FINAL REPORT:
CONNECTION STRENGTH TESTING

TENSAR GEOGRIDS WITHIN MESA STANDARD BLOCKS
AND MESA STANDARD CONNECTORS

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1. **INTRODUCTION**

SGI Testing Services, LLC (SGI) conducted a laboratory testing program to evaluate the connection strength between Tensar geogrids and Mesa standard block units. The testing program was conducted in accordance with the test procedures and conditions specified by Mr. Andy Anderson, P.E. of Tensar International Corporation (Tensar). All of the connection strength tests were conducted at SGI located in Norcross, Georgia.

2. **TEST MATERIALS**

Three types of materials were used in this testing program. Descriptions of these materials are given below:

- Geosynthetic Reinforcement: Six (6) Tensar Geogrids (i.e., UX1100MSE, UX1400MSE, UX1500MSE, UX1600MSE, UX1700MSE, and LH800) manufactured by Tensar.
- Segmental Retaining Wall (SRW) Facing Units: Mesa Standard Concrete Units. A full-size Mesa Standard Concrete Unit used during this testing program had dimensions of approximately 18 in. wide by 11 in. long by 8 in. high, and weighed 78 lbs.
- Connectors: Mesa Standard Connectors.

All of the test materials used in the testing program were provided by Tensar International Corporation.

3. **TEST EQUIPMENT**

The connection strength tests were conducted in SGI's connection testing device that had plan dimensions of 3 ft by 7 ft and an overall depth of 20 in. The connection testing device had a normal loading system consisting of three hydraulic cylinders and a horizontal loading system consisting of two hydraulic cylinders. A photo of the connection testing device is shown in Figure A-1.

4. **TEST METHOD AND PROCEDURES**

The connection strength tests were performed in accordance with the American Society for Testing and Materials (ASTM) Standard Test Method D 6638, "Determining Connection Strength between Geosynthetic Reinforcement and Segmental Concrete Units". The specific testing procedures used to conduct connection testing are described in Appendix A.
5. TEST RESULTS

Six series of connection strength tests were performed to evaluate the connection strength between the six Tensar Geogrids and Mesa Standard Concrete Units in this testing program. For each connection strength test series, the test results are presented on a summary page in Appendix B. The summary page includes:

- Connection force versus displacement figure;
- Connection strength versus normal load figure; and
- A table that summarizes test conditions, peak, and 0.75 in. connection strength.

The results of the six connection test series are also summarized in Table 1.

6. CLOSURE

The reported test results apply only to the materials and test conditions used in the laboratory testing program. The test results do not necessarily apply to other materials or test conditions. The test results should not be used in engineering analysis unless the test conditions model the anticipated field conditions. The testing was performed in accordance with general engineering testing standards and requirements. This testing report is submitted for the exclusive use of Tensar International Corporation.
## Table 1: Summary of Connection Strength Test Results

Tensar International Corporation  
Mesa Geogrids/Mesa Standard Block with Mesa Standard Connectors

