TEST REPORT:

ROSETTA HARDSCAPES GRAND LEDGE RETAINING WALL BLOCKS

BLOCK-TO-BLOCK INTERFACE SHEAR CAPACITY

Tested By:
Aster Brands
2940 Parkview Drive
Petoskey, Michigan 49770
866-222-8400

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1.0 Introduction

This report presents the results of a laboratory testing project that was performed to evaluate the block-to-block interface shear capacity between Rosetta Hardscapes Grand Ledge retaining wall block units. The testing was performed by Aster Brands personnel, under the supervision of Aster Brands engineers at its testing facility located in Charlevoix, Michigan from December 2020 to January 2021. Rosetta Hardscapes is an Aster Brands company.

2.0 Purpose

The objective of the test series for this project was to investigate the block-to-block interface shear capacity of full-size Rosetta Hardscapes 12-inch by 20-inch (305 mm by 508 mm) by 3-, 4-, 5-, and 6-foot (0.91, 1.22, 1.52, and 1.8 meter) Grand Ledge retaining block units under varying normal loads using a large testing frame.

3.0 Materials

Rosetta Hardscapes Grand Ledge blocks are wetcast concrete, precast modular block (PMB) units with a consistent height of 12 inches (305 mm), and a depth (parallel to wall face) of 12 inches (305 mm) plus the face texture of about 8 inches (25 mm), for a total width of approximately 20 inches (508 mm). The width (parallel with the wall face) of the blocks varies in 12-inch (305 mm) increments from 3 feet (0.91 m) to 6 feet (1.83 m). Standard block dimensions are as shown in **Figure 1** below. The blocks are manufactured from wet cast, first purpose, air-entrained, non-reconstituted, structural grade concrete mixes in accordance with ASTM C94 or ASTM C685. They have a minimum specified 28-day compressive strength of 4,000 psi (27.6 MPa) and weigh approximately 660 lbs (300 kg) to 1,350 lbs (612 kg).

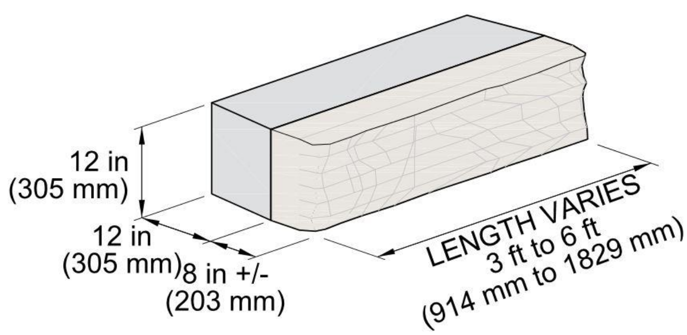

Figure 1 – Grand Ledge Block Dimensions

Shear engagement between subsequent rows of blocks is achieved by two shear heels protruding from the bottom of the block that interlock with the back of the top of the blocks below, as well as friction. The shear heels also set the wall batter at a nominal value of approximately 10.6 degrees (2 ¼ inches (57 mm) per course). Blocks are designed to be dry stacked in a running bond configuration with the vertical joints offset, or staggered.

Blocks used for this series of testing were produced by High Format at its Charlevoix, Michigan facility. The blocks were produced in October 2019 and cured for 55 to 98 days prior to testing.

Average compressive strength of the concrete that was used to produce the test blocks was 3,517 psi (24.2 MPa), as determined by ASTM C39 on 4-inch by 8-inch (102 mm by 203 mm) field-cured concrete cylinder specimens. Because all test blocks had compressive strength values at the time of testing below the minimum specified 28-day value for Rosetta Hardscapes Grand Ledge blocks (4,000 psi), the tested values of interface shear were assumed to be lower bound values, and no attempt was made to adjust test results for concrete strength.

