APPENDIX E

Results of Laboratory Tests from 2003 Geotechnical Investigation

Geo Test Unlimited

Test Equipment Design & Fabrication
Laboratory & Field Testing
Consulting Services

Dr. Anders Bro

September 1, 2004

Amy Padovani
Rutherford & Chekene
427 Thirteenth St.
Oakland, CA 94612

Dear Amy,

Thanks very much for using my lab to perform these modulus, unconfined compression and Cerchar tests. This short letter briefly summarizes the sample behavior. The raw data sheets, plots, and standard test procedures are appended to this letter, along with a diskette containing the raw data files, the reduced data files, and the GRAPHER plot files and the digital photos of the samples both before and after testing.

Two types of sandstone were tested. Both appeared to be quite weak and altered, with no noticeable quartz content. One of the sandstone types contained large quantities of shell fragments that possibly were fossilized. The other sandstone type contained no visible shell fragments. The samples contained no visible planes of weakness. The samples were so weak that they were wrapped with heat shrink plastic wrap to help strengthen the samples during sample preparation. The plastic wrap was removed prior to testing.

The testing program was quite straightforward and the samples exhibited no unusual behavior. The moduli were quite low, as were the unconfined strengths. The samples were characterized by moduli of 138×10^3 psi and 66×10^3 psi for Sample 6-83 and 6-93 respectively. The unconfined strengths were 312 and 198 psi. respectively. The rock also had quite low densities with values of 132.4 and 133.1 pcf .

The Cerchar indices were 0.8 for Sample 3-35 and 2.2 for Sample 6-99. These numbers indicated that the Sample 6-99 was a more abrasive than Sample 3-35. In any case, both of these abrasivity indices are quite low compared to more indurated and quartz-rich rock.

for GeoTest Unlimited

Dr. Anders Bro

27069 N. Bloomfield Rd., Nevada City, CA 95959 Tel/Fax (530)470-0583 email: abro@saber.net

Geo Test Unlimited

DATA SHEET
Determination of Rock Modulus and Poisson's Ratio (ASTM D3148)

Date: 8/1/04
Technician: A.Bro

Client: Rutherford & Chekene
Job: #186-SLAC LCLS Tunnel
Sample ID: 6-83 (Boring LCLS 6)
Sample Description: Grayish tan silty fine grained sandstone - massive.

Sample Depth: 83.5-84.6' Sample Condition: received & tested moist

d_1	d_2
2.040	2.018
2.041	2.027
2.036	2.034
2.034	2.033
2.040	2.032

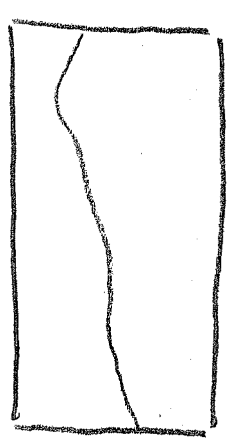
(x.0001")*

l_1	l_2
+10	+10
+5	+5
±5	±5
+10	-10
+10	+10

Avg. diameter : 2.034" Avg. length : 4.466"
Sample area : 3.249 l/d ratio : 2.20
Sample volume(in^3) : 14.511
Sample weight (g) : 504.38
Density : 34.75 g/in³ = 132.4 pcf (1 g/in³=3.8095lb/ft³)
Gauge length: 2.000"

Comments: roughness due to loose sand grains on surface

FAILED BY AXIAL SPLITTING



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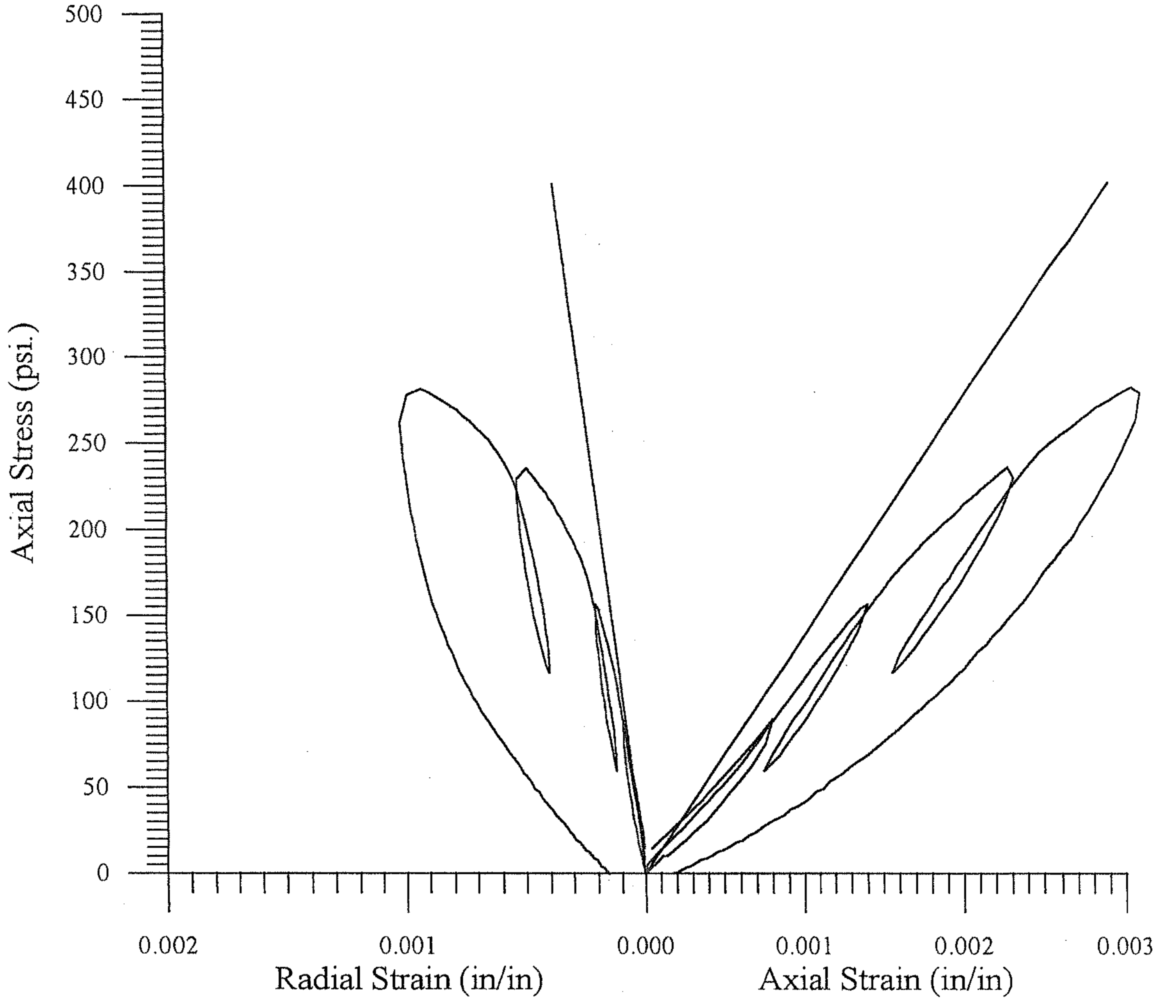


ELASTIC MODULUS TEST
Axial Stress vs. Axial & Radial Strain

Sample: 6-83
Boring: LCLS-6
Depth: 83.5-84.6'

DESCRIPTION
Grayish tan silty fine-grained sandstone.

Modulus: 138,000 psi
Poisson's Ratio: .13
Density: 132.4 pcf

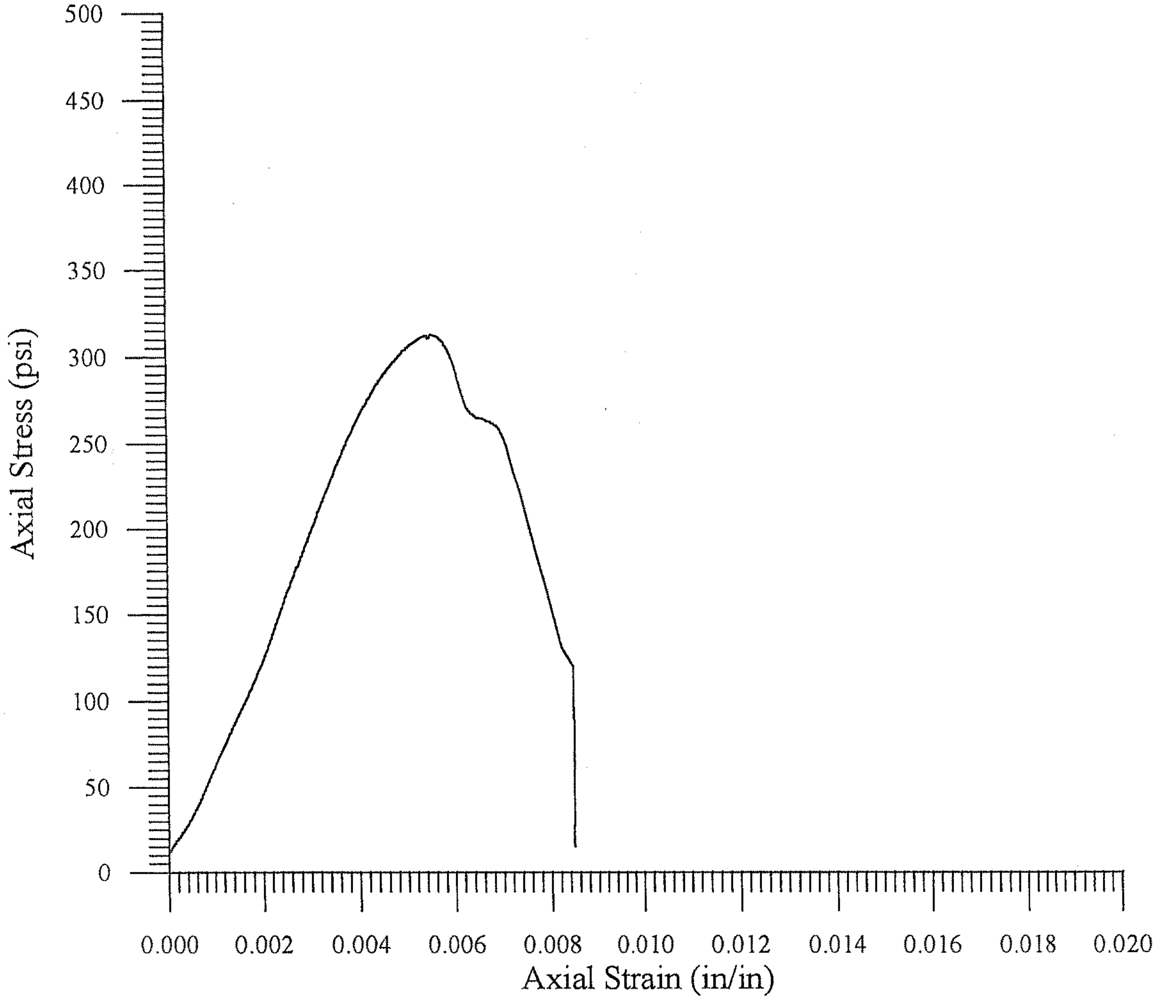
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: Rutherford & Chekene
427 Thirteenth St.
Oakland, CA 94612

Project: SLAC LCLS Tunnel

Project Number: 2002-060G2

Test Date: September 1, 2004



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 6-83
Boring: LCLS-6
Depth: 83.5-84.6'

DESCRIPTION

Grayish tan silty fine-grained sandstone.

Density: 132.4 pcf
Strength: 312 psi

Geo Test Unlimited GTU

27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: Rutherford & Chekene
427 Thirteenth St.
Oakland, CA 94612

Project: SLAC LCLS Tunnel

Project Number: 2002-060G2

Test Date: September 1, 2004

Geo Test Unlimited

DATA SHEET

Determination of Rock Modulus and Poisson's Ratio (ASTM D3148)

Date: 9/1/04
Technician: A.Bro

Client: Rutherford & Chekene
Job: #186-SLAC LCLS Tunnel
Sample ID: 6-93 (Boring LCLS6)
Sample Description: Tan fine to medium grained sandstone with layers of shell-rich sandstone. Bedding about 75° to the core axis.