<table>
<thead>
<tr>
<th>Test Series No.</th>
<th>Test Conditions</th>
<th>Geogrid Width (inches)</th>
<th>Number of Ribs</th>
<th>Normal Stress (psi)</th>
<th>Normal Load (lb/ft)</th>
<th>Total Connection Load</th>
<th>Connection Strength At 3/4&quot; (lbs)</th>
<th>Peak (lbs)</th>
<th>Peak At 3/4&quot; (lb/ft)</th>
<th>Peak (lb/ft)</th>
<th>Ave. Peak (lb/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tensar UX1100MSE (Lot#18944-067, TLOT=4564 lb/ft) connected to one Mesa Standard Unit with two Mesa Standard Connectors</td>
<td>18.4</td>
<td>21</td>
<td>2.0</td>
<td>264</td>
<td>1911</td>
<td>1911</td>
<td>1247</td>
<td>1247</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>18.4</td>
<td>21</td>
<td>5.0</td>
<td>660</td>
<td>1931</td>
<td>1931</td>
<td>1259</td>
<td>1259</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Tensar UX1400MSE (Lot#19118-03, TLOT=5029 lb/ft) connected to one Mesa Standard Unit with two Mesa Standard Connectors</td>
<td>17.8</td>
<td>21</td>
<td>4.3</td>
<td>528</td>
<td>1915</td>
<td>1945</td>
<td>1291</td>
<td>1311</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>17.8</td>
<td>21</td>
<td>8.0</td>
<td>1056</td>
<td>2053</td>
<td>2053</td>
<td>1384</td>
<td>1384</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Tensar UX1500MSE (Lot#18973-01, TLOT=8452 lb/ft) connected to one Mesa Standard Unit with two Mesa Standard Connectors</td>
<td>17.9</td>
<td>21</td>
<td>6.0</td>
<td>792</td>
<td>3395</td>
<td>3395</td>
<td>2276</td>
<td>2276</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>17.9</td>
<td>21</td>
<td>10.0</td>
<td>1320</td>
<td>3514</td>
<td>3514</td>
<td>2355</td>
<td>2355</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Tensar UX1600MSE (Lot#18434-24, TLOT=10,700 lb/ft) connected to one Mesa Standard Unit with two Mesa Standard Connectors</td>
<td>17.9</td>
<td>21</td>
<td>6.0</td>
<td>792</td>
<td>4357</td>
<td>4357</td>
<td>2921</td>
<td>2921</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>17.9</td>
<td>21</td>
<td>12.0</td>
<td>1584</td>
<td>4500</td>
<td>4500</td>
<td>3017</td>
<td>3017</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Tensar UX1700MSE (Lot#19140-34, TLOT=12,650 lb/ft) connected to one Mesa Standard Unit with two Mesa Standard Connectors</td>
<td>17.9</td>
<td>21</td>
<td>8.0</td>
<td>1056</td>
<td>5169</td>
<td>5169</td>
<td>3465</td>
<td>3465</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>17.9</td>
<td>21</td>
<td>16.0</td>
<td>2112</td>
<td>5190</td>
<td>5190</td>
<td>3479</td>
<td>3479</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Tensar LH800 (Lot#211318) connected to two Mesa Standard Units with four Mesa Standard Connectors</td>
<td>34.5</td>
<td>32</td>
<td>0.5</td>
<td>59</td>
<td>2647</td>
<td>3028</td>
<td>921</td>
<td>1053</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>34.5</td>
<td>32</td>
<td>2.7</td>
<td>360</td>
<td>2723</td>
<td>2878</td>
<td>947</td>
<td>1001</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>34.5</td>
<td>32</td>
<td>4.5</td>
<td>600</td>
<td>2870</td>
<td>3117</td>
<td>998</td>
<td>1084</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>34.5</td>
<td>32</td>
<td>6.8</td>
<td>900</td>
<td>2819</td>
<td>3087</td>
<td>980</td>
<td>1074</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:** N/A

Date Reported: 04/16/2007

Figure No.

Project No.: SGI:5007

Document No.: SGI07003

File No.
APPENDIX A:

Summary of Test Procedures
TEST PROCEDURES

For each connection test, the test specimen was set up in accordance with the following procedures and tested under the specific conditions as described below:

- A lower course of concrete block units (a full block unit at the center and a half block unit on each side) was placed in the lower half of the pullout box. The concrete block units were oriented so that the back of the concrete block units were against the front wall of the pullout box;

- A geogrid specimen was trimmed from the bulk sample and placed on the top of the lower block units. Two Mesa standard connectors were fitted through specific apertures of the geogrid specimen into the pre-cast slot on top of a lower block unit. The front end of the geogrid was connected to the loading harness of the connection testing device;

- The upper course of concrete block units (two full blocks) was placed directly on top of the geogrid. The concrete block units were oriented so that the back of the concrete block units were against the front wall of the pullout box;

- A specific normal stress was applied to the top of the upper concrete block units using a loading system consisting of three hydraulic cylinders;

- After application of the normal stress, the geogrid specimen was pulled at a constant tensile strain rate, which was calculated based on the exposed length of the geogrid specimen. Pulling out of the geogrid specimen was continued until a constant or decreasing pullout load was recorded; and

- Uniaxial geogrids were tested in the machine direction and LH800 was tested in the cross-machine direction.

