Connection 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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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.

7/21/2020

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7/21/2020

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

1. INTRODUCTION

The connection strength between a geosynthetic reinforcement and segmental retaining wall (SRW) unit is a design component of any mechanically stabilized earth system. This connection strength is determined through testing in accordance with ASTM D6638-11, *Standard Test Method for Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks)* (Ref. 1). In this project, the connection strength between “Murata” segmental retaining wall units and “SG350” geosynthetic reinforcement were 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 connection 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 connection 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. CONNECTION STRENGTH PROCEDURES

The connection strength tests were performed in accordance with ASTM D6638-11. All tests were performed on the same configuration as described below and in the accompanying photographs.

- A bottom course was constructed using “Murata” units. Three 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 31.4 inch (0.8 m) piece of the geosynthetic reinforcement was placed on top of the bottom course of units (Figure 4).
- A second course of “Murata” units were 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, steel plates, and a steel beam were placed on the top course of units to provide uniform axial load distribution (Figure 6).
- From the rear of the frame, the geosynthetic was rolled around a steel spreader bar to connect to the hydraulic rams. An aluminum frame was connected to the geosynthetic, which in turn was used to attach two linear displacement potentiometers to measure the amount of geosynthetic pullout and deformation during testing (Figure 7).
- The overall nominal length of the tested configuration was 3.93 feet (1.19 m). The length of the geosynthetic used for testing was 2.6 feet (0.8 m)

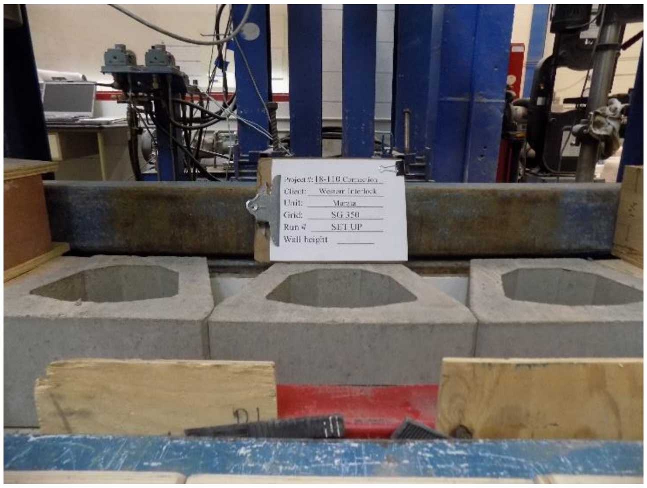


Figure 2 – First Course of SRW Units

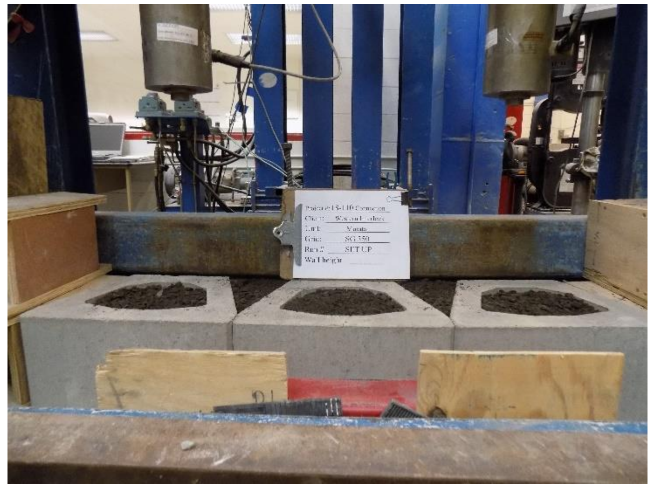


Figure 3 – First Course with Compacted Aggregate

Figure 4 – Placement of Geosynthetic

Figure 5 – Second Course of SRW Units with Aggregate

Figure 6 – Neoprene Pads, Loading Plates, and Beam

Figure 7 – Rear of Testing Frame

Once the test specimens were constructed they were tested using the procedures defined by ASTM D6638-11:

- Normal load was applied to the wall specimen through a dual ram hydraulic loading system applied to the steel beam, plates, and neoprene pad. The magnitude of the normal load for each hydraulic ram was maintained at a constant level and monitored using electronic load cells and a data acquisition system.
- With the normal load applied, the geosynthetic was subjected to a horizontal load by displacing the geosynthetic at a rate equal to 10 percent of the initial free length of grid per minute using a dual ram hydraulic load system and steel spreader bar. The free length of grid is defined as the distance from the back of the units to the loading clamp, and is 10 in. (254 mm) for this test setup. The displacement rate was 1.0 in./min (25.4 mm/min). Each test was continued until the connection strength began to decrease.
- Horizontal displacement of the geosynthetic grid 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 connection strength tests.

4. RESULTS

Connection strength is defined as the connection load divided by the test width of the geosynthetic reinforcement. The peak connection strength is defined as the highest recorded value of connection strength. ASTM D6638-11 requires reporting of serviceability connection 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 at 0.75 inch (19.0mm) displacement.

Results for the connection 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 725 lb/ft (10.8 kN/m), and the results of those tests were within the general range of repeatability of the test method (± 10 percent from the mean of the three tests for the peak connection strength).

