Connection Strength Evaluation of the EP Henry Cast Stone Wall System and Tencate Mirafi 2XT Geosynthetic Soil Reinforcement

for

EP Henry Corporation
PO Box 615
Woodbury, NJ 08096

Project No. 14-539-1
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Conducted by:

NATIONAL CONCRETE MASONRY ASSOCIATION
RESEARCH & DEVELOPMENT LABORATORY

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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.

3/19/2015

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Nicholas R. Lang, Director of Research and Development — Date

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Connection Strength Evaluation of the EP Henry Cast Stone Wall System and Tencate Mirafi 2XT Geosynthetic Soil Reinforcement

1.0 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 Block)* (Ref. 1). In this project, the connection strength of the EP Henry Cast Stone Wall System with Tencate Mirafi 2XT geosynthetic was evaluated, the results of which are reported herein.

2.0 MATERIALS

All SRW units and geosynthetic reinforcement were sampled and provided by the client. The SRW units are dry-cast concrete blocks and part of the 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.

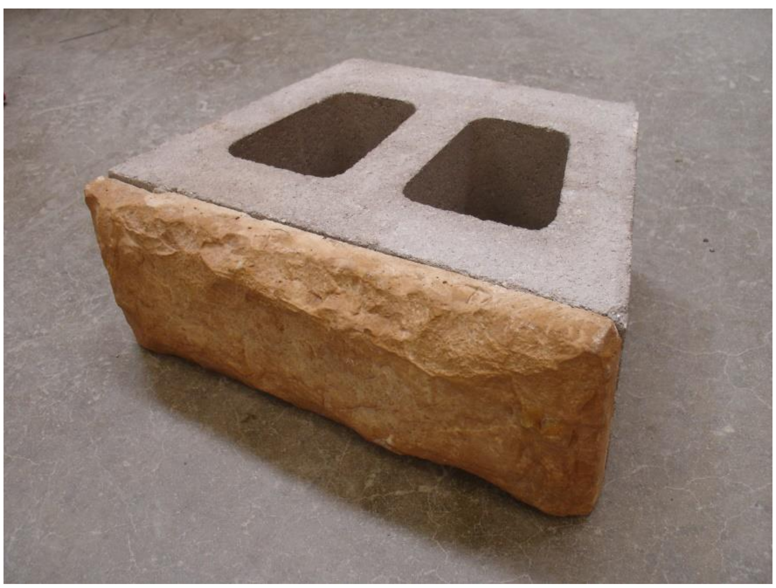
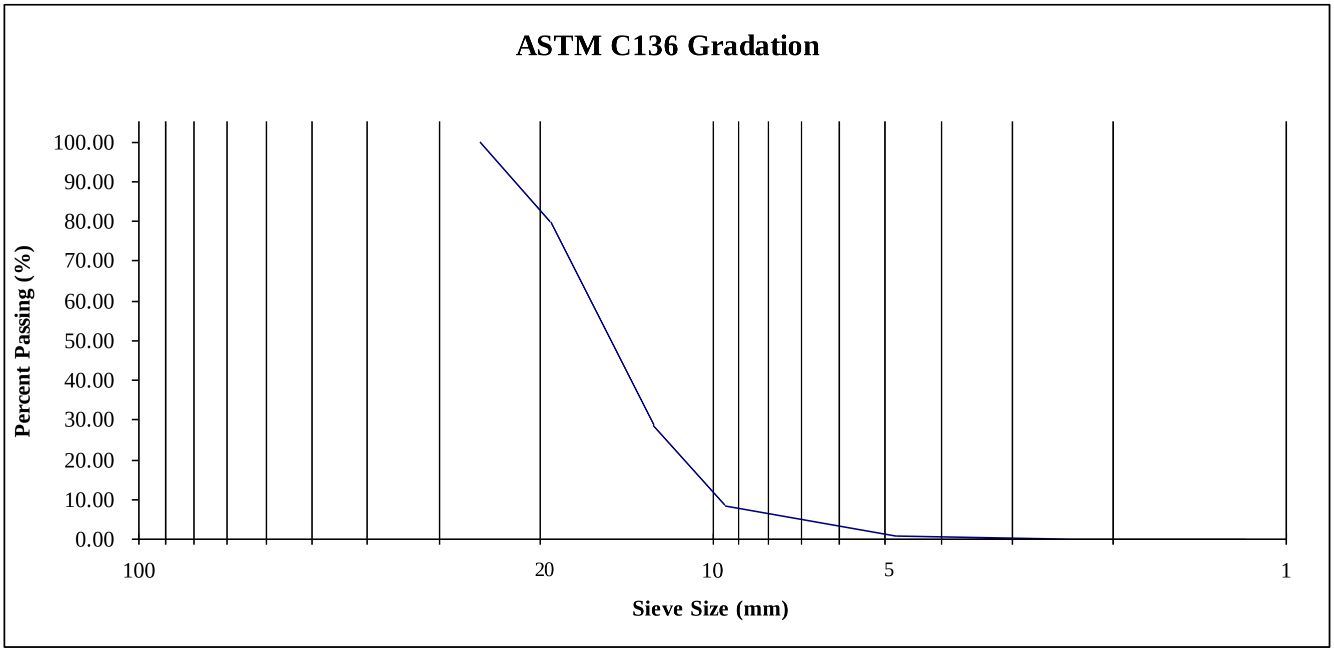


