

Shear Strength Evaluation of the EP Henry Cast Stone Wall System

for

**EP Henry Corporation
PO Box 615
Woodbury, NJ 08096**

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Conducted by:



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Shear Strength Evaluation of the EP Henry Cast Stone Wall System

1.0 INTRODUCTION

The shear strength of a segmental retaining wall (SRW) unit system is a design component of these systems. This shear strength is determined through testing in accordance with ASTM D6916-06c (2011), *Standard Test Method for Determining the Shear Strength Between Segmental Concrete Units (Modular Concrete Blocks)* (Ref. 1). In this project, the shear strength of the EP Henry Cast Stone Wall System without geosynthetic was evaluated, the results of which are reported herein.

2.0 MATERIALS

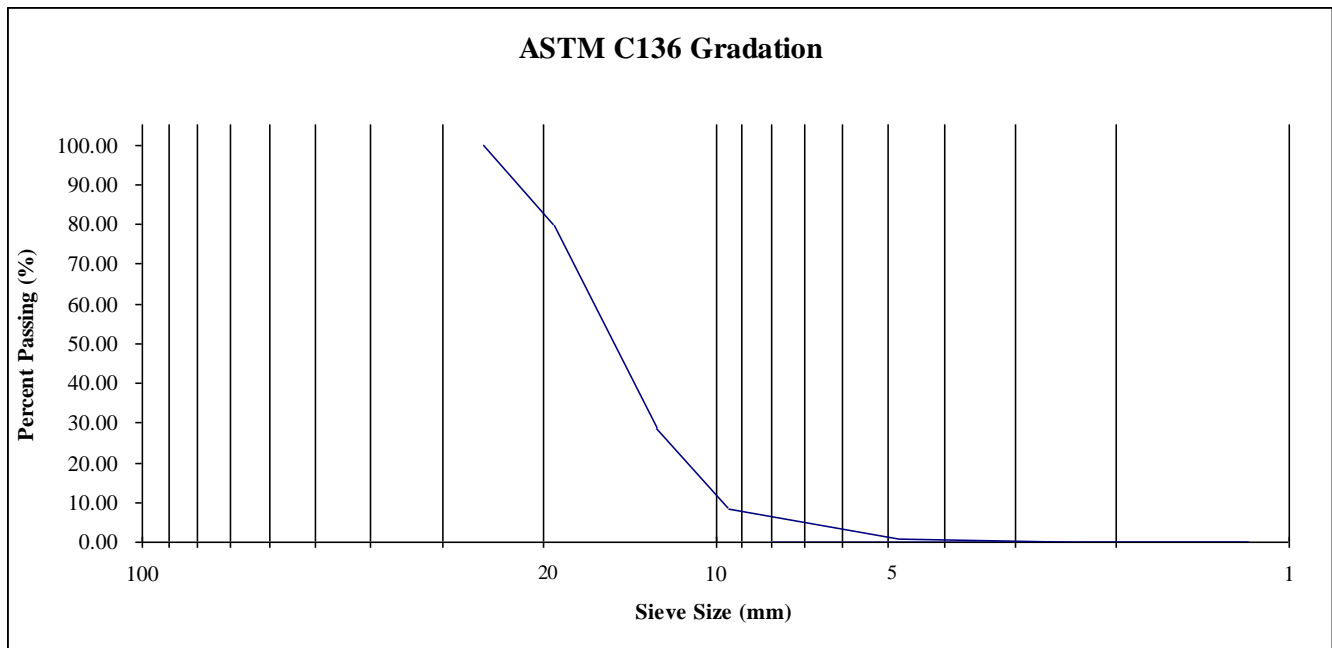
All SRW units and alignment connectors were sampled and provided by the client. The SRW units are dry-cast concrete blocks and part of the wall system with the trade name 'EP Henry Cast Stone Wall System'. Figure 1 shows the configuration of these units. Table 1 provides the representative dimensions of the units determined by the Laboratory as applicable to this testing program. At the direction of the client, testing for other unit physical properties, such as compressive strength and absorption, were not determined as part of this project.



Figure 1 – Representative SRW Unit

Table 1 – Representative SRW Unit Physical Properties	
Length front of unit, in. (mm)	16.0 (406)
Length back of unit, in. (mm)	10.5 (267)
Height front of unit, in. (mm)	6.0 (152)
Width, in. (mm)	11.5 (292)
Received weight, lb (kg)	48.18 (21.85)

For shear strength testing the cores and spaces between the SRW units were filled with aggregate. The gradation of the aggregate was determined in accordance with ASTM C136-06, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates* (Ref. 3). Figure 2 shows the gradation of the aggregate used. The aggregate was compacted into the voids between the units.