Sample Depth: 93-93.8'   Sample Condition: received & tested moist

d_1	d_2
2.034	2.045
2.023	2.042
2.044	2.044
2.024	2.043
2.046	2.050

(X.0001")*

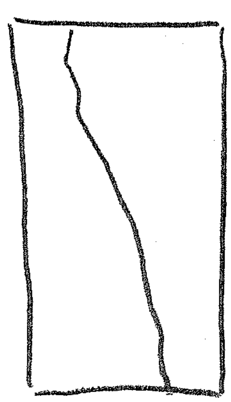
l_1	l_2
+10	-30
	-70
±10	±10
	+40
-10	-10

Avg. diameter : 2.040"
Sample area : 3.269
Sample volume(in^3) : 14.614
Sample weight (g) : 510.68
Density : 34.94 g/in^3 = 133.1 pcf   (1 g/in^3=3.8095lb/ft^3)
Gauge length: 2.000"

Avg. length : 4.471"
l/d ratio : 2.19

Comments: *roughness due to loose sand grains

FAILED BY SHEAR



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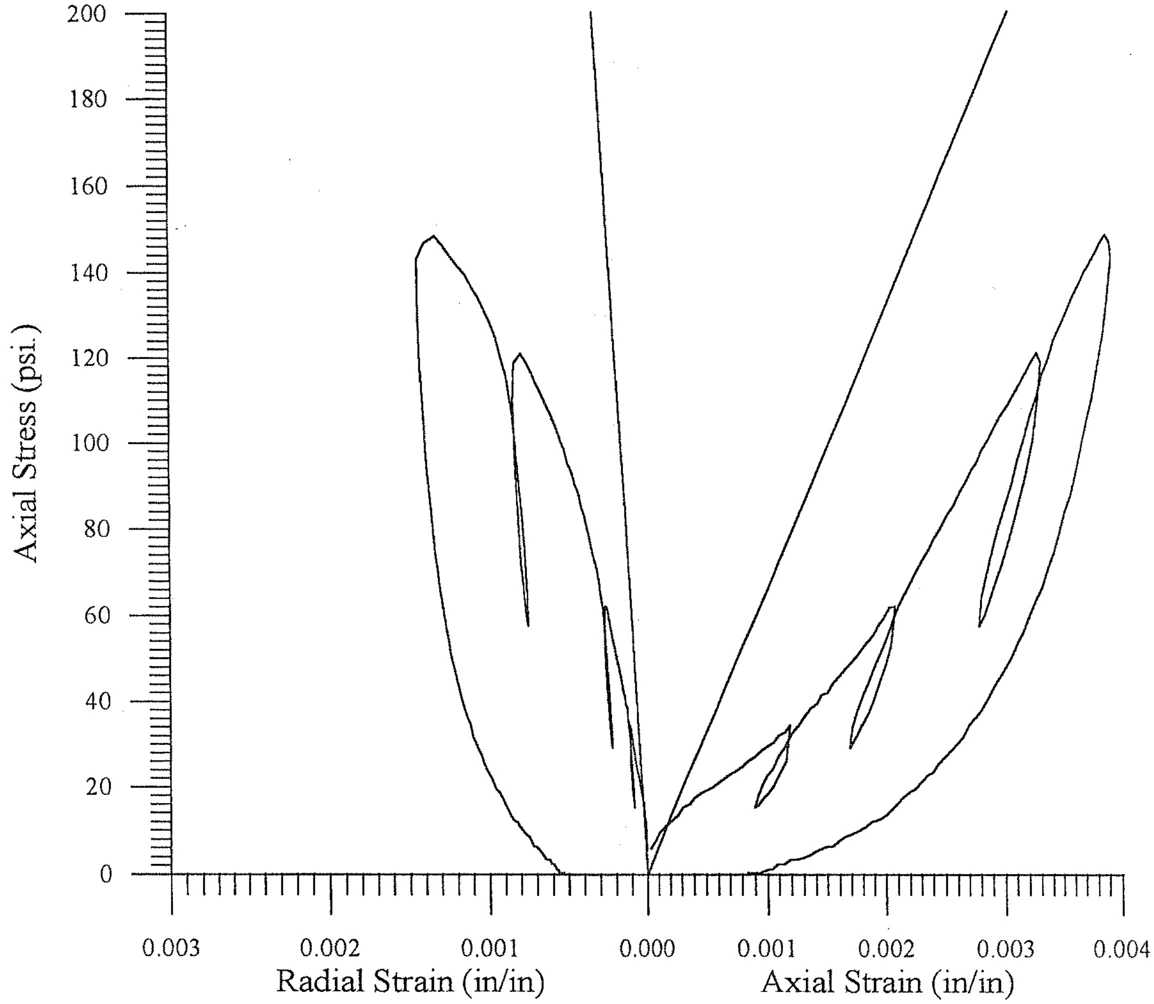


ELASTIC MODULUS TEST
Axial Stress vs. Axial & Radial Strain

Sample: 6-93
Boring: LCLS-6
Depth: 93-93.8'

DESCRIPTION

Tan fine to medium grained sandstone with layers of shell-rich sandstone. Bedding about 75 degrees to the core axis.

Modulus: 66,000 psi
Poisson's Ratio: .11
Density: 133.1 pcf

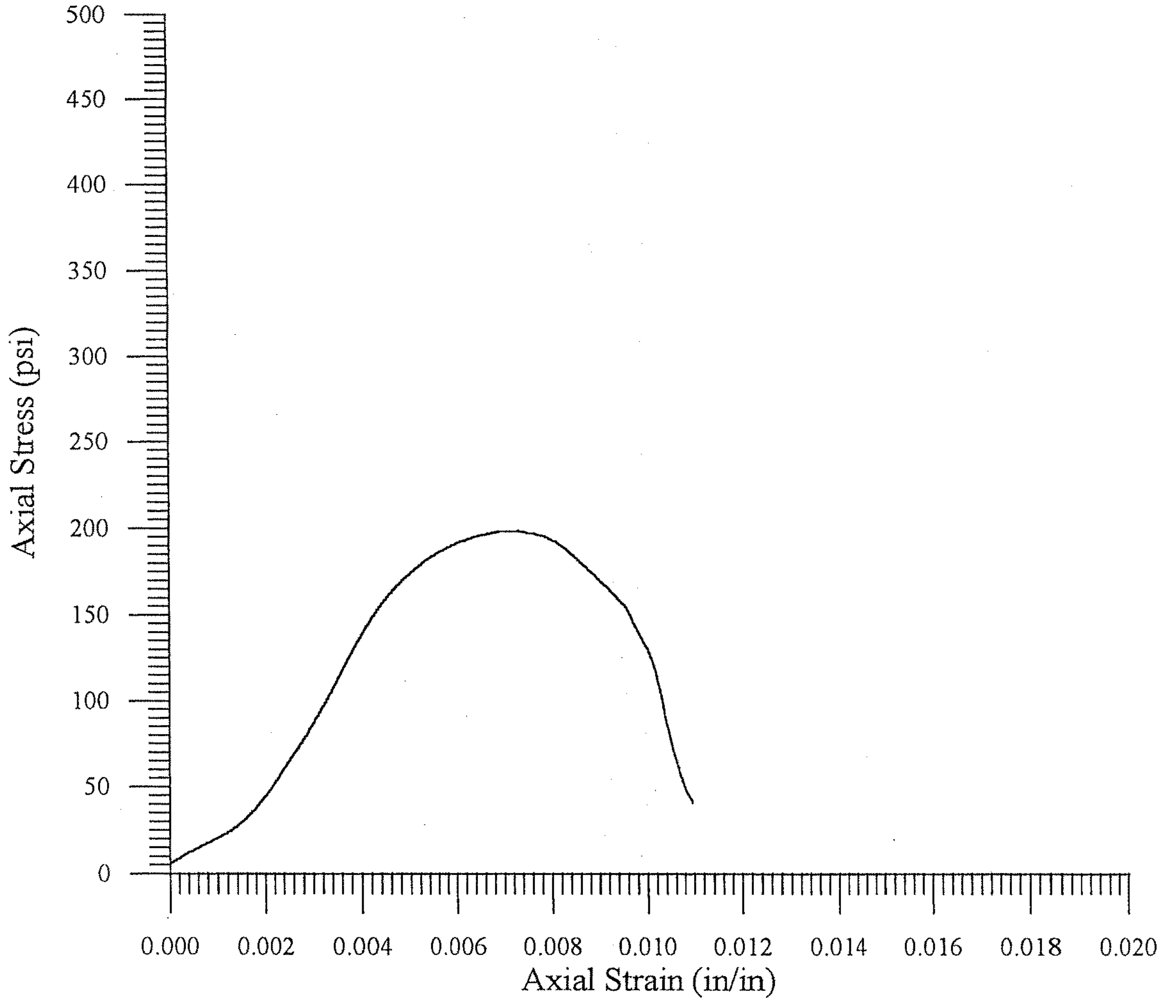
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: Rutherford & Chekene
427 Thirteenth St.
Oakland, CA 94612

Project: SLAC LCLS Tunnel

Project Number: 2002-060G2

Test Date: September 1, 2004



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 6-93
Boring: LCLS-6
Depth: 93-93.8'

DESCRIPTION

Tan fine to medium grained sandstone with layers of shell-rich sandstone. Bedding about 75 degrees to the core axis.

Density: 133.1 pcf
Strength: 198 psi

Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Rutherford & Chekene**
427 Thirteenth St.
Oakland, CA 94612

Project: **SLAC LCLS Tunnel**

Project Number: 2002-060G2

Test Date: September 1, 2004

Geo Test Unlimited (GTU)

DATA SHEET
Cerchar Abrasion Index

Client: Rutherford & Chekene
Job: #186- SLAC LCLS Tunnel

Date: 9/1/04
Technician: A.Bro

Sample ID	Depth (ft.)	Sample Description	Point Hardness (RC)	Wear Width (x0.1mm)		Cerchar Index
3/3*-35	35-35.5'	Tan Fine to Coarse sandstone with little quartz (if any) Weaken altered	41.9	0.1	0	0.8
				0.7	1.0	
				0.2	0.4	
				1.1	1.4	
				1.4	1.4	
5/6-99	99.6-100.1'	Light to Medium gray shell-rich sandstone (~30% Fossil shell(s)) no apparent quartz..	41.9	1.7	1.9	2.2
				1.7	2.0	
				2.4	2.3	
				3.0	2.9	
				1.8	1.8	
			41.9			
			41.9			
			41.9			

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Modulus Determination of Rock Core
(in accordance with ASTM D3148)

Test Equipment

The samples are cut to length using an MK saw with a 14 inch diameter continuous rim diamond blade. The ends of the samples are ground flat and parallel to each other using a Norton surface grinder and a diamond wheel. The samples are held in a cylindrical sample holder which in turn is clamped in a Vee block and held to the grinding table. This arrangement precisely orients the sample so that the end surfaces are ground flat and parallel to each other (typically within a tolerance of 0.0005 inches across an HQ size sample).

An 8-inch digital Mitutoyo caliper (with a resolution of 0.0005 inches) is used to measure the sample diameters and the average sample length. A Federal dial gauge (with 0.0001 inch gradations) is used to determine the planarity of the sample ends.

A stiff, 4-post, 200 kip press fabricated by GTU is used to load the specimens. The loading platens consist of one fixed platen and one spherical seat (both made by GTU). The platens have the same diameter as the nominal core diameter.

The pressure is applied to the loading ram using a computer controlled loading system fabricated by GTU. The load is monitored with a suitably sized load cell. Four load cells can be incorporated into the system, a 200 kip cell, a 50 kip cell, a 10 kip cell and a 2 kip cell. The three highest capacity cells are shear web cells made by Interface, Inc. and the 2 kip cell is a shear web cell fabricated by Lebow.

The axial displacements are measured using a pair of clip gauges (fabricated by GTU) based on Macro Sensor $\pm$ 0.025 inch stroke LVDTs with a gauge length of 2 inches. The change in sample diameter is measured with a pair of LVDTs mounted perpendicular to the core axis on a floating ring supported by three soft springs. These two LVDTs are mounted 90° apart, thus measuring two orthogonal diameter changes. These gauges devices employ Schaevitz $\pm$ 0.02 inch stroke LVDTs to measure the displacements.

The time, axial load and axial and circumferential displacements are monitored using a Computer Boards, Inc. Data Acquisition System (CIO-DAS1600/16) which has a 16 bit resolution and can monitor up to 16 single ended channels. The LVDTs are conditioned using MacroSensor Model DCM-1000 LVDT conditioners. The load cell is conditioned with a Daytronic Model 9178A strain gauge conditioner.

Test Procedure

A representative section of core is identified for testing. It is cut to length (with a length to diameter ratio of a little more than 2:1) and the ends are ground flat and parallel. If the sample is very weak, special techniques may need to be used to prepare the sample ends with plaster or capping compound. The sample diameter and lengths are measured to determine the sample area and to evaluate the planarity and parallelness of the surfaced ends.

Power is applied to the data acquisition system and signal conditioners at least one hour prior to testing to permit the electronics to reach thermal equilibrium. Once stabilized, the load cell conditioning system is adjusted with the help of a shunt calibration resistor. The LVDT conditioners are also adjusted with the help of a Mitutoyo digital micrometer or a Federal Products precision micrometer head, LVDT holding jig.

The two axial clip gauges and the radial gauges are attached to the sample and the sample is installed in the loading frame, along with the loading platens. The LVDTs are then suitably positioned and the loading piston is then extended until a small load is applied to the sample.

The data acquisition system is directed to start acquiring data and the loading ram is slowly advanced under computer control. Loading continues until an indication of reaching the nonelastic region is seen (by a departure from linearity in the load-displacement curve) or until a clearly linear trend has been established. During this procedure, at least three partial unloading-loading cycles are attempted to capture the unloading-reloading modulus.

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If the sample needs to tested to failure, the clip gauges are removed and at a later time the sample is tested in the manner described in the test procedure, "Unconfined Compression Test of Rock Core (in accordance with ASTM D2938)". (Since the sample has already been prepared, no further preparation is required.)

All of the modulus test data are recorded in a computer data file which includes a title block identifying the client, job, sample and sample dimensions. The data block includes data legends and units along with columns of time, axial load, axial displacement, and change in circumference. These files are used to develop computer generated plots of the sample behavior.

The modulus and poisson's ratios are derived from the stress-strain plots. Many interpretations of the stress-strain curves are possible. GTU's approach is to report the unloading-reloading modulus, at some arbitrary level of stress. The straight lines, depicted on the stress-strain curves, that pass through the origin are the linear approximations of the unloading-reloading curves used to calculate the modulus and poisson's ratios. (It should be noted that many other approximations are possible. The choice would depend on the judgement of the engineer, the stress level encountered in the structure being analyzed, and the loading history. Generally for weak or fractured rock, no single number can properly represent the elasticity of the sample.) Following the ASTM procedure, the modulus is calculated as the slope of the linear approximation of the axial stress-strain curve. The poisson's ratio is calculated as the ratio of the slope of the line used to approximate the lateral deformation curve to the slope of the line used to approximate the axial deformation curve.

