

**REPORT**  
**RESULTS OF**  
**REDI-ROCK NATURESCAPES 115 SERIES UNIT**  
**SHEAR CAPACITY TESTING**  
submitted to  
**REDI-ROCK INTERNATIONAL**

**CONFIDENTIAL**

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## Introduction

This report gives the results of a shear capacity testing program carried out to evaluate the mechanical/frictional performance of the shear capacity between Redi-Rock Naturescapes 115 Series<sup>®</sup> (RR-N 115) modular concrete block units manufactured by Redi-Rock International, LLC.

The test program was initiated in response to a verbal authorization to proceed from Mr. Jack Bergmann of Redi-Rock International, LLC. received 22 April 2009.

The tests were carried out at the laboratories of Bathurst, Clarabut Geotechnical Testing, Inc. in Kingston, Ontario, under the supervision of Mr. Peter Clarabut.

## Objectives of test program

The interface shear capacity between RR-N 115 block concrete units placed in a staggered joint (running bond) configuration was investigated using a large-scale test apparatus.

The principal objective of the testing was to evaluate the mechanical/frictional performance of the shear connection between successive layers of RR-N 115 block units. A second objective was to make recommendations for the selection of interface shear capacities to be used in the design and analysis of retaining wall systems that employ RR-N 115 block units.

## Materials

RR-N 115 block units are hollow core concrete blocks weighing approximately 55 pounds per unit (68 pounds per units when units are core filled with 3/4 inch crushed limestone, weight/unit measured in our laboratory). The nominal dimensions of the block are 11 inches wide (toe to heel) by 6 inches high by 18 inches long. Construction alignment and wall batter is achieved by means of two cast-in-place concrete keys on the top surface of the units. The installation arrangement is illustrated in **Figure 1**. The blocks used in this series of tests were supplied by Redi-Rock International of Charlevoix, Michigan and designated as BIC 09-022 received 28 April 2009.

## Apparatus and general test procedure

The SRWU-2 method of test as reported in the NCMA Segmental Retaining Wall Design Manual (1993) and ASTM D 6916-03 was used in this investigation. A brief description of the apparatus and test methodology is presented here. The apparatus used to perform the tests is illustrated in **Figure 1**. The test apparatus allows horizontal loads of up to 35,000 lbf to be applied across the interface between two block layers. The segmental units were laterally restrained at the bottom and surcharged vertically. A single block was placed over one centrally located running bond (joint) formed by the two underlying units to simulate the staggered construction procedure typically used in the field. The spaces between blocks were infilled

## Interface Shear

Series BCGT2504

with a 3/4 inch, 100% crushed limestone aggregate and lightly compacted. **Figure 2** illustrates the particle size distribution of the infill used in this test series. Wall heights were simulated by placing a single block over the interface and applying additional normal load using the air bag arrangement shown in **Figure 1**. The horizontal (shear) force was applied at a constant rate of displacement using a computer-controlled hydraulic actuator. The load and displacements measured by the actuator and displacement transducers were recorded continuously during the test by a microcomputer/data acquisition system. Each test was continued until large shear displacements were achieved. Following each test, the blocks were removed and the units examined to confirm failure modes.

The only variable in this series of interface shear tests was the magnitude of surcharge (i.e. the magnitude of normal load applied to the top segmental unit). The normal loads used in the test program are given in **Table 1**.

**Test results**

Results of interface shear tests are summarized in **Table 1**. Peak interface shear capacities and shear capacity at the displacement criterion (0.12 inch) are plotted against normal load in **Figure 3**. The displacement criterion was calculated to be 0.12 inch based on 2% of the block height. The minimum *peak* shear capacity recorded from the test series was 975 lb/ft. In all tests, failure was observed as failure of the concrete shear key.

The test results reveal some scatter in shear capacity for tests carried out at nominal similar normal loads. The three tests carried out at a nominal equivalent normal load of about 804 lb/ft (**Tests 1, 4 and 7**) gave peak shear capacity values that ranged from 1620 to 1755 lb/ft with a mean value of 1675 lb/ft. This scatter is less than  $\pm 10\%$  of the mean peak shear criterion required by the NCMA (e.g. maximum variability is 4.8%) and is likely the result of small differences in the setting up of the blocks, placement of the granular infill and compaction. The trends in data for shear loads at 0.12 inches of displacement and at peak shear loads have been plotted using linear curves.

**Implications to interface shear capacity design and construction with RR-N 115 block units**

The interface shear strength in the field may be less than the values determined in this test series for the same method and quality of construction. The NCMA Segmental Retaining Wall Design Manual (First Edition, 1993) recommends that the design shear capacity at a given normal load for a critical wall structure be the lesser of: a) the peak capacity divided by a minimum factor of safety (not less than 1.5) or; b) the capacity based on the 0.12 inch displacement criterion. The *design* interface shear capacity envelope shown in **Figure 4** is controlled by the peak shear capacity criterion.

The design shear capacity envelope illustrated in **Figure 4** should be used with caution. The actual design capacity envelope should be lower if the quality of construction in the field is less

## Interface Shear

Series BCGT2504

than that adopted in this controlled laboratory investigation and/or lower quality concrete is used in the manufacture of the blocks. In addition, the interface concrete surfaces should be free of aggregate particles in order to maximize the frictional resistance that is developed between the concrete surfaces.

**Summary of conclusions**

A laboratory testing program was carried out to evaluate the mechanical/frictional performance of the shear connection between RR-N 115 block segmental concrete units. The following conclusions can be drawn:

1. The minimum *peak* shear capacity recorded from this test series was 975 lb/ft (height above interface equal to 6.3 block units).
2. Variability in shear capacity was observed between nominal identical tests due to small differences in setting up of the blocks, placement and compaction of the granular infill and possibly small variations in block dimensions.
3. The design envelope in **Figure 4** is based on interpretation of test data as recommended in the NCMA Segmental Retaining Wall Design Manual (First Edition, 1993). The choice of design interface shear capacity may vary with quality of construction in the field and hence lower design values than those taken from **Figure 4** may be appropriate.

