XL BLOCK
INTERFACE SHEAR DESIGN PARAMETERS

Block Type: **R-5236 52" Hollow Core Retaining Block** Test Methods: ASTM D6916 & NCMA SRWU-2

INTERFACE SHEAR DATA[a]

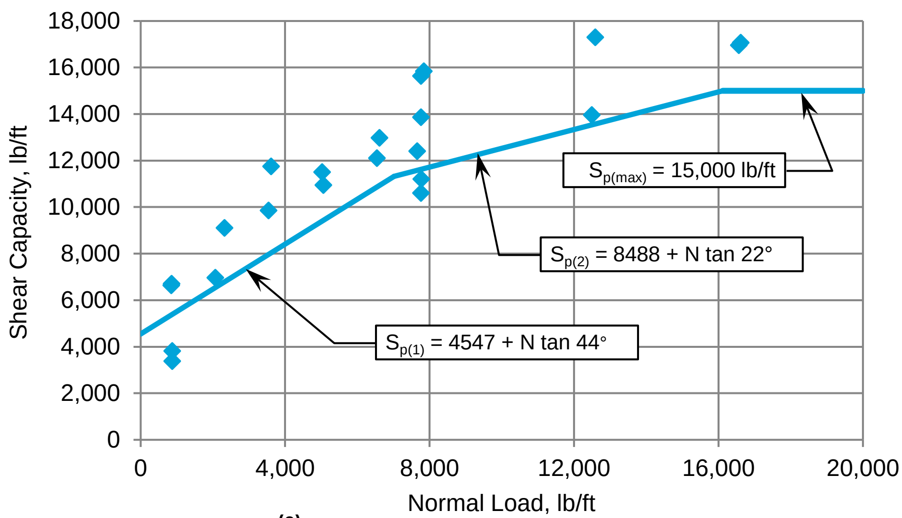
Tested By: TRI Environmental | Dec. 10-21, 2017

Test No.	Normal Load, lb/ft	Peak Shear, lb/ft	Observed Failure[b]
1	872	3,812	Test stopped - uplift
2	5,026	11,503	Knob/face shear
3	872	3,383	Test stopped - uplift
4	16,562	16,962	Test stopped - capacity
5	2,062	6,970	Test stopped - uplift
6	3,539	9,857	Test stopped - uplift
7	7,773	11,210	Knob/face shear
8	7,765	10,601	Test stopped - back cracked
9	7,656	12,405	Test stopped - back cracked
10	6,541	12,112	Test stopped - uplift
11	12,496	13,962	Test stopped - back cracked

Tested By: Redi-Rock International | Mar. 14-23, 2018

Test No.	Normal Load, lb/ft	Peak Shear, lb/ft	Observed Failure[b]
1	7,759	15,635	Test stopped - back cracked
2	7,840	15,843	Test stopped - back cracked
3	7,761	13,859	Knob/face shear
4	16,617	17,070	Test stopped - back cracked
5	12,588	17,305	Knob/face shear
6	842	6,643	Knob/face shear
7	858	6,708	Knob/face shear
8	2,324	9,102	Test stopped - back cracked
9	3,609	11,747	Test stopped - back cracked
10	5,060	10,943	Test stopped - back cracked
11	6,612	12,978	Test stopped - back cracked

INTERFACE SHEAR CAPACITY



Peak Shear Envelope:[c]

$S_{p(1)}$ = 4547 + N tan 44°	**(N < 7,017 lb/ft)**
$S_{p(2)}$ = 8488 + N tan 22°	**(7017 lb/ft ≤ N < 16,118 lb/ft)**
$S_{p(max)}$ = 15,000 lb/ft	**(N ≥ 16,118 lb/ft)**

Inflection Points:

N_1 = 0 lb/ft	**S_1 = 4547 lb/ft**
N_2 = 7017 lb/ft	**S_2 = 11,323 lb/ft**
N_3 = 16,118 lb/ft	**S_3 = 15,000 lb/ft**

(a) The average compressive strength of concrete blocks as-tested was 5,350 psi.
(b) In many cases, the test was stopped before peak shear load occured because of significant uplift of upper block, damage to the back of upper block where horizontal load was applied, or maximum capacity of test apparatus was reached.
(c) 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 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.

Issue date: May 23, 2018.