Geo Test Unlimited (GTU)

Unconfined Compression Test of Rock Core
(in accordance with ASTM D2938)

Test Equipment

The samples are cut to length using an MK saw with a 14 inch diameter continuous rim diamond blade. The ends of the samples are ground flat and parallel to each other using a Norton surface grinder with a diamond grinding wheel.

A Starrett height gauge standing on a flat granite plate is used to measure the sample heights and a Starrett dial gauge mounted to the height gauge is used to determine the planarity of the sample ends. An 8-inch Mitutoyo caliper is used to measure the sample diameters.

GTU's 200 kip loading frame is used to load the specimens. The loading platens consist of one fixed platen and one spherical seat (both made by GTU). The platens have the same diameter as the nominal core diameter.

The pressure is applied to the loading ram using a computer controlled loading system fabricated by GTU. The load is monitored with a suitably sized load cell. Four load cells can be incorporated into the system, a 200 kip cell, a 50 kip cell, a 10 kip cell and a 2 kip cell. The three highest capacity cells are shear web cells made by Interface, Inc. and the 2 kip cell is a shear web cell fabricated by Lebow.

The axial displacement is monitored using a $\pm$ 0.1 inch stroke Schaevitz LVDT measuring the displacement between the fixed pedestal just above the load cell and the bottom loading platen immediately adjacent to the specimen. Thus the measured axial displacement includes the deformation of the load cell.

The time, axial load and axial displacements are monitored using a Computer Boards, Inc. Data Acquisition System (CIO-DAS1600/16) which has a 16 bit resolution and can monitor up to 16 channels. The LVDT is conditioned using a Daytronics Model 9130 LVDT conditioner. The load cell is conditioned with a Daytronics Model 9170 DC excitation strain gauge conditioner.

Test Procedure

A representative section of core is identified for testing. It is cut to length (with a length to diameter ratio of a little more than 2:1) and the ends are ground flat and parallel. If the sample is very weak, special techniques need to be used to prepare the sample ends with plaster or capping compound (many innovative procedures are required to prepare a weak rock sample). The sample diameter and lengths are measured for determining the sample area and to evaluate the planarity and parallelness of the surfaced ends.

Power is applied to the data acquisition system and signal conditioners at least one hour prior to testing to permit the electronics to reach thermal equilibrium. Once stabilized, the load cell conditioning system is adjusted with the help of a shunt calibration resistor. The LVDT conditioner is also adjusted (the null, zero, span and symmetry) with the help of a Mitutoyo digital micrometer and LVDT holding jig.

The sample is installed in the loading frame, along with the loading platens and the LVDT is properly positioned to maximize its travel during the test. The loading piston is extended until a small load is applied to the sample.

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The acquisition is directed to start acquiring data and the loading ram is slowly advanced under computer control. If failure is catastrophic, the test is terminated immediately after failure. If the failure is plastic, the test continues until a post-peak plateau develops.

The loads and displacements are printed on the computer screen along with a plot of axial load vs. displacement. Thus one has a clear image of the sample behavior at any stage of the test.

All of the data are recorded in a computer data file which includes a title block identifying the client, job, sample and sample dimensions. The data block includes data legends and units along with columns of time, axial load and axial displacement. These files are used to develop computer generated plots of the sample behavior.

Geo Test Unlimited (GTU)

Cerchar Abrasion Test[1]
(a non-ASTM or ISRM procedure)

Test Equipment

Rock core samples are cut to a 2 inch length using an MK brand brick saw with continuous rim diamond blade. These flat surfaces provide the flat surface that is to be tested.

The Cerchar device (fabricated by GTU) consists of a translating stage on which is mounted a vise for clamping the sample. A parallelepiped pair of arms is located above the vise in such a manner that the axis of the Cerchar pin is positioned perpendicular to the sawn sample surface and yet allows free movement of the pin in the vertical direction. A steel dead-weight provides the axial load (of 7 kg) which presses the point of the pin against the rock surface. The translating stage is displaced relative to the pin with a screw advance mechanism, and a pair of adjustable stops limits the travel of the displacement stage to one cm.

The abrasion of the pin tips is measured with an inverted microscope in which the tip of the sample is viewed on end. This 100x magnification microscope is used to view the tip and a cross-hair reticule is used as a reference for measuring the width of the abraded tip. The pin is mounted to a translating stage which can then be moved sideways by the advancement of a digital micrometer head.

The 1/2 inch diameter pins are fabricated of 4340 steel which has been heat treated to a Rockwell C 41.9. (It is difficult to get an accurate heat treating to exactly RC 40.) The ends of the pins are ground with a conical point with an apex angle of 90 degrees. The conical points are ground with a surface grinder and the side of a fine abrasive wheel. A spin-fixture is used to hold the pin and rotate it about its axis as it is being ground. Water is used during the grinding process to ensure that the pin temper is maintained.

Test Procedure

The Cerchar pins are first all ground so that the conical ends are smooth surfaced conical tips that come to a sharp point. Care needs to be taken to ensure that no flat surfaces develop on the conical surface of the tip. Five pins need to be ground for each test sample.

The samples are then sawn to an appropriate length. For the apparatus used at GTU, an approximate length of two inches is suitable. No special care is required for this operation. In fact some have suggested that unsawn fracture surfaces be used for the rock surface. Only sawn surfaces are used at GTU. This sample preparation removes the possible variability in the test results due to surface texture.

A sample is then clamped into the vise with the flat surface oriented in a horizontal plane. The translating stage is moved against one stop, and a pin is inserted into the device. The position of the pin is adjusted and clamped so that the arms of the parallelepiped are oriented horizontally. This positioning ensures that the shear reaction force vector will not contribute to the vertical force. The dead-weight is then placed on top of the pin. In one single stroke, the sample is then translated under the pin for a displacement of one cm. This displacement takes approximately 10 seconds. The weight and pin are removed, the sample is repositioned to present an unabraded surface to a new pin, a new pin is installed, the weight is reapplied and the procedure is repeated. A total of 5 abrasion tests are performed on each sample.

In most cases a small burr forms on the downstream edge of the pins. This burr is carefully lapped off using a very fine abrasive stone. The conical surface of the pin is positioned against the stone, abrading away the burr while rotating the pin, using the conical surface as a reference edge.

The pin is inserted into the holder on the microscope. The reticule is aligned with one edge of the wear flat. The micrometer is zeroed and then the pin is translated sideways until the other edge of the wear flat is aligned with the reticule. The width of the wear flat is then recorded in units of tenths of millimeters. The wear is measured both parallel to and perpendicular to the orientation of the wear scratches. These ten values are then averaged together to result in the Cerchar Abrasion index.

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Discussion of Test Procedures and Apparatus

The Cerchar system design presented by West essentially consists of a pin that passes through a fixed plate and positioned using a "holder". The sample is then translated underneath the pin using a dead-weight to apply the vertical load. The possible shortcoming with this design is that the friction between the pin and the holder might significantly modify the force between the pin and the sample. Since the tip of the pin is being pushed sideways by the rock sample, a moment develops which must be reacted by the holder. Therefore if the pin tends to ride up or down, shear forces would add or subtract a component of vertical force to that of the dead-weight. This action would probably tend to generally increase the tip wear and result in higher than expected abrasion values.

The metal from which GTU's pins are fabricated is not the same as that used in France or England. The problem is that there are no standard metal equivalents between these countries. The English standard, as used by West was EN24 hardened to a Rockwell 40C. On a new Norton Fine India Oilstone, FB24, this metal results in a Cerchar index of 2.04 to 2.11.

One of the American steels which crosses to the English EN24 is a 4340 steel. As it turns out, the Colorado School of Mines uses this steel in their Cerchar apparatus. They harden their pins to a Rockwell 40C. During the development of GTU's Cerchar device, a set of pins was made with 4340 steel hardened to a Rockwell 40C. When used on the reference Norton Fine India Oilstone FB24, these pins resulted in a Cerchar abrasiveness of 2.1 and 2.2. These values were sufficiently similar to West's results to use this steel and hardness for GTU's standard test configuration.

West reports abrasiveness to two decimal places (ie 0.001mm). This precision is not appropriate for any of the measurements taken at GTU. The abrasion surfaces are rough and uneven resulting in uneven edges. Since the edges between the conical surface and the wear surface are not clearly defined, it is hard to justify such precision. Furthermore, for each direction, the width of the wear flat can differ by more than 0.02 mm. Thus GTU does not report the width of the wear flat to any greater precision than 0.01 mm. (or one decimal place in terms of Cerchar index).

It should be noted that there are essentially three modes of wear. One is considered to be invalid, in which the pin skates over the surface of the rock, and does not penetrate the rock. The wear surface of the steel in these cases is quite regular, with very fine abrasions to the steel, resulting in an even circular wear spot on the end of the tip. West considers this wear mode to be invalid, as there is not a proper rock/point interaction. In this case, a fine line of steel particles is deposited on the rock surface.

A valid test, as suggested by West, consists of the point penetrating the rock, creating a groove during the test. There are two steel wear mechanisms for these sorts of interactions. The most common wear mechanism is one in which the rock abrades the steel leaving fine to coarse scratch marks on a flat wear surface. The other mechanism is expressed by small chunks of steel being torn off the steel substrate in an irregular manner, leaving behind a stippled pattern, characteristic of tensile failure. In either type of wear, the wear can occur on the side of the point if the point is imbedded in the rock. These scratch marks which are elevated up the sides of the conical tip make it difficult to accurately estimate the width of the wear flat.

1. West, G., Rock Abrasiveness Testing for Tunnelling. *Int. J. Rock Mech. Min. Sci. & Geomech. Abstr.* Vol. 26, No. 2, pp 151-160, 1989.

California State Certified Laboratory No.2153

CERCO
analytical, inc.

3942-A Valley Avenue
Pleasanton, CA 94566-4715
Tel: 925.462.2771
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15 September, 2004

Job No.0408228
Cust. No.11288

Ms. Amy Padovani
Rutherford & Chekene
427 13th Street
Oakland, CA 94612-2601

Subject: Project No.: 2002-060G2
Project Name: Stanford Linear Accelerator Center, Menlo Park
Corrosivity Analysis – ASTM Test Methods

Dear Ms. Padovani:

Pursuant to your request, CERCO Analytical has analyzed the soil samples submitted on August 27, 2004. Based on the analytical results, a brief corrosivity evaluation is enclosed for your consideration.

Based upon the resistivity measurements, Samples No.003 and No.004 are classified as "severely corrosive", Sample No.002 is classified as "corrosive" and Samples No.001, No.005 and No.006 are classified as "moderately corrosive". All buried iron, steel, cast iron, ductile iron, galvanized steel and dielectric coated steel or iron should be properly protected against corrosion depending upon the critical nature of the structure. All buried metallic pressure piping such as ductile iron firewater pipelines should be protected against corrosion.

The chloride ion concentrations range from none detected to 500 mg/kg. Because the chloride ion concentrations are greater than 300 mg/kg, they are determined to be sufficient to attack steel embedded in a concrete mortar coating.

The sulfate ion concentrations range from none detected to 85 mg/kg, and are determined to be insufficient to damage reinforced concrete structures and cement mortar-coated steel at these locations.

The pH of the soils range from 7.7 to 8.3 which does not present corrosion problems for buried iron, steel, mortar-coated steel and reinforced concrete structures.

The redox potentials range from 440 to 460-mV, which are indicative of aerobic soil conditions.

This corrosivity evaluation is based on general corrosion engineering standards and is non-specific in nature. For specific long-term corrosion control design recommendations or consultation, please call *JDH Corrosion Consultants, Inc. at (925) 927-6630.*

We appreciate the opportunity of working with you on this project. If you have any questions, or if you require further information, please do not hesitate to contact us.

Very truly yours,
CERCO ANALYTICAL, INC.

J. Darby Howard, Jr., P.E.
President

JDH/jdl
Enclosure

CERCO Analytical, Inc.

3942-A Valley Avenue, Pleasanton, CA 94566-4715 (925) 462-2771 Fax (925) 462-2775

FINAL RESULTS

Client:	Rutherford & Chekene	Date Sampled:	07/19-08/18/04
Client's Project No.:	2002-060G2	Date Received:	27-Aug-2004
Client's Project Name:	Stanford Linear Accelerator Center, Menlo Park, CA	Date of Report:	15-Sep-2004
Authorization:	Signed Chain of Custody	Matrix:	Soil

Job/Sample No.	Sample I.D.	Redox (mV)	pH	Conductivity (umhos/cm)*	Resistivity (100% Saturation) (ohms-cm)	Sulfide (mg/kg)*	Chloride (mg/kg)*	Sulfate (mg/kg)*
0408228-001	LCLS-1 @ 5.5-6'	450	8.0	-	5,400	-	N.D.	N.D.
0408228-002	LCLS-3A @ 33.8-34.3'	440	8.2	-	920	-	31	85
0408228-003	LCLS-4 @ 18.2-18.8'	460	7.7	-	400	-	500	N.D.
0408228-004	LCLS-4 @ 29.2-29.8'	460	7.8	-	460	-	370	N.D.
0408228-005	LCLS-5 @ 98.8-99.3'	460	8.3	-	3,100	-	N.D.	N.D.
0408228-006	LCLS-6 @ 108-108.5'	460	8.3	-	3,600	-	N.D.	N.D.

