# INTERFACE SHEAR DESIGN PARAMETERS

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Test Methods: ASTM D6916 & NCMA SRWU-2
Block Type: 28" Positive Connection (PC) Block
Test Facility: Bathurst, Clarabut Geotechnical Testing, Inc.
Test Dates: 10/21/2011 - 6.75" Shear Knob Test
10/14/2011 - 10" Shear Knob Test

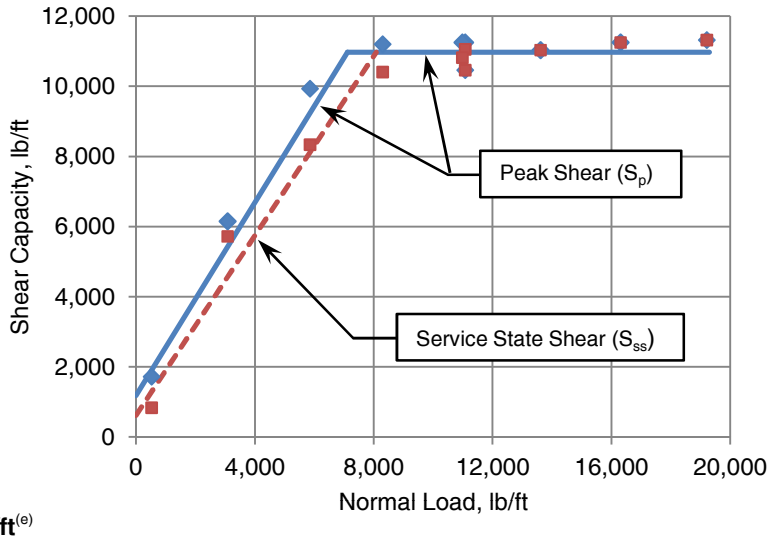
## 6.75" KNOB INTERFACE SHEAR DATA[a]

| Test No. | Normal Load, lb/ft | Service State Shear, lb/ft[c] | Peak Shear, lb/ft | Observed Failure[d] |
|---|---|---|---|---|
| 1 | 522 | 838 | 1,724 | Test Stopped |
| 2 | 19,209 | 11,324 | 11,324 | Test Stopped |
| 3 | 16,303 | 11,252 | 11,252 | Test Stopped |
| 4 | 13,612 | 11,036 | 11,036 | Test Stopped |
| 5 | 11,075 | 10,462 | 10,462 | Test Stopped |
| 6 | 11,074 | 11,060 | 11,252 | Knob Shear |
| 7 | 8,299 | 10,408 | 11,204 | Test Stopped |
| 8 | 5,854 | 8,337 | 9,935 | Knob Shear |
| 9 | 3,077 | 5,722 | 6,153 | Knob Shear |
| 10 | 10,981 | 10,821 | 11,252 | Knob Shear |

**Peak Shear: $S_p$ = 1,178 + N tan 54°, $S_{p(max)}$ = 10,970 lb/ft[e]**

**Service State Shear: $S_{ss}$ = 616 + N tan 52°, $S_{ss(max)}$ = 10,970 lb/ft[e]**

## 6.75" KNOB INTERFACE SHEAR CAPACITY



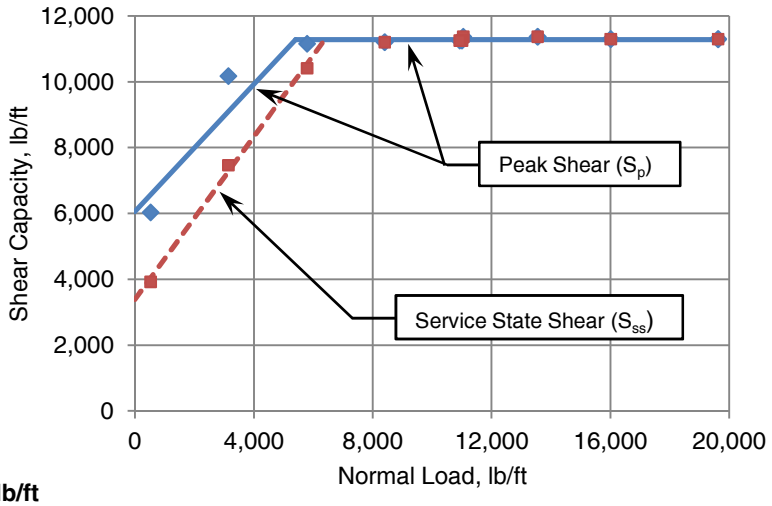

## 10" KNOB INTERFACE SHEAR DATA[b]

| Test No. | Normal Load, lb/ft | Service State Shear, lb/ft[c] | Peak Shear, lb/ft | Observed Failure[d] |
|---|---|---|---|---|
| 1 | 19,619 | 11,300 | 11,300 | Test Stopped |
| 2 | 16,007 | 11,300 | 11,300 | Test Stopped |
| 3 | 13,546 | 11,371 | 11,371 | Test Stopped |
| 4 | 11,042 | 11,371 | 11,371 | Test Stopped |
| 5 | 8,400 | 11,204 | 11,204 | Test Stopped |
| 6 | 10,999 | 11,252 | 11,252 | Test Stopped |
| 7 | 10,922 | 11,252 | 11,252 | Test Stopped |
| 8 | 5,786 | 10,414 | 11,156 | Test Stopped |
| 9 | 3,137 | 7,469 | 10,174 | Test Stopped |
| 10 | 522 | 3,926 | 6,033 | Test Stopped |

