Shear Strength Evaluation of the Segmental Retaining Wall Unit “Murata” and “SG350” Geosynthetic Soil Reinforcement

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CONDUCTED FOR:
Western Interlock Inc.
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CONDUCTED BY:

NATIONAL CONCRETE MASONRY ASSOCIATION
NCMA LAB
RESEARCH & DEVELOPMENT

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The measured and calculated values provided in this report are the official values resulting from this body of work. Values in parenthesis are mathematical conversions provided for reference only and may differ slightly from the official values due to conversion rounding.

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Results for ultimate strength of geosynthetic reinforcement in accordance with ASTM D6637 were provided by the manufacturer. These results have not been evaluated by the NCMA Research and Development Laboratory nor are they covered in the Laboratory's scope of accreditation. The gradation of aggregate was provided by the client. It is not evaluated by the NCMA Research and Development Laboratory.

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7/21/2020

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Table of Contents

Shear Strength Evaluation of the Segmental Retaining Wall Unit “Murata” and “SG350” Geosynthetic Soil Reinforcement

1. 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 “Murata” segmental retaining wall units and “SG350” geosynthetic reinforcement was evaluated, the results of which are reported herein.

2. MATERIALS

All SRW units and geosynthetic reinforcement were sampled and provided by the client. The SRW units are dry-cast concrete blocks with the trade name “Murata”. Table 1 provides the representative dimensions of the units determined by the Laboratory as applicable to this testing program.

Figure 1 –“Murata” SRW Unit

Table 1 – Representative "Murata" SRW Unit Physical Properties	
Length front of unit, in. (mm)	15.72 (399.28)
Length back of unit, in. (mm)	9.43 (239.52)
Height, in. (mm)	7.91 (200.91)
Width, in. (mm)	11.6 (294.64)
Received weight, lb (kg)	58.78 (26.66)

For shear strength testing, the cells of the units and the spaces between the SRW units were filled with aggregate. The client provided aggregates and requested to perform the shear strength testing with an aggregate moisture content of approximately 12.5 %. The client reported that the aggregate supplied met the gradation targets shown in table 2 (Ref. 2).

Table 2: Aggregate Gradation for Dense-graded Aggregate (Ref. 2)

Sieve Size	Percent Passing (by weight)				
3/4"	–	–	55 - 75	–	90 - 100
1/2"	–	–	–	55 - 75	–
3/8"	–	–	–	–	55 - 75
1/4"	30 - 45	30 - 45	35 - 50	40 - 55	40 - 60
No. 4 [1]	–	–	–	–	–
No. 10	[2]	[2]	[2]	[2]	[2]

[1] Report percent passing sieve when no grading requirements are listed

[2] Of the fraction passing the 1/4 inch sieve, 40 percent to 60 percent shall pass the No. 10 sieve

The connection strength was determined using geosynthetic reinforcement with the trade name "SG350", manufactured by Strata. This geosynthetic is constructed out of high molecular weight and high tenacity polyester multifilament yarns which are woven in tension and finished with PVC coating. The manufacturer's website (www.geogrid.com) contains published information for the ultimate tensile strength of the geosynthetic materials used in this project. As provided by the manufacturer the ultimate tensile strength reportedly obtained when tested in accordance with ASTM D6637-2015, *Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi Rib Tensile Method* (Ref. 3), is 5,000 lb/ft (73.0 kN/m) for this geosynthetic.

3. SHEAR STRENGTH PROCEDURES

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

- A bottom course was constructed using “Murata” units. Two SRW units were used for the construction of the bottom course (Figure 2).
- Aggregate was added to the spaces between the units as needed. The aggregate was compacted after placement (Figure 3).
- A 16 inch (0.41 m) piece of the geosynthetic reinforcement was placed on top of the bottom course of units (Figure 4).
- A third “Murata” unit was placed on top of the lower course of units and the geosynthetic reinforcement. The spaces between the units in the second course were filled with aggregate. The aggregate was compacted after placement (Figure 5).
- 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 6).
- 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 (Figure 7). Two linear displacement potentiometers were attached to the front corners of the top unit to measure the amount of shear displacement during testing.
- The resulting length of the shear interface using this testing configuration was 1.3 ft (0.40 m).

Figure 2 – Bottom Course of SRW Units

Figure 3 – Bottom Course with Compacted Aggregate

Figure 4 – Placement of Geosynthetic

Figure 5 – Top SRW Units with Aggregate

Figure 6 – Neoprene Pads, Loading Plates, and Beam

Figure 7 – Overall 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 5 ± 1 mm/min (0.20 ± 0.04 in./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. RESULTS

Shear strength is defined as the shear load divided by the length of the shear interface, which for this project is taken equal to the largest length 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 shear strength is determined based on the critera outlined in ICC-ES AC276, *Acceptance Criteria for Segmental Retaining Walls*, (Ref. 4), which requires the deformation criterion to either be 0.75 inch (19.0 mm) or a value equal to 2 percent of the block height, whichever is less. The height of these units is 7.91 inch (200.9 mm), and thus would be limited by the 2 percent criteria which is 0.16 inch (4.1 mm).