Figure 1 – Representative SRW Unit

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, in. (mm)	6.0 (152)
Width, in. (mm)	11.5 (292)
Received weight, lb (kg)	48.18 (21.85)

For connection 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. 2). Figure 2 shows the gradation of the aggregate used. The aggregate was consolidated into the cells and voids of the SRW assemblies by rodding.



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

Figure 2 – Aggregate Gradation

The connection strength was determined using geosynthetic reinforcement with the trade name "Mirafi 2XT", manufactured by Tencate Geosynthetics. This geosynthetic is constructed out of high molecular weight and high tenacity polyester yarns utilizing a complex knitting process and a polymeric 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 (2010), *Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi Rib Tensile Method* (Ref. 3), is 2,000 lb/ft (29.2 kN/m) for this geosynthetic.

3.0 CONNECTION STRENGTH PROCEDURES

The connection strength tests were performed in accordance with ASTM D6638-11. All tests were performed with the same configuration. The testing configuration is described below and accompanying photographs are provided below.

- The bottom course was constructed using the SRW units as shown in Figure 3 and aggregate was added to the cores of the units and spaces between the units as needed.
- A 36.0 in. (914 mm) piece of geosynthetic reinforcement was placed on top of the units so that it would meet the edge of the bottom course units (Figure 4).
- A course of SRW units was placed on top of the lower course of units and the geosynthetic reinforcement. The top units were place so there was no setback between the bottom and the top courses. The cores of the units and spaces between the units were filled with aggregate (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.
- The overall nominal length of the tested configuration was 4.0 ft. (1.22 m).