4.0 Test Apparatus

All tests were completed in a high-capacity structural testing frame located at the Aster Brand testing facilities in Charlevoix, Michigan, USA. This testing frame consists of a reconfigurable, steel reaction frame mounted to a 40-inch (1.0 m) thick solid concrete “strong floor”.

Testing forces were induced by a precision hydraulic actuator system. The system is capable of providing up to 12 inches (300 mm) of travel movement and a maximum of 150,000-pound force (670 kN) simultaneously in two directions using two separate hydraulic pump systems. This allows for precise control of both horizontal and vertical loading. The hydraulic systems are controlled by high-precision directional flow control, needle, and pressure relief valves.

Forces, pressures, and displacements were 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. Displacements were measured with an integral LDT sensor mounted inside the horizontal hydraulic 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.

5.0 Methodology

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 load is applied to the back of the top block. A normal load is applied vertically on top of the top block to simulate varied wall heights.

The upper block is then pushed horizontally to failure to determine the peak interface shear capacity between the block units. Steel beams with rubber pads are used to spread the loads evenly across the surfaces of the blocks. Tests are run until there is excessive deflection, visible cracking seen in the test blocks, or significant reduction in applied load. Details of the test set-up are shown in **Figure 2**.

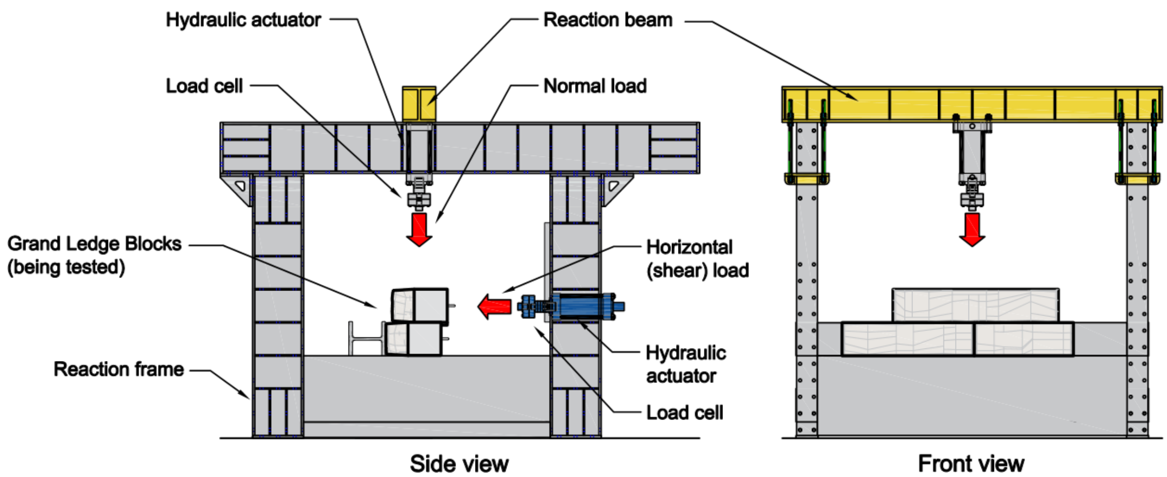

Figure 2: Schematic test frame set-up

All interface shear tests were taken to the point of maximum shear load to induce failure of the shear heels, when possible. However, before the top block was destructively tested for interface shear, a non-destructive friction test was performed first. In this initial step, the top block was carefully placed with the shear heels approximately ¾-inch behind the top of the lower two blocks. A friction test was then performed in order to gather the data required to properly analyze a wall section that did not incorporate the shear heels (shear heels removed).

In step two of the testing program, the block was moved forward so both of the shear heels were fully aligned and engaged, and an initial load (alignment load) was placed on the block before deflection measurements were recorded.