Method:	ASTM D1498	ASTM D4972	ASTM D1125M	ASTM G57	ASTM D4658M	ASTM D4327	ASTM D4327
Detection Limit:	-	-	10	-	50	15	15
Date Analyzed:	8-Sep-2004	10-Sep-2004	-	10-Sep-2004, 13-Sep-2004 & 14-Sep-2004	-	27-Aug-2004	9-Sep-2004

* Results Reported on "As Received" Basis

N.D. - None Detected

Cheryl McMillen
Laboratory Director

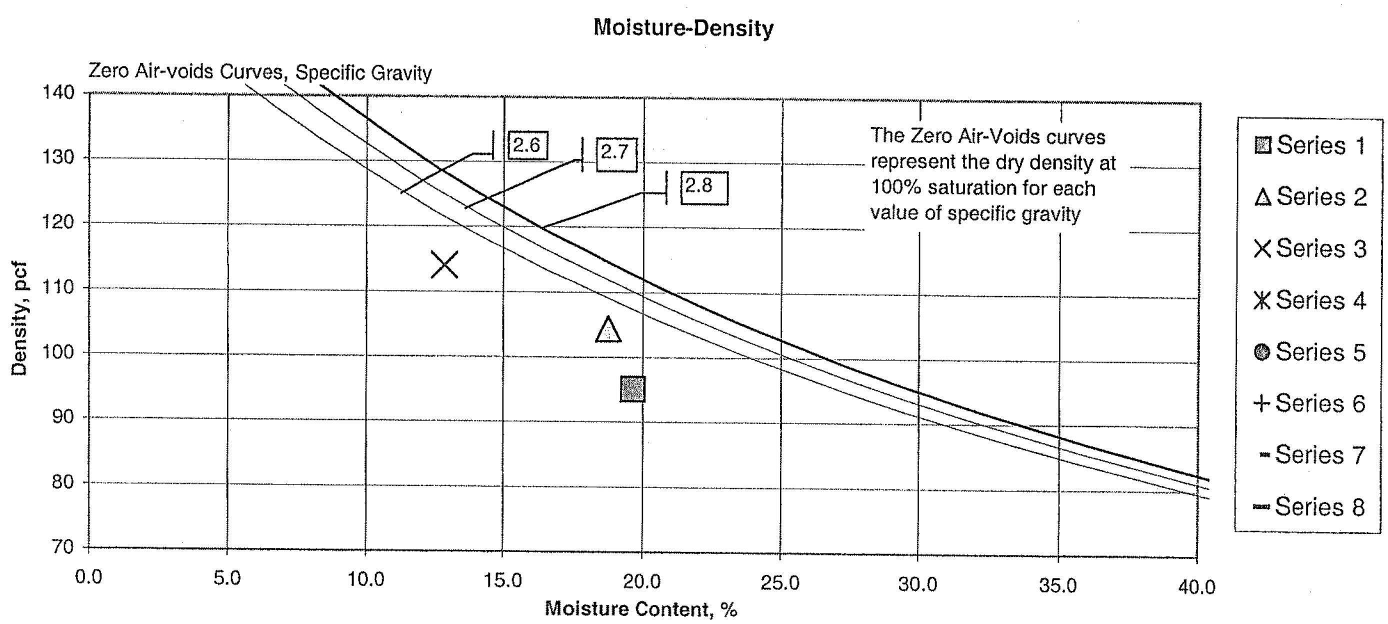
<u>Quality Control Summary</u> - **All laboratory quality control parameters were found to be within established limits**

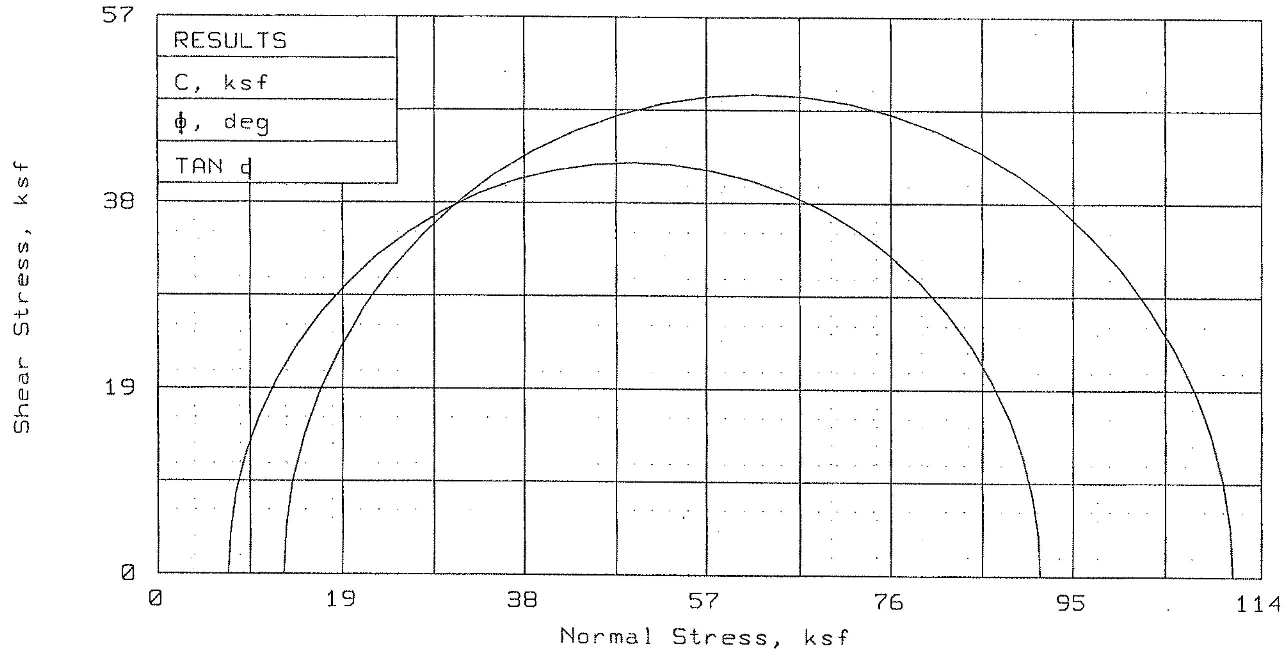
Moisture-Density-Porosity Report

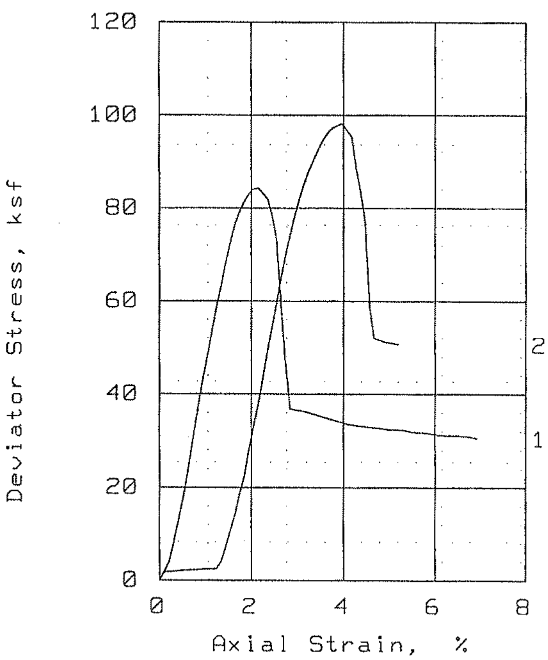
Cooper Testing Labs, Inc.

Job No:	335-067	Date:	06/24/03
Client:	Rutherford & Chekene	By:	PJ
Project:	SLAC Tunnel Expansion - 2003-060-T	Remarks:	

Boring:	SB-A	SB-C	SB-E					
Sample:	8	24	38					
Depth, ft:	73.4	23.5	89.7					
Description	Brown SAND with clay and sandstone	Brown weathered SANDSTON E	Brown weathered SANDSTON E					
Actual G_s								
Assumed G_s	2.70	2.70	2.70					
Total Vol cc	447.03	420.06	440.12					
Vol Solids,cc	251.91	259.96	297.53					
Vol Voids,cc	195.12	160.10	142.59					
Moisture, %	19.6	18.7	12.9					
Wet Unit, pcf	113.7	123.9	128.8					
Dry Unit, pcf	95.1	104.4	114.0					
Saturation, %	68.5	82.1	72.7					
Porosity, %	43.6	38.1	32.4					
Void Ratio	0.775	0.616	0.479					
Series	1	2	3	4	5	6	7	8







SAMPLE NO.:		1	2
INITIAL	WATER CONTENT, %	15.0	14.1
	DRY DENSITY, pcf	116.6	118.3
	SATURATION, %	91.1	90.0
	VOID RATIO	0.445	0.424
	DIAMETER, in	2.40	2.40
	HEIGHT, in	5.00	5.00
AT TEST	WATER CONTENT, %	14.6	13.9
	DRY DENSITY, pcf	117.6	118.9
	SATURATION, %	90.8	89.9
	VOID RATIO	0.434	0.418
	DIAMETER, in	2.39	2.39
	HEIGHT, in	4.99	5.00
Strain rate, %/min		0.50	0.50
BACK PRESSURE, ksf		0	0
CELL PRESSURE, ksf		7	13
FAIL. STRESS, ksf		84	98
ULT. STRESS, ksf			
σ_1 FAILURE, ksf		91	111
σ_3 FAILURE, ksf		7	13

TYPE OF TEST:
Consolidated Undrained

SAMPLE TYPE: Core; Undisturbed?

DESCRIPTION: Brown weathered SANDSTONE

SPECIFIC GRAVITY= 2.7

REMARKS: Sample sheared at field moisture.
Strength picked at peak deviator stress.

Fig. No.: ______

CLIENT: Rutherford & Chekene

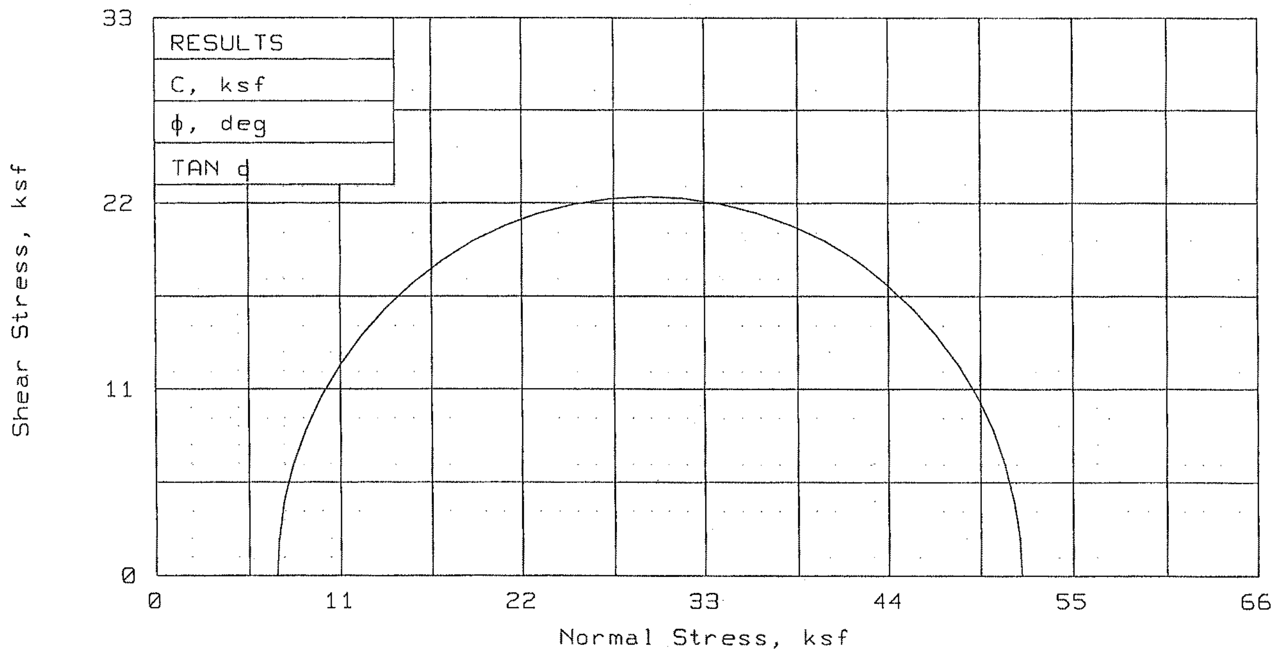
PROJECT: SLAC Tunnel Expansion 2003-060-T

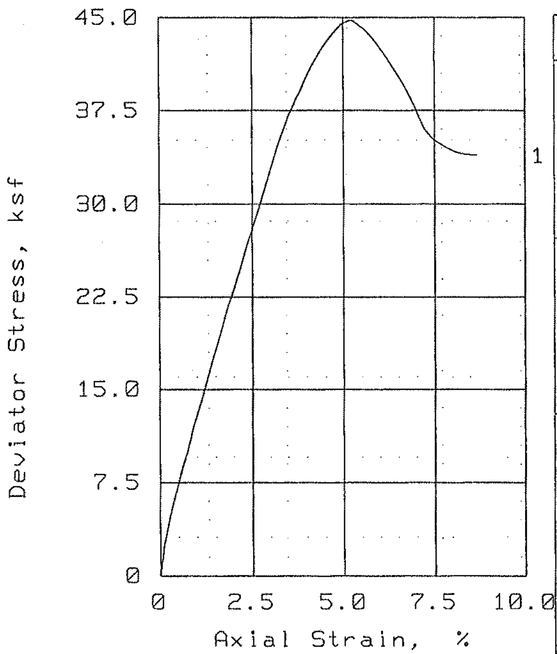
SAMPLE LOCATION: 1)SBA-2 @ 63.9
2)SBA-2 @ 63.9

PROJ. NO.: 335-067e DATE: 6/25/03

TRIAXIAL SHEAR TEST REPORT

COOPER TESTING LABORATORY





	SAMPLE NO.:	1
INITIAL	WATER CONTENT, %	16.5
	DRY DENSITY, pcf	115.8
	SATURATION, %	97.8
	VOID RATIO	0.455
	DIAMETER, in	2.36
	HEIGHT, in	5.00
AT TEST	WATER CONTENT, %	16.1
	DRY DENSITY, pcf	116.6
	SATURATION, %	97.7
	VOID RATIO	0.445
	DIAMETER, in	2.37
	HEIGHT, in	4.94
	Strain rate, %/min	0.50
	BACK PRESSURE, ksf	0.0
	CELL PRESSURE, ksf	7.2
	FAIL. STRESS, ksf	44.8
	ULT. STRESS, ksf	
	σ_1 FAILURE, ksf	52.0
	σ_3 FAILURE, ksf	7.2

TYPE OF TEST:
Consolidated Undrained

SAMPLE TYPE: Core; Undisturbed?

