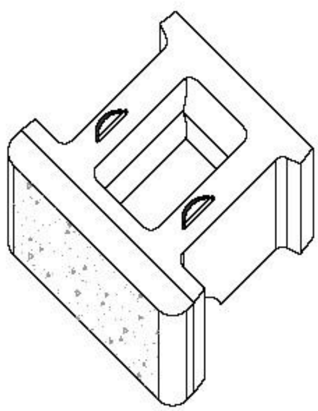
Interaction Testing Report

6 SF Units with Synteen Geogrids

Stone Strong Systems
Lincoln, Nebraska



Prepared for:
Stone Strong Systems
1620 South 70th Street, Suite 105
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May 27, 2005
TG Project No. 02546.2

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INTRODUCTION

Thiele Geotech, Inc., in association with Tadros Associates, LLC, has completed an interaction testing program to evaluate the interface shear capacity and the connection strength between Stone Strong Systems 6 SF precast concrete segmental retaining wall blocks and Synteen SF55 and SF110 geogrids used in the construction of segmental retaining walls. The results of the testing program were used to define relationships for surcharge load representing stacked Stone Strong units with facing/geogrid connection strength and with interface shear strength both with and without geogrid inclusions.

Due to the large size of the Stone Strong blocks, a custom testing frame was designed by Tadros Associates, LLC. This large test frame accommodates full scale tests under conditions that reproduced field shear and connection conditions. Testing was performed by personnel from Tadros Associates and Thiele Geotech.

MATERIALS

Stone Strong Systems 6 SF blocks are precast concrete blocks used for construction of segmental retaining walls. These units are typically used as accessories with the 24 SF blocks to make elevation transitions, but they are sometimes used as a stand-alone product to construct tight radius curves or for other special applications.

The 6 SF unit has nominal face dimensions of 48 inches long and 18 inches tall for a total face area of 6 square feet. The unit has a depth (measured horizontally from the face to the tail) of approximately 44 inches. The units have dual center webs, and the face and tail flanges extend beyond the webs. The rear flange is tapered to allow the blocks to be laid on a curve. Each unit weighs approximately 1,450 to 1,550 pounds empty, depending on the aggregate used to manufacture the block. When installed in a retaining wall, the block voids are filled with aggregate. The infilled weight is approximately 2,550 to 2,850 pounds, depending on the unit weights of the concrete and aggregate fill.

Synteen SF55 and SF110 geogrids are uni-directional grids composed of high strength polyester yarns coated with a PVC material. The SF55 and SF110 Geogrids have average ultimate tensile strengths of 3,774 pounds per foot and 10,212 pounds per foot, respectively, based on published test data.

TEST PROCEDURES

TEST FRAME

The apparatus used to conduct the tests consisted of a steel frame anchored to a rigid concrete mat foundation. The frame is capable of applying 150,000 pounds of surcharge load and 100,000 pounds of shear/pullout force simultaneously. Rollers were mounted between the test frame and the loading beam to allow for block movement during shear testing. Photographs and schematics of the test frame are included in the Appendix of this report.

Surcharge and shear/pullout loads were placed on the blocks using two (2) Enerpac PEJ-1301 submerged hydraulic pumps capable of delivering 20 in^3 per minute at 10,000 psi each. Loads were measured by the use of Omega PX303 pressure transducers with 0 to 10,000 psig range and an accuracy of 0.25 percent FS. Mounted on each pump is a manifold to distribute hydraulic fluid to the two (2) 25 ton, 6 inch stroke (Enerpac RC256) surcharge actuators and the two (2) 25 ton, 6 inch stroke (Enerpac RC256) shear/pullout actuators and to the pressure transducers. The flow of fluid to the shear/pullout actuators is adjustable by an Enerpac V-8F needle valve.

Displacements were measured by the use of two (2) 3 inch stroke and one (1) 6 inch stroke linear potentiometers with 0.15 percent maximum linearity (0.07 percent typical) and less than 0.01 mm hysteresis.

Loads and displacements were continuously measured and recorded during the test by a Data Translation DT9802 date acquisition module connected to a laptop computer via USB interface. Sensor excitation was provided by an Omega 5v regulated power supply. Loads and displacements were recorded a minimum of once per second using DT Measure Foundry software.

INTERFACE SHEAR TESTS

The NCMA SRWU-2 and ASTM D6638 methods of test were used to determine the shear strength between Stone Strong Systems 6 SF concrete block units. The tests were carried out with and without a layer of geosynthetic reinforcement between layers of Stone Strong units. Six bottom blocks were installed and braced against the front of the load frame. Crushed limestone infill was placed in the voids between the bottom blocks. When a geogrid layer was included, the geosynthetic reinforcement was centered over the bottom blocks. Three Stone Strong units were stacked in a running bond and centered over the bottom blocks. Crushed limestone infill was placed in the voids between the top blocks.

The top unit was loaded with a constant vertical surcharge load applied to the concrete webs, simulating an equivalent height of stacked blocks. The shear force was applied at a constant rate of displacement until large shear displacements were achieved. The load and displacements were continuously measured and recorded during the test by a microcomputer/data acquisition system. The tests were continued until failure of the interface components occurred, causing a sustained loss of shearing resistance, or to a displacement of 1½ inches.