For this testing program, normal load levels were varied from 208 to 6,513 lb/ft (3.0 to 95.0 kN/m) to simulate the performance of block-to-block interface shear at different vertical locations in a wall cross-section. These values correspond to wall heights ranging from approximately 1 to 29 feet (0.3 to 8.8 m). Additional tests were run at the same nominal normal load near the middle of the range of normal loads in order to check the repeatability of the testing protocol.

Blocks were preloaded with horizontal loads ranging from approximately 194 to 516 lb (0.9 to 2.3 kN) to set and align the blocks. Displacement was measured at the point of load by the integral LDT sensor mounted inside the horizontal hydraulic cylinder. The displacement rate (velocity) at which the load was applied to the blocks as they were tested was manually controlled with an average displacement rate of 0.20 inches per minute (5.1 mm/min), which is within the tolerance of the rate specified in ASTM D6916 of 0.197 inches per minute +/- 0.04 inches per min (5 mm/min +/- 1mm/min).

6.0 Laboratory Test Results

The first interface shear test attempt, a small normal load increment was used, and block tipping (rotation) was observed with neither of the shear heels breaking off. For all following tests, a shear failure through both of the shear heels was observed, as shown in **Figures 3 and 4.** Occasionally, one shear heel would fail, and the other would remain intact, as shown in **Figure 5.**

Tests using a 6-ft block on top in combination with normal loads above 1,070 lb/ft (1,592 kg/m) exhibited block cracking. The observed cracks were generally perpendicular to the width (long dimension) of the block, running through the block face as shown in **Figure 6**. No cracks were observed in any of the 3-, 4-, or 5-foot blocks.

Figure 3 – Both Shear Heels sheared off bottom

Figure 4 - Both shear heels left behind after test

Figure 5 - One shear heel failed, one intact

Figure 6 – 6 ft block cracked under high load

Block displacement plotted against horizontal load for friction tests is shown in **Figure 7**. A summary of the friction test results is shown in **Table 1**.