All specimens failed due to rupture of the geosynthetic reinforcement in combination with some geosynthetic displacement. Figure 8 shows the typical failure mode for this project.

Test Number	Average Axial Load lb/ft (kN/m)	Approximate Wall Height based on Axial Load ft (m)	Service State Connection Strength lb/ft (kN/m)	Peak Connection Strength lb/ft (kN/m)
1	360 (5.4)	4.0 (1.22)	589 (8.6)	735 (10.7)
2	725 (10.8)	8.1 (2.45)	868 (12.6)	1,046 (15.3)
3	533 (8.0)	5.9 (1.80)	620 (9.0)	896 (13.1)
4	728 (10.9)	8.1 (2.46)	863 (12.6)	1,112 (16.2)
5	905 (13.5)	10.1 (3.06)	769 (11.2)	1,073 (15.7)
6	723 (10.8)	8.0 (2.45)	905 (13.2)	1,158 (16.9)
7	1,083 (16.2)	12.0 (3.66)	816 (11.9)	1,262 (18.4)

Table 3 – Summary of Connection Strength Tests – "Murata" Unit and SG350

Figure 8 – Typical Failure Mode

5. DISCUSSION

The following discussion is not a required portion of the ASTM D6638-11 standard, but is provided for the reference and convenience of the reader.

A plot of normal load versus connection strength is also provided in the Appendix of this report. As can be seen from these figures, a relationship can be determined for the peak connection strengths as a function of the normal loads. Using a best-fit linear trend line, a relationship is determined in accordance with the NCMA *Design Manual for Segmental Retaining Walls, Third Edition* (ref.5). Relationships are provided for the peak connection strength (T_{cl}) and service state connection strength (T_{cw}) within the range of the normal loads tested in this study.

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

6. REFERENCES

1. ASTM Standard D6638, 2011, "Standard Test Method for Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks)", 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

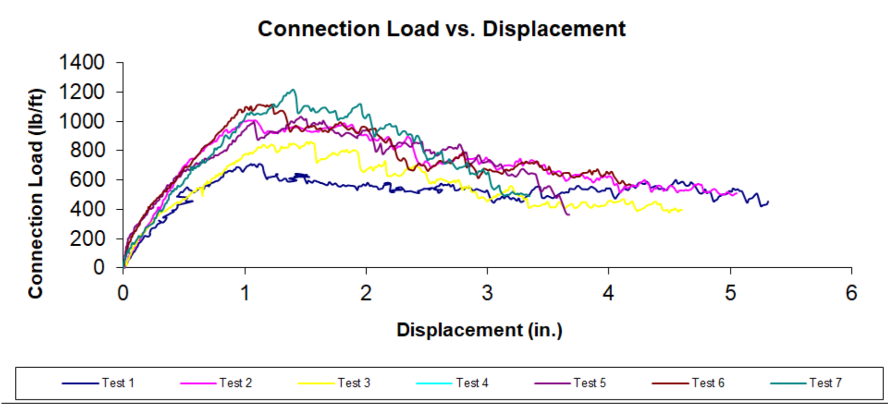
APPENDIX A- "MURATA" UNIT AND "SG350"

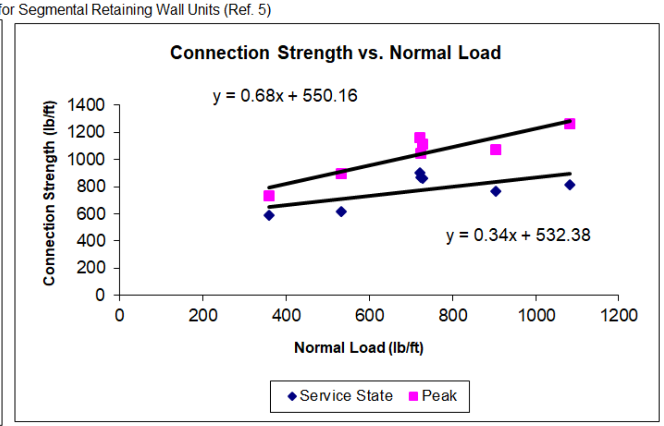
Test Set *Murata* / SG350
Segmental Retaining Wall Units - *Murata*
Geosynthetic -SG350 (Ultimate Tensile Strength, Tindex (ASTM D6637)) = 5000 lb/ft

NCMA Job Number 18-110-1A

Test Series Number	Geosynthetic Width (ft)	Average Axial Load (lb)	Average Axial Load (lb/ft)	Approximate Wall Height Corresponding to Applied Axial Load (ft)	Slack Tension (lb)	Tensile Load at Service State Deformation[1] (lb)	Service State Connection Strength (lb/ft)	Service State Displacement (in.)	Peak Tensile Load (lb)	Peak Connection Strength (lb/ft)	Peak Displacement (in.)
1	2.6	1440	360	4.0	170	1590	589	0.76	1910	735	1.05
2	2.6	2900	725	8.1	190	2340	868	0.75	2720	1046	1.04
3	2.6	2130	533	5.9	180	1670	620	0.76	2330	896	1.54
4	2.6	2910	728	8.1	170	2330	863	0.75	2890	1112	1.22
5	2.6	3620	905	10.1	150	2080	769	0.75	2790	1073	1.46
6	2.6	2890	723	8.0	130	2440	905	0.76	3010	1158	1.12
7	2.6	4330	1083	12.0	170	2200	816	0.75	3280	1262	1.40