Results for the shear strength testing are provided in the Appendix and are summarized in Table 3. In addition to the data presented, a plot of connection strength versus displacement as well as connection strength versus normal load is 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 720 lb/ft (10.5 kN/m), and the results of those tests were within the general range of repeatability of the test method (± 10% from the mean of the three tests for the peak shear strength). For each test run the system failed by displacement of the upper unit. Figure 8 shows a typical failure mode seen in this project.

Table 3 – Summary of Shear Strength Tests – "Murata" unit and SG350				
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	360 (5.3)	4.0 (1.22)	525 (7.7)	630 (9.2)
2	720 (10.5)	8.0 (2.44)	743 (10.8)	930 (13.6)
3	540 (7.9)	6.0 (1.83)	728 (10.6)	885 (12.9)
4	728 (10.6)	8.1 (2.46)	773 (11.3)	803 (11.7)
5	900 (13.1)	10.0 (3.05)	998 (14.6)	1,230 (18.0)
6	713 (10.4)	7.9 (2.41)	833 (12.2)	833 (12.2)
7	1,095 (16.0)	12.2 (3.71)	1,005 (14.7)	1,005 (14.7)

Figure 8 – Typical Failure Mode

5. 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. Using best-fit linear trend lines, relationships are determined in accordance with the NCMA *Design Manual for Segmental Retaining Walls* (Ref. 5). 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. 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, aggregate, and grid used in this study.

6. REFERENCES

1. ASTM Standard D6916, 2006c (Reapproved 2011), "Standard Test Method for Determining the Shear Strength Between Segmental Concrete Units (Modular Concrete Block)", www.astm.org.
2. Oregon DOT Standard Specification for Construction, 2018, https://www.oregon.gov/odoT
3. ASTM Standard D6637, 2015, "Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method", www.astm.org.
4. ICC-ES AC276, *Acceptance Criteria for Segmental Retaining Walls*, 2004, ICC Evaluation Service, LLC, www.icc-es.org.
5. *NCMA Design Manual for Segmental Retaining Walls, Third Edition*, 2009, National Concrete Masonry Association, www.ncma.org

APPENDIX A- “MURATA” UNIT AND “SG350”

Shear Strength Test Murata / SG350

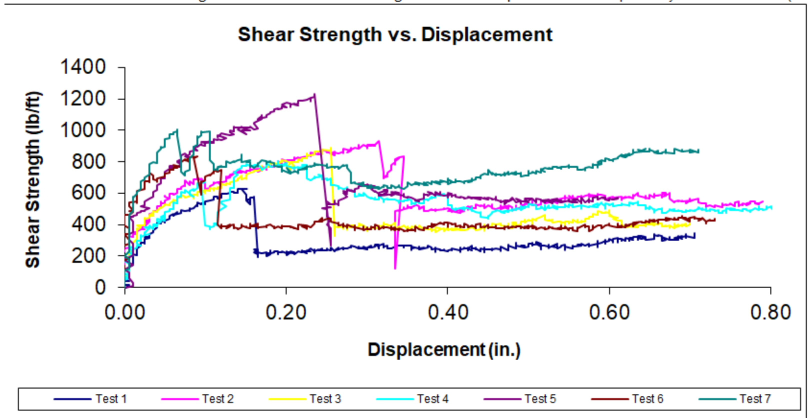
NCMA Job Number 18-110-2A

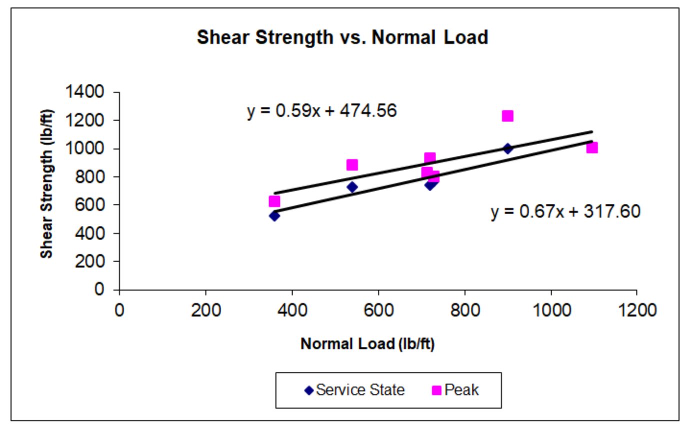
Segmental Retaining Wall Units - Murata

Geosynthetic - SG350 (Ultimate Tensile Strength, Tindex (ASTM D6637)) = 5000 lb/ft