Note – to convert sieve size to inch, divide by 25.4.

Figure 2 – Aggregate Gradation

3.0 SHEAR STRENGTH PROCEDURES

The shear strength tests were performed in accordance with ASTM D6916-06c (2011). All tests were performed with the same configuration. The testing configuration is described below and accompanying photographs are provided below.

- A bottom course was constructed using two SRW units (Figure 3) and aggregate was added to the cores of the units and spaces between the units as needed.
- A third SRW unit was placed on top of the lower course of units. The top unit was placed so there was no setback between the bottom and the top courses. The cores of the unit was filled with aggregate (Figure 4).
- A neoprene pad and steel plate was placed on the top unit. Rollers were placed on top of this plate to facilitate even loading during testing (Figure 5).
- A steel plate was placed on top of the rollers and additional spacers were added to allow for contact with the vertical hydraulic ram and load cell. Two linear displacement potentiometers were attached to the front corners of the top unit to measure the amount of shear displacement during testing (Figure 6).
- The resulting shear interface using this testing configuration was 1.3 ft (0.40 m).



Figure 3 – Lower Units



Figure 4 – Top Unit



Figure 5 – Plate and Rollers



Figure 6 – Complete Test Setup

Once the test specimen was constructed it was tested using the procedures defined by ASTM D6916-06c (2011):

- Normal load was applied to the test specimen through a hydraulic loading system applied to the steel spacers, plates, and neoprene pad. The magnitude of the normal load was maintained at a constant level and monitored using an electronic load cell and a data acquisition system.
- With the normal load applied, the upper SRW unit was subjected to a horizontal load by displacing the loading arm that contacts the top SRW unit at a rate equal to 0.20 in./min (5 mm/min). The test was continued until either the shear strength significantly decreased or the displacement exceeded the capacity of the testing equipment.
- Horizontal displacement of the upper SRW unit was recorded during testing.

Testing was performed at five unique normal load levels. One normal load was repeated twice, for a total of seven unique shear strength tests.

4.0 RESULTS

Shear strength is defined as the shear load divided by the width of the shear interface, which for this project is taken equal to the largest width of the top segmental retaining wall unit. The peak shear strength is defined as the highest recorded value of shear strength. ASTM D6916-06c (2011) requires reporting of serviceability shear strength, but the displacement that defines the serviceability strength is not specified. In this project, the service state connection strength is determined based on the criteria outlined in ICC-ES AC276, *Acceptance Criteria for Segmental Retaining Walls* (Ref. 3), which requires the deformation criterion to either be ¾ inch (19 mm) or a value equal to 2 percent of the block height, whichever is less. The height of these units is 6.0 inch (152 mm) and thus would be limited by the 2% criteria, which is 0.12 inch (3.0 mm).

Results for the shear strength testing are provided in the appendix and the results are summarized in Table 2. In addition to the data presented, a plot of shear strength vs. displacement as well as shear strength vs. normal load is also provided in the appendix.

As required by the test method, one axial load level was tested three times to determine repeatability. The axial load repeated was 590 lb/ft (8.6 kN/m), and the results of those tests were within the general range of repeatability of the test method ($\pm 10\%$ from the mean of the three tests for the peak shear strength).

Test Number	Average Axial Load lb/ft (kN/m)	Approximate Wall Height based on Axial Load ft (m)	Service State Shear Strength lb/ft (kN/m)	Peak Shear Strength lb/ft (kN/m)
1	233 (3.4)	2.4 (0.74)	255 (3.7)	450 (6.6)
2	593 (8.7)	6.1 (1.87)	443 (6.5)	1,080 (15.8)
3	405 (5.9)	4.2 (1.28)	315 (4.6)	593 (8.7)
4	585 (8.5)	6.1 (1.85)	413 (6.0)	923 (13.5)
5	780 (11.4)	8.1 (2.47)	503 (7.3)	1,133 (16.5)
6	593 (8.7)	6.1 (1.87)	450 (6.6)	975 (14.2)
7	960 (14.0)	10.0 (3.04)	713 (10.4)	1,418 (20.7)

For each test run, the system failed by displacement of the lower unit. Figure 7 shows a typical failure seen in this project.



Figure 7 – Typical Failure Mode

5.0 DISCUSSION

The following discussion is not a required portion of the ASTM D6916-06c (2011) standard, but is provided for the reference and convenience of the reader.