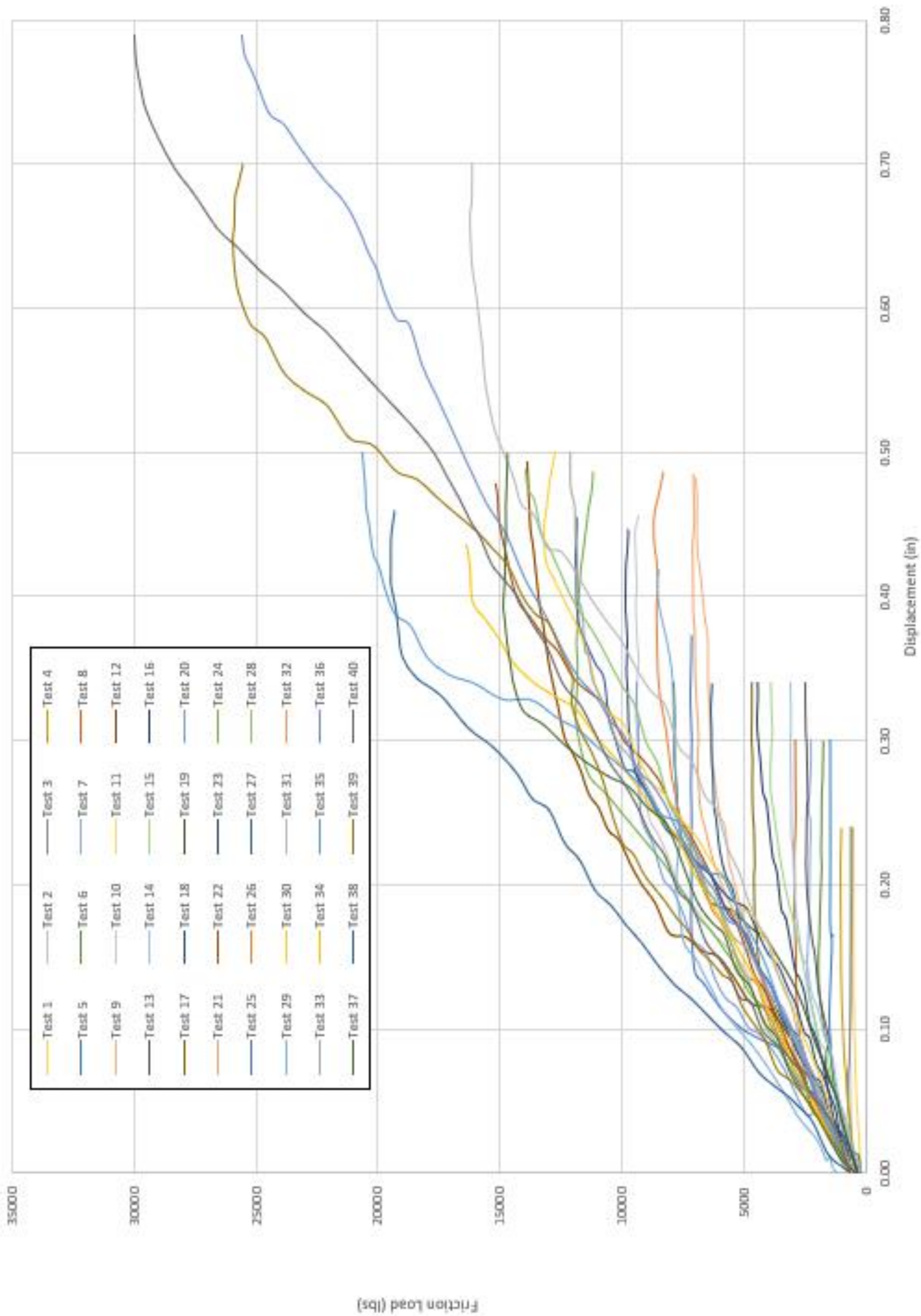

Figure 7 - Horizontal Interface Friction Force versus Horizontal Displacement

Table 1 – Summary of Friction Test Results

Test No.	Block Width (ft)	Normal Load (lb/ft)	Normal Load (kN/m)	Friction Load (lb/ft)	Friction Load (kN/m)
1	3	208	3.0	158	2.3
2	4	214	3.1	159	2.3
3	5	208	3.0	153	2.2
4	6	218	3.2	168	2.5
5	3	655	9.6	513	7.5
6	4	663	9.7	500	7.3
7	5	657	9.6	486	7.1
8	6	655	9.6	484	7.1
9	3	3,218	47.0	2,321	33.9
10	4	3,214	46.9	2,348	34.3
11	5	3,257	47.5	2,340	34.1
12	6	3,237	47.2	2,314	33.8
13	3	1,087	15.9	811	11.8
14	4	1,078	15.7	757	11.0
15	5	1,067	15.6	779	11.4
16	6	1,059	15.5	738	10.8
17	3	2,164	31.6	1,507	22.0
18	4	2,155	31.4	1,595	23.3
19	5	2,155	31.4	1,575	23.0
20	6	2,152	31.4	1,559	22.7
21	3	3,198	46.7	2,338	34.1
22	4	3,234	47.2	2,533	37.0
23	5	3,241	47.3	2,449	35.7
24	6	3,225	47.1	2,374	34.6
25	3	3,224	47.0	2,372	34.6
26	4	3,230	47.1	2,131	31.1
27	5	3,231	47.1	2,378	34.7
28	6	3,223	47.0	2,314	33.8
29	3	4,310	62.9	2,589	37.8
30	4	4,344	63.4	3,302	48.2
31	5	4,317	63.0	3,245	47.3
32	6	4,360	63.6	2,975	43.4
33	3	5,635	82.2	3,993	58.3
34	4	5,313	77.5	4,079	59.5
35	5	5,369	78.3	4,131	60.3
36	6	5,358	78.2	4,276	62.4
37	3	6,404	93.4	4,901	71.5
38	4	6,421	93.7	4,838	70.6
39	5	6,427	93.8	5,153	75.2
40	6	6,468	94.4	5,032	73.4

The friction test results shown in **Table 1** were used to calculate the coefficient of friction, and the average coefficient of friction for the 40 individual test results for was 0.74, which yields an average friction angle of 36.4 degrees.