**Peak Shear: $S_p$ = 6,061 + N tan 44°, $S_{p(max)}$ = 11,276 lb/ft**

**Service State Shear: $S_{ss}$ = 3,390 + N tan 51°, $S_{ss(max)}$ = 11,276 lb/ft**

## 10" KNOB INTERFACE SHEAR CAPACITY




(a) The maximum 28-day compressive strength of all concrete blocks tested in the 6.75 inch knob interface shear test series was 4,694 psi.
(b) The 28-day compressive strength of all concrete blocks tested in the 10 inch knob interface shear test series was 4,474 psi.
(c) Service State Shear is measured at a horizontal displacement equal to 2% of the block height. For Redi-Rock blocks, displacement = 0.36 inches.
(d) In most cases, the test was stopped before block rupture or knob shear occured to prevent damage to the test apparatus.
(e) Design shear capacity inferred from the test data reported herein should be lowered when test failure results from block rupture or knob shear if the compressive strength of the blocks used in design is less than the blocks used in this test. The data reported represents the actual laboratory test results. The equations for peak and service state shear conditions have been modified to reflect the interface shear performance of concrete with a minimum 28-day compressive strength equal to 4,000 psi. No further adjustments have been made. Appropriate factors of safety for design should be added.

# REPORT

# RESULTS OF

# REDI-ROCK 28 INCH PC BLOCK UNIT

# (6 INCH DOME)

# INTERFACE SHEAR CAPACITY TESTING

submitted to

REDI-ROCK INTERNATIONAL

CONFIDENTIAL

Distribution:

2 copies Redi-Rock International LLC.
05481 US 31 South
Charlevoix, Michigan 49720
USA

2 copies Bathurst, Clarabut Geotechnical Testing, Inc.
1167 Clyde Court, Kingston, Ontario
K7P 2E4 CANADA

**Introduction**

This report gives the results of an interface shear testing program carried out to evaluate the mechanical/frictional performance of the shear capacity between Redi-Rock® 28 inch PC modular concrete block units.

The test program was initiated in response to a verbal authorization to proceed from Mr. Jamie Johnson of Redi-Rock International, LLC received 9 August 2011.

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 Redi-Rock 28 inch PC block units (6 inch dome) was investigated using a large-scale test apparatus.

The principal objective of the testing was to evaluate the mechanical/frictional performance of the shear capacity between successive layers of Redi-Rock 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 Redi-Rock block units.

**Materials**

Redi-Rock 28 inch PC Middle Block units are solid concrete blocks weighing approximately 1540 lb per unit (estimated weight based on volume of concrete and assuming a concrete unit weight of 143 lb/ft$^3$). The nominal dimensions of the block are 28 inches (toe to heel) by 18 inches high by 46 inches long. Construction alignment and interface shear is achieved by means of two 6.75 inch (6 inch) diameter dome shaped concrete shear keys cast into the top surface of the units. A photograph of the dome shaped shear key is shown in **Figure 1**. A photograph of the block system in the large scale test frame is shown in **Figure 2** The blocks used in this series of tests were supplied by Redi-Rock International and were received at our laboratory on 9 August 2011. The specific blocks used in each test are reported on **Table 1**.

**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 were used in this investigation. A brief description of the apparatus and test methodology is presented here. The test apparatus allows horizontal loads in excess of 12,000 lb/ft to be applied across the interface between two block layers. The segmental units were laterally restrained at the bottom and surcharged vertically. Wall heights were simulated by placing a single block over the interface and applying additional normal load using the hydraulic ram 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 re-

corded continuously during the test by a microcomputer/data acquisition system. Each test was continued until the safe working limit of the apparatus was reached or block dialation/ rotation occured. Following each test, the blocks were removed and the units examined to confirm failure modes (if any).

The only variable in this series of connection tests was the magnitude of surcharge load.

**Test results**

Results of interface shear tests are summarized in **Table 1**. Peak interface shear capacities and shear capacity at the displacement criterion (if achieved) are plotted against normal load in **Figure 4**. The displacement criterion was calculated to be 0.36 inches based on 2% of the block height. The minimum *peak* shear capacity recorded from the test series was 6153 lb/ft. **Test 1** was stopped after significant block dilation and some column rotation was observed. **Tests 2, 3, 4, 5** and **7** were stopped before failure of the blocks occurred in order to prevent damage to the test apparatus. **Tests 6, 8, 9** and **10** ended in shearing of the concrete shear dome. In **Tests 2, 3, 4** and **5** measured peak shear capacity was achieved before 0.36 inches of displacement.

**Implications to interface shear capacity design and construction with Redi-Rock 28 inch PC block units**

The maximum shear capacity values for **Tests 2, 3, 4, 5** and **7** reported herein are conservative estimates of the peak shear capacity of the Redi-Rock block system because the safe working capacity of the test apparatus was exceeded. Hence, the use of the maximum shear capacity values reported herein will result in an unquantified additional margin of safety for the nominal identical system in the field. 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 0.36 inch displacement criterion. Nevertheless, the design shear capacity envelope inferred from the test data reported herein 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 capacity between Redi-Rock 28 inch PC block segmental concrete units. The following conclusions can be drawn:

1. The minimum *peak* shear capacity recorded from this test series was 6153 lb/ft (height above interface equal to approximately 1 block unit).