A plot of normal load versus shear strength is also provided in the appendix. As can be seen from this figure, a relationship can be determined for both the serviceability shear strength (at 0.12 in. [3.0 mm] displacement) as well as the peak shear strength as a function of normal load. Using best-fit linear trend lines, relationships are determined in accordance with the NCMA *Design Manual for Segmental Retaining Walls* (Ref. 4). The third edition of this design manual does not include provisions for the serviceability shear strength. While ASTM D6916-06c (2011) requires that serviceability shear strength be determined, it does not define the specified displacement, leaving this displacement to be prescribed by the user. A value of 0.12 in. (3.0 mm) is reported here as this value is required by ICC-ES AC276. Relationships are provided for both the peak shear strength (V_u) as well as the service state shear strength (V'_u) within the range of normal load tested in this study.

These relationships apply to the combination of SRW units and aggregate used in this study.

6.0 REFERENCES

1. ASTM Standard D6916, 2006c (Reapproved 2011), “Standard Test Method for Determining the Shear Strength Between Segmental Concrete Units (Modular Concrete Block)”, ASTM International, West Conshohocken, PA, www.astm.org.
2. ASTM Standard C136, 2006, “Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates”, ASTM International, West Conshohocken, PA, www.astm.org.
3. ICC-ES AC276, *Acceptance Criteria for Segmental Retaining Walls*, 2004, ICC Evaluation Service, LLC, Whittier, CA, www.icc-es.org.
4. *NCMA Design Manual for Segmental Retaining Walls, Third Edition*, 2009, National Concrete Masonry Association, 13750 Sunrise Valley Drive, Herndon, VA 20171-4662.

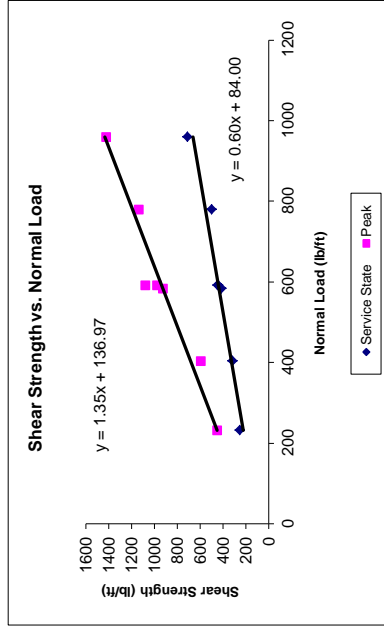
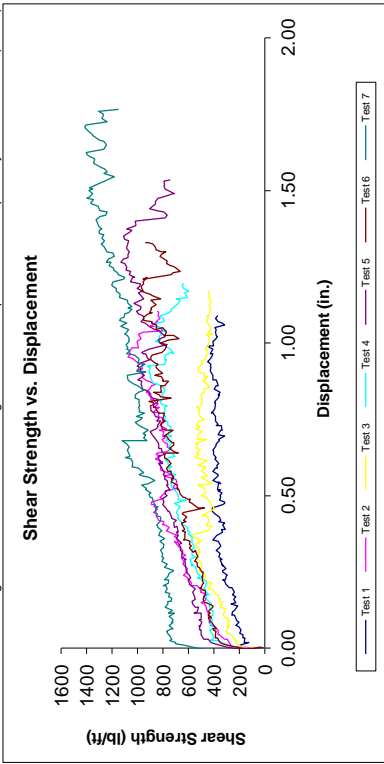
APPENDIX A – EP HENRY CAST STONE WALL SYSTEM SRW RESULTS

NCMA Job Number 14-539-2A

Shear Strength Test Set EP Henry Cast Stone Wall System Segmental Retaining Wall Units - EP Henry Cast Stone Wall System Geosynthetic - None

Test Series Number	Shear Interface Width (ft)	Average Axial Load (lb)	Average Axial Load (lb/ft)	Approximate Wall Height Corresponding to Applied Axial Load (ft)	Shear Load at Service State Deformation ¹ (lb)	Service State Shear Strength (lb/ft)	Service State Displacement (in.)	Peak Shear Load (lb)	Peak Shear Strength (lb/ft)	Peak Displacement (in.)
1	1.3	310	233	2.4	340	255	0.12	600	450	0.94
2	1.3	790	593	6.1	590	443	0.12	1440	1080	0.96
3	1.3	540	405	4.2	420	315	0.12	790	593	0.37
4	1.3	780	585	6.1	550	413	0.12	1230	923	0.93
5	1.3	1040	780	8.1	670	503	0.12	1510	1133	1.27
6	1.3	790	593	6.1	600	450	0.12	1300	975	1.17
7	1.3	1280	960	10.0	950	713	0.12	1890	1418	1.71

¹ - Service State Shear Strength defined as the shear strength at 0.12 in. displacement as required by ICC-ES AC208.2 (Ref. 4)