**Concluding remarks**

The test results presented here are applicable to conventional and geosynthetic reinforced-soil segmental retaining wall designs that employ RR-N 115 block units. The inclusion of a layer of geosynthetic reinforcement may reduce the interface shear capacity to values less than those reported in this investigation.



P. Clarabut



R. J. Bathurst, Ph.D., P. Eng.

**Table 1****Test Program:****Shear capacity results for RR-N 115 modular block units**

Test number	normal load (lb/ft)	approximate wall height (feet)	approximate number of blocks	Shear load at 0.12 inches displacement (lb/ft)	shear load at PEAK (lb/ft)
1	794	8.8	17.6	1358	1650
2	284	3.2	6.3	902	975
3	539	6.0	12.0	1058	1065
4	809	9.0	18.0	1613	1620
5	1079	12.0	24.0	1697	1935
6	1349	15.0	30.0	2031	2220
7	809	9.0	18.0	1632	1755
8	1799	20.0	40.0	1827	2265

**REFERENCES**

ASTM D 6638-01. Standard Test Method for Determining Connection Strength between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks), American Society for Testing and Materials, West Conshohocken, PA 19428-2958 USA.

Bathurst, R.J. and Simac, M.R., 1993. Laboratory Testing of Modular Unit/Geogrid Facing Connections, *ASTM Symposium on Geosynthetic Soil Reinforcement Testing Procedures*, San Antonio, 19 January 1993.

Simac, M.R., Bathurst, R.J., Berg, R.R. and Lothspeich, S.E., 1993. *NCMA Segmental Retaining Wall Design Manual (First Edition)*, National Concrete Masonry Association, 2302 Horse Pen Road, Herndon, VA 22071-3406.

Interface Shear

- |   |                      |    |                         |
|---|----------------------|----|-------------------------|
| 1 | loading frame        | 2  | horizontal actuator     |
| 3 | horizontal load cell | 4  | reaction beam           |
| 5 | vertical load cell   | 6  | air bag                 |
| 7 | platform             | 8  | spacers                 |
| 9 | RR-N 115 block       | 10 | displacement transducer |

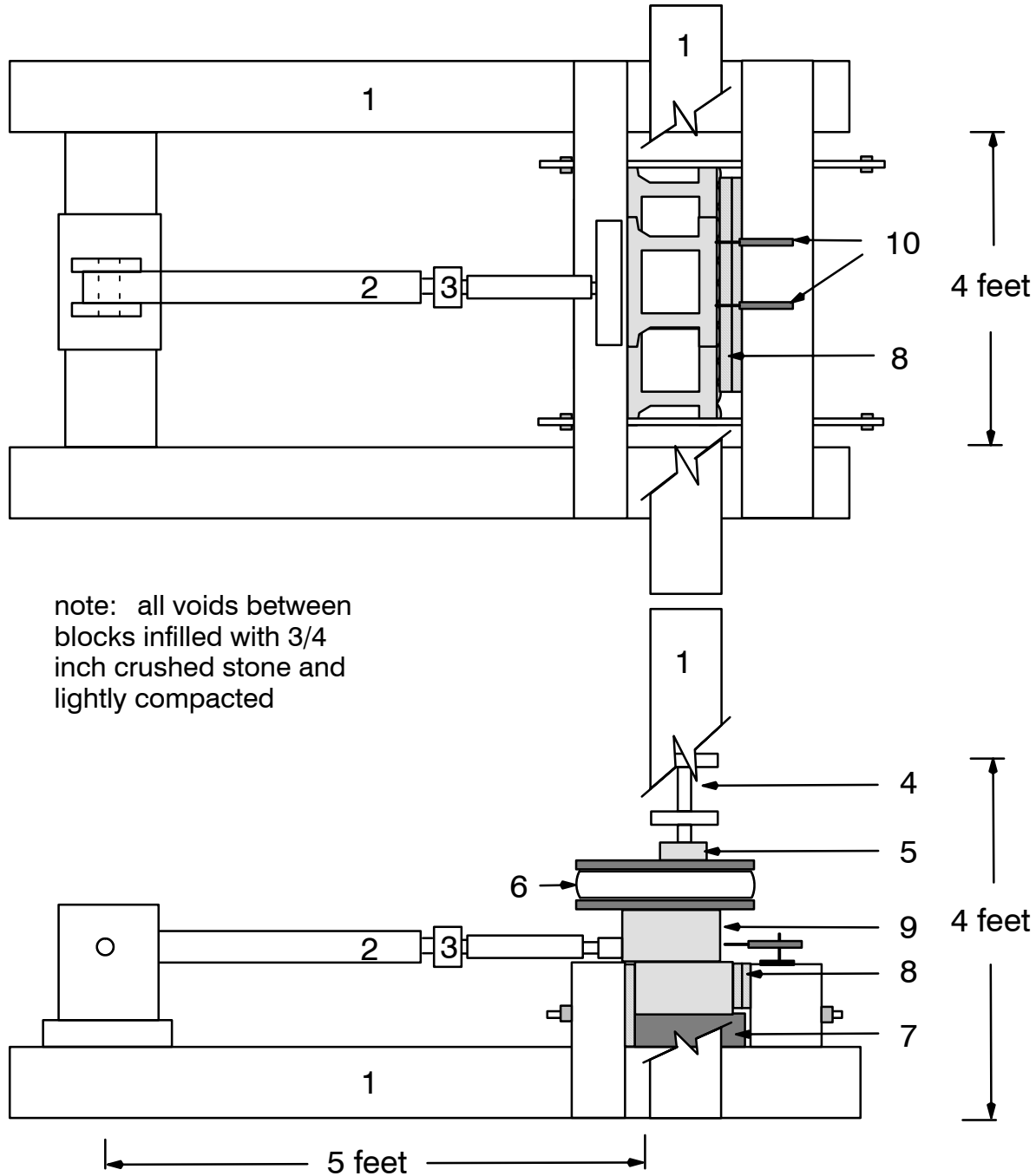


Figure 1: Schematic of shear capacity test apparatus showing RR-N 115 block segmental concrete units