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	480	360	4.0	700	525	0.14	840	630	0.14
2	1.3	960	720	8.0	990	743	0.16	1240	930	0.32
3	1.3	720	540	6.0	970	728	0.16	1180	885	0.26
4	1.3	970	728	8.1	1030	773	0.16	1070	803	0.19
5	1.3	1200	900	10.0	1330	998	0.16	1640	1230	0.24
6	1.3	950	713	7.9	1110	833	0.09	1110	833	0.09
7	1.3	1460	1095	12.2	1340	1005	0.06	1340	1005	0.06

[1] - Service State Shear Strength defined as the shear strength at 0.16 in. displacement as required by ICC-ES AC276 (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, Vu, (kN/m) = Normal Load * tan 30.54° + 474.56 lb/ft

Service State Shear Strength, Vu, (kN/m) = Normal Load * tan 33.82° + 317.60 lb/ft

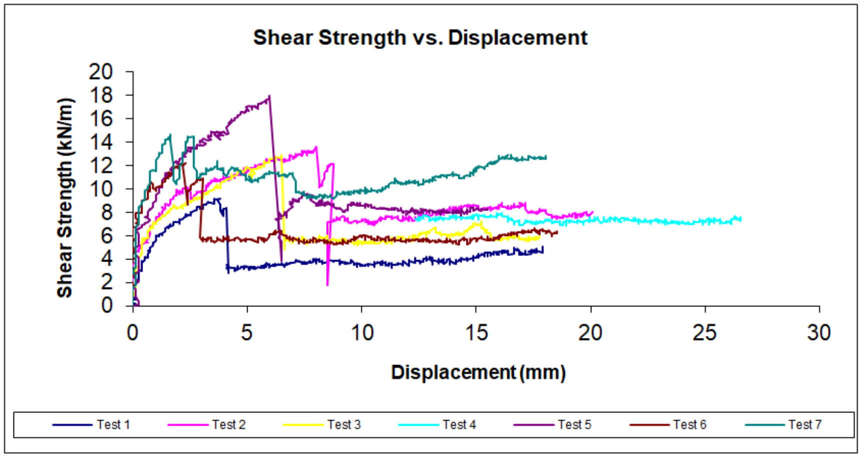
Shear Strength Test Murata / SG350 NCMA Job Number 18-110-2B

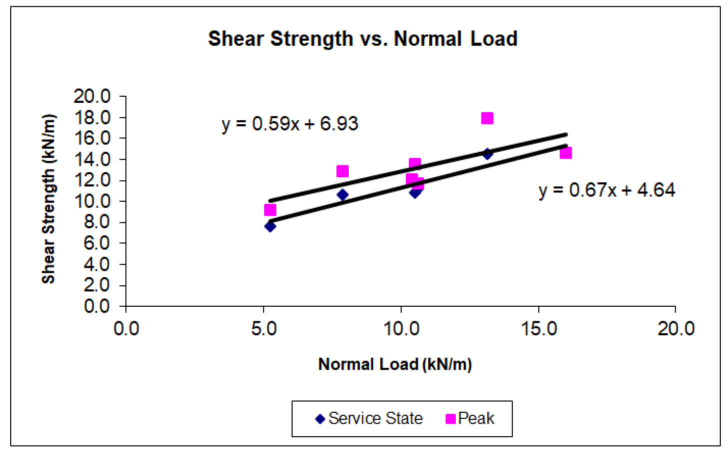
Segmental Retaining Wall Units - Murata

Geosynthetic - SG350 (Ultimate Tensile Strength, Tindex (ASTM D6637)) = 73 kN/m

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	2.1	5.3	1.22	3.1	7.7	3.6	3.7	9.2	3.6
2	0.41	4.3	10.5	2.44	4.4	10.8	3.9	5.5	13.6	8.0
3	0.41	3.2	7.9	1.83	4.3	10.6	3.9	5.3	12.9	6.5
4	0.41	4.3	10.6	2.46	4.6	11.3	3.9	4.8	11.7	4.8
5	0.41	5.3	13.1	3.05	5.9	14.6	3.9	7.3	18.0	6.0
6	0.41	4.2	10.4	2.41	4.9	12.2	2.3	4.9	12.2	2.3
7	0.41	6.5	16.0	3.71	6.0	14.7	1.7	6.0	14.7	1.7

[1] - Service State Shear Strength defined as the shear strength at 4.1 mm displacement as required by ICC-ES AC276 (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, Vu, (kN/m) = Normal Load * tan 30.54° + 6.93 kN/m

Service State Shear Strength, Vu, (kN/m) = Normal Load * tan 33.82° + 4.64 kN/m