The following relationships are not required by D6916-06c (2011), but are provided for reference. Using best fit linear trend lines, the following relationships have been determined using the methodology found in the NCMA Design Manual for Segmental Retaining Walls (Ref. 5):

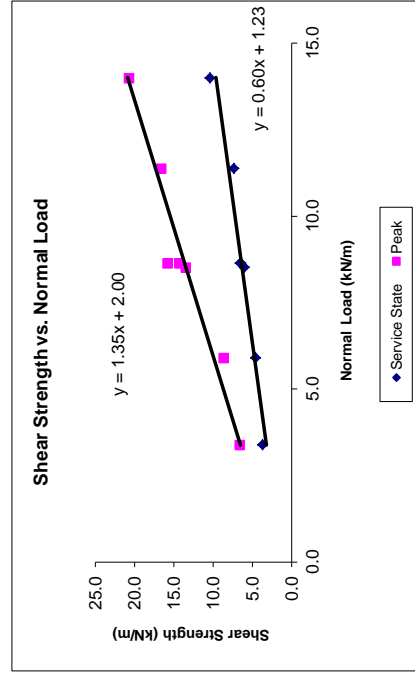
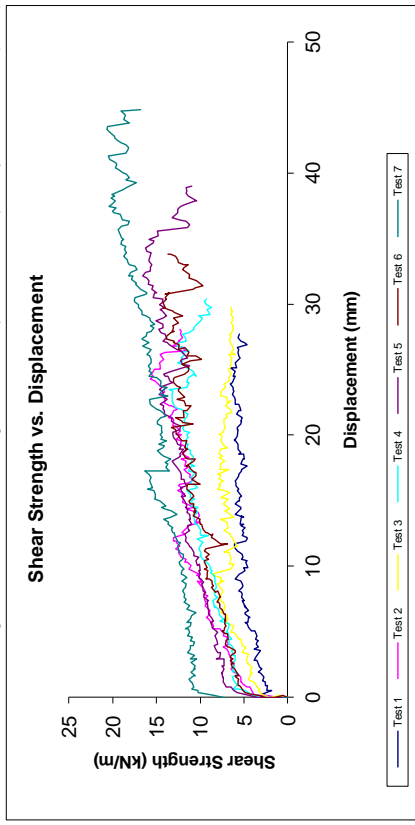
$$\text{Peak Shear Strength, } V_u \text{ (lb/ft)} = \text{Normal Load} * \tan 53.5^\circ + 137 \text{ lb/ft}$$

$$\text{Service State Shear Strength, } V_u \text{ (lb/ft)} = \text{Normal Load} * \tan 31.0^\circ + 84 \text{ lb/ft}$$

Shear Strength Test Set EP Henry Cast Stone Wall System
 Segmental Retaining Wall Units - EP Henry Cast Stone Wall System
 Geosynthetic - None

Test Series Number	Shear Interface Width (m)	Average Axial Load (kN)	Average Axial Load (kN/m)	Approximate Wall Height Corresponding to Applied Axial Load (m)	Shear Load at Service State Deformation ¹ (kN)	Service State Shear Strength (kN/m)	Service State Displacement (mm)	Peak Shear Load (kN)	Peak Shear Strength (kN/m)	Peak Displacement (mm)
1	0.41	1.4	3.4	0.74	1.5	3.7	3.0	2.7	6.6	23.9
2	0.41	3.5	8.7	1.87	2.6	6.5	2.9	6.4	15.8	24.3
3	0.41	2.4	5.9	1.28	1.9	4.6	3.0	3.5	8.7	9.4
4	0.41	3.5	8.5	1.85	2.4	6.0	3.0	5.5	13.5	23.5
5	0.41	4.6	11.4	2.47	3.0	7.3	2.9	6.7	16.5	32.1
6	0.41	3.5	8.7	1.87	2.7	6.6	3.0	5.8	14.2	29.7
7	0.41	5.7	14.0	3.04	4.2	10.4	2.9	8.4	20.7	43.3

¹ - Service State Shear Strength defined as the shear strength at 3.0 mm displacement as required by ICC-ES AC208 (Ref. 4)



The following relationships are not required by D6916-06c (2011), but are provided for reference. Using best fit linear trend lines, the following relationships have been determined using the methodology found in the NCMA Design Manual for Segmental Retaining Walls (Ref. 5):

Peak Shear Strength, V_u (kN/m) = Normal Load * $\tan 53.5^\circ + 2.0$ kN/m
 Service State Shear Strength, V_u (kN/m) = Normal Load * $\tan 31.0^\circ + 1.2$ kN/m