2. Care must be taken during the installation of Redi-Rock block units in order to prevent accumulation of soil and rock debris at the concrete block interface surfaces. This debris may significantly reduce the shear capacity of the Redi-Rock block facing unit system.
3. The actual peak shear capacity of the Redi – Rock 28 inch PC block system may be expected to be greater than the values reported herein since the safe working capacity of the test apparatus was exceeded before shear failure of the blocks could be achieved.

**Concluding remarks**

The test results presented here are applicable to gravity and geosynthetic reinforced-soil segmental retaining wall designs that employ Redi-Rock 28 inch (6 inch dome) PC block units. However, the inclusion of a layer of geosynthetic reinforcement between courses may reduce the interface shear capacity to values less than those reported in this investigation.

## Table 1:

## Test program:
## Interface shear capacity of Redi-Rock 28 inch PC segmental concrete block units

| Test number | normal load (lb/ft) | shear strength at 0.36 inches displacement (lb/ft) | peak shear capacity (lb/ft) | block reference |
|---|---|---|---|---|
| 1 | 522 | 838 | 1724 | RR061611-10 over RR061611-6 |
| 2 | 19209 | 11324 | 11324 | RR062411-10 over RR062411-6 |
| 3 | 16303 | 11252 | 11252 | RR062411-10 over RR062411-6 |
| 4 | 13612 | 11036 | 11036 | RR062411-10 over RR062411-6 |
| 5 | 11075 | 10462 | 10462 | RR061611-10 over RR062411-6 |
| 6 | 11074 | 11060 | 11252 | RR061411-10 over RR062411-6 |
| 7 | 8299 | 10408 | 11204 | RR061411-10 over RR061411-6 |
| 8 | 5854 | 8337 | 9935 | RR061411-10 over RR061411-6 |
| 9 | 3077 | 5722 | 6153 | RR062211-10 over RR062211-6 |
| 10 | 10981 | 10821 | 11252 | RR062111-10 over RR062111-6 |

P. Clarabut

# REFERENCE

ASTM D 6916-03. Standard Test Method for Determining Shear Strength between Segmental Concrete Units (Modular Concrete Blocks), American Society for Testing and Materials, West Conshohocken, PA 19428-2958 USA.