The setup of the connection strength test is shown Figure A-2 (test photo) and Figure A-3 (schematic diagram).
Figure A1: SGI's Connection Test Device

Figure A2: Tensar International Corporation’s UX1400MSE geogrid placed on top of Mesa Standard Block with 2 Standard Connectors.
Figure A3: Schematic Diagram of Test Cross-Section (Not to scale.)
APPENDIX B:

Summary of Connection Results
**Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (ASTM D 6638)**

**TEST SERIES NO. 1:** Tensar UX1100MSE Geogrid (Lot #18944-67, Lot ultimate strength = 4564 lb/ft) in machine direction within Mesa Standard Block Units with 2 Mesa Standard Connectors per block.

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Test Specimen Width (in.)</th>
<th>Test Normal Stress (psi)</th>
<th>Equivalent Normal Load (lb/ft)</th>
<th>0.75-in. Load (lbs)</th>
<th>Peak Load (lbs)</th>
<th>0.75-in. Strength (lb/ft)</th>
<th>Peak Strength (lb/ft)</th>
<th>Connection Strength Equations ($T_{con}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>18.4</td>
<td>2.0</td>
<td>264</td>
<td>1911</td>
<td>1911</td>
<td>1247</td>
<td>1247</td>
<td>0.75-in.</td>
</tr>
<tr>
<td>1B</td>
<td>18.4</td>
<td>5.0</td>
<td>660</td>
<td>1931</td>
<td>1931</td>
<td>1259</td>
<td>1259</td>
<td>0.75-in.</td>
</tr>
</tbody>
</table>

**NOTES:**
- Failure Mode of Geogrid: CMD bars sheared beyond outer 4 teeth of MESA standard connector and center portion of the geogrid between connectors pulled out in each test.
- Failure Mode of Connector: none.
- Failure of Block: none.
- Geogrid Specimen Dimensions: 1 aperture long by 21 ribs wide and equivalent width = 21 ribs/13.70 rib/ft = 12 = 18.4 in.
- Average Strain Rate for Tests 1A and 1B: 7.9 and 7.3 (%/min).
- DATE TESTED: 1 to 3 April 2005.
## Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (ASTM D 6638)

**TEST SERIES NO. 2: Tensar UX1400MSE Geogrid (Lot #19118-03, Lot ultimate strength = 5029 lb/ft) in machine direction within Mesa Standard Block Units with 2 Mesa Standard Connectors per block**

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>0.75-in. Normal Stress (psi)</th>
<th>0.75-in. Normal Load (lb/ft)</th>
<th>Peak Load (lbs)</th>
<th>Peak Strength (lb/ft)</th>
<th>Connection Strength Equations ($T_{conn}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2A</td>
<td>4.0</td>
<td>528</td>
<td>1915</td>
<td>1945</td>
<td>1291</td>
</tr>
<tr>
<td>2B</td>
<td>8.0</td>
<td>1056</td>
<td>2053</td>
<td>2053</td>
<td>1384</td>
</tr>
</tbody>
</table>

**NOTES:**

- **Failure Mode of Geogrid:** CMD bars sheared beyond outer 4 teeth of MESA standard connector and center portion of the geogrid between connectors pulled out in each test.
- **Failure Mode of Connector:** none
- **Failure of Block:** none
- **Geogrid Specimen Dimensions:** 1 apertures long by 21 ribs wide and equivalent width = 21 ribs/14.18 rib/ft*12 = 17.8 in.
- **Average Strain Rate for Tests 2A and 2B:** 8.0 and 9.4 (%/min)