DESCRIPTION: Brown weathered SANDSTONE

SPECIFIC GRAVITY= 2.7

REMARKS: Sample sheared at field moisture.
Strength picked at peak deviator stress.

Fig. No.: ______

CLIENT: Rutherford & Chekene

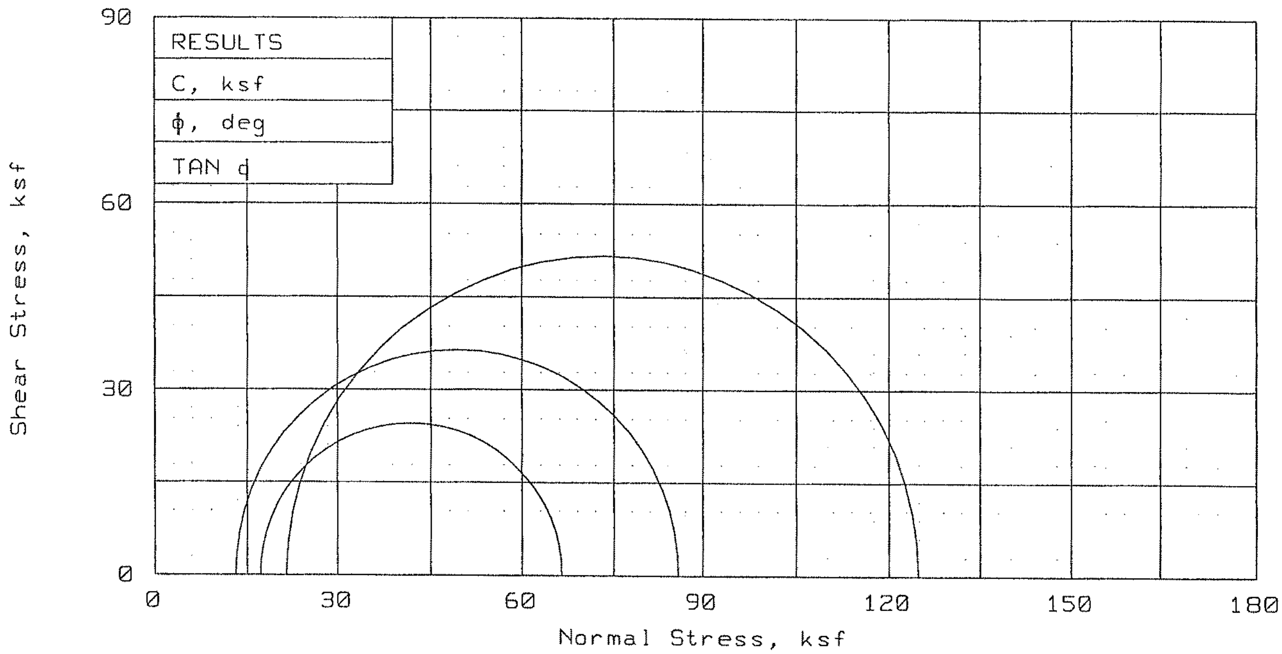
PROJECT: SLAC Tunnel Expansion 2003-060-T

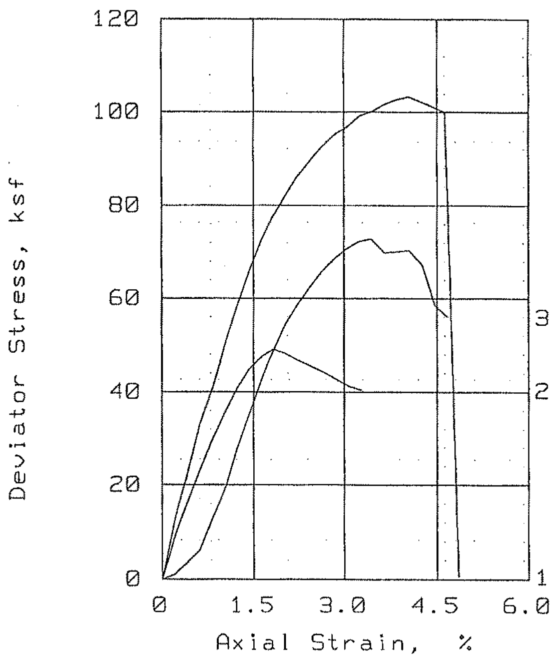
SAMPLE LOCATION: 1) SBB-11 @ 63.8'

PROJ. NO.: 335-067g DATE: 6/24/03

TRIAXIAL SHEAR TEST REPORT

COOPER TESTING LABORATORY





SAMPLE NO.:		1	2	3
INITIAL	WATER CONTENT, %	12.8	12.1	13.2
	DRY DENSITY, pcf	121.3	120.9	120.1
	SATURATION, %	81.5	82.9	88.2
	VOID RATIO	0.441	0.394	0.403
	DIAMETER, in	2.42	2.42	2.40
	HEIGHT, in	5.00	5.00	5.00
AT TEST	WATER CONTENT, %	12.8	11.9	12.6
	DRY DENSITY, pcf	122.6	121.5	121.4
	SATURATION, %	84.5	82.7	87.8
	VOID RATIO	0.425	0.387	0.388
	DIAMETER, in	2.41	2.43	2.39
	HEIGHT, in	4.95	4.95	4.97
Strain rate, %/min		0.50	0.50	0.50
BACK PRESSURE, ksf		0	0	0
CELL PRESSURE, ksf		22	17	13
FAIL. STRESS, ksf		103	49	73
ULT. STRESS, ksf				
σ_1 FAILURE, ksf		125	66	86
σ_3 FAILURE, ksf		22	17	13

TYPE OF TEST:
Consolidated Undrained

SAMPLE TYPE: Core; Undisturbed?

DESCRIPTION: Brown weathered SANDSTONE

SPECIFIC GRAVITY= 2.8

REMARKS: Sample sheared @ field moist. Spec.#1-broke top cap & porous stone. Strength picked @ peak deviator stress

Fig. No.: ______

CLIENT: Rutherford & Chekene

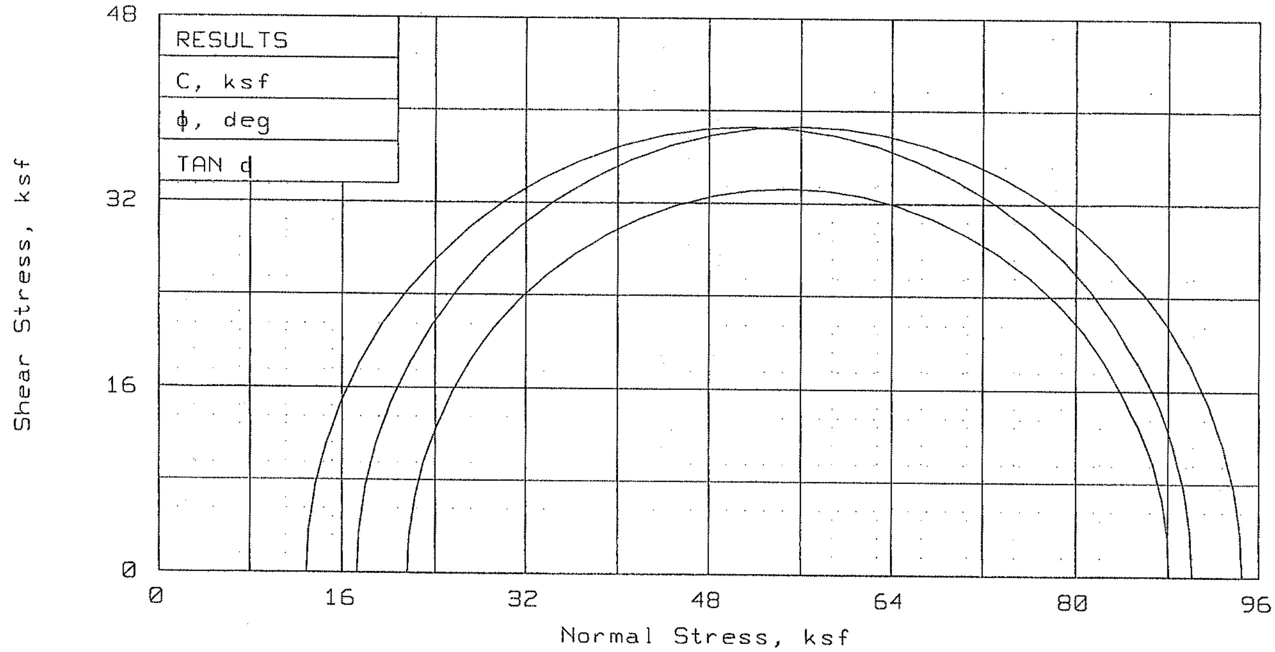
PROJECT: SLAC Tunnel Expansion 2003-060-T

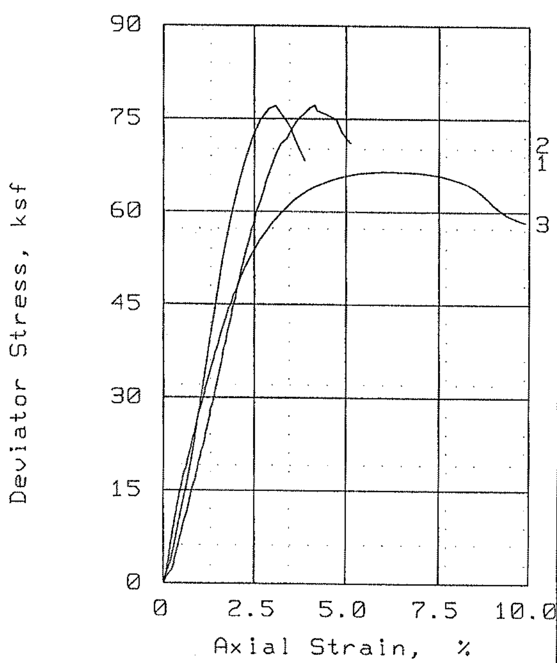
SAMPLE LOCATION: 1) SBD-34 @ 69'
2) SBD-33 @ 68.1' 3) SBD-32 @ 67.6'

PROJ. NO.: 335-067K DATE: 6/24/03

TRIAXIAL SHEAR TEST REPORT

COOPER TESTING LABORATORY





SAMPLE NO.:		1	2	3
INITIAL	WATER CONTENT, %	13.3	13.9	15.5
	DRY DENSITY, pcf	121.3	117.3	113.6
	SATURATION, %	92.2	86.0	86.7
	VOID RATIO	0.389	0.437	0.483
	DIAMETER, in	2.42	2.42	2.37
	HEIGHT, in	5.00	5.00	5.00
AT TEST	WATER CONTENT, %	13.1	13.5	15.0
	DRY DENSITY, pcf	121.9	118.2	114.6
	SATURATION, %	92.0	85.6	86.3
	VOID RATIO	0.383	0.427	0.470
	DIAMETER, in	2.43	2.43	2.37
	HEIGHT, in	4.94	4.93	4.95
Strain rate, %/min		0.50	0.50	0.50
BACK PRESSURE, ksf		0.0	0.0	0.0
CELL PRESSURE, ksf		13.0	17.3	21.6
FAIL. STRESS, ksf		77.1	77.2	66.5
ULT. STRESS, ksf				
σ_1 FAILURE, ksf		90.1	94.5	88.1
σ_3 FAILURE, ksf		13.0	17.3	21.6

TYPE OF TEST:
Consolidated Undrained

SAMPLE TYPE: Core; Undisturbed?

DESCRIPTION: Brown weathered SANDSTONE

SPECIFIC GRAVITY= 2.7

REMARKS: Sample sheared at field moisture.
Strengths picked at peak deviator stress.