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

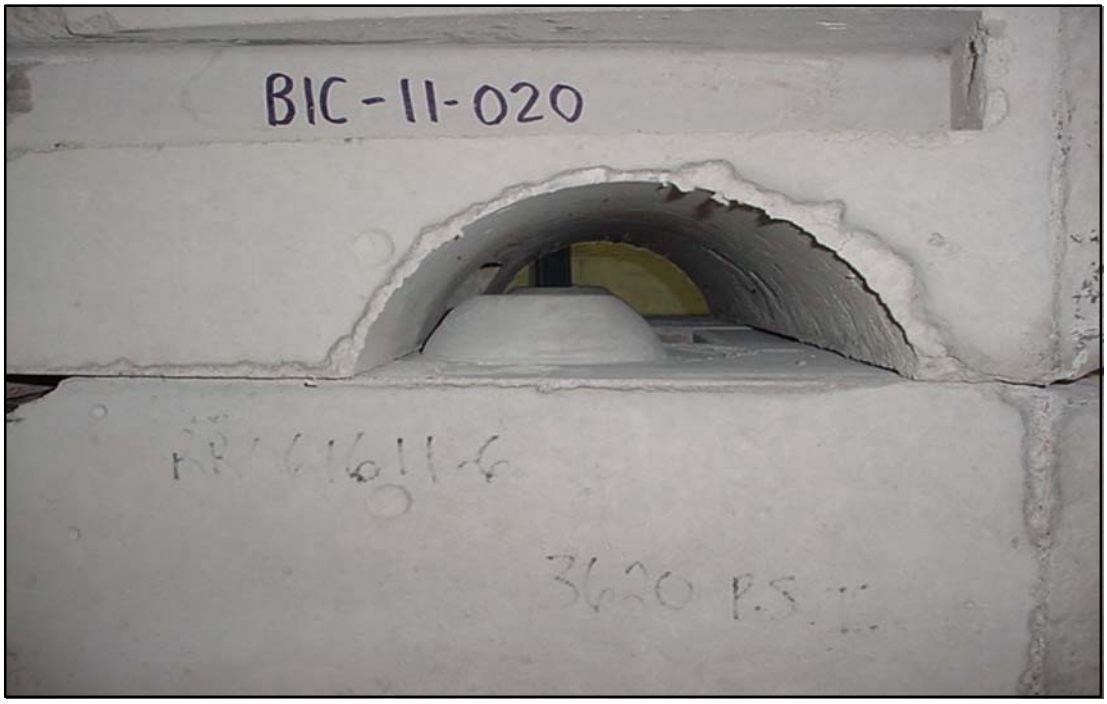



Figure 1: Photograph of the Redi-Rock blocks in the shear test frame

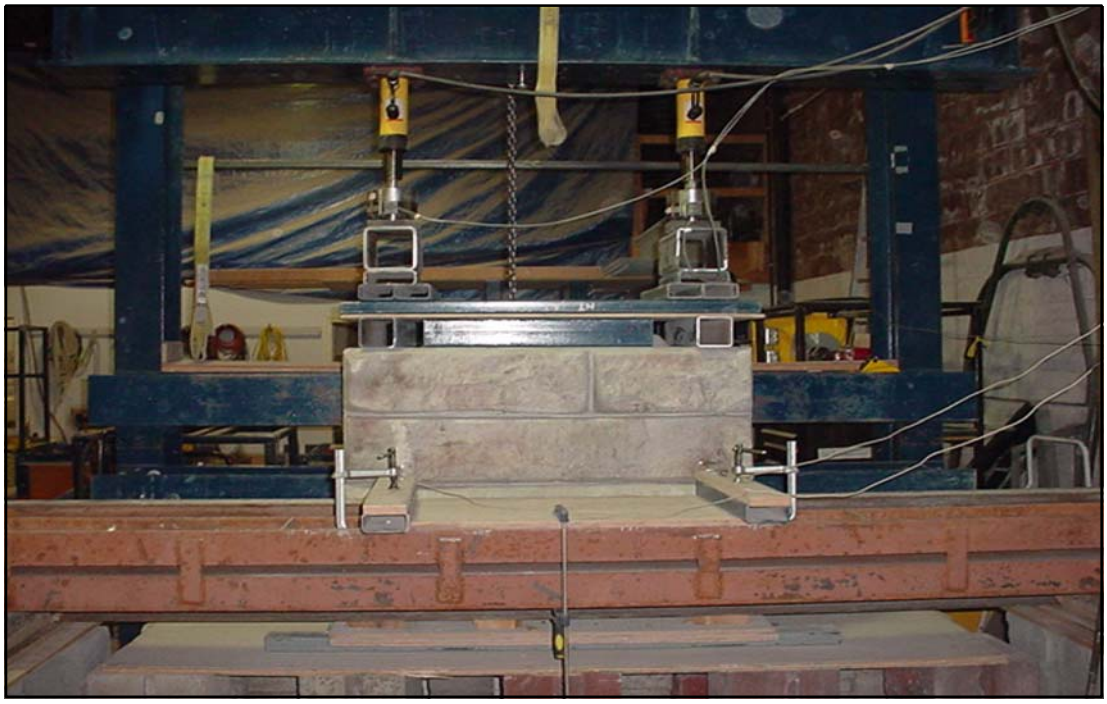


Figure 2: Photograph of the Redi-Rock blocks in the shear test frame

| | | | | | |
|---|---|---|---|---|---|
| 1 | Redi-Rock block | 6 | actuator support | 11 | reaction beam |
| 2 | load cell | 7 | LVDT | 12 | computer controlled hydraulic actuator |
| 3 | loading platen | 8 | 2 actuators | | |
| 4 | piston | 9 | loading frame | | |
| 5 | lateral restraining system | 10 | spacers | | |