CONNECTION STRENGTH PULLOUT TESTS

The NCMA SRWU-1 and ASTM D6638 methods of test were used to determine the connection strength between geosynthetic reinforcement and Stone Strong Systems 6 SF concrete block units. The tests were carried out with a layer of geosynthetic reinforcement between layers of Stone Strong units. Four bottom blocks were installed and braced against the back of the load frame. Crushed limestone infill was placed in the voids between the bottom blocks. The geosynthetic reinforcement was centered over the bottom blocks and attached to a clamping device. The top layer of Stone Strong units was placed over the geogrid and centered over the bottom block layer. Crushed limestone infill was placed in the voids between the top blocks, and the blocks were braced against the back of the frame.

The top units were loaded with a constant vertical surcharge load applied to the concrete webs, simulating an equivalent height of stacked blocks. A tensile force was placed on the geosynthetic reinforcement under constant rate of displacement until failure of the connection system occurred. The load and displacements were continuously measured and recorded during the test by a microcomputer/data acquisition system. Tests were continued until failure occurred as excessive deformation or slippage of the geogrid in the connection or failure of the blocks occurred, causing a sustained loss of tensile resistance recorded.

TEST RESULTS

INTERFACE SHEAR TESTS

Results of the interface shear tests are attached in tables and graphs recorded in the Appendix of this report. The peak interface shear capacity and shear capacity at the displacement criterion of ¾ inch were plotted versus the normal load. The peak interface shear strength between Stone Strong Systems 6 SF units and Synteen SF110 Geogrid for equivalent wall heights between 4.3 and 32.6 feet high ranged between 2,100 and 12,228 pounds per foot. Tests repeated using the same normal load had peak shear capacity values within 10 percent of the mean peak shear capacity of the identical tests; therefore, they are within the NCMA recommended limits for demonstrating test repeatability. The service state criterion is defined as the load at ¾ inch deflection.

Lines were best fit to the test data for the individual tests series. Interface shear properties were interpolated from the data, and are summarized in Table 1.

Table 1, Interface Shear Properties

Case	Ultimate			Service State Criterion		
	Minimum (lbs/ft)	**Friction Angle (degrees)**	**Maximum (lbs/ft)**	**Minimum (lbs/ft)**	**Friction Angle (degrees)**	**Maximum (lbs/ft)**
Block shear (no geogrid)	1,309	36.4	12,228	1,257	35.0	12,000
Shear w/ SF110 inclusion	1,271	20.2	7,038	1,036	17.0	6,198

The peak interface shear strength between Stone Strong Systems 6 SF units and Synteen SF55 Geogrid was not tested. During testing of the Stone Strong Systems 24 SF units, it was found that interface shear strengths were generally better with the Synteen SF55 Geogrid than with the Synteen SF110 Geogrid. Therefore, when using the 6 SF units with Synteen SF55 Geogrid, the interface shear test data for 6 SF units with Synteen SF110 Geogrid should be used for analysis.

CONNECTION STRENGTH PULLOUT TESTS

Results of the connection strength tests are summarized in tables and graphs recorded in the Appendix of this report. The peak connection capacity and connection capacity at the displacement criterion of ¾ inch were plotted versus the normal load. The recorded peak connection strengths between Stone Strong Systems 6 SF units and Synteen SF55 and SF110 Geogrid were 2,428 and 4,690 pounds per foot, respectively, for equivalent wall heights between 4.3 and 36.2 feet high. Tests repeated using the same normal load had peak shear capacity values within 10 percent of the mean peak shear capacity of the identical tests; therefore, they are within the NCMA recommended limits for demonstrating test repeatability.

Lines were best fit to the test data for the individual tests series. Interface shear properties were interpolated from the data, and are summarized in Table 2.

Table 2, Connection Strength Properties

Case	Ultimate			Service State Criterion		
	Minimum (lbs/ft)	**Friction Angle (degrees)**	**Maximum (lbs/ft)**	**Minimum (lbs/ft)**	**Friction Angle (degrees)**	**Maximum (lbs/ft)**
Connection Strength w/ SF55 Geogrid	1,743	9.5	2,210	993	9.4	1,390
Connection Strength w/ SF110 Geogrid	1,765	12.1	4,690	1,238	9.5	3,614

CONCLUSIONS

The design curves illustrated on the graphs in the appendix are based on interpretation of the test data, based on the NCMA Segmental Retaining Wall Design Manual. The design curves are controlled by the ¾ inch displacement criterion. The design values taken from the graphs should be used with caution, as shear and connection strengths may vary based on actual site conditions and construction quality.

Respectfully submitted,
Thiele Geotech, Inc.

Daniel J. Thiele, P.E.

