 0.10"$ and $B.D. \geq 0.50"$, will be determined after initial test results have been compiled. It is anticipated that approximately 12 specimens from both types of bridge distance will be tested. For a baseline, at least 4 specimens containing no holes will be tested as well; therefore, the total number of specimens to be tested is anticipated to be approximately 190.

I. Production of Analog Specimens

Analog specimens will be produced in accordance with UCCSN Quality Assurance approved Implementing Procedures that will be produced for this task.

J. Compression Testing of Analog Specimens

Testing will take place at a location yet to be determined. Testing will be performed in accordance to UCCSN Quality Assurance approved Implementing Procedures. These Implementing Procedures have not yet been written. In accordance to QA regulations, all equipment will be calibrated prior to use

F. Results

Results from the unconfined compression testing of the analog specimens will be presented as curves showing the effect of lithophysal porosity, varied by the cavity distribution and size, on the Young's Modulus and uniaxial compressive strength of the specimens. These curves will help to describe the influence of lithophysal geometry and distribution on the mechanical properties of rock.

These results found through analog testing will then be compared to results found through UDEC modeling. This comparison will allow for a verification of numerical PFC.

3.3 NUMERICAL ANALYSIS

Numerical analysis will be performed using Universal Distinct Element Code (UDEC), a command driven code. UDEC version 3.1 will be used to forecast the mechanical behavior of all analog specimens. UDEC will forecast these events by simulating the response of a discontinuous media (such as a jointed rock mass) subjected to either static or dynamic loading.

UDEC requires calibration so that it may accurately reflect the analog material's behavior. Initial specimen tests will be used to calibrate the media so that it is representative of the selected analog material. Calibration will be completed prior to any forecasting. It is anticipated that numerous experimental tests will be required to accurately calibrate the discontinuous media as the analog material.

Once fully calibrated, UDEC will be used to forecast all remaining experimental tests prior to actual, laboratory testing. Upon completion of both numerical and experimental analysis, the result sets will be compared and analyzed to provide insight into the future usage and accuracy of UDEC as a modeling tool for lithophysal rock.

3.4 PERSONNEL REQUIREMENTS

No skills additional to those described within Position Description are necessary for this task.

3.5 TEST CONDITIONS

All samples will be prepared, stored, and tested in a controlled laboratory setting. As all samples will be subject to the same conditions, uniformity of test conditions will be maintained.

4.0 PROJECT SCHEDULE

See Table 4.0.1 for a schedule of the work planned.

Table 4.0.1: Tentative Schedule for Task 013

Work Performed	Fiscal Year								
	2004			2005				2006	
	2nd Quarter	3rd Quarter	4th Quarter	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	1st Quarter	2nd Quarter
Subtask #1 Test Planning	■	■	■						
Subtask #2 Material Scoping		■	■						
Subtask #3 Specimen Preparation			■	■	■	■			
Subtask #4 Testing			■	■	■	■	■	■	
Subtask #5 Numerical Analysis				■	■	■	■	■	
Quality Assurance	■	■	■	■	■	■	■	■	■
Preparation of IPs	■	■							
Data Submittal					■			■	■
Final Report								■	■

5.0 INTERFACE CONTROLS

The personnel involved in this task are listed below.

Internal Interfaces

PI: Moses Karakouzian, PhD, PE
Investigator: Mohammad Islam
Analyst: Justin Fenton

External Interfaces

Yucca Mountain Cooperative Agreement Liaison: Raymond Keeler
DOE Technical Task Representative: Jaime Gonzalez

6.0 STANDARDS

Any required industry standards or criteria will be addressed in accordance with UCCSN Quality Assurance approved Implementing Procedures as addressed in Section 7.0. No special standards are anticipated as being required.

7.0 IMPLEMENTING PROCEDURES AND SCIENTIFIC NOTEBOOKS

Implementing Procedures (IPs) to be used will be dependent upon the selection of analogue material. Current and planned IPs for both Plaster of Paris and Hydrostone® are listed below:

Plaster of Paris:	IPLV-034:	"Producing Plaster of Paris Specimens with Holes"
	IPLV-048:	"Surface Preparation of Plaster of Paris Specimens"
Hydrostone®:	IPLV-0XX:	"Producing Hydrostone® Specimens with Holes"
	IPLV-0XX:	"Surface Preparation of Hydrostone® Specimens"
General:	IPLV-003:	"Analytical & Top-Loading Balance Use"
	IPLV-0XX:	"Procedure for use, calibration, and data collection for the [compression tester TBD]"

All additional IPs required for Task 013 will be prepared in accordance with QAP-2.0, "Quality Assurance Program-Preparation, Approval, and Revision of Procedures."