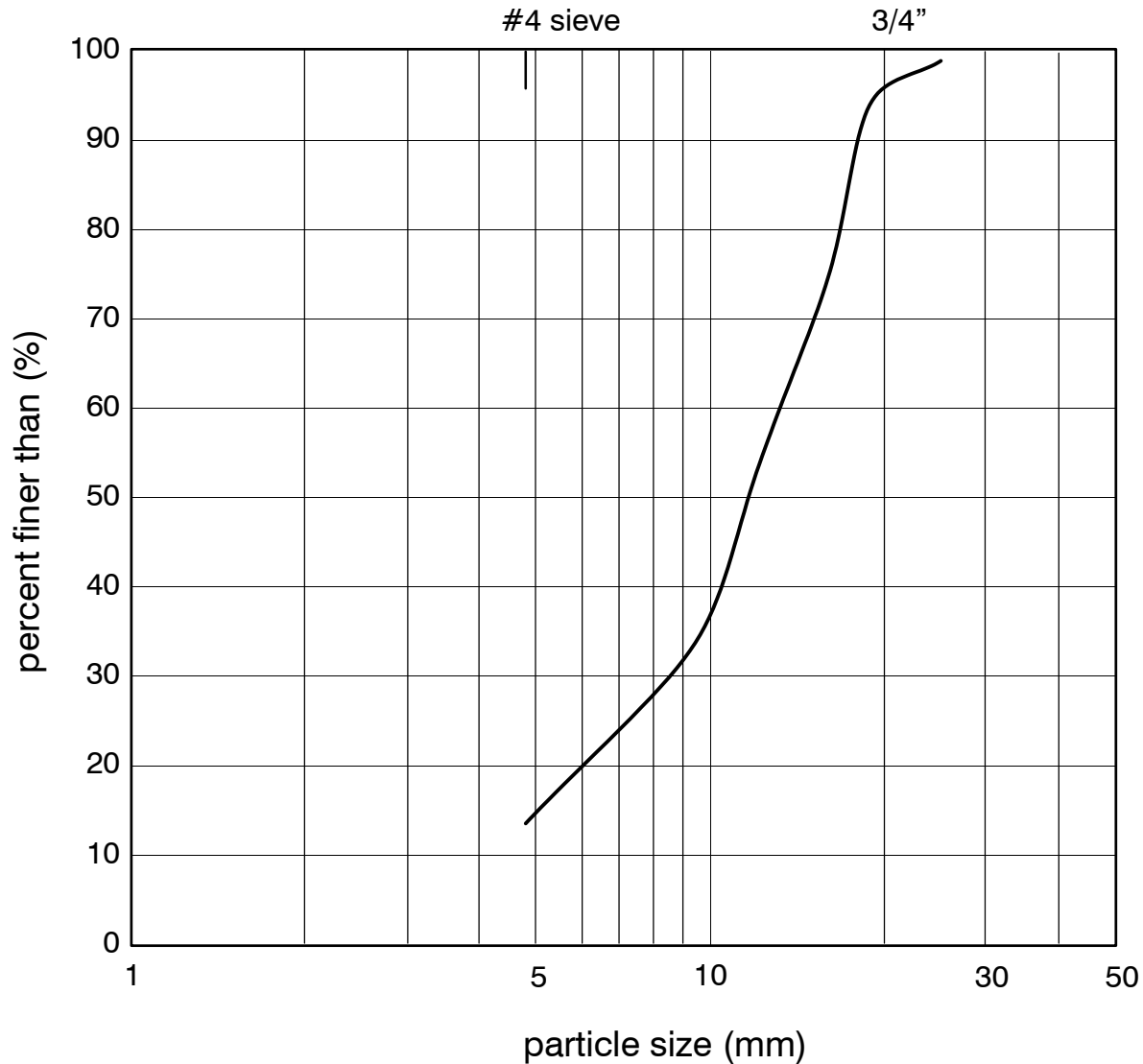


Figure 2: Particle size distribution for 100% crushed granular stone used in RR-N 115 block tests