[1] - Service State Displacement defined as the connection strength at 0.75 in. displacement as recommended by the NCMA Design Manual for Segmental Retaining Wall Units (Ref. 5)





The following relationships are not required by D6638-11, 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 Connection Strength, Tcl, (lb/ft) = Normal Load * tan 34.22° + 550.16 lb/ft

Service State Connection Strength, Tcw (lb/ft) = Normal Load * tan 18.78° + 532.38 lb/ft

Test Set Murata / SG350

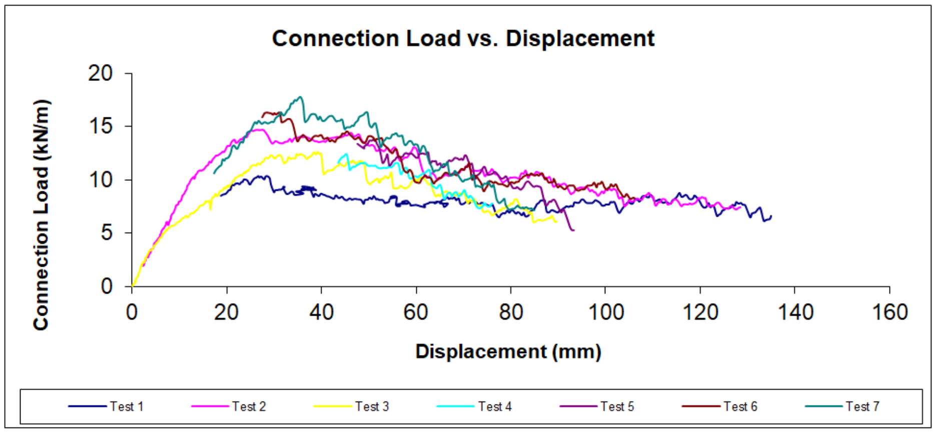
NCMA Job Number 18-110-1B

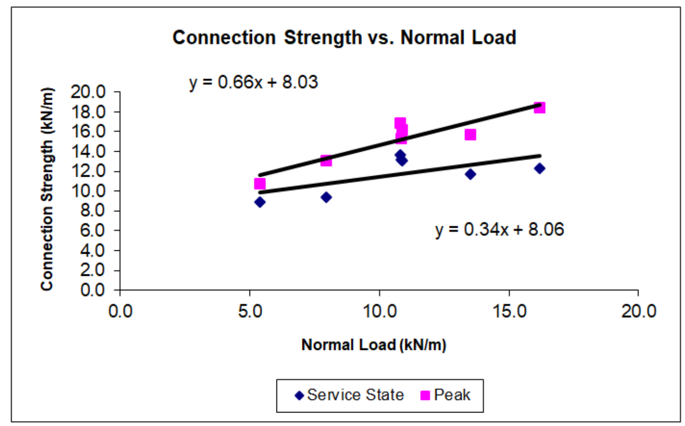
Segmental Retaining Wall Units - Murata

Geosynthetic - SG350 (Ultimate Tensile Strength, Tindex (ASTM D6637)) = 73.0 kN/m

Test Series Number	Geosynthetic Width (m)	Average Axial Load (kN)	Average Axial Load (kN/m)	Approximate Wall Height Corresponding to Applied Axial Load (m)	Slack Tension (kN)	Tensile Load at Service State Deformation[1] (kN)	Service State Connection Strength (kN/m)	Service State Displacement (mm)	Peak Tensile Load (kN)	Peak Connection Strength (kN/m)	Peak Displacement (mm)
1	0.79	6.4	5.4	1.22	0.8	7.1	8.9	19.2	8.5	10.7	26.7
2	0.79	12.9	10.8	2.45	0.8	10.4	13.1	19.1	12.1	15.3	26.3
3	0.79	9.5	8.0	1.80	0.8	7.4	9.4	19.2	10.4	13.1	39.1
4	0.79	12.9	10.9	2.46	0.8	10.4	13.1	19.1	12.9	16.2	31.0
5	0.79	16.1	13.5	3.06	0.7	9.3	11.7	19.1	12.4	15.7	37.1
6	0.79	12.9	10.8	2.45	0.6	10.9	13.7	19.3	13.4	16.9	28.4
7	0.79	19.3	16.2	3.66	0.8	9.8	12.3	19.1	14.6	18.4	35.6

[1] - Service State Displacement defined as the connection strength at 19 mm displacement as recommended by the NCMA Design Manual for Segmental Retaining Wall Units (Ref. 5)





The following relationships are not required by D6638-11, 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 Connection Strength, Tcl, (kN/m) = Normal Load * tan 33.42° + 8.03 kN/m

Service State Connection Strength, Tcw (kN/m) = Normal Load * tan 18.26° + 8.06 kN/m