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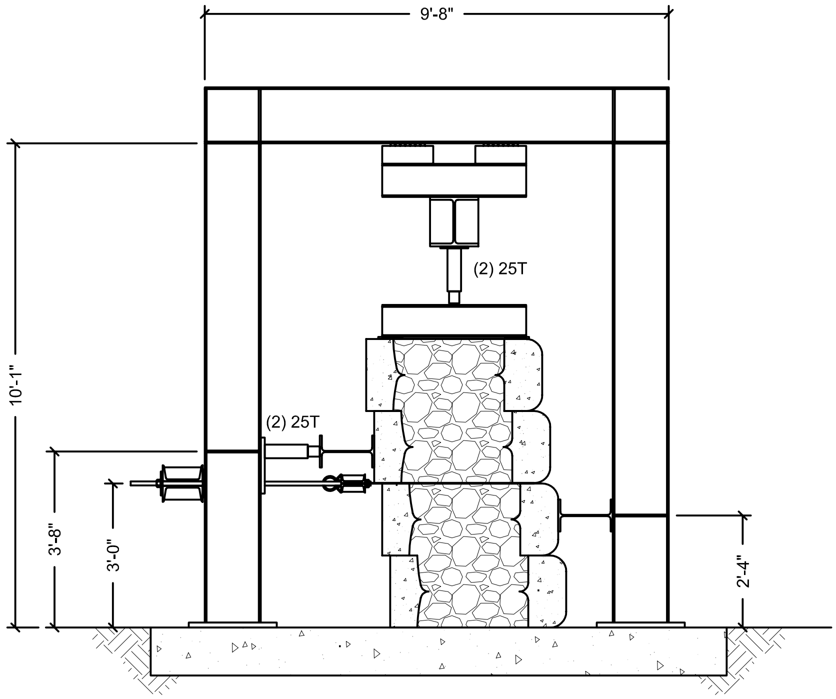
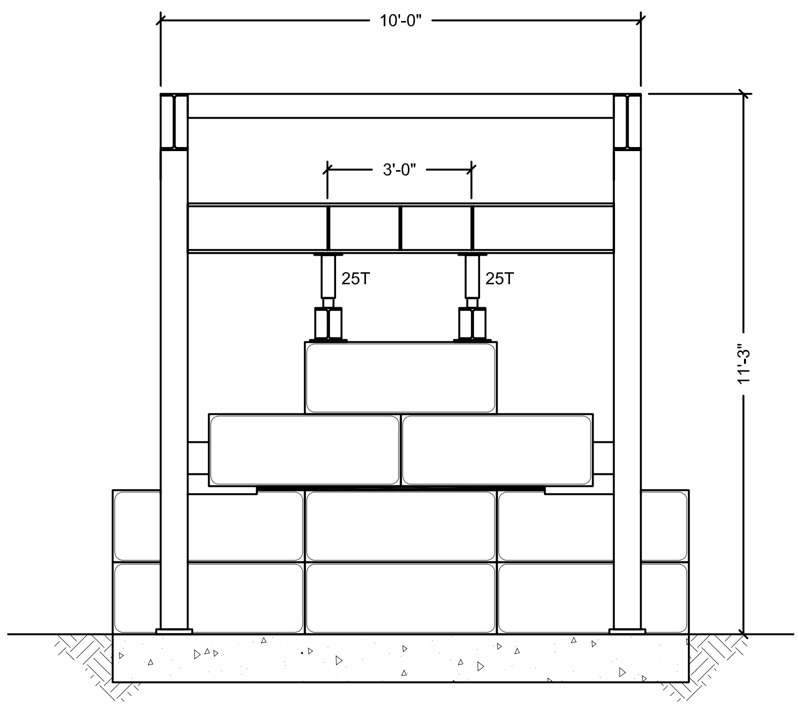
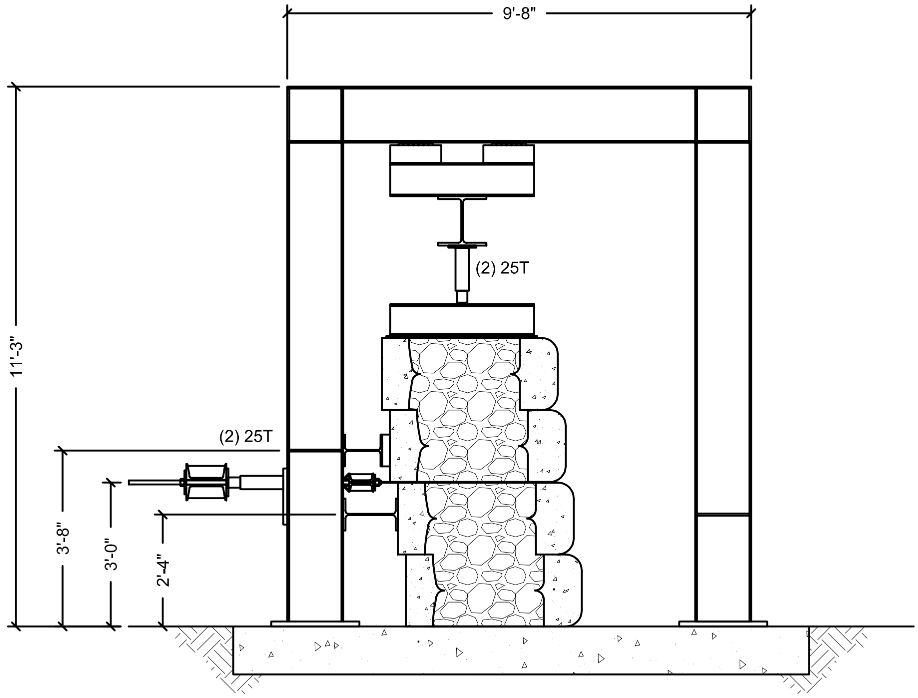
APPENDIX