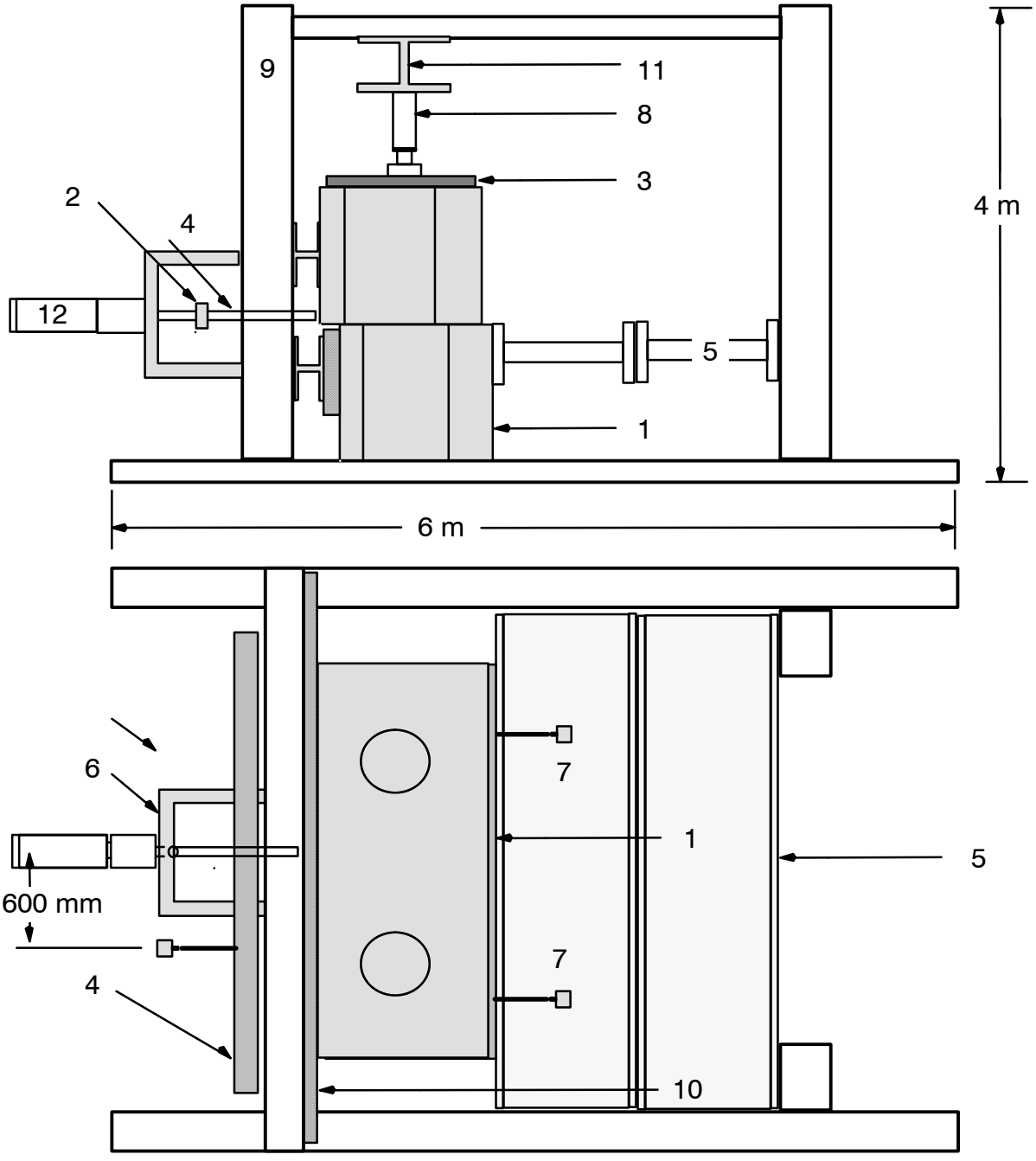



Figure 3: Schematic of large scale shear test apparatus showing Redi-Rock 28 inch PC block units

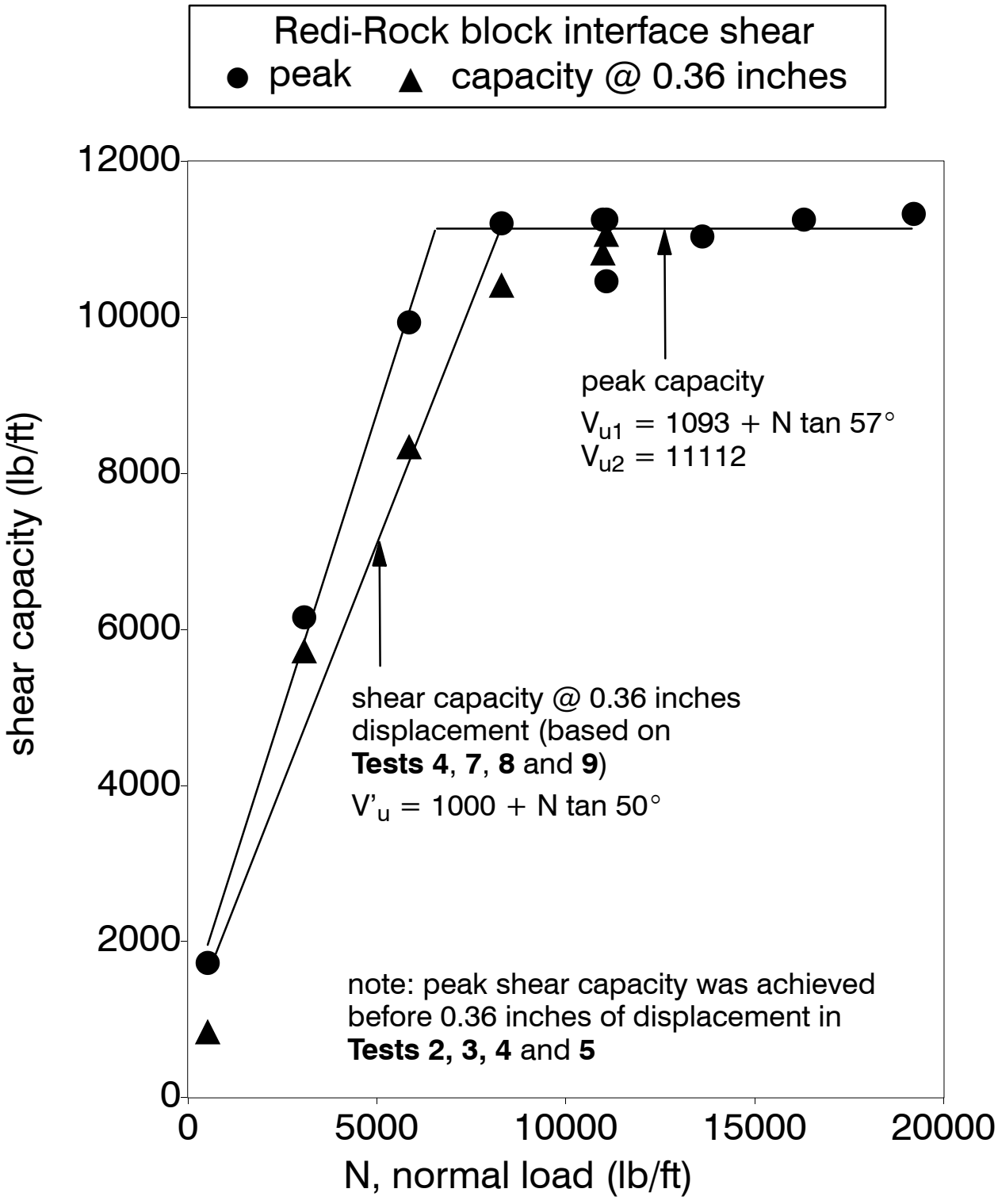



Figure 4: Summary of interface shear capacities for Redi-Rock 28 inch PC block units

# REPORT

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# (10 INCH DOME)

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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 Redi-Rock 28 inch PC block units (10 inch dome) was investigated using a large-scale test apparatus.