Initialization and use of the Scientific Notebook will be performed in accordance with QAP-3.0 "Scientific Investigation Control". Mr. Mohammad Islam and Mr. Justin Fenton will be responsible for recording data in the Scientific Notebook and also will be responsible for the control of the Scientific Notebook.

8.0 SAMPLES

No outside samples will be required for Task 013. Management of all produced samples will follow UCCSN QAP – 8.0, "Identification and Control of Items and Samples". To assure that these guidelines are met, sample management will be properly addressed as necessary within the IP's used for this task.

9.0 EQUIPMENT AND INSTRUMENTATION

All testing equipment/instrumentation will be calibrated by Bechtel Nevada or other qualified suppliers through the UCCSN Cooperative Agreement. Calibration frequencies and requirements will be established in accordance with QAP 12.0, "Control of Measuring and Test Equipment". The specific items that will require calibration will be determined through the duration of Subtask 1 but will include:

- Load Cell
- LVDTs
- Electronic Balance
- Digital Calipers
- Standard Calibration Weight

All testing equipment/instrumentation will be controlled following UCCSN QAP 12.0, "Control of Measuring and Test Equipment".

10.0 SOFTWARE AND MODELS

No software will be developed in this task. The software packages that may be used in this study include:

- UDEC Version 3.1
- Spreadsheet and productivity software, as found in Microsoft Office

These items will be controlled in accordance with QAP 3.2, "Software Management".

No models will be generated or used in this task.

11.0 PROCUREMENTS AND SUBCONTRACTS

Calibration items (standards), calibration services, test materials, and specimen testing will be procured, as necessary, in accordance with QAP-7.0, "Control of Quality-Affecting Procurement and Receipt" and QAP-12.0, "Control of Measuring and Test Equipment." A subcontract may be considered for the testing described in Section 3.2, J.

12.0 HOLD POINTS / DECISION POINTS

12.1 DECISION POINTS

There are several decision points (DP's) associated with this SIP. The decision points designated below will be further developed during Subtask 1 of this study:

DP 1. *ANALOG MATERIAL*. Determine analog material(s) to use in Subtask 3 and correspondingly in Subtask 4.

DP 2. *TEST METHOD*. Determine the type of test and associated measuring test equipment to use in Subtask 4.

DP 3. *DATA*. Determine what type of data to record, how to record the data, precision of recorded data, and how to reduce the data acquired in Subtask 4.

DP 4. *CALIBRATION*. Determine calibration checks and calibration frequencies for measuring devices for use in Subtask 3 and Subtask 4.

DP 5. *DETERMINATION OF ACCURACY, PRECISION, AND REPRESENTATIVENESS OF RESULTS*. Objectives and methods of determining these parameters will be developed for data generated during Subtask 4.

DP 6. *MEASUREMENT ERRORS AND UNCERTAINTY*. Determine possible errors and uncertainties for Subtask 4.

12.2 DECISION POINT RESOLUTIONS

DP 1. *ANALOG MA*TERIAL.

This decision will be resolved upon the completion of Subtask 2: Material Scoping.

DP 2. *TEST METHODS*

The analog specimens will be tested under unconfined compression conditions. The testing equipment is yet unknown as it will be dependent on DP 1. This decision point will be resolved during Subtask 1.

DP 3. *DATA*

The type of data to record, how to record the data, and how to reduce the data will be covered in Implementing Procedures covering the testing methods that will be utilized.

DP 4. *CALIBRATION*

All equipment and instrumentation will be calibrated by Bechtel Nevada or other qualified suppliers through the UCCSN Cooperative Agreement. All calibration requirements will be addressed as necessary within the proper Implementing Procedures.

DP 5. *DETERMINATION OF ACCURACY, PRECISION AND REPRESENTATIVENESS OF RESULTS*

Decision Point 5 is addressed in Section 13.1 of this SIP.

DP 6. *ERROR AND UNCERTAINTY*

Decision Point 6 is addressed in Section 13.2 of this SIP.