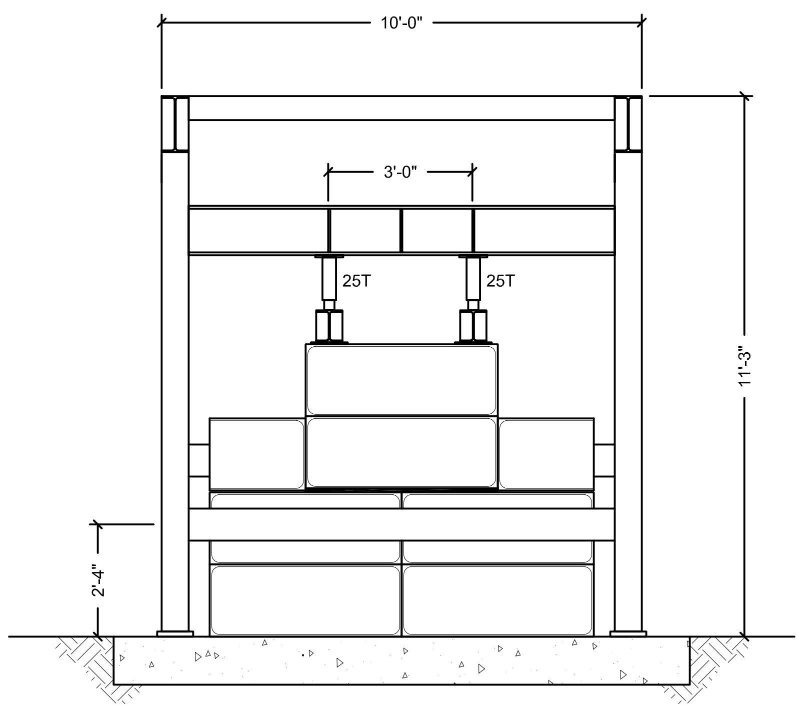




Tadros Associates, LLC
6910 Pacific Street, Suite 204, Omaha, NE 68106
Phone: (402) 553-0234 Fax: (402) 553-0201

Project: SSS Grid Testing	Project No.: NE058-04P01	Designed By:	Rev.:
	Date: 11/03/04	Checked By:	Rev. Date:
Title: Shear Frame Setup	Scale: None	Detailed By: NAM	Page of





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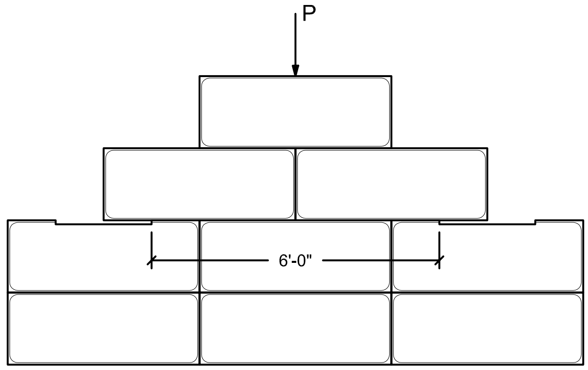
Project: SSS Grid Testing	Project No.: NE058-04P01	Designed By:	Rev.:
	Date: 11/03/04	Checked By:	Rev. Date:
Title: Grid Pullout Frame Setup	Scale: None	Detailed By: NAM	Page of

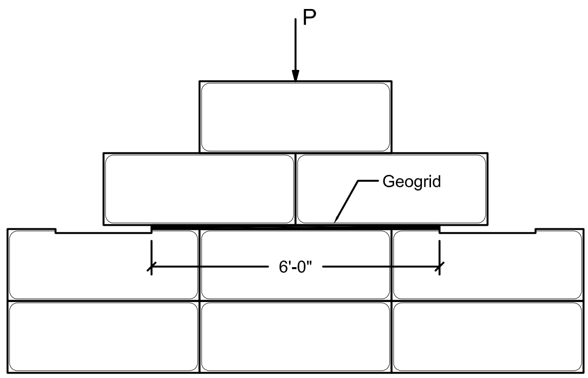
6SF Block Shear



$$\text{Normal Force}\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{P kips}}{\text{6 ft}}$$

$$\text{Shear Force}\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{V kips}}{\text{6 ft}}$$