REPORT

RESULTS OF

Redi-Rock 52" XL
Hollow Core Retaining Block
SHEAR CAPACITY TESTING

Submitted to

REDI-ROCK INTERNATIONAL

CONFIDENTIAL

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Introduction

This report gives the results of a block shear testing program carried out to evaluate the mechanical/frictional performance of the shear capacity between Redi-Rock 52" XL Hollow Core Retaining Blocks (Redi-Rock 52" XL Blocks). The test program was initiated in response to an email authorization to proceed from Mr. Matt Walz of Redi-Rock international on November 28, 2017. The tests were carried out at the laboratories of TRI Environmental, Inc. in Austin Texas.

Objective of the Testing Program

The interface shear capacity between Redi-Rock 52" XL Blocks placed in a staggered joint (running bond) configuration was investigated using a very large-scale test apparatus. The principal objective of the testing was to evaluate the mechanical/frictional performance of the shear between successive layers of Redi-Rock 52" XL Block units.

Materials

Redi-Rock 52" XL Block units are hollow concrete blocks weighing approximately 3300 lbs per unit (weight/unit provided by Redi-Rock international). The nominal dimensions of the block are 46.6 inches wide (toe to heel) by 36 inches high by 46.1 inches long. Construction alignment and wall batter is achieved by means of concrete knobs on the top surface of the blocks with a corresponding channel along the bottom of each block. The installation arrangement is illustrated in **Figure 1**. A photograph of the Redi-Rock 52" XL Block units used in this series of tests is shown in **Figure 2**. A photograph of the block system in the connection frame is shown in **Figure 3**. The blocks used in this series of tests were supplied by Redi-Rock international and received at our laboratory in Austin Texas, on 30 November 2017. These block units were manufactured by MDC Contracting between the dates of 3rd and 14th of November, 2017. Concrete compression strengths for each block were determined by Redi-Rock international. No infill materials were utilized in this testing program.

Test Procedure

The SRWU-2 method of test as reported in the NCMA Segmental Retaining Wall Design Manual (1993) and ASTM D6916 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 289 kN (force) (65,000 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. Wall heights were simulated by placing a single block over the interface and applying additional normal load using a manually controlled hydraulic pump. The horizontal (shear) force was applied at a constant rate of displacement (i.e. 5 mm/minute) 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, block overturning/rotation was observed, or cracking of the blocks was observed. Following each test, the blocks were removed and the units examined to confirm failure modes.

Test results for shear testing with Redi-Rock 52" XL Block units

The principal 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). Results of interface shear tests are summarized in **Table 1**. The maximum measured interface shear loads are plotted against normal load and a summary of observations for each test are given in **Figure 4**. A plot of shear load versus displacement is shown in **Figure 5**.

Closing

We appreciate the opportunity to work with you on this project and look forward to providing additional services in the future.

Jeffrey A. Kuhn, Ph.D., P.E.
Division Director
Geotechnical and Interaction Laboratories

Mike Domingo
Senior Technician
Interaction Laboratory

REFERENCES

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.

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.

1	Block unit	6	actuator support	11	reaction beam
2	Geogrid (optional)	7	potentiometer	12	computer controlled hydraulic actuator
3	loading platen	8	surcharge actuators		
4	steel piston	9	loading frame	13	ridgid platform base
5	lateral restraining system	10	spacers		