Figure 3 – Lower Units

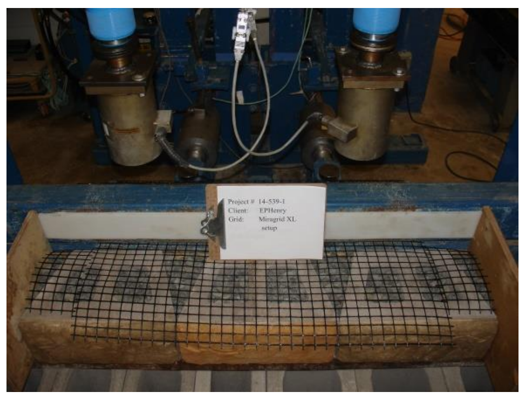


Figure 4 – Placement of Geosynthetic

Figure 5 – Top Course of Units

Figure 6 – Placement of Neoprene Pad, Steel Plates, and Steel Beam

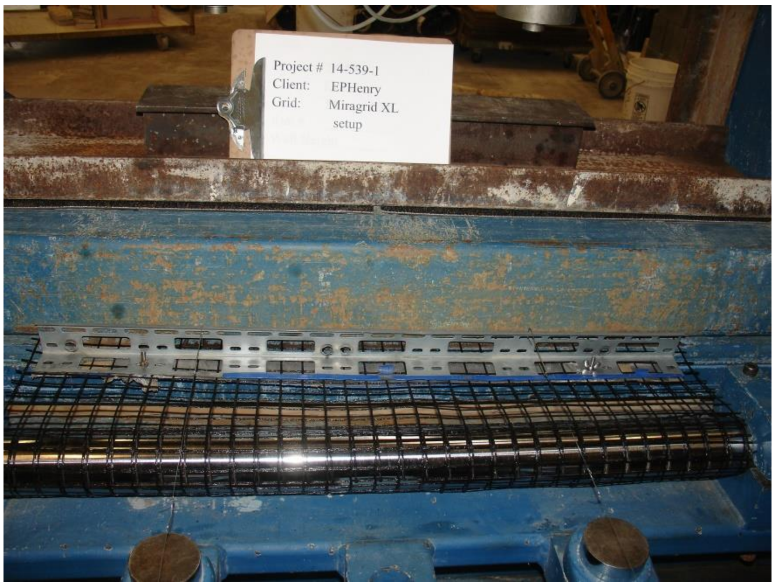


Figure 7 – Rear of Testing Setup

Once the test specimen was constructed it was 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% 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). The test was continued until the connection strength began to decrease.
- Horizontal displacement of the geosynthetic 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.

4.0 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. Currently, the NCMA *Design Manual for Segmental Retaining Wall Units, Third Edition* (Ref. 4) does not include any recommendations for serviceability connection strength, nor is this value required by the design provisions within that manual. In this project, however, the connection strength at 19 mm (0.75 in.) horizontal displacement, as measured from the back of the unit, is defined as the serviceability connection strength, as this value has been historically used and was previously recommended by the NCMA *Design Manual for Segmental Retaining Wall Units, Second Edition* (Ref. 5).

Results for the connection strength testing are provided in the appendix and are summarized in Table 2. In addition to the data presented, a plot of connection strength vs. displacement as well as connection 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 630 lb/ft (9.2 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 connection strength).

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

Table 2 – Summary of Connection Strength Tests

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	258 (3.8)	2.7 (0.83)	637 (9.3)	1,150 (16.8)
2	625 (9.1)	6.6 (2.02)	1,022 (14.9)	1,370 (20.0)
3	440 (6.4)	4.7 (1.42)	766 (11.2)	1,293 (18.9)
4	628 (9.2)	6.7 (2.03)	851 (12.4)	1,417 (20.7)
5	813 (11.9)	8.6 (2.63)	1,062 (15.5)	1,587 (23.2)
6	630 (9.2)	6.7 (2.04)	825 (12.0)	1,303 (19.0)
7	1,005 (14.7)	10.7 (3.25)	1,233 (18.0)	1,733 (25.3)

Figure 8 – Typical Failure Mode

5.0 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. As can be seen from this figure, a relationship can be determined for both the serviceability connection strength (at 0.75 in. [19 mm] displacement) as well as the peak connection 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). As noted before, the third edition of this design manual does not include provisions for the serviceability connection strength. While ASTM D6638-11 requires that serviceability connection strength be determined, it does not define the specified displacement, leaving this displacement to be prescribed by the user. A value of 0.75 in. (19 mm) is reported here as this value has been used historically. Relationships are provided for both the peak connection strength (T_{cl}) as well as the service state connection strength (T_{cw}) within the range of normal load tested in this study.