Block displacement plotted against horizontal load for interface shear tests is shown in **Figure 8**. A summary of the peak shear test results is shown in **Table 2**.

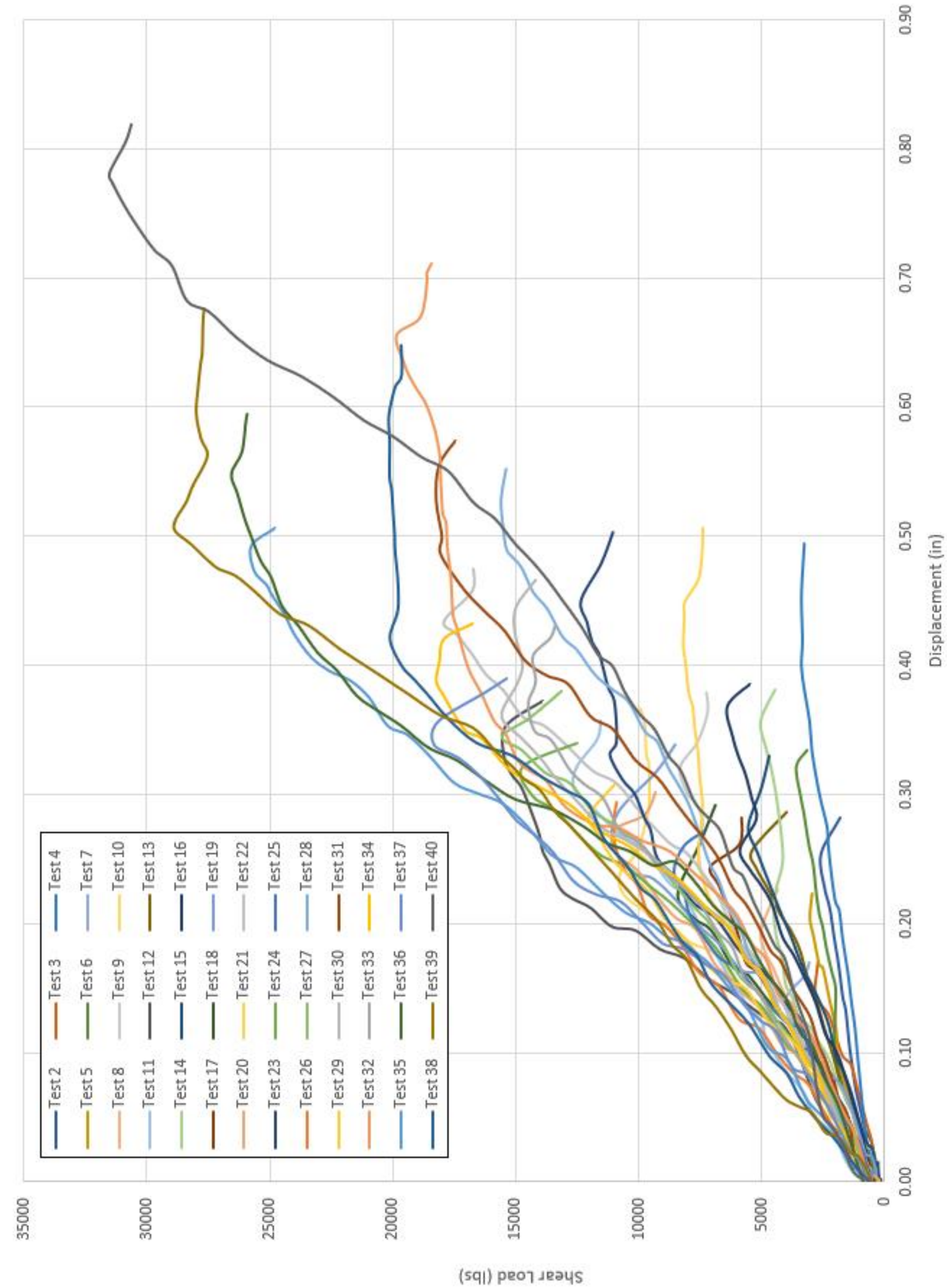

Figure 8 - Horizontal Interface Shear Force versus Horizontal Displacement

Table 2 – Summary of Peak Interface Shear Test Results

Test Number	Block Size (ft)	Normal Load lb/ft	Normal Load kN/m	Peak Shear lb/ft	Peak Shear kN/m
2	4	214	3.12	702	10.24
3	5	208	3.04	639	9.33
4	6	218	3.18	567	8.27
5	3	655	9.56	1,078	15.7
6	4	673	9.82	922	13.5
7	5	656	9.57	848	12.4
8	6	657	9.59	876	12.8
9	3	3,244	47.3	2,832	41.3
10	4	3,240	47.3	2,772	40.5
11	5	3,197	46.7	2,572	37.5
12	6	3,288	48.0	2,641	38.5
13	3	1,099	16.0	1,881	27.5
14	4	1,085	15.8	1,294	18.9
15	5	1,071	15.6	1,141	16.7
16	6	1,074	15.7	1,087	15.9