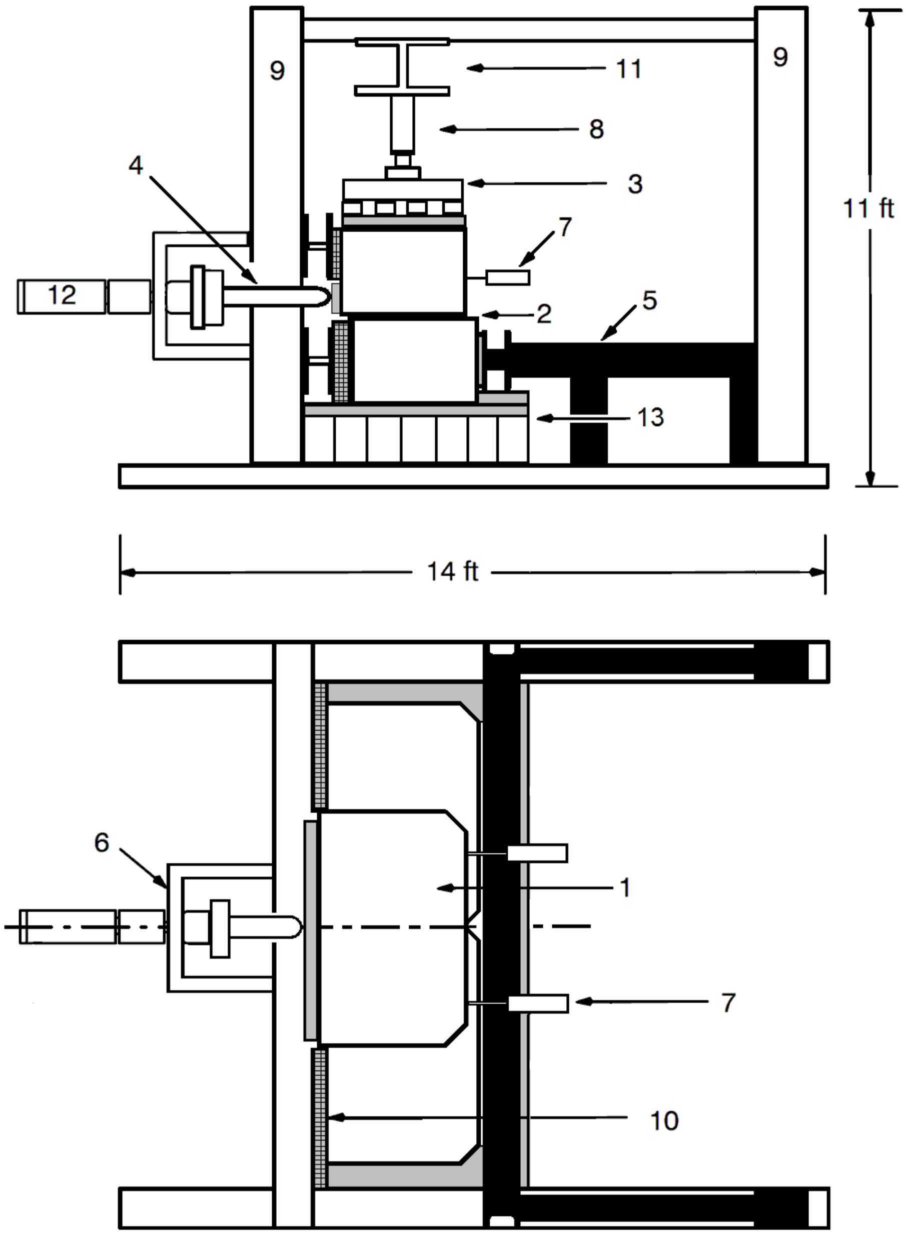


Figure 1: Schematic diagram of the shear test apparatus.

Figure 2: Photograph showing Redi-Rock 52" XL Block unit.

Figure 3: Photograph of the Redi-Rock 52" XL Block units in the test frame.