**DATE TESTED:** 1 to 3 April 2005

**FIGURE NO.: C-2**

**PROJECT NO.: SGI5007**

**DOCUMENT NO.: SGI07003**

**FILE NO.:**
**Determining Connection Strength Between**
**Geosynthetic Reinforcement and Segmental Concrete Units (ASTM D 6638)**

**TEST SERIES NO. 3: Tensar UX1500MSE Geogrid (Lot #18973, Lot ultimate strength = 8452 lb/ft) in machine direction**
**within Mesa Standard Block Units with 2 Mesa Standard Connectors per block**

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Test Specimen Width (in.)</th>
<th>Test Normal Stress (psi)</th>
<th>Equivalent Normal Load (lb/ft)</th>
<th>0.75-in. Load (lbs)</th>
<th>Peak Load (lbs)</th>
<th>0.75-in. Strength (lb/ft)</th>
<th>Peak Strength (lb/ft)</th>
<th>Connection Strength Equations $T_{conn}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3A</td>
<td>17.9</td>
<td>6.0</td>
<td>792</td>
<td>3395</td>
<td>3395</td>
<td>2276</td>
<td>2276</td>
<td></td>
</tr>
<tr>
<td>3B</td>
<td>17.9</td>
<td>10.0</td>
<td>1320</td>
<td>3514</td>
<td>3514</td>
<td>2355</td>
<td>2355</td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**
- Failure Mode of Geogrid: CMD bars sheared beyond outer 4 teeth of MESA standard connector and center portion of the geogrid between connectors pulled out in each test.
- Failure Mode of Connector: none
- Failure of Block: none
- Geogrid Specimen Dimensions: 1 apertures long by 21 in. wide and equivalent width = 21 in./14.10 rib/ft*12 = 17.9 in.
- Average Strain Rate for Tests 3A and 3B: 7.7 and 8.3 (%/min)

**DATE TESTED:** 1 to 3 April 2005

**SGI Testing Services, LLC**

**FIGURE NO.:** C-3
**PROJECT NO.:** SGI5007
**DOCUMENT NO.:** SGI07003
**FILE NO.:** 050071003
## Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (ASTM D 6638)

**TEST SERIES NO. 4:** Tensar UX1600MSE Geogrid (Lot #18434-24, Lot ultimate strength = 10700 lb/ft) in machine direction within Mesa standard block units with 2 MESA standard connectors per block

### Test Results

<table>
<thead>
<tr>
<th>Specimen Width (in.)</th>
<th>Normal Stress (psi)</th>
<th>Equivalent Width (lb/ft)</th>
<th>0.75-in. Load (lbs)</th>
<th>Peak Load (lbs)</th>
<th>0.75-in. Strength (lb/ft)</th>
<th>Peak Strength (lb/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4A</td>
<td>17.9</td>
<td>6.0</td>
<td>792</td>
<td>4357</td>
<td>2921</td>
<td>2921</td>
</tr>
<tr>
<td>4B</td>
<td>17.9</td>
<td>12.0</td>
<td>1584</td>
<td>4500</td>
<td>3017</td>
<td>3017</td>
</tr>
</tbody>
</table>

### Connection Strength Equations

\[
T_{con} = \text{Connection Strength}
\]

### Notes:

- **Failure Mode of Geogrid:** CMD bars sheared beyond outer 4 teeth of MESA standard connector and center portion of the geogrid between connectors pulled out in each test.
- **Failure Mode of Connector:** none
- **Failure of Block:** none

**Geogrid Specimen Dimensions:** 1 apertures long by 21 ribs wide and equivalent width = 21 ribs/14.05 rib/ft*12 = 17.9 in.