17	3	2,166	31.6	2,415	35.2
18	4	2,175	31.7	2,137	31.2
19	5	2,173	31.7	2,313	33.8
20	6	2,160	31.5	1,923	28.1
21	3	3,230	47.1	2,750	40.1
22	4	3,245	47.4	3,014	44.0
23	5	3,264	47.6	3,107	45.3
24	6	3,224	47.1	3,019	44.1
25	3	3,226	47.1	2,990	43.6
26	4	3,260	47.6	2,792	40.7
27	5	3,229	47.1	3,196	46.6
28	6	3,219	47	2,602	38.0
29	3	4,335	63.3	4,116	60.1
30	4	4,335	63.3	3,967	57.9
31	5	4,296	62.7	3,689	53.8
32	6	4,316	63.0	3,335	48.7
33	3	5,612	81.9	4,900	71.5
34	4	5,333	77.8	4,625	67.5
35	5	5,369	78.4	5,210	76.0
36	6	5,366	78.3	4,443	64.8
37	3	6,513	95.1	6,351	92.7
38	4	6,428	93.8	5,053	73.7
39	5	6,419	93.7	5,824	85.0
40	6	6,452	94.2	5,296	77.3

Peak interface shear loads were taken as the maximum measured load during each interface shear test. Peak loads plotted against normal loads are shown in **Figure 9**.

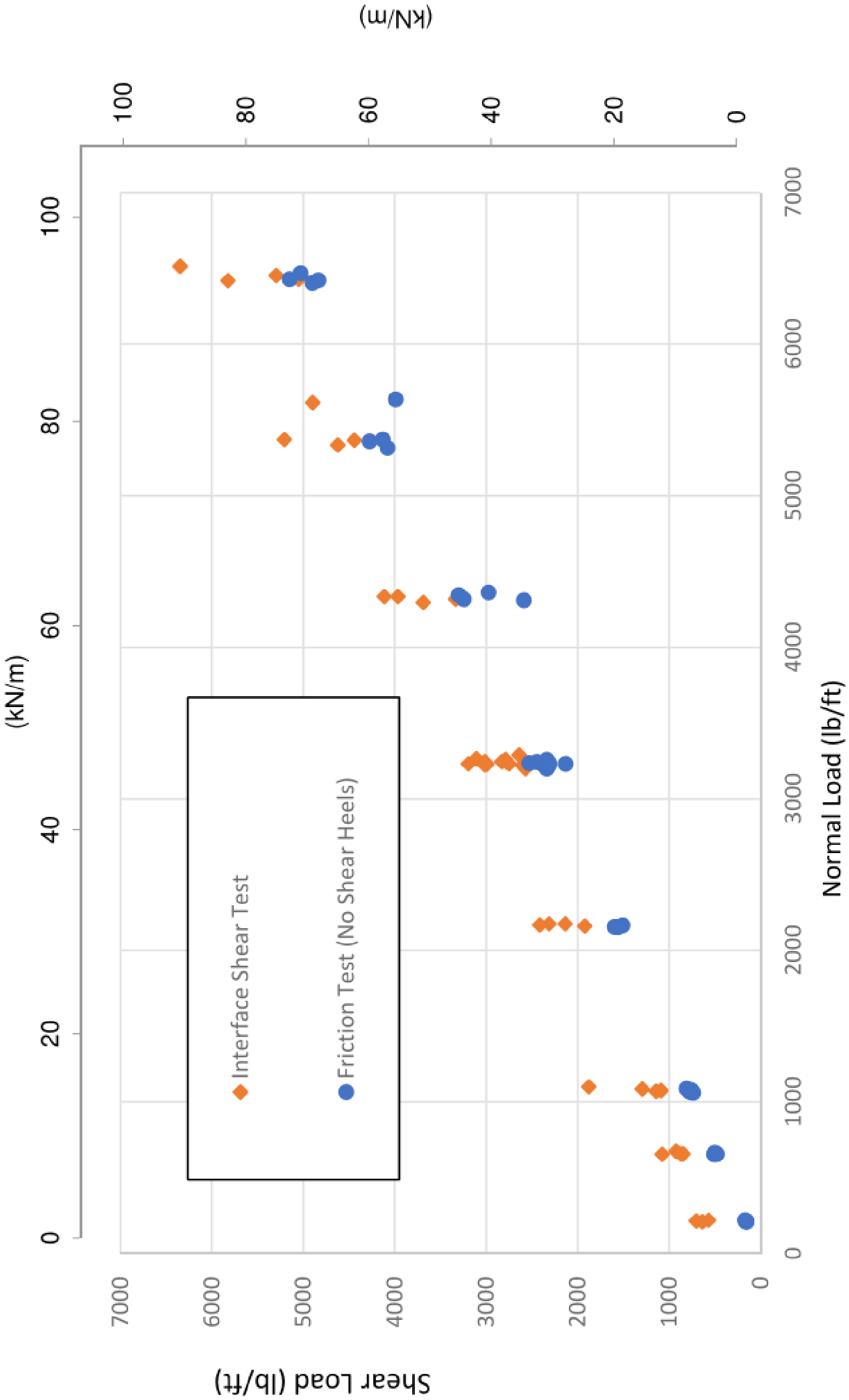

Figure 9 – Peak Shear Load versus Normal Load: Friction and Interface Shear

Additional tests were run at approximately 3,200 lb/ft (46.7 kN/m) normal load to check repeatability of the testing protocol. ASTM D6916 indicates a value of ±10% variation for each test from the mean of the tests as a measure of repeatability. Upon review of the total combined data, the high and low values fall within 10% of the mean of the test results.

The recommended interface shear capacity envelope for design purposes can be found in the design resources for Grand Ledge Wall Block.

7.0 Closure

The data and conclusions contained herein should be used with care. The user should verify that project conditions are equivalent to laboratory conditions and should account for any variations.

This test data is accurate to the best of our knowledge and understanding. It is the responsibility of the end user to determine suitability for the intended use.

ASTER BRANDS

Douglas L. Hula, P.E.
Senior Engineer

Matthew A. Walz, P.E
Testing Manager

Nils W. Lindwall, P.E.
Chief Engineer