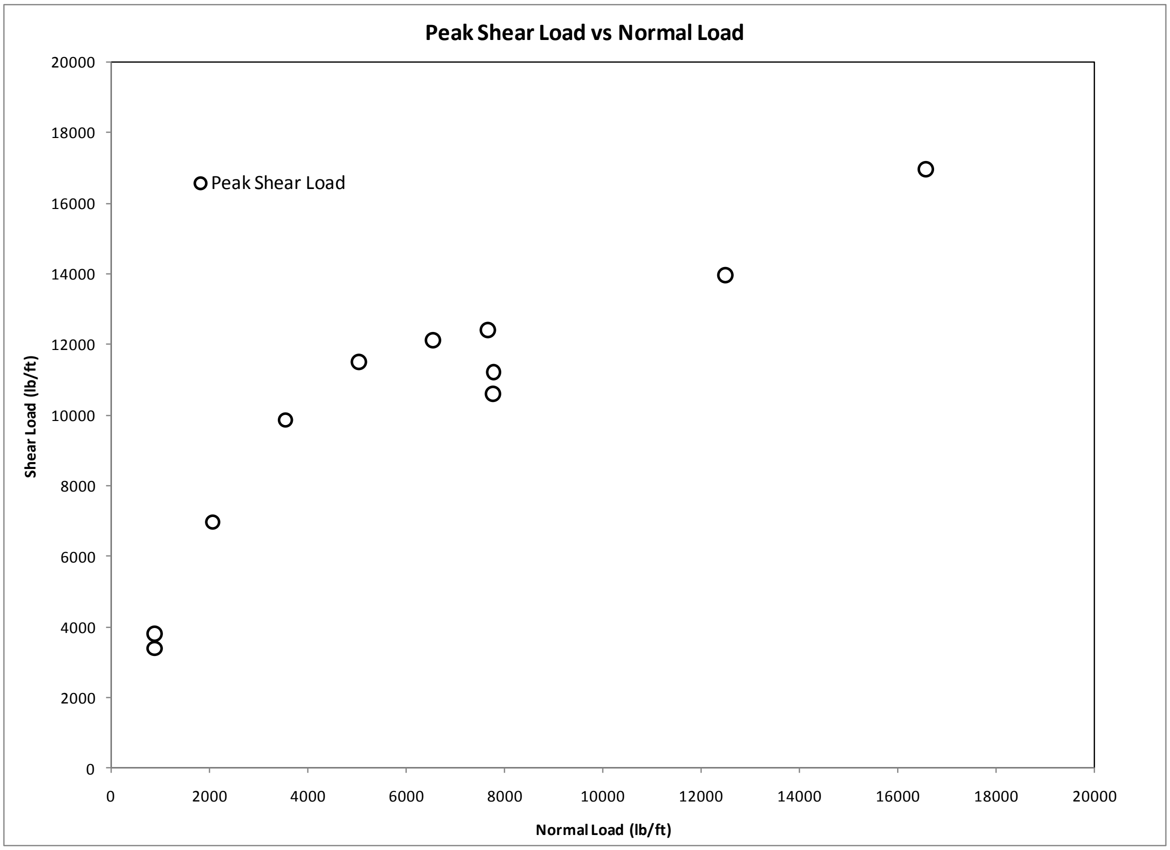


Figure 4: Summary of shear capacities for Redi-Rock 52" XL Block units

Table 1: Data Summary for Redi Redi-Rock 52" XL Block units

Test	Normal Load (lb/ft)	Peak Shear Load (lb/ft)	Observations
1	872	3812	stopped test after uplift of top block
2	5026	11503	broke upper left area of bottom right block
3	872	3383	stopped test after uplift of top block
4	16562	16962	stopped test after reaching over 65000 lbs of horizontal load
5	2062	6970	stopped test after uplift of top block
6	3539	9857	stopped test after uplift of top block, slight cracked formed at the back of the top block
7	7773	11210	cracked knob of bottom right block
8	7765	10601	back bottom of top block cracked
9	7656	12405	back bottom of top block cracked
10	6541	12112	block uplift
11	12496	13962	back bottom of top block cracked

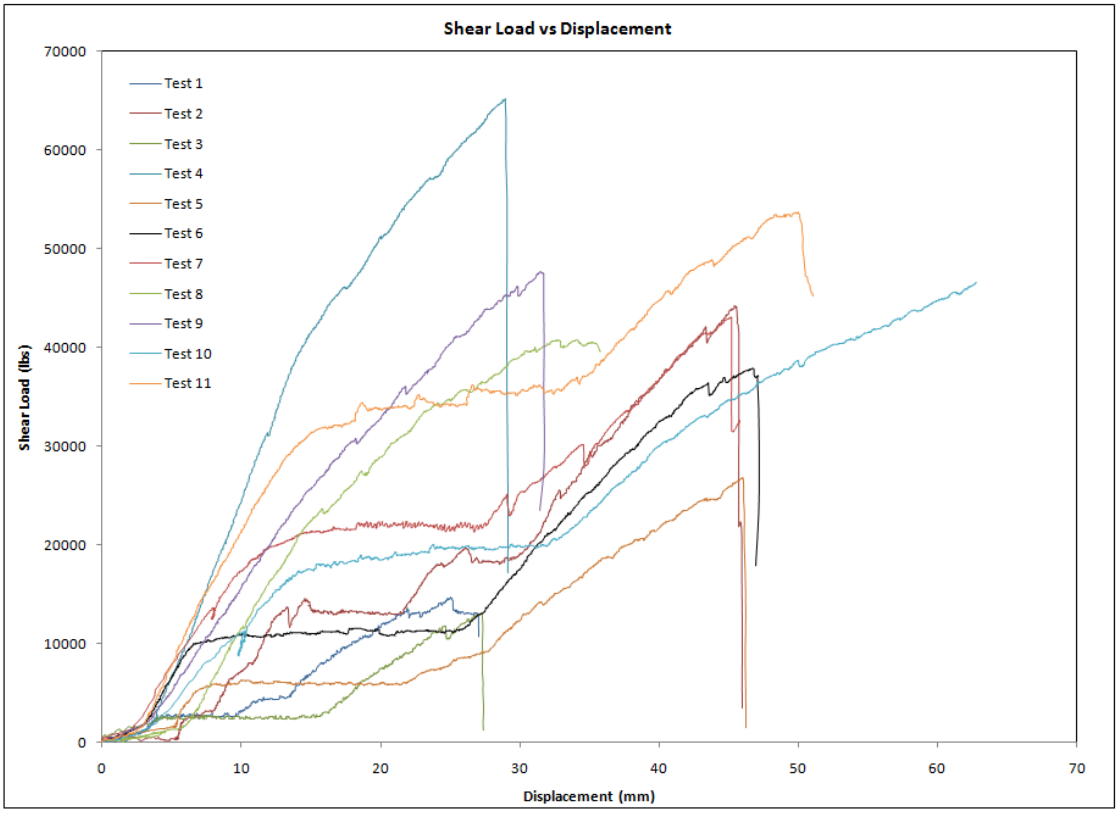
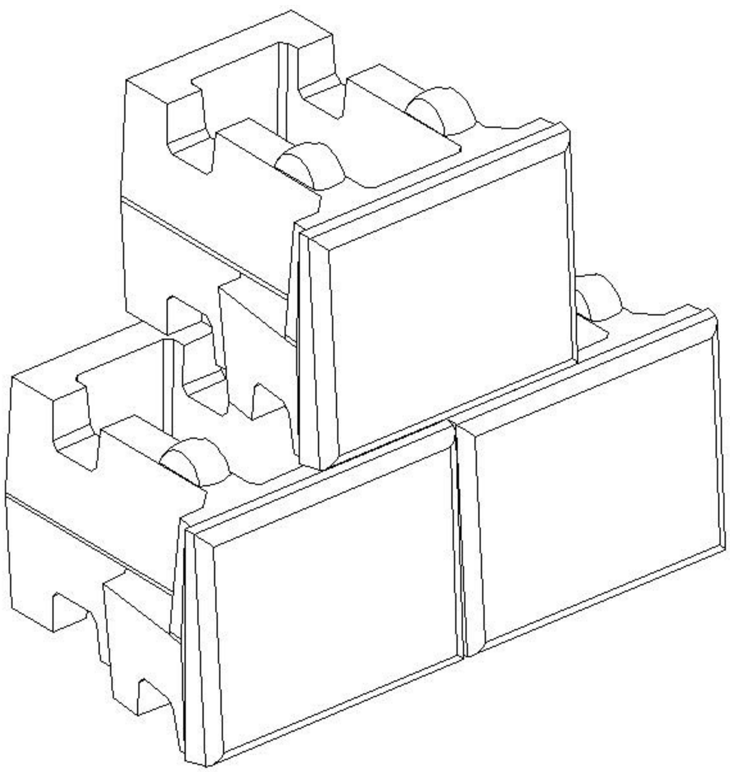


Figure 5: Summary plot of shear load versus displacement.

Test Report

Results from:
Block-to-Block Interface Shear Testing of
Redi-Rock 52" XL Hollow Core Retaining Block



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REDI-ROCK™

Introduction and Objectives:

The purpose of this testing program was to evaluate the interface shear capacity of the Redi-Rock Hollow Core Retaining Block System. This block system consists of three sizes of concrete blocks that, when stacked and filled with stone, create an integral earth retaining structure. The test program was undertaken with the following objectives:

- Evaluate the interface shear capacity of a wall up to approximately 30' tall.
- Determine the typical structural failure modes of the Hollow Core Block.
- Validate the testing protocol and verify the repeatability of testing results.

Tests were carried out in the high-capacity structural testing frame of Redi-Rock International. Tests were completed between the dates of March 14th and March 23rd, 2018.

Materials:

Redi-Rock Hollow Core Retaining Blocks are cast from high-quality, wet-cast concrete with a minimum specified 28-day compressive strength of 4,000 psi. For additional strength, the blocks contain an integral rebar cage. Blocks are interconnected by two dome-shaped shear knobs protruding from the top of the block that interlock with a groove cast in the bottom of the block.

In order to provide the most conservative estimates of interface shear, the smallest of the blocks, the Redi-Rock 52" XL Hollow Core Retaining Block (Figure 1), was chosen for the tests. In addition, stone infill was not used in the cores for these tests.

Figure 1: Photo of Typical Redi-Rock 52" XL Hollow Core Retaining Block

Test blocks were cast between the dates of December 1st and December 20th, 2017. They were cured for a minimum of 28 days before testing and had an average 28-day compressive strength of 5,200 psi. Individual blocks were weighed and actual block weights were used in the calculation of the normal load. Average block weight was 3,250 lbs.

Testing Frame and Systems:

All tests were completed in a high-capacity structural testing frame (Figure 2) located at the facilities of Redi-Rock International. This testing frame consists of a reconfigurable, steel reaction frame mounted to a 40” thick solid concrete “strong floor” with the capacity to test up to several hundred thousand pounds in any direction.