The principal objective of the testing was to evaluate the mechanical/frictional performance of the shear capacity between successive layers of Redi-Rock 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 Redi-Rock block units.

**Materials**

Redi-Rock 28 inch PC Middle Block units are solid concrete blocks weighing approximately 1540 lb per unit (estimated weight based on volume of concrete and assuming a concrete unit weight of 143 lb/ft$^3$). The nominal dimensions of the block are 28 inches (toe to heel) by 18 inches high by 46 inches long. Construction alignment and interface shear is achieved by means of two 10 inch diameter dome shaped concrete shear keys cast into the top surface of the units. A photograph of the dome shaped shear key is shown in **Figure 1**. A photograph of the block system in the large scale test frame is shown in **Figure 2** The blocks used in this series of tests were supplied by Redi-Rock International (Redi-Rock concrete batch #RR062211) and were received at our laboratory on 9 August 2011 and designated as BIC-11-023 and BIC-11-024. The tested compressive strength of the concrete from batch #RR062211 was 4474 psi (as reported by Redi-Rock International).

**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 were used in this investigation. A brief description of the apparatus and test methodology is presented here. The test apparatus allows horizontal loads in excess of 12,000 lb/ft to be applied across the interface between two block layers. The segmental units were laterally restrained at the bottom and surcharged vertically. Wall heights were simulated by placing a single block over the interface and applying additional normal load using the hydraulic ram 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 the safe working limit of the apparatus was reached or block dialation/ rotation occured. Following each test, the blocks were removed and the units examined to confirm failure modes (if any).

The only variable in this series of connection tests was the magnitude of surcharge load.

**Test results**

Results of interface shear tests are summarized in **Table 1**. Peak interface shear capacities and shear capacity at the displacement criterion (0.36 inches) are plotted against normal load in **Figure 4**. The displacement criterion was calculated to be 0.36 inches based on 2% of the block height. The minimum *peak* shear capacity recorded from the test series was 6033 lb/ft. **Tests 1-8** were stopped before failure of the blocks occurred in order to prevent damage to the test apparatus. Tests 9 and 10 were stopped after significant block dilation and some column rotation was observed. In **Tests 1-7** measured peak shear capacity was achieved before 0.36 inches of displacement.

**Implications to interface shear capacity design and construction with Redi-Rock 28 inch PC block units**

The maximum shear capacity values for **Tests 1-8** reported herein are conservative estimates of the peak shear capacity of the Redi-Rock block system because the safe working capacity of the test apparatus was exceeded. Hence, the use of the maximum shear capacity values reported herein will result in an unquantified additional margin of safety for the nominal identical system in the field. 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 0.36 inch displacement criterion. Nevertheless, the design shear capacity envelope inferred from the test data reported herein 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 capacity between Redi-Rock 28 inch PC block segmental concrete units. The following conclusions can be drawn:

1. The minimum *peak* shear capacity recorded from this test series was 6033 lb/ft (height above interface equal to 1 block unit).

2. The average maximum shear capacity recorded from this test series was 11,276 lb/ft (**Tests 1-8**).
3. Care must be taken during the installation of Redi-Rock block units in order to prevent accumulation of soil and rock debris at the concrete block interface surfaces. This debris may significantly reduce the shear capacity of the Redi-Rock block facing unit system.
4. The actual peak shear capacity of the Redi – Rock 28 inch PC block system may be expected to be greater than the values reported herein since the safe working capacity of the test apparatus was exceeded before shear failure of the blocks could be achieved.

**Concluding remarks**

The test results presented here are applicable to gravity and geosynthetic reinforced-soil segmental retaining wall designs that employ Redi-Rock 28 inch PC block units. However, the inclusion of a layer of geosynthetic reinforcement between courses may reduce the interface shear capacity to values less than those reported in this investigation.

## Table 1:

Test program:
Interface shear capacity of Redi-Rock 28 inch PC segmental concrete block units

| Test number | normal load (lb/ft) | shear strength at 0.36 inches displacement (lb/ft) | peak shear capacity (lb/ft) |
|---|---|---|---|
| 1 | 19619 | 11300 | 11300 |
| 2 | 16007 | 11300 | 11300 |
| 3 | 13546 | 11371 | 11371 |
| 4 | 11042 | 11371 | 11371 |
| 5 | 8400 | 11204 | 11204 |
| 6 | 10999 | 11252 | 11252 |
| 7 | 10922 | 11252 | 11252 |
| 8 | 5786 | 10414 | 11156 |
| 9 | 3137 | 7469 | 10174 |
| 10 | 522 | 3926 | 6033 |

P. Clarabut

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Figure 1: Photograph of the Redi-Rock blocks in the shear test frame