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

6.0 REFERENCES

1. ASTM Standard D6638, 2011, "Standard Test Method for Determining Connection Strength Between Geosynthetic Reinforcement and 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. ASTM Standard D6637, 2010, "Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method", ASTM International, West Conshohocken, PA, www.astm.org.
4. *NCMA Design Manual for Segmental Retaining Walls, Third Edition*, 2009, National Concrete Masonry Association, 13750 Sunrise Valley Drive, Herndon, VA 20171-4662.
5. *NCMA Design Manual for Segmental Retaining Walls, Second Edition, Third Printing,* 2002, National Concrete Masonry Association, 13750 Sunrise Valley Drive, Herndon, VA 20171-4662.

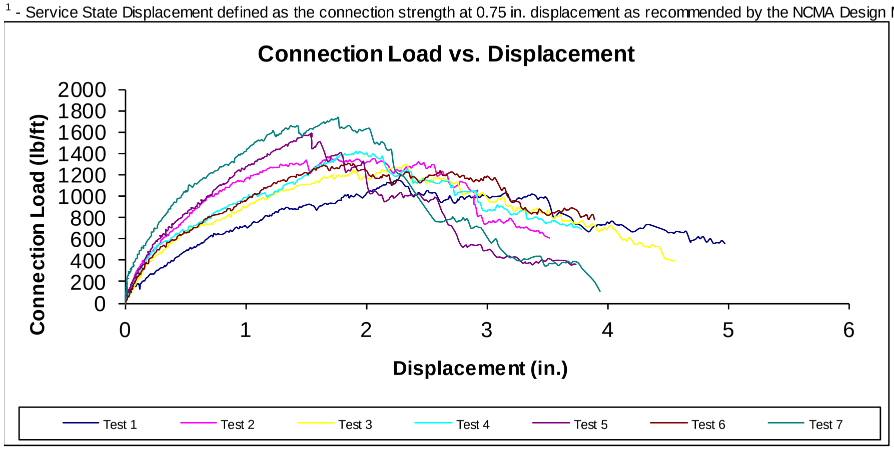
APPENDIX A – MIRAFI 2XT RESULTS

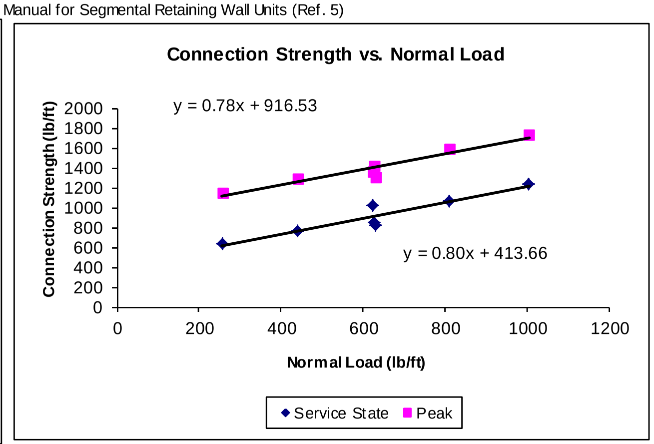
Test Set EP Henry Cast Stone Wall System / Miragrid 2XT Geosynthetic
Segmental Retaining Wall Units - EP Henry Cast Stone Wall System
Geosynthetic - Miragrid 2XT (Ultimate Tensile Strength, Tindex (ASTM D6687)) = 2,000 lb/ft

NCMA Job Number 14-539-1A

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	3.0	1030	258	2.7	110	1910	637	0.76	3450	1150	2.26
2	3.0	2500	625	6.6	190	3070	1022	0.75	4110	1370	1.68
3	3.0	1760	440	4.7	190	2300	766	0.75	3880	1293	2.34
4	3.0	2510	628	6.7	170	2550	851	0.76	4250	1417	1.92
5	3.0	3250	813	8.6	190	3190	1062	0.75	4760	1587	1.55
6	3.0	2520	630	6.7	180	2470	825	0.75	3910	1303	1.85
7	3.0	4020	1005	10.7	150	3700	1233	0.75	5200	1733	1.77

[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. 4 and 5):