Figure 2: Photo of Redi-Rock 52” XL Hollow Core Retaining Block in Test Frame

Testing forces are induced by a precision hydraulic actuator system. This system is capable of providing up to 12” of movement and a maximum of 150,000 pound force simultaneously in two directions. This is acheived by two separate hydraulic pump systems which allow for precise control of both horizontal and vertical loading. The hydraulic system is controlled by high-precision directional flow control, needle, and pressure relief valves.

Forces, pressures, and displacements are recorded with electronic sensing devices. Forces were measured with load cells mounted to the ends of the hydraulic cylinders and pushing directly on the block. Forces can be also verified with electronic pressure gauges installed in the hydraulic systems. Displacements were measured with two linear potentiometers with a 2” stroke length capacity. In addition, position of the horizontal hydraulic cylinder is know due to an integral LVDT sensor mounted inside the cylinder.

All measurements were recorded with a National Instruments cDAQ, data acquisition module and Labview data acquisition software. Data was recorded a minimum of one datum per sensor per second.

Test Procedure:

Interface shear capacity testing was completed in general accordance with ASTM D6916 “Standard Test Method for Determining the Shear Strength Between Segmental Concrete Units (Modular Concrete Blocks)”. In this test method one block is set on top of two blocks in a staggered, running bond pattern. Base blocks are firmly fixed and a normal load is applied vertically to simulate varied height walls. The upper block is then pushed horizontally to failure to determine the peak interface shear capacity between the block units. Several tests are run at different normal loads until there is excessive deflection or visible cracking seen in the test blocks. See Figure 3 for a schematic drawing of the test frame set-up.

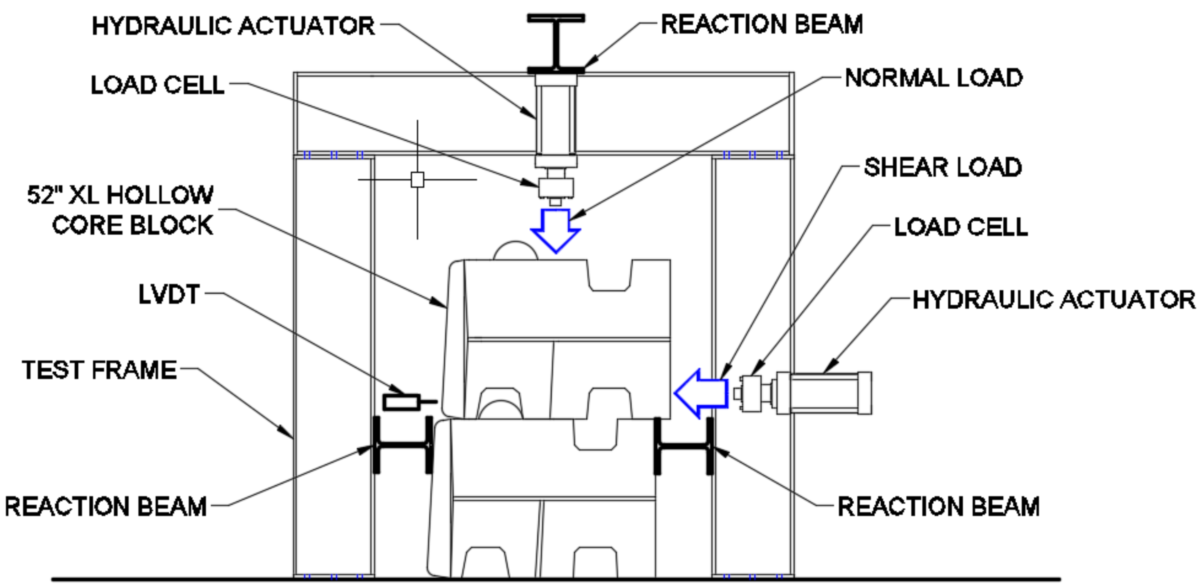

Figure 3: Test Procedure

For this testing program, normal load levels were determined based on a maximum stone-filled gravity wall height of 30 ft. Testing began with three identical tests simulating a mid-range height (approx 18’ wall) to check repeatability of the testing protocol. Two tests were then completed above this range to determine the upper end capacity of the wall system. It was anticipated that most gravity walls with this block system will be designed under 18’ tall, so more points were chosen in the lower normal load levels. Six tests were completed at these levels, including two tests with just the weight of the block as normal load.

The only known deviation from the ASTM D6916 test method was in the displacement rate (velocity) at which the blocks were tested. Tests were manually controlled with an average displacement rate of 2 mm/min (0.094” per minute) instead of the 5 mm/min (0.197” per minute) rate specified in the ASTM. This displacement rate was chosen to slow down the test due to high anticipated loads and unknown failure modes. It was deemed appropriate because of the intent of the test to mimic static conditions in the field.

Test Results:

Upon completion of the tests, the horizontal shear force was plotted versus horizontal displacement of the upper block (Figure 4). A peak shear force was determined from each of these graphs and is summarized in Table 1. Peak shear force is plotted versus normal load in Figure 5. Note that repeated tests, tests 1 through 3, are within the within the general range of repeatability (within 10% of average) as stated in Section 7.2.8 of ASTM D6916.

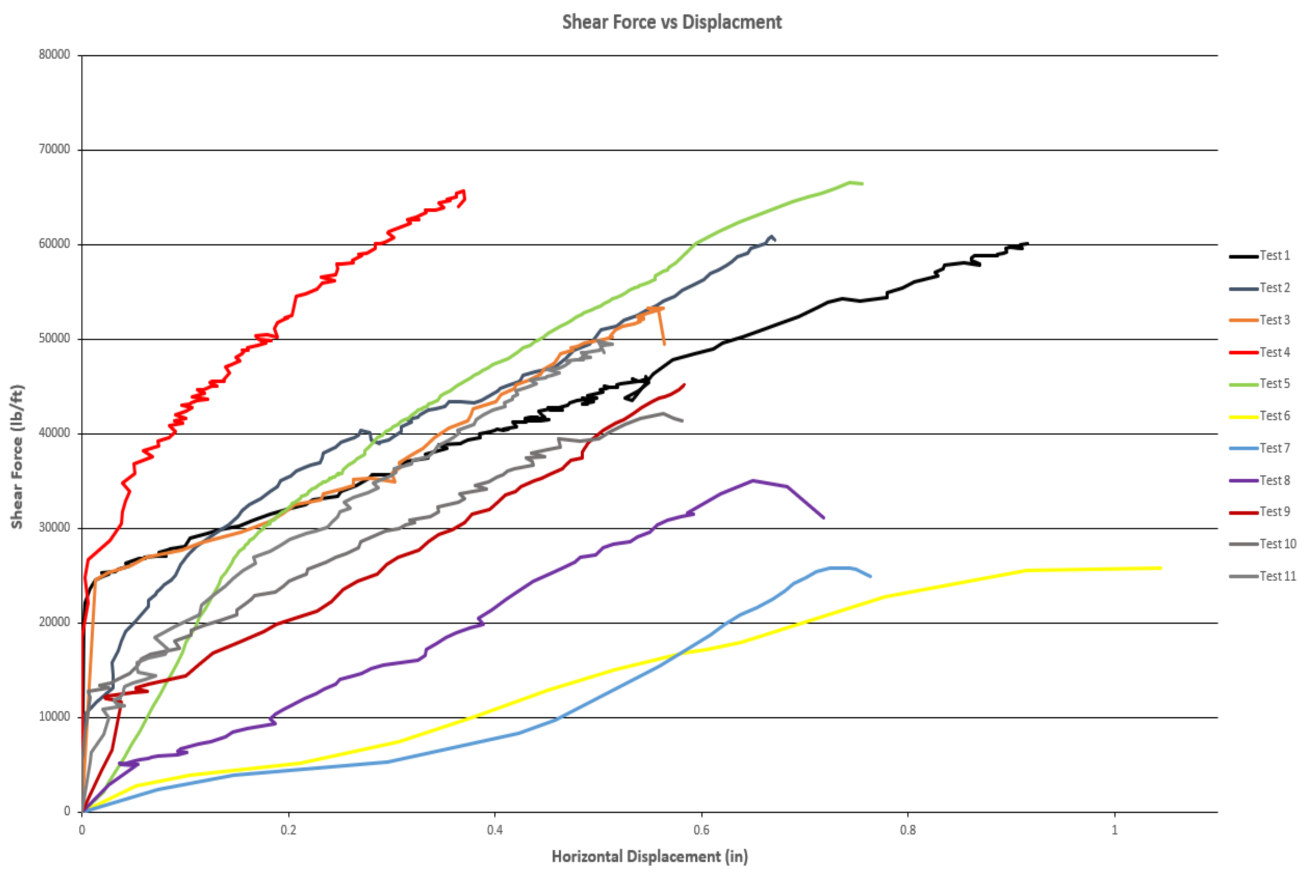

Figure 4: Horizontal Shear Force versus Horizontal Displacement

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Table 1: Results from interface shear testing