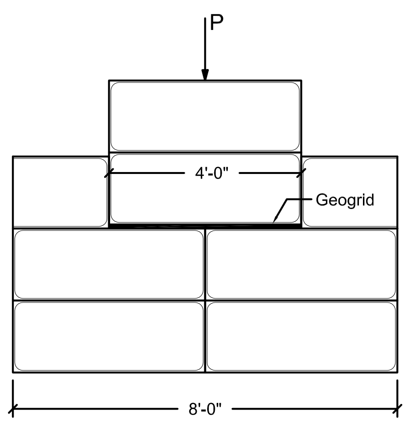
6SF Grid Shear



$$\text{Normal Force}\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{P kips}}{\text{6 ft}}$$

$$\text{Shear Force}\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{V kips}}{\text{6 ft}}$$

6SF Grid Pullout



$$\text{Normal Force}\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{P kips}}{\text{4 ft}}$$

$$\text{Grid Pullout}\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{T kips}}{\text{4 ft}}$$

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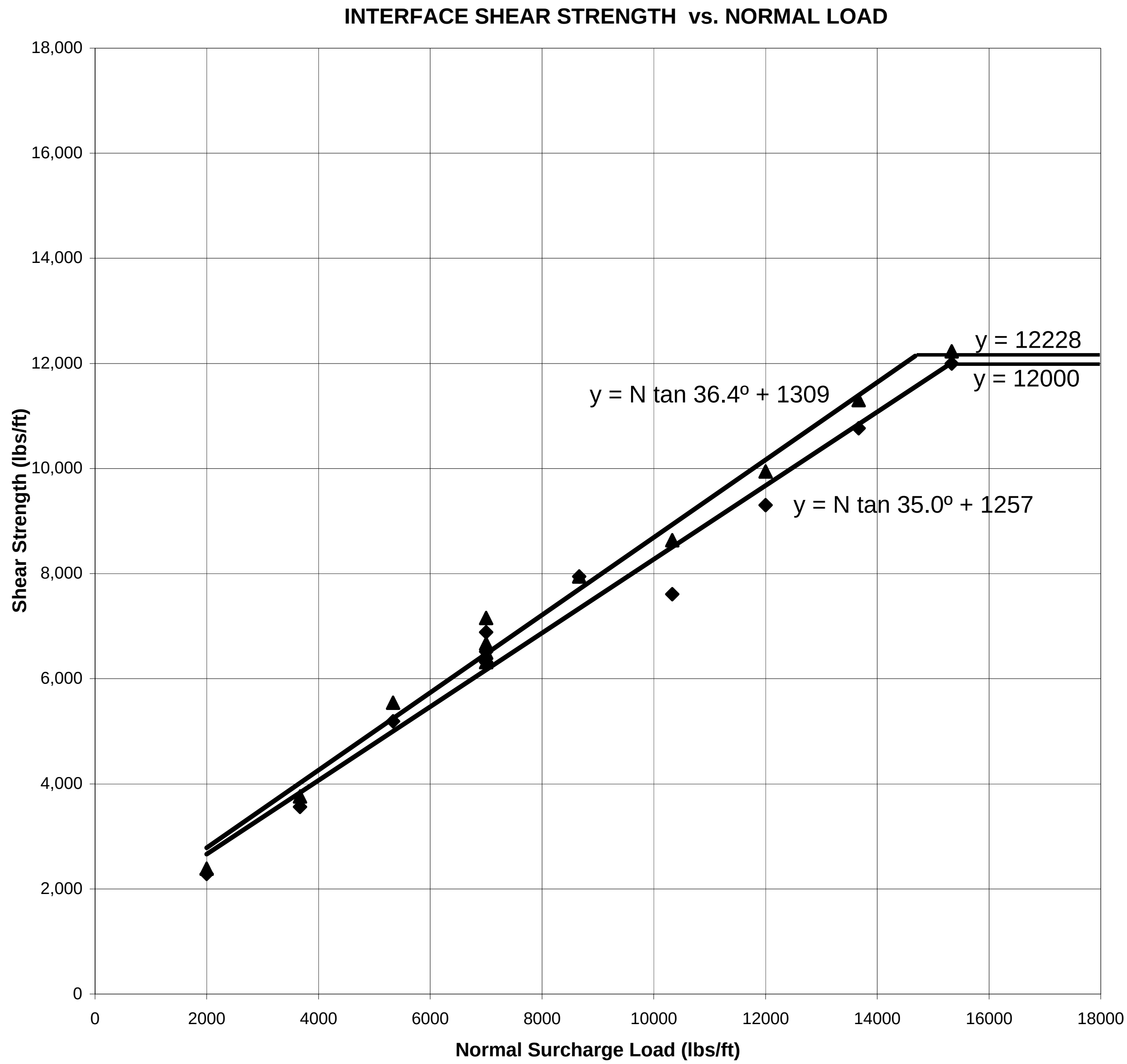
	Date: 11/03/04	Checked By:	Rev. Date:
Title: Test Setup	Scale: None	Detailed By: NAM	Page of