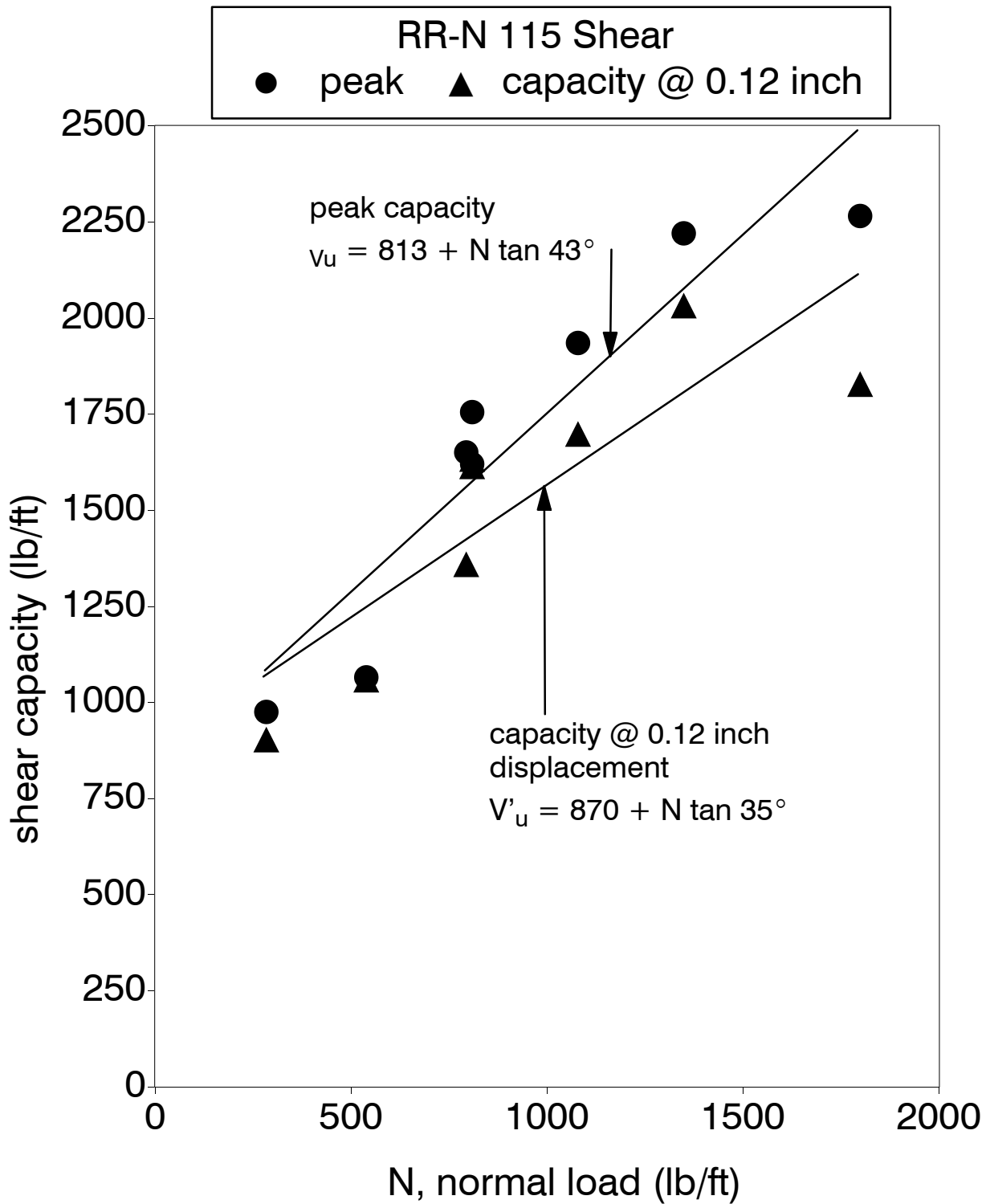


Figure 3: Summary of interface shear capacities for RR-N 115 block



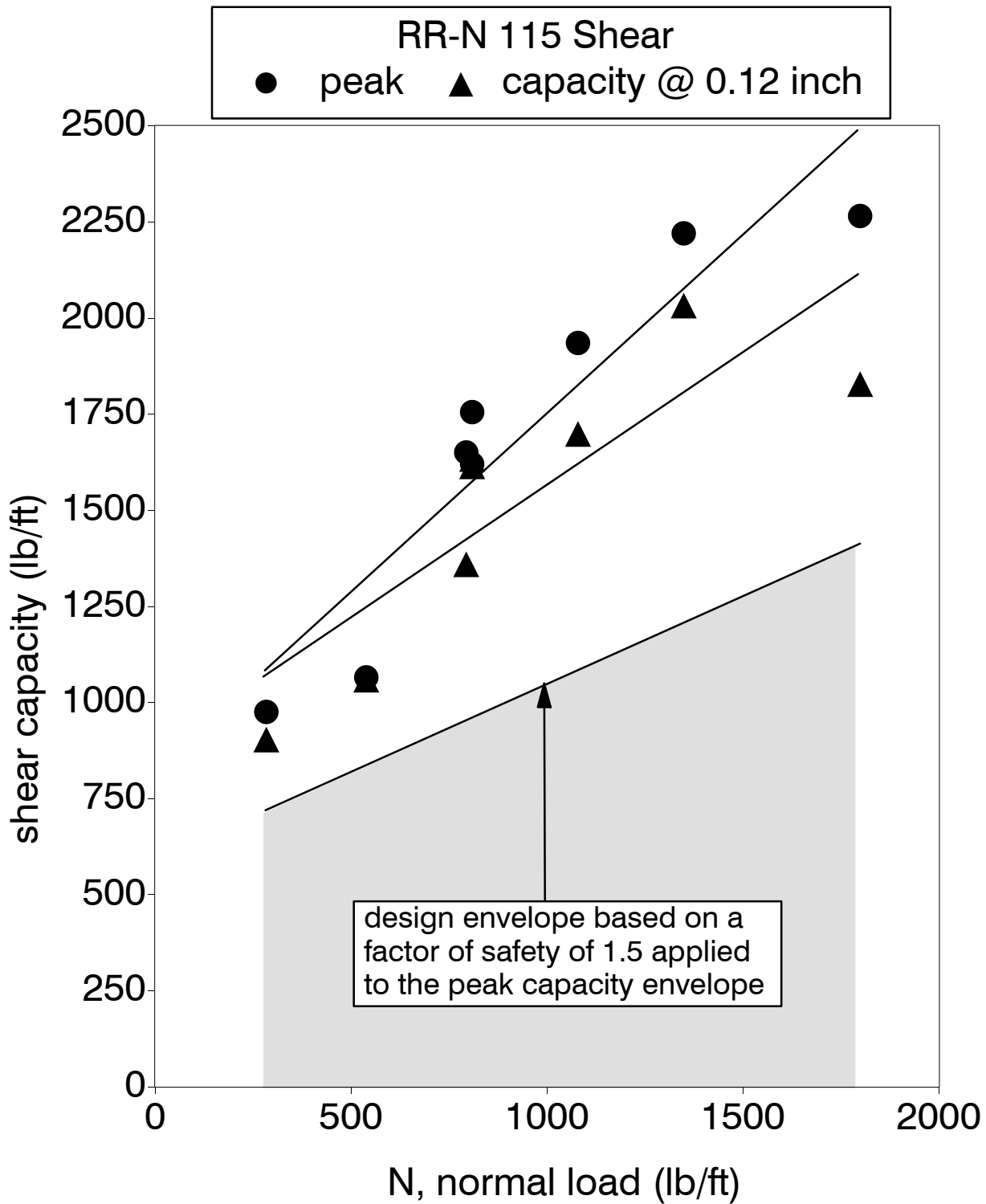


Figure 4: Preliminary design envelope of interface shear capacities for RR-N 115 block

**REPORT**  
**RESULTS OF**  
**REDI-ROCK NATURESCAPES 115 SERIES UNIT**  
**WITH A SINGLE LAYER INCLUSION OF**  
**MIRAGRID 5XT**  
**SHEAR CAPACITY TESTING**

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## Introduction

This report gives the results of a shear capacity testing program carried out to evaluate the mechanical/frictional performance of the shear capacity between Redi-Rock Naturescapes 115 Series<sup>®</sup> (RR-N 115) modular concrete block units manufactured by Redi-Rock International, LLC with a single layer inclusion of Miragrid 5XT.