**Average Strain Rate for Tests 4A and 4B:** 8.8 and 9.9 (%/min)

**Date Tested:** 1 to 3 April 2005
## Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (ASTM D 6638)

TEST SERIES NO. 5: Tensar UX1700MSE Geogrid (Lot #19140-34, Lot ultimate strength = 12650lb/ft) in machine direction within Mesa Standard Block Units with 2 Mesa Standard Connectors per block

### Test Results

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Specimen Width (in.)</th>
<th>Test Normal Stress (psi)</th>
<th>Equivalent Normal Load (lb/ft)</th>
<th>0.75-in. Peak Load (lbs)</th>
<th>Peak Load (lbs)</th>
<th>0.75-in. Strength (lb/ft)</th>
<th>Peak Strength (lb/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5A</td>
<td>17.9</td>
<td>8.0</td>
<td>1056</td>
<td>5169</td>
<td>5169</td>
<td>3465</td>
<td>3465</td>
</tr>
<tr>
<td>5B</td>
<td>17.9</td>
<td>16.0</td>
<td>2112</td>
<td>5190</td>
<td>5190</td>
<td>3479</td>
<td>3479</td>
</tr>
</tbody>
</table>

### Notes:
- **Failure Mode of Geogrid:** CMD bars partially sheared beyond outer 4 teeth of MESA standard connector in each test.
- **Failure Mode of Connector:** rupture of teeth and flags
- **Failure of Block:** portion of concrete in the back (tail side) of one connector sheared off in each test
- **Geogrid Specimen Dimensions:** 1 apertures long by 21 ribs wide and equivalent width = 21 ribs/14.10 rib/ft = 17.9 in
- **Average Strain Rate for Tests 5A and 5B:** 8.8 and 10.0 (%/min)

### Connection Strength Equations

\[
T_{conn} = \text{Connection Strength (lb/ft)}
\]

### Figures

- **Figure No. C-5**
- **Project No. SGI5007**
- **Document No. SGI07003**
- **File No. 050010003**

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SGI Testing Services, LLC
Determined Connection Strength Between
Geosynthetic Reinforcement and Segmental Concrete Units (ASTM D 6638)

TEST SERIES NO. 6: Tensar LH800 Geogrid in cross-machine direction (Lot # 211318) between two courses of round-face Mesa Standard Blocks with 2 unsplit Mesa Standard Connectors per block

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Geogrid Specimen Nominal Width (in.)</th>
<th>Geogrid Nominal Stress (psi)</th>
<th>Equivalent Normal Load (lb/ft)</th>
<th>0.75-in. Peak Load (lb)</th>
<th>Peak Load (lb)</th>
<th>0.75-in. Peak Strength (lb/ft)</th>
<th>Peak Strength (lb/ft)</th>
<th>Connection Strength Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>9A</td>
<td>34.5</td>
<td>0.5</td>
<td>59</td>
<td>2647</td>
<td>3028</td>
<td>921</td>
<td>1053</td>
<td>$T_{\text{conn}} = 1030 + (N) \tan(30^\circ)$</td>
</tr>
<tr>
<td>9B</td>
<td>34.5</td>
<td>2.7</td>
<td>360</td>
<td>2723</td>
<td>2878</td>
<td>947</td>
<td>1001</td>
<td>$T_{\text{conn}} = 920 + (N) \tan(50^\circ)$</td>
</tr>
<tr>
<td>9C</td>
<td>34.5</td>
<td>4.5</td>
<td>600</td>
<td>2870</td>
<td>3117</td>
<td>998</td>
<td>1084</td>
<td></td>
</tr>
<tr>
<td>9D</td>
<td>34.5</td>
<td>6.8</td>
<td>900</td>
<td>2819</td>
<td>3087</td>
<td>980</td>
<td>1074</td>
<td></td>
</tr>
</tbody>
</table>

NOTES:
Dimensions of Block: 18 in. wide by 11.0 in. long and 8.0 in. high.
Dimensions of Geogrid Specimen within Connection: 34.5" (32 rib) wide by 6" long.
Weight of a Full-Size Block: 78 lbs.
Failure Mode of Geogrid: outer teeth of Mesa standard connectors sheared thru CMD bars in each test.

DATE TESTED: 30 August 2006
FIGURE NO.: C-9
PROJECT NO.: SGI6005
DOCUMENT NO.: SGI07003
FILE NO.: