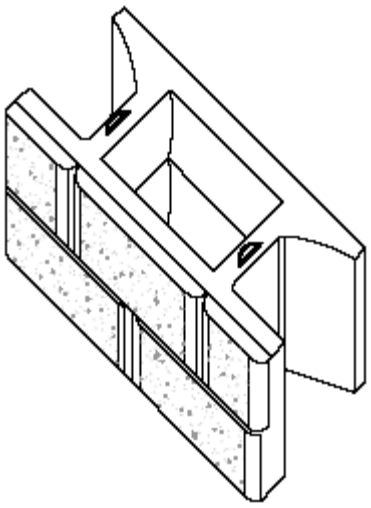
Tadros Associates, LLC
Structural Engineering Consultants

thiele geotech inc TG

Interaction Testing Report

24 SF Units with Synteen Geogrids

Stone Strong Systems
Lincoln, Nebraska



Prepared for:
Stone Strong Systems
1620 South 70th Street Suite 105
Lincoln, Nebraska 68506

September 17, 2004
TG Project No. 02546.2

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24 SF Units with Synteen Geogrids

Table of Contents

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 24 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 24 SF blocks are precast concrete blocks used for construction of segmental retaining walls.

The 24 SF unit has nominal face dimensions of 96 inches long and 36 inches tall for a total face area of 24 square feet. The unit has a depth (measured horizontally from the face to the tail) of approximately 44 inches. The units have a center void between twin 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 5,800 to 6,200 pounds empty, depending on the aggregate used to manufature the block. When installed in a retaining wall, the block voids are filled with aggregate. The infilled weight is approximately 10,200 to 11,000 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 resisting 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 loptop 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 24 SF concrete block units. The tests were carried out with and without a layer of geosynthetic reinforcement between layers of Stone Strong units. The bottom block was installed and braced against the front of the load frame. Portions of the top of the block were recessed with a bush hammer to control the dimension of the loaded area. Crushed limestone infill was placed in the void of the bottom block. When a geogrid layer was included, the geosynthetic reinforcement was centered over the bottom block. The top Stone Strong unit layer was centered over the bottom block. Crushed limestone infill was placed in the void of the top block.

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 24 SF concrete block units. The tests were carried out with a layer of geosynthetic reinforcement between layers of Stone Strong units. The bottom block was installed and braced against the back of the load frame. Crushed limestone infill was placed in the voids of the bottom block. The geosynthetic reinforcement was centered over the bottom block and attached to a clamping device. Sacrificial pieces of geogrid were placed over the extended flanges to maintain even load distribution across the block unit. The top Stone Strong unit layer was placed over the geogrid and centered over the bottom block. Crushed limestone infill was placed in the voids of the top block, and the block was braced against the back of the frame.

The top unit was 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 minimum peak shear capacity recorded was 2,822 pounds per foot. The peak interface shear strength between Stone Strong Systems 24 SF units and Synteen SF55 and SF110 Geogrid for equivalent wall heights between 9.6 and 57.4 feet high ranged between 8,667 and 12,371 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)	362	35.2	19,000	360	33.0	18,000
Shear w/ SF 55 inclusion	2,018	22.5	10,115	1,901	20.5	9,450
Shear w/ SF 110 inclusion	1,640	19.2	10,835	1,640	16.6	9,500

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 minimum peak connection capacity recorded was 2,268 pounds per foot. The recorded peak connection strengths between Stone Strong Systems 24 SF units and Synteen SF55 and SF110 Geogrid were 2,847 and 6,198 pounds per foot, respectively, for equivalent wall heights between 4.8 and 28.7 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/ SF 55 inclusion	1,555	16.6	3,090	806	15.0	2,822
Connection Strength w/ SF 110 inclusion	2,233	24.3	6,126	1,624	22.4	4,065

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

Test Setup

Photographs

Interface Shear Test Results

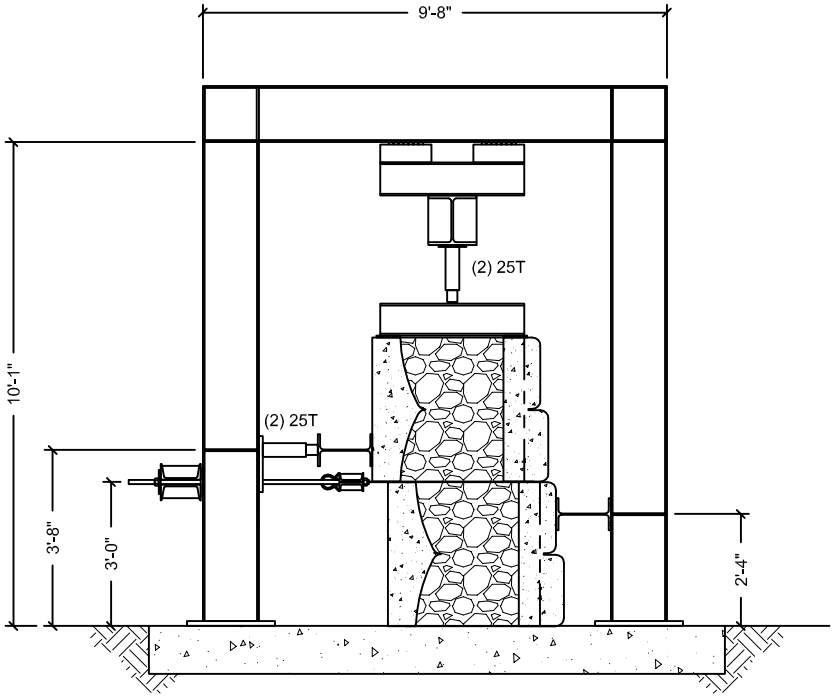
SF55 Pullout Results

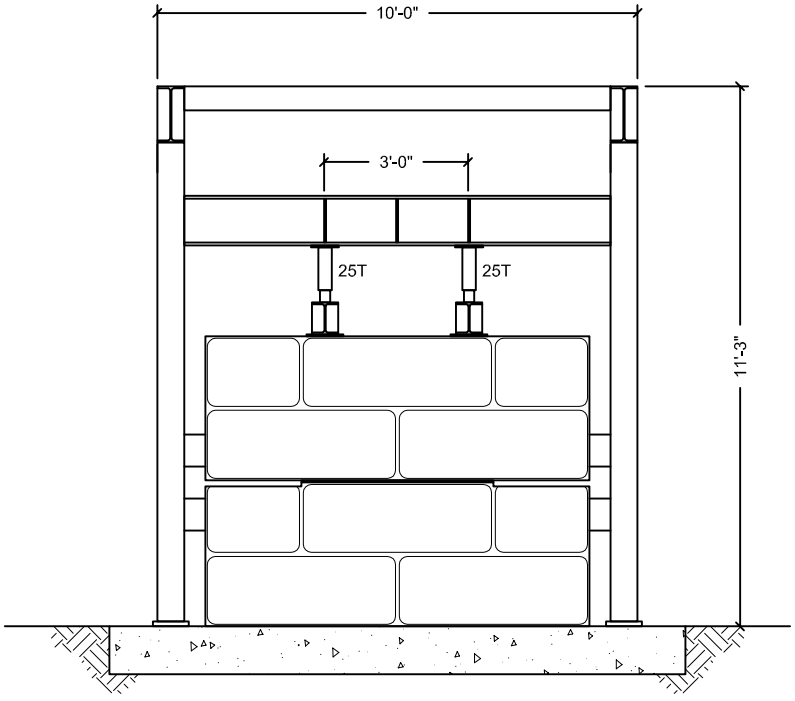
SF55 Interface Shear Results

SF110 Pullout Results

SF110 Interface Shear Results

Aggregate Test Reports





Tadros Associates, LLC
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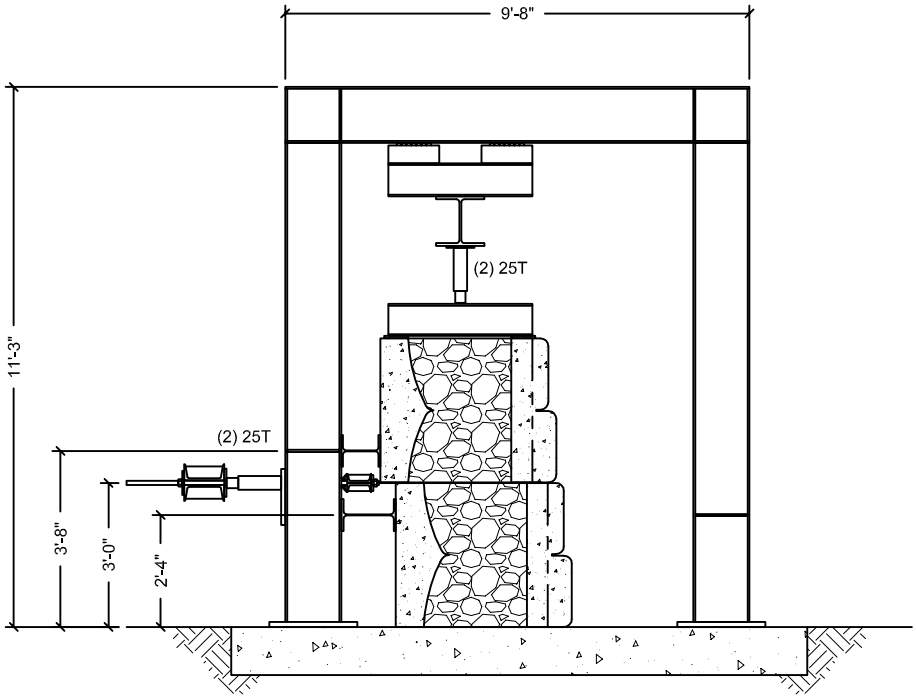
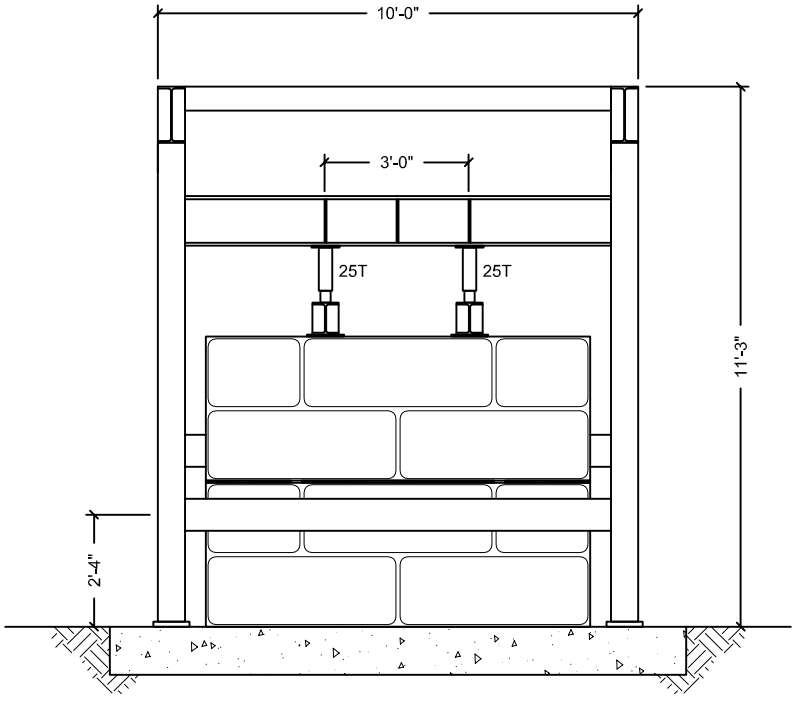
Phone: (402) 553-0234 Fax: (402) 553-0201

Project: SSS Grid Testing		Project No.: NE058-04P01	Designed By:	Rev.:
Title: Shear Frame Setup		Date: 9/15/04	Checked By:	Rev. Date:
		Scale: None	Detailed By: NAM	Page of





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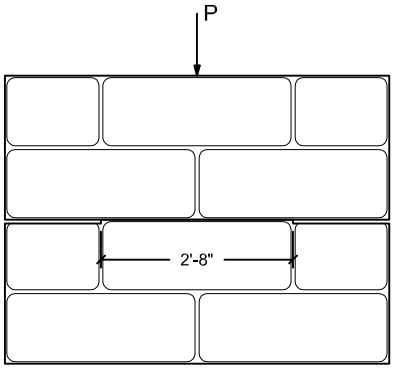
Project: SSS Grid Testing	Project No.: NE058-04P01	Designed By:	Rev.:	
	Date: 9/15/04	Checked By:	Rev. Date:	
Title: Grid Pullout Frame Setup	Scale: None	Detailed By: NAM	Page of	

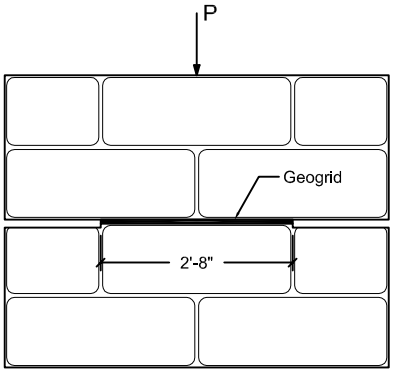
24SF Block Shear



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

Shear Force $\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{V kips}}{4\text{ ft}}$

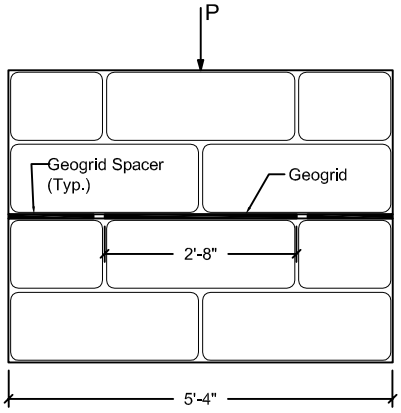
24SF Grid Shear



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

Shear Force $\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{V kips}}{4\text{ ft}}$

24SF Grid Pullout



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

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SSS Grid Testing	NE058-04P01		
Title	Date 9/15/04	Checked By	Rev. Date
Test Setup	Scale None	Detailed By NAM	Page of

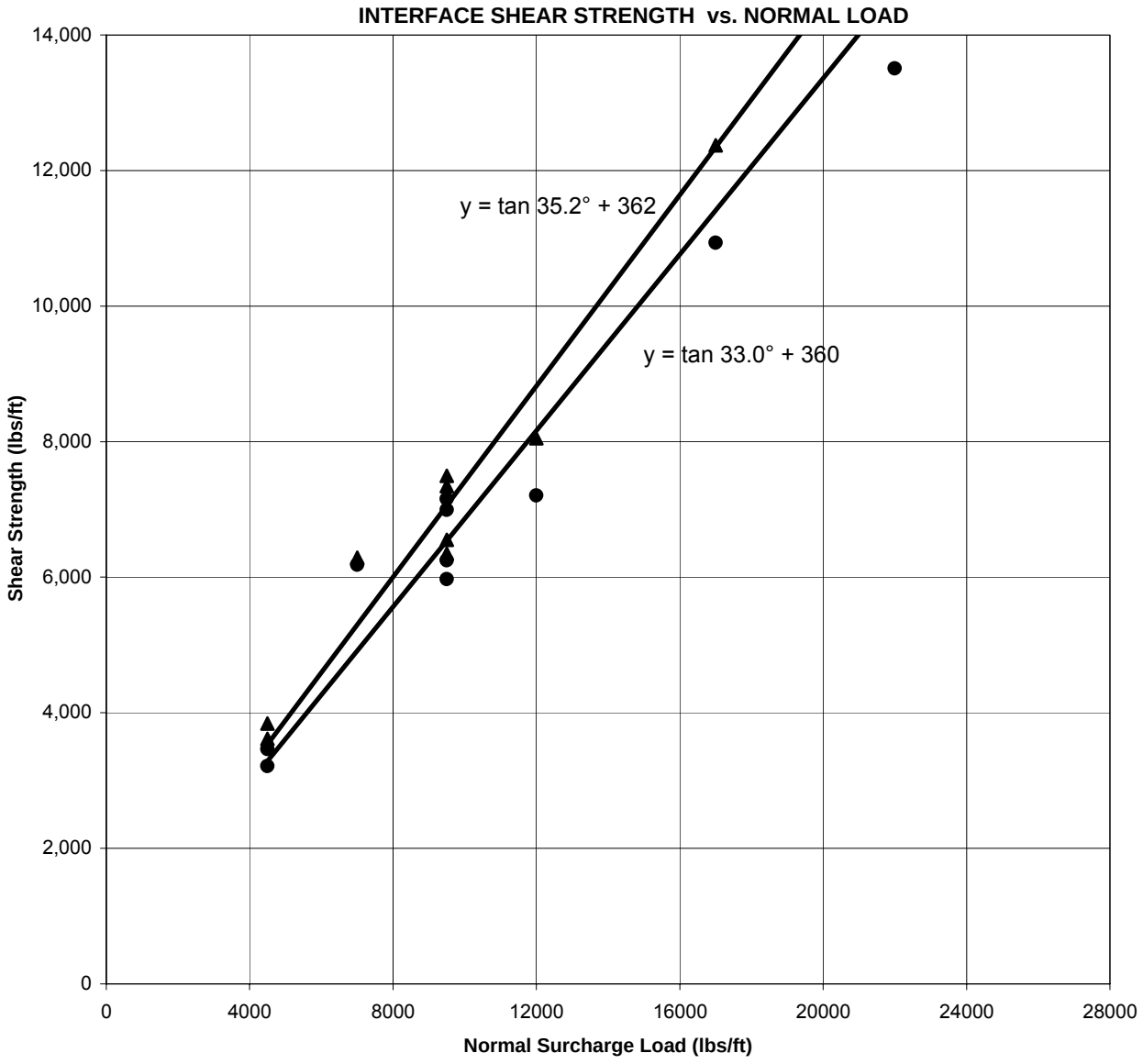
PHOTO NUMBER 1
Test Frame Setup

PHOTO NUMBER 2
Geogrid Pullout System

PHOTO NUMBER 3
Pullout Test Setup

INTERFACE SHEAR TESTS
24 SF UNITS

Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Shear @ 3/4" displacement (lbs/ft)	Peak Shear (lbs/ft)
1	4,500	9.6	3.2	3,212	3,616
2	4,500	9.6	3.2	3,464	3,842
3	7,000	14.9	5.0	6,185	6,286
4	9,500	20.2	6.7	6,992	7,344
5	9,500	20.2	6.7	7,155	7,496
6	9,500	20.2	6.7	6,249	6,349
7	9,500	20.2	6.7	5,971	6,551
8	12,000	25.5	8.5	7,206	8,050
9	17,000	36.2	12.1	10,935	12,371
10	22,000	46.8	15.6	13,505	14,084
11	27,000	57.4	19.1	19,149	21,013

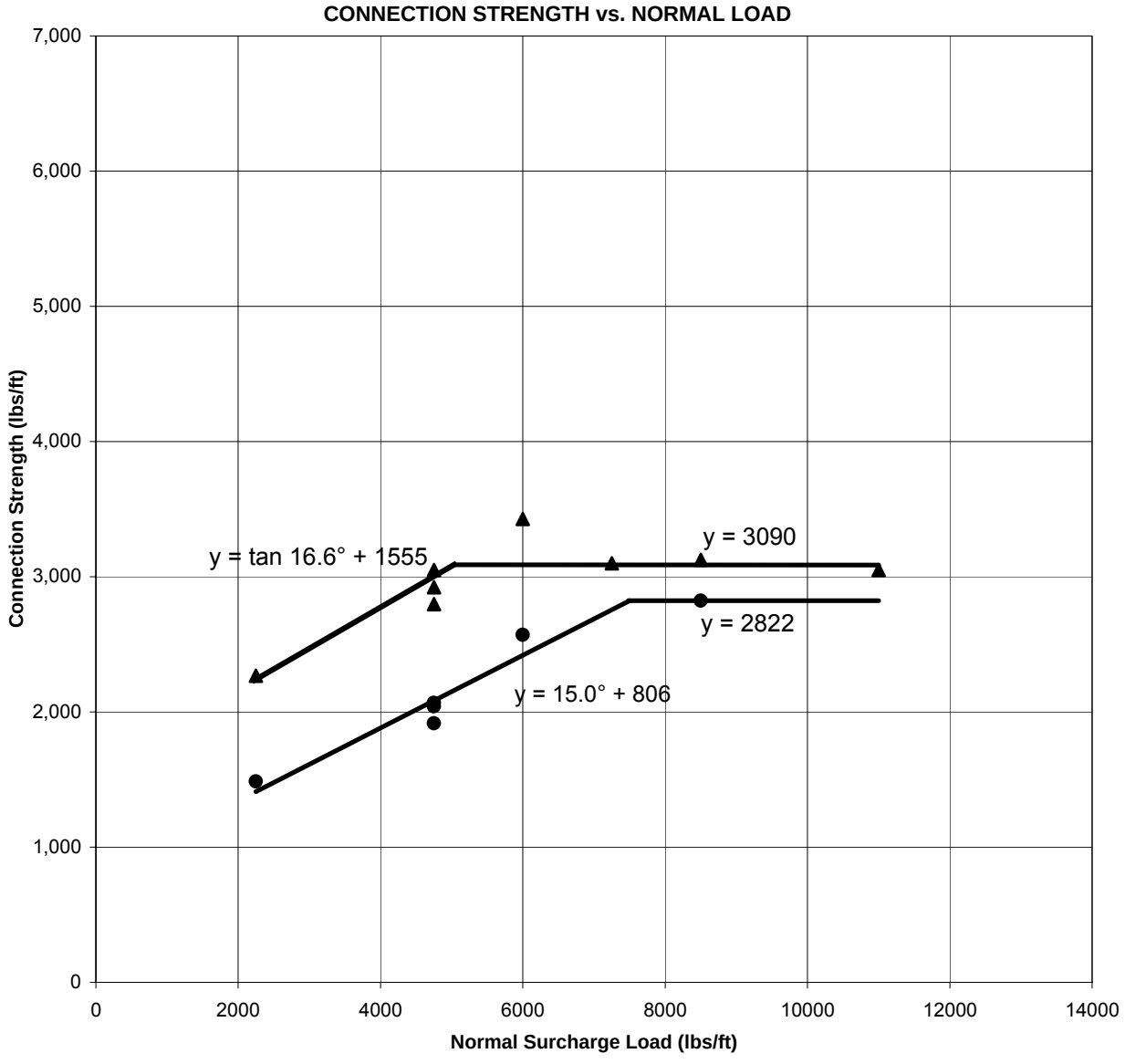


GEOGRID PULLOUT TESTS

24 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	2,250	4.8	1.6	1,487	2,268
2	4,750	10.1	3.4	2,041	3,049
3	4,750	10.1	3.4	1,915	2,797
4	4,750	10.1	3.4	2,066	2,923
5	6,000	12.8	4.3	2,570	3,427
6	7,250	15.4	5.1	2,771	3,099
7	8,500	18.1	6.0	2,822	3,124
8	11,000	23.4	7.8	0*	3,049
9	13,500	28.7	9.6	0*	2,847

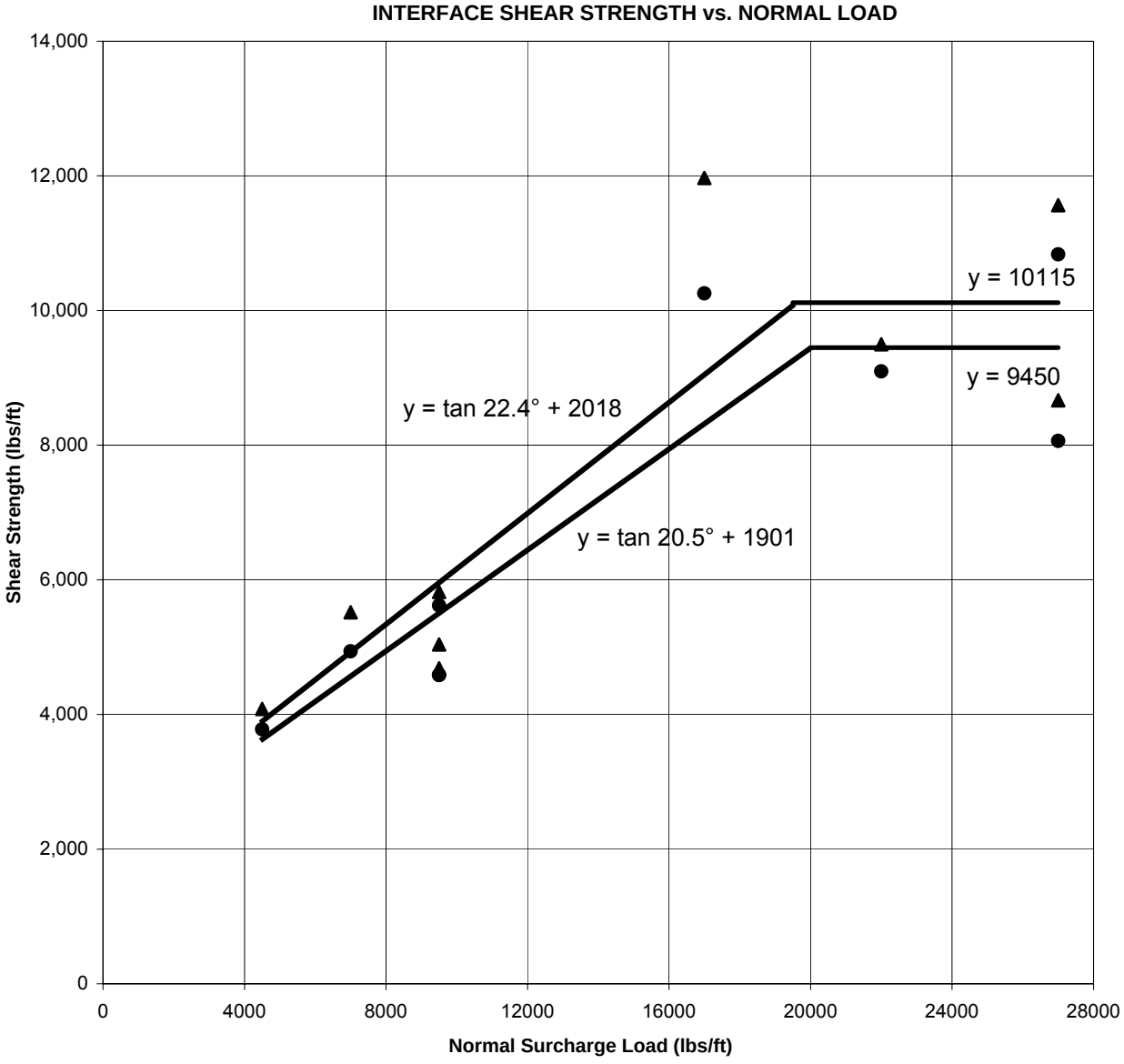
* - geogrid ruptured before reaching 3/4" displacement



INTERFACE SHEAR TESTS

24 SF UNITS w/ SYNTEEN SF55 INCLUSION

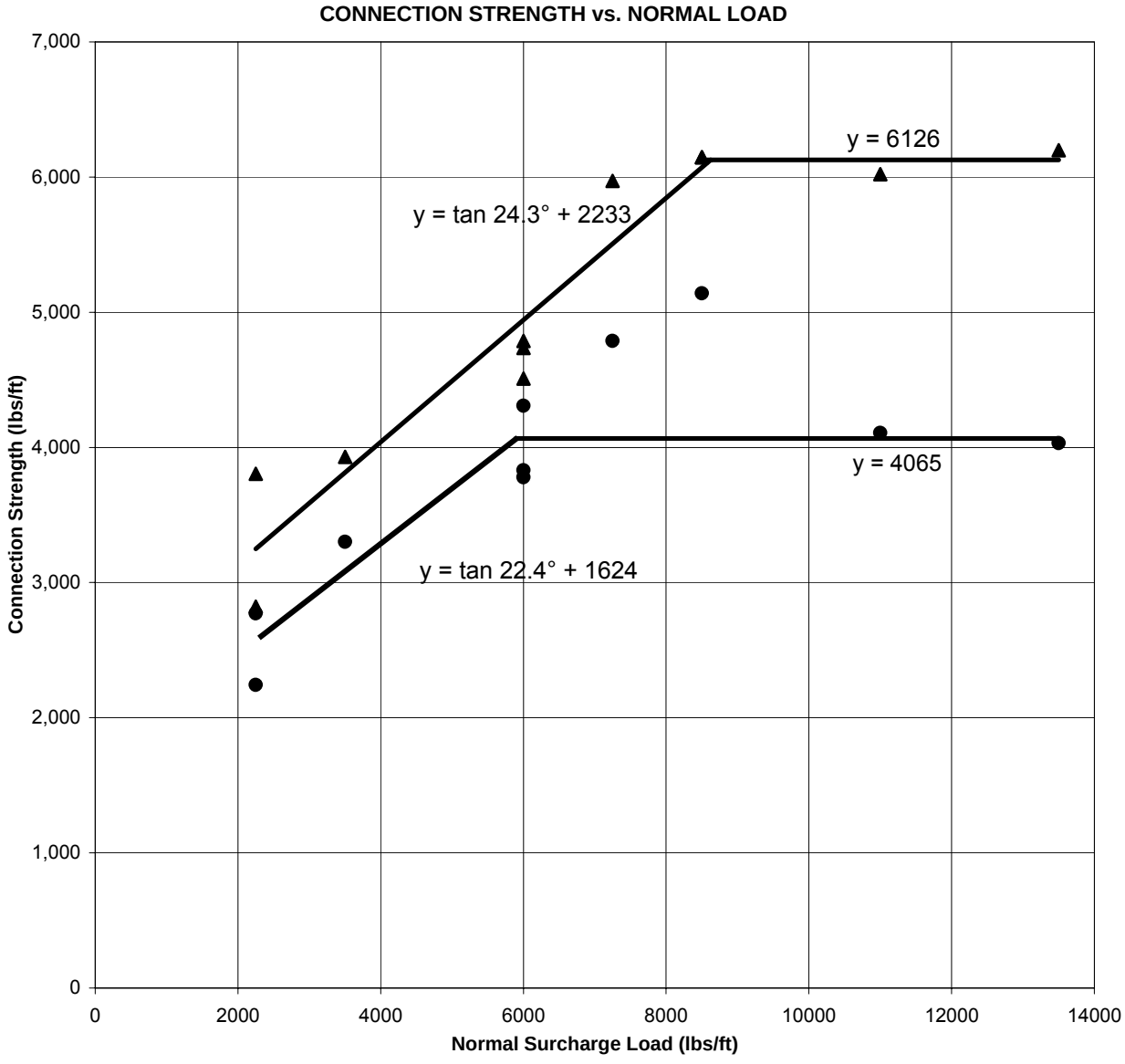
Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Shear @ 3/4" displacement (lbs/ft)	Peak Shear (lbs/ft)
1	4,500	9.6	3.2	3,779	4,082
2	7,000	14.9	5.0	4,938	5,518
3	9,500	20.2	6.7	4,586	4,686
4	9,500	20.2	6.7	5,619	5,820
5	9,500	20.2	6.7	4,586	5,039
6	17,000	36.2	12.1	10,255	11,968
7	22,000	46.8	15.6	9,096	9,499
8	27,000	57.4	19.1	8,063	8,667
9	27,000	57.4	19.1	10,834	11,565



GEOGRID PULLOUT TESTS

24 SF UNITS w/ SYNTEEN SF110 GEOGRID

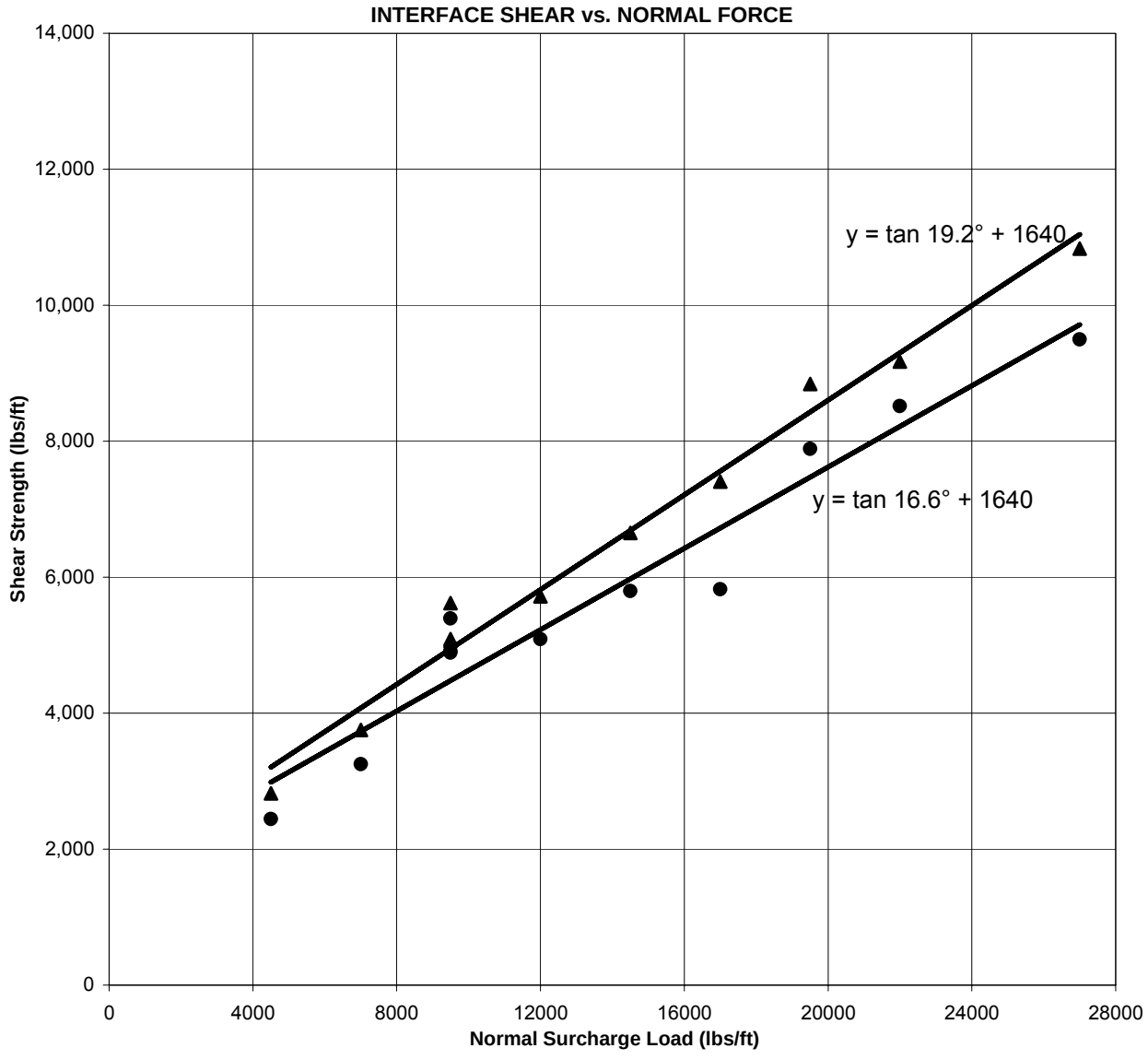
Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Tension @ 3/4" displ (lbs/ft)	Peak Tension (lbs/ft)
1	2,250	4.8	1.6	2,242	2,822
2	2,250	4.8	1.6	2,771	3,805
3	3,500	7.4	2.5	3,301	3,930
4	6,000	12.8	4.3	4,308	4,787
5	6,000	12.8	4.3	3,830	4,737
6	6,000	12.8	4.3	3,779	4,510
7	7,250	15.4	5.1	4,787	5,971
8	8,500	18.1	6.0	5,140	6,148
9	11,000	23.4	7.8	4,107	6,022
10	13,500	28.7	9.6	4,031	6,198



INTERFACE SHEAR TESTS

24 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	4,500	9.6	3.2	2,444	2,822
2	7,000	14.9	5.0	3,250	3,754
3	9,500	20.2	6.7	5,392	5,619
4	9,500	20.2	6.7	4,913	5,089
5	9,500	20.2	6.7	4,888	5,064
6	12,000	25.5	8.5	5,089	5,719
7	14,500	30.9	10.3	5,795	6,652
8	17,000	36.2	12.1	5,820	7,407
9	19,500	41.5	13.8	7,886	8,844
10	22,000	46.8	15.6	8,516	9,171
11	27,000	57.4	19.1	9,499	10,834



THIELE GEOTECH, INC

AGGREGATE REPORT

Project	Job No.
Stone Strong Systems	02546.0
Location	**Date**
Lincoln, NE	7/31/03

US Standard Sieve No.	Cumulative Percent		Specification Percent	
	Retained	Passing	Retained	Passing
1 1/2"	0.3	99.7		
3/4"	39.4	60.6	0 to 40	60 to 100
3/8"	96.3	3.7		
# 4	96.9	3.1	60 to 100	0 to 40
# 10	97.1	2.9		
# 20	97.3	2.7		
# 40	97.5	2.5		
# 100	97.9	2.1		
# 200	98.2	1.8	95 to 100	0 to 5

Sample of: Limestone Unit Fill

Sampled at: Workman Precast from stockpile

Source:

Date Received: 7/22/03

Remarks: Dry Unit Weight by Rodding ASTM C29 90.5 pcf

Lab No._____

THIELE GEOTECH, INC

AGGREGATE REPORT

Project	Job No.
Stone Strong Systems	02546.0
Location	**Date**
Lincoln, NE	8/6/03

US Standard Sieve No.	Cumulative Percent		Specification Percent	
	Retained	Passing	Retained	Passing
1 1/2"	0.0	100.0		
3/4"	33.9	66.1	0 to 40	60 to 100
3/8"	95.5	4.5		
# 4	96.4	3.6	60 to 100	0 to 40
# 10	96.6	3.4		
# 20	96.8	3.2		
# 40	96.9	3.1		
# 100	97.3	2.7		
# 200	97.5	2.5	95 to 100	0 to 5

Sample of: Limestone Unit Fill

Sampled at: Workman Precast from stockpile

Source:

Date Received:

Remarks: Sample #2

Lab No._____

THIELE GEOTECH, INC

AGGREGATE REPORT

Project	Job No.
Stone Strong Systems	02546.0
Location	**Date**
Lincoln, NE	3/11/04

US Standard Sieve No.	Cumulative Percent		Specification Percent	
	Retained	Passing	Retained	Passing
1 1/2"	0.0	100.0		
3/4"	33.9	66.1	0 to 40	60 to 100
3/8"	95.5	4.5		
# 4	96.4	3.6	60 to 100	0 to 40
# 10	96.6	3.4		
# 20	96.8	3.2		
# 40	96.9	3.1		
# 100	97.3	2.7		
# 200	97.5	2.5	95 to 100	0 to 5

Sample of: Limestone Unit Fill

Sampled at: Workman Precast from stockpile

Source:

Date Received:

Remarks: Sample #3

Lab No._____

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