The test program was initiated in response to a verbal authorization to proceed from Mr. Jack Bergmann of Redi-Rock International, LLC. received 22 April 2009.

The tests were carried out at the laboratories of Bathurst, Clarabut Geotechnical Testing, Inc. in Kingston, Ontario, under the supervision of Mr. Peter Clarabut.

## Objectives of test program

The interface shear capacity between RR-N 115 block concrete units placed in a staggered joint (running bond) configuration was investigated using a large-scale test apparatus.

The principal objective of the testing was to evaluate the mechanical/frictional performance of the shear connection between successive layers of RR-N 115 block units with a single layer inclusion of Miragrid 5XT. A second objective was to make recommendations for the selection of interface shear capacities to be used in the design and analysis of retaining wall systems that employ RR-N 115 block units.

## Materials

RR-N 115 block units are hollow core concrete blocks weighing approximately 55 pounds per unit (68 pounds per units when units are core filled with 3/4 inch crushed limestone, weight/unit measured in our laboratory). The nominal dimensions of the block are 11 inches wide (toe to heel) by 6 inches high by 18 inches long. Construction alignment and wall batter is achieved by means of two cast-in-place concrete keys on the bottom surface of the units. The installation arrangement is illustrated in **Figure 1**. The blocks used in this series of tests were supplied by Redi-Rock International of Charlevoix, Michigan and designated as BIC 09-022 received 28 April 2009.

Miragrid 5XT is a bi-directional grid composed of 100% polyester multifilament yarn with a tensile strength of 4300 lb/ft in the machine direction (based on ASTM D 6637 method of test, and reported in the 2007 Geosynthetics Specifier's Guide, published December 2006). The geogrid specimens used in this series of testing were cut from roll/lot # 031387847/07294-1-3 received at our laboratory on 27 August 2008.

## Apparatus and general test procedure

The SRWU-2 method of test as reported in the NCMA Segmental Retaining Wall Design Manual (1993) and ASTM D 6916-03 was used in this investigation. A brief description of the

apparatus and test methodology is presented here. The apparatus used to perform the tests is illustrated in **Figure 1**. The test apparatus allows horizontal loads of up to 35,000 lbf to be applied across the interface between two block layers. The segmental units were laterally restrained at the bottom and surcharged vertically. A single block was placed over the geogrid and one centrally located running bond (joint) formed by the two underlying units to simulate the staggered construction procedure typically used in the field. The spaces between blocks were infilled with a 3/4 inch, 100% crushed limestone aggregate and lightly compacted. **Figure 2** illustrates the particle size distribution of the infill used in this test series. Wall heights were simulated by placing a single block over the interface and applying additional normal load using the air bag arrangement shown in **Figure 1**. The horizontal (shear) force was applied at a constant rate of displacement using a computer-controlled hydraulic actuator. The load and displacements measured by the actuator and displacement transducers were recorded continuously during the test by a microcomputer/data acquisition system. Each test was continued until large shear displacements were achieved. Following each test, the blocks were removed and the units examined to confirm failure modes.

The only variable in this series of interface shear tests was the magnitude of surcharge (i.e. the magnitude of normal load applied to the top segmental unit). The normal loads used in the test program are given in **Table 1**.

### Test results

Results of interface shear tests are summarized in **Table 1**. Peak interface shear capacities and shear capacity at the displacement criterion (0.12 inch) are plotted against normal load in **Figure 3**. The displacement criterion was calculated to be 0.12 inch based on 2% of the block height. The minimum *peak* shear capacity recorded from the test series was 825 lb/ft. In all tests, failure was observed as failure of the concrete shear key.

The test results reveal some scatter in shear capacity for tests carried out at nominal similar normal loads. The three tests carried out at a nominal equivalent normal load of about 819 lb/ft (**Tests 1, 4 and 8**) gave peak shear capacity values that ranged from 1740 to 1935 lb/ft with a mean value of 1810 lb/ft. This scatter is less than  $\pm 10\%$  of the mean peak shear criterion required by the NCMA (e.g. maximum variability is 6.9%) and is likely the result of small differences in the setting up of the blocks and geogrid, placement of the granular infill and compaction. The trend in data for shear loads at 0.12 inches of displacement has been plotted using a linear curve. The trend in data for peak shear loads has been plotted using a bi-linear curve.

### Implications to interface shear capacity design and construction with RR-N 115 block units with a single layer inclusion of Miragrid 5XT

The interface shear strength in the field may be less than the values determined in this test series for the same method and quality of construction. The NCMA Segmental Retaining Wall Design Manual (First Edition, 1993) recommends that the design shear capacity at a given nor-

mal load for a critical wall structure be the lesser of: a) the peak capacity divided by a minimum factor of safety (not less than 1.5) or; b) the capacity based on the 0.12 inch displacement criterion. The *design* interface shear capacity envelope shown in **Figure 4** is controlled by the peak shear capacity criterion.

The design shear capacity envelope illustrated in **Figure 4** should be used with caution. The actual design capacity envelope should be lower if the quality of construction in the field is less than that adopted in this controlled laboratory investigation and/or lower quality concrete is used in the manufacture of the blocks. In addition, the interface concrete surfaces should be free of aggregate particles in order to maximize the frictional resistance that is developed between the concrete surfaces.

### Summary of conclusions

A laboratory testing program was carried out to evaluate the mechanical/frictional performance of the shear connection between RR-N 115 block segmental concrete units with a single layer inclusion of Miragrid 5XT. The following conclusions can be drawn:

1. The minimum *peak* shear capacity recorded from this test series was 825 lb/ft (height above interface equal to 6.3 block units).
2. Variability in shear capacity was observed between nominal identical tests due to small differences in setting up of the blocks, placement and compaction of the granular infill and possibly small variations in block dimensions.
3. The design envelope in **Figure 4** is based on interpretation of test data as recommended in the NCMA Segmental Retaining Wall Design Manual (First Edition, 1993). The choice of design interface shear capacity may vary with quality of construction in the field and hence lower design values than those taken from **Figure 4** may be appropriate.

### Concluding remarks

The test results presented here are applicable to conventional and geosynthetic reinforced-soil segmental retaining wall designs that employ RR-N 115 block units together with Miragrid 5XT. The inclusion of a layer of geosynthetic reinforcement other than Miragrid 5XT may reduce the interface shear capacity to values less than those reported in this investigation.



P. Clarabut



R. J. Bathurst, Ph.D., P. Eng.

## REFERENCES

ASTM D 6638-01. Standard Test Method for Determining Connection Strength between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks), American Society for Testing and Materials, West Conshohocken, PA 19428-2958 USA.

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**Table 1****Test Program:**

Shear capacity results for RR-N 115 modular block unit combination with a single layer inclusion of Miragrid 5XT

Test number	normal load (lb/ft)	approximate wall height (feet)	approximate number of blocks	Shear load at 0.12 inches displacement (lb/ft)	shear load at PEAK (lb/ft)
1	824	9.2	18.3	1274	1935
2	284	3.2	6.3	818	825
3	539	6.0	12.0	1148	1185
4	809	9.0	18.0	1505	1740
5	1094	12.2	24.3	1611	2040
6	1334	14.8	29.6	1869	2325
7	1799	20.0	40.0	2109	2265
8	824	9.2	18.3	1223	1755

- |    |                      |    |                         |
|----|----------------------|----|-------------------------|
| 1  | loading frame        | 2  | horizontal actuator     |
| 3  | horizontal load cell | 4  | reaction beam           |
| 5  | vertical load cell   | 6  | air bag                 |
| 7  | platform             | 8  | spacers                 |
| 9  | RR-N 115 block       | 10 | displacement transducer |
| 11 | Miragrid 5XT         |    |                         |

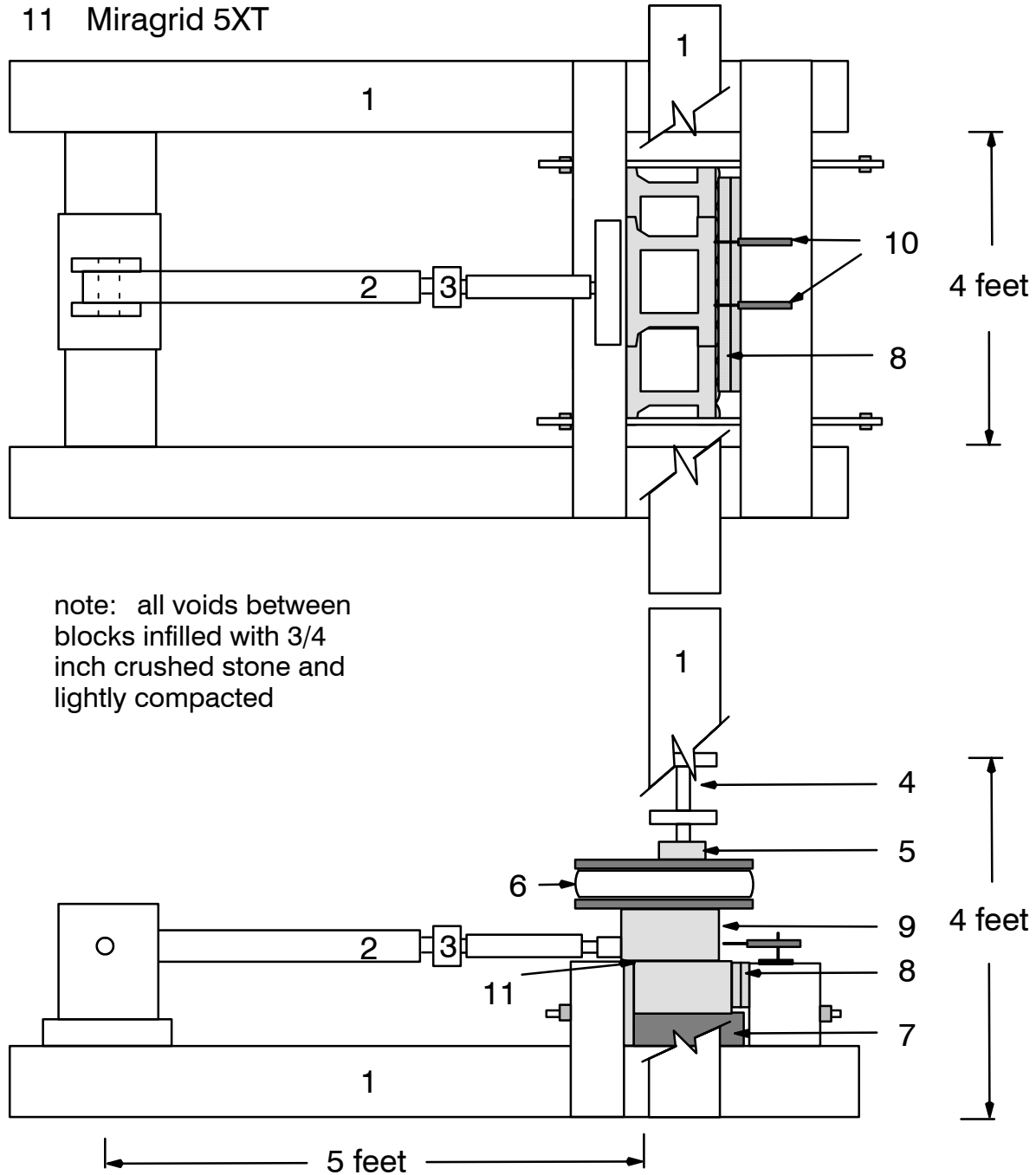


Figure 1: Schematic of shear capacity test apparatus showing RR-N 115 block segmental concrete units