13.0 QUALITY CONTROL

13.1 ACCURACY, PRECISION, AND REPRESENTATIVENESS

A. Accuracy

Accuracy is a generic concept related to the closeness of agreement between test results and an accepted test value (ASTM E177). For Task 013, the accuracy concept is only related to the accuracy of a measuring process. Accuracy of the measuring processes will be ensured using the following techniques:

- Ensuring all equipment has been calibrated and the calibration period has not elapsed.
- Following Quality Assurance approved Implementing Procedures for all testing and measuring processes.

B. Precision

The precision of a measurement process is a generic concept related to the closeness of agreement among multiple test results obtained under prescribed like conditions from the measurement process being evaluated (ASTM E177). For Task 013, precision will be evaluated through the comparison of triplicate specimens.

C. Representativeness

Representativeness of the work will depend solely on the representativeness of the specimens. Though the current analog material is yet to be determined, it will be a manmade material with all specimens being prepared using Quality Assurance approved Implementing Procedures under controlled laboratory conditions. The methods used to produce specimens and the manner in which the holes will be distributed will ensure the representativeness of the test specimens.

13.2 POTENTIAL SOURCES OF ERROR/UNCERTAINTY

A. Human Error

Proper QA and IP training as well as maintained attention to detail should minimize the risk of human error.

B. Instrumentation and Equipment Error

Ensuring calibration and checks of instrument compliance with calibration should minimize the risk of instrumentation and equipment error.

C. Specimen Preparation Error

For the mechanical testing of specimens, it is very important that specimens meet or exceed the required specimen tolerances; therefore, specimen preparation will follow a Quality Assurance approved Implementing Procedure to minimize the risk of specimen preparation error.

D. Uncertainty

Uncertainty throughout this task may occur but will attempt to be minimized throughout this task. Uncertainty due to the limited number of samples tested may occur but is addressed through the testing of three like specimens. Nevertheless, all predictions, extrapolations, professional judgments, and assumptions derived from the numerical model and experimental testing must be put through uncertainty analysis.

14.0 DATA RECORDING, REDUCTION, AND REPORTING

All data recording, reduction, and reporting issues will be addressed in the Implementing Procedures that will be developed for Task 013. These Implementing Procedures will meet all requirements of QAP – 3.1, “Control of Electronic Data” and QAP – 3.6, “Submittal of Data”.

15.0 REVIEWS AND VERIFICATIONS

Internal verification of all data will be performed to check compliance with the Implementing Procedures and to verify the accuracy of data reduction. Internal technical review will be performed and documented on data, scientific notebooks, and deliverables generated in this task.

Any report of generated data without full internal verification will be labeled as preliminary data. Technical reports described and other products will be reviewed in accordance with QAP-3.4, “Technical Reports.” Scientific notebooks will be reviewed in accordance with QAP-3.0, “Scientific Investigation Control.” Technical QA reviews will be conducted when reports have been completed.

16.0 RECORDS AND SUBMITTALS

16.1 QA Records

QA Records produced as a result of the IPs and the UCCSN QA Program will be controlled in accordance with QAP-17.0, "Quality Assurance Records." QA Records designated in the UCCSN QAPs and IPs listed include but are not limited to:

- Hard copies and/or electronic media containing raw and reduced concentrated data including calibrations and QC results
- Scientific Notebooks including attachments, if applicable
- Calibration and checks for laboratory equipment, if applicable

16.2 Deliverables

Reports containing technical information will be prepared in accordance with QAP-3.4, "Technical Reports." Data will be submitted to the YMP Technical Data Management System in accordance with QAP-3.6, "Submittal of Data." Deliverables include but are not limited to:

- Quarterly progress reports will be prepared in accordance with cooperative agreement guidelines and submitted on a timely basis to the cooperative agreement administrator. These reports contain no technical data. These reports will be delivered following every quarter.
- Data Submittal to the Technical Data Archive (TDA). Data will be submitted on January 10, 2006.
- The Final Technical Report will be provided to QA for review on January 31, 2006, and then submitted to DOE on February 28, 2006.

17.0 REFERENCES

ASTM E-177, "Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods"
IPLV-003: "Analytical & Top-Loading Balance Use"
IPLV-034: "Producing Plaster of Paris Specimens with Holes"
IPLV-048: "Surface Preparation of Plaster of Paris Specimens"