Cornerstone Segmental Retaining Wall Unit
Shear Strength Test

Prepared for
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# TABLE OF CONTENTS

1.0  **INTRODUCTION**  ................................................................. 4  
2.0  **SHEAR STRENGTH TEST PROCEDURES**  ............................................. 4  
3.0  **SHEAR STRENGTH TEST RESULTS**  ................................................ 5  
4.0  **ALLOWABLE SHEAR STRENGTH – NCMA METHODOLOGY**  ................. 7  

Appendix A – Load Deformation Plots for Cornerstone 100 Series  .......... A-1  
Appendix B – Load Deformation Plots for Cornerstone 100 Series with GG 45  . B-1
1.0 INTRODUCTION

The shear strength between courses of segmental retaining wall (SRW) units is an important component of any SRW design. Testing of the shear strength for reinforced soil SRWs evaluates the unit-to-unit and unit-to-geosynthetic-to-unit interface shear strengths. Conventional (gravity) SRWs require only the evaluation of the block-to-block interface shear strength. The National Concrete Masonry Association (NCMA) has developed a standard method for testing the shear strength: NCMA Test Method SRWU-2, Determination of Shear Strength between Segmental Concrete Units.

A testing program was developed to evaluate the shear strength of Cornerstone SRW units (Series 100) and SI Geosolutions® geogrid reinforcement. SI Geosolutions geogrid reinforcement consists of high molecular weight, high tenacity polyester (PET) yarns woven into a dimensionally stable network of high modulus tensile members. SI Geosolutions geogrid is coated with polyvinyl chloride (PVC) for additional dimensional stability.

The Cornerstone SRW units (Series 100) used for the tests referenced herein are dry cast concrete blocks. The standard unit is 18 inches wide at the front split face, 8 inches high, and 12 inches deep with a hollow core (all dimensions are nominal). The Cornerstone SRW unit (Series 100) has an approximate weight of 75 lbs., and the approximate unit weight for the Cornerstone SRW unit (Series 100) with core fill is 110 lbs. Figure 1 shows the geometry of a standard unit.

The testing program consisted of evaluating the interface shear between Cornerstone SRW units and Cornerstone SRW units with the inclusion of SI Geosolutions GG 45 geogrid. The tests were performed at normal loads between 140 and 2100 lb./ft. Six (6) tests were conducted for each setup, resulting in twelve (12) individual tests.

2.0 SHEAR STRENGTH TEST PROCEDURES

The connection tests were performed in accordance with NCMA Test Method SRWU-2, Determination of Shear Strength between Segmental Concrete Units.

The configuration of the test specimens for each shear strength test is shown in Figure 2 and Figure 3. The test procedure is described from the bottom to the top of the test chamber as follows:

- Lower course of two (2) Cornerstone SRW units placed with the 18-inch nominal dimension parallel to the wall face (12-inch nominal dimension perpendicular to the wall face).
- Granular infill placed and compacted to density as in field.
- The geogrid was placed on top of the first course of units. The geogrid extends beyond the edge of the upper unit to assure complete influence on the interface surface. The grid was placed such that the first transverse rib was positioned just to the inside surface of the face shell of the front of the units (Figure 2).

- Second course of Cornerstone SRW unit placed on top of the first course and the installed geogrid.

- Granular infill placed and compacted to density as in field.

For each setup, the shear strength test was conducted as follows:

- Normal load was applied to the wall specimen through a single ram hydraulic loading system to steel spreader beams, bearing plates with steel rollers, and a layer of hard neoprene bearing pads placed on the top course (Figure 3). The magnitude of normal load for the hydraulic ram was maintained at a constant level and monitored using an electronic load cell throughout each test.

- After application of the normal load, each setup was subjected to a seating load, not to exceed 10% of the peak shear strength or 50 lbs., whichever is smaller.

- Each test setup was subjected to a transverse load, by displacing the upper SRW unit across the top of the lower course of SRW units, at a rate of 0.01 to 0.03 in./min. The test was continued until a constant or decreasing transverse load was recorded. The normal load was maintained at a constant magnitude throughout each test.

- All of interface shear tests were conducted with the transverse load applied perpendicular to the back of the upper SRW Unit

### 3.0 SHEAR STRENGTH TEST RESULTS

The shear force is defined as the shear load divided by the width of the unit-to-unit interface. The peak shear strength is defined as the peak value of applied shear force. The shear strength at 0.75 inches horizontal displacement, as measured at the back of the Cornerstone SRW unit, is defined as the shear force at this displacement (see Section 4.0 – Allowable Shear Strength – NCMA Methodology).

The results of each series of six (6) tests are summarized in Tables 1 and 2.
### TABLE 1
**SUMMARY OF TEST RESULTS**
Cornerstone SRW Unit to Cornerstone SRW Unit

<table>
<thead>
<tr>
<th>TEST NUMBER</th>
<th>NORMAL LOAD (lb/ft)</th>
<th>APPROXIMATE WALL HEIGHT (ft)</th>
<th>PEAK SHEAR STRENGTH (lb/ft)</th>
<th>SERVICEABILITY SHEAR STRENGTH (lb/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>147</td>
<td>1.33</td>
<td>972</td>
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<td>2</td>
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<td>1550</td>
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<td>3061</td>
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<td>19.33</td>
<td>3988</td>
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</tbody>
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### TABLE 2
**SUMMARY OF TEST RESULTS**
Cornerstone SRW Unit to Cornerstone SRW Unit with SI Geosolutions GG 45