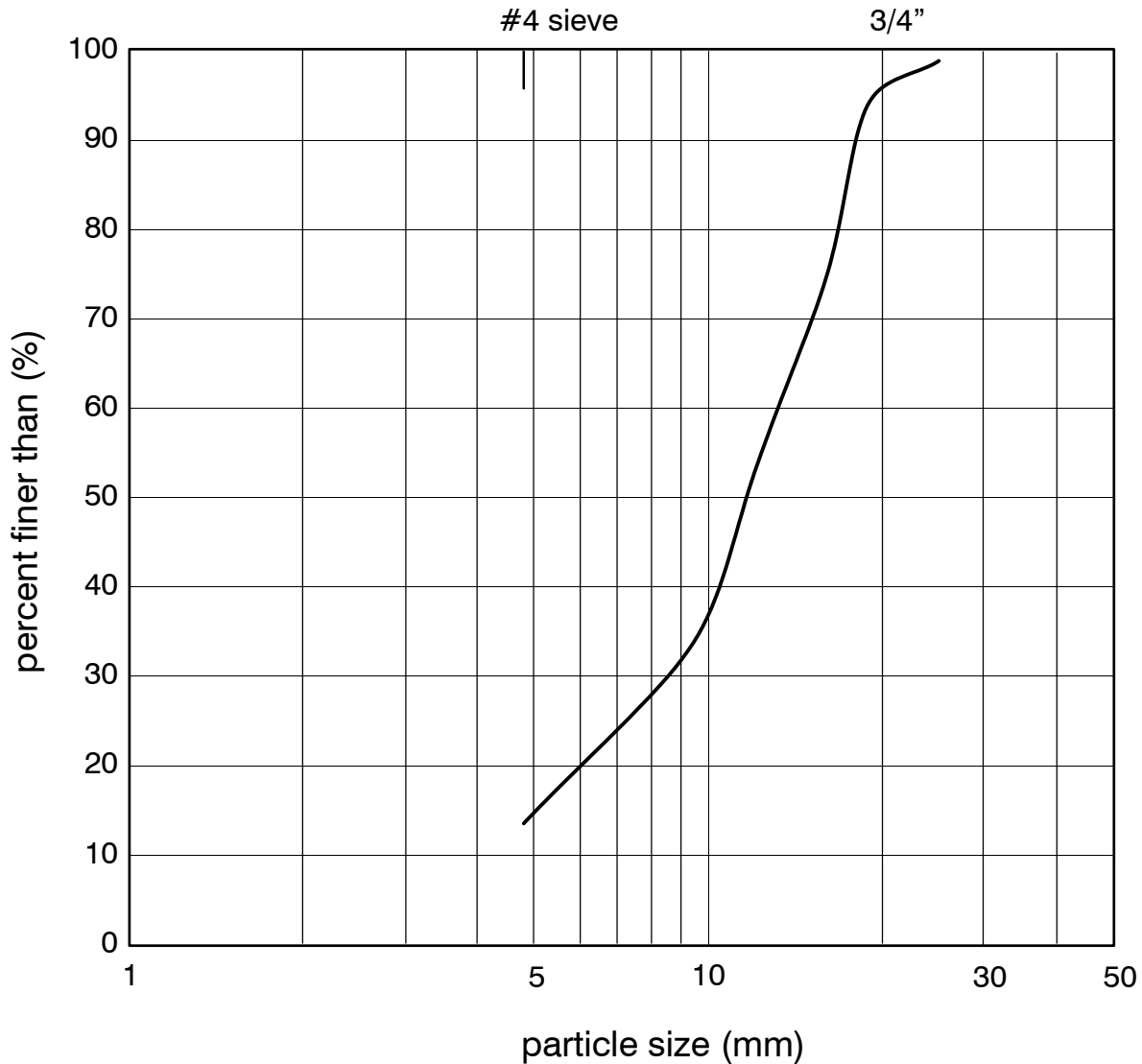


Figure 2: Particle size distribution for 100% crushed granular stone used in RR-N 115 block tests