PHOTO NUMBER 1
Front View of Test Setup

PHOTO NUMBER 2
Side View of Test Setup

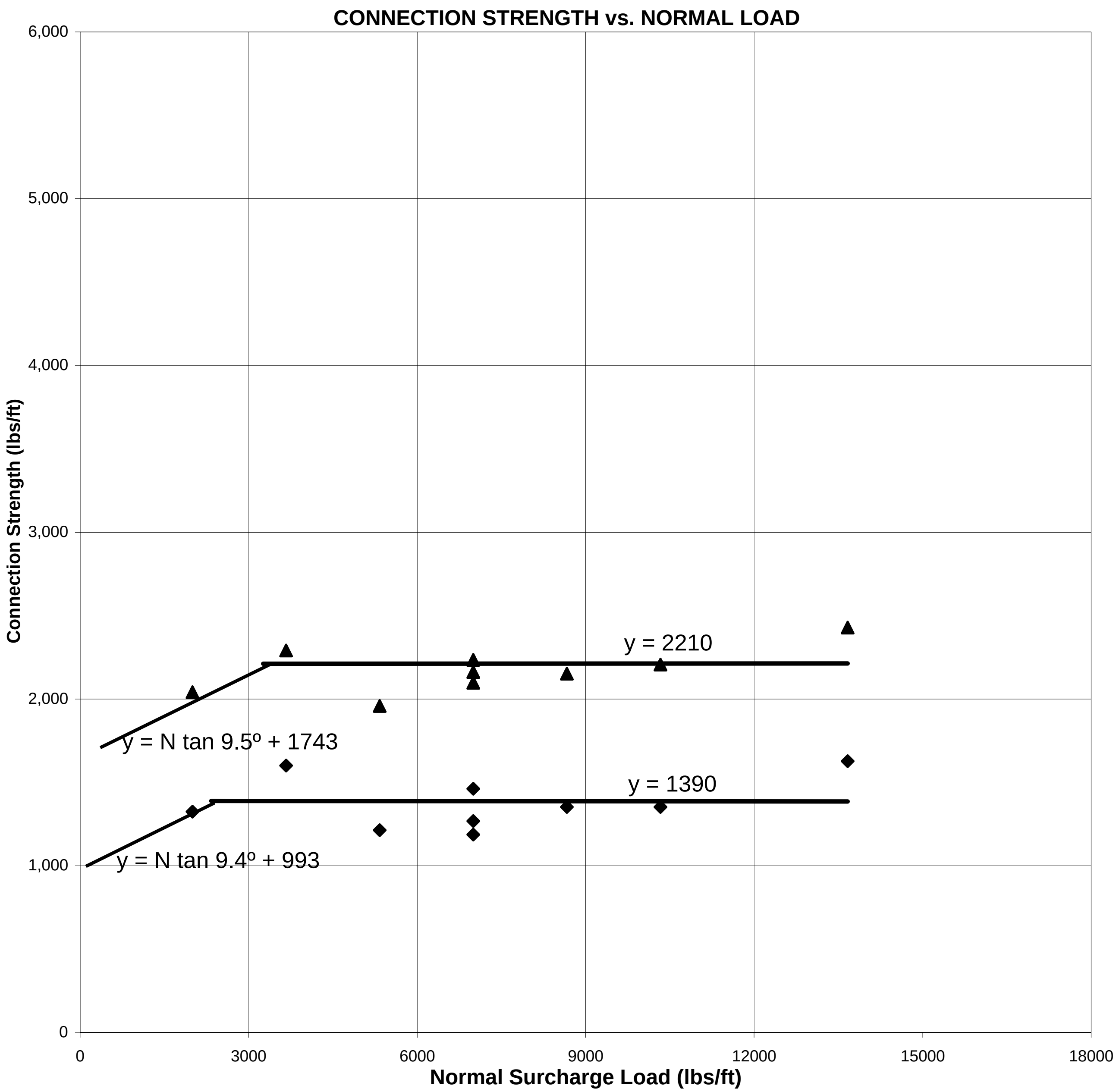
INTERFACE SHEAR TESTS
6 SF UNITS

Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Shear @ 3/4" displacement (lbs/ft)	Peak Shear (lbs/ft)
1	2,000	4.3	1.4	2,284	2,385
2	3,667	7.8	2.6	3,561	3,763
3	5,333	11.3	3.8	5,190	5,543
4	7,000	14.9	5.0	6,316	6,316
5	7,000	14.9	5.0	6,383	6,500
6	7,000	14.9	5.0	6,517	6,668
7	7,000	14.9	5.0	6,887	7,156
8	8,667	18.4	6.1	7,945	7,945
9	10,333	22.0	7.3	7,609	8,634
10	12,000	25.5	8.5	9,306	9,944
11	13,667	29.1	9.7	10,767	11,304
12	15,333	32.6	10.9	12,000	12,228