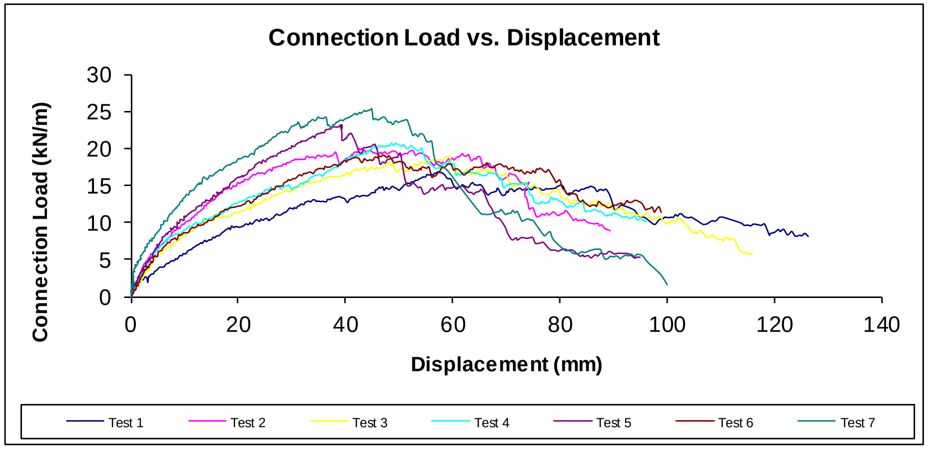
Peak Connection Strength, Tcl, (lb/ft) = Normal Load * tan 38.0° + 917 lb/ft

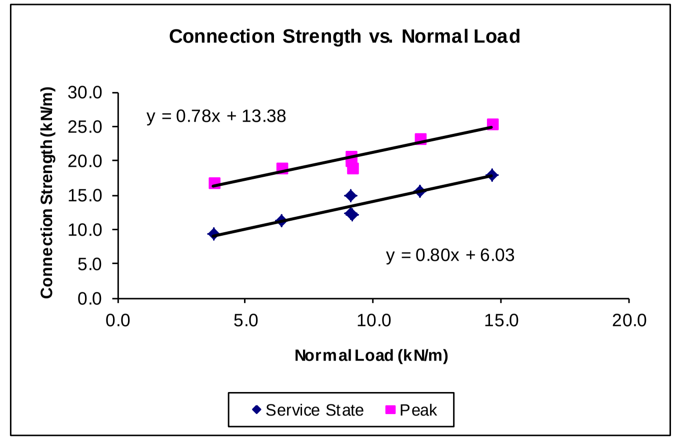
Service State Connection Strength, Tcw (lb/ft) = Normal Load * tan 38.7° + 414 lb/ft

Test Set EP Henry Cast Stone Wall System / Miragrid 2XT Geosynthetic
Segmental Retaining Wall Units - EP Henry Cast Stone Wall System
Geosynthetic - Miragrid 2XT (Ultimate Tensile Strength, Tindex (ASTM D6687)) = 29.2 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	0.91	4.6	3.8	0.83	0.5	8.5	9.3	19.2	15.3	16.8	57.3
2	0.91	11.1	9.1	2.02	0.8	13.7	14.9	19.1	18.3	20.0	42.7
3	0.91	7.8	6.4	1.42	0.8	10.2	11.2	19.1	17.3	18.9	59.4
4	0.91	11.2	9.2	2.03	0.8	11.3	12.4	19.2	18.9	20.7	48.6
5	0.91	14.5	11.9	2.63	0.8	14.2	15.5	19.1	21.2	23.2	39.4
6	0.91	11.2	9.2	2.04	0.8	11.0	12.0	19.1	17.4	19.0	47.0
7	0.91	17.9	14.7	3.25	0.7	16.5	18.0	18.9	23.1	25.3	45.0

[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. 4 and 5):

Peak Connection Strength, Tcl, (kN/m) = Normal Load * tan 38.0° + 13.4 kN/m

Service State Connection Strength, Tcw (kN/m) = Normal Load * tan 38.7° + 6.0 kN/m