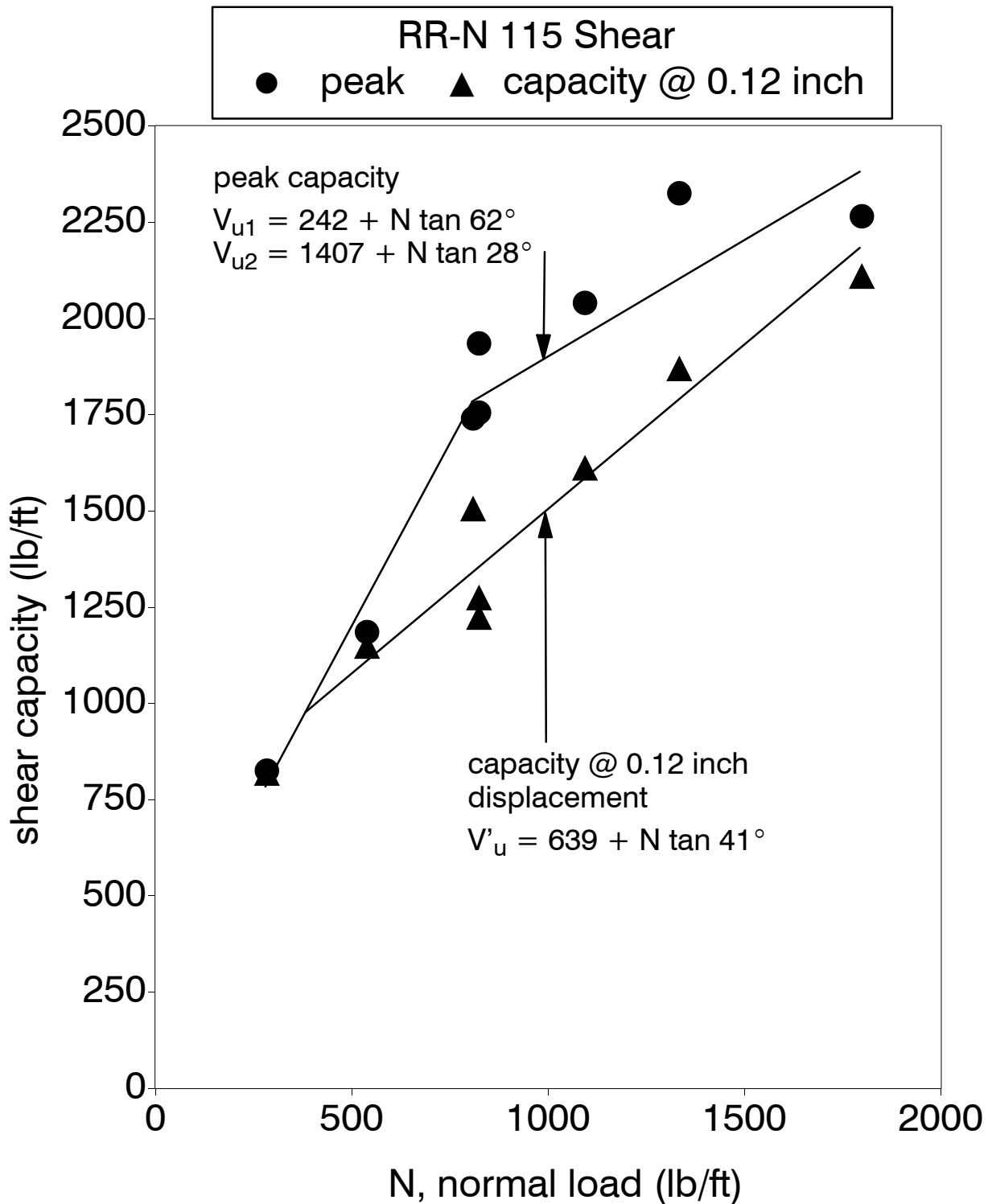


Figure 3: Summary of interface shear capacities for RR-N 115 block with a single layer inclusion of Miragrid 5XT

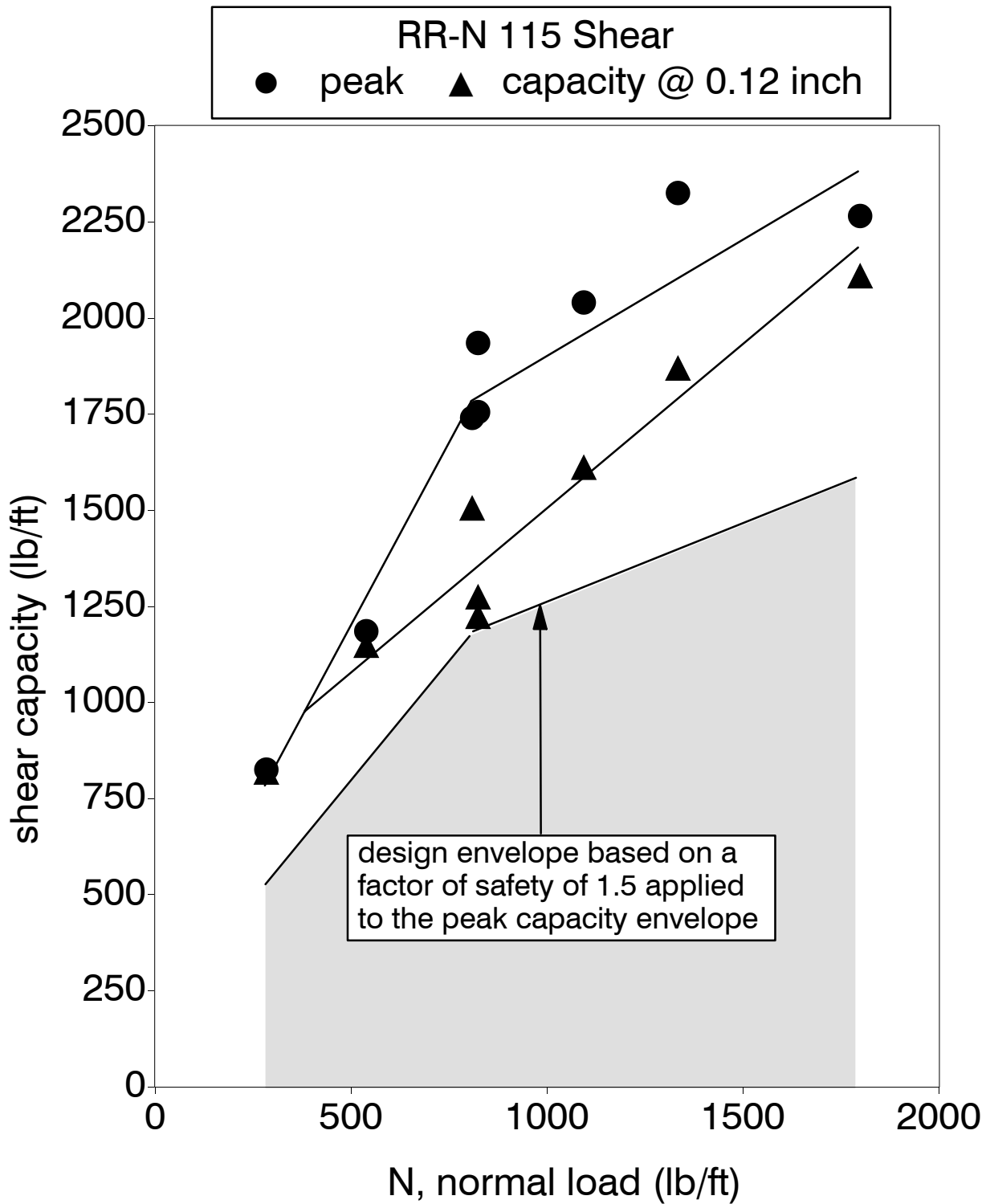


Figure 4: Preliminary design envelope of interface shear capacities for RR-N 115 block with a single layer inclusion of Miragrid 5XT