GEOGRID PULLOUT TESTS
6 SF UNITS w/ SYNTEEN SF55 GEOGRID

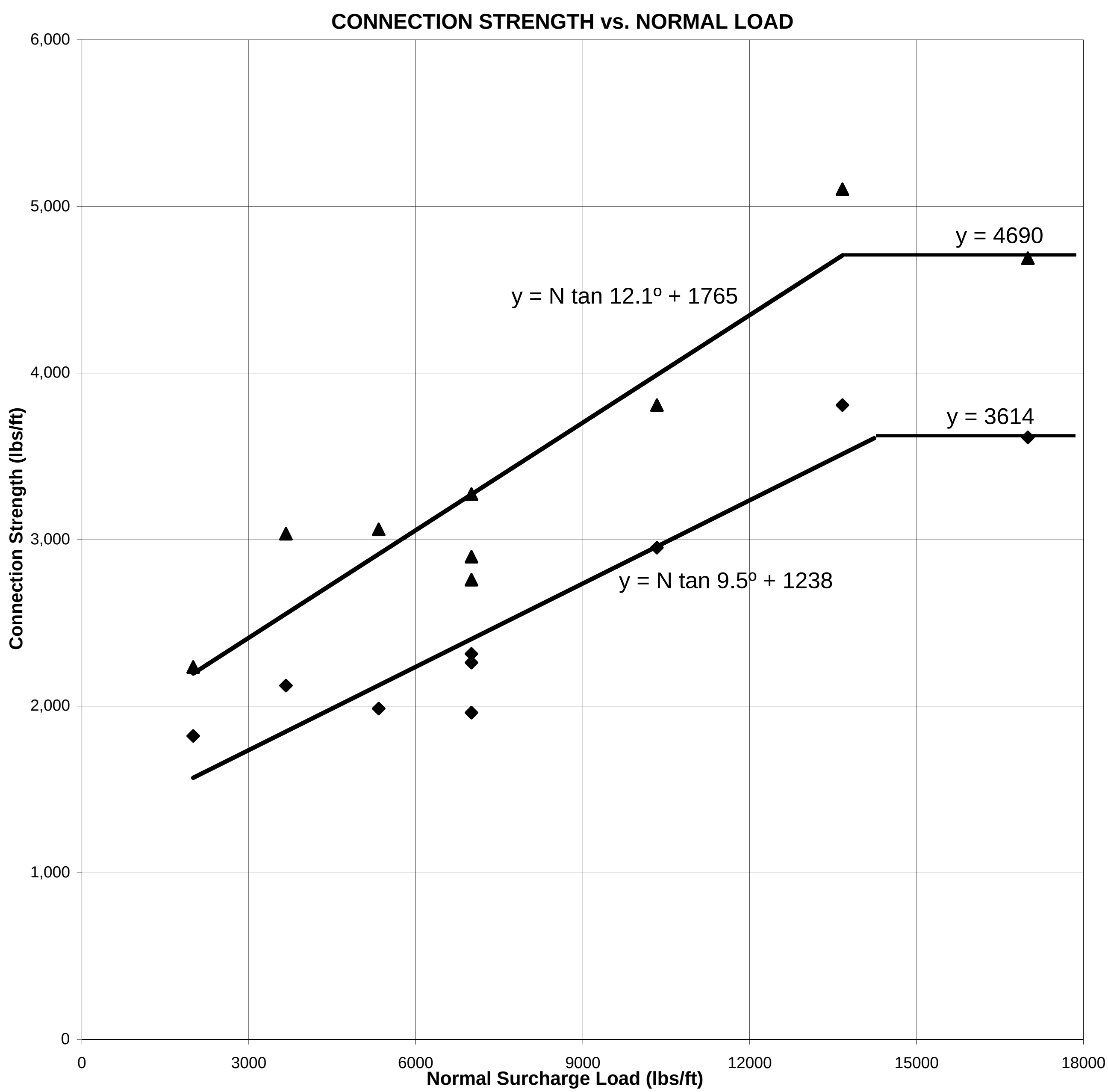
Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Tension @ 3/4" displ (lbs/ft)	Peak Tension (lbs/ft)
1	2,000	4.3	1.4	1,324	2,042
2	3,667	7.8	2.6	1,600	2,290
3	5,333	11.3	3.8	1,214	1,959
4	7,000	14.9	5.0	1,186	2,097
5	7,000	14.9	5.0	1,268	2,162
6	7,000	14.9	5.0	1,462	2,235
7	8,667	18.4	6.1	1,352	2,152
8	10,333	22.0	7.3	1,352	2,207
9	13,667	29.1	9.7	1,628	2,428



GEOGRID PULLOUT TESTS

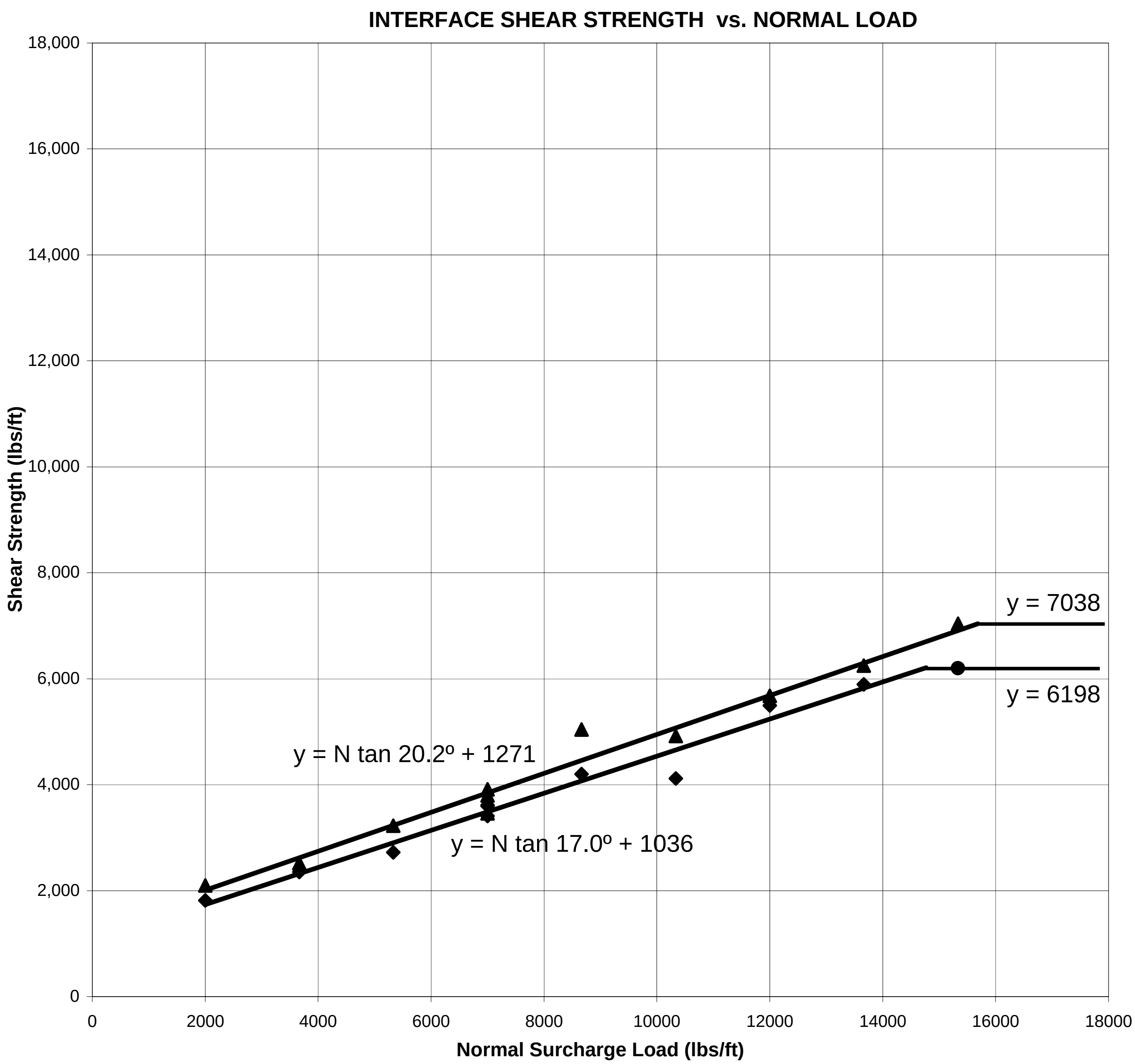
6 SF UNITS w/ SYNTEEN SF110 GEOGRID

Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Tension @ 3/4" displ (lbs/ft)	Peak Tension (lbs/ft)
1	2,000	4.3	1.4	1,821	2,235
2	3,667	7.8	2.6	2,124	3,035
3	5,333	11.3	3.8	1,987	3,062
4	7,000	14.9	5.0	1,961	2,759
5	7,000	14.9	5.0	2,314	3,274
6	7,000	14.9	5.0	2,262	2,897
7	10,333	22.0	7.3	2,952	3,807
8	13,667	29.1	9.7	3,807	5,104
9	17,000	36.2	12.1	3,614	4,690



INTERFACE SHEAR TESTS
6 SF UNITS w/ SF110 INCLUSION

Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Shear @ 3/4" displacement (lbs/ft)	Peak Shear (lbs/ft)
1	2,000	4.3	1.4	1,814	2,100
2	3,667	7.8	2.6	2,352	2,520
3	5,333	11.3	3.8	2,721	3,225
4	7,000	14.9	5.0	3,611	3,796
5	7,000	14.9	5.0	3,595	3,914
6	7,000	14.9	5.0	3,410	3,460
7	8,667	18.4	6.1	4,199	5,039
8	10,333	22.0	7.3	4,115	4,922
9	12,000	25.5	8.5	5,493	5,677
10	13,667	29.1	9.7	5,896	6,249
11	15,333	32.6	10.9	6,198	7,038



THIELE GEOTECH, INC

AGGREGATE REPORT

Project	Job No.
Stone Strong Systems	02546.0
Location	**Date**
Lincoln, NE	6/1/04

US Standard Sieve No.	Cumulative Percent		Specification Percent	
	Retained	Passing	Retained	Passing
1 1/2"	0.0	100.0		
3/4"	5.4	94.6	0 to 40	60 to 100
3/8"	44.9	55.1		
# 4	81.3	18.7	60 to 100	0 to 40
# 10	89.4	10.6		
# 20	92.1	7.9		
# 40	93.3	6.7		
# 100	94.4	5.6		
# 200	94.9	5.1	95 to 100	0 to 5

Sample of: Limestone Unit Fill

Sampled at: Workman Precast from stockpile

Source:

Date Received: 5/25/04

Remarks: Sample #4

Lab No. G825