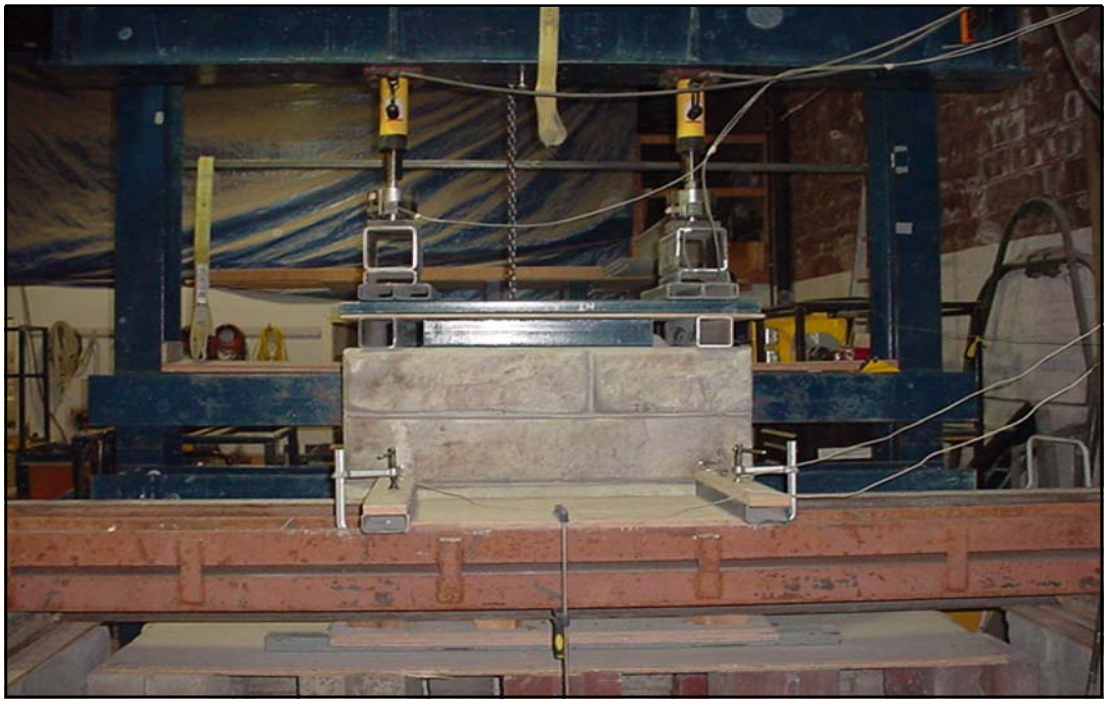

Figure 2: Photograph of the Redi-Rock blocks in the shear test frame

| | | | | | |
|---|---|---|---|---|---|
| 1 | Redi-Rock block | 6 | actuator support | 11 | reaction beam |
| 2 | load cell | 7 | LVDT | 12 | computer controlled hydraulic actuator |
| 3 | loading platen | 8 | 2 actuators | | |
| 4 | piston | 9 | loading frame | | |
| 5 | lateral restraining system | 10 | spacers | | |