<table>
<thead>
<tr>
<th>TEST NUMBER</th>
<th>NORMAL LOAD (lb/ft)</th>
<th>APPROXIMATE WALL HEIGHT (ft)</th>
<th>PEAK SHEAR STRENGTH (lb/ft)</th>
<th>SERVICEABILITY SHEAR STRENGTH (lb/ft)</th>
</tr>
</thead>
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<tr>
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<td>4.67</td>
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<td>2070</td>
<td>19.33</td>
<td>4132</td>
<td>4132</td>
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</table>
4.0 ALLOWABLE SHEAR STRENGTH – NCMA METHODOLOGY

The NCMA “Design Manual for Segmental Retaining Walls” has adopted a procedure for determining the allowable shear strength between SRW units that considers both a limit shear strength and a serviceability shear strength. The shear strength between SRW units provides two functions. One, the shear strength between SRW units provides additional sliding resistance when evaluating internal sliding, a potential internal sliding failure that propagates along the surface of a geosynthetic reinforcement layer and through the interface between SRW units. Two, the shear strength between SRW units provides resistance to the theoretical horizontal earth pressure being applied between layers of geosynthetic reinforcement (resistance to bulging), maintaining the relative position of one course to the next. The shear strength is a function of applied pressure, vertical spacing of geosynthetic reinforcement and shear strength between SRW units. The procedure for determining the shear strength (capacity) is presented below:

The peak shear strength ($V_{u(n)}$) at any interface is determined as follows:

$$V_{u(n)} = a_u + W_{w(n)} \tan \lambda_u$$

Where:

- $a_u = \text{apparent shear capacity (lb/ft)}$
- $\lambda_u = \text{apparent peak interface friction angle between SRW units (deg)}$
- $W_{w(n)} = \text{total weight of column of dry-stacked SRW units between surface and hinge height relative to the sliding surface (lb/ft)}$

Limiting movement of the wall face over the life of the structure (serviceability) is also considered.

$$V'_{u(n)} = a'_u + W_{w(n)} \tan \lambda'_u$$

Where:

- $a'_u = \text{apparent serviceability shear capacity (lb/ft)}$
- $\lambda'_u = \text{apparent serviceability interface friction angle between SRW units (deg)}$
- $W_{w(n)} = \text{total weight of column of dry-stacked SRW units between surface and hinge height relative to the sliding surface (lb/ft)}$
The limit state and serviceability shear strengths are provided in Tables 1 and 2 for each test setup and level of normal load. A plot of the peak and serviceability shear strength verses applied normal is shown in Figures 4 and 5, and individual load deformation plots for each test can be found in Appendices A and B.
Figure 1 – Cornerstone Segmental Retaining Wall Unit Geometry

Figure 2 – Shear Strength Test Setup – Cornerstone SRW Unit with SI Geosolutions GG 45 Geogrid
Figure 3 - Shear Strength Test Setup - Cornerstone SRW Unit
Cornerstone Shear Strength

\[ V_u = W_w \tan(\theta_u) + a_u \]
\[ a_u = 1065 \text{ lb/ft} \]
\[ \theta_u = 58^\circ \]

\[ V'_u = W_w \tan(\theta'_u) + a'_u \]
\[ a'_u = 766 \text{ lb/ft} \]
\[ \theta'_u = 57^\circ \]
Cornerstone Shear Strength with GG 45

\[ V_u = W_w \tan(l_u) + a_u \]
\[ a_u = 842 \text{ lb/ft} \]
\[ l_u = 57^\circ \]

\[ V'_u = W_w \tan(l'_u) + a'_u \]
\[ a'_u = 801 \text{ lb/ft} \]
\[ l'_u = 56^\circ \]
Appendix A – Load Deformation Plots for Cornerstone 100 Series
Figure A-1 - Transverse Load Deformation Response

Normal Load = 147 lb/ft

Peak Shear Force = 972 lb/ft
Figure A-2 - Transverse Load Deformation Response

Normal Load = 473 lb/ft

Peek Shear Force = 1862 lb/ft
Figure A-3 - Transverse Load Deformation Response
Normal Load = 1270 lb/ft

Peak Shear Force = 3489 lb/ft
Figure A-4 - Transverse Load Deformation Response

Normal Load = 1273 lb/ft

Peak Shear Force = 3139 lb/ft

Service State Deformation

Transverse Load (lb/ft) vs. Average Deformation (in)
Figure A-5 - Transverse Load Deformation Response
Normal Load = 1266 lb/ft

Peak Shear Force = 3416 lb/ft

Average Deformation (in)

Average Load (lb/ft)
Figure A-6 - Transverse Load Deformation Response
Normal Load = 2078 lb/ft

Peak Shear Force = 3988 lb/ft
Appendix B – Load Deformation Plots for Cornerstone Series 100 with SI Geosolutions GG 45 Geogrid
Figure B-1 - Transverse Load Deformation Response
Normal Load = 147 lb/ft

Peak Shear Force = 825 lb/ft
Figure B-2 - Transverse Load Deformation Response
Normal Load = 471 lb/ft

Peak Shear Force = 2035 lb/ft
Figure B-3 - Transverse Load Deformation Response

Normal Load = 1268 lb/ft

Peak Shear Force = 2630 lb/ft

Service State Deformation

Average Deformation (in)

Transverse Load (lb/ft)
Figure B-4 - Transverse Load Deformation Response
Normal Load = 1275 lb/ft

Peak Shear Force = 2501 lb/ft
Figure B-5 - Transverse Load Deformation Response
Normal Load = 1276 lb/ft

Peak Shear Force = 2842 lb/ft
Figure B-6 - Transverse Load Deformation Response
Normal Load = 2070 lb/ft

Peak Shear Force = 4132 lb/ft