Test Number	Normal Load (lb/ft)	Peak Shear Load (lb/ft)	Notes:
1	7759	15635	Stopped test due to cracking in back of top block.
2	7840	15843	Stopped test due to cracking in back of top block.
3	7761	13859	Cracked left-hand knob and through face of lower right-hand block.
4	16617	17070	Stopped test due to cracking in back of top block.
5	12588	17305	Cracked knobs on both lower blocks.
6	842	6643	Cracked through face of lower left-hand block. Partially cracked left-hand knob of lower right block.
7	858	6708	Cracked right-hand knob of lower left-hand block.
8	2324	9102	Completely crushed back of upper block. Did not break knobs.
9	3609	11747	Stopped test due to cracking in back of top block.
10	5060	10943	Completely crushed back of upper block.
11	6612	12978	Stopped test due to cracking in back of top block and large deflections.

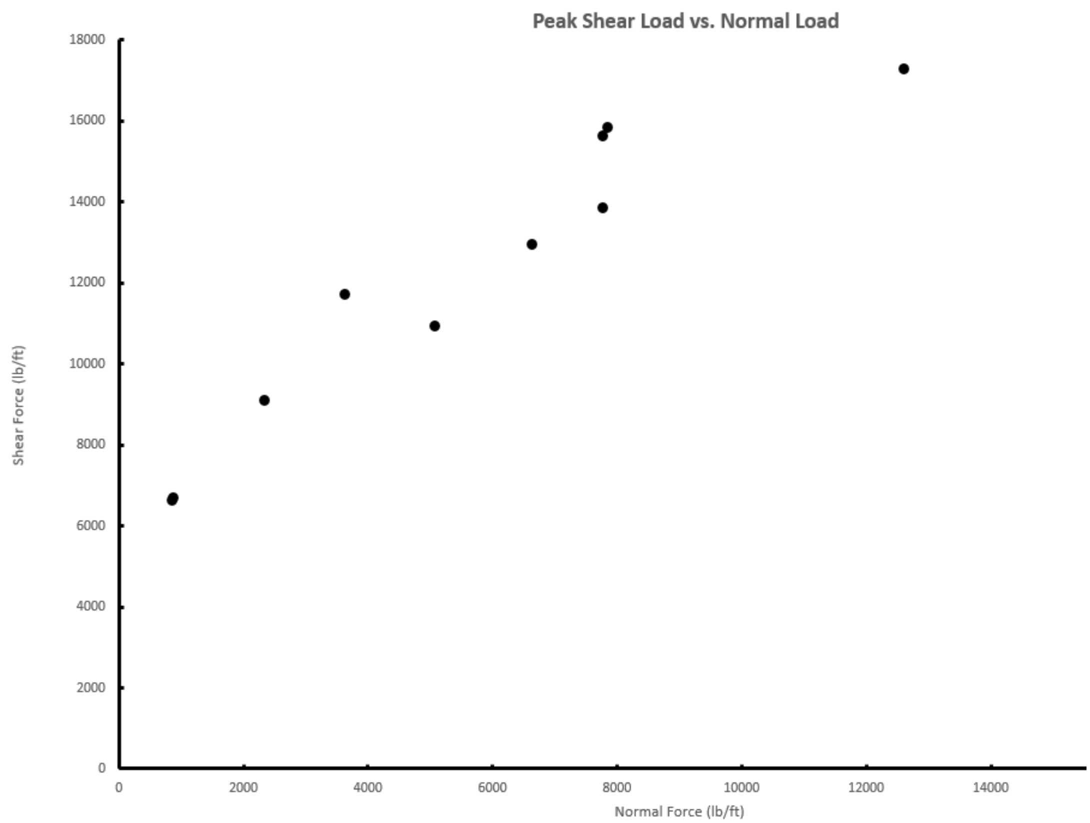

Figure 5: Graph of Peak Shear Force versus Normal Load

Block Failure Modes:

Two main failure modes were seen at the horizontal shear interface between layers of blocks. These were cracking directly through the shear knob (Figure 6) or cracking at an angle down and below the shear knob (Figure 7). In each case, the failure began with localized crushing of the knob into the groove in the block above. However, no significant damage beyond localized crushing was noted in the grooves. It is interesting to note that, even at low normal loads, blocks only slightly uplifted or rotated throughout testing.

Figure 6: Typical Broken Shear Knob Failure

Figure 7: Typical Deep-Seated Shear Knob Failure