Fig. No.: ______

CLIENT: Rutherford & Chekene

PROJECT: SLAC Tunnel Expansion 2003-060-T

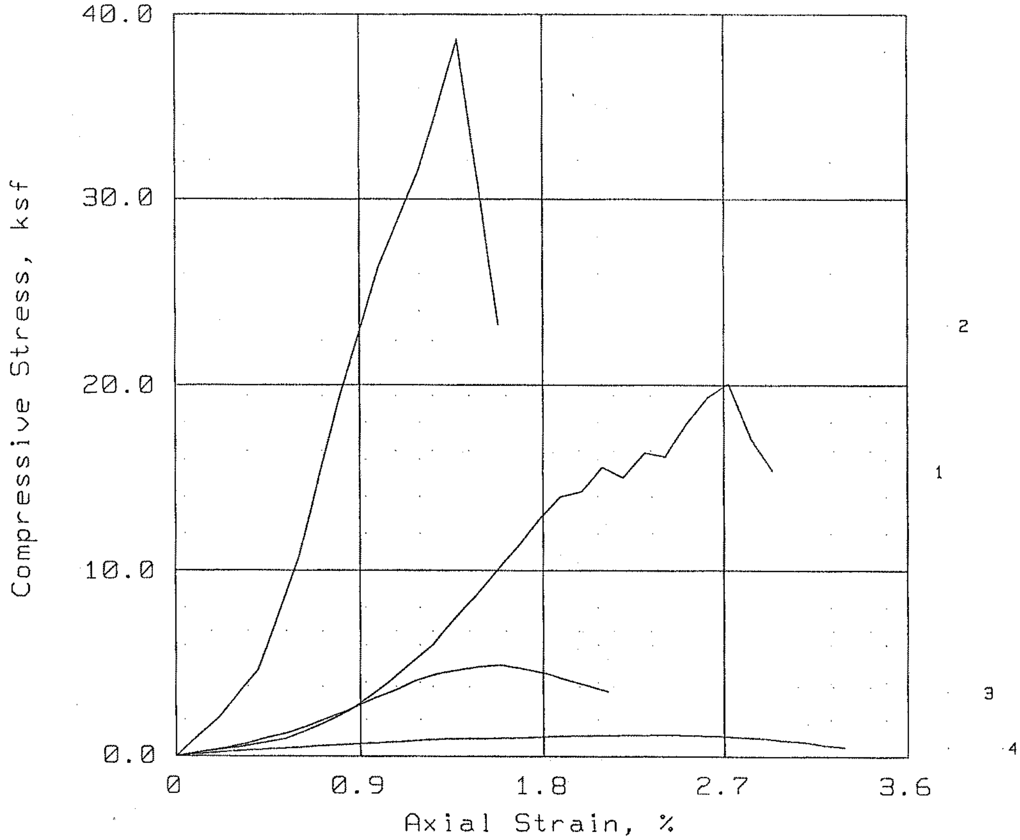
SAMPLE LOCATION: 1) SBE-37 @ 88.9'
2) SBE-37 @ 88.9' 3) SBE-39 @ 93.4'

PROJ. NO.: 335-067m DATE: 6/24/03

TRIAXIAL SHEAR TEST REPORT

COOPER TESTING LABORATORY

UNCONFINED COMPRESSION TEST



SAMPLE NO.:	1	2	3	4
Unconfined strength, ksf	20.1	38.6	4.9	1.2
Undrained shear strength, ksf	10.0	19.3	2.5	0.6
Failure strain, %	2.7	1.4	1.6	2.4
Strain rate, %/min	1.00	1.00	1.00	1.00
Water content, %	13.8	15.4	15.9	15.3
Wet density, pcf	135.7	135.1	125.4	118.3
Dry density, pcf	119.2	117.0	108.2	102.6
Saturation, %	90.3	94.4	76.8	64.3
Void ratio	0.4140	0.4401	0.5582	0.6424
Specimen diameter, in	2.43	2.41	2.35	2.47
Specimen height, in	5.00	5.23	5.00	5.03
Height/diameter ratio	2.06	2.17	2.13	2.04

Description: Brown weathered SANDSTONE

GS= 2.7 | Type: Core

Project No.: 335-067

Date: 6/24/03

Remarks:

Fig. No.: ____

Client: Rutherford & Chekene

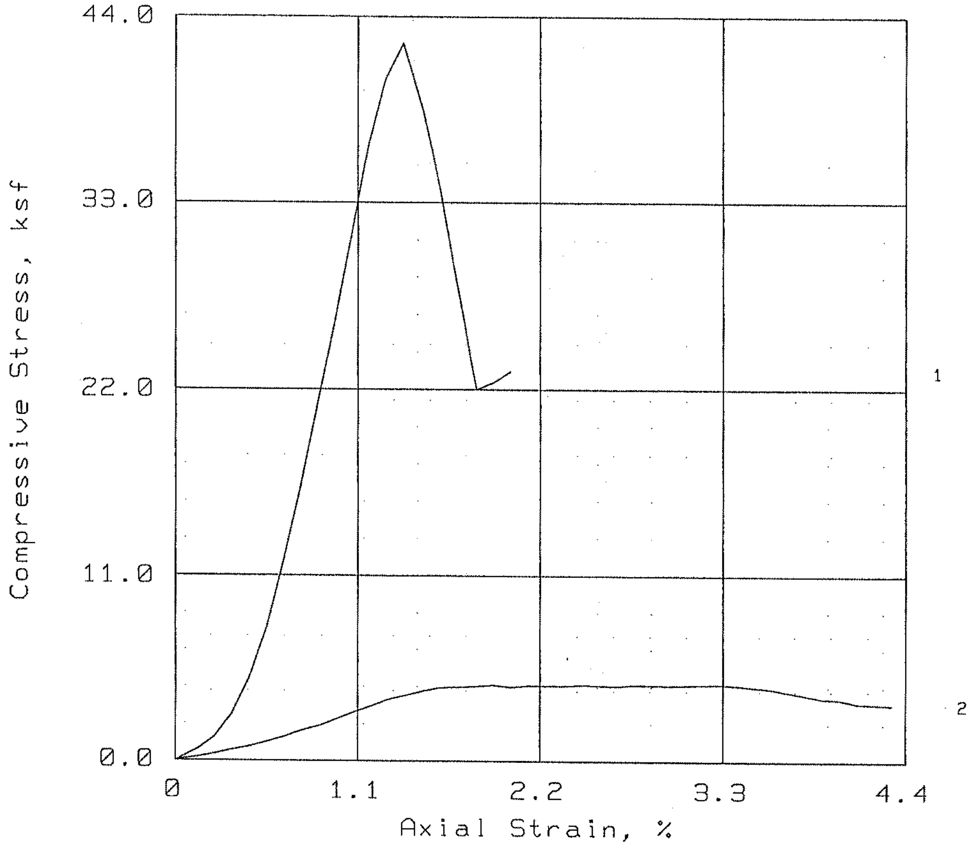
Project: SLAC Tunnel Expansion 2003-060-T

Location: 1)SBA3@65.2' 2)SBA5@70.2'
3)SBA-7 @ 72.8' 4)SBB-9 @ 53.5'

UNCONFINED COMPRESSION TEST

COOPER TESTING LABORATORY

UNCONFINED COMPRESSION TEST



SAMPLE NO.:	1	2		
Unconfined strength, ksf	42.4	4.6		
Undrained shear strength, ksf	21.2	2.3		
Failure strain, %	1.4	3.3		
Strain rate, %/min	1.00	1.00		
Water content, %	14.8	17.7		
Wet density, pcf	132.9	122.8		
Dry density, pcf	115.8	104.3		
Saturation, %	87.5	77.6		
Void ratio	0.4551	0.6163		
Specimen diameter, in	2.39	2.41		
Specimen height, in	5.00	5.05		
Height/diameter ratio	2.09	2.10		

Description: Brown weathered SANDSTONE

GS= 2.7 Type: Core; Undisturbed?

Project No.: 335-067a
Date: 6/24/03
Remarks:

Fig. No.: ____

Client: Rutherford & Chekene

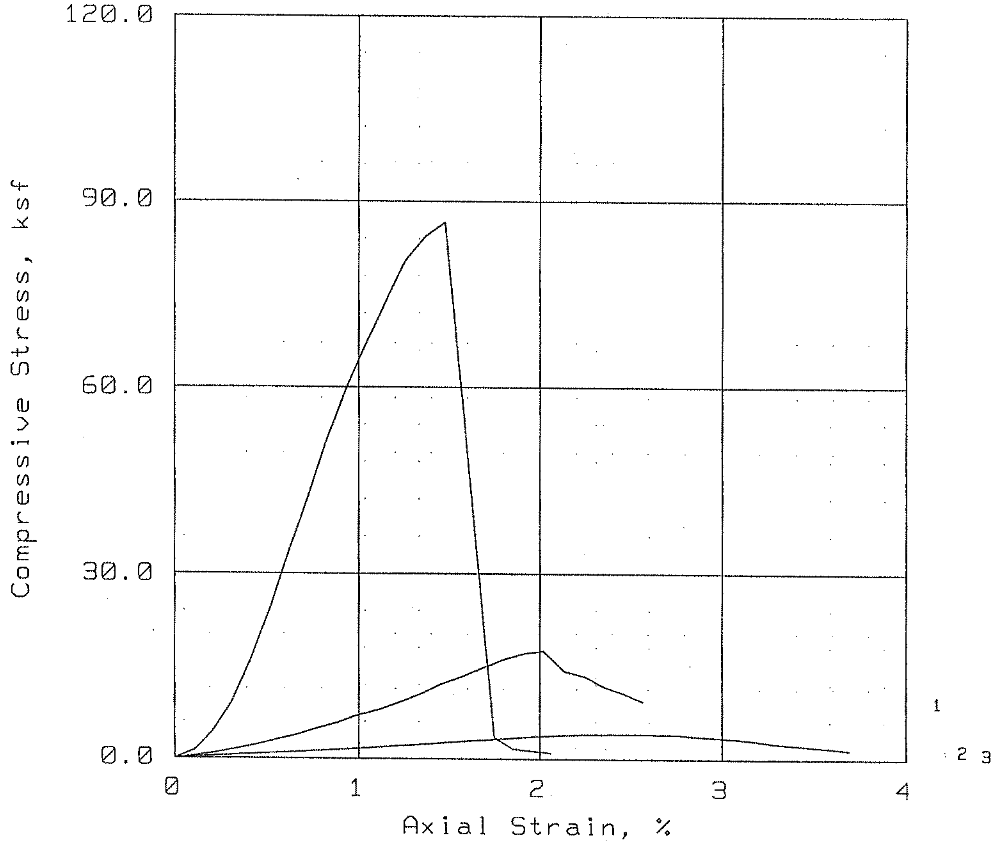
Project: SLAC Tunnel Expansion 2003-060-T

Location: 1)SBB-10 @ 61.6'
2)SBC-21 @ 16.2'

UNCONFINED COMPRESSION TEST

COOPER TESTING LABORATORY

UNCONFINED COMPRESSION TEST



SAMPLE NO.:	1	2	3	
Unconfined strength, ksf	17.5	4.1	86.6	
Undrained shear strength, ksf	8.7	2.0	43.3	
Failure strain, %	2.0	2.6	1.5	
Strain rate, %/min	1.00	1.00	1.00	
Water content, %	16.4	15.2	12.1	
Wet density, pcf	122.9	125.5	132.1	
Dry density, pcf	105.5	108.9	117.8	
Saturation, %	74.3	75.1	75.8	
Void ratio	0.5973	0.5471	0.4304	
Specimen diameter, in	2.39	2.41	2.40	
Specimen height, in	4.72	5.00	5.01	
Height/diameter ratio	1.97	2.07	2.09	

Description: Brown weathered SANDSTONE

GS= 2.7 | Type: Core; Undisturbed?

Project No.: 335-067B

Date: 6/24/03

Remarks:

Fig. No.: ———

Client: Rutherford & Chekene

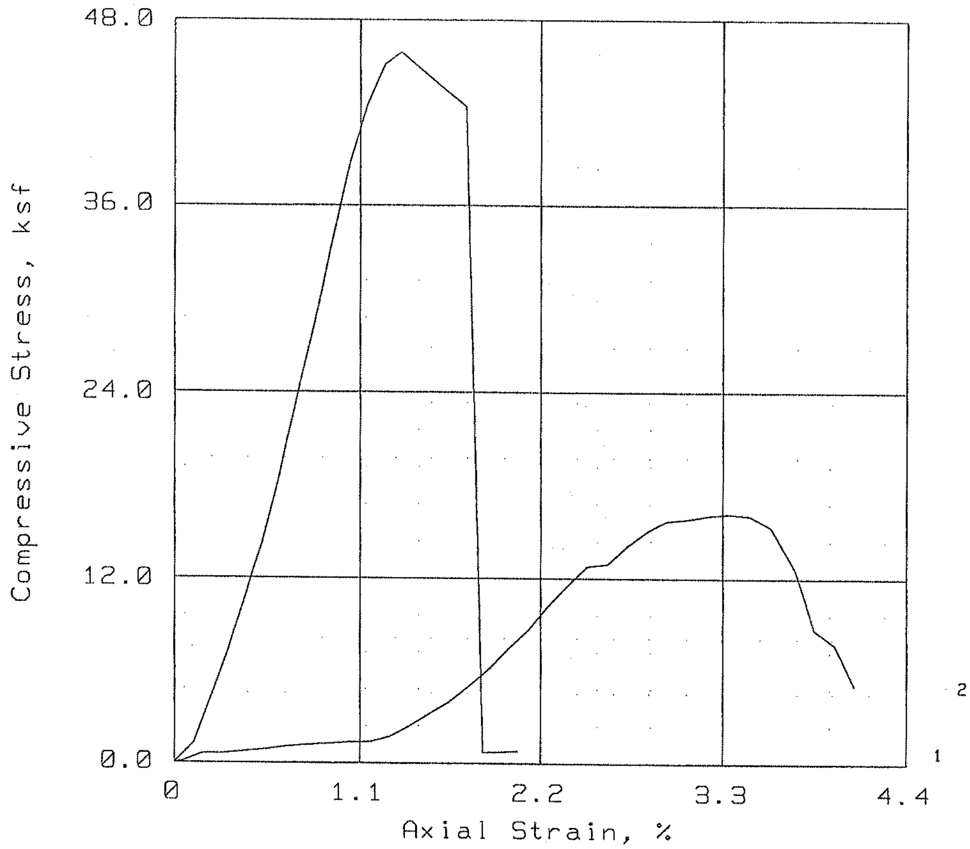
Project: SLAC Tunnel Expansion 2003-060-T

Location: 1)SBC-23 @ 21.8'
2)SBC-28 @ 28.0' 3)SBD-29 @ 50.9'

UNCONFINED COMPRESSION TEST

COOPER TESTING LABORATORY

UNCONFINED COMPRESSION TEST



SAMPLE NO.:	1	2		
Unconfined strength, ksf	45.9	16.2		
Undrained shear strength, ksf	23.0	8.1		
Failure strain, %	1.4	3.3		
Strain rate, %/min	1.00	1.00		
Water content, %	11.9	12.4		
Wet density, pcf	136.5	123.3		
Dry density, pcf	121.9	109.7		
Saturation, %	84.2	62.5		
Void ratio	0.3824	0.5364		
Specimen diameter, in	2.41	2.40		
Specimen height, in	5.01	4.30		
Height/diameter ratio	2.08	1.79		

Description: Brown weathered SANDSTONE

GS= 2.7 | Type: Core; Undisturbed?