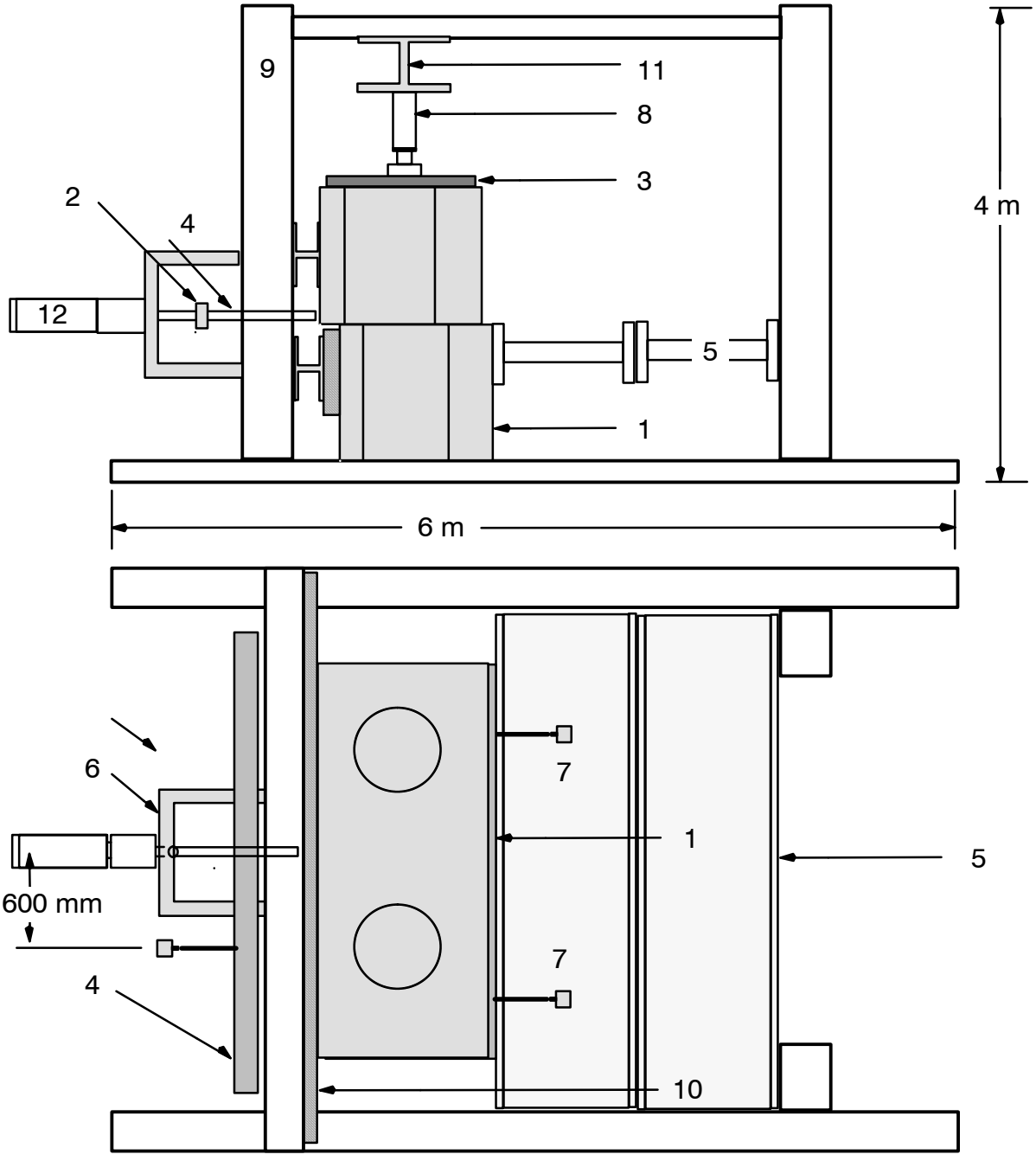


Figure 3: Schematic of large scale shear test apparatus showing Redi-Rock 28 inch PC block units

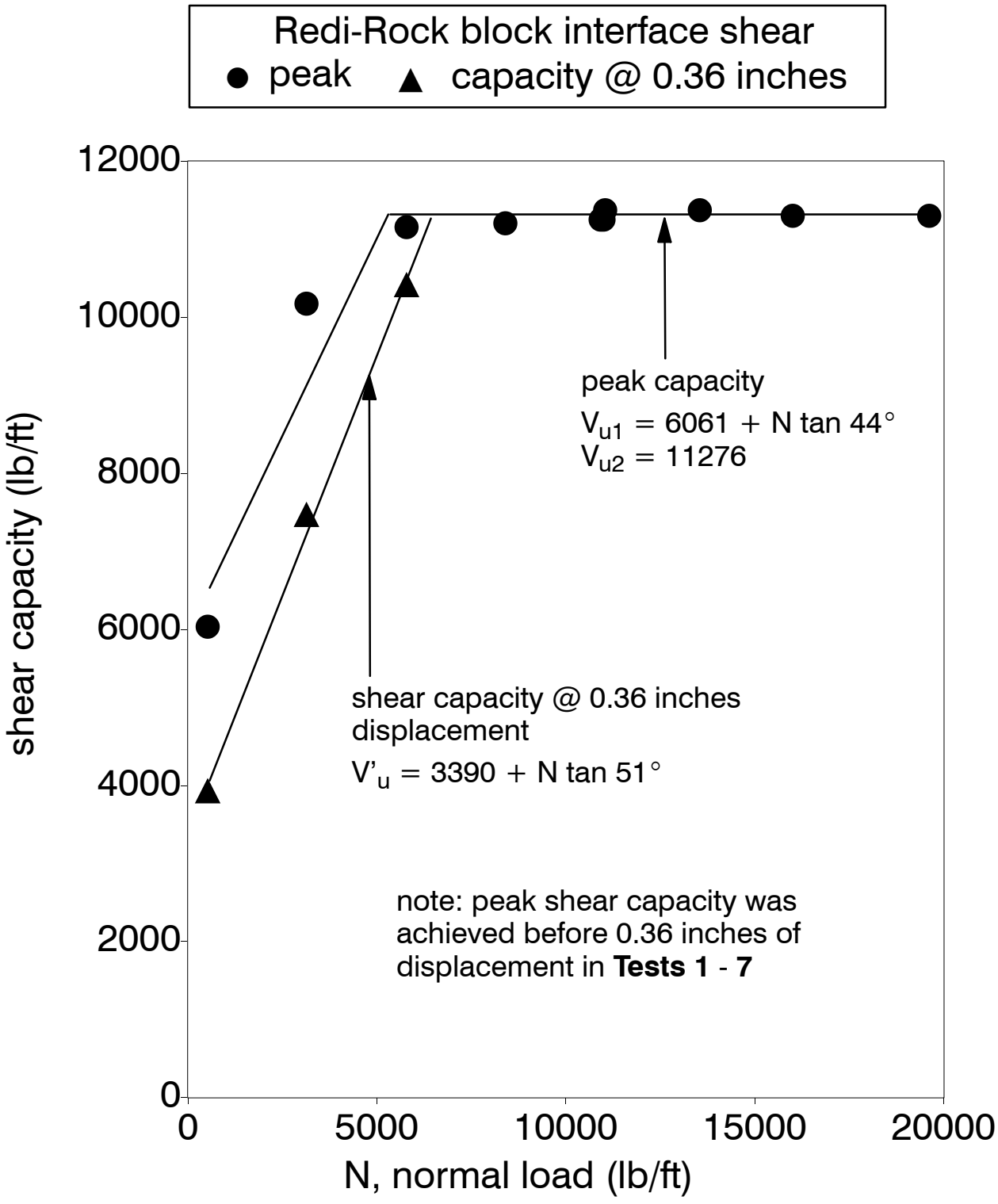


Figure 4: Summary of interface shear capacities for Redi-Rock 28 inch PC block units