Project No.: 335-067C

Date: 6/24/03

Remarks:

Fig. No.: ____

Client: Rutherford & Chekene

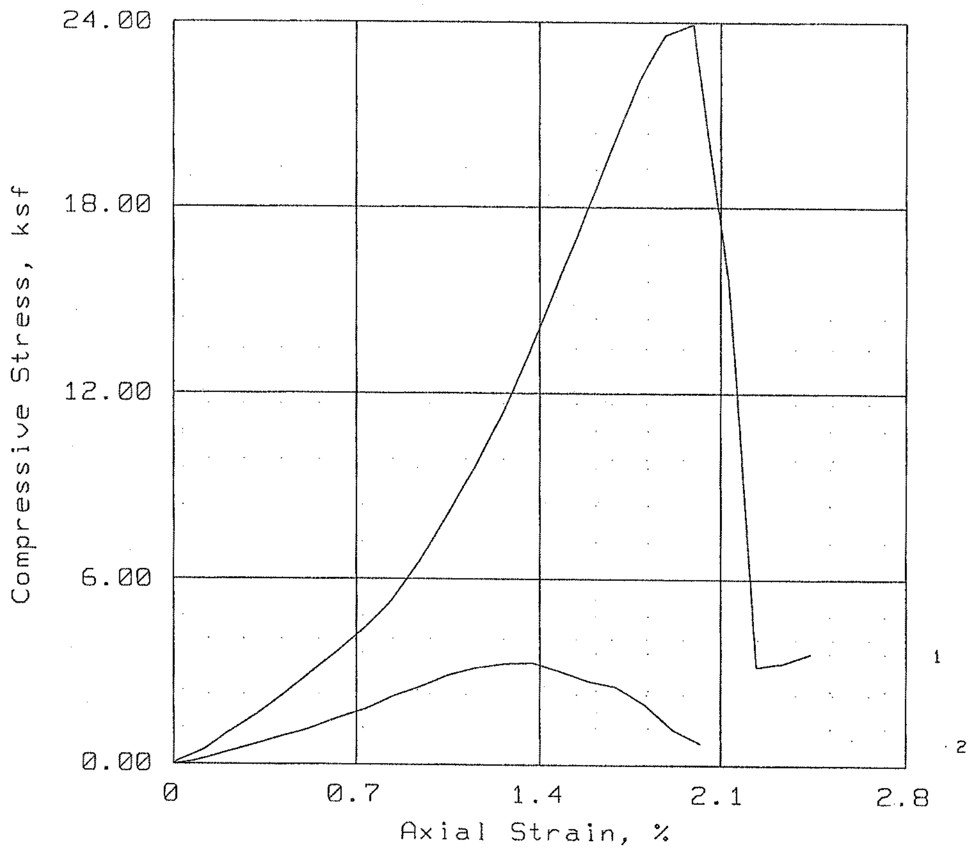
Project: SLAC Tunnel Expansion 2003-060-T

Location: 1) SBD-34 @ 69'
2) SBE-35 @ 80.7'

UNCONFINED COMPRESSION TEST

COOPER TESTING LABORATORY

UNCONFINED COMPRESSION TEST



SAMPLE NO.:	1	2		
Unconfined strength, ksf	23.93	3.28		
Undrained shear strength, ksf	11.96	1.64		
Failure strain, %	2.0	1.4		
Strain rate, %/min	1.00	1.00		
Water content, %	13.1	14.0		
Wet density, pcf	130.9	124.1		
Dry density, pcf	115.7	108.8		
Saturation, %	77.7	68.9		
Void ratio	0.4567	0.5491		
Specimen diameter, in	2.40	2.30		
Specimen height, in	5.02	4.81		
Height/diameter ratio	2.09	2.09		

Description: Brown weathered SANDSTONE

GS= 2.7 Type: Core; Undisturbed?

Project No.: 335-067D
Date: 6/24/03
Remarks:

Fig. No.: ____

Client: Rutherford & Chekene

Project: SLAC Tunnel Expansion 2003-060-T

Location: 1) SBE-36 @ 87.9'
2) SBE-39 @ 93.4'

UNCONFINED COMPRESSION TEST

COOPER TESTING LABORATORY

Slake Durability
ASTM D 4644-87

COOPER TESTING LABORATORY

CTL Job No: 335-067a **Project No.:** 2003-060-T
Client: Rutherford & Chekene **Date:** 6/24/2003
Project Name: SLAC Tunnel Expansion **By:** PJ

Boring:	SB-A	SB-A	SB-B	SB-B	SB-C	SB-D
Sample:	3	8	10	11	24	30
Depth, ft:	65.2	73.4	61.6	63.8	22.9	61.6
Soil Description:	Brown weathered SANDSTONE	Brown SAND w/ Clay & Sandstone	Brown weathered SANDSTONE	Brown weathered SANDSTONE	Brown weathered SANDSTONE	Brown weathered SANDSTONE
NATURAL MOISTURE CONTENT OF SAMPLE:						
DrumNo.	2	1	1	1	2	2
Drum wt. (g)	1724.1	1747.3	1747.3	1747.3	1724.1	1724.1
Total wet wt. (g)	2251.2	2221.5	2289.2	2087.5	2223.3	2273.3
Total dry wt (g)	2187.7	2152	2219.2	2038.6	2144	2211.8
Natural % H2O	**13.7**	**23.2**	**6.5**	**67.6**	**25.5**	**8.1**
Cycle # 1						
Beginning H2O Temp (°C)	19.6	23.5	19.6	21.6	23.5	21.6
Ending H2O Temp (°C)	19.7	23.2	19.7	21.2	23.2	21.2
Avgerage H2O Temp (°C)	19.7	23.4	19.7	21.4	23.4	21.4
Drum & Dry Rock (g)	1799.4	1746.9	1757.7	1752.3	1824.8	1724.9
Cycle # 2						
Beginning H2O Temp (°C)	23.8	21.5	23.8	22.4	21.5	22.4
Ending H2O Temp (°C)	23.5	21.2	23.5	22.0	21.2	22.0
Avgerage H2O Temp (°C)	23.7	21.4	23.7	22.2	21.4	22.2
Drum & Dry Rock (g)	1731.1	1747.4	1749.3	1748.4	1791.2	1724.6
SLAKE DURABILITY INDEX (second cycle)	**1.5**	**5.4**	**5.1**	**7.7**	**16.0**	**0.1**
Standard Verbal Description and comments (Type I - Retained pieces remain virtually unchanged) (Type II - Retained material consists of large & small pieces. (Type III - Retained material is exclusively small fragments)	**Type III Largest fragment is 14.3 g**	**Type III 2 sand grains remaining**	**Type III**	**Type III**	**Type III Largest fragment is 5.1 g.**	**Type III**

Slake Durability
ASTM D 4644-87

COOPER TESTING LABORATORY

CTL Job No: 335-067b **Project No.:** 4059
Client: Rutherford & Chekene **Date:** 6/23/2003
Project Name: SLAC Tunnel Expansion **By:** PJ

Boring:	SB-E					
Sample:	38					
Depth, ft:	89.7-90.4					
Soil Description:	Brown weathered rock (Sandstone)					
NATURAL MOISTURE CONTENT OF SAMPLE:						
DrumNo.	1					
Drum wt. (g)	1747.3					
Total wet wt. (g)	2114.7					
Total dry wt (g)	2074.2					
Natural % H2O	**12.4**					
Cycle # 1						
Beginning H2O Temp (°C)	21.2					
Ending H2O Temp (°C)	21.0					
Avgerage H2O Temp (°C)	21.1					
Drum & Dry Rock (g)	1747.5					
Cycle # 2						
Beginning H2O Temp (°C)	20.5					
Ending H2O Temp (°C)	20.2					
Avgerage H2O Temp (°C)	20.4					
Drum & Dry Rock (g)	1747.5					
SLAKE DURABILITY INDEX (second cycle)	**0.1**					
Standard Verbal Description and comments (Type I - Retained pieces remain virtually unchanged) (Type II - Retained material consists of large & small pieces. (Type III - Retained material is exclusively small fragments)	**Type III**					

John Wakabayashi
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Hayward, CA 94544
Phone: (510) 887-1796
FAX: (510) 887-2389
email: wako@tdl.com
website: http://www.tdl.com/~wako/
3 July, 2003

Dr. Gyimah Kasali
Rutherford & Chekene
Consulting Engineers
427 Thirteenth Street
Oakland, CA 94612

Gyimah:

The following is a write up of the petrographic analysis of the rock core samples from SLAC. If you have any questions, feel free to call or email me.

Sample Preparation Notes

One thin section was prepared from each of the eight core samples. All of the rock samples were weak, crumbly, and porous, and needed considerable impregnation with epoxy before the rock could be slabbed, polished, and mounted on a glass slide. The diamond saw cut through these rocks more easily than any samples I can recall cutting (this is generally a measure of the hardness, strength, and abrasion resistance of the material). The samples fell apart and flaked when in contact with water, indicating that the presence of swelling clays in the cement of these sandstones. However, the overall abundance of swelling clays in the samples is likely not very high because the samples could be easily polished with abrasives in water. Samples with high swelling clay content cannot be polished using water, because the swelling clays will continually absorb water, roughening the polished surface.

Summary of Microscopic Observations: Observations applicable to all samples.

All eight samples are weakly cemented sandstones. These sandstones are have a high proportion of lithic grains (sand grains composed of other rocks in contrast to sand grains composed of a single mineral), and the cement for the sandstones are clay minerals. Calcite occurs, but not as a significant cement. Quartz contents of the sandstones range from about 25 to 35%. An unusual feature of the sandstones is that all of them contain significant amounts of serpentinite grains, ranging from about 5 to 20%. The serpentinite is composed mainly of lizardite but also includes chrysotile, an asbestos mineral. Chrysotile was observed in all of the samples. The asbestos contents in each of the 8 samples may exceed 0.25%, a cut off concentration for various regulations. It is recommended that samples of this rock unit be analyzed by a laboratory certified in asbestos analysis using California Air Resources Board (CARB) Test Method 435 for quantification of the asbestos concentration in these rocks.

Microscopic description of Individual samples

SBC @ 87.9

This sandstone consists of subangular to subrounded grains 0.1-0.5 mm in size, with most grains between 0.2 and 0.3 mm. Of the various sand grains, 25-30% are quartz, 40-45% are feldspar (mostly plagioclase with some potassium feldspar), and 25 to 35% are lithic grains. The lithic grains are mostly sedimentary rocks (siltstones and mudstones), with some chert, metachert, volcanic rocks, and a significant amount of serpentinite (about 5%-10% of the rock volume). Calcite occurs mostly as isolated grains and clots, rather than cement, but is present in significant amounts (a few percent). Cement of this sandstone is composed of clay minerals. The total quartz content of this rock (including quartz grains, and the quartz that is part of various quartz-bearing lithic grains) is about 30-35%.

SBA @ 63.9

This sandstone is broadly similar to SBC @ 87.9 except it is higher in lithic grains (40-50%) and correspondingly lower in quartz and feldspar. Total quartz content is about 25%. Serpentinite is very common in this sandstone and serpentinite grains are the most abundant of the lithic grains, comprising 15-20% of the rock. Carbonate occurs both as discrete clots and grains as in SBC @ 87.9, and also as numerous fine crystals (generally less than 0.01 mm in size) growing both in lithic fragments and near grain boundaries. These crystals do not link to form a cement, however.

SBD @ 68.1

This sandstone resembles SBC 87.9 and is similar in all respects, except for a somewhat lower serpentinite clast content (about 5% or slightly less).

SBB @ 61.6

This sandstone is nearly identical to SBA 63.9 and has similar proportions for all constituents.

SBC @ 26.

This sandstone is a high lithic sandstone, similar to SBA 63.9, but with somewhat lower serpentinite grain concentrations (about 10 to 15%). Sedimentary lithic grains are more abundant than serpentinite in this rock. Calcite is common both as clots, grains, disseminated fine crystals, and as common fossil fragments.

SBC @ 65.2

This is a lithic rich sandstone similar to SBA @ 63.9, with similar proportions of all constituents.

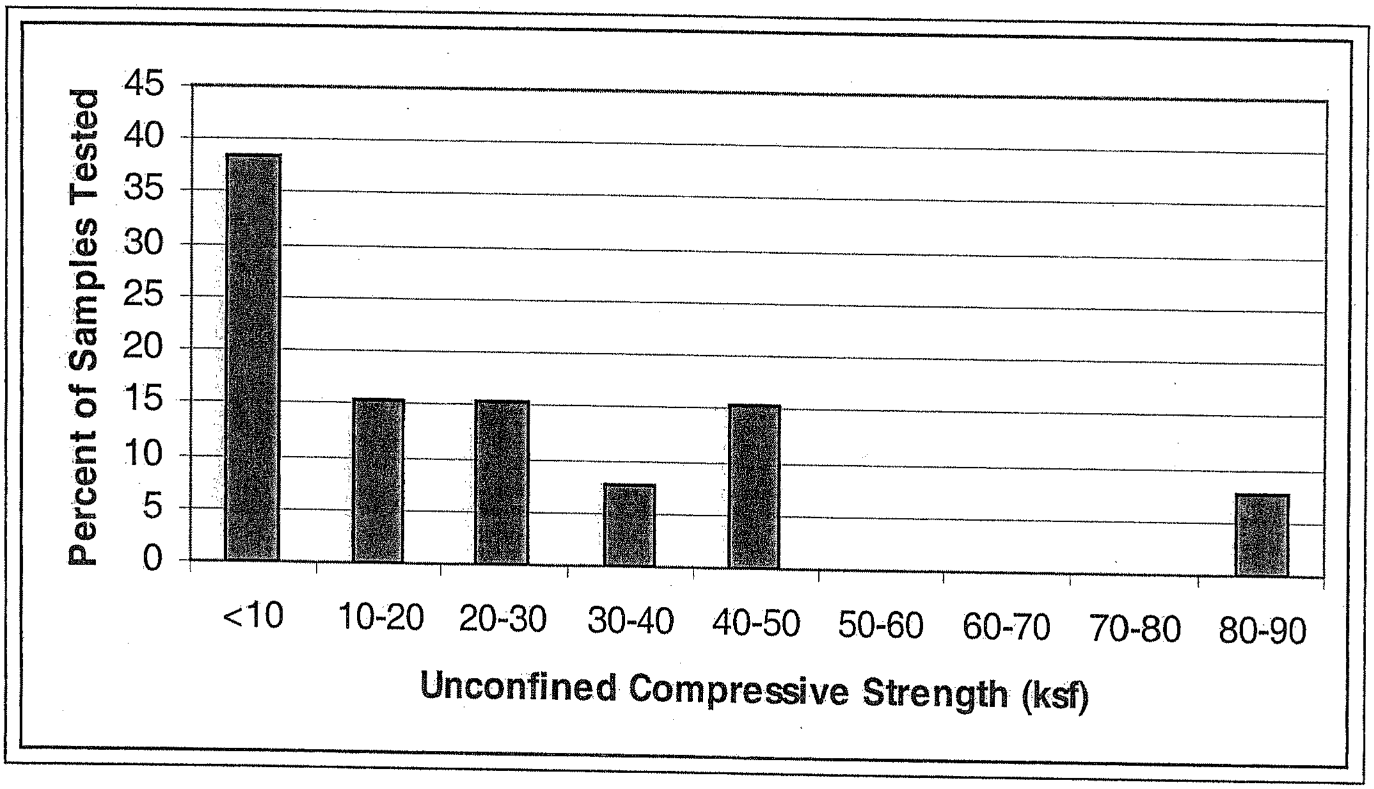
SBB @71.5

This is a lithic rich sandstone similar to SBA @ 63.9 except that serpentinite is less abundant (~15%), so that sedimentary lithic grains are more abundant than serpentinite. Some large volcanic lithic grains (one of which is 1 mm long) also occur. There is not as much of the fine, disseminated calcite crystals in this sample as in SBA @ 63.9.

SBB @ 21.8

This sandstone resembles SBC @ 87.9 and has about 5% serpentinite clasts.

Figure 13. Summary of Unconfined Compressive Strength



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Summary of Unconfined Compressive Strength
Proposed LCLS Tunnel Project
Stanford Linear Accelerator Center
Menlo Park, California

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Figure 14. Summary of Total Unit Weights

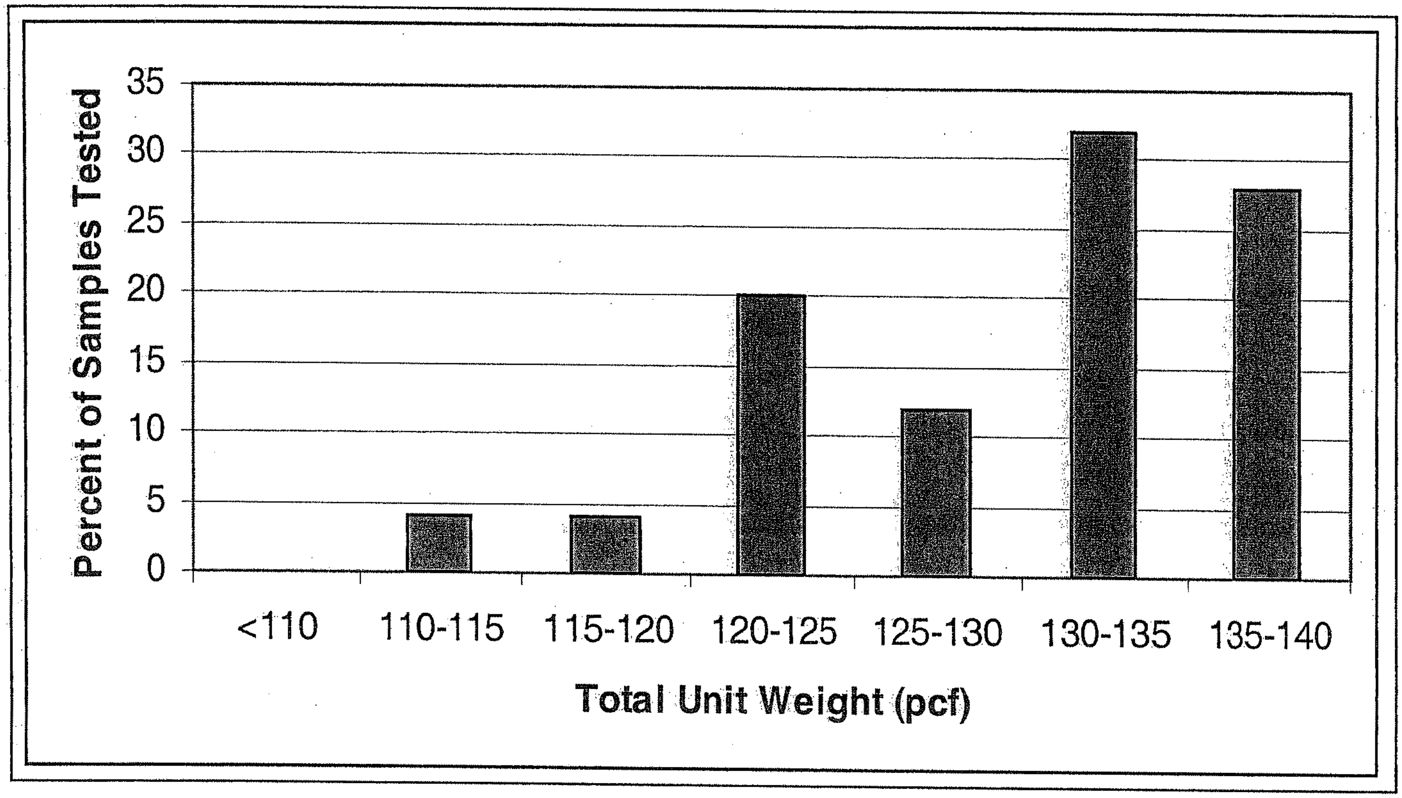

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Figure 15. Summary of Moisture Contents

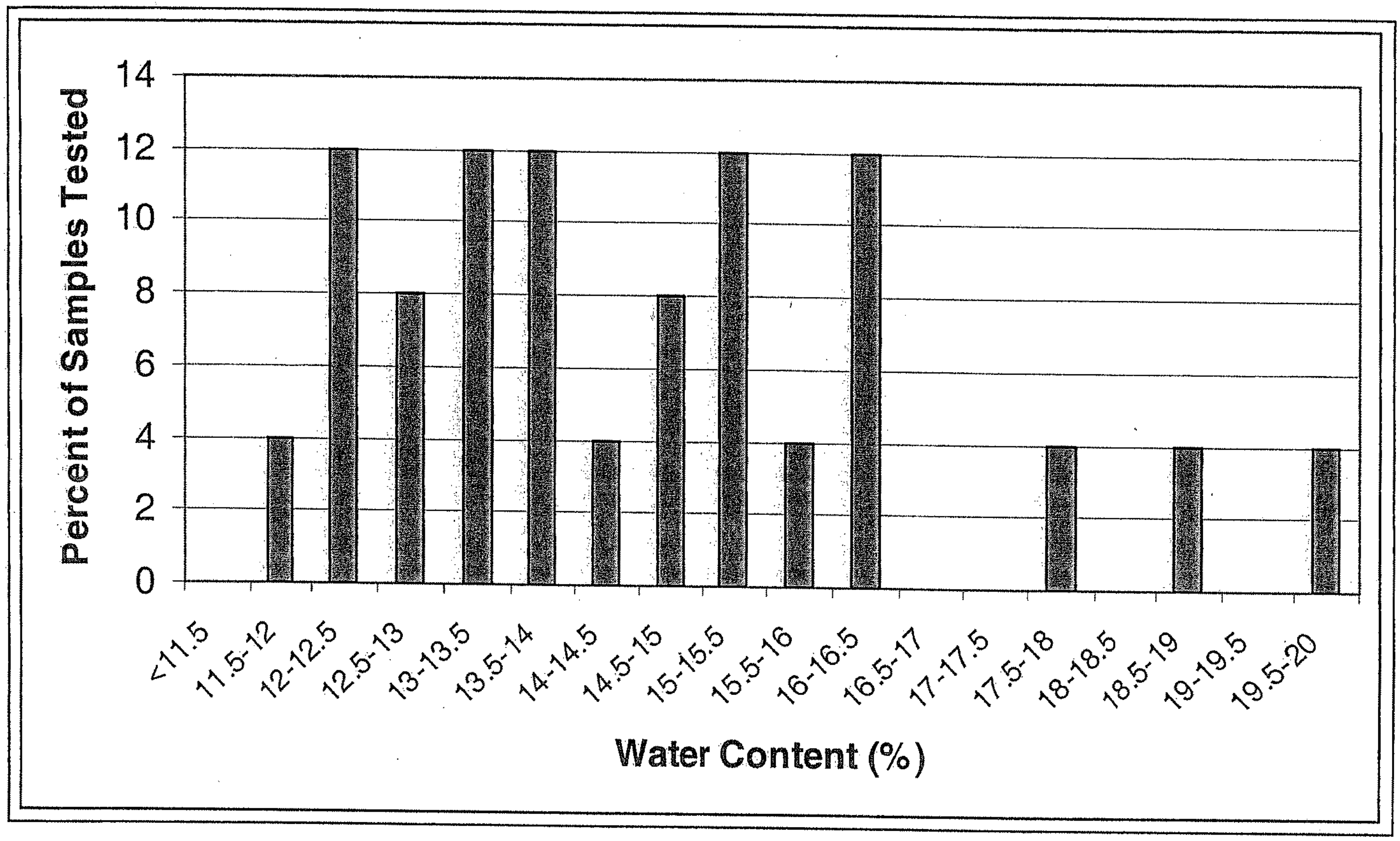

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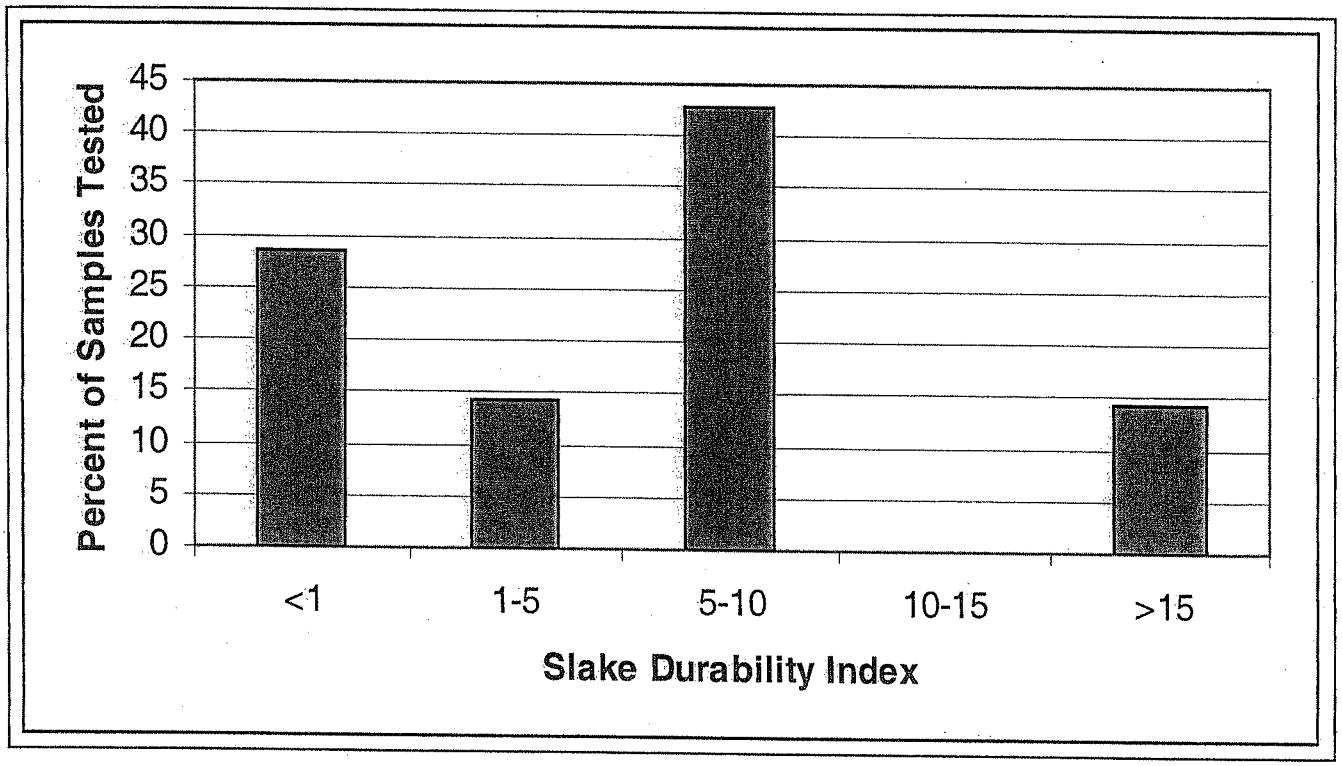
Figure 16. Summary